Relion® 650 series

Switchsync™ PWC600 Version 1.1

User manual



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Section 1 Introduction

1.1 This manual

The user manual provides basic instructions on how to install and use Switchsync PWC600. The manual also describes setting up a secure system, including password procedures and levels of access in the system. The manual provides instructions for engineering, mechanical and electrical installing, commissioning and operating, to cover the common use cases of the product.

1.2 Intended audience

This manual addresses new users as well as not frequent users of Switchsync PWC600, providing an easy start or refresh on using the product. The manual offers quick assistance to operators and field personnel as well as engineering and commissioning personnel.

1.3 Product documentation

1.3.1 Product documentation set

The user manual provides basic instructions on how to install and use Switchsync PWC600. The manual provides instructions for engineering, mechanical and electrical installing, commissioning and operating, to cover the common use cases of the product.

The communication protocol manual describes a communication protocol supported by the IED. The manual concentrates on vendor-specific implementations.

The cyber security deployment guideline describes setting up a secure system, including password procedures and levels of access in the system.

The technical manual contains application and functionality descriptions and lists function blocks, logic diagrams, input and output signals, setting parameters and technical data sorted per function. The manual can be used as a technical reference during the engineering phase, installation and commissioning phase, and during normal service.

1.3.1.1 Related documents

Documents related to Switchsync PWC600	Identity number
Communication protocol manual, IEC 61850	1MRK 511 464-UEN
Cyber Security deployment guidelines	1MRK 511 465-UEN
User Manual	1MRK 511 463-UEN
Technical manual	1MRK 511 462-UEN
MICS	1MRG 035 293
PICS	1MRG 035 460
PIXIT	1MRG 035 547[1)]
TICS	1MRG 035 548[1)]

1) Switchsync PWC600 1.1 is based on Relion 650 series, version 1.3. So the PIXIT and TICS from Relion 650 series, version 1.3 are applicable for Switchsync PWC600 1.1 too.

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1.3.2 Document revision history

Document revision/date	Product version	History
A/2020-02	1.1	First release

1.4 Symbols and conventions

1.4.1 Symbols



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. It is important that the user fully complies with all warning and cautionary notices.

1.4.2 Document conventions

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

  For example, to navigate between the options, use  and  .
- HMI menu paths are presented in bold.
  For example, select **Main menu/Settings**.
- LHMI messages are shown in `Courier` font.

  For example, to save the changes in non-volatile memory, select `Yes` and press  .
- Parameter names are shown in italics.
  For example, the function can be enabled and disabled with the *Operation* setting.

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Section 2 Safety information

2.1 Safety information

2.1.1 Symbols on the product



All warnings must be observed.



Read the entire manual before doing installation or any maintenance work on the product.



Class 1 Laser product. Take adequate measures to protect your eyes and do not view directly with optical instruments.

2.1.2 Warnings

Observe the warnings during all types of work related to the product.



Only electrically skilled persons with the proper authorization and knowledge of any safety hazards are allowed to carry out the electrical installation.



National and local electrical safety regulations must always be followed. Working in a high voltage environment requires serious approach to avoid human injuries and damage to equipment.



Do not touch circuitry during operation. Potentially lethal voltages and currents are present.



Always use suitable isolated test pins when measuring signals in open circuitry. Potentially lethal voltages and currents are present.



Never connect or disconnect a wire and/or a connector to or from a IED during normal operation. Hazardous voltages and currents are present that may be lethal. Operation may be disrupted and IED and measuring circuitry may be damaged.

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



Always connect the IED to protective earth, regardless of the operating conditions. This also applies to special occasions such as bench testing, demonstrations and off-site configuration. This is class 1 equipment that shall be earthed.



Never remove any screw from a powered IED or from a IED connected to powered circuitry. Potentially lethal voltages and currents are present.



Take adequate measures to protect the eyes. Never look into the laser beam.

2.1.3 Caution signs



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



The IED contains components which are sensitive to electrostatic discharge. ESD precautions shall always be observed prior to touching components.



Always transport PCBs (modules) using certified conductive bags.



Do not connect live wires to the IED. Internal circuitry may be damaged



Always use a conductive wrist strap connected to protective earth when replacing modules. Electrostatic discharge (ESD) may damage the module and IED circuitry.



Take care to avoid electrical shock during installation and commissioning.

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Changing the active setting group will inevitably change the IED's operation. Be careful and check regulations before making the change.

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Section 3 Switchsync PWC600 overview

3.1 Introduction

Switchsync PWC600 is a point-on-wave controller for high-voltage circuit breakers. Its purpose is to delay circuit breaker operation commands such that current inception or current interruption occurs at a phase angle that minimizes stress on the switched load or the circuit breaker. The PWC600 device (IED, intelligent electronic device) is usually installed in the control room in the bay control cabinet, where all required signals are present.

3.2 Hardware overview



Figure 1: Switchsync PWC600 front view

1 Enlosure
2 Local HMI

A label with the IED ordering number and serial number is attached to the local HMI.

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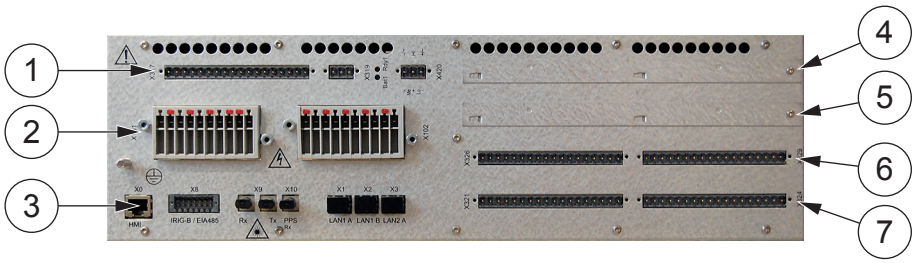


Figure 2: Switchsync PWC600 rear panel with hardware modules

1	PSM02/PSM03: Power supply module with options for 48...125 VDC or 110...250 VDC
2	TRM01: Instrument transformer module with 4 current and 6 voltage inputs
3	COM03 + CPU02: Communication and high performance processing module
4 and 5	Not used, slots are empty in Switchsync PWC600
6	BIO01: Binary input/output module
7	PIO01: Precision binary input/output module with event time resolution of 100 µs

For more information on connections, see Section 7.1.

3.3 Functioning principle

The connection of PWC600 in a power system and its high-level functioning principle can be understood from Figure 3. Upon receiving an **Open** or **Close** command, PWC600 evaluates the optimal controlled switching instants for each phase from a primary reference signal. In most cases, the reference is taken from a source side voltage transformer (1). The evaluation considers the design and connection configuration of the load as well as the dielectric and mechanical characteristics of the circuit breaker. Consequently, it issues a synchronized opening or closing command to the respective operating coil (2 or 3) of each circuit breaker pole.

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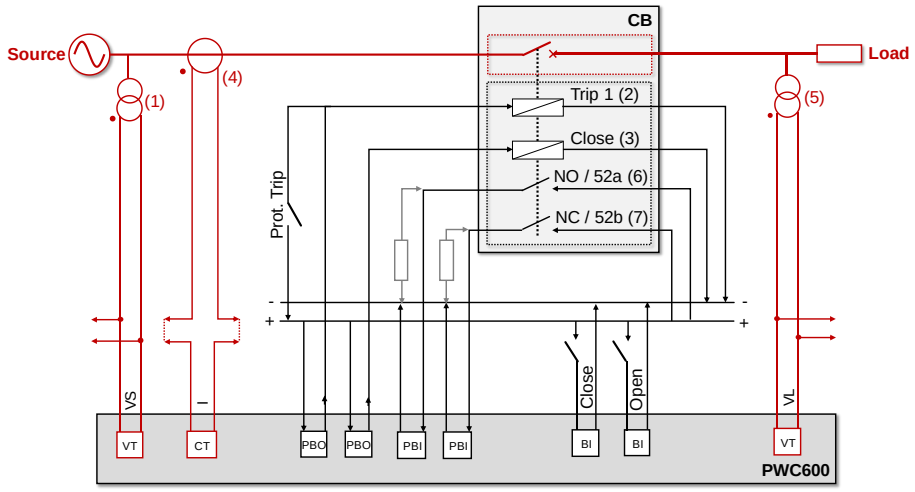


Figure 3: Overview of PWC600 integration in a power system

PWC600 also monitors the electrical and mechanical health of the circuit breaker as well as the performance of controlled switching during the previous operation. This information is obtained by detection the instants of inception or interruption of the primary feedback signal, which can be load current (4) or load side voltage (5). If no suitable primary feedback signals are available, monitoring is based on the changeover instants of CB auxiliary contacts 52a/NO (6) and 52b/NC (7). From the available feedback signals, PWC600 calculates the target error (difference between expected switching time and actual switching time from last operation) and applies a timing correction in the next operation. This process is known as “adaptive correction”.

Refer to Section 4.4.2 and Section 4.5 for more details on adaptation and monitoring.

PWC600 also has a facility for measuring CB operating times during pre-commissioning through temporarily connecting to the primary contacts of individual circuit breaker poles.

Figure 4 shows a block diagram of the interfaces to PWC600. The source side voltage, load side voltage and load current are connected to the Analog input module (or alternatively received on an IEC 61850-9-2(LE) compliant process bus). Incoming Open or Close commands and output commands to the circuit breaker coils are connected to the binary input & output modules. Also, the pole-wise auxiliary contacts and spring charge level (applicable for specific drive designs) indicators are connected to binary input module. The power supply to the PWC600 is provided through Power supply module. Alarms related to the health of the circuit breaker as well as the performance of controlled switching operations can be generated by relay contacts on the Binary output modules. The PWC600 IED continuously monitors itself and in event of any internal failure, generates Internal relay failure (IRF) alarm. The user may interact with PWC600 through the local user interface (LHMI) or through a web interface (WHMI). Like for all ABB Relion IEDs, settings and configuration of PWC600 are prepared in PCM600 tool.

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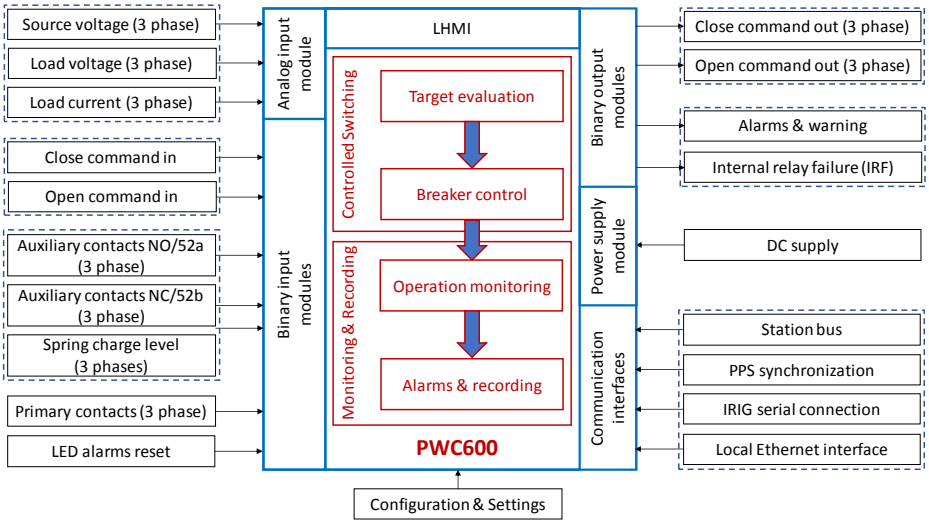


Figure 4: External interfaces of PWC600 device

Refer Section 7 for more details on hardware interfaces of PWC600.

3.4 Application overview

Controlled switching, provided by Switchsync PWC600, is used for minimizing harmful electrical transients upon planned switching of loads such as capacitor banks, shunt reactors, power transformers, and power cables. The method is also gaining acceptance for re-energizing of EHV transmission lines, and replacing traditional pre-insertion resistors.

3.4.1 Common applications

The most common applications of controlled switching are listed below. Note that PWC600 is intended only for intentional switching operations, not for protection trips.

Shunt capacitor banks

Basic aim is to control energization to minimize the voltage transients as well as inrush currents. To improve interrupting performance, controlled opening can also be utilized.

Shunt reactors

Basic aim is to control de-energization to ensure reignition-free current interruption. In addition, controlled closing also serves as a useful method for minimizing inrush currents.

Power transformers

Basic aim is to control energization to minimize inrush currents. This is enabled by controlled de-energization, to set a repeatable residual flux pattern, which is taken into account for the subsequent energization.

Unloaded transmission lines and power cables

Basic aim is to control energization to minimize overvoltage transients and to prevent missing current zeroes on fully compensated cables. To improve interrupting performance, controlled opening can also be utilized.

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3.4.2 Variable applications

In a 1½ circuit breakers arrangement, the middle (tie) breaker is connected to a load on each end. The same is applicable to every breaker in a ring layout. These two loads may be of the same type but more often they are different.

The traditional approach to optimize controlled switching of both loads is to install two point-on-wave (POW) controllers for the breaker, together with a hardware logic for transferring control to the appropriate POW controller. PWC600 1.1 and higher can accommodate these functionalities in a single device through a feature called Setting Groups, which allows automatic selection of different parameter sets based on external signals or conditions.

Variable applications, where setting groups are beneficial, include:

- For the tie breaker in 1½-CB or ring arrangements, select the appropriate reference source and switching strategy depending on the status of adjacent switches and/or voltage sources.
- In a double-busbar arrangement, select the appropriate busbar VT as reference, without the need for external circuits for switching the VT signals.
- For power transformers, apply a fallback strategy for closing (assuming zero residual flux) whenever the CB was opened not by PWC600.
- For loads with variable electrical configuration, e.g. switchable earthing of neutral point, apply the optimal switching strategy in all cases.
- For any application, bypass the controlled switching functionality whenever an external or internal binary signal is asserted.
- For FAT or similar situations, where the actual CB is switching low voltage, provide a set of alternate CB settings (e.g. RDDS) that does not interfere with the original settings to be applied in the high-voltage grid.

3.5 User interfaces

The user can interact with Switchsync PWC600 in several ways.

- Local Human-Machine Interface (LHMI) on the front panel of the IED, featuring LCD screen, pushbuttons and status LEDs
- Web interface via web browser
- Various tools in Protection and Control Manager PCM600, installed on a PC

3.6 Communication

The IED supports communication protocols IEC61850-8-1 and HTTPS over Ethernet, and IEC 61850-9-2(LE) over separate Ethernet process bus.

All operational information and controls are available through these protocols. However, some communication functionality, for example, horizontal communication (GOOSE) between the IEDs, is only enabled by the IEC 61850-8-1 communication protocol.

Waveform (disturbance) files are accessed using IEC 61850 or the Web interface. Disturbance files are also available to any Ethernet based application in the standard COMTRADE format. The IED can send binary signals to other IEDs (so called horizontal communication) using the IEC 61850-8-1 GOOSE (Generic Object Oriented Substation Event) profile. Binary GOOSE messaging can, for example, be employed for protection and interlocking-based protection schemes. The IED meets the GOOSE performance requirements for tripping applications in distribution substations, as defined by the IEC 61850 standard. Furthermore, the IED supports

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the sending and receiving of analog values using GOOSE messaging. Analog GOOSE messaging enables fast transfer of analog measurement values over the station. The IED interoperates with other IEC 61850 compliant IEDs, tools and systems and simultaneously reports events to five different clients on the IEC 61850 station bus. IEC 61850-9-2(LE) is supported for subscribing to current and voltage signals in digital sampled value format.

All communication connectors, except for the front port connector, are placed on the integrated communication module. The IED is connected to Ethernet-based communication systems via the RJ-45 connector (10/100BASE-TX) or the fibre-optic multimode LC connector (100BASE-FX).

The IED supports the following time synchronization methods with a timestamping resolution of 1 ms:

Ethernet communication based:

- SNTP (simple network time protocol)

With special time synchronization wiring:

- IRIG-B
- PPS (pulse per second)

PPS signals are used for IEC 61850-9-2(LE) process synchronisation with accuracy of 4 µs.

3.7 PCM600 tool

Protection and Control IED Manager PCM600 offers all the necessary functionality to work throughout all stages of the IED life cycle.

- Planning
- Engineering
- Commissioning
- Operation and disturbance handling
- Functional analysis



When using PCM600 for writing to the IED, ensure that the LHMI or WHMI is not in a menu position where settings can be changed. Only one active writing transaction, from LHMI, WHMI, or PCM600, is allowed at a time.

With the individual tool components, you can perform different tasks and functions. PCM600 can operate with various topologies, depending on the customer needs.



For more information, see PCM600 documentation.

3.7.1 Connectivity packages

A connectivity package is a software component that consists of executable code and data which enable system tools to communicate with a specific type of IED. Connectivity packages are used to create configuration structures in PCM600.

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A connectivity package with its associated IED Module(s) includes all of the data which is used to describe the IED. For example it contains a list of what parameters exist, which data format is used, the units, the setting range, the access rights and visibility of the parameter. In addition it contains code which allows software packages in PCM600 to properly communicate with the IED. It also allows for localization of text even when it is read from the IED in a standard format such as COMTRADE.

The connectivity package for PWC600 includes a product specific tool, Switchsync Setting Tool (SST), for entering the required settings for the application. SST comes with a library of ABB circuit breakers that can be used for controlled switching.

Update Manager is a tool that helps installing the appropriate connectivity package versions for different system products and tools. Update Manager is included with PCM600.

3.8 Environmental aspects

3.8.1 Sustainable development

Sustainability has been taken into account from the beginning of the product design including the pro-environmental manufacturing process, long life time, operation reliability and disposing of the IED.

The choice of materials and the suppliers have been made according to the EU RoHS directive (2002/95/EC). This directive limits the use of hazardous substances which are the following:

Table 1: Maximum concentration values by weight per homogeneous material

Substance	Permitted maximum concentration
Lead - Pb	0.1%
Mercury - Hg	0.1%
Cadmium - Cd	0.01%
Hexavalent Chromium Cr (VI)	0.1%
Polybrominated biphenyls - PBB	0.1%
Polybrominated diphenyl ethers - PBDE	0.1%

Operational reliability and long life time have been assured with extensive testing during the design and manufacturing processes. Moreover, long life time is supported by maintenance and repair services as well as by the availability of spare parts.

Design and manufacturing have been done under a certified environmental system. The effectiveness of the environmental system is constantly evaluated by an external auditing body. We follow environmental rules and regulations systematically to evaluate their effect on our products and processes.

3.8.2 Disposing of the IED

Definitions and regulations of hazardous materials are country-specific and change when the knowledge of materials increases. The materials used in this product are typical for electric and electronic devices.

All parts used in this product are recyclable. When disposing of an IED or its parts contact a local waste handler who is authorized and specialized in disposing electronic waste. These handlers can sort the material by using dedicated sorting processes and dispose of the product according to the local requirements.

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Table 2: Materials of the IED parts

IED	Parts	Material
Unit	Metallic plates, parts and screws	Steel
	Plastic parts	PC[1)], LCP[2)]
	LHMI display module	Various
Package	Box	Cardboard
Attached material	Manuals	Paper

1) Polycarbonate
2) Liquid crystal polymer

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Section 4 Application

4.1 Introduction

Switchsync PWC600 is a point-on-wave controller, which is used to reduce electrical stresses imposed on the circuit breaker as well as on the switched load during energization and de-energization operations. Switchsync PWC600 can be used for switching of all major load applications including reactors, capacitor banks, cables, transformers and transmission lines with various design and connection configurations. Circuit breaker closing and opening commands that are not time critical are routed through Switchsync PWC600. The device (IED) then issues individual commands to the circuit breaker poles depending on the load to be switched, considering its connection and design configuration.

Recommended switching targets for common load types are programmed into the software tools. From release 1.1.0 on, PWC600 is able to dynamically select one out of several controlled switching scenarios, which is relevant, for example, for the middle (tie) breaker in a 1½ CB arrangement.

After completion of a controlled switching operation, Switchsync PWC600 compares the actual with the target switching instants. The results are used to optimize the estimated operating times of the circuit breaker in the next operation. This process is known as “adaptive correction”; it compensates for systematic changes in the circuit breaker’s operation characteristics.

Deterministic changes in operating times due to internal or external parameters, such as auxiliary voltage, idle time, ambient temperature, drive energy, can also be compensated using individual compensation curves. Respective sensor signals are either connected to the IED directly, or they can be received from remote sources via IEC 61850 analog GOOSE messages.

Switchsync PWC600 is capable of calculating the expected remaining life of the circuit breaker in terms of number of operations and electrical interrupter wear (ablation of arcing contacts, erosion of nozzles). This is based on interrupted primary current and status signals of CB auxiliary contacts.

On every supervised signal, Switchsync PWC600 can generate warnings and alarms when crossing assigned limits. Such conditions can be indicated visually by LEDs on the LHMI, electrically by alarm contacts on the IED, or remotely via its Ethernet communication interfaces. Each supervision alarm can be individually enabled or disabled.

4.2 Load applications

Switchsync PWC600 is designed for point-on-wave switching (also known as controlled switching) of capacitor banks, reactors, transformers, transmission lines, and power cables. For each type of equipment and its design and connection configuration, the Switchsync Setting Tool (SST) proposes controlled switching strategies based on CIGRE recommendations. These switching strategies can be directly adopted by the user or modified as needed. This provides full flexibility in accommodating load applications other than the pre-defined ones.

The following load applications are included in PWC600 along with recommended switching strategies. Refer Section 5.1 for more details on individual applications.

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4.2.1 Capacitor banks

Non-ideal energization of a capacitor bank may result in high transient inrush currents and, in turn, high switching over-voltages. To minimize the inrush currents, energization shall be performed near gap voltage zero of each pole of the circuit breaker connected to the capacitor bank. In this regard, the connection configuration of the capacitor bank shall be considered for deciding the optimum switching targets for individual poles of the circuit breaker.

Controlled de-energization is typically not needed, given that most modern CBs show a very low probability of re-strikes; however, in some cases, an increased safety against re-strikes may be preferred. Controlled opening targets are set to ensure sufficient arcing time such that an adequate gap is achieved between contacts at the time of arc extinction. The time between arcing contact separation until natural current zero where arc is expected to be quenched is known as “arcing time”. Consequently, arcing times shall be determined considering the expected natural current zero across individual poles of the circuit breaker based on the connection configuration of the capacitor bank.

4.2.2 Shunt reactors

When de-energizing a reactor, interaction between the reactor's inductance and stray capacitances will cause oscillating voltage transients with frequency in the range of kHz. Generally, for latest generation of CBs, the current is interrupted in the in vicinity of natural current zero for individual poles with very low value of chopping currents. Consequently, the voltage transient across the breaker (TRV) may not have too high magnitude, but will have a very short rise time in range of a millisecond. This can lead to breakdown of the dielectric withstand of the contact gap and hence, reappearance of the current through arcing. This phenomenon is known as a re-ignition and is not desirable because it can be harmful to both shunt reactor and circuit breaker. Controlled opening is used to reduce the probability of re-ignitions by ensuring sufficient gap between arcing contacts at time of natural current zero, where arc is expected to be quenched. The needed arcing time shall be evaluated considering the last half-cycle length (which may be extended or shortened due to interaction between phases) and probable over-voltage across the contact gap for each CB pole post the successful interruption.

Controlled energization of reactors may be implemented to reduce the asymmetry in charging current due to initial DC component. It is worth noting that reactor cores do not typically saturate and hence, the charging current will have sinusoidal waveshape (power frequency only) with exponentially decaying DC component. The energization target is gap voltage peak for individual pole of the CB.



Certain magnetic reactor designs or electrical connection configurations will create inter-phase coupling effects upon switching. These include 3-limb core design, which causes magnetic coupling between phases, and Y (ungrounded) or delta connection schemes. The switching targets for individual poles of CB should be evaluated considering these effects.

4.2.2.1 Re-ignition free window

Adequate arcing times shall be ensured to minimize the probability of re-ignitions. The value of minimum arcing time derived from standardized reactor switching duty type test as specified in IEC 62271-110 serves as the base of this evaluation. It is worth noting that, for certain reactor configurations, the probable over-voltages post successful interruption and last loop length may be different for individual CB poles based on the rating, design and connection configuration of the reactor. Therefore,the optimal arcing times for controlled opening may also differ between phases.

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For controlled de-energization of a non-coupled YN-connected reactor, the initial target arcing times for each CB pole are derived from the concept of "re-ignition free window", as shown in Figure 5.

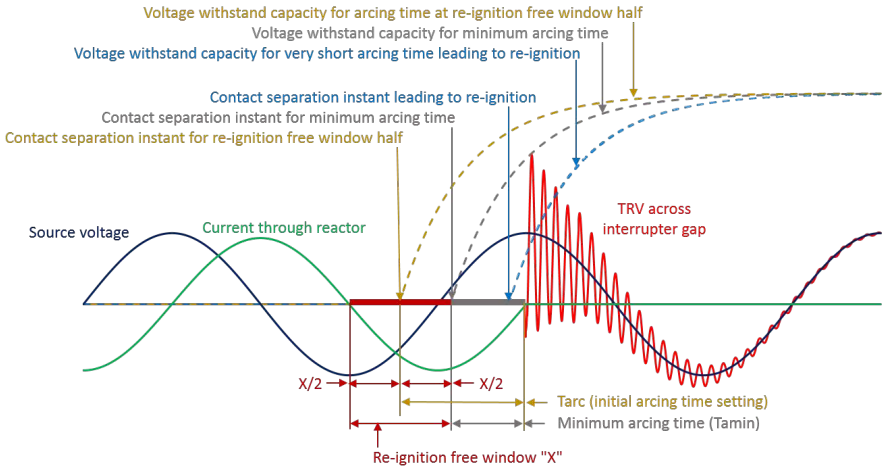


Figure 5: Re-ignition free window for a non-coupled grounded reactor

Whenever the rising dielectric strength of the opening contact gap intersects the TRV, the interrupter will re-ignite. This is usually the case for short arcing times. Hence, the arcing time should not be lower than the minimum arcing time for re-ignition free interruption. Figure 5 shows that the re-ignition free window of arcing times ranges from minimum arcing time, as obtained from type testing, to the length of the last half cycle. To cater for variations in the transient recovery voltage (TRV) due to rating of the reactor, mechanical & dielectric characteristics of the CB and site conditions, the center of the re-ignition free window is chosen as initial target arcing time for controlled opening.

As mentioned above, the length of last half cycle and the probable overvoltage post current interruption depend upon rating, design, and connection configuration of the reactor. Therefore, the initial target arcing time shall be evaluated for individual phases considering these parameters. In this regard, the minimum arcing times are re-evaluated based on gap voltage factors observed across individual interrupting poles for reactors with non-solidly grounded systems. Consequently, the re-ignition free window and initial arcing times are derived for individual circuit breaker poles. As the re-evaluation is based on linear approximation, the minimum arcing time is always taken as lower limit for the re-evaluated initial arcing time.

Initial arcing time values are provided as guidance as they are based on circuit breaker characteristics and standard IEC applications, and may require further adjustment depending on system specific considerations. As an example, for reactors with very low nominal currents, the TRV may become higher than what is specified in standard testing, and hence, may require longer target arcing time. Please contact the circuit breaker factory for guidance.

4.2.3 Power transformers

During no-load energization of a transformer, controlled switching is used for reducing inrush currents and, consequently, voltage distortion in the power system. For a weak grid, this distortion can lead to considerable voltage dip. If the transformer is directly connected to a long transmission line, it may create temporary overvoltage due to resonance of the line

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capacitance with the transformer inductance. This can even lead to nuisance tripping of other equipment connected on the same grid.

The latest generation of power transformers exhibits very low levels of no-load losses (in range of 0.5-1% of the full load current). To achieve the same with optimum design, magnetizing curve of transformers are designed with high operating flux densities with saturation point just above the rated voltage of the transformer. This may lead to very steep rise in magnetizing inrush current for a very small level of asymmetry in the operating flux. In addition, the interphase coupling effects either because of electrical coupling due to at least one delta connected winding or due to magnetically coupled phases, will result into inter-dependency between resultant fluxes linking with individual phase windings. Therefore, asymmetry in resultant flux of one phase will impact the resultant flux linkage and hence, inrush current in other windings. In this context, the fluxes linking with individual phases are termed as “dynamic fluxes”.

It can be well appreciated that achieving symmetrical flux on energization requires consideration of residual fluxes in the core observed during the previous de-energization, effect of interphase dependency (dynamic fluxes) based on winding configurations (vector group), and core design type (3 limb, 4/5 limb or single-phase bank) of the transformer. Consequently, the switching strategy aims at energizing the individual poles on the reference voltage waveform in such a way that the resultant dynamic fluxes will be symmetric. To mitigate magnetic inrush current, no-load energization of a transformer should be performed at a phase angle where the source side flux will be equal to transformer side flux. This will create symmetric resultant flux in each limb, avoiding core saturation and resulting in minimized magnetizing current. The information required on residual fluxes is derived by controlled opening as a support for the subsequent controlled closing. The purpose of controlled opening is to set a repeatable pattern of residual fluxes. The subsequent closing for individual poles is targeted in such a way that the resultant flux will have minimum level of asymmetry. Refer Section 5.1.6 for proposed switching strategies for controlled switching of transformers with different design and connection configurations.

4.2.4 Discharged transmission lines and cables

For transmission lines and power cables, controlled energization is used to minimize the switching overvoltage on the line. To achieve this, controlled energization is targeted for gap voltage zero for individual poles of the circuit breaker.

Often, long cables or lines are compensated with shunt reactors at one or two ends to minimize reactive power pull during off-load condition. In such condition, energization targets shall be checked against missing zero phenomenon, which carries a risk of circuit breaker failure in case of protection trip during energization of the cable.

Like capacitor bank switching, controlled opening is typically not needed for cables and transmission lines. Nevertheless, controlled de-energization can be used for ensuring re- strike free operation of the circuit breaker.

4.3 Switching targets

On arrival of a switching command, the PWC600 IED calculates the optimal switching target phase angles with respect to the reference voltage or reference current signals. The calculations are based on the load to be switched, its connection and design configuration, and the switching duty considering operating time variations and external parameter variations.

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4.3.1 Target reference

Controlled switching targets in Switchsync PWC600 are defined with respect to a reference signal.

- For load energization (controlled CB closing), primary voltage is always used as reference. Voltage measurement may be single-phase or three-phase, for phase-to-ground or phase-to-phase voltage.
- For load de-energization (controlled CB opening), either the primary source voltage (same as for closing operations) or the load current may be used as reference. Current measurement must be taken from all three phases, and the CT secondary current should not be lower than 50 mA.

Reference signals can be provided by conventional VTs/CTs, or from IEC 61850-9-2(LE) compliant NCITs. Analog signals are sampled at a rate of 80 samples per power cycle, i.e. sampling frequency of 4000 S/s at 50 Hz or 4800 S/s at 60 Hz. This sampling frequency cannot be changed.

The selected reference signal can be used only when its amplitude is sufficiently high. For signal levels below the "dead value" threshold, the IED will declare missing reference signal. If it receives a controlled switching command in this condition it will fall back to a user-defined contingency action of either unsynchronized switching (bypass) or blocking the CB operation.

4.3.2 Target definition

With the reference signal selected, the individual switching targets are specified as phase angles of the intended electrical switching instants, relative to a positive-going zero crossing in the reference phase. The phase that should be switched first is called "lead phase" (some applications require two lead phases to operate at the same time).

In PWC600 1.1, the reference phase is always L1 regardless which VT phases are connected to the IED. Conversely, the lead phase can be selected arbitrarily according to the application requirements.

For common controlled switching applications, the optimal switching targets are predefined in Switchsync Setting Tool (SST), considering L1 as the lead phase. These should give good results in most use cases. The user just needs to specify the type of load, its electrical connections (vector group) and possibly few other design or application parameters. The tool chooses the recommended controlled switching strategies from its built-in database and presents them as default values. The user may directly adopt the proposed switching targets, or adapt them to any special targeting requirements in the application. Details on specifying controlled switching strategies in PWC600 are given in the following subsections.

4.3.2.1 Controlled energization targets

The making target for the L1 pole is specified as phase angle relative to a positive-going voltage zero of the L1 phase-ground voltage, regardless which VT phases are connected to the IED. For L2 and L3, the making targets are specified as phase angles relative to the L1 target.

As an example, the intended controlled closing strategy for a non-coupled grounded reactor is to energize each phase at its phase-to-ground voltage peak. With L1 as lead phase, this will give L1 making target as 90°, L3 making target at 60° after L1, and L2 target at 120° after L1. Figure 6 shows the way targets are defined in SST based on selected application by the user. The IED will further optimize and convert these electrical into mechanical target points (based on circuit breaker characteristics) and further into release instants (based on mechanical CB properties) for each breaker pole without further user input.

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The optimized electrical target points for individual phases are presented in the operation log as “Target current making angle”. Contrary to the definition above, though, each target making angle stored in operation log is specified relative to the preceding positive-going voltage zero crossing in the same phase (e.g. the L2 target making angle is given relative to a L2 voltage zero). This is shown in Figure 6. For more details on operation evaluation, refer Section 4.5. For this example, considering an “ideal” circuit breaker, for which the impact of circuit breaker characteristics (RDDS and scatter) can be neglected, the pre-defined targets to appear in SST and in the operation log are shown in Table 3.

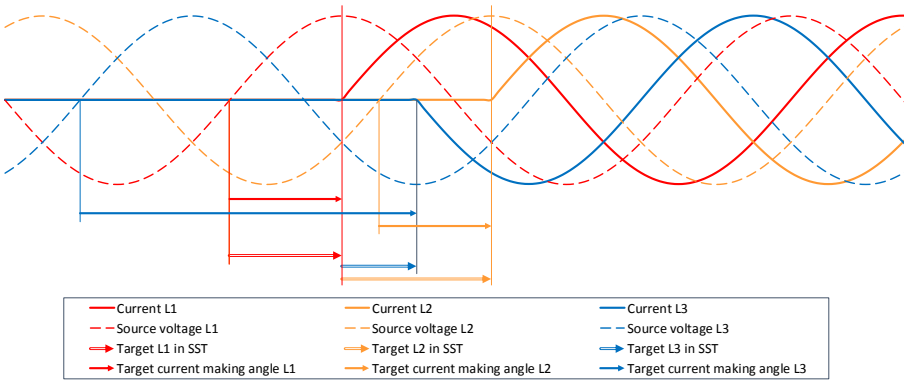


Figure 6: Target definition for controlled energization of non-coupled reactor

Table 3: Targets in SST and operation log for energization of a non-coupled grounded reactor

Making targets	L1 (lead phase)	L2	L3
Defined in SST	90°	120°	60°
Recorded in operation log	90°	90°	270°

4.3.2.2 Controlled de-energization targets

The targets for controlled de-energization are specified in two parts for each phase:

- Expected angle of current interruption, which usually occurs at a natural current zero. Elongation or shortening of the last current half cycle before interruption, due to electrical or magnetic coupling between phases, needs to be taken into account.
- Target arcing time for reliable current interruption. This will give the target instant of CB contact separation.

The current interruption target for phase L1 is specified as phase angle relative to a positive-going zero crossing of either source voltage or breaker current in that phase. The interruption targets in L2 and L3 are specified relative to the L1 target.

As an example, the L1 current interruption target for a non-coupled grounded reactor with L1 as lead phase will be 270° with its source voltage as reference, or 180° with its current as reference. For the second interrupting phase L3, it will be being 60° later than L1, and for the last interrupting phase L2 it will be 120° later than L1. The arcing times for all three phases will be identical (assumed to be 7.5 ms in this example) for a non-coupled grounded reactor. Figure 7 shows the way targets are defined in SST based on selected application by the user. The IED will phase wise convert the current interruption instances into output commands based on defined arcing times for individual phases. Table 4 shows the pre-defined targets to appear in SST for both source voltage and current as reference.

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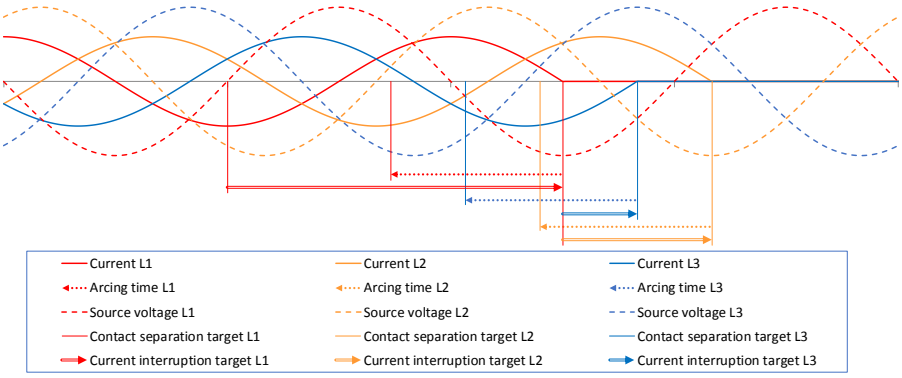


Figure 7: Target definition for controlled de-energization of non-coupled reactor, source voltage reference

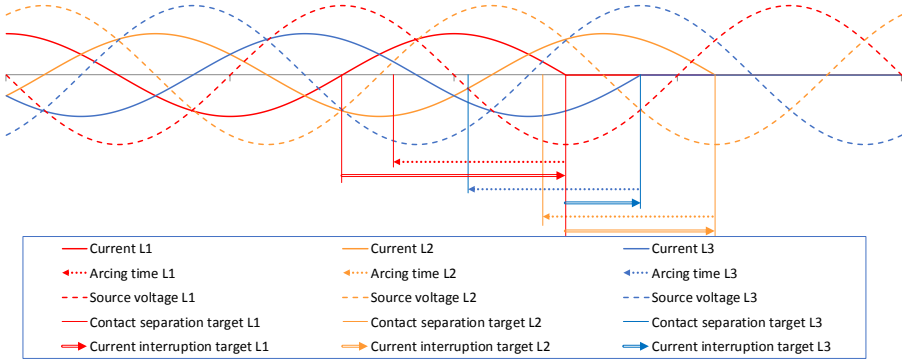


Figure 8: Target definition for controlled de-energization of non-coupled reactor, current reference

Table 4: Targets in SST for de-energization of a non-coupled grounded reactor

Reference signal	Current interruption targets at natural current zero			Arcing time (ms)		
	L1 (lead phase)	L2	L3	L1 (lead phase)	L2	L3
Source voltage	270°	120°	60°	7.5	7.5	7.5
Load current	180°	120°	60°			

SST by default suggests L1 as lead phase for the different applications. Specify a different lead phase by entering a negative value for the L2 and/or L3 interruption target. Refer Section 5.2.3 for more details.

The predefined switching targets are optimized for single-pole operated (SPO) circuit breakers, which are considered best suitable for controlled switching. However, it is possible to perform controlled switching for three-pole-operated (TPO) circuit breakers with ganged operation or mechanical staggering. Refer Section 5.2.2 for more details.

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4.3.3 Circuit breaker properties

Knowledge of key parameters of the circuit breaker is essential for successful controlled switching. These key parameters are usually separate for Close and Open operations.

- Mechanical behavior under nominal conditions (timing, accuracy)
- Dielectric properties (RDDS, re-ignition free window)
- Impact of external influences, such as DC control voltage or temperature, on operating times (compensation curves)
- Permitted limits on deviation from default values
- etc.

Some of these parameters are defined by the circuit breaker design; these can be provided in advance. Others are specific to each pole and are ideally obtained on site during (or prior to) commissioning.

Switchsync Setting Tool (SST) provides easy access to all relevant parameters. The installation package of the Switchsync PWC600 Connectivity Package also includes a library of ABB circuit breaker models, containing design-related parameters. In case the actual circuit breaker model is not included, the user may define a new “custom” circuit breaker type by modifying data from the library, or create a new circuit breaker type altogether.

For acquisition of pole-specific parameters prior to live switching, Switchsync PWC600 provides a “CB timing test mode”. With the main contacts temporarily connected to dedicated inputs, offline switching operations are controlled and evaluated by the IED. The properties thus learned are used in regular operations.

4.4 Optimization of accuracy

The operating times (switching times) of the circuit breaker may change with certain parameters, such as time (age), temperature, idle time since the last operation, and DC control voltage. To optimize the controlled switching performance against such changes, Switchsync PWC600 provides two features, parameter compensation and adaptive correction. Based on these features, the release instants of the circuit breaker are adjusted for optimal targeting during controlled switching operations.

4.4.1 Parameter compensation

The Switchsync PWC600 IED has the facility to compensate for the influences of external and internal parameters, namely, DC control voltage, idle time, temperature, drive pressure, spring charge, and an additional user-defined parameter. For each of these, it applies individual parameter compensation curves consisting of parametric variation vs. required operating time correction. Separate curves are provided for Close and Open operations. The individual compensation values are added up to yield a total compensation value for each CB pole.

The library of ABB circuit breakers includes compensation curves for each CB type. During engineering in Switchsync Setting Tool, the user only needs to specify which sensors are connected to the IED. Accordingly, the compensation functions are activated. It is possible to enable, disable or modify individual compensation curves manually. Respective sensor signals are either connected to the IED directly, or are received from external acquisition devices (such as ABB RIO600) via IEC 61850 analog GOOSE messages. See Table 5 below.

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Table 5: Compensation facilities in pre-configuration

Parameter	Sensor	Qty.	Inputs to IED
DC control voltage	Voltage sensor	1	DC supply on PSM module
Idle time	Internal calculation based on status of current signal, load voltage signal, and/or CB auxiliary contacts	3	CT or VT inputs on TRM module, current or voltage samples via IEC 61850-9-2, or binary inputs on PIO module
Stored energy in CB drive	Set of 1 or 2 binary level contacts	1 or 3 sets	Binary inputs on BIO module
Temperature	Temperature sensor (e.g. Pt100) connected to external acquisition device	1 or 3	Analog GOOSE
Drive pressure	Pressure sensor connected to external acquisition device	1 or 3	Analog GOOSE
Additional quantity (user-specified)	Sensor for additional quantity, connected to external acquisition device	1 or 3	Analog GOOSE

Compensation values are continuously updated. Thus, the actual compensation value is available at the time when a controlled switching operation is executed. Furthermore, each sensor signal is checked against supervision thresholds, and an alarm can be raised on crossing a limit.

4.4.2 Adaptive correction

After completion of a controlled switching operation, Switchsync PWC600 acquires the instants when the switching actually took place. For this purpose, it analyzes the primary analog signals (load current, load voltage) and the timing of binary signals from auxiliary contacts in the CB drive, as available. The instants of inception or interruption of the primary signals are determined using adjustable detection thresholds, see Section 4.5.1.2.

Recommendations on the selection of feedback signals are given in Section 4.5.4.

The actual switching instants are compared with the target instants; the difference is called Target error. It is the basis for adaptive correction and other monitoring features.

4.4.2.1 Adaptive correction for closing

For closing operations, a fraction β (Beta factor) of the target error is used as correction value, to update the estimated CB operating time for the next controlled closing operation. This process is known as “adaptive correction”; its purpose is to compensate systematic changes in the circuit breaker’s operation characteristics over time.

PWC600 maintains internal adaptive correction values T_3 for each breaker pole. After each controlled closing operation, T_3 is updated with the target error ε according to

$$T_{3(new)} = T_{3(old)} + \beta \cdot \varepsilon$$

(Equation 1)

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Higher values of β will make the adaptive correction converge faster but may cause overshoot in case of fluctuating target errors. Conversely, lower values of β will provide smooth approach to the ideal target but will take longer to converge.

These calculations are done for each phase individually. Separate β factors are provided for electrical and mechanical feedback; however, it is recommended to use adaptive correction only on either electrical or mechanical feedback and set the other β factor to zero.

When using load current or load voltage for detecting the actual switching instants, adaptive correction is limited to adjusting for target errors not exceeding a quarter cycle. Hence, it is important to validate the actual controlled switching performance from the waveform records during commissioning. If high target errors are observed, the appropriate settings must be adjusted for good initial target accuracy.

4.4.2.2 Adaptive correction for opening

For opening operations, detection of each restrike/ reignition in any phase will cause increment in target arcing time by 1 ms for the respective phase for the next operations. The number of allowed increments (re-strike/re-ignition corrections) can be configured as disabled, 1 ms or 3 ms. If exceeding the number of allowed re-strike/re-ignition corrections, CB operations will be blocked irrespective of the contingency mode set by the user.

The internal values for adaptive correction and operation logs are periodically written to non-volatile memory to be preserved against power loss. To maximize the life of the memory elements, the write interval has been defined as 1 hour; this cannot be changed by the user. Therefore, to prevent loss of data, the IED should not be powered off within 1 hour of the last switching operation.

4.4.3 Overall optimization

4.4.3.1 Optimization of closing operations

For Close operations, the target instant T_{tC} of mechanical contact touch in each phase is internally calculated as follows.

$T_{tC} = T_0 + T_1 + T_2 + T_3 + T_4$

where

T_0 = ideal making target

T_1 = offset from ideal target, to cater for dielectric and mechanical scatter

T_2 = total combined correction value from parameter compensations

T_3 = total combined correction value for electrical and/or mechanical adaptation

T_4 = expected pre-arcing time (time between current inception and mechanical contact touch)

To achieve best possible performance considering dielectric and mechanical scatter, the difference in pre-strike voltage at both boundaries of the target making window shall be minimized. Consequently, the final (strategic) making target is slightly shifted from the ideal

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target: forward for gap voltage zero target and back for gap voltage peak target. T_1 and T_4 during controlled closing operation at voltage peak target and voltage zero target are demonstrated in Figure 9 and Figure 10 respectively.

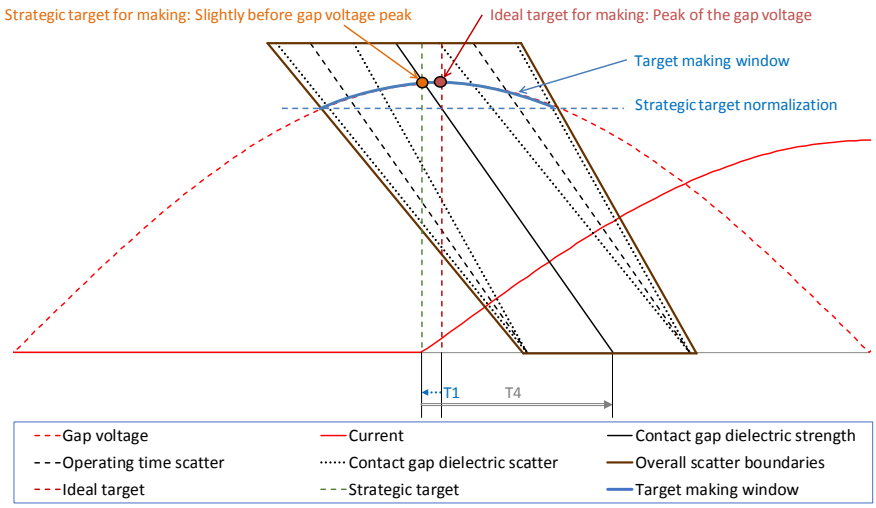


Figure 9: Switching target optimization for controlled closing, voltage peak targeting

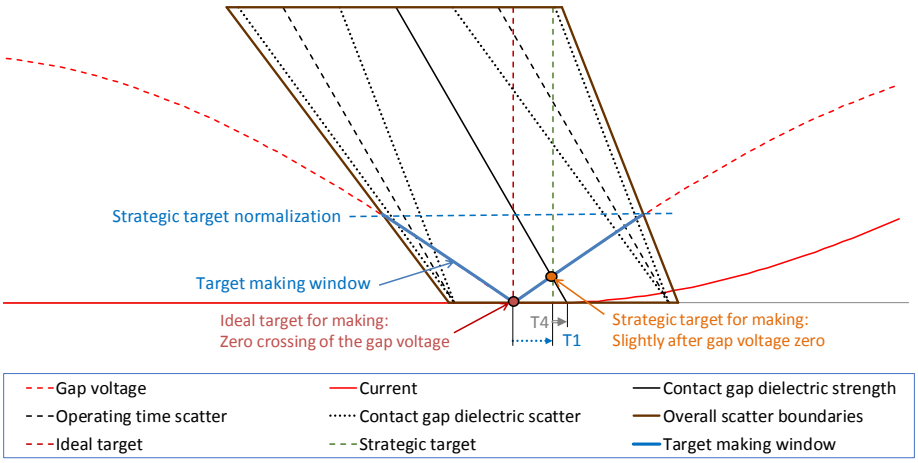


Figure 10: Switching target optimization for controlled closing, voltage zero targeting

Whenever the making target is specified as 0° or 90°, PWC600 optimizes the actual target instants as described above. For any other making target, no optimization is done but the actual target instants are constrained to the range spanned by the strategic targets for 0° and 90°.

4.4.3.2 Optimization of opening operations

For controlled opening operations, the target instant T_{tO} of mechanical contact separation is calculated as:

$$T_{tO} = T_0 - T_3 - T_4 = T_0 - T_5$$

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where

T_0 = ideal interrupting target

T_3 = adaptive correction value for target arcing time due to re-strike or re-ignition detection

T_4 = initial target arcing time (time between mechanical contact separation and current interruption)

T_5= Extended arcing time due to adaptive correction

T_3, T_4 and T_5 are shown in Figure 11, which depicts current interruption at reference voltage peak.

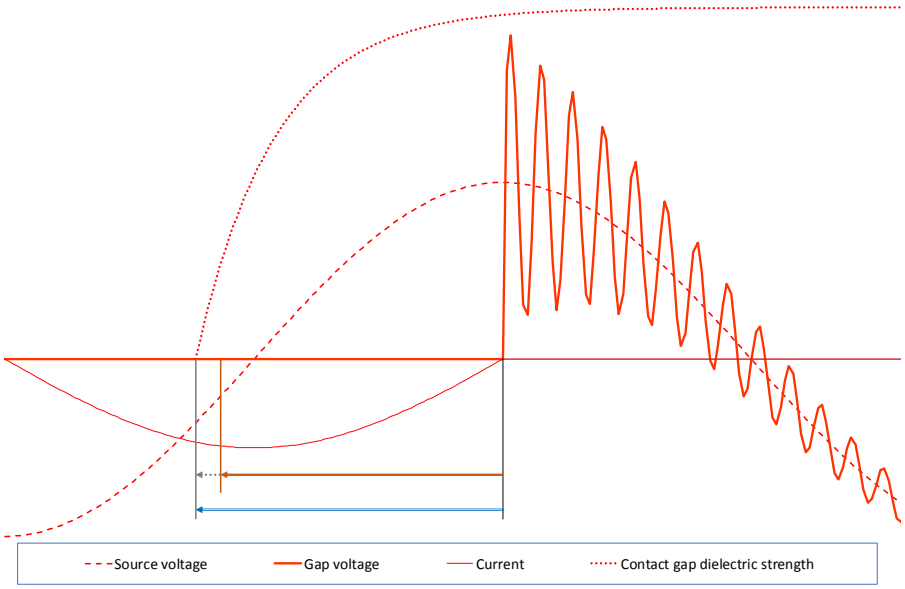


Figure 11: Optimization of contact separation target for controlled opening (source voltage reference)

4.5 Monitoring and supervision

All signals acquired by the Switchsync PWC600 IED are primarily used for execution and optimization of controlled switching operations. In addition, the same signals can be used for monitoring and supervision of the circuit breaker's switching performance and its aging (due to number of operations or interrupter wear).

On receiving a switching command, the available compensation signals are evaluated for compensation values. After issuing a switching command, the IED monitors the input signals for status changes. The sequence of these events is evaluated to determine actual operating times and further conditions such as re-ignitions/re-strikes. All these data are recorded in the operation log.

The very first operation records (default: 20) are stored as "fingerprint records" in a separate instance of the operation log for later reference.

Table 6 summarizes the potential use of external signals (if available).

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Table 6: Circuit breaker monitoring features

Signals	Controlled switching optimization	Monitoring and supervision
Current through CB	• Adaptive correction of electrical switching times • Idle-time compensation of mechanical switching times	• Electrical switching target errors • Electrical making times and interrupting times • Re-ignition/re-strike • Interrupter wear (contact ablation, nozzle erosion) • Circuit breaker status (open, closed) • Idle time (time since last CB operation) • Externally initiated switching operation • CB operations count
Load voltage	• Adaptive correction of electrical switching times • Idle-time compensation of mechanical switching times	• Electrical switching target errors • Electrical making times and interrupting times • Circuit breaker status (open, closed) • Idle time (time since last CB operation) • Externally initiated switching operation • CB operations count
Auxiliary contacts status	• Adaptive correction of mechanical switching times • Idle-time compensation of mechanical switching times	• Mechanical switching target errors • Mechanical closing times and opening times • Initial delay time, moving time • Idle time (time since last CB operation) • Externally initiated switching operation • CB operations count
DC control voltage	• Voltage compensation of mechanical switching times	• Limit supervision
Temperature	• Temperature compensation of mechanical switching times	• Limit supervision
Drive pressure	• Pressure compensation of mechanical switching times	• Limit supervision
Spring charge	• Spring charge compensation of mechanical switching times	• Limit supervision
Additional quantity (user defined)	• Additional compensation of mechanical switching times	• Limit supervision
Trip circuit voltage	-	• Trip circuit supervision

For estimating interrupter wear, it is recommended to use protection class CT cores.

Various supervision alarms have been pre-defined to indicate if the associated parameter crosses the limit. Each alarm can have two stages: warning and alarm, for which user can define the limits, and which can be individually enabled or disabled.

4.5.1 Electrical operations monitoring

Following every controlled switching operation, certain parameters are extracted from the recorded feedback signals, which can be selected as CB current or load voltage. They are

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summarized in Table 7. Close and Open commands refer to the control signals given to the circuit breaker drive.

Table 7: Monitored electrical parameters

Parameter	Definition	Remarks
Circuit breaker status	Current through CB, or load voltage, is above threshold	For loads of type power transformer, transmission line, or power cable, the nominal load current needs to be set to the expected charging current under no-load conditions.
Current making angle	Phase angle of detected current inception instant, relative to positive-going reference voltage zero crossing	Relevant for CB closing operations only.
Electrical operating time (making time, interrupting time)	Closing (current making): Time from CB Close command to current inception	Obtained from CB current or load voltage signals
	Opening (current interruption): Time from CB Open command to final current interruption	
Arcing time	Time from estimated instant of mechanical separation of arcing contacts to final current interruption	Relevant only for CB opening operations.
Electrical target error	Difference between actual (measured) electrical operating time and predicted (target) electrical operating time	
Re-ignition/re-strike	Re-occurrence of CB current detected after the expected current interruption instant	Every detected re-ignition/re-strike increases a counter and increases the target arcing time (up to a set limit).
Interrupter wear	Combined figure of contact erosion, nozzle ablation, and so on, based on interrupted primary current	

4.5.1.1 Circuit breaker electrical status

Switchsync PWC600 attempts to detect electrical status change of the circuit breaker (current making or current interruption) from the primary current or load voltage signals. The strategies employed vary by the set load type.

- For capacitor bank and shunt reactor type loads, it can be assumed that load current is generally above dead-band value when energized.
- Power transformers exhibit very low magnetizing currents when energized. These currents are usually too low for reliable electrical operation detection. Electrical status detection is therefore based on load voltage only, if available. However, in case of electrical or magnetic coupling, additional measures are needed for correct detection of the making instants. Refer to Section 5.2.5 for details.



Electrical and magnetic coupling between phases can mislead the status detection algorithm. Hence, it is recommended to connect auxiliary contacts to the IED to allow mechanical status detection especially when load voltage is not used to detect the electrical operations.

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In case of a weak source, switching operations may cause voltage interference between phases for loads that are not solidly grounded. Therefore it is recommended to use current as feedback signal except for transformer application.

4.5.1.2 Detection of electrical switching instants

Detecting the precise instant of current making or current interruption is crucial to maintaining optimal accuracy by adaptive correction, and for faithful reporting of the controlled switching success. For detecting the actual instants when the selected electrical feedback signal starts or stops, PWC600 checks the signal against two thresholds.

1. Coarse threshold: The percentage of base value of voltage or current (based on selected feedback for monitoring and adaptation) to eliminate incorrect detection. This threshold should be high enough for reliable discernment of the presence or absence of the feedback signal even in the presence of noise, crosstalk, or inter-phase coupling effects.

2. Fine threshold: The percentage of base value of voltage or current (based on selected feedback for monitoring and adaptation) at which making or interruption is to be detected. This threshold should be low enough to achieve accurate inception or interruption instant detection while eliminating the effect of noise.

Always the fine threshold setting should be lower than the coarse threshold setting for both energization and de-energization operations.

Table 8 shows the proposed values of thresholds to be set in SST for different load applications.

Table 8: Suggested coarse and fine threshold settings for various applications

Load	Feedback signal	Close		Open	
		Coarse threshold	Fine threshold	Coarse threshold	Fine threshold
Capacitor	Current	10%	3%	20%	3%
Reactor	Current	10%	3%	20%	3%
Transformer	Load voltage	30%	20%	20%*)	3%*)
Transmission line or cable	Load voltage	10%	3%	20%	10%
*) not relevant as load voltage cannot be used for detecting interruption instants.					

Generally, the proposed values given in Table 8 provide good accuracy in detection. In case of initially incorrect results the thresholds should be adjusted to provide sufficient margin considering possible variations in noise level.

PWC600 further converts the detected instants of current making and current interruptions into electrical operating times and actual switching angles. These values are recorded in the operation log and used for further monitoring purposes as described above.

Making instant detection
During closing operation, the algorithm initially detects the point where the absolute value of the signal first rises above the coarse threshold. From there, it back-tracks the waveform till it crosses the fine threshold. The earliest point where the signal crosses the fine threshold is declared as the inception instant.

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Figure 12 demonstrates the way fine and coarse threshold are set for correct detection of making instant based on electrical current feedback. It can be observed that with proper adjustment of these thresholds, current start with very low magnitude can be detected with good accuracy. The error in detection is the time difference between the green and the red points marked in the figure, which happens to be very small.

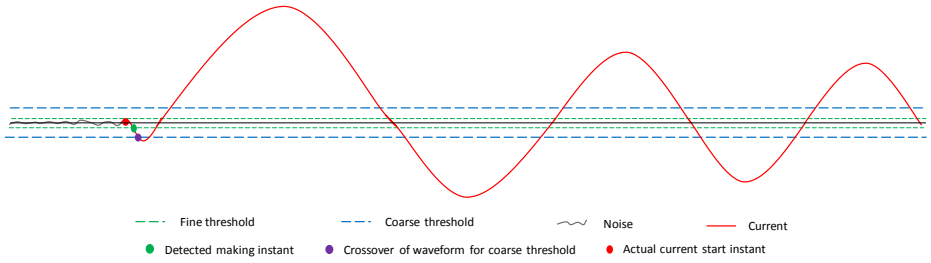


Figure 12: Defining thresholds for making instant detection during energization

Interrupting instant detection

For load de-energization, current interruption in most cases occurs at a natural current zero. Thus, the actual instant of contact separation cannot be deduced from the primary voltage and current signals. However, Switchsync PWC600 checks the current signals for signs of re-ignitions/re-strikes, in particular final current interruption occurring significantly later than expected. Moreover, after actual current interruption, many times, noise having decaying DC or L-C oscillatory nature is observed. This may lead to wrong re-ignition detection. To ensure proper detection, coarse and fine threshold settings shall be adjusted as shown in Figure 13.

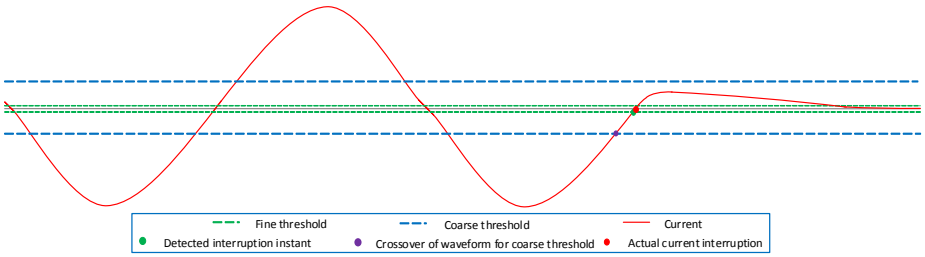


Figure 13: Defining thresholds for current interruption instant detection during de-energization

During opening operation, the algorithm initially detects the point where the absolute value of the signal last drops below the coarse threshold. From there, it forward-tracks the waveform till it crosses the fine threshold. The instant of crossing the fine threshold is declared as the interruption instant. As shown in Figure 13, the coarse detection threshold should be set to a fairly low value to enable detection of re-ignitions of low current amplitude. Moreover, this value should be set to provide sufficient margin against noise, decaying DC, or fast oscillatory signals.

4.5.1.3 Detection of re-ignitions/re-strikes

During opening, the circuit breaker is usually expected to interrupt the primary current at its natural zero. If current starts flowing again after that current zero, this is called a re-ignition (for inductive loads) or re-strike (for capacitive loads). The steep voltage front of current restart may damage the interrupter, hence it is desirable to avoid such events.

In every controlled opening operation, Switchsync PWC600 checks the electrical interrupting time from the load current signal (when available). If final current interruption is observed

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within 1/4 of the power cycle later than expected, this is interpreted as re-ignition as shown in Figure 14.

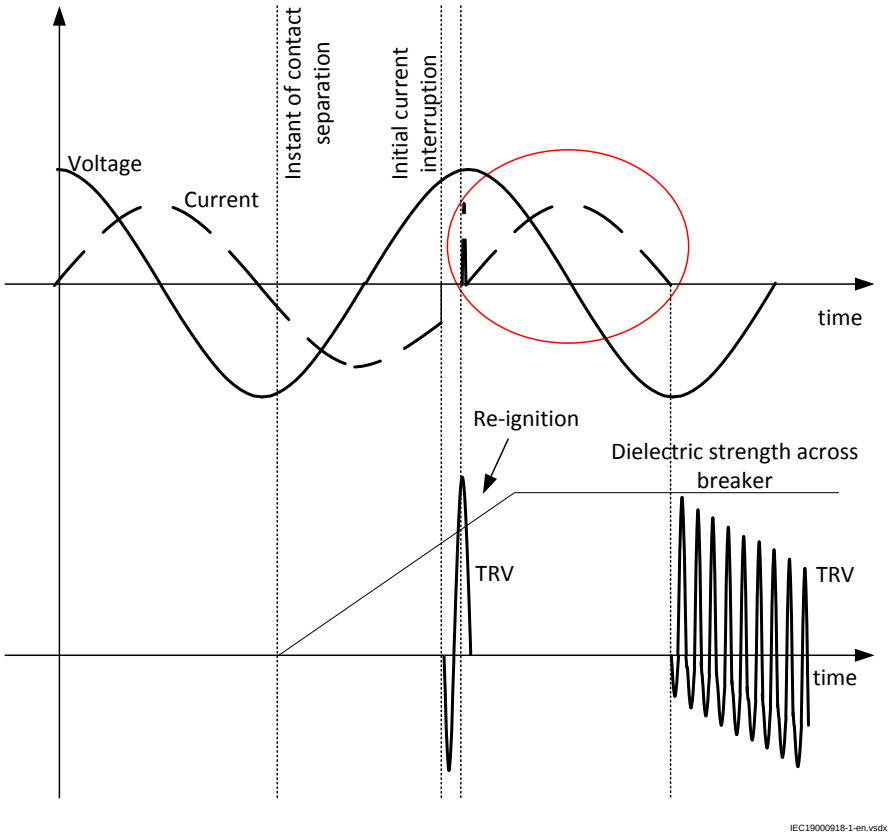


Figure 14: Re-ignition in an inductive load

On the other hand, if the current interrupt interrupts later than 1/4 of the power cycle than expected, its considered as re-strike as shown in Figure 15.

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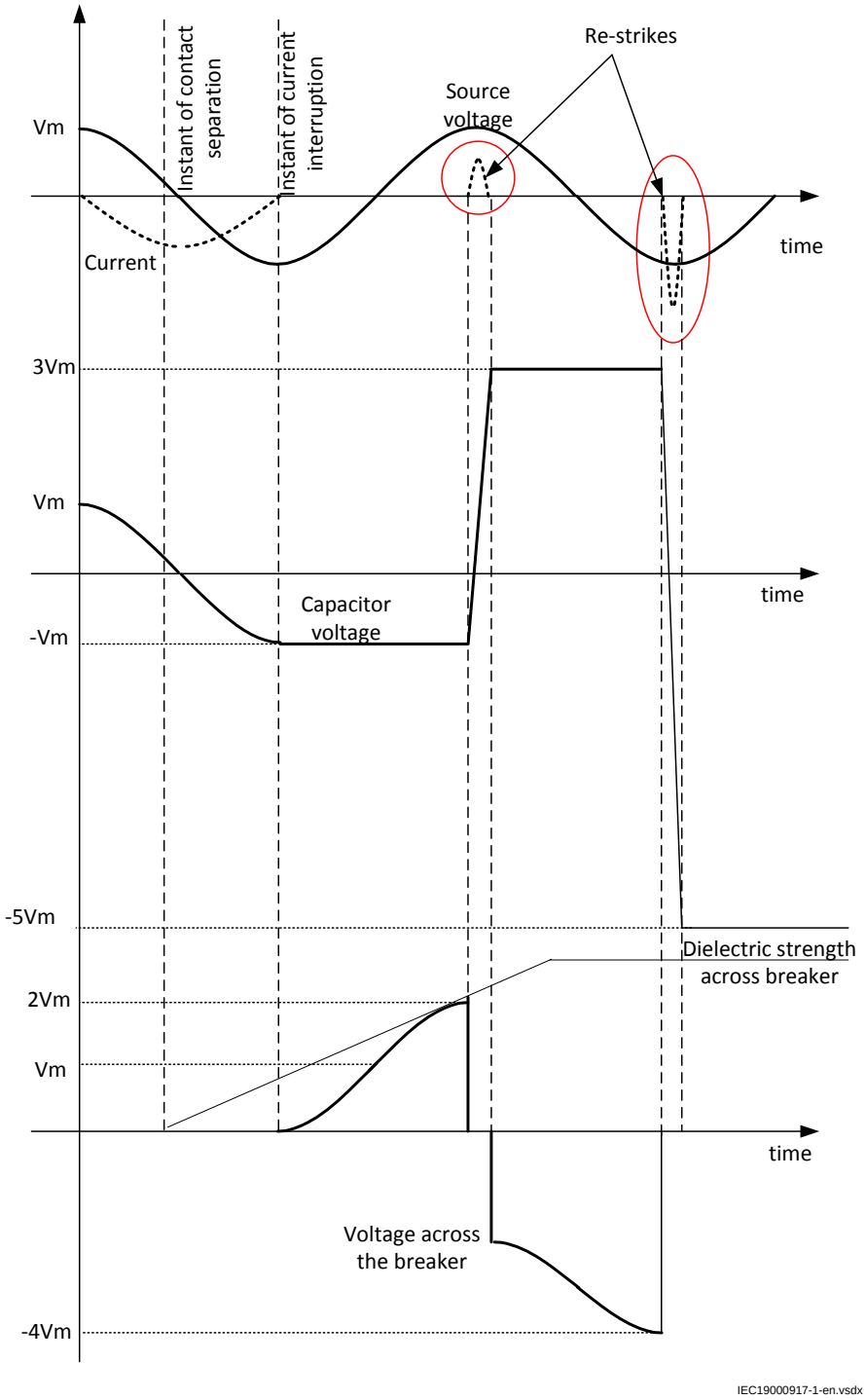


Figure 15: Re-strike on a capacitive load

4.5.1.4 Interrupter wear

In new condition, a circuit breaker is rated for a certain number of mechanical operations, that is, interrupting no or very low currents. It is also rated for a certain (low) number of operations interrupting maximum fault current. Between these extremes, the interrupted current in every Open operation causes some erosion of the contacts and ablation of the nozzles, until the CB

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loses its ability to reliably switch off currents. This interrupter wear characteristic is often given in form of a curve.

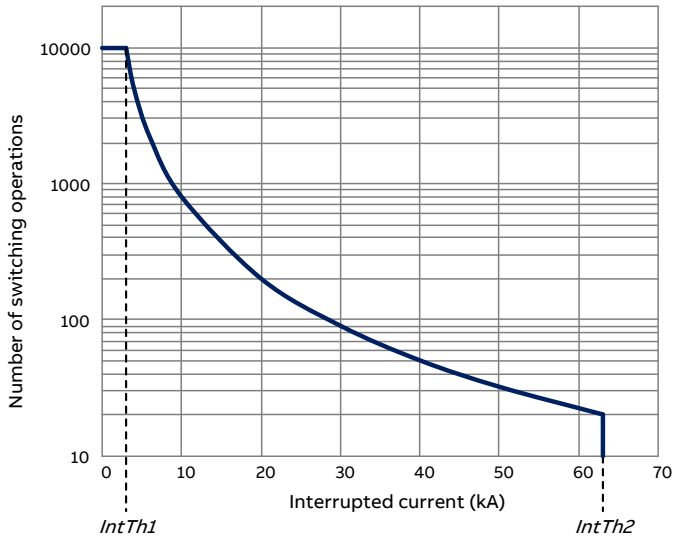


Figure 16: Example of interrupter wear characteristic of a circuit breaker rated for 10000 mechanical operations (interrupting currents up to IntTh1 = 3000 A) or 20 interruptions of rated fault current IntTh2 = 63 kA

Switchsync PWC600 calculates interrupter wear as the equivalent number of mechanical operations that the circuit breaker has lost after interrupting a specific current. This individual value and the cumulated interrupter wear are recorded in the operation log. Upon reaching the limits specific to each breaker type, a warning or alarm will be raised. The algorithm for calculation of interrupter wear is explained in the Technical Manual.

It is recommended to contact ABB for obtaining the optimal coefficients for interrupter wear of any circuit breaker type that is not included in the CB library of SST.

4.5.2 Mechanical operations monitoring

Following every switching operation, certain parameters are calculated from recorded instants of auxiliary contacts' changeover. They are summarized in Table 9, assuming both contact types (52a/NO and 52b/NC) are connected to the Switchsync PWC600 IED. Close and Open commands refer to the control signals given to the circuit breaker drive.

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Table 9: Monitored mechanical parameters

Parameter	Definition	Remarks
Initial delay time	Closing: T_{NC} = Time from Close command to opening of 52b (NC) contact Opening: T_{NO} = Time from Open command to opening of 52a (NO) contact	Can be calculated only if respective auxiliary contact signals are available.
Moving time T_{NONC}	Closing: $T_{NO} – T_{NC}$ = Time from opening of 52b (NC) to closing of 52a (NO) contact Opening: $T_{NC} – T_{NO}$ = Time from opening of 52a (NO) to closing of 52b (NC) contact	Can be calculated only if both auxiliary contact signals are available.
Mechanical operating time (closing time, opening time)	Closing: T_{main} = Time from Close command to estimated point of contact touch Opening: T_{main} = Time from Open command to estimated point of contact separation	Linear estimation, based on initial delay time and moving time.
Mechanical target error	Difference between actual (measured) mechanical operating time and target mechanical operating time	
Unstable operating times	Fluctuation between several consecutive operating times higher than threshold	Indication of unstable operating times must be cleared manually.

Figure 17 shows a typical circuit breaker closing operation, to demonstrate the mechanical monitoring parameters. The main portion of the linear travel curve (gray) is approximated by a straight line (black) connecting the changeover points of the 52a (NO) and 52b (NC) auxiliary contacts. The vertical axis marks the time when the closing command is given to the CB drive (t=0).

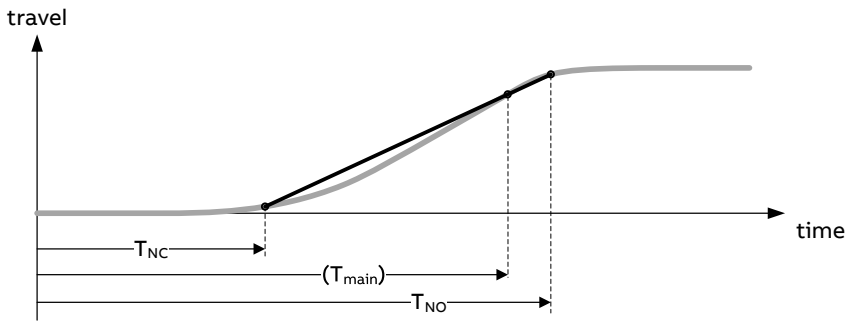


Figure 17: Definition of mechanical monitoring parameters for a CB Close operation. Definition for Open operations is equivalent.

4.5.3 Recommended alarms

Table 10 shows the list of user settable alarms to be enabled for different applications. For the alarms listed in the table, if any application is not mentioned, the respective alarm can be disabled. User requirements take precedence.

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Table 10: Recommended alarms to be enabled for various applications

Alarm list	Application
Unsynchronized switching operation	All
Actual switching instants, or CB operating time, out of limit	All
Re-ignition/re-strike	Reactor, capacitor, cable
Unstable circuit breaker operating characteristics	Overhead transmission lines
Loss of reference signal	All

The full list of possible alarms and other diagnostic indications is given in Section 16.1.

4.5.4 Selection of feedback signals

Table 11 shows the list of required feedback signals for various load applications. The mentioned signals are applicable for any design and connection configuration of the specified load. For any type of load, the source voltage (1 or 3 phases) must be used as reference for controlled closing operations.

Table 11: Recommended list of reference and feedback signals for various applications

Load	**Purpose**	**Required signals**	**Remark**
Capacitor bank, shunt reactor	Controlled opening reference	Load current (3 phases) or Source voltage (1 or 3 phases)	
	Switching evaluation, adaptive correction, re-strike detection	Load current (3 phases)	
Power transformer	Controlled opening reference	Source voltage (1 or 3 phases)	
	Adaptive correction	Mechanical status indication (from auxiliary contacts) or Load voltage	Selection of feedback among mechanical status indication or load voltage is done based on CB model and system conditions. Contact ABB for guidance.
Discharged transmission line, power cable	Controlled opening reference	Source voltage (1 or 3 phases)	
	Adaptive correction, re-strike detection	Load voltage (3 phases, phase to ground)	The charging current for cables are generally low so current is not available for selection as feedback. However, for long cables having higher charging currents, current feedback may be suitable for adaptation in closing as well as for re-strike/re-ignition detection in opening. For such cases, use capacitor bank as the load to use current feedback.

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In case of severely distorted current signal, high errors in switching instant detection may be observed even with adjusting the threshold. In such cases, the load voltage signal should be used for feedback.

4.5.5 Trip circuit supervision

Three of the binary outputs of the PWC600 IED feature additional circuitry for supervising the status of a CB trip circuit. Whereas these outputs are not used in PWC600, the trip circuit supervision (TCS) functionality can be applied to the controlled circuit breaker.

The TCS continuously injects a small DC current into the coil circuit and measures the resulting voltage at its terminals. This voltage is expected to fall in a certain range. If the voltage is too low this indicates a short circuit. Similarly, if the voltage is too high this indicates an open circuit. Both conditions will raise an alarm, if enabled.

Implementation of TCS is explained in Section 7.5.

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Section 5 Specific load applications

This section describes the controlled switching strategies and related settings for different load applications. Target settings to be applied in PWC600 for common load applications having different design and connection configurations are described in Section 5.1. Few special applications including switching sequence having lead phase other than L1, switching with gang operated mechanically staggered circuit breakers, controlled switching of impedance grounded reactors, and variable applications taking advantage of setting groups, are discussed in Section 5.2.

5.1 Standard load applications

In this section, switching strategies for standard load applications are discussed, namely, capacitor banks, reactors, transformers, cables and discharged transmission lines. Recommended controlled switching strategies are given in the following subsections.

These considerations always assume

- Solidly grounded source of the power system
- Phase rotation L1-L2-L3
- Single-pole operated circuit breaker
- Lead phase (first phase to operate) L1

PWC600 takes into account different configurations of the power system and the load automatically, same as the properties of the “real” circuit breaker. As an example, if the source/system or the load is ungrounded then the controlled switching strategies for an ungrounded load are applied. The dissimilarity in gap voltage factors (during energization) and last half cycle loop lengths (during de-energization) for individual poles of the circuit breaker are considered while calculating the recommended targets.

Contact ABB for load applications or connection configurations other than the ones described in this section. Also, contact ABB for non-standard applications such as switching of shunt reactor compensated cables.

Table 12 lists the application cases for various load configurations covered in this section.

Table 12: Application of controlled switching to various load configurations

Load	Configuration	Neutral	Section
Capacitor bank	YN	Grounded	Section 5.1.1
	Y/D	Ungrounded/not applicable	Section 5.1.2
Shunt reactor	YN – Individual bank, 4-limb or 5-limb core	Grounded	Section 5.1.3
	Y/D – any core design	Ungrounded	Section 5.1.4
	YN – 3-limb core	Grounded	Section 5.1.5
Table continues on next page			

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Load	Configuration	Neutral	Section
Power transformer	YNyn/YNy or similar – Non-coupled transformer charged from YN winding	Grounded on side of charging	Section 5.1.6
	YNd/YNynd/YNyd or similar – Electrically and/or magnetically coupled transformer charged from YN winding	Grounded on side of charging	
	Yyn/Yy/Yd/Dyn/Dy/Dd or similar – Any transformer charged from Y or D winding	Ungrounded on side of charging	
Transmission line and power cable	Discharged at time of energization	Not applicable	Section 5.1.7

5.1.1 Grounded capacitor bank

A discharged star-connected capacitor bank with grounded neutral is ideally energized at a source voltage zero crossing in each individual phase. If energizing polarity is not critical, the recommended sequence is L1-L3-L2 with 60° spacing between energization of the phases. For de-energization of a grounded star-connected capacitor bank, the recommended current interruption sequence is again L1-L3-L2 with 60° phase difference between phases. Optimum arcing times for all three phases will be identical as the phases are not coupled.

Table 13 shows the recommended targets for energization and de-energization of a grounded capacitor bank.

Table 13: Controlled switching targets for grounded capacitor bank

	Making targets			Current interruption targets at natural current zero		
	L1 (lead phase)	L2	L3	L1 (lead phase)	L2	L3
Switching strategy	Slightly after negative-going zero crossing of L1 phase-to-ground voltage	120° after L1	60° after L1	Positive-going zero crossing of L1 phase current	120° after L1	60° after L1

5.1.1.1 Controlled energization

Table 14 shows the settings to be applied for controlled closing with PWC600 to achieve the switching strategy described in Table 13.

Table 14: Settings for controlled closing with PWC600 for grounded capacitor bank

Target making angle (deg)			Gap voltage prior to current making (p.u.)		
L1 (lead phase)	L2	L3	L1	L2	L3
180°	120°	60°	1.00	1.00	1.00

Internally, PWC600 will add an offset to the entered making targets, to cater for the dielectric and mechanical characteristics of the specific circuit breaker, as explained in Section 4.4.3.1. These optimized targets can be seen as **Target current making angle** in the operation log.

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Figure 18 shows the waveform representation for controlled energization of a grounded capacitor bank.

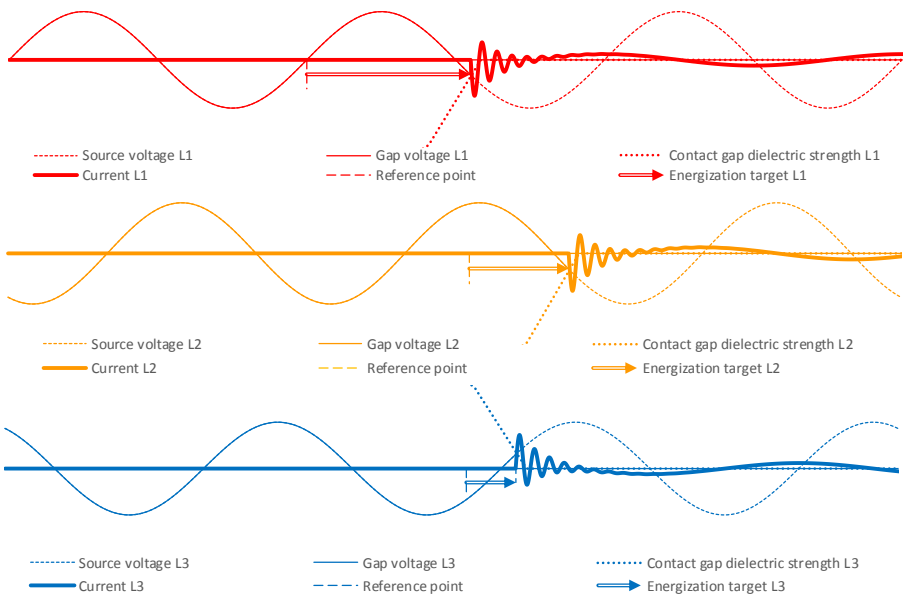


Figure 18: Controlled energization of a grounded capacitor bank

5.1.1.2 Controlled de-energization

Table 15 shows the settings to be applied for controlled opening with PWC600 to achieve the switching strategy described in Table 13.

Table 15: Settings for controlled opening with PWC600 for grounded capacitor bank

Interruption target (deg)			**Arcing time (ms)**					
L1 (lead phase)	**L2**	**L3**	**50 Hz**			**60 Hz**		
			L1 (lead phase)	**L2**	**L3**	**L1 (lead phase)**	**L2**	**L3**
Source voltage reference								
270°	120°	60°	5.5			4.6		
Load current reference								
360°	120°	60°	5.5			4.6		

Figure 19 shows the waveform representation of controlled de-energization of a grounded capacitor bank.

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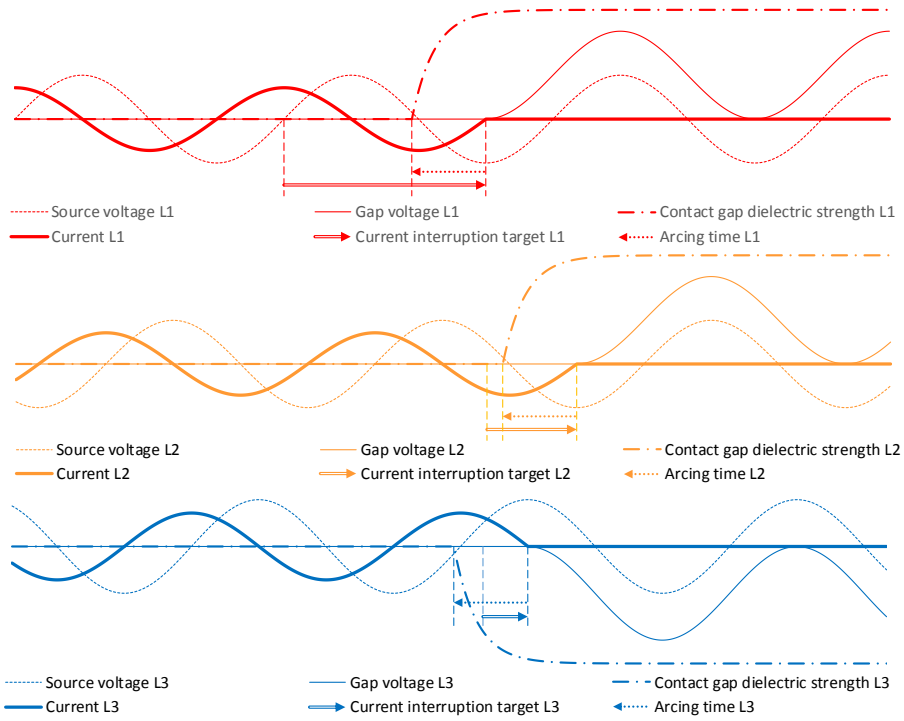


Figure 19: Controlled de-energization of a grounded capacitor bank using source voltage as reference

5.1.2 Ungrounded or delta connected capacitor bank

A discharged star-connected ungrounded or delta connected capacitor bank is ideally energized in L1-L2-L3 sequence. The first energizing phase L1 will see no pre-strike until first following pole L2 energizes, as the current will not flow until two circuit breaker poles are closed. In this case, the second energizing pole L2 will see line-to-line voltage of 1.73 pu prior to current making, and the ideal making target is at zero crossing of this voltage. After energizing of L1 & L2 poles, the last pole to close L3 will see 1.5 pu gap voltage due to neutral voltage shift and its ideal energization target is at zero crossing of this voltage, which appears 90° after L1 & L2 energization. The dissimilarity in gap voltages for individual circuit breaker poles is considered while evaluating the pre-arcing times for individual phase targets.

For an ungrounded capacitor bank, current interruption will take place in one pole initially followed by remaining two poles together. Moreover, due to shift in neutral point potential, the last loop length (that is, length of the last current half-cycle prior to interruption) in the second and third phases to open will become dissimilar. First interrupting pole will have 180° last loop length, whereas the second pole will see 30° shortening and the third pole will see 30° elongation in last loop length. The recommended sequence of current interruption is therefore, L1-L2L3. Also, the individual poles will see dissimilar over voltages across the contact gap. However, due to slow rising gap voltage for all three interrupting poles, target arcing times can be set identical for all three phases.

Table 16 shows the proposed targets for energization and de-energization of an ungrounded capacitor bank.

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Table 16: Controlled switching targets for ungrounded capacitor bank

	Making targets			Current interruption targets at natural current zero		
	L1 (lead phase)[1)]	**L2**	**L3**	**L1 (lead phase)**	**L2**	**L3**
Switching strategy	150° - Φ_D	Φ_D after L1	90° after L2	Positive-going zero crossing of L1 phase current	L2 & L3 together: 90° after L1	

1) Φ_D advancement in target of L1 to ensure that the switching of L1 happens prior to L2 and pre-strike happens across L2 only.

In some cases, L1L2-L3 switching strategy for energization is used, where first two poles (L1 & L2) are energized together followed by the last phase (L3) 90° later. Contact ABB for more details.

5.1.2.1 Controlled energization

Table 17 shows the settings to be applied for controlled closing with PWC600 to achieve the switching strategy described in Table 16. The source side voltage is considered as reference for the application.

Table 17: Settings for controlled closing with PWC600 for ungrounded capacitor bank

Target making			Gap voltage prior to current making (p.u.)		
L1 (lead phase)*	**L2**	**L3**	**L1**	**L2**	**L3**
150° -Φ_D	Φ_D	90° +Φ_D	0	1.73	1.5

Internally, PWC600 will add an offset to the entered making targets, to cater for the dielectric and mechanical characteristics of the specific circuit breaker, as explained in Section 4.4.3.1. These optimized targets can be seen as **Target current making angle** in the operation log.

Figure 20 shows the waveform representation for controlled energization of an ungrounded capacitor bank.

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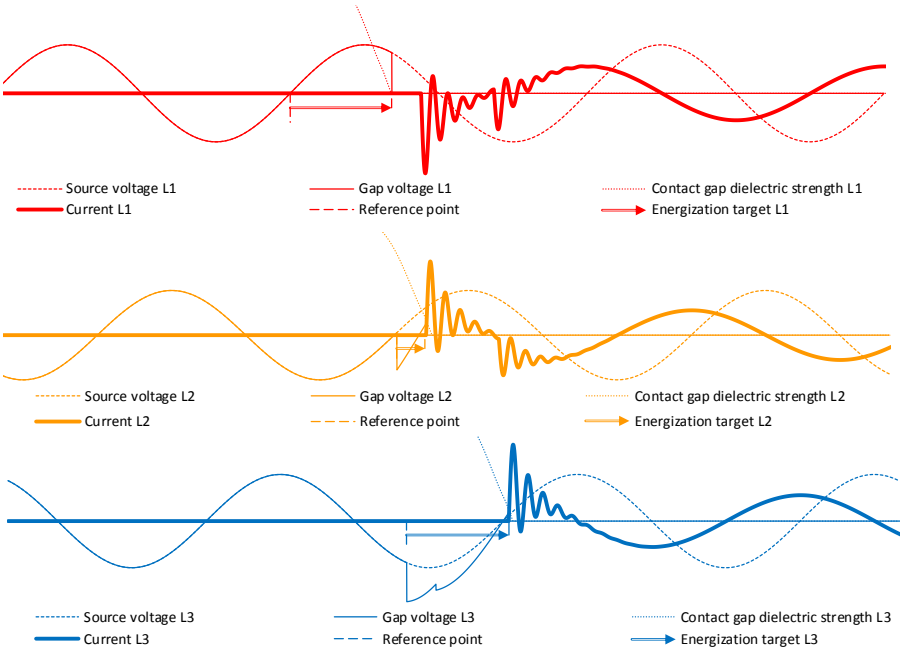


Figure 20: Controlled energization of an ungrounded capacitor bank

If electrical monitoring is selected, to achieve proper monitoring and adaptation, disable adaptive correction for first energizing pole (L1) and put the maximum possible RDDS value, since no prestrike will be observed in first pole to close. Also, large electrical target errors will be recorded for this phase. To prevent raising of false alarms, remove the threshold supervision for the lead phase. Refer to Section 9.4.6.2. In the operation records for closing operations, the “Electrical operating time” and “Current making angle” values for the first energizing pole (L1) can be disregarded.

5.1.2.2 Controlled de-energization

Table 18 shows the settings to be applied for controlled opening with PWC600 to achieve the switching strategy described in Table 16.

Table 18: Settings for controlled opening with PWC600 for ungrounded capacitor bank

Interruption target (deg)			**Arcing time (ms)**					
L1 (lead phase)	**L2**	**L3**	**50 Hz**			**60 Hz**		
			L1 (lead phase)	**L2**	**L3**	**L1 (lead phase)**	**L2**	**L3**
Source voltage reference								
270°	90°	90°	5.5			4.6		
Load current reference								
360°	90°	90°	5.5			4.6		

Figure 21 shows the waveform representation of controlled de-energization of an ungrounded capacitor bank.

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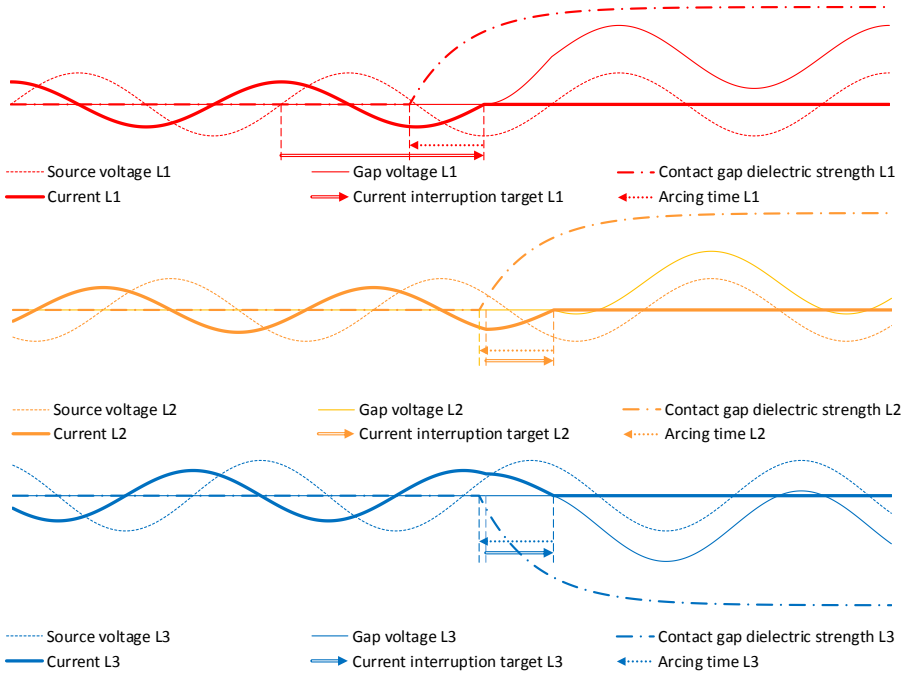


Figure 21: Controlled de-energization of ungrounded capacitor bank using source voltage as reference

5.1.3 Grounded non-coupled reactor

A three-phase reactor is considered non-coupled if it has a four-limb, five-limb, or bank type core and is connected in YN (star grounded) circuit. This kind of reactor is ideally energized at a source voltage peak in the individual phases. If energizing polarity is not critical, the recommended sequence is L1-L3-L2 with 60° spacing between energization instants.

For de-energization of a grounded non-coupled reactor, the recommended current interruption sequence is again L1-L3-L2 with 60° shift between phases. Last loop length and expected gap voltage (TRV) post successful interruption will be same for all phases in this configuration. Consequently, the target arcing times will be identical for all three phases. The initial arcing times are evaluated based on the procedure described in Section 4.2.2.1.

Table 19 shows the recommended targets for energization and de-energization of a grounded non-coupled reactor.

Table 19: Controlled switching targets for grounded non-coupled reactor

	Making targets			**Current interruption targets at natural current zero**		
	L1 (lead phase)	**L2**	**L3**	**L1 (lead phase)**	**L2**	**L3**
Switching strategy	Slightly before positive peak of L1 phase-to-ground voltage	120° after L1	60° after L1	Negative-going zero crossing of L1 phase current	120° after L1	60° after L1

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5.1.3.1 Controlled energization

Table 20 shows the settings to be applied for controlled closing with PWC600 to achieve the switching strategy described in Table 19.

Table 20: Settings for controlled closing with PWC600 for non-coupled grounded reactor

Target making angle (deg)			Gap voltage prior to current making (p.u.)		
L1 (lead phase)	L2	L3	L1	L2	L3
90°	120°	60°	1.00	1.00	1.00

Internally, PWC600 will add an offset to the entered making targets, to cater for the dielectric and mechanical characteristics of the specific circuit breaker, as explained in Section 4.4.3.1. These optimized targets can be seen as **Target current making angle** in the operation log.

Figure 22 shows the waveform representation for controlled energization of a non-coupled grounded reactor.

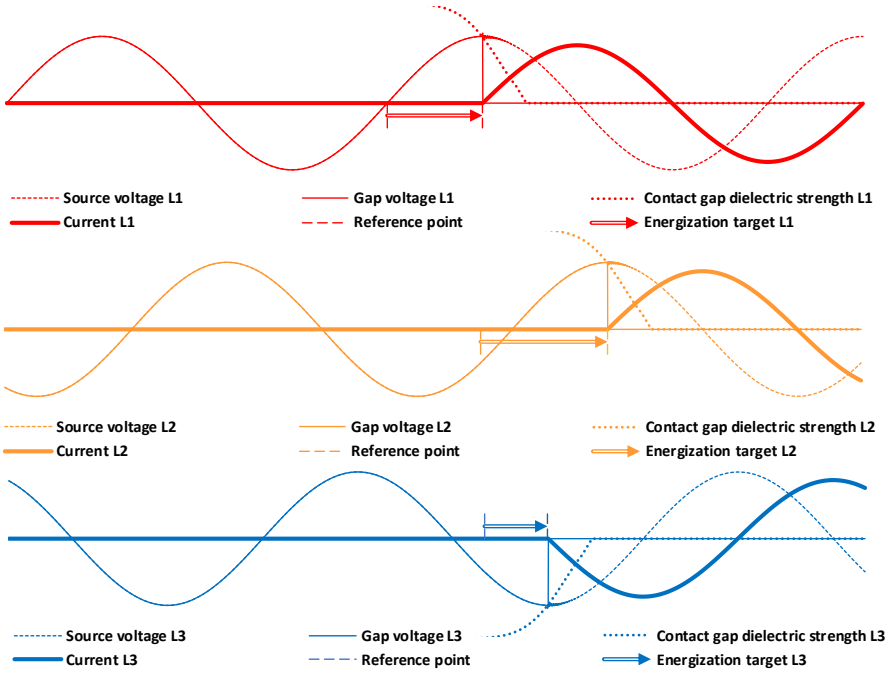


Figure 22: Controlled energization of a non-coupled grounded reactor

5.1.3.2 Controlled de-energization

Table 21 shows the settings to be applied for controlled opening with PWC600 to achieve the switching strategy described in Table 19. The arcing times for all three phases will be same, since the last loop length for all three phases will be identical having current interruption sequence of L1-L3-L2 with 60° difference between individual phases.

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Table 21: Settings for controlled opening with PWC600 for non-coupled grounded reactor

Interruption target			Arcing time (ms)					
L1 (lead phase)	L2	L3	50 Hz			60 Hz		
			L1 (lead phase)	L2	L3	L1 (lead phase)	L2	L3
Source voltage reference								
270°	120°	60°	$Tarc_{50}$			$Tarc_{60}$		
Load current reference								
180°	120°	60°	$Tarc_{50}$			$Tarc_{60}$		

$Tarc_{50}$ is initial arcing time setting for 50 Hz, $Tarc_{60}$ is for 60 Hz.

Initial arcing time values are provided as guidance as they are based on circuit breaker characteristics and standard IEC applications, see Section 4.2.2.1; they may require further adjustment depending on properties of the system or the reactor. If initial operations result in unintended re-ignitions, please consult the circuit breaker manufacturer for guidance.

Figure 23 shows the waveform representation of controlled de-energization of a grounded non-coupled reactor.

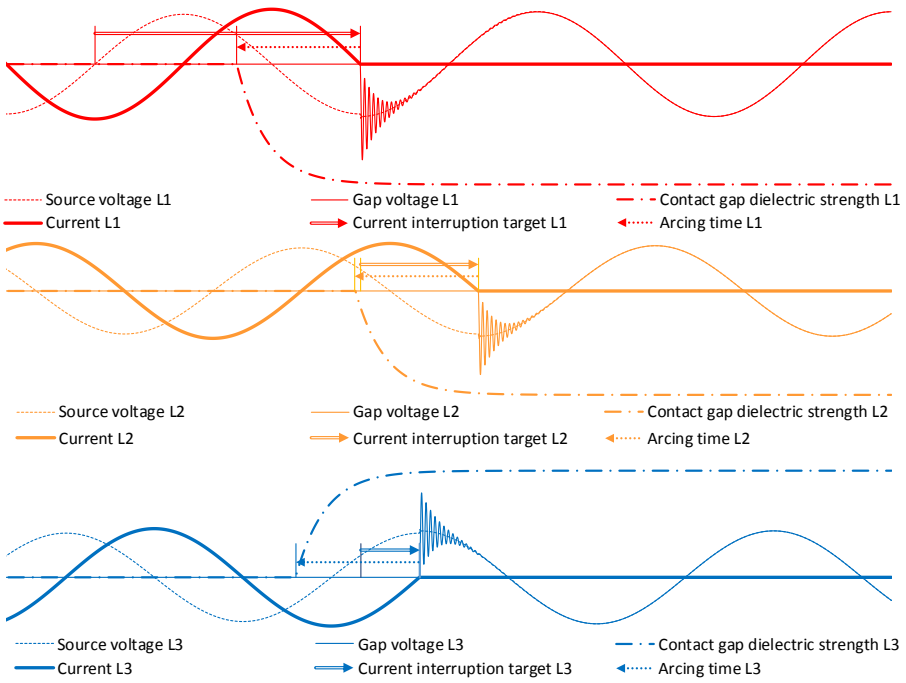


Figure 23: Controlled de-energization of a grounded non-coupled reactor using source voltage as reference

5.1.4 Non-coupled ungrounded or delta connected reactor

A non-coupled ungrounded or delta connected reactor is ideally energized in L1-L2-L3 sequence. The first energizing phase L1 will see no pre-strike until first following pole L2

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energizes, as the current will not flow until two circuit breaker poles are closed. In this case, the second energizing pole L2 will see line-to-line voltage, i.e., 1.73 pu prior to current making, and the ideal making target is at peak of this voltage. After energizing of L1 & L2 poles, the last pole to close L3 will see 1.5 pu gap voltage due to neutral voltage shift; its ideal energization target is at peak of this voltage, which appears 90° after L2 energization. The dissimilarity in gap voltages for individual circuit breaker poles is also considered while evaluating the pre-arcing times for individual phase targets.

For a non-coupled un-grounded or delta connected reactor, current interruption will take place in one pole initially followed by remaining two poles together. Moreover, due to shift in neutral point potential, the last loop length (that is, length of the last current half-cycle prior to interruption) will become dissimilar. First interrupting pole will have 180° last loop length, whereas the second pole will see 30° shortening and the third pole will see 30° elongation in last loop length. This will cause simultaneous current interruption in second and third poles, as already mentioned. The recommended sequence of current interruption is therefore, L1-L2L3. Also, the individual poles will see dissimilar over-voltages across the contact gap. The initial arcing time settings are evaluated according to the procedure described in Section 4.2.2.1 considering the mentioned dissimilarities in last loop length as well as in the gap voltage across individual circuit breaker poles.

Table 22 shows the recommended making targets for energization as well as de-energization of a non-coupled ungrounded reactor, using a positive-going zero crossing of L1 source voltage as reference.

Table 22: Controlled switching targets for non-coupled ungrounded reactor

	Making targets			**Current interruption targets at natural current zero**		
	L1 (lead phase)	**L2**	**L3**	**L1 (lead phase)**	**L2**	**L3**
Switching strategy	60° - Φ_D	Φ_D	90° after L2	Negative-going zero crossing of L1 phase current	L2 & L3 together: 90° after L1	

Φ_D advancement in target of L1 is to ensure that the switching of L1 happens prior to L2 and pre-strike happens across L2 only.

In some cases, L1L2-L3 switching strategy for energization is used, where first two poles (L1 & L2) are energized together followed by the last phase (L3) 90° later. Contact ABB for details.

5.1.4.1 Controlled energization

Table 23 shows the settings to be applied for controlled closing with PWC600 to achieve the switching strategy described in Table 22.

Table 23: Settings for controlled closing with PWC600 for non-coupled ungrounded reactor

Target making angle			**Gap voltage prior to current making (p.u.)**		
L1 (lead phase)*	**L2**	**L3**	**L1**	**L2**	**L3**
60° - Φ_D	Φ_D	90° +Φ_D	0	1.73	1.5

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Internally, PWC600 will add an offset to the entered making targets, to cater for the dielectric and mechanical characteristics of the specific circuit breaker, as explained in Section 4.4.3.1. These optimized targets can be seen as **Target current making angle** in the operation log.

Figure 24 shows the waveform representation for controlled energization of a non-coupled ungrounded reactor.

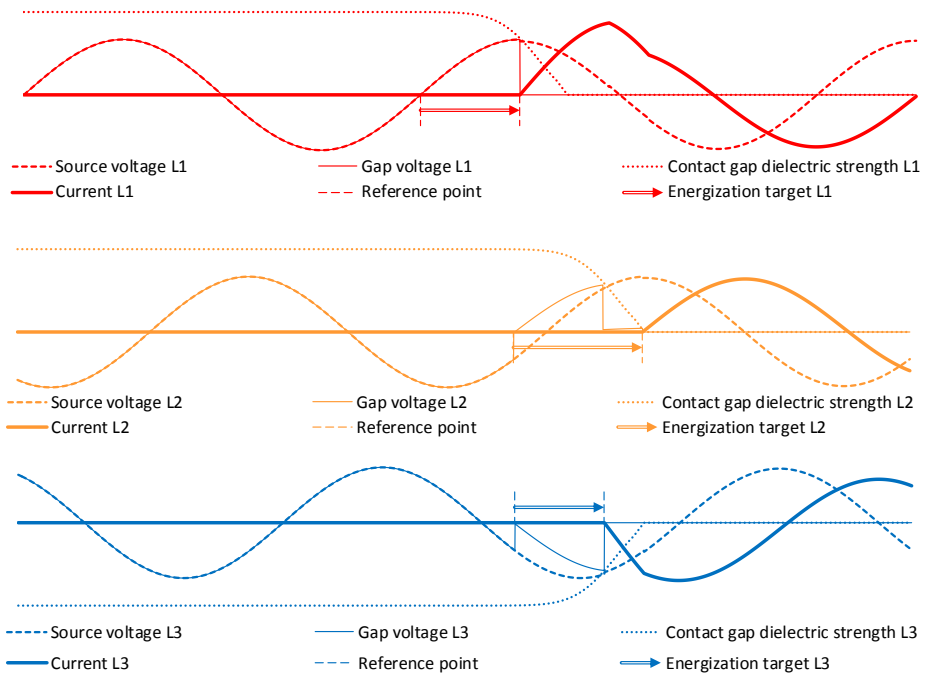


Figure 24: Controlled energization of a non-coupled ungrounded reactor

If electrical monitoring is selected, to achieve proper monitoring and adaptation, disable adaptive correction for first energizing pole (L1) and put the maximum possible RDDS value, since no prestrike will be observed in first pole to close. Also, large electrical target errors will be recorded for this phase. To prevent raising of false alarms, remove the threshold supervision for the lead phase. Refer to Section Section 9.4.6.2. In the operation records for closing operations, the “Electrical operating time” and “Current making angle” values for the first energizing pole (L1) can be disregarded.

5.1.4.2 Controlled de-energization

Table 24 shows the settings to be applied for controlled opening with PWC600 to achieve the switching strategy described in Table 22. For an ungrounded non-coupled reactor, the first pole to interrupt (L1) will see higher overvoltage across its contacts compared to the last two interrupting poles (L2 & L3).

Arcing time and interruption target for individual poles are set accordingly.

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Table 24: Settings for controlled opening with PWC600 for non-coupled ungrounded reactor

Interruption target (deg)			Arcing time (ms)					
			50 Hz			60 Hz		
L1 (lead phase)	L2	L3	L1 (lead phase)	L2	L3	L1 (lead phase)	L2	L3
Source voltage reference								
270°	90°	90°	$Tarc_{50_1}$	$Tarc_{50_2}$	$Tarc_{50_2}$	$Tarc_{60_1}$	$Tarc_{60_2}$	$Tarc_{60_2}$
Load current reference								
180°	90°	90°	$Tarc_{50_1}$	$Tarc_{50_2}$	$Tarc_{50_2}$	$Tarc_{60_1}$	$Tarc_{60_2}$	$Tarc_{60_2}$

$Tarc_{50}$ is initial arcing time setting for 50 Hz, $Tarc_{60}$ is for 60 Hz.

Initial arcing time values are provided as guidance as they are based on circuit breaker characteristics and standard IEC applications, see Section 4.2.2.1; they may require further adjustment depending on properties of the system or the reactor. If initial operations result in unintended re-ignitions, please consult the circuit breaker manufacturer for guidance.

Figure 25 shows the waveform representation of controlled de-energization of a non-coupled ungrounded reactor.

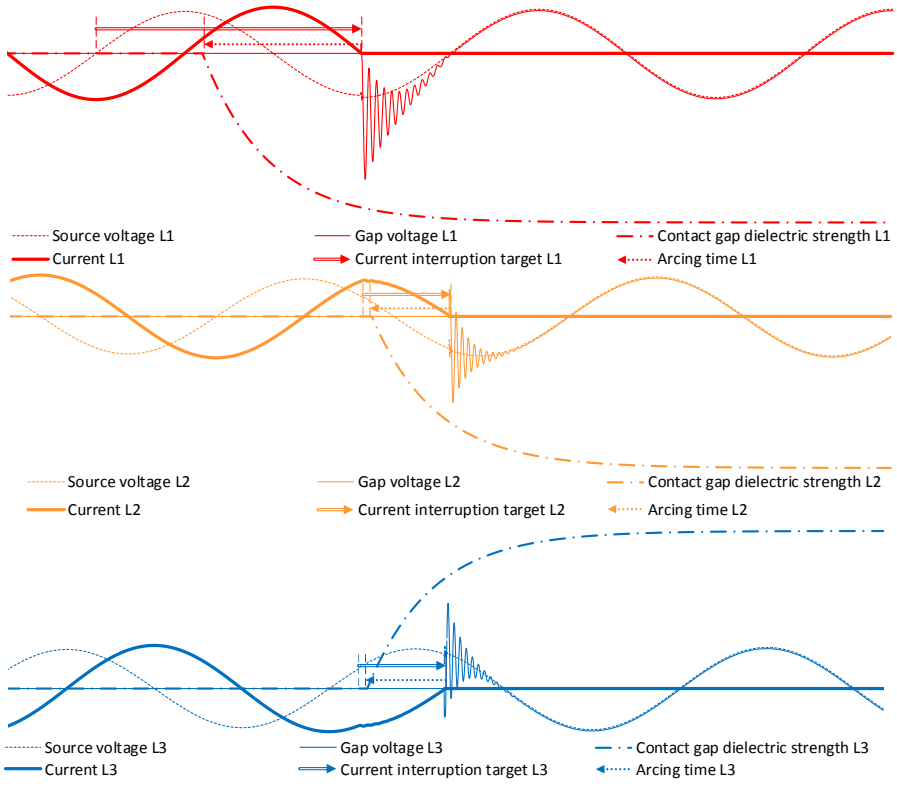


Figure 25: Controlled de-energization of non-coupled ungrounded reactor using source voltage as reference

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5.1.5 Magnetically coupled grounded reactor

For a magnetically coupled (three-limb) reactor, the first phase (L1) is ideally energized at gap voltage peak. The second phase (L3) is energized 90° after the first. The third phase (L2) is energized slightly (Φ_D) after the second. In this L1-L3-L2 switching sequence, the Φ_D delay in L2 target is intentionally applied to ensure the mentioned switching sequence. With these energization targets, first pole to close L1 will see gap voltage of 1 pu, whereas the following phase L3 will see 0.86 pu. After energization of the first two poles, the voltage across the last pole to close will become zero and hence, no prestrike will be observed for this pole.

The recommended current interruption sequence is L1-L3-L2 with 60° phase difference between phases. The slight dissimilarity in last half cycle loop length and TRV for individual phases is neglected while defining the initial targets.

Table 25 shows the recommended targets for energization and de-energization of a magnetically coupled reactor in YN circuit, using a positive-going zero crossing of L1 source voltage as reference.

Table 25: Controlled switching targets for magnetically coupled (3-limb) grounded reactor

	Making targets			**Current interruption targets at natural current zero**		
	L1 (lead phase)	**L2**	**L3**	**L1 (lead phase)**	**L2**	**L3**
Switching strategy	Slightly before positive-going peak of L1	90° + Φ_D after L1	90° after L1	Negative-going zero crossing of L1 phase current	Φ_{D2} after L1	Φ_{D3} after L1

Φ_D delay in L2 making target is intentionally applied to ensure the L1-L3-L2 energizing sequence.

Φ_{D2} and Φ_{D3} for grounded 3-limb reactor are generally very close to 120° and 60° respectively. The actual value should be measured from the waveform record of first de-energization, to update the settings accordingly.

5.1.5.1 Controlled energization

Table 26 shows the settings to be applied for controlled closing with PWC600 to achieve the switching strategy described in Table 25.

Table 26: Settings for controlled closing with PWC600 for a magnetically coupled (3-limb) grounded reactor

Target making angle (deg)			**Gap voltage prior to current making (p.u.)**		
L1 (lead phase)	**L2**	**L3**	**L1**	**L2**	**L3**
90°	90°+ Φ_D	90°	1.0	0.0	0.86

Φ_D denotes delay in L2 target which is intentionally applied to ensure the L1-L3-L2 switching sequence.

Internally, PWC600 will add an offset to the entered making targets, to cater for the dielectric and mechanical characteristics of the specific circuit breaker, as explained in Section 4.4.3.1. These optimized targets can be seen as **Target current making angle** in the operation log.

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Figure 26 shows the waveform representation for controlled energization of a magnetically coupled (3-limb) grounded reactor.

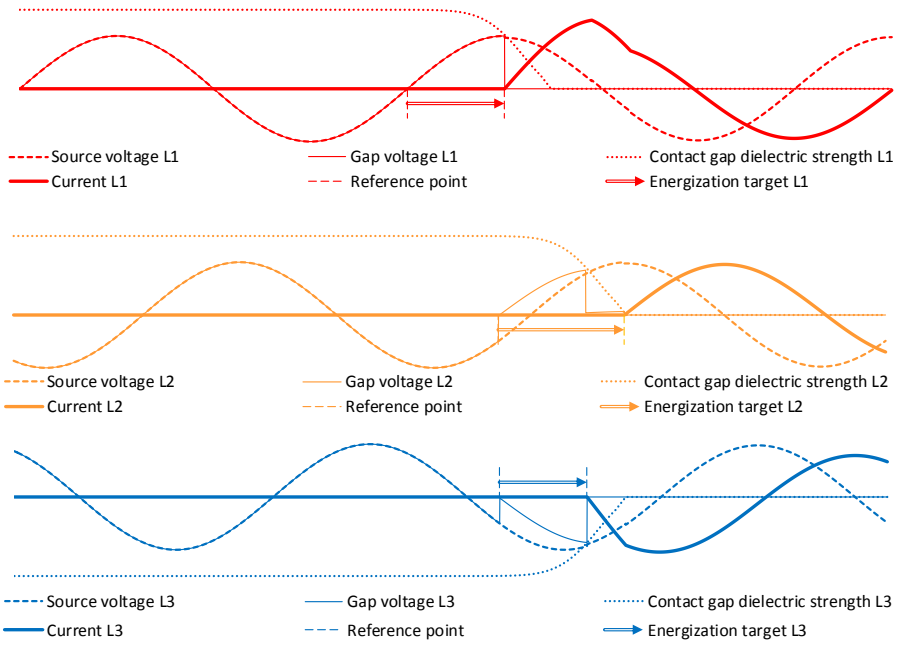


Figure 26: Controlled energization of a magnetically coupled (3-limb) grounded reactor

To achieve proper monitoring and adaptation, disable adaptation for last energizing pole (L2) and put the maximum possible RDDS value, since no prestrike will be observed in last pole to close. Also, large electrical target errors will be recorded for this phase. To prevent raising of false alarms, remove the threshold supervision for L2 phase. Refer to Section 9.4.6.1. In the operation records for closing operations, the “Electrical operating time” and “Current making angle” values for the last energizing pole (L2) can be disregarded.

5.1.5.2 Controlled de-energization

Table 27 shows the settings to be applied for controlled opening with PWC600 to achieve the switching strategy described in Table 25.

Table 27: Settings for controlled opening with PWC600 for magnetically coupled (3-limb) grounded reactor

Interruption target			**Arcing time (ms)**					
L1 (lead phase)	**L2**	**L3**	**50 Hz**			**60 Hz**		
			L1	**L2**	**L3**	**L1**	**L2**	**L3**
Source voltage reference								
270°	120°	60°	$Tarc_{50}$			$Tarc_{60}$		
Load current reference								
180°	120°	60°	$Tarc_{50}$			$Tarc_{60}$		

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$Tarc_{50}$ is initial arcing time setting at 50Hz, whereas, $Tarc_{60}$ is at 60Hz.

Generally, for magnetically coupled grounded reactors, the dissimilarity in last loop length between phases is very small. Furthermore, the highest gap voltage will appear for last pole to interrupt and will be similar to that of non-coupled grounded reactor configuration. Therefore, the same settings as for noncoupled grounded reactor configuration (equal target arcing times for all three poles) are applied in this case. The actual last loop lengths shall be checked after first controlled de-energization operation and settings shall be modified as needed.

Initial arcing time values are provided as guidance as they are based on circuit breaker characteristics and standard IEC applications, and may require further adjustment depending on system specific considerations. If initial operations result in unintended re-ignitions, please consult the circuit breaker manufacturer for guidance.

Figure 27 shows the waveform representation of controlled de-energization of a magnetically coupled (3-limb) grounded reactor.

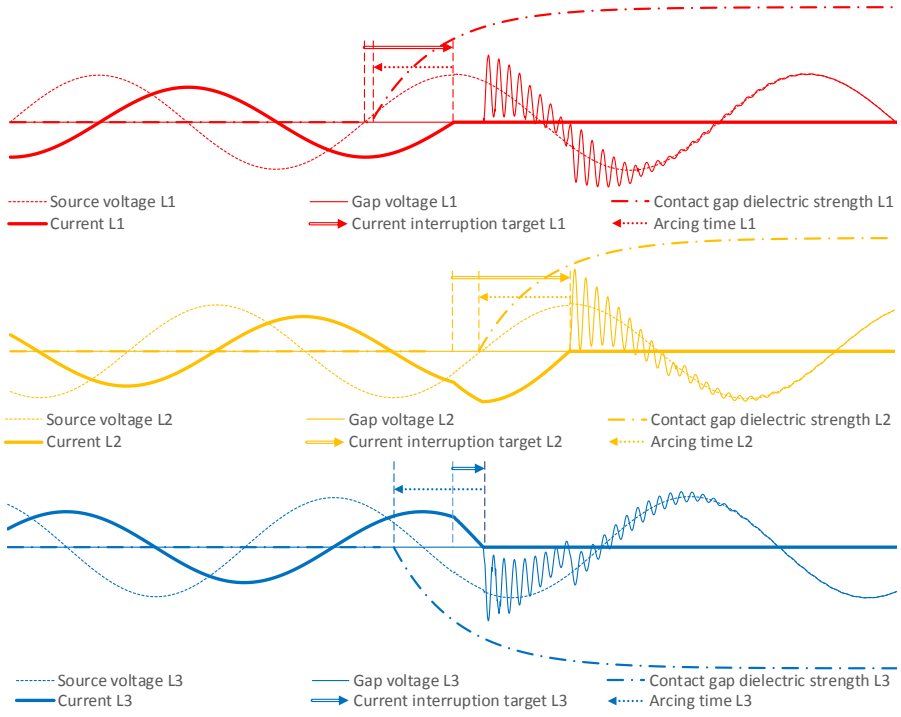


Figure 27: Controlled de-energization of a magnetically coupled (3-limb) grounded reactor using source voltage as reference

5.1.6 Transformers with different configurations

Energization of a power transformer is ideally done at a phase angle where the prospective flux matches the residual flux in the core. PWC600 1.1 does not measure the residual flux but applies controlled de-energization for impressing a repeatable residual flux pattern on the transformer core. The de-energization strategies are designed to keep the residual flux close to zero. With that, controlled energization assuming no residual flux will give reasonably good results. Further optimization of the energization strategy can be done based on the observed inrush currents.

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This section covers the most common transformer configurations:

- *YNyn/YNy* or similar – *Non-coupled transformer with switching from YN*
  Being electrically as well as magnetically independent, energization of any one phase doesn't have impact on the other phases. Hence, the making targets can be independently chosen in each phase, usually near phase-to-ground voltage peak.
  During de-energization, current interruption is targeted in L1-L3-L2 sequence, 60° apart.
  The below figures show commonly used transformer configurations in this category.

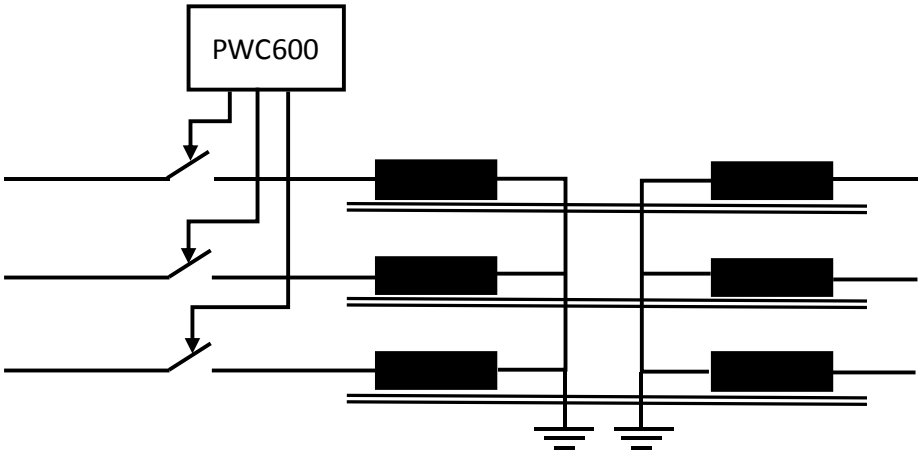


Figure 28: Non-coupled YNyn transformer to be energized from YN side

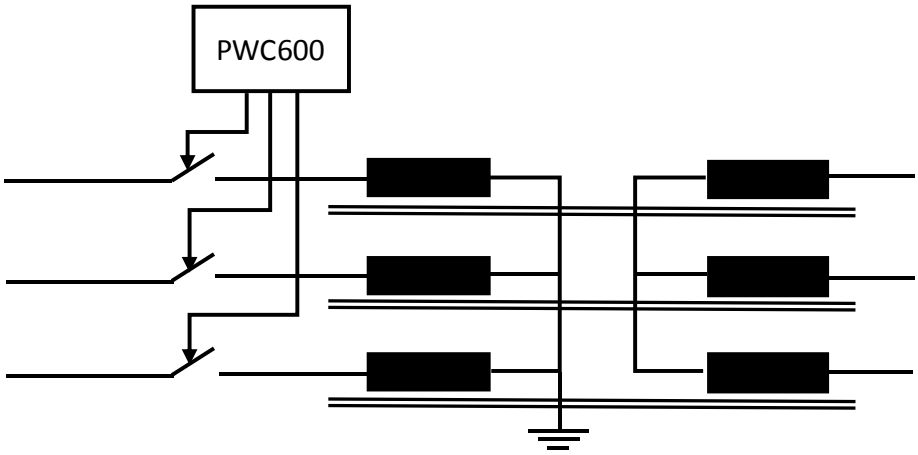


Figure 29: YNy transformer to be energized from YN side

- *YNd/YNynd/YNyd or similar – electrically coupled with switching from YN side; YNyn, YNy, or similar, with three-limb core – magnetically coupled with switching from YN side*
  A delta-connected secondary or tertiary winding creates electrical coupling between the phases. Similarly, a common three-limb core creates magnetic coupling between the phases. In both cases, the first phase is energized based on the residual flux in the transformer limb associated to that phase. Hereupon, the electrical or magnetic coupling creates dynamic magnetic fluxes also in the limbs that carry the windings of the non-energized phases. Therefore, the energization targets for the later two phases are chosen based on the residual flux as well as the dynamic fluxes induced post first-phase energization.
  For de-energization, current interruption is targeted in L1-L3-L2 sequence, but due to coupling, the latter two interrupting phases will experience elongation and shortening. In

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ideal conditions, the first following phase L3 will get shortened and interrupt the current 30° later than the first interrupting phase L1. The last interrupting phase L2 will interrupt the current 120° post current interruption in L1. However, due to the non-sinusoidal nature of magnetizing currents, the actual interruption angles will deviate from the ideal ones. The current interruption targets are defined considering this effect.
The below figures show commonly used transformer configurations in this category.

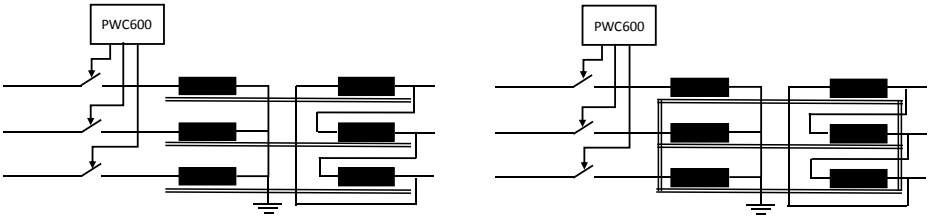


Figure 30: Single-phase bank or 3-limb type YNd transformer to be energized from YN side

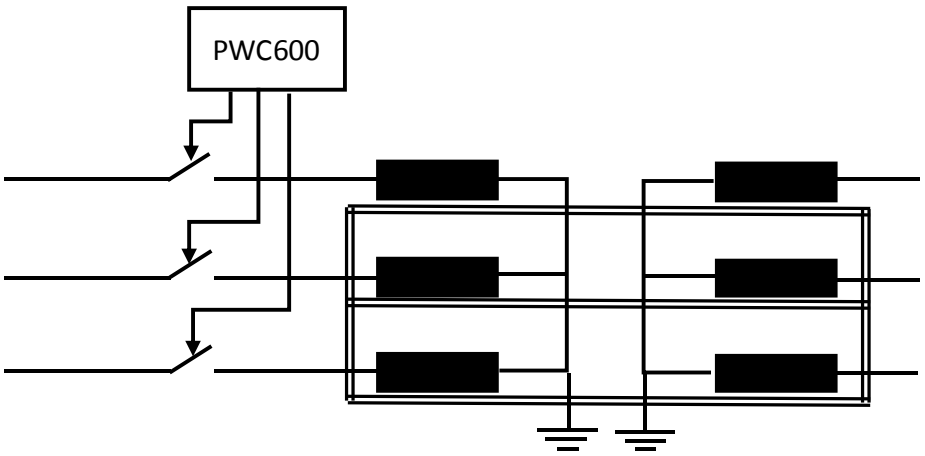


Figure 31: YNyn three-limb transformer to be energized from YN side

- *Yd, Dyn, Dy, Dd, or similar – electrically coupled with switching from Y or D side; Yyn, Yy, or similar, with three-limb core – magnetically coupled with switching from Y or D side*

When charging an ungrounded or delta connected winding, current can flow only when two poles of the CB are closed. Therefore, the making target for the first two poles is determined from the residual fluxes in the associated transformer limbs and from the line-to-line voltage across these poles. Hereupon, electrical or magnetic coupling creates dynamic fluxes also in the limb that carries the winding of the non-energized phase. Therefore, the energization target for the third phase is chosen based on the residual flux as well as the dynamic flux induced post energization of the first two phases.

For de-energization of a coupled transformer from Y or Delta winding side, current interruption is targeted in L1-L2L3 sequence. In ideal conditions, current interruption will occur simultaneously in the last two phases (L2 & L3), 90° after current interruption in L1. The current interruption targets are defined considering this behavior.

The below figures show commonly used transformer configurations in this category.

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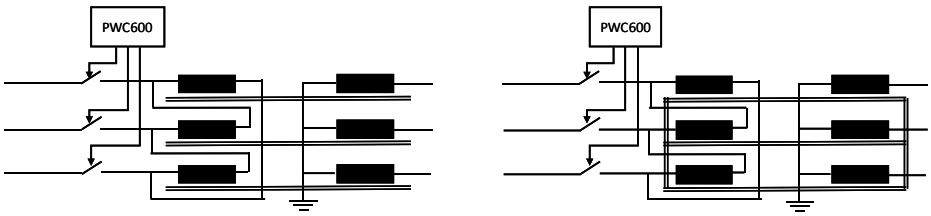


Figure 32: Single-phase bank or 3-limb type Dyn transformer to be energized from D side

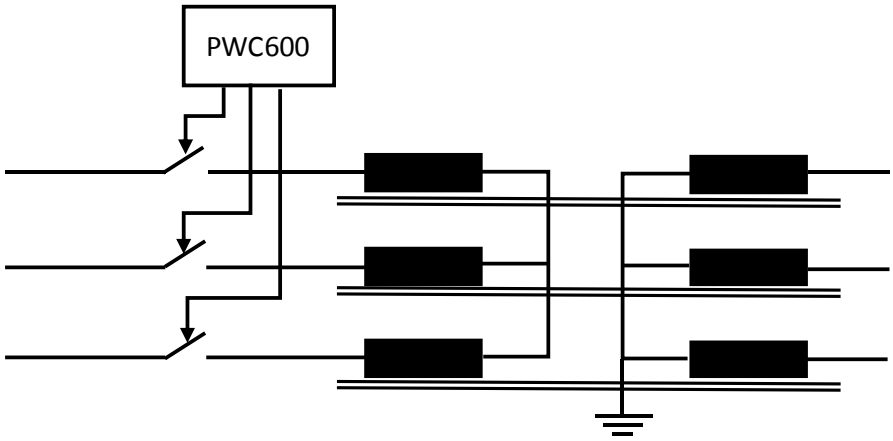


Figure 33: Yyn single-phase bank type transformer to be energized from ungrounded Y side

Table 28 shows the recommended targets for controlled switching of the transformer configurations listed above. The effects of electrical as well as magnetic coupling between the phases and the windings have been considered while defining the switching targets.

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Table 28: Controlled switching initial targets for various transformer configurations

Configuration	Side of switching	Making targets			Current interruption targets		
		L1 (lead phase)	L2	L3	L1 (lead phase)	L2	L3
YNyn / YNy or similar – non-coupled	YN	Slightly before positive peak of L1 phase-to-ground voltage	120° after L1	60° after L1	270° after positive-going zero crossing of L1 phase-to-ground voltage	120° after L1	60° after L1
YNd / YNynd / YNyd or similar – electrically and/or magnetically coupled (3-limb core)	YN	Slightly before negative peak of L1 phase-to-ground voltage	90° + Φ_{D1} after L1	90° after L1	270° after positive-going zero crossing of L1 phase-to-ground voltage	120° after L1	30° after L1
Yd / Dyn / Dy / Dd with any core design, or Yyn / Yy with 3-limb (magnetically coupled) core	D / Y	60° – Φ_{D2} after positive-going zero crossing of L1 phase-to-ground voltage	Φ_{D2} after L1	90° after L2	270° after positive-going zero crossing of L1 phase-to-ground voltage	L2 & L3 together: 90° after L1	

Φ_{D1} delay in L2 target is intentionally applied to ensure the L1-L3-L2 energizing sequence. Φ_{D2} advancement in target of L1 is applied to ensure that L1 closes prior to L2 and pre-strike happens across L2 only.

For controlled switching of a transformer having any other connection configuration than the ones mentioned above, contact ABB.

5.1.6.1 Controlled energization

Table 29 shows the settings to be applied for controlled closing with PWC600 to achieve the energization strategies listed in Table 28.

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Table 29: Initial settings for controlled closing with PWC600 for various transformer configurations

Configuration	Side of switching	Target making angle (deg)			Gap voltage prior to current making (p.u.)		
		L1 (lead phase)	L2	L3	L1	L2	L3
YNyn / YNy or similar – non-coupled	YN	90°	120°	60°	1.00	1.00	1.00
YNd / YNynd / YNyd or similar – electrically and/or magnetically coupled (3-limb core)	YN	270°	90°+ Φ_{D1}	90°	1.0	0.0	0.86
Yd/Dyn/Dy/Dd with any core design or Yyn/Yy with 3-limb (magnetically coupled) core	D/Y	60°- Φ_{D2}	Φ_{D2}	90°+ Φ_{D2}	0	1.73	1.5

Φ_{D1} denotes delay in L2 target intentionally applied to ensure the L1-L3-L2 switching sequence. Φ_{D2} advancement in target of L1 is to ensure that the switching of L1 happens prior to L2 and pre-strike happens across L2 only.

Internally, PWC600 will add an offset to the entered making targets, to cater for the dielectric and mechanical characteristics of the specific circuit breaker, as explained in Section 4.4.3.1. These optimized targets can be seen as **Target current making angle** in the operation log.

To achieve proper monitoring and adaptation, it may be necessary to make some changes to the application configuration in PWC600. Refer to Section 9.4.6 for details. In the operation records for closing operations, the “Electrical operating time” and “Current making angle” values for phase that was modified can be disregarded.

The application of controlled closing for a YNd transformer (either electrically and/or magnetically coupled) transformer is elaborated here. Energization is performed in L1-L3-L2 sequence. Each phase is ideally energized when source-side prospective flux is equal to load-side (transformer side) flux. Consequently, for the first pole (L1), the energization is targeted at the angle where L1 source-side prospective flux matches L1 residual flux. Due to coupling, this produces dynamic fluxes in the other two phases (L2 & L3). Energization of these two phases is targeted at the angle where these dynamic fluxes equal the source-side prospective fluxes.

Figure 34 demonstrates the ideal making targets in absence of residual flux, for controlled energization of an YN connected transformer having at least one delta connected winding, from the YN connected side. The lead phase L1 and the targets are shown with last phase L2 to energize 18° post L3 energization to maintain L1-L3-L2 switching sequence.

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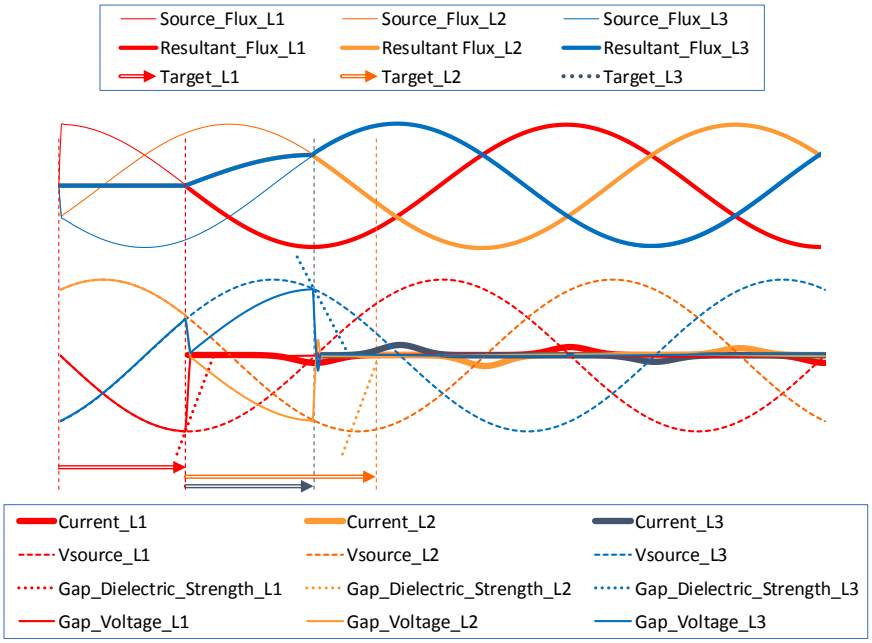


Figure 34: Closing on default targets in absence of residual fluxes

Controlled opening shall precede every controlled closing operation with targets set in such a way that minimum level of residual flux is set for each phase. Therefore, first step of for on-site commissioning is to perform controlled opening operation, with the targets discussed in Section 5.1.6.2. Thereafter, the first controlled energization operation is performed at ideal targets assuming zero residual fluxes.

In the next step, targets can be manually adjusted based on inrush current signature and relative value of current peaks in the individual phases obtained during the first energization operation. These adjustments are individual to each transformer. The results for the example used here are shown in Figure 35 and Figure 36, where the L3 making target is shifted to the left.

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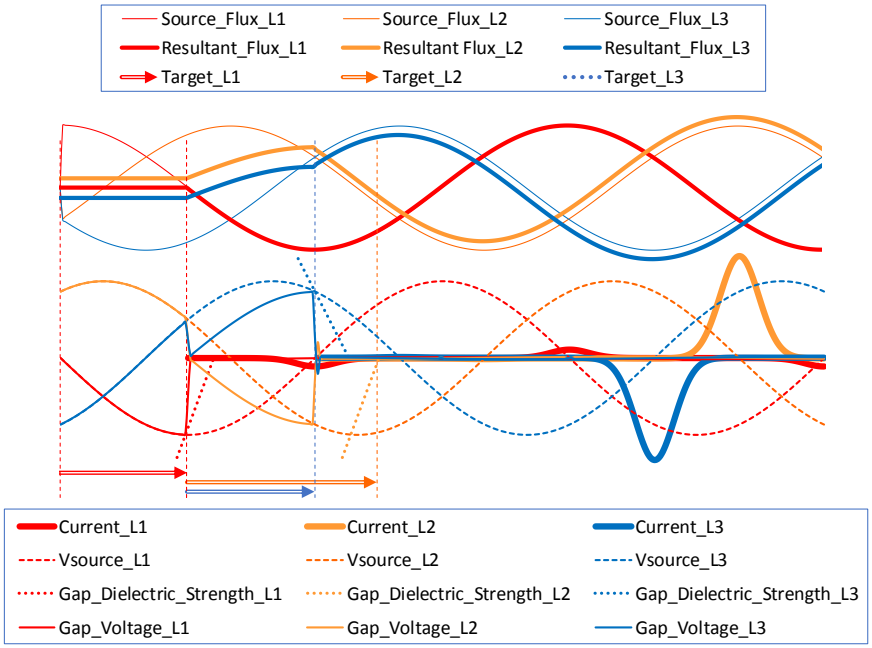


Figure 35: Controlled closing on default targets in presence of residual fluxes

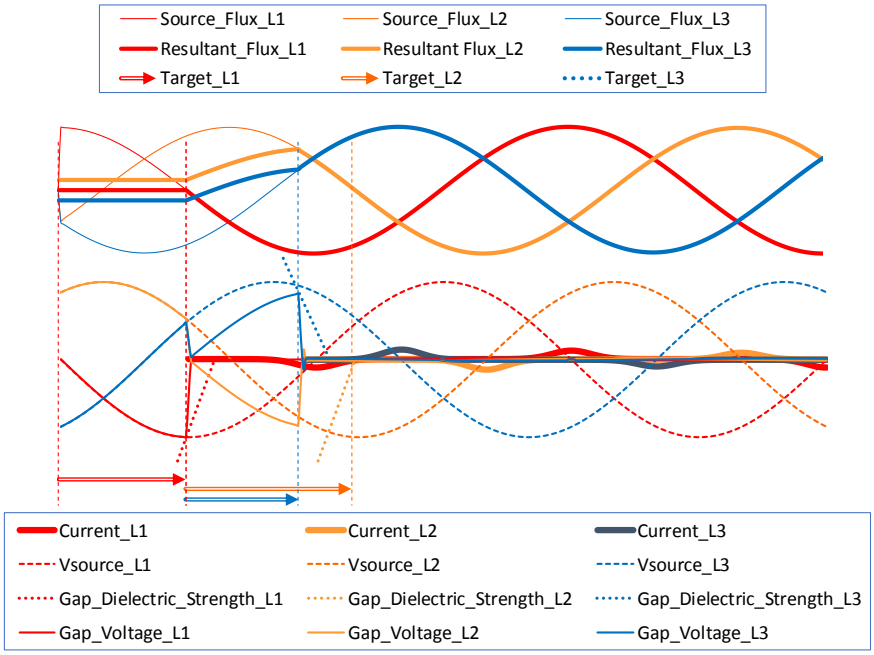


Figure 36: Controlled closing on corrected targets in presence of residual fluxes

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As mentioned in Section 4.5.1.1 and Table, current is not a suitable feedback signal for monitoring or adaptation of transformer switching application. (However, it is still recommended to connect the current signals to PWC600 for inclusion in the waveform recording to assess the switching performance during commissioning.) Therefore, either mechanical status indication from auxiliary contacts or load voltage shall be chosen as feedback for transformer application. Moreover, in case of electrical or magnetic coupling of the phases in the load, with load voltage being used for electrical operation detection, special arrangements are needed. Refer Section 5.2.5 for more details.

5.1.6.2 Controlled de-energization

As discussed above, the controlled energization targets are set for matching a residual flux pattern that was achieved by means of a previous controlled de-energization. The asymmetry in current interruption for individual poles due to magnetic (3-limb) and/or electric (delta connected winding) coupling is considered while defining the interruption targets. Table 30 shows the settings to be applied for controlled opening with PWC600 to achieve an optimum switching strategy.

Table 30: Settings for controlled opening with PWC600 for various transformer configurations with source voltage reference

Configuration	Side of switching	Interruption target (deg)			Arcing time (ms) at 50 Hz or 60 Hz		
		L1 (lead phase)	L2	L3	L1 (lead phase)	L2	L3
YNyn / YNy or similar – non-coupled	YN	270°	120°	60°	Tarc_trafo		
YNd / YNynd / YNyd or similar – electrically and/or magnetically coupled (3-limb core)	YN	270°	120°	30°			
Yd / Dyn / Dy / Dd with any core design, or Yyn / Yy with 3-limb (magnetically coupled) core	D/Y	270°	90°	90°			

The interruption targets are defined based on inter-phase coupling effects assuming a pure sinusoidal current wave with a phase shift of 90° from the voltage signal. However, realistic magnetizing currents contain harmonics and the current interruption targets may deviate from the ones mentioned in the table. Nevertheless, the targets are only used to set a residual flux pattern through controlled opening. Fine tuning during controlled energization is used to mitigate any magnetizing current effects.

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The target arcing times for all phases (Tarc_trafo) are set in such a way that contact separation starts just prior to the target interruption instant in each phase. This will ensure that a minimum level of residual flux is set for each phase.

Primary current cannot be used as reference for controlled de-energization of no-load transformers, as it is usually non-sinusoidal and of very low amplitude.

Figure 37 shows the waveform representation of controlled de-energization of a YNd transformer to be de-energized from grounded YN side. As per Table 30, current interruption in the first following phase L3 should occur 30° after the first interrupting phase L1, and 120° after L1 in the last interrupting phase L2. However, due to harmonics present in the magnetizing current, there may be slight variation in the interruption instants. Also, the contact separation is targeted just prior to the voltage peak so that residual fluxes can be set to best possible minimum value.

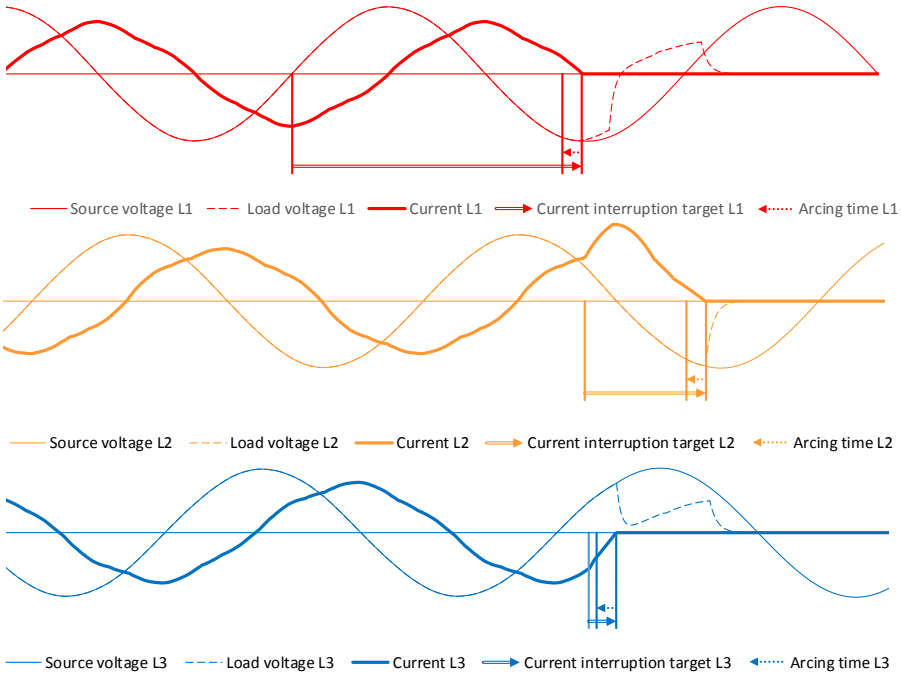


Figure 37: Controlled de-energization of an electrically and/or magnetically coupled transformer to be switched from YN side using source voltage as reference

5.1.7 Transmission line and power cable

An unloaded transmission line or power cable is ideally energized at gap voltage zero of the individual CB poles. This strategy minimizes the switching overvoltages, which could otherwise exceed 2 pu at the far end of the line or cable due to reflection at the open end.

For a highly compensated cable or line, the energization strategy is usually a compromise between two contradicting goals:

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1. Minimize switching overvoltage by energizing near gap voltage zero (as explained above).
2. Obtain symmetrical inrush current to prevent missing current zeros, by energizing near gap voltage peak.

In such a case, the optimal energization targets need to be determined individually for every installation, based on a network study. Please contact ABB for guidance.

Although modern circuit breaker types are classified as having low or very low probability of re-strike, controlled de-energization of cables or transmission lines can further reduce the probability of re-strikes. Table 31 shows the recommended switching strategies for transmission lines and power cables.

Table 31: Controlled switching targets for unloaded transmission lines and power cables

	Making targets			Current interruption targets at natural current zero		
	L1 (lead phase)	**L2**	**L3**	**L1 (lead phase)**	**L2**	**L3**
Switching strategy	Slightly after positive-going zero crossing of L1 phase-to-ground voltage	120° after L1	240° after L1	Positive-going zero crossing of L1 phase current	120° after L1	60° after L1

The same controlled energization strategy can be employed during re-energization. However, trapped charges are not considered. Thus, the switching overvoltage will likely be higher than during energization of a discharged line or cable, but lower than in worst-case uncontrolled reclosing.

The charging current for cables are generally low so current is not available for selection as feedback. However, for long cables having higher charging currents, current feedback may be suitable for adaptation in closing as well as for re-strike/re-ignition detection in opening. For such cases, use capacitor bank as the load to use current feedback.

5.1.7.1 Controlled energization

Table 32 shows the settings to be applied for controlled closing with PWC600 to achieve the switching strategy described in Table 31.

Table 32: Settings for controlled closing with PWC600 on power cable or transmission line

Target making angle (deg)			Gap voltage prior to current making (p.u.)		
L1 (lead phase)	**L2**	**L3**	**L1**	**L2**	**L3**
0°	120°	240°	1.00	1.00	1.00

Internally, PWC600 will add an offset to the entered making targets, to cater for the dielectric and mechanical characteristics of the specific circuit breaker, as explained in Section 4.4.3.1. These optimized targets can be seen as **Target current making angle** in the operation log.

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Figure 38 shows the waveform representation for controlled energization of a discharged transmission line or power cable.

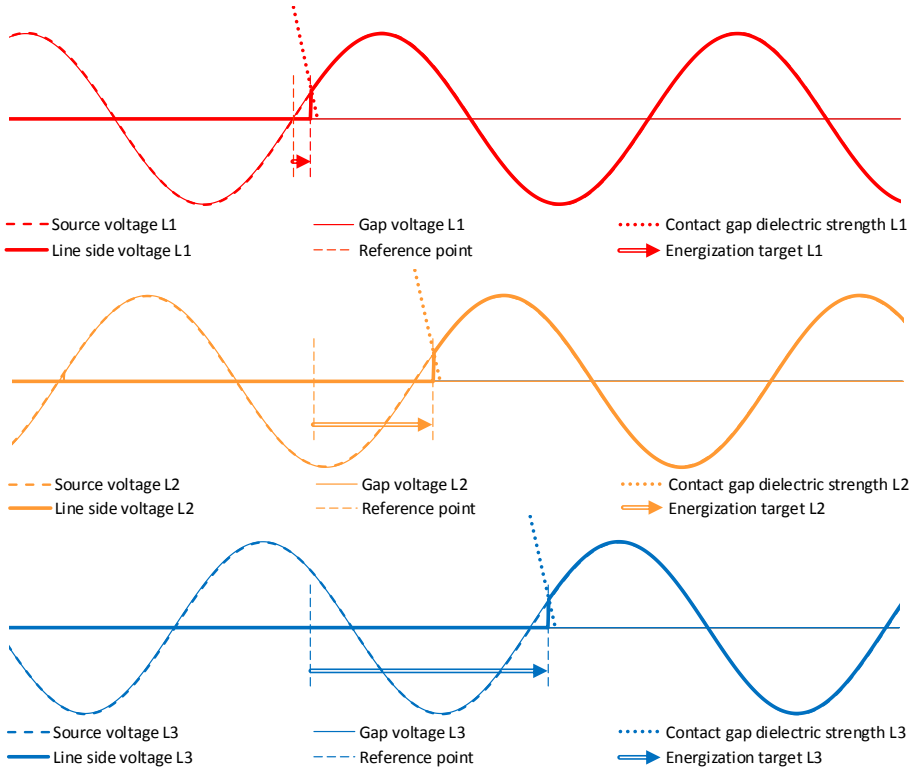


Figure 38: Controlled energization of an unloaded transmission line or power cable

5.1.7.2 Controlled de-energization

Table 33 shows the settings to be applied for controlled opening with PWC600 to achieve the switching strategy described in Table 31.

Table 33: Settings for controlled opening with PWC600 for an unloaded transmission line or power cable

Interruption target (deg)			**Arcing time (ms)**					
L1 (lead phase)	**L2**	**L3**	**50 Hz**			**60 Hz**		
			L1 (lead phase)	**L2**	**L3**	**L1 (lead phase)**	**L2**	**L3**
Source voltage reference								
270°	120°	60°	5.5			4.6		

The user may modify the interruption targets, for example, for implementing a different phase sequence. SST validates the entered target instants against the expected length of the last current half cycle loop, to ensure alignment of the strategy with load behavior.

Figure 39 shows the waveform representation of controlled de-energization of a discharged transmission line or power cable.

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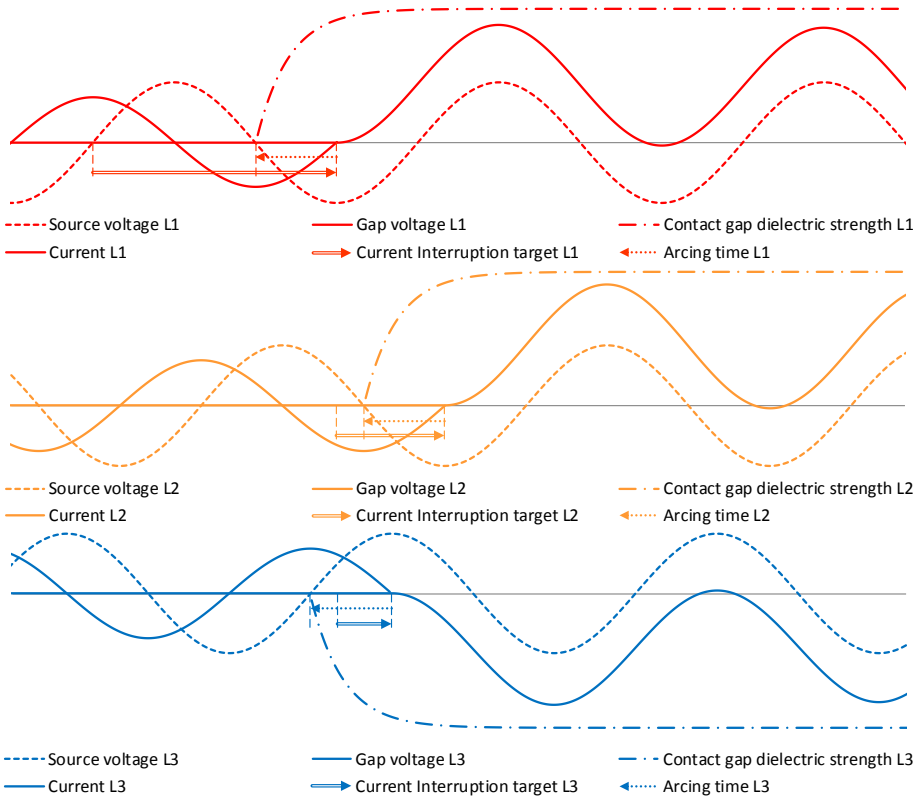


Figure 39: Controlled de-energization of an unloaded transmission line or power cable using source voltage as reference

5.2 Special load applications

Switchsync PWC600 can also be used for some special applications where customized settings need to be applied. In this section, few examples of such cases are described as listed in Table 34.

Table 34: Special application cases for various load configurations

Application	Configuration	Neutral	Section
Shunt reactor	Impedance grounded reactor, all common core designs	Impedance grounded (Resistor or reactor)	Section 5.2.1
Three-pole operated circuit breaker	Capacitor bank energization	Ungrounded	Section 5.2.2
Lead phase other than L1	Example of non-coupled reactor energization and de-energization with L3 as lead phase	Grounded	Section 5.2.3
Handling of two loads with Setting groups functionality	Example of switching of capacitor bank and transformer with circuit breaker in the tie bay.	Grounded	Section 5.2.4
Coupled transformers	Adaptation in case of coupled transformers using load voltage feedback	Grounded/ Ungrounded	Section 5.2.5

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5.2.1 Impedance grounded reactor

Reactors are provided with impedance grounding to limit short circuit currents as well as improving success rate for secondary arc extinction during auto-reclosure for transmission lines with shunt reactor compensation. Generally, the reactors are grounded through reactor. At lower voltage levels, reactors are occasionally grounded through a resistor.

During de-energization, the impedance grounding creates neutral potential shift and hence, the TRV post current interruption and the last half cycle loop lengths may be dissimilar for individual CB poles. In this case, the shortening and elongation of the last half cycle loop length will be in range of 0° to 30°.

For reactors grounded through a reactor, the last half cycle loop of the second phase to be de-energized is elongated based on design (magnetically coupled or non-coupled) of the reactor and on the inductance value of the inductor used for grounding. The last half cycle loop length for first and third phases will be 180°.

For reactors grounded through a resistor, the last half cycle loop length for both second and third interrupting poles will get altered. Generally, for same voltage and power rating, in same system, the TRV for non-coupled reactors with neutral grounding inductor is found to be comparatively higher than that for non-coupled reactors grounded through a resistor as well as for coupled reactors grounded through a resistor or reactor.

A reactor with Neutral Grounding Reactor (NGR) is ideally energized at a peak of the gap voltage in each CB pole. The magnitude and phase angle of gap voltage for individual CB poles depends upon design of the reactor (coupled or non-coupled) and the value and type (inductor or resistor) of neutral grounding. The ideal controlled switching strategies for reactor with NGR are shown in Table 35.

Table 35: Controlled switching targets for impedance grounded reactor

	Making targets			**Current interruption targets at natural current zero**		
	L1 (lead phase)	**L2**	**L3**	**L1 (lead phase)**	**L2**	**L3**
Switching strategy	Φ_{E1} after positive-going zero crossing of L1 phase-to-ground voltage	Φ_{E2} after L1 phase	Φ_{E3} after L1 phase	Negative-going zero crossing of L1 phase current	Φ_{D2} after L1	Φ_{D3} after L1

Φ_{E1}, Φ_{E2} & Φ_{E3} are the deviations from ideal gap voltage peak targets in individual CB poles, based on reactor design (coupled or non-coupled) and on the impedance of the neutral grounding resistor or reactor.

Initially, Φ_{D2} and Φ_{D3} are considered as 120° and 60° respectively. During commissioning, the actual interruption instants should be measured from the waveform record of first de-energization and the settings shall be updated accordingly.

5.2.1.1 Controlled energization

Table 36 shows the settings to be applied for controlled closing with PWC600 to achieve the switching strategy described in Table 35.

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Table 36: Settings for controlled closing with PWC600 for impedance grounded reactor with L1 phase source voltage reference

Target making angle (deg) (L1-L3-L2 switching sequence)			**Gap voltage prior to current making (p.u.)**		
L1 (lead phase)	**L2**	**L3**	**L1**	**L2**	**L3**
Φ_{E1}	Φ_{E2}	Φ_{E3}	1.0	U_2	U_3

Φ_{E1} denotes optimized energization target based on design of the reactor and the phase angle between impedance of reactor and the neutral grounding resistor or reactor. In case of reactor grounded reactor, Φ_{E1} will be 90°.

Φ_{E2} denotes the optimized energization target for L2 phase (last to energize) from target of phase L1. For reactor grounded systems, it is always 120°, whereas for resistor grounded systems, the value depends upon the design and the resistance of the grounding resistor.

Φ_{E3} denotes the optimized energization target for L3 phase (second to energize after L1) from target of phase L1. The value of adjustment in all the cases depends upon the design of the reactor and the value of resistance or inductance of the neutral grounding impedance.

U_2 and U_3 denote the gap voltage factors for L2 and L3 phases. For any reactor design, the gap voltage for first energizing phase (L1) will always be 1 pu. For non-coupled reactors with either resistance or inductor grounded systems, the last two energizing phases (L3 & L2) will observe gap voltages other than 1 pu, depending upon the design of the reactor and the value of resistance or reactance of the neutral grounding impedance.

For all configurations, PWC600 will internally add an offset to the entered making targets, to cater for the respective gap voltage in each phase and for the dielectric and mechanical characteristics of the specific circuit breaker, as explained in Section 4.4.3.1. These optimized targets can be seen as **Target current making angle** in the operation log.

The values of Φ_{E1}, Φ_{E2} and Φ_{E3} are shown in Table 37.

Table 37: Target making angles for different impedance grounded reactor configurations

Reactor configuration	**Φ_{E1}(L1)**	**Φ_{E2}(L2)**	**Φ_{E3}(L3)**
Non-coupled, grounded through inductor	90°	120°	Φ_C
Non-coupled, grounded through resistor	Φ_{C1}	Φ_{C2}	Φ_{C3}
Magnetically coupled, grounded through inductor	90°	120°	60°
Magnetically coupled, grounded through resistor	Φ_{C4}	165°	100°

For magnetically coupled reactors with resistance grounding, the ideal switching targets depend on multiple parameters and are therefore given as approximated values.

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$$\phi_c = \frac{180^\circ}{\pi} \cdot \tan^{-1} \frac{\sqrt{3}}{1 + \frac{2K}{K+1}}$$

(Equation 2)

where *K* is the ratio of neutral impedance to phase impedance, defined as “k factor” in this document.

$$\phi_{c1} = \frac{180^\circ}{\pi} \cdot \tan^{-1}\left(\frac{1}{K}\right)$$

(Equation 3)

$$\phi_{c2} = 210^\circ - \frac{180^\circ}{\pi} \cdot \tan^{-1}\left(\frac{1}{K}\right)$$

(Equation 4)

$$\phi_{c3} = 150^\circ - \frac{180^\circ}{\pi} \cdot \tan^{-1}\left(\frac{1}{K}\right)$$

(Equation 5)

$$\phi_{c4} = \frac{180^\circ}{\pi} \cdot \tan^{-1}\left(\frac{2}{3K}\right)$$

(Equation 6)

The values of U_2 and U_3 are shown in Table 38 below.

Table 38: Gap voltage factors for different impedance grounded reactor configurations

Reactor configuration	U2	U3
Non-coupled, grounded through inductor	U_{11}	U_{21}
Non-coupled, grounded through resistor	1	U_{22}
Magnetically coupled, grounded through inductor	1	1
Magnetically coupled, grounded through resistor	1	1.3

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$$U_{11} = \frac{1+3K}{1+2K}$$

(Equation 7)

$$U_{21} = \sqrt{\frac{(1+3K+3K^2)}{(1+K)^2}}$$

(Equation 8)

$$U_{22} = 0.1006K^3 - 0.6233K^2 + 1.21K + 0.981$$

(Equation 9)

The formula for U_{22} is an approximation obtained by curve fitting for various values of K.

The target angles and gap voltage factors (U) for impedance grounded reactors are initial values (proposed by SST), which may need modification to optimize controlled switching performance. Especially for magnetically coupled reactors, the proposed values are based on approximation. The values highly depend upon magnetic circuit design and the grounding impedance. For further guidance please inquire with the local ABB representative.

Figure 40 shows the waveform representation for controlled energization of a non-coupled reactor, grounded with inductance having a k factor greater than 0.3. The targets are chosen based on switching strategy described in the Table 36.

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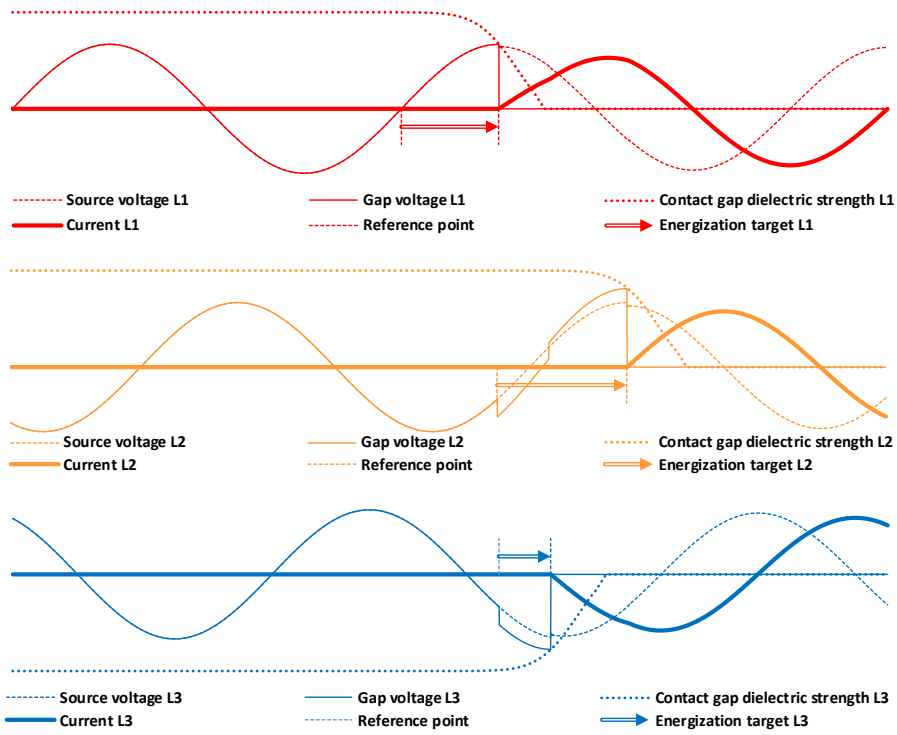


Figure 40: Controlled energization of an inductance grounded non-coupled reactor

5.2.1.2 Controlled de-energization

Table 39 shows the settings to be applied for controlled opening with PWC600 to achieve the switching strategy described in Table 35.

Table 39: Settings for controlled opening with PWC600 for impedance grounded reactor

Interruption target (deg)			Arcing time (ms)					
L1 (lead phase)	L2	L3	50 Hz			60 Hz		
			L1	L2	L3	L1	L2	L3
Source voltage reference								
270°	120°	θ	$Tarc_{1_50}$	$Tarc_{2_50}$	$Tarc_{3_50}$	$Tarc_{1_60}$	$Tarc_{2_60}$	$Tarc_{3_60}$
Load current reference								
180°	120°	θ	$Tarc_{1_50}$	$Tarc_{2_50}$	$Tarc_{3_50}$	$Tarc_{1_60}$	$Tarc_{2_60}$	$Tarc_{3_60}$

The values of θ for various impedance grounded reactor configurations are given in Table 40.

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Table 40: Current interruption target in L3 for different impedance grounded reactor configurations

Reactor configuration	θ
Non-coupled, grounded through inductor	Tm
Magnetically coupled, grounded through inductor (k factor ≥0.3)	Tm
Magnetically coupled, grounded through inductor (k factor <0.3)	60°
Non-coupled, grounded through resistor	60°
Magnetically coupled, grounded through resistor	60°

$$Tm = \left(\frac{180}{\pi} \tan^{-1}(\sqrt{3} \cdot (1 + 2K) \right)$$

(Equation 10)

Initial target arcing times are calculated by SST based on reactor data. The settings should be adjusted, if necessary, from the result of the first controlled opening operation.

Figure 41 shows the waveform representation of controlled de-energization of an inductance grounded non-coupled reactor using source voltage as reference.

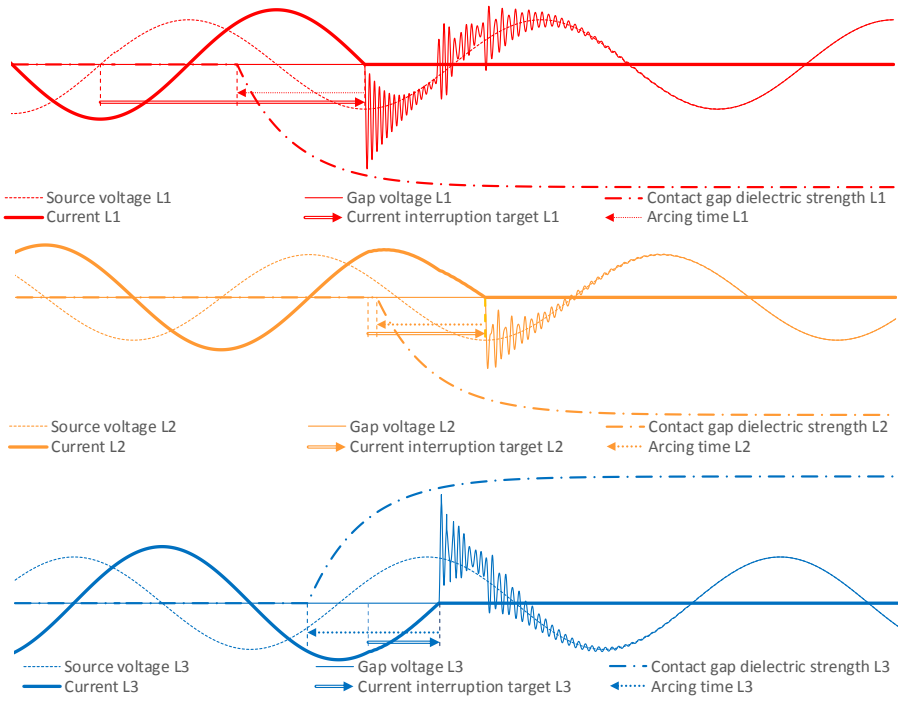


Figure 41: Controlled de-energization of an inductance grounded non-coupled reactor using source voltage as reference

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5.2.2 Energization of ungrounded capacitor bank with three-pole operated circuit breaker

Three-pole operated (TPO) circuit breakers with mechanically staggered design are frequently used for controlled switching in medium-voltage applications, especially for energization of ungrounded capacitor banks. The mechanical staggering between poles depends upon the application and switching sequence to be achieved. Therefore, to achieve controlled switching with three-pole operated mechanically staggered circuit breakers, full details in context to the rating, design and connection configuration of the power equipment needs to be furnished in advance to the circuit breaker supplier unit. Based on these details, circuit breaker switching sequence for the specific application and needed staggering between the poles are defined. In this section, application of a three-pole operated operated circuit breaker for controlled energization of an ungrounded capacitor bank is discussed.

With simultaneous closing strategy, two phases of a discharged ungrounded capacitor bank are energized together, followed by the third phase 90° later. Considering L1-L3-L2 switching sequence, L1 & L3 can be energized together followed by L2 phase 90° later (L1L3-L2). To achieve this sequence, closing time of the middle pole (L2) needs to be increased by 5 ms at 50 Hz or 4.2 ms at 60 Hz over the closing times of the remaining two poles (L1 & L3). For a TPO circuit breaker, the operating command can be wired only to the closing coil of the common drive between the poles. Thus, with a single drive to operate the circuit breaker, only the target of phase L1 will contribute to the controlled switching, whereas the targets defined for L2 and L3 will have no practical effect. Similarly, adaptive correction in L2 and L3 will not be possible.

Table 41 shows the PWC600 configuration details for this application.

Table 41: PWC600 settings for energization of ungrounded capacitor bank with TPO breaker

Target making angle (deg) (L1L3-L2 sequence)			**Gap voltage prior to current making (p.u.)**		
L1 (lead phase)	**L2**	**L3**	**L1**	**L2**	**L3**
30° + Φ_{D1}	90°	0	1	1.5	1

Internally, PWC600 will add an offset to the entered making targets, to cater for the dielectric and mechanical characteristics of the specific circuit breaker, as explained in Section 4.4.3.1. These optimized targets can be seen as **Target current making angle** in the operation log.

Figure 42 shows the waveform record of controlled energization of an ungrounded capacitor bank with a TPO circuit breaker. The L1L3-L2 energization sequence has been achieved with the circuit breaker poles being mechanical staggered as mentioned previously.

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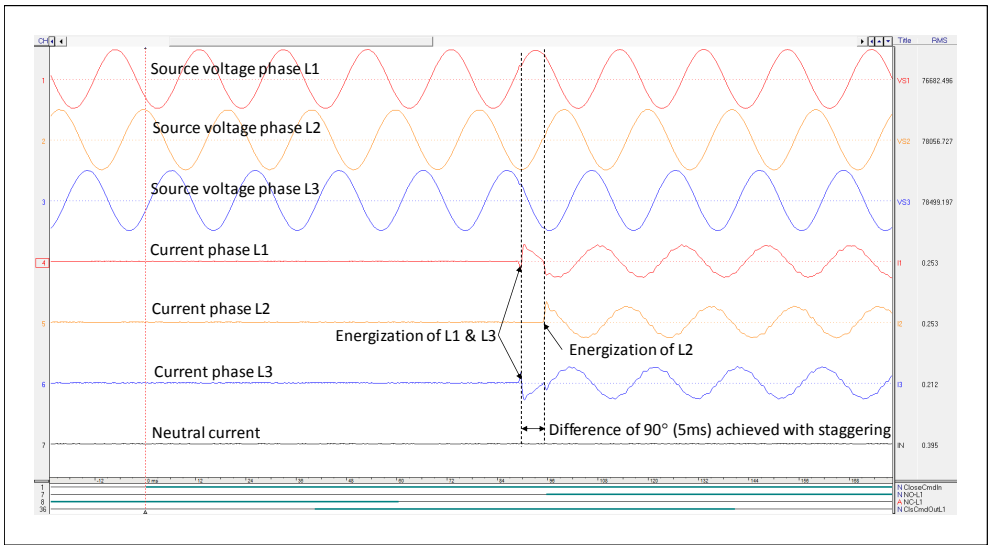


Figure 42: Waveform record of controlled energization of an ungrounded capacitor bank with TPO circuit breaker in L1L3-L2 switching sequence

The binary signals included in the waveform records are:

- CloseCmdIn: Closing command at input of PWC600
- NO-L1: “52a” auxiliary contact status
- NC-L1: “52b” auxiliary contact status
- ClsCmdOutL1: Closing command out to Closing coil of Circuit breaker

For application with a TPO circuit breaker, some changes need to made in application configuration of PWC600, to enable monitoring and adaptation only for the first phase L1 on which the controlled switching is targeted. Consequently, commands and circuit breaker status signals related to only phase L1 are displayed in waveform record. The corresponding view of operation record is shown in Figure 43. Contact ABB for details.

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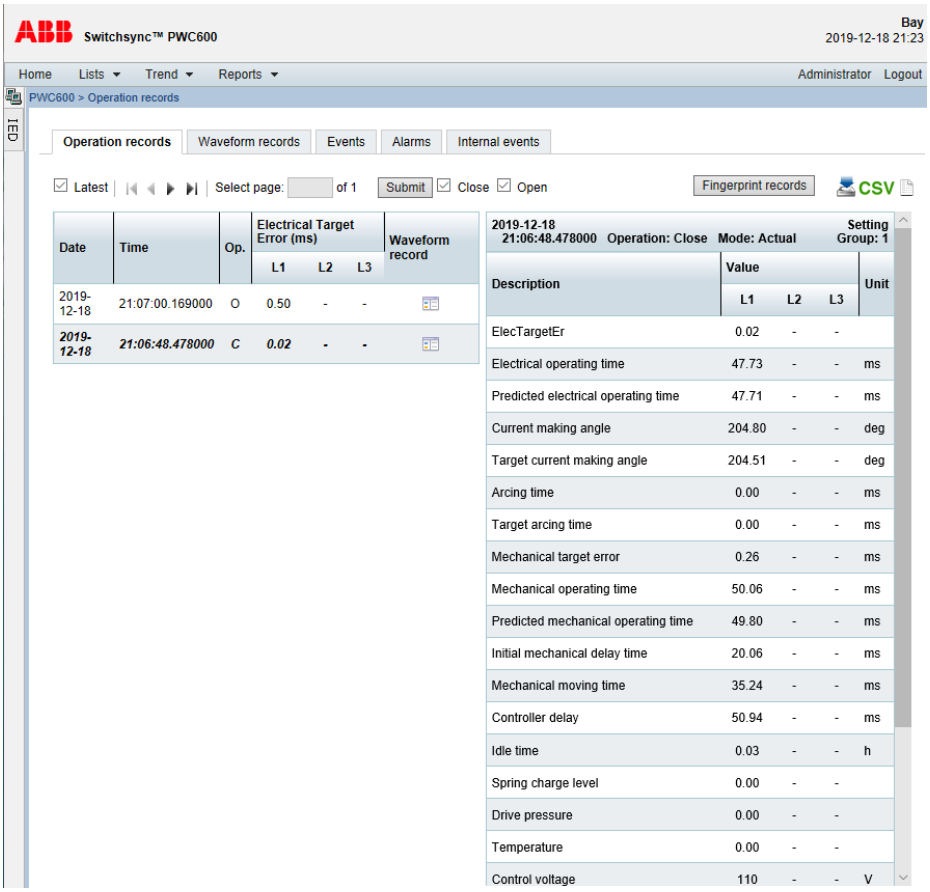


Figure 43: Operation record of controlled energization of an ungrounded capacitor bank with TPO circuit breaker in L1L3-L2 switching sequence

5.2.3 Non-coupled Reactor energization and de-energization with L3 as lead phase

PWC600 always proposes the switching strategies for both energization and de-energization operations, considering L1 as lead phase. However, the suggested targets for individual phases can be modified in the range of -1800° to +1800° to facilitate flexibility in switching strategies. As example, this section explains the targets to be applied for controlled switching (both closing and opening) of a non-coupled grounded reactor with L3-L2-L1 switching sequence.

5.2.3.1 Controlled energization

Figure 44 shows the switching targets to be applied for energization, using the targets definition from Section 4.3.2.1.

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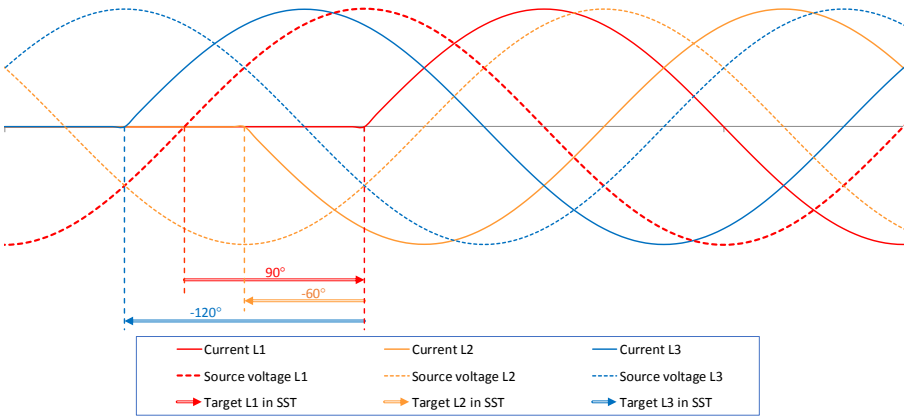


Figure 44: Controlled energization of a non-coupled grounded reactor in L3-L2-L1 sequence

As the energization target for first phase L1 is defined with reference to a zero crossing of source voltage L1, the ideal energization target for L1 will be 90°. The targets for L2 and L3 are defined with reference to L1 target; hence, for L3-L2-L1 sequence, L2 will be energized 60° earlier than L1 (-60°) and L3 will be energized 120° earlier than L1 (-120°), as shown in Figure 44. PWC600 further optimizes the targets internally, considering gap voltage factor for individual poles and mechanical and dielectric characteristics of the circuit breaker. Refer to Section 4.4.3.1 for details.

5.2.3.2 Controlled de-energization

Figure 45 shows the current interruption targets at natural current zero in each phase. The applied switching targets are relative to source voltage zero, using the targets definition from Section 4.3.2.2. The initial arcing times for all three phases are considered as 7.5 ms.

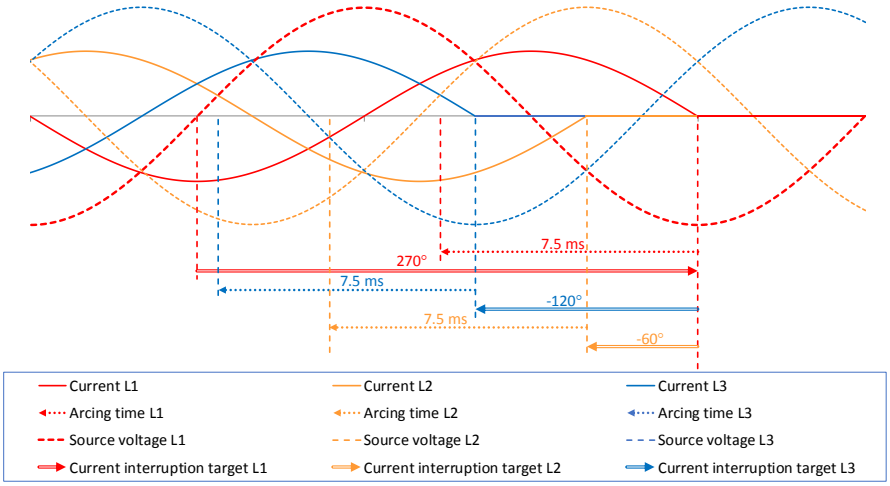


Figure 45: Controlled de-energization of a non-coupled grounded reactor in L3-L2-L1 sequence, voltage reference

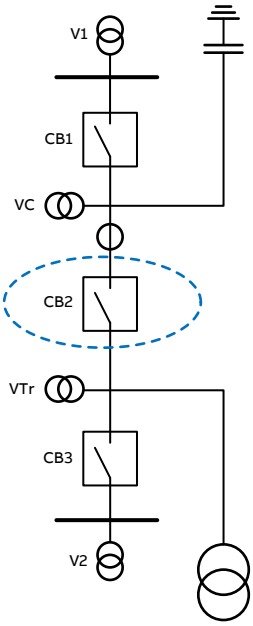
As the de-energization target for first phase L1 is defined with reference to a zero crossing of source voltage L1, the current interruption target (at natural current zero in L1), will be 270°.

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The targets for L2 and L3 are defined with reference to L1 target; hence, for L3-L2-L1 sequence, L2 will interrupt 60° earlier than L1 (-60°) and L3 will interrupt 120° earlier than L1 (-120°), as shown in Figure 45. From these electrical targets, the mechanical target contact separation instants are obtained by subtracting the arcing times, which here are given as 7.5ms for all three phases.

5.2.4 Variable applications

In a 1½ circuit breakers arrangement, the middle (tie) breaker is connected to a load on each end. The same would apply to every breaker in a ring layout. These two loads may be of the same type but more often they are different. See Figure 46 for an example, where the tie breaker CB2 is connected to both a capacitor bank and a power transformer.



IEC19000988-en.vsdx

Figure 46: Example SLD of a CB switching two loads

In this example, the ideal energization strategies for the two loads (capacitor and transformer) are not the same: Whereas the capacitor bank should be energized near voltage zero to minimize the switching overvoltages and inrush currents, the transformer should be energized near voltage peak (depending on residual flux). Thus, for successful controlled energization in each case, the controlled closing strategy needs to be matched to the load that will be energized at that time.

Rather than installing two separate PWC600 devices to control CB2 – one for each load – PWC600 1.1 and higher can accommodate this functionality in a single device through a feature called Setting Groups. It allows automatic application of different parameter sets based on external signals or conditions. Selecting a setting group applies the parameters of that group immediately, without application restart or similar delay factors.

In the example of Figure 46, Setting Group 1 (SG1) could be programmed for energizing the power transformer from the capacitor end of CB2 and Setting Group 2 (SG2) for energizing the capacitor bank from the transformer end of CB2. The recommended controlled switching strategies for each of these load types are described in Section 5.1.

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In addition to the controlled switching strategies, the application also needs to select the appropriate VT to be used as reference source for targeting. Here, the selected setting group should define one VT as reference source and the other as feedback signal. If the voltage transformers VTr and VC are present in the example diameter, these are the preferred VTs to be connected to PWC600. Otherwise, the busbar VTs V1 and V2 can be used as reference, albeit they will not allow seeing the actual voltage feedback on the load being switched.

Another aspect that may vary in two-loads situations is the selection of feedback signals for detecting the actual switching instants. Different load types may require different feedback signals, as explained in previous sections. Also, the availability of load VTs and precision auxiliary contacts must be considered. In the example above, CB auxiliary contacts could be defined as feedback signal for transformer energization, and the current through CB2 for capacitor energization.

When defining the feedback signals consider the number of available inputs. For example, only one three-phase current transformer (preferably measuring the current through the CB) can be connected to the IED. If more analog input signals are required, they can be provided via IEC 61850-9-2(LE) process bus.

When each end of the circuit breaker is connected to a load, the current direction when switching the first load will be the opposite of when switching the second one. This does not affect PWC600 functionality but will be reflected in the waveform records, in that the phase relation (leading or lagging) between current and voltage may be inverted.

The crucial step for correct application of setting groups is defining the criteria for automatic selection of the appropriate group. In the example of Figure 46, the following criteria lend themselves to straightforward implementation.

1. RMS of voltage signal, computed inside PWC600 from VT signal: If VTr is off (below the zero-level threshold), the next CB2 closing will presumably energize the transformer; hence apply SG1, which uses VC or V1 as reference source. Otherwise apply SG2, which uses VTr or V2 as reference source for energizing the capacitor.
2. Status of external switchgear, taken from its auxiliary contact via binary input(s): If CB1 is closed, the next CB2 closing will presumably energize the transformer, hence apply SG1. Otherwise apply SG2.

These criteria could be refined by including the status of disconnectors and other switches in the diameter. Possibly a combined selection signal can be extracted from the diameter interlocking logic. However, bear in mind that the goal is assuring appropriate controlled switching under live conditions, hence a simple binary criterion will often suffice.

Similar applications that are easily handled by setting groups include:

- In a double-busbar arrangement, select the appropriate busbar VT as reference, without the need for external circuits for switching the VT signals. An obvious criterion is the position of a busbar disconnector, obtained from its auxiliary contact.
- For power transformers, apply a fallback strategy for closing (assuming zero residual flux) whenever the CB was opened not by PWC600. This condition can be derived inside PWC600 through logic functions.
- For loads with variable electrical configuration, e.g. switchable earthing of neutral point, apply the optimal switching strategy in all cases. The criterion is the position of the relevant switch.
- For any application, bypass the controlled switching functionality whenever an external or internal binary signal is asserted.

Implementation of setting groups for controlled switching is described in Section 9.4.14.

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5.2.5 Adaptive correction for coupled transformers using load voltage feedback

For magnetically and/or electrically coupled transformers, voltage start is observed in all three phases as soon as first phase is energized, even if the second and third poles are still open. Therefore, special adjustments are needed for correctly detecting the making instants from load side voltage in the later phases, to obtain proper adaptive correction in case of coupled transformers.

Example of an electrically coupled transformer with vector group YNd1 or YNd11 to be energized from YN side is discussed here. Primary phase-to-ground voltage is measured on the YN side of the transformer. Therefore, the voltages measured by the VT directly replicate the voltage across the individual transformer windings.

As soon as the first phase L1 is energized, voltage is seen in all three phases of the transformer. To sense the electrical making instants separately for the first energizing phase L1 and the first following phase L3, a differential arrangement is used as shown in Figure 47. Here, the L1 making instant is determined from the differential winding voltage V_{L1}–V_{L2} (between L1 and L2 phases). The energization instant for the first following phase (L3) is likewise obtained from the differentially winding voltage $V_{L2} – V_{L3}$ (between L2 and L3 phases), which is almost zero prior to L3 energization. Furthermore, as soon as first following phase (L3) energizes, due to the coupling effect, full voltage also appears on the last phase still to be energized (L2). Hence, the energizing instant for last energizing phase (L2) cannot be sensed from the load voltage feedback and its adaptation shall be disabled. Moreover, the resultant flux for this phase is locked as soon as the first two phases (L1 & L3) are energized. Therefore, the variation in energization instant of the last energizing phase (L2) doesn’t impact the peak inrush current variations.



To achieve proper monitoring and adaptation, disable adaptive correction for the last energizing pole (L2) and put the maximum possible RDDS value, since no prestrike will be observed in last pole to close. Also, large electrical target errors will be recorded for this phase. To prevent raising of false alarms, remove the threshold supervision for L2 phase. Refer to Section 9.4.6.3 . In the operation records for closing operations, the “Electrical operating time” and “Current making angle” values for the last energizing pole (L2) can be disregarded.

Figure 47 also shows that it is not possible to detect the actual making instants from the primary current signals, as it does not rise immediately upon energization.

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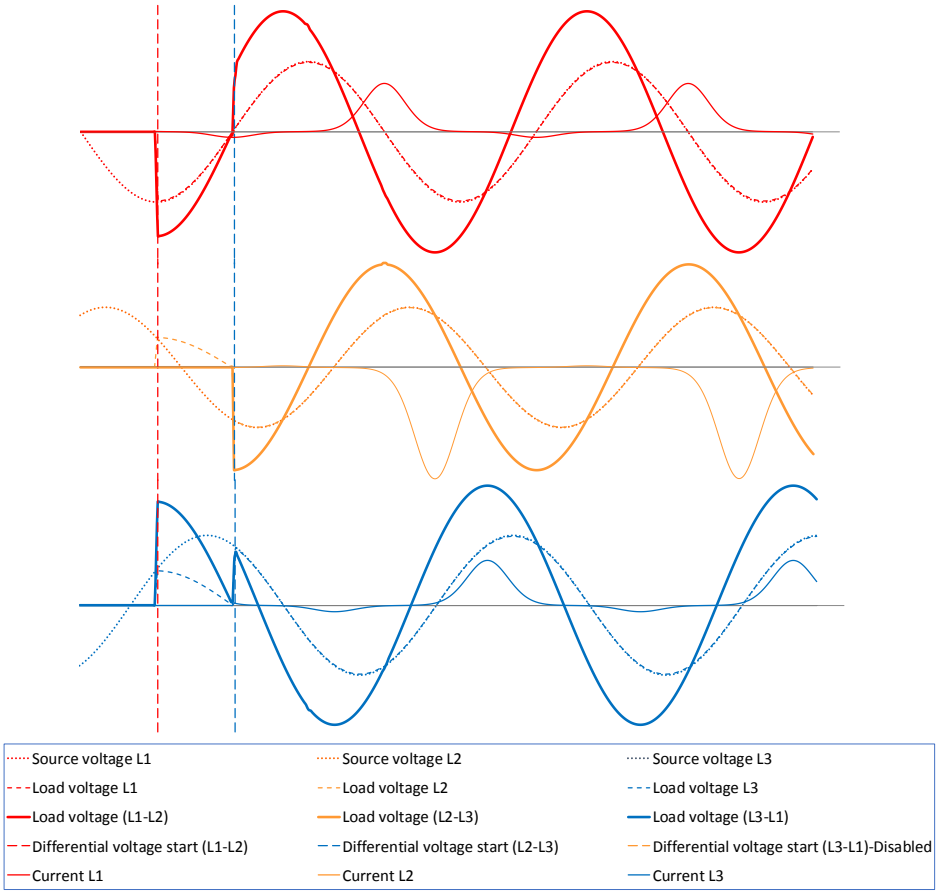


Figure 47: Transformer side voltages arranged for sensing energization instants of coupled transformer to be energized from YN side

Table 42 shows transformer side voltage feedback to be used for some example transformer configurations. It is assumed that each voltage transformer measures the phase-to-ground voltage.

Table 42: Feedback signals for some transformer configurations with YN connected voltage transformer

Configuration	Side of energization	Vector group	Transformer winding having load VT	Feedback to PWC600 for individual phase inputs		
				L1	L2	L3
Non-coupled transformer	YN	YNyn0	YN/yn	V_{L1}	V_{L2}	V_{L3}
Electrically or magnetically coupled transformers	YN	YNd1 / YNd11	YN	V_{L1}-V_{L2}	V_{L2}-V_{L3}	V_{L2}-V_{L3}
		YNd1	d	V_{L1}	V_{L3}	V_{L3}
		YNd11		V_{L1}	V_{L2}	V_{L2}
	D	Dyn1 / Dyn11	D	V_{d1}-V_{d3}	V_{d2}-V_{d1}	V_{d3}-V_{d2}
		Dyn1	yn	V_{L1}-V_{L2}	V_{L2}-V_{L3}	V_{L3}-V_{L1}
		Dyn11		V_{L1}-V_{L2}	V_{L3}-V_{L1}	V_{L2}-V_{L3}

Where,

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V_{L1}, V_{L2} and V_{L3} are the phase-to-ground measured voltages from voltage transformer respectively.

$V_{d1} = V_{L1} – V_{L2}$,

$V_{d2} = V_{L2} – V_{L3}$,

$V_{d3} = V_{L3} – V_{L1}$

Measurement of the differential voltages can be realized either by external wiring or through a modification of the PWC600 application configuration. Contact ABB for further details.



For voltage feedback using a voltage transformer not measuring phase-to-ground voltage, contact ABB.



The suitability of the voltage transformer feedback signal depends upon the type of voltage transformer design (capacitive voltage transformer vs. electro-magnetic voltage transformer), the design and connection configuration of the power transformer, and adjacent equipment to be switched together with the transformer (for example, a long cable connected to any one winding of the transformer). This needs to be checked individually for every installation.

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Section 6 Installation

6.1 Unpacking, inspecting and storing

6.1.1 Removing transport packaging

IEDs require careful handling.

1. Examine the delivered products to ensure that they have not been damaged during the transport.
2. Remove the transport packing carefully without force.



The cardboard packaging material is 100% recyclable.

6.1.2 Inspecting the product

6.1.2.1 Identifying the product

1. Locate the IED's order number from the label attached to the IED's case.
2. Compare the IED's order number with the ordering information to verify that the received product is correct.

6.1.2.2 Checking delivery items

Check that all items are included in the delivery in accordance with the delivery documents.

6.1.2.3 Inspecting the IED

IEDs require careful handling before installation on site.

- Check the IED to see if any damage occurred during transportation.

If the IED has been damaged during transportation, make a claim against the transport contractor, and notify the local ABB representative.

6.1.2.4 Returning an IED damaged in transit

If damage has occurred during transport, appropriate actions must be taken against the latest carrier. Please inform the nearest ABB office or representative. Notify ABB immediately if there are any discrepancies in relation to the delivery documents.

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6.1.3 Storing

If the IED is stored before installation, it must be done in the original transport packaging in a dry and dust free place. Observe the environmental requirements stated in the technical data section.

6.2 Checking environmental conditions and mounting space

The mechanical and electrical environmental conditions at the installation site must be within the limits described in the technical data.

- Avoid installation in dusty, damp places.
- Avoid places susceptible to rapid temperature variations, powerful vibrations and shocks, surge voltages of high amplitude and fast rise time, strong induced magnetic fields or similar extreme conditions.
- Check that sufficient space is available.
  Sufficient space is needed at the front and rear of the IED to allow access to wires and optical fibres and to enable maintenance and future modifications.

6.3 Rack mounting the IED

1. Attach the mounting brackets to both ends of the IED using the screws enclosed with the rack mounting kit.

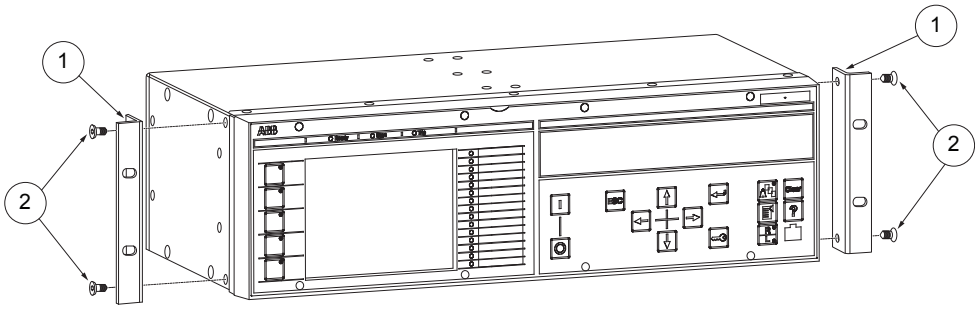


Figure 48: Mounting the brackets

1 Mounting brackets

2 Screws

2. Tighten the screws using a Torx T25 screwdriver.
3. Mount the IED with the rack mounting panels to the 19" rack.
4. Tighten the screws.

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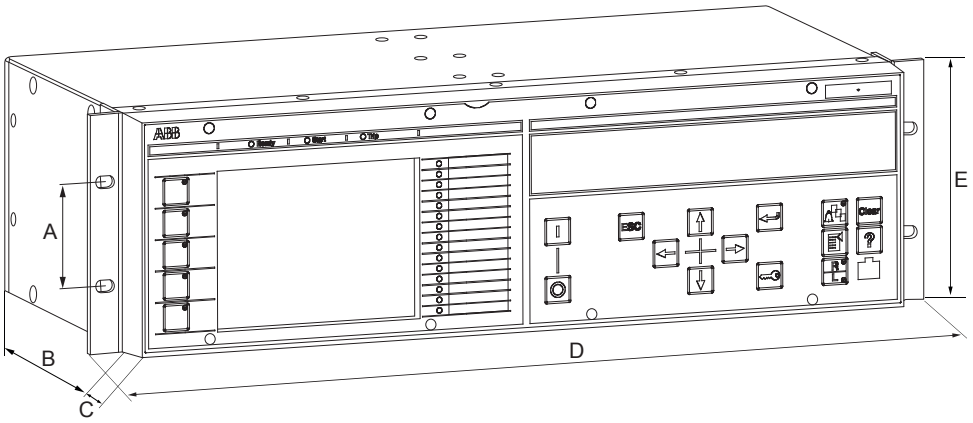


Figure 49: Rack mounted 3U IED

A 57.2 mm (2.25”)

B 224 mm (8.82”) + 12 mm (0.47”) with ring-lug connector

C 25.5 mm (1”)

D 482 mm (19”)

E 132 mm (5.20”), 3U

6.4 Arranging ventilation

Ventholes are located at the bottom and on the back plate of the IED. Reserve sufficient space around the IED to ensure adequate ventilation.

- Reserve at least 2U below and above the unit.
- Reserve for rack mount approximately 10 cm behind the unit, measured from the surface of the cover.
- Ensure sufficient space for the wiring and the installation of cable ducts.

6.5 Safety against laser exposure

The Tx output of the X9 communication port features a class 3R laser diode for long-range communication. However, this port is never used ins Switchsync PWC600. Hence, the Tx output shall be covered at all times.



Always keep the factory supplied cap on the Tx output of port X9, to prevent exposure to laser radiation.

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Section 7 Hardware interfaces

7.1 Connectors

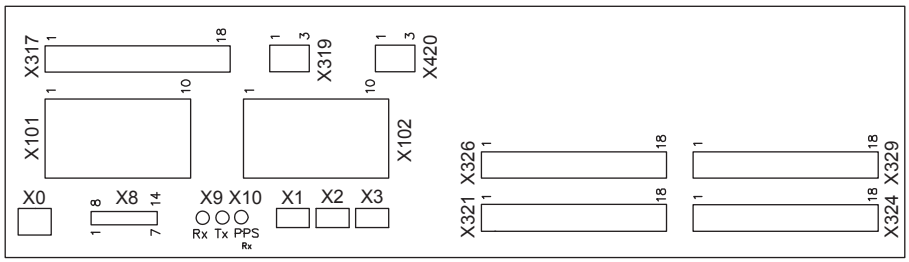


Figure 50: Rear panel connectors

Table 43: Interfaces used in the default pre-configuration of the Switchsync PWC600 IED

Connector	Description
X0	Connection for Detached HMI (Not used in Switchsync PWC600)
X1	Station bus: IEC61850-8-1, Web interface
X2	Redundant station bus, optional
X3	Process bus, sampled values from IEC 61850-9-2LE compliant merging units
X8	EIA-485 and IRIG-B serial connection
X9	Legacy optical serial communication (Not used in Switchsync PWC600)
X10	Optical 1PPS signal input for time synchronisation
X101, X102	Conventional CT and VT inputs
X317, X326	Signalling outputs
X319	IRF (Internal failure output)
X321	Open and close command outputs
X324	Circuit breaker auxiliary switch position inputs
X329	Close/Open command and CB drive energy status inputs
X420	Auxliary supply voltage input

7.2 Physical connections

7.2.1 Connecting protective earthing

Connect the IED to earth using a 16.0 mm^2 (AWG 5) flat copper cable. Use an earth lead of maximum 1500 mm (59”) length. Note that extra length is required for door mounting.

1. Loosen the nut from the protective earth pin to connect a separate earth protection lead.

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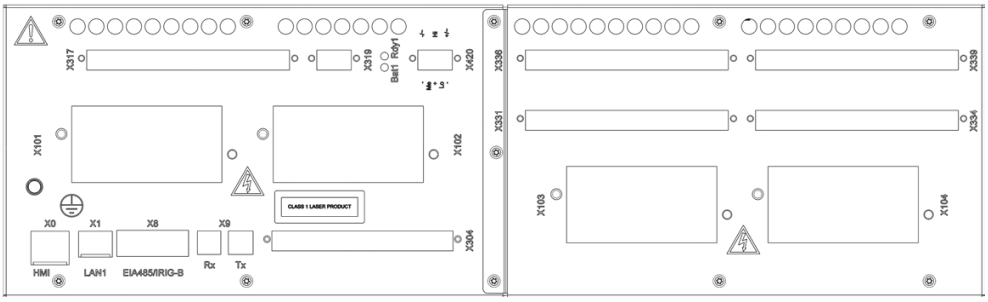


Figure 51: The protective ground pin is located to the left of connector X101 on the 3U full 19" case

Each IED must have its own earth lead connected to the earth circuit connector.

2. Connect the earth lead to the earth bar.
3. Thread the copper cable on the protective earth pin.
4. Tighten the nut on the protective earth pin.
5. Support the earth lead so that it cannot break or weaken.
   Observe the situations for mechanical, chemical or electrochemical conditions.

7.2.2 Connecting wires

1. Connect each signal connector terminal with one 0.5...2.5 mm^2 (AWG 20...13) wire or with two 0.5...1.0 mm^2 (AWG 20...17) wires.
2. Connect each compression type (X101 and X102) terminal for CTs/VTs with one 0.5...6.0 mm^2 (AWG 20...10) wire or with two wires of maximum 2.5 mm^2 (AWG 13).
3. Connect each terminal on the communication module for IRIG-B with one 0.2 - 1.0 mm^2 (AWG 24…17) wire.
4. Connect each terminal on the communication module for EIA-485 with one 0.2 - 1.0 mm^2 (AWG 24…17) wire.

See the following subsections for product-specific terminal assignments in the pre-configuration.

7.2.2.1 Connecting to screw-compression type terminals

Terminal blocks of screw-compression type are used for electrical connections.

1. Open the screw terminal before inserting a wire into it for the first time. To open the screw terminal, turn the fixing screw anti-clockwise until the terminal hole is wide open (the inside of the terminal hole is surrounded by metal).
2. Insert the wire and turn the fixing screw clockwise until the wire is firmly fixed.

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7.3 Inputs

7.3.1 Measuring inputs

Each terminal for CTs/VTs is dimensioned for one 0.5...6.0 mm^2 (AWG 20...10) wire or for two wires of maximum 2.5 mm^2 (AWG 13).

Table 44: Assignment of conventional CT and VT inputs in pre-configuration

Connector	Pin	Signal	Description	Software signal
X101	1	L1 I N	L1 phase current	TRM_2.CH1(I)
X101	2	L1 I L		
X101	3	L2 I N	L2 phase current	TRM_2.CH2(I)
X101	4	L2 I L		
X101	5	L3 I N	L3 phase current	TRM_2.CH3(I)
X101	6	L3 I L		
X101	7	-	Not used	TRM_2.CH4(I)
X101	8	-		
X101	9	L1 V1 N	Source voltage L1 / L1-L2 / only available single phase	TRM_2.CH5(U)
X101	10	L1 V1 L		
X102	1	L2 V1 N	Source voltage L2 / L2-L3	TRM_2.CH6(U)
X102	2	L2 V1 L		
X102	3	L3 V1 N	Source voltage L3 / L3-L1	TRM_2.CH7(U)
X102	4	L3 V1 L		
X102	5	L1 V2 N	Load voltage L1 (optional)	TRM_2.CH8(U)
X102	6	L1 V2 L		
X102	7	L2 V2 N	Load voltage L2 (optional)	TRM_2.CH9(U)
X102	8	L2 V2 L		
X102	9	L3 V2 N	Load voltage L3 (optional)	TRM_2.CH10(U)
X102	10	L3 V2 L		

A single-phase reference VT shall always be connected to terminals X101:9-10, regardless which system phase(s) it measures. If it does not measure L1 then the application configuration should be adjusted for proper recording and display of the signals (see Section 9.4.3.9).

The CT connector features an automatic short-circuit mechanism for the current terminals. Therefore, detaching the connector from the unit will not open the secondary circuit of the CT, which otherwise could cause dangerously high voltages.

To avoid mismatch between CT and VT connections the connectors are mechanically encoded and cannot be inserted in the wrong location.

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7.3.2 Auxiliary supply voltage input

The auxiliary voltage of the IED is connected to terminals X420-1 and X420-2/3 by one 0.5…2.5 mm^2 (AWG 20…13) wire or by two 0.5…1.0 mm^2 (AWG 20…17) wires. The terminals used depend on the power supply.

The permitted auxiliary voltage range of the IED is marked on the identification sticker on the IED's enclosure.

Table 45: Auxliary supply voltage input

Connector	Pin	Signal	Description	Software signal
X420	1	UB-	IED supply voltage (battery voltage)	PSM_102.BATTAMPL
X420	2	UB+ Me	IED supply voltage (battery voltage) for 48…125V DC variant	
X420	3	UB+ Hi	IED supply voltage (battery voltage) for 110… 250V DC variant	



Connect the power supply only to connector X420. Since connectors X420 and X319 are the same size, make sure not to accidentally plug the power supply connector into X319.

The two LEDs next to X420 indicate the following conditions:

- Bat1 = input voltage (e.g. station battery) is within the expected range.
- Rdy1 = output voltage of internal power supply is within the expected range (no IED internal short circuit or overvoltage).

7.3.3 Binary inputs

Each connector terminal is connected with one 0.5…2.5 mm^2 (AWG 20…13) wire or with two 0.5…1.0 mm^2 (AWG 20…17) wires.

Table 46: Circuit breaker auxiliary switch position inputs

Connector	Pin	Signal	Description	Software signal
X324	1	L1 NO/52a -	UB-	PIO_3.PBI4
X324	2	L1 NO/52a +	L1 auxiliary contact NO (52a), the other pole of which is connected to UB+	
X324	3	L2 NO/52a -	UB-	PIO_3.PBI5
X324	4	L2 NO/52a +	L2 auxiliary contact NO (52a), the other pole of which is connected to UB+	
X324	5	L3 NO/52a -	UB-	PIO_3.PBI6
X324	6	L3 NO/52a +	L3 auxiliary contact NO (52a), the other pole of which is connected to UB+	
X324	7	L1 NC/52b -	UB-	PIO_3.PBI7
X324	8	L1 NC/52b +	L1 auxiliary contact NC (52b), the other pole of which is connected to UB+	
X324	9	L2 NC/52b -	UB-	PIO_3.PBI8
X324	10	L2 NC/52b +	L2 auxiliary contact NC (52b), the other pole of which is connected to UB+	

Table continues on next page

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Connector	Pin	Signal	Description	Software signal
X324	11	L3 NC/52b -	UB-	PIO_3.PBI9
X324	12	L3 NC/52b +	L3 auxiliary contact NC (52b), the other pole of which is connected to UB+	
X324	13	L1 prim -	UB-	PIO_3.PBI10
X324	14	L1 prim +	L1 primary contact (make available on terminal; only used during commissioning)	
X324	15	L2 prim -	UB-	PIO_3.PBI11
X324	16	L2 prim +	L2 primary contact (make available on terminal; only used during commissioning)	
X324	17	L3 prim -	UB-	PIO_3.PBI12
X324	18	L3 prim +	L3 primary contact (make available on terminal; only used during commissioning)	

For full timing accuracy, a resistor for discharging the cable capacitance should be permanently connected in parallel to each precision binary input. Resistance value and power rating depend on the length of the wires between IED and the circuit breaker, and the nominal battery voltage. Table 47 lists some suggested values.

Table 47: Recommended shunt resistor ratings for precision binary inputs

Cable length	110...127 V supply	220...250 V supply
Up to 30 m	100 kΩ, 0.5 W	100 kΩ, 2 W
Up to 150 m	33 kΩ, 2 W	33 kΩ, 5 W
Up to 300 m	15 kΩ, 3 W	15 kΩ, 15 W
Above 300 m	4.7 kΩ, 10 W	4.7 kΩ, 30 W

Table 48: Inputs for close/open commands and CB drive energy level

Connector	Pin	Signal	Description	Software signal
X329	1	Close in -	Close command input from bay control	BIO_4.BI1
X329	2	Close in +		
X329	4	Open in -	Open command input from bay control	BIO_4.BI2
X329	5	Open in +		
X329	8	L1 Spr -	L1 spring charge level (common terminal)	*
X329	9	L1 Spr OCObk +	L1 spring charge level: OCO blocked	BIO_4.BI4
X329	10	L1 Spr CObk +	L1 spring charge level: CO blocked	BIO_4.BI5
X329	12	L2 Spr -	L2 spring charge level (common terminal)	*
X329	13	L2 Spr OCObk +	L2 spring charge level: OCO blocked	BIO_4.BI6
X329	14	L2 Spr CObk +	L2 spring charge level: CO blocked	BIO_4.BI7
X329	16	L3 Spr -	L3 spring charge level (common terminal)	*
X329	17	L3 Spr OCObk +	L3 spring charge level: OCO blocked	BIO_4.BI8
X329	18	L3 Spr CObk +	L3 spring charge level: CO blocked	BIO_4.BI9
X321	13	LED Rst -	Reset latched status LEDs	PIO_3.PBI1
X321	14	LED Rst +		

Table continues on next page

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Connector	Pin	Signal	Description	Software signal
X321	15	PBI2	Spare precision input 2	PIO_3.PBI2
X321				
X321	15	PB13	Spare precision input 3	PIO_3.PBI3
X321				
* No separate software designation, as this is the common terminal for the next two signals.				

Binary inputs for spring charge level are intended for circuit breakers in which the drive energy and the operating capability can differ with the position of the main storage element (spring). This occurs in spring-hydraulic drives such as ABB models HMB/HMC. The spring charge information is used for compensation of operating times and for reporting the CB's operating capability. However, if the breaker is not used for fast reclosing and if the spring is always fully charged prior to each operation, these inputs need not be connected. Similarly, these inputs are not used with drives in which the spring is always fully charged by design.

7.4 Outputs

7.4.1 Outputs for circuit breaker control

Each connector terminal is connected with one one 0.5…2.5 mm² (AWG 20…13) wire or with two 0.5…1.0 mm² (AWG 20…17) wires.

Table 49: Open and close command outputs

Connector	Pin	Signal	Description	Software signal
X321	1	L1 Close -	Controlled close command output L1	PIO_3.PBO1
X321	2	L1 Close +		
X321	3	L2 Close -	Controlled close command output L2	PIO_3.PBO2
X321	4	L2 Close +		
X321	5	L3 Close -	Controlled close command output L3	PIO_3.PBO3
X321	6	L3 Close +		
X321	7	L1 Open -	Controlled open command output L1	PIO_3.PBO4
X321	8	L1 Open +		
X321	9	L2 Open -	Controlled open command output L2	PIO_3.PBO5
X321	10	L2 Open +		
X321	11	L3 Open -	Controlled open command output L3	PIO_3.PBO6
X321	12	L3 Open +		

7.4.2 Outputs for signalling

Signal output contacts are used for signalling alarms and warning conditions.

Each signal connector terminal is connected with one 0.5…2.5 mm² (AWG 20…13) wire or with two 0.5…1.0 mm² (AWG 20…17) wires.

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Table 50: Signalling outputs

Connector	Pin	Signal	Description	Software signal
X317	13	Al Discr NO	Alarm: Breaker testing discrepancy trip	PSM_102.BO7_SO
X317	14			
X317	15	Al 9-2 NO	Warning: Loss of 9-2 data or synchronization	PSM_102.BO8_SO
X317	16			
X317	17	Al SigPr NO	Alarm: Error in signal processing	PSM_102.BO9_SO
X317	18			
X326	7	Wa Reig NO	Warning: Re-Strike / re-ignition detected	BIO_4.BO4_SO
X326	8			
X326	9	Wa Accur NO	Warning: Reduced accuracy of last controlled switching operations	BIO_4.BO5_SO
X326	10			
X326	11	Wa LComp NO	Warning: Loss of compensation signal	BIO_4.BO6_SO
X326	12			
X326	13	Wa Thresh NO	Threshold supervision warning	BIO_4.BO7_SO
X326	14	Al Thresh NO	Threshold supervision alarm	BIO_4.BO8_SO
X326	15	Thresh Com	Threshold supervision (common)	-
X326	16	Wa Uncont NC	Warning: Controlled switching not possible	BIO_4.BO9_SO
X326	17	Wa Uncont NO		
X326	18	Wa Uncont Com		

7.4.3 IRF

The IRF contact functions as a change-over output contact for the self-supervision system of the IED. Under normal operating conditions, the IED is energized and one of the two contacts is closed. When a fault is detected by the self-supervision system or the auxiliary voltage is disconnected, the closed contact drops off and the other contact closes.

The connector is delivered with the device. Each connector terminal is connected with one 0.5…2.5 mm² (AWG 20…13) wire or with two 0.5…1.0 mm² (AWG 20…17) wires.

Table 51: IRF contact on PSM

Connector	Pin	Description
X319	1	Closed: no IRF, and U_{aux} connected
X319	2	Closed: IRF, or U_{aux} disconnected
X319	3	IRF, common

7.5 Trip circuit supervision (TCS)

TCS continuously injects a small DC current of approximately 1 mA into the supervised circuit and checks whether the resulting voltage falls in a fixed range. If not, this is interpreted as a fault in the circuit (either short circuit or open circuit) and the function raises an alarm.

The PWC600 IED features TCS in three of the power outputs on the PSM. As these outputs are normally not used in PWC600, TCS can be used on its own for supervising either the Trip coils or the Close coils of the circuit breaker.

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Each connector terminal is connected with one 0.5…2.5 mm² (AWG 20…13) wire or with two 0.5…1.0 mm² (AWG 20…17) wires.

Table 52: Power outputs with trip coil supervision

Connector	Pin	Signal	Description	Software signal
X317	1	L1 TCS -	Trip circuit supervision L1	PSM_102.TCS_BO1
X317	2	L1 TCS +		
X317	3	L2 TCS -	Trip circuit supervision L2	PSM_102.TCS_BO2
X317	4	L2 TCS +		
X317	5	L3 TCS -	Trip circuit supervision L3	PSM_102.TCS_BO3
X317	6	L3 TCS +		

Usually, the Trip coil circuit is interrupted by an auxiliary contact when the CB is open; likewise, the Close coil circuit is interrupted when the CB is closed. Preventing false TCS alarms in this situation can be achieved by two methods: Adding an external resistor to ensure a closed coil circuit at all times, or blocking the TCS when the CB is open (or closed, respectively, when supervising the Close coil circuit). Electrical connections for the two methods are explained below; associated software engineering is described in Section 9.4.15.

7.5.1 TCS with external resistor

An external resistor R_{ext} is connected to the supervised coil (Rs) via an additional auxiliary contact. This is shown in Figure 52 for the Trip coil of CB pole L1.

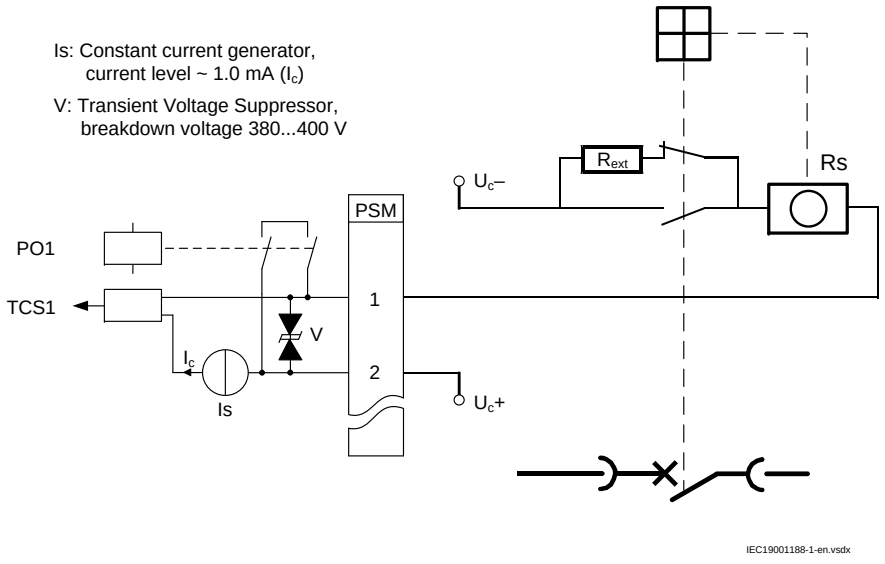


Figure 52: Connecting trip circuit supervision with external resistor

The external resistor shall be dimensioned such that the voltage across the TCS input is higher than 20 V in normal service. Of course, the current through the resistor must be very low so as not to excite the deactivated coil. Some recommended values are listed in Table 53.

Table 53: Recommended values for external shunt resistor

Battery voltage U_c	Shunt resistor R_{ext}
110 V	33 kΩ, 5 W
220 V	68 kΩ, 5 W

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With this circuit, continuity of the coil circuit is permanently supervised regardless of the CB status.

7.5.2 TCS without external resistor

Figure 53The below figure shows the TCS wiring for the Trip coil (Rs) of CB pole L1.

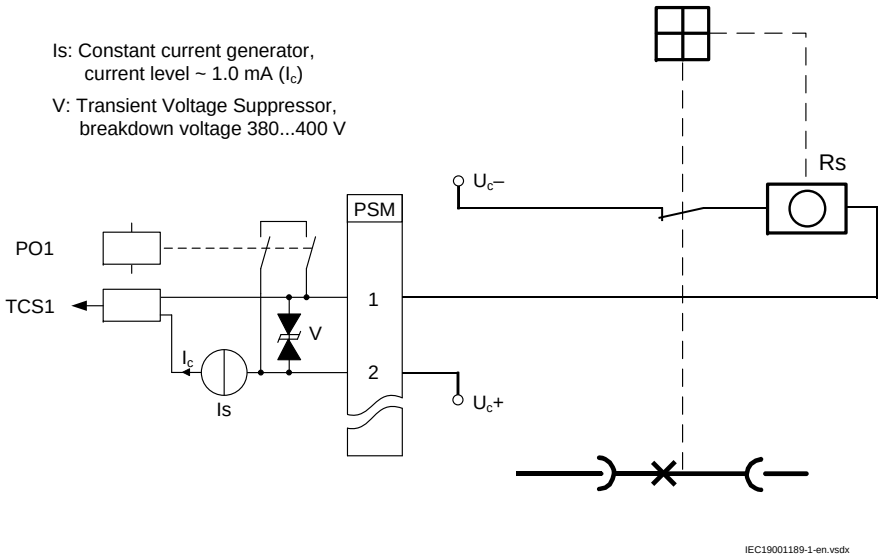


Figure 53: Connecting trip circuit supervision without external resistor

When the CB is open, the auxiliary contact interrupts the Trip coil circuit. Preventing false alarms in this situation requires the CB status information from another auxiliary contact. As the status is used for blocking the TCS function this need not be a precision contact; however, if such a contact is already connected to the IED (Section 7.3.3) it can be reused internally for this purpose. The required change in application configuration is described in Section 9.4.15.

7.6 Communication interfaces

The IED's LHMI is provided with an RJ-45 connector. This interface is intended for temporarily connecting a PC, for interrogation, configuration, and setting purposes.

Station bus and process bus communication runs on the communication module via the optical interfaces (LC Ethernet connectors) on the rear panel. If both are used, the process bus shall run as a separate network from the station bus to prevent interference of control data with the sampled values stream.

Rear communication via the X8/EIA-485/IRIG-B connector uses a communication module with the galvanic EIA-485 serial connection.

The HMI connector X0 and the serial interface X9 are not used in Switchsync PWC600.

7.6.1 Ethernet RJ-45 front connection

The IED's LHMI is provided with an RJ-45 connector designed for Ethernet point-to-point use. This interface is intended for configuration and setting purposes. The interface on the PC has to be configured in a way that it obtains the IP address automatically if the DHCP server is enabled in the IED. The DHCP server inside the IED can be activated for the front interface only.

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Usually this port is used only for temporary connection, thus no permanent wiring is required. Events, setting values and all input data such as operation records and waveform records can be read via the front communication port.

Only one of the possible clients can be used for parametrization at a time.

- PCM600
- LHMI
- WHMI

The default IP address of the IED through this port is 10.1.150.3.

The front port supports TCP/IP protocol. A standard Ethernet CAT 5 crossover cable with RJ-45 connector is used with the front port.

7.6.2 Station communication rear connection

The default IP address of the IED through the rear Ethernet port is 192.168.1.10. The physical connector is X1/LAN1 A. The communication speed is 100 Mbps for the 100BASE-FX LC interface.

For redundant communication, X1/LAN1 A and X2/LAN1 B can be used.

Table 54: Station bus

Connector	Pin	Signals	Description
X1	All	LAN1 A	Station bus
X2	All	LAN1 B	Redundant station bus, optional

For specification of the optical fibers to be used, see the corresponding technical data.

7.6.3 EIA-485 serial rear connection

The communication module follows the EIA-485 standard and is intended to be used in multi-point communication.

Table 55: EIA-485 and IRIG-B connections

Connector	Pin	Signals	Description
X8	1	RS485_GNDC	RS485 ground through capacitance
X8	2	RS485_RXTERM	Termination for RS485 receiver
X8	3	RS485_RX +	RS485 receiver
X8	4	RS485_TXTERM	Termination for RS485 transmitter
X8	5	RS485_SIGGND	Signal ground for RS485
X8	6	IRIG-B -	Time synchronization input
X8	7	IRIG-B_GNDC	IRIG-B ground through capacitance
X8	8	RS485_GND	RS485 ground
X8	9	RS485_RX -	RS485 receiver
X8	10	RS485_TX +	RS485 transmitter
X8	11	RS485_TX -	RS485 transmitter
X8	12	RS485_SIGGND	Signal ground for RS485
X8	13	IRIG-B +	Time synchronization input
X8	14	IRIG-B_GND	IRIG-B ground

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EIA-485 communication is not enabled in this product.

7.6.4 Process bus rear connection

Switchsync PWC600 can receive digital sampled values (voltage and/or current) via IEC 61850-9-2(LE) process bus at its X3/LAN2 A interface. Up to four logical merging units can be connected, which are distinguished by their sampled values ID (svID). The specifications of X3 are identical to X1 and X2.

Hardware synchronization of the sampled values is achieved by a 1PPS signal received on optical input X10. Time synchronization via SNTP or IRIG-B cannot be used for this purpose.

If the 9-2 process values to Switchsync PWC600 originate from two or more separate physical merging units, they should be synchronized to the same master. Otherwise, occasional communication interruptions may occur.

Table 56: Process bus

Connector	Pin	Signals	Description
X3	All	9-2LE	Process bus: sampled values from one or more merging units compliant to IEC 61850-9-2 (LE)

Table 57: Optical 1PPS signal

Connector	Pin	Signals	Description
X10	Rx	1PPS	Optical 1PPS signal from time synchronization master

For specification of the optical fibers to be used, see the corresponding technical data table.

7.6.5 Recommended industrial Ethernet switches

ABB recommends ABB industrial Ethernet switches.

7.7 Connection diagrams

The connection diagrams are delivered on the IED Connect USB stick as part of the product delivery. They can be accessed through the IED's context menu (item **Documentation**), or directly on the USB stick.

The latest versions of the connection diagrams can be downloaded from http://new.abb.com/high-voltage/monitoring/switchsync.

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https://manual-hub.com/

Section 8 Setting up a project in PCM600

8.1 Protection and Control IED Manager PCM600

PCM600 provides versatile functionalities for the entire life cycle of the protection and control IEDs in transmission and distribution applications.

- Planning
- Engineering
- Commissioning
- Operation and disturbance handling
- Functional analysis

With the individual tool components, it is possible to perform different tasks and functions and control the whole substation.

PCM600 is compliant with IEC 61850, which simplifies the IED engineering and enables information exchange with other IEC 61850 compliant tools. The hierarchical presentation model that reflects the real system topology enables efficient viewing and editing of the power system information.

Some features and functions are product-specific and not available for all the products.

Switchsync PWC600 1.1 requires PCM600 Version 2.9 or higher.

8.2 PCM600 projects

A project in PCM600 typically comprises one or several IED objects in a substation, arranged in a plant structure. Each IED object represents a physical device and contains the complete configuration data of the IED and the application. It may also include data downloaded from the device in service.

Several projects can be created and managed by PCM600, but only one project can be active at a time.

8.3 Installing Connectivity packages

A Connectivity package contains the complete description of the IED data signals, parameters and protocol addresses for a certain IED type and version. Several types of IEDs can be managed in one PCM600 project, thus the corresponding Connectivity package has to be installed on the PC. Connectivity Packages and Connectivity Package Updates are managed in Update Manager.

PCM600 must be installed before the connectivity packages can be installed.

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Always install the latest released connectivity package for PWC600, as it includes previous releases as well. The connectivity package releases to be used can be selected in Update Manager.

8.3.1 Installing IED Connectivity package from USB stick

The Connectivity package is available on the USB stick that is distributed with the IED. This part is to be updated when the installer USB stick is available.

1. Close PCM600 before running the IED connectivity package installation.
2. Select and run setup.exe. It is recommended to run the .exe as 'Run as administrator'.

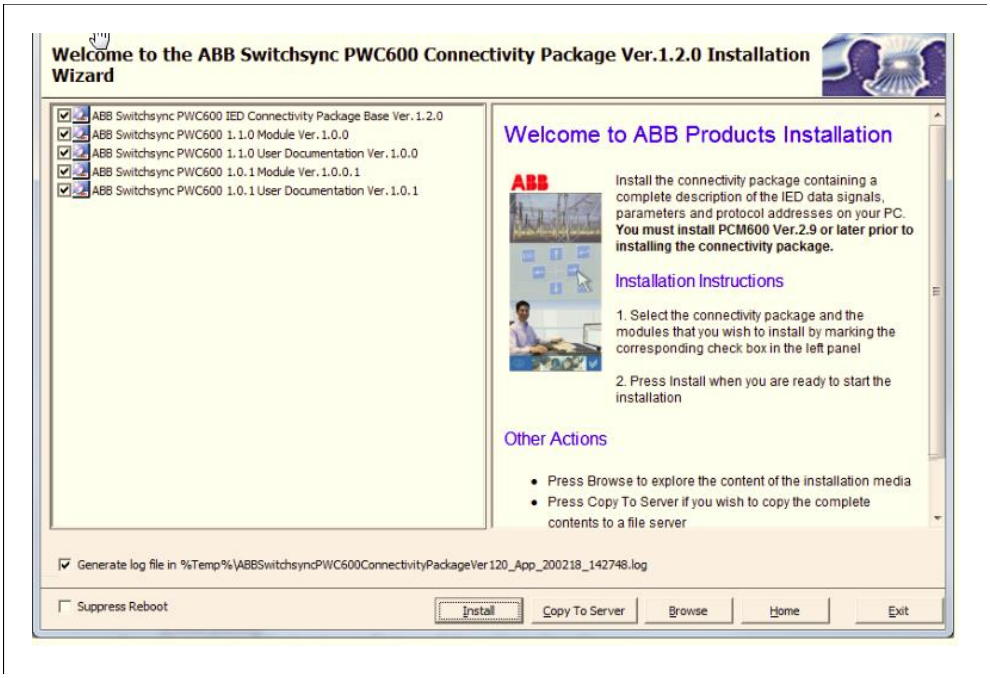


Figure 54: Installing Switchsync™ PWC600 Connectivity Package

3. Select the connectivity package and modules to install by marking the corresponding check boxes.
4. Press **Install** to start installation of the selected packages.
5. Press **Next** to confirm the selection. The user will be guided through the installation of various packages.

8.3.2 Installing IED Connectivity package from Update Manager

Update Manager has been installed together with, but is a separate program from, PCM600. It gives access to the latest updates of software and documentation for ABB Relion products.

1. Close PCM600 before running Update Manager.
2. Ensure that the PC has a working Internet connection.
3. Start Update Manager by double-clicking on the desktop icon, or from the corresponding Start menu item.
4. If queried whether Update Manager should be started with Administrator rights, click **Run As Administrator**.
5. Confirm the User Account Control question by clicking **Yes**, to allow Update Manager to install new or updated software packages.

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6. During the first run of Update manager, click **Settings** in the left frame to bring up the program options in the right frame.
7. Under **Proxy settings**, specify how Update Manager can access the Internet. These settings may be obtained from the network administrator.
8. In the section **Add-Ons installed with connectivity packages**, check the desired options. It is recommended to include **IED Documentation** / *IEC* and **Pre Configuration** / *ANSI* or *IEC*.

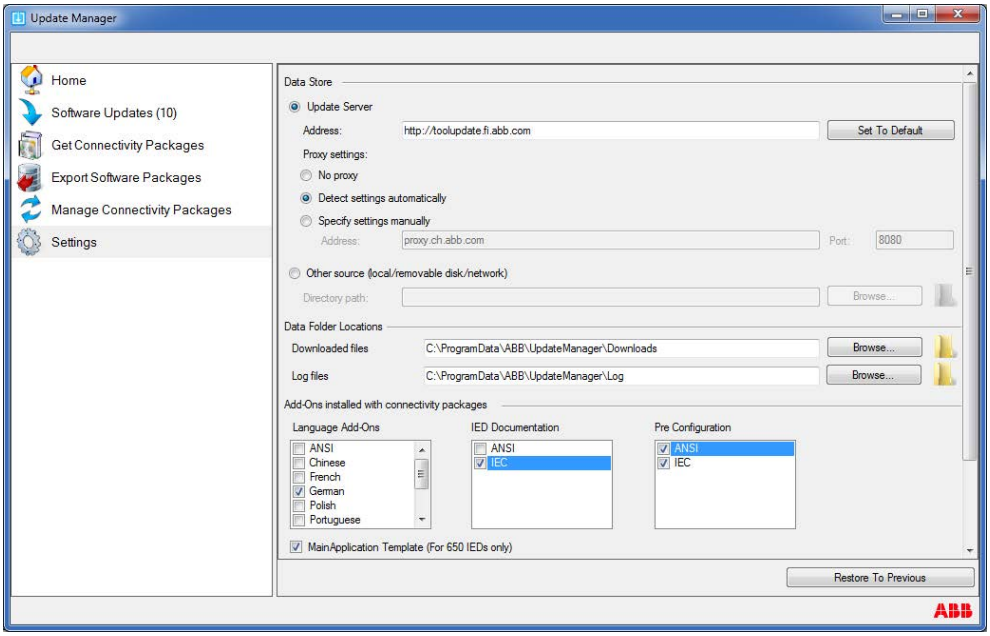


Figure 55: Recommended Add-on settings for Update Manager

9. After start-up, Update Manager automatically checks for available software updates. This is indicated by a status message with animated icon in the bottom left corner of the main window. Wait until the message “Update completed” is displayed there.
10. In the left frame, click **Get Connectivity Packages**. The right frame brings up a list of available products.
11. In the right frame, check the checkbox for “PWC600 Series”. This will include all product related software and documentation in the installation.
12. If desired, click on the **+** icon for expanding the tree node, to include or exclude individual software modules.
13. Click **Download and Install** to start the installation.
14. Read and accept the license agreement and click **OK**.
15. Installation progress is indicated by text with animated icon in the bottom left corner of the main window. Wait until the message “Completed” is displayed there.
16. After completing the installation, you may exit Update Manager by closing the window.

8.4 Project handling in PCM600

PCM600 supports the following tasks for handling projects.

- Opening existing a project
- Importing a project
- Creating new a project
- Exporting a project
- Deleting projects
- Renaming a project
- Copying and pasting a project
- Migrating projects from one product version to another

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It is possible to open projects created in previous versions of PCM600 to the current version, but the opposite is not possible.

Extensions of the exported project file is *.pcmp or *.pcma, and those files are only used for exporting and importing the projects between different instances of PCM600.

8.4.1 Creating a new project

1. Select **File** and **Open/Manage Project** to see the projects that are currently available in the PCMDataBases.
2. Open **Projects on my computer**.
3. Click the **New Project** icon. To create a new project, currently open projects and object tools must be closed. The **New Project** window opens, see Figure 56.

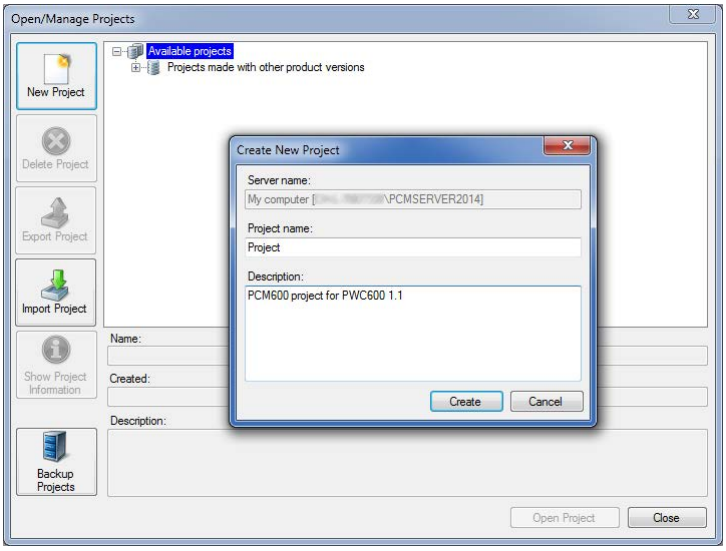


Figure 56: PCM600: Create a new project window

4. Name the project and include a description (optional).
5. Click **Create**. PCM600 sets up a new project that is listed under **Projects on my computer**.
6. Select the newly created project in the list and click **Open Project**.

8.4.2 Importing a project

This option is used for making an exported PCM600 project available to this PCM600 instance.

1. Select **File / Open/Manage Project**, or click the **Open/Manage Project** icon, to bring up the projects dialog.
2. Click **Import Project**.
3. In the file selector, navigate to the location of the exported project.
4. Select the project file to be imported and click **Open**.

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5. After completion of the process, the imported project will be listed under **Available projects**.
6. If the imported project is not shown on the top level, it was likely created in a different version of PCM600. In this case, click the **+** icon next to **Projects made with other product versions** and locate the project in the extended list.
7. Select the imported project in the list and click **Open Project**.

8.4.3 Opening a project

This option is used for opening a PCM600 project that was previously created in, or imported to, this computer.

1. Select **File / Open/Manage Project**, or click the **Open/Manage Project** icon, to bring up the projects dialog.
2. Locate the project in the list under **Available projects**.
3. If the project is not shown on the top level, it was likely created in a different version of PCM600. In this case, click the **+** icon next to **Projects made with other product versions** and locate the project in the extended list.
4. Select the project in the list and click **Open Project**.

8.4.4 Exporting a project

This option is used for transferring a PCM600 project to another computer or to a backup location.

1. Select **File / Open/Manage Project**, or click the **Open/Manage Project** icon, to bring up the projects dialog.
2. Select the project in the list under **Available projects**.
3. Click **Export Project** to open the file selector dialog.
4. Browse to the target location, type the name for the exported file.



The default file name extension for exported projects is .pcmp, which is used for exchanging project files between the same version of PCM600. Therefore, it is advisable to include the PCM600 version number in the file name or in the folder path. For exchanging project between different versions of PCM600, the file type .pcma can be used, which however is less efficient in terms of file size and time for exporting/importing.

5. Click **Save** to store a full copy of the project in the selected location.

8.4.5 Backing up projects

This option will export local copies of selected PCM600 projects, which can then be backed up (manually or through other tools) on a different medium. The backup process can be initiated manually or on a recurring schedule.

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1. Select **File / Open/Manage Project**, or click the **Open/Manage Project** icon, to bring up the projects dialog.
2. Click **Backup Projects**.
3. Select one of the displayed options, either to **Backup now** or to **Schedule backup**.
4. In the Backup dialog, check the projects that should be backed up. For scheduled backup, additionally define the backup settings and the recurrence pattern.
5. Click **Backup selected** (for immediate backup) or **OK** (for scheduled backup).
6. For immediate backup, select the target folder for exporting the backup files in the **Browse for Folder** dialog, and click **OK**.

Project backup files are stored as .pcmp files, same as manually exported project files. For restoring a project from a backup, use the **Import project** function. When using scheduled backup, the selected projects are exported at the specified time to location PCMDataBases \Scheduled Project Backups\[project name] as individual files named [project name]_[date]_[time].pcmp.

8.4.6 Exporting the substation to SCD file

An SCD (Substation Configuration Description) file contains the substation configuration description, as defined in the IEC 61850-6 standard, of the entire hierarchy of objects. (See the Switchsync PWC600 IEC 61850 *Communication protocol manual* for further information on communications engineering.)

1. In the plant structure, right-click the Substation object (which may bear a different name).
2. Select **Export** from the context menu.

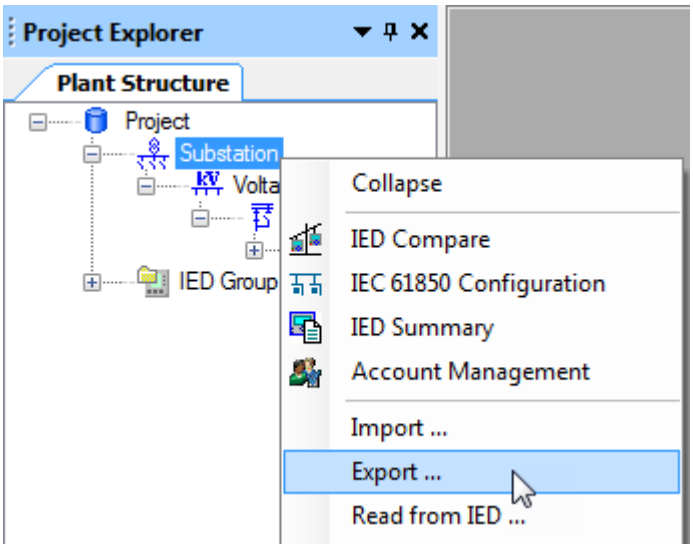


Figure 57: Exporting the substation object

3. In the file selector dialog, navigate to the destination path, enter the file name, and click **Save**.
4. In the SCL Export Options dialog, click **Export**.
5. A small dialog displays the progress of the exporting process. When the dialog closes the export is completed.

Switchsync PWC600 1.1 supports only IEC 61850 edition 1.

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8.5 Building a plant structure

The plant structure is used to identify each IED in its location within the substation organization. It is a structural image of the substation and the bays within the substation. The organization structure for the IEDs may differ from the structure of the primary equipment in the substation. In PCM600 it is possible to set up a hierarchical structure of five levels for the IED identification.

Build up the plant structure according to the project requirements. PCM600 offers several levels to build the hierarchical order down to the IEDs in a bay.

Five levels are available.

1. Project = Project name
2. Substation = Name of the substation
3. Voltage Level = identifies to which grid type or part in the substation the IED belongs to
4. Bay = Bay within the voltage level
5. IED = selection of the IED, which is used in the bay. Several IEDs are possible within a bay, for example one bay controller, one point-on-wave controller and two protection IEDs.

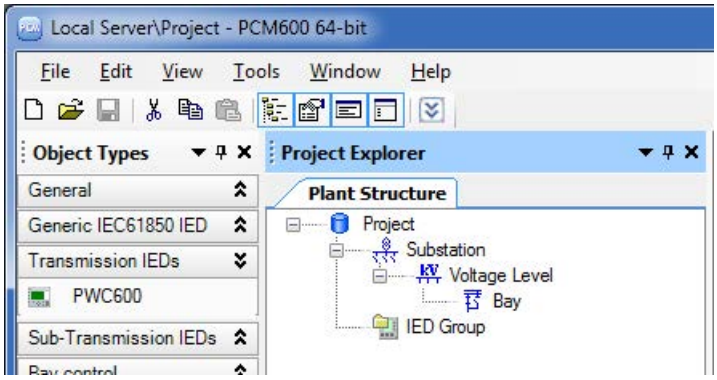


Figure 58: PCM600: Set up a plant structure

Once a plant structure is built each level in the structure should be renamed by the names/identifications used in the grid. Use the right mouse button to build the plant structure by selecting the elements from the context menu. Rename the level after insertion, using the **Rename** option or the **Object Properties**. Figure 58 shows the start of a project with plant structure elements placed, but not yet individually renamed, down to the levels where an IED object can be inserted.

The plant structure can be built to correspond to the complete grid including the needed IEDs.

Build a plant structure in one of these alternative ways.

- Right-click the plant structure and select **New** and **Create from Template**.
- Right-click in the plant structure and select **New/General** and select one of the elements **IED Group** or **Substation**.
- Click **View** in the menu bar and select **Object Types**. Select the needed elements and drag and drop them into the plant structure. Close the window if it does not close automatically.

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8.5.1 IEC 61850 naming conventions to identify an IED

This section is only applicable when the IEC 61850 standard is used for station bus communication. According to IEC 61850-6 clause 8.4, the SCL model allows two kinds of project designation in the object properties.

- A technical key is used on engineering drawings and for signal identifications. The technical key is used within SCL for referencing other objects. Observe that *name* is a relative identification within a hierarchy of objects.
- A user oriented textual designation is contained in attribute *desc*. Attributes are not allowed to contain carriage return, line feed or tab characters. The semantics of *desc* shall also be relative within an object hierarchy.

PCM600 takes care of these two possibilities. The two possible signal designations are available per object in the object properties for all hierarchical levels beginning with the station as the highest level. The IED's object property *Caption* is copied to the *desc* attribute in the SCL file, the technical key to the *name* attribute.

For every new object in the plant structure, PCM600 automatically generates a technical key based on the rules and type specifications of IEC 81346 and the extended definitions for substations. The technical key is shown in the **Object Properties** under *Technical Key*.

- The station level is predefined by "AA1", where 1 is the station index.
- The voltage level is predefined by "J1", where 1 is the voltage level index, for the default *Voltage Range* "From 20 to 30 kV". Other voltage ranges apply a different initial letter by default.
- The bay level is predefined by "Q01", where 01 is the bay index.
- The IED is predefined by "A1", where 1 is the IED index.

The predefined full path name of the technical key for the first IED would be AA1J1Q01A1.

For all practical engineering purposes (both towards the IED and towards the 61850 engineering process), the user should keep the default SCL technical key. It is however possible, due to for example company naming policies, to rename the SCL technical key for the station level, voltage level, bay level and IED level using the Object properties window as shown in Figure 59.

- The station level has been renamed as "DMSTAT"
- The voltage level has been renamed as "C1"
- The bay level has been renamed as "Q1"
- The IED has been renamed as "P1"

The renamed full path name of the technical key for the IED would be DMSTATC1Q1P1.

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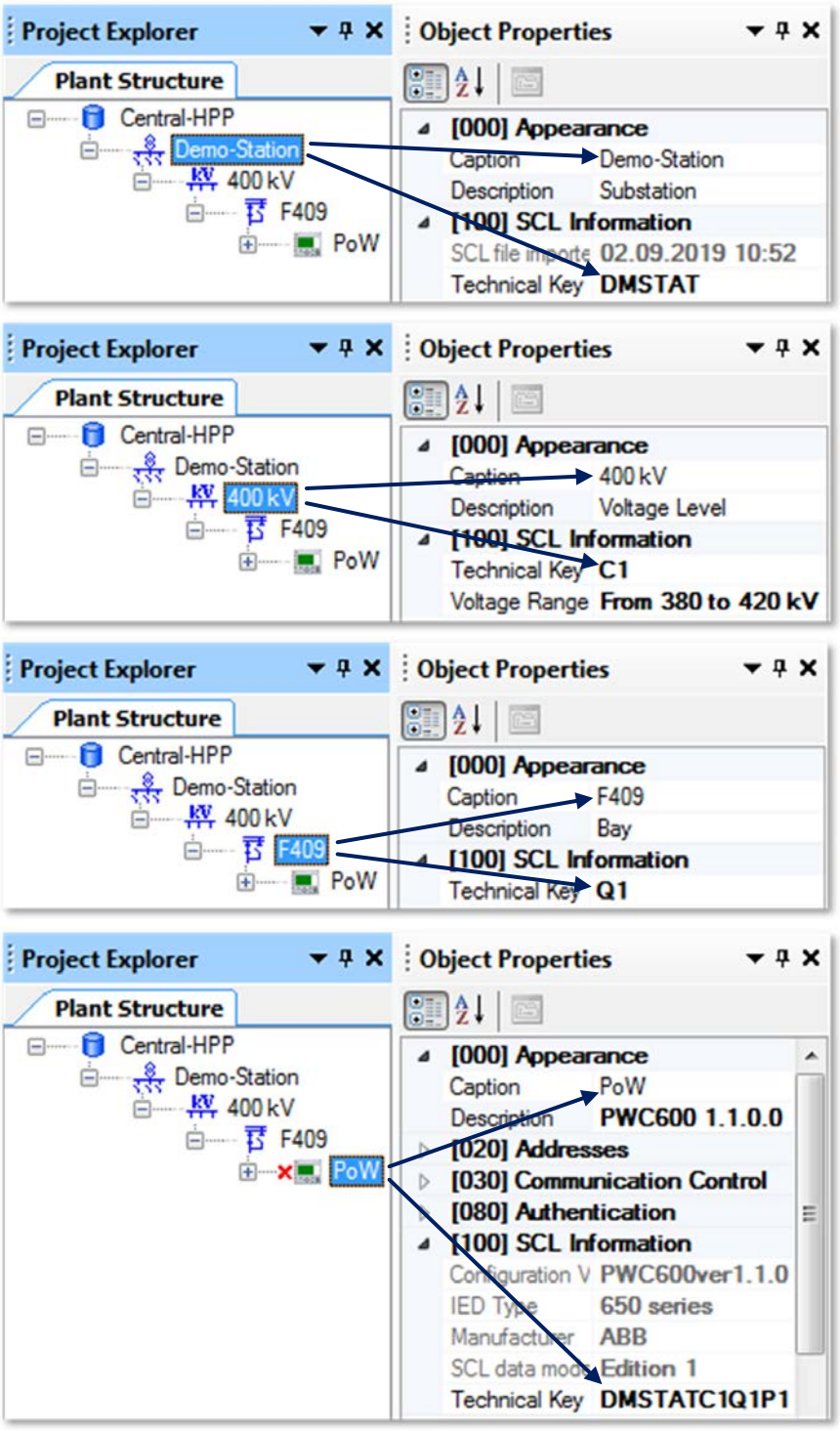


Figure 59: PCM600: IEC 61850 object designation concept

An IED group does not have a *Technical Key* property. IED objects in an IED group can be assigned an arbitrary technical key.

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8.6 Inserting a PWC600 IED

IED objects are created on the bay level in the plant structure, or in in IED group. PCM600 provides several options for inserting an IED. PWC600 will work properly only with an application configuration based on the appropriate pre-configuration. Hence, a PWC600 IED object should be created only through one of these methods:

- Import a template IED available in the template library as a *.pcmt file.
- Import a configured IED available as a *.pcmi file.

Basic templates for all common applications can be installed from the "IED Connect" USB stick supplied with the IED, or through Update Manager.

8.6.1 Inserting an IED from the template library

A template is a complete description of an IED including the full configuration as well as the parameter values of the tool components. ABB provides packages of default templates on the "IED Connect" USB memory or through Update Manager. Furthermore, an IED in the plant structure can be exported as a template (*.pcmt). The user can build up a template library with all the exported IED templates.

It is possible to insert an IED from the template library to create a new IED in the plant structure. Change the IP address, the name and the technical key that corresponds to the physical IED after a template IED has been imported.

A template IED can only be inserted when the target bay or IED group is selected in the plant structure.

1. Right-click the Bay or IED group in the plant structure.
2. Select **New** and **Create from Template** to open the **Create New Object from Template** window.

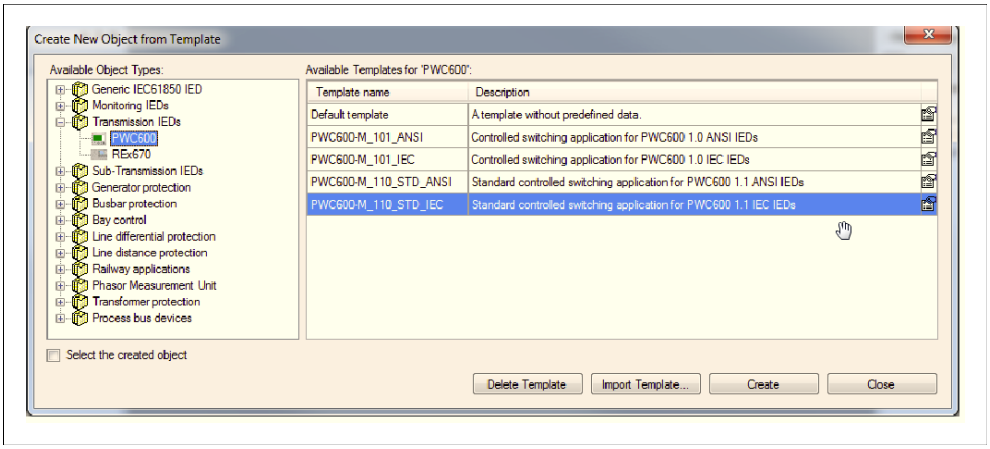


Figure 60: Creating new object from template

3. Under **Available Object Types**, open the **Transmission IEDs** object tree and select **PWC600**.
4. Under **Available Templates for 'PWC600'**, select the appropriate template.

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The available default templates shown in the list depend on the **Pre Configuration** selection in **Settings** of Update Manager.

5. Click the icon in the rightmost column of the list of available templates to open **Template Properties**. Verify the template information, and click **Close** to close the window.

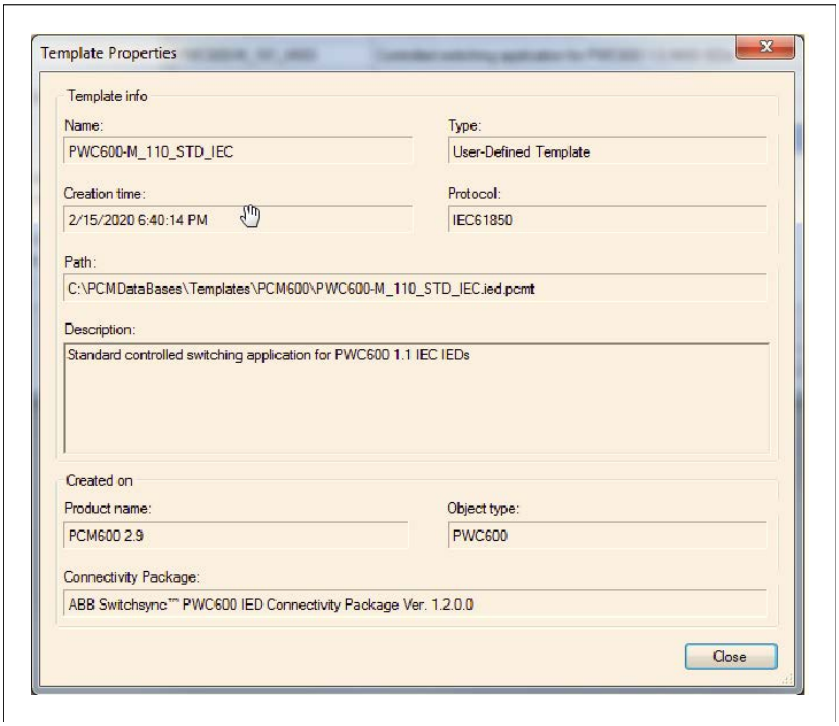


Figure 61: PCM600: IED Template Properties

6. Click **Create** to insert the selected IED to the bay.

It is possible to insert more than one IED from the **Create New Object from Template** window. The window will remain open until the user clicks **Close**.

8.6.2 Inserting a configured IED

Configured IEDs are available as *.pcmi files and include all information that is related to the IED object in PCM600. The configured IEDs are bound to a specific hardware configuration. They are created by exporting a configured IED object from PCM600 (see Section 8.9).

1. Right-click the bay and select **Import** from the context menu.

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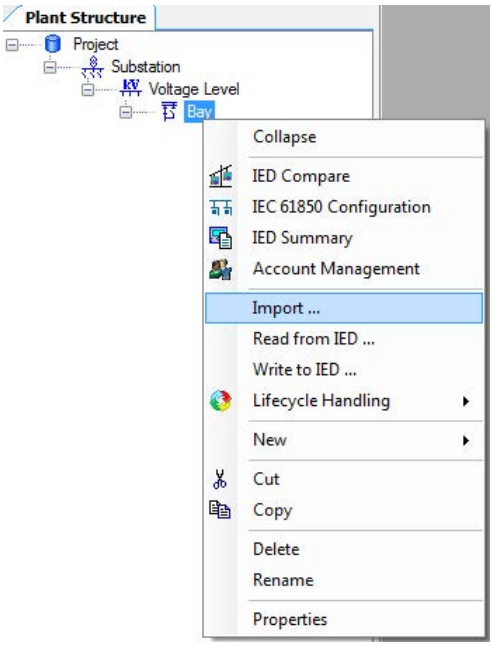


Figure 62: Import an IED from the context menu

2. In the **Import** file selector, navigate to the folder where the configured IED file is located and select the *.pcmi file.
3. Click **OK** to insert the new IED object in the plant structure.

8.6.3 Setting an IED's IP address in the project

The IED object in PCM600 must have the same IP address and subnetwork mask as the front or rear port on the physical IED to which the PC is connected. The IP addresses of the physical IED's front and rear ports cannot be set from PCM600 but only from LHMI.

Set the IP address to be used for communication in the **Addresses** section of the **Object Properties** of the IED.

1. Select the IED to enter the IP address.
2. Right-click the IED. Under **Communication Port**, select the port that shall be used for communication with the IED.

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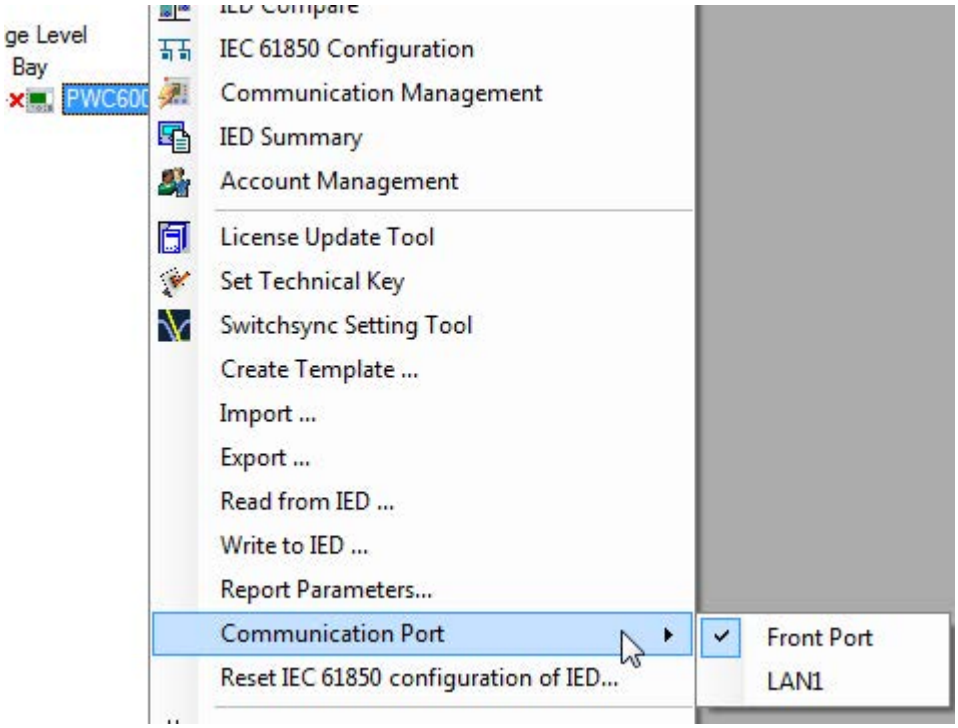


Figure 63: Selecting communication port

3. Open the **Object Properties** window.

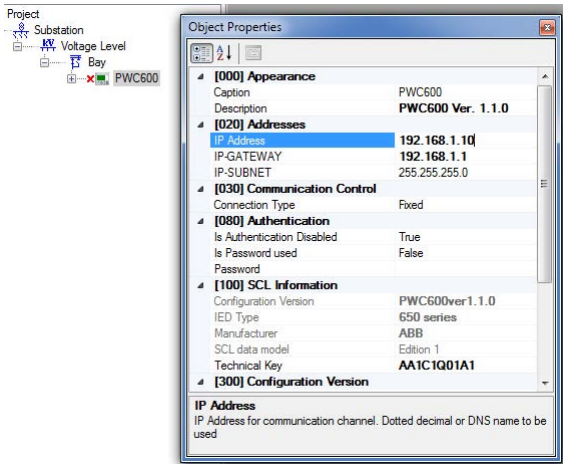


Figure 64: Setting IP address via IED Object Properties window

4. Place the cursor in the *IP Address* field and enter the IP address.
5. Repeat the above step for the *IP-GATEWAY* and *IP-SUBNET* fields.

When connected via station bus (LAN1), the IP address of each IED in the PCM600 project has to be unique for the communication to the IED to work.

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8.7 Setting up communication between PCM600 and the IED

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

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

Each IED has an RJ-45 Ethernet interface connector on the front. The front Ethernet connector 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.

To connect PCM600 to the IED, two basic variants are available.

- 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.



If station communication is routed through a firewall it is necessary to open certain IP ports. See the *Switchsync PWC600 Cyber Security Deployment Guideline* for details.

8.7.1 Setting up IP addresses

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

- The default IP address for the IED front port is 10.1.150.3 and the corresponding subnetwork mask is 255.255.255.0. These data can be adjusted via the local HMI path **Main menu/Configuration/Communication/TCP-IP configuration/ETHFRNT:1**.
- The default IP address for the IED rear port is 192.168.1.10 and the corresponding subnetwork mask is 255.255.255.0. These data can be adjusted via the local HMI path **Main menu/Configuration/Communication/TCP-IP configuration/ETHLAN1_AB:1**.

8.7.2 Setting up the PC or workstation for point-to-point access to IEDs front port

A special cable is needed to connect two physical Ethernet interfaces together without a hub, router, bridge, or switch in between. The Tx and Rx signal wires must be crossed in the cable to

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connect Tx with Rx on the other side and vice versa. These cables are known as cross-over cables. The maximum length is 2 m. The connector type is RJ-45.

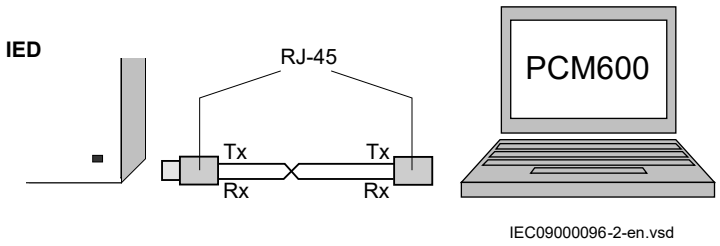


Figure 65: Point-to-point link between IED and PCM600 using a cross-over Ethernet cable

Some PCs have the feature to automatically detect that Tx signals from the IED are received on the Tx pin on the PC. In this case, a straight (standard) Ethernet cable can be used.

The following description is an example valid for standard PCs using Microsoft Windows operating system. The example is taken from a Laptop with one Ethernet interface.

Administrator rights are required to change the PC communication setup.

When a PC is connected to the IED and the setting *DHCPServer* is set to "On" via the local HMI path **Main menu/Configuration/Communication/TCP-IP configuration/ETHFRNT:1**, the IED's embedded DHCP server for the front port assigns an IP address for the PC. The PC must be configured to obtain its IP address automatically (described for Windows 10).

1. In the Windows Start menu, click the **Settings** icon.

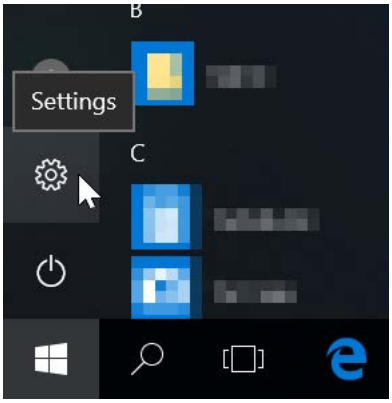


Figure 66: Invoking Windows 10 Settings

2. In **Windows Settings**, click **Network and Internet**.

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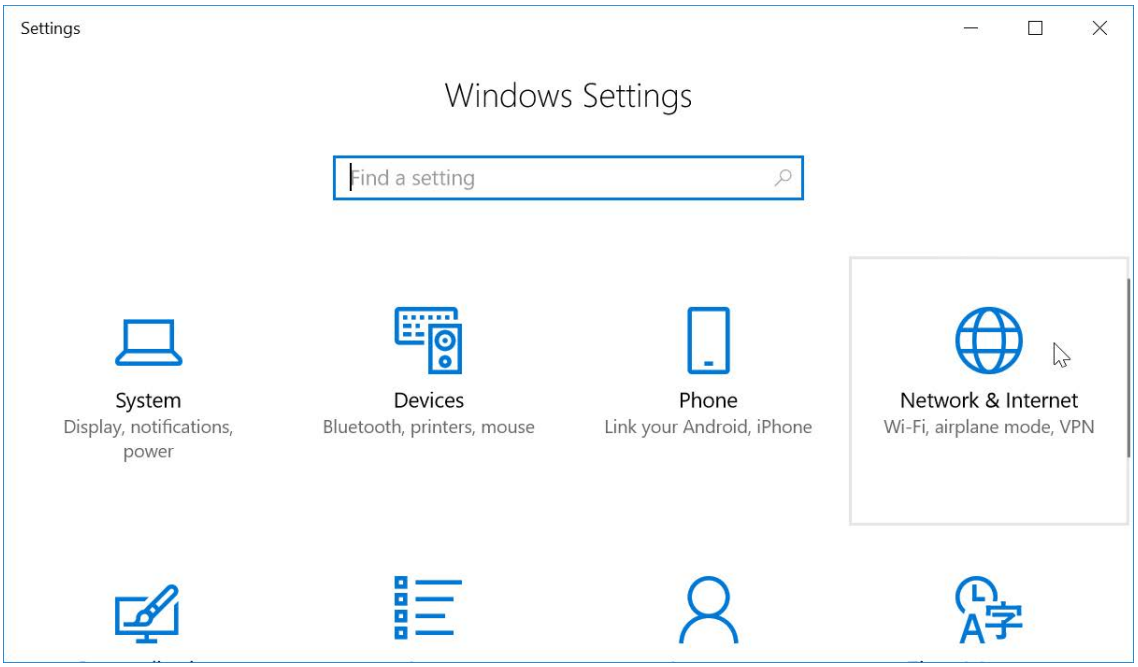


Figure 67: Invoking Network and Internet from Windows Settings

3. Under **Change your network settings**, click **Change adapter options**.

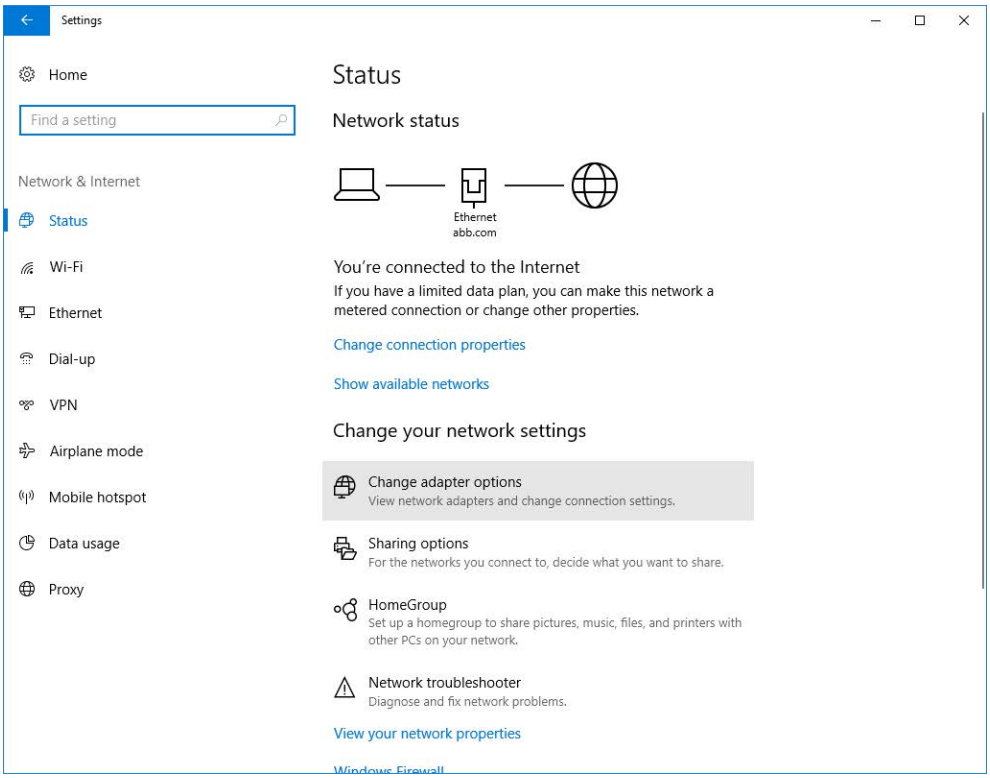


Figure 68: Changing adapter options from Windows network settings

4. Right-click on the applicable **Ethernet** item and select **Properties**.

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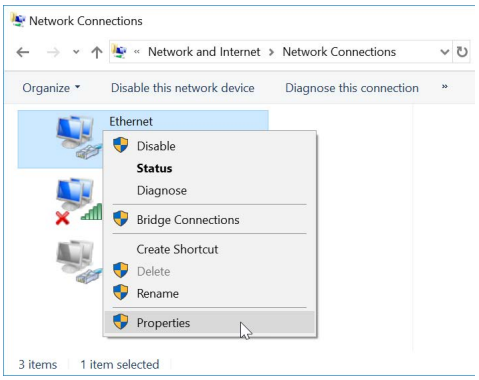


Figure 69: Accessing properties of Ethernet connection

5. Confirm the User Account Control query to allow making changes to the device.
6. Select the TCP/IPv4 protocol from the list of configured components using this Ethernet link, and click **Properties**.

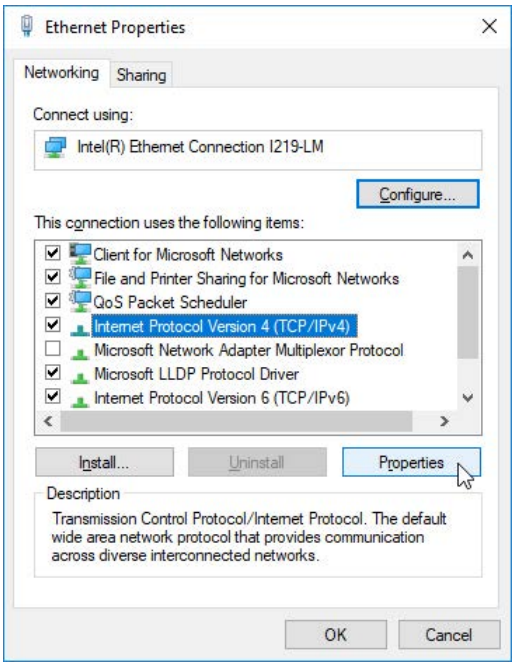


Figure 70: Opening properties of TCP/IPv4 protocol

7. Under **Proxy settings**, specify how Update Manager can access the Internet. These settings may be obtained from the network administrator.
8. If *DHCPServer* is set to "On" in the IED, select **Obtain an IP address automatically**.

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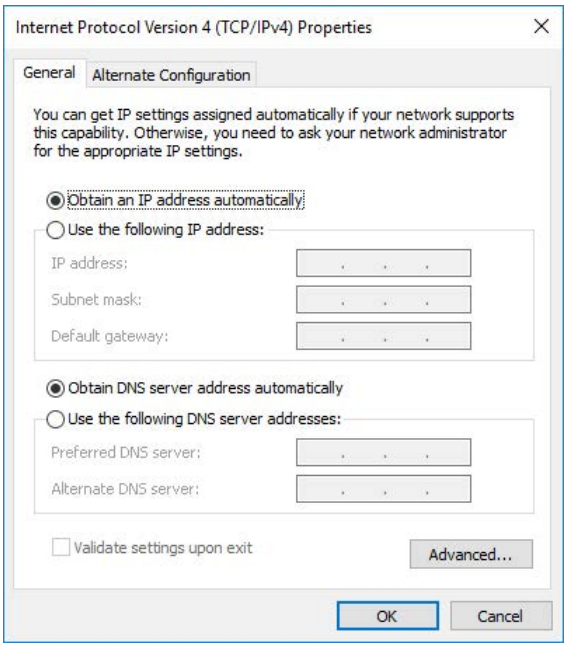


Figure 71: PC configuration for obtaining an IP address automatically

9. If the front port is used but *DHCPServer* is set to "Off" in the IED, click on the **Alternate Configuration** tab.

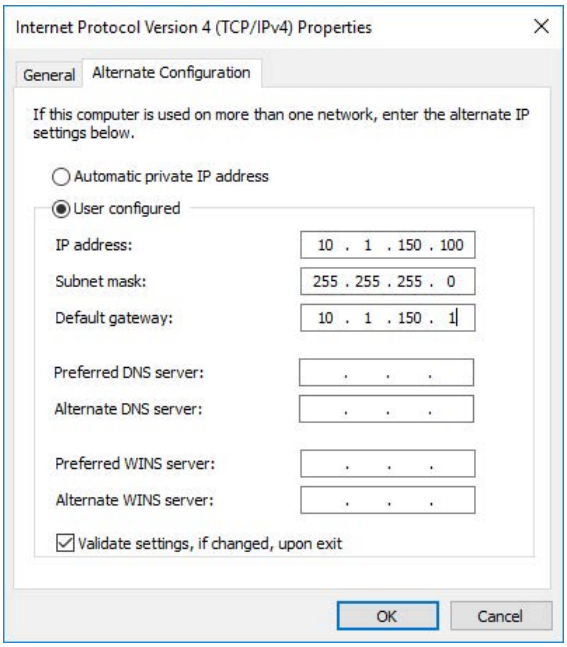


Figure 72: PC configuration for manually specified IP address

10. Select **User configured**.
11. Enter a suitable *IP address* and *Subnet mask* for the PC, see Figure 72. The *IP address* here must be different from the *IPAddress* set in the IED.
12. Close all open windows by clicking **OK**.

8.7.3 Setting up the PC to access the IED via a network

This task depends on the used LAN/WAN network. Obtain the required PC settings from the network administrator.

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The PC and IED must belong to the same subnetwork for this setup to work.

8.7.4 Security warning

To ensure secure communication between the parties, the IED will send its self-signed server certificate to be installed on the PC. When first connecting to an IED, PCM600 will pop up a security warning message.

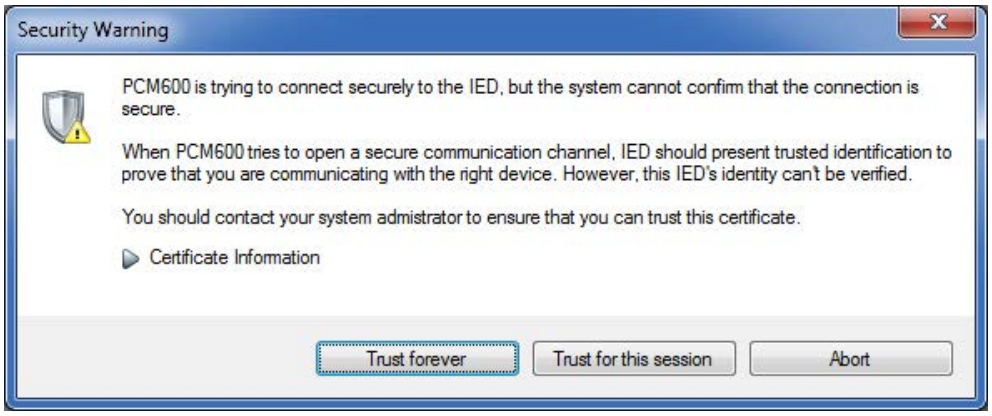


Figure 73: PCM600 security warning on first connecting to an IED

Click **Trust forever** or **Trust for this session** to approve the connection and install the certificate.

Change in the technical key or IP address of the IED results in the installation of a new server certificate, which again must be accepted by the user.

- Under **Proxy settings**, specify how Update Manager can access the Internet. These settings may be obtained from the network administrator.

8.8 Setting technical key

Both a physical IED and an IED object in PCM600 have a technical key as identifier for communication in the substation. The purpose of the technical key is unique identification of an IED, for example, to prevent download of a configuration to wrong IED. The technical key in the IED and PCM600 must be the same, otherwise it is not possible to exchange information. Each IED in a PCM600 project must have a unique technical key. It is therefore not possible to set the same technical key for several IEDs in the same PCM600 project.

The *Technical Key* property in PCM600 corresponds to the IED *name* attribute in SCL files. Avoid changing the IED *name* attribute outside PCM600, because data in PCM600 might be lost when importing SCL files.

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When using PCM600 for writing to the IED, it is important that the LHMI or WHMI is not in a menu position where settings can be modified. Only one active transaction, from LHMI, WHMI, or PCM600, is allowed at any one time.

When communicating with the IED, PCM600 checks for matching technical keys in the PCM600 IED object and in the physical IED. For communication between the IED and PCM600 the technical key must be the same. Users have the option to read the technical key from the IED and update it to PCM600 or write the PCM600 technical key to the IED. The user can also define an own technical key. In case of mismatch between PCM600 and IED technical keys, an error message is displayed as shown in Figure 74.

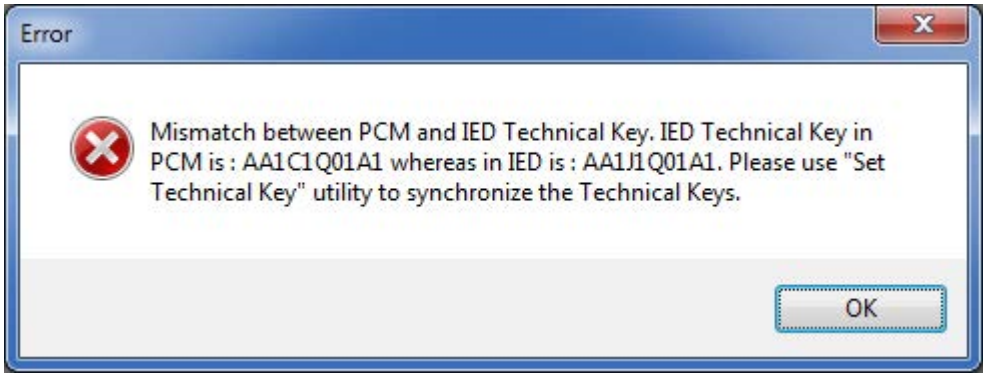


Figure 74: Error message due to mismatch between PCM600 and IED technical key

The technical key for an IED object in PCM600 can also be changed in the **Object properties** window.

Ensure that the IED object in PCM600 has the same IP address as the physical IED.

1. Select the IED in **Plant Structure**.
2. Right-click and select **Set Technical Key**, see Figure 75.

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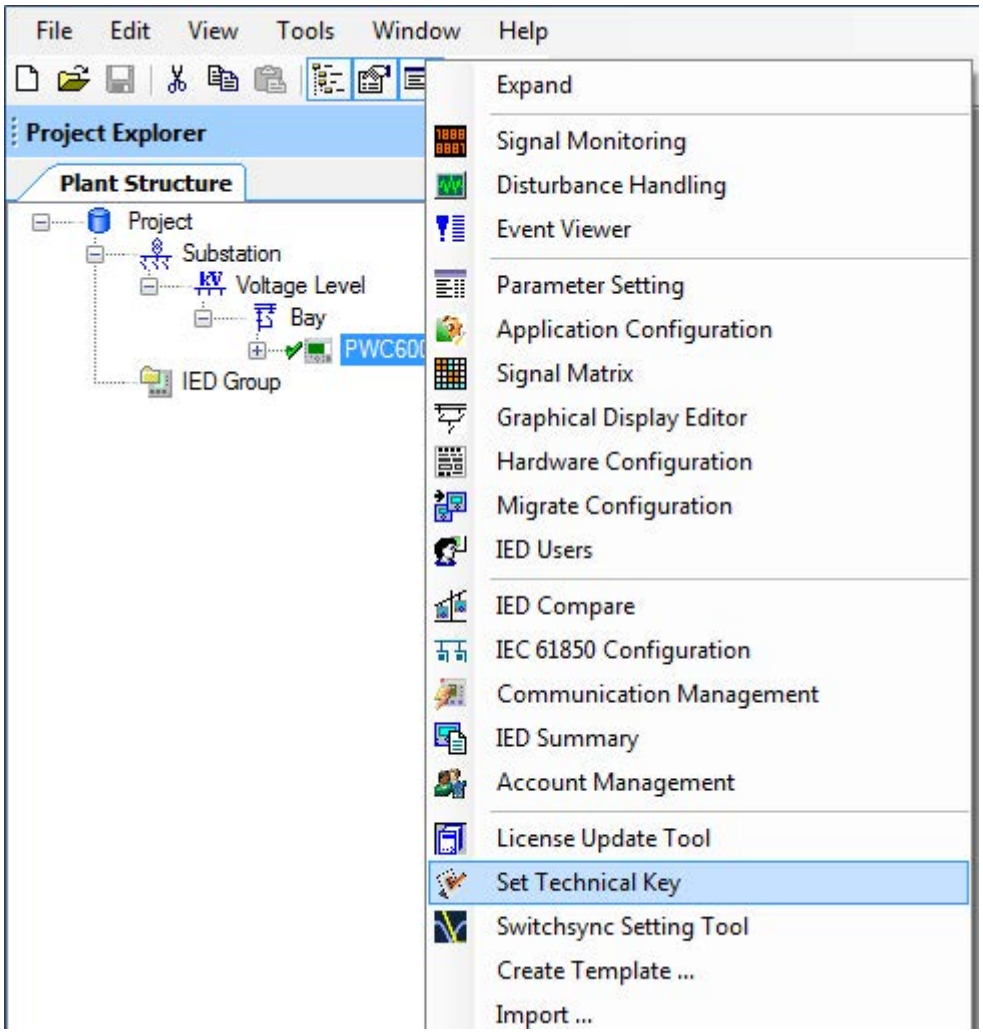


Figure 75: PCM600: Set technical key menu at IED level

A dialog box opens to inform about the technical key concept.

3. Click **OK** in the dialog box.
4. If PCM600 raises a security warning, click **Trust forever** or **Trust for this session** for enabling secure communication using the currently set technical key.
5. The technical key is read from the IED and the Technical Key Editor window opens, see Figure 76.

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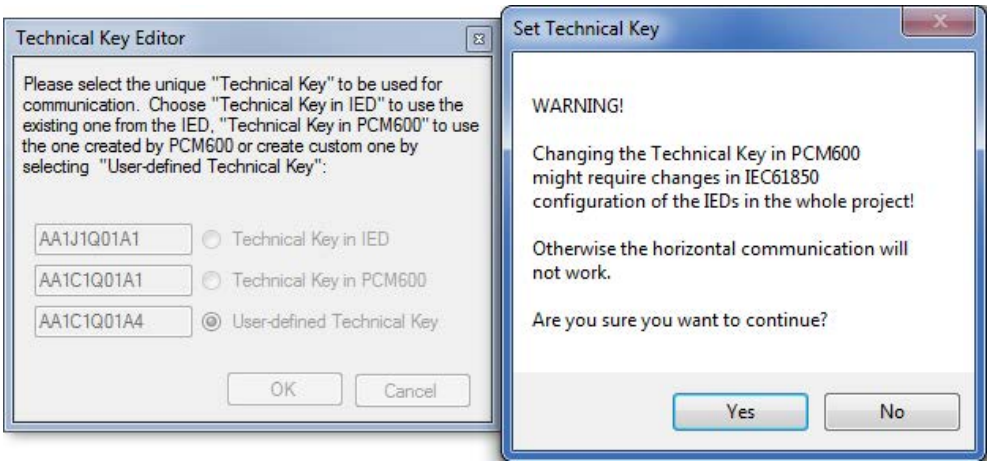


Figure 76: PCM600: Technical key editor

6. Select one of the available options:
   - Use the existing technical key in the IED
   - Use the existing technical key defined for the IED object in PCM600 or
   - Enter a user defined technical key, which changes the technical key for both the physical IED and the IED object in PCM600.

Do not use a technical key with more than 13 characters.

7. Click **OK** to confirm the selection.

It is not possible to set a user defined name or select **Technical key in IED** if the value is the same as already given to another IED object in the PCM600 project. An error message opens if this is the case.

8.9 Exporting an IED object

An IED object in the plant structure can be exported to a local file, which may be shared with another PC or backed up for archiving.

1. In the plant structure, right-click the IED object.
2. Select **Export** from the context menu.
3. In the file selector dialog, navigate to the destination path, enter the file name, select the destination file type, and click **Save**.
4. A small dialog displays the progress of the exporting process. When the dialog closes the export is completed.

IED objects can be exported to the following file types:

- PCMI (PCM600 IED)
  The file contains the IED's complete configuration as prepared in PCM600. PCMI files can be imported to, or exported from, IED objects.
- CID (configured IED description)
  The file contains the configured IED description as defined in the IEC 61850-6 standard. Private sections of the tool components, if defined, are also included in the file. CID files can be imported to, or exported from, IED objects.
- ICD (IED capability description)

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The file defines the complete capability of an IED as defined in the IEC 61850-6 standard. ICD files can be imported to, or exported from, IED objects.

- IID (instantiated IED description)
  The file contains the project-specific configuration of an IED as defined in the IEC 61850-6 standard. IID files can be exported from IED objects.

Further information on CID, ICD, and IID files can be found in the Switchsync PWC600 IEC 61850 Communication protocol manual.

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Section 9 Application engineering

Switchsync PWC600 comes with a default pre-configuration that covers most controlled switching applications. All necessary adjustments to the actual installation are done by settings. These settings are preferably entered and modified by a dedicated PCM600 tool, Switchsync Setting Tool (SST).

If necessary, the application configuration can be viewed and modified using other tools in PCM600.

9.1 Engineering process overview

This process applies to a Switchsync PWC600 IED object, which has been created and set up in PCM600, assuming no changes in application configuration (ACT) or other tools would be required.

1. Enter or modify settings in Switchsync Setting Tool (offline)
2. Write settings to the IED in Parameter Setting tool (online) or through general **Write to IED**.

9.2 Using Switchsync Setting Tool

9.2.1 General description

Switchsync Setting Tool, SST, comes as part of the PWC600 Connectivity Package in PCM600. It is a wizard-style tool for entering the settings relevant for the controlled switching application. It works with a pre-configuration of Switchsync PWC600 product. Switchsync PWC600 is delivered with a default configuration loaded. However, in most cases, the configuration settings and parameters do not match the actual application. SST guides the user through the selection of network parameters, type and properties of circuit breaker, switched load, etc. The aim is to consolidate all the relevant settings for clarity and ensure that no important settings are overlooked. Completed or partial configurations can be loaded or saved to/from file, duplicated and modified for use in another IED.

The wizard guides the user through each setting. It proposes default values based the type of application, model of Switchsync PWC600 and circuit breaker data. It also considers choices during previous steps.

If the information required is not available at the moment, save the partial configuration and exit the wizard. Continue and finish the setup process later. The wizard completes the final step by storing the data in the data server of PCM600 after saving the complete configuration.

SST is an offline tool. Parameters can be written to the IED using Parameter Setting Tool or Common Write tool.

The application setup wizard stores all the user inputs together with the resulting data. The fields are pre-populated with the previously entered data, when running the wizard for the same IED again.

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If the user has changed settings directly in Parameter Setting Tool, these settings may be overwritten when re-running SST. In such cases, it is recommended to make a backup of the IED object before starting SST, and running IED Compare tool after completion of SST, to assure that the correct settings will be applied.

Switchsync Setting Tool (SST) operates only on Setting Group 1, regardless how many setting groups are enabled.

9.2.2 Starting Switchsync Setting Tool

1. In the PCM600 **Plant Structure**, right-click the **PWC600** object and select **Switchsync Setting Tool**.

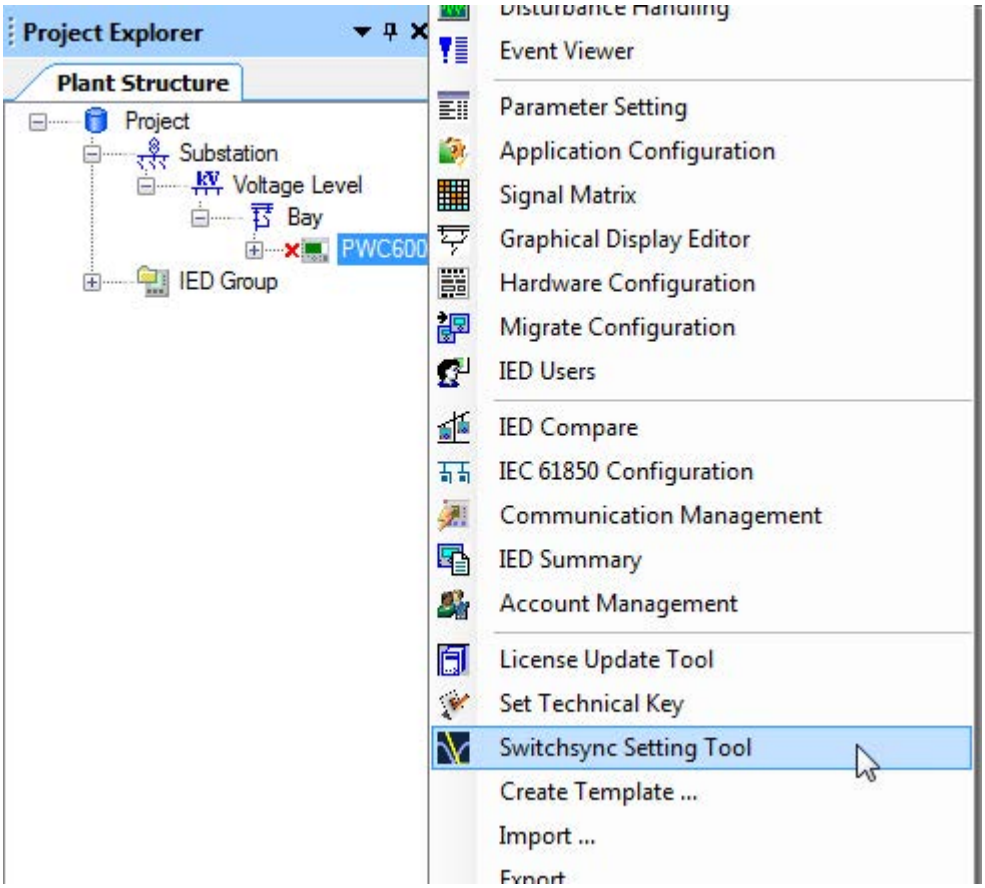


Figure 77: Starting SST from the plant structure in PCM600

All other tools in PCM600 must be closed before invoking Switchsync Setting Tool.

2. In the **Switchsync Setting Tool** initial dialog box, select the appropriate option.

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- Select **Start new session** to start the tool with new settings for a newly inserted IED, or with the existing settings that had previously been entered through Switchsync Setting Tool.
- Select **Continue with partially saved settings** to run the tool with saved settings from a previous session that had been terminated without completing the workflow.

If no partially saved data are available, or if the workflow of the Switchsync Setting Tool was completed during the last run, the option to **Continue with partially saved settings** is disabled.

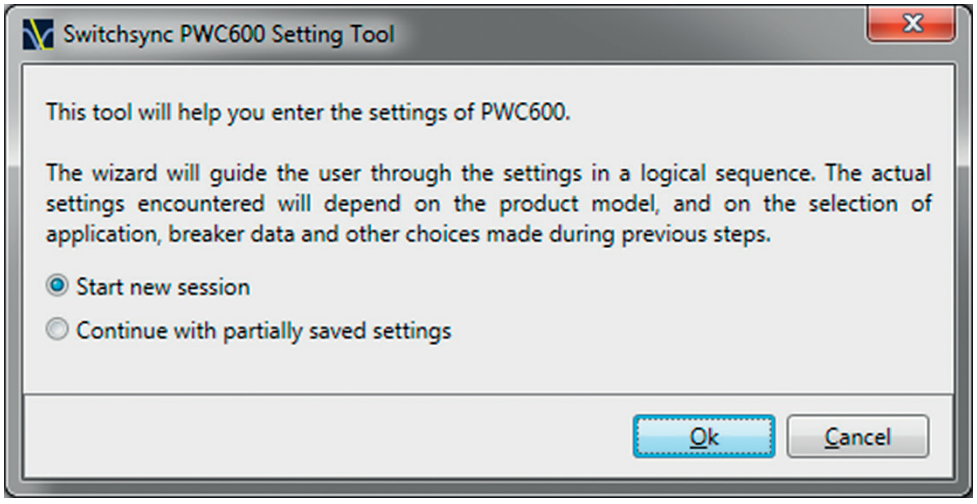


Figure 78: Switchsync Setting Tool starting options

3. Click **OK**.
4. Click **OK** on the reminder to always use a dot (.) for decimal point.
5. When re-starting after the first complete run, Switchsync Setting Tool displays a notification that re-running may overwrite settings that were manually changed in Parameter Setting Tool (PST). See Figure 79. Click **OK** to acknowledge this notification, or **Cancel** to abort Switchsync Setting Tool without making any changes.

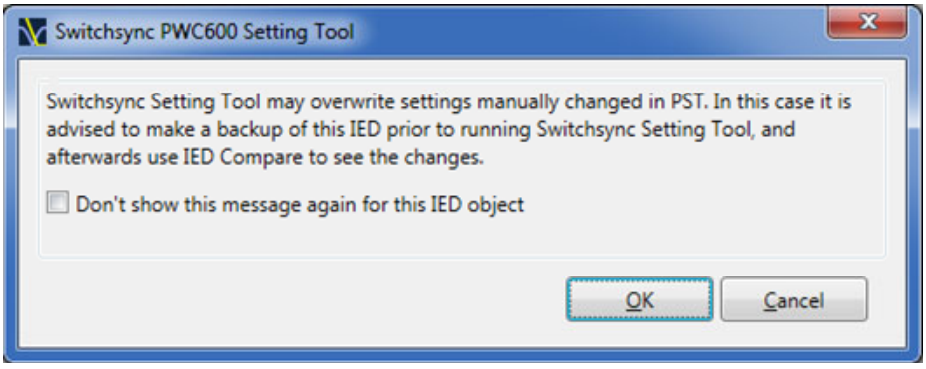


Figure 79: SST start-up notification of possible overwriting of settings manually changed in PST

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9.2.3 Navigating between steps

1. Click **Next** or **Back** to navigate between the steps.
2. Jump directly to the first page of a milestone by clicking the milestone name in the left pane.

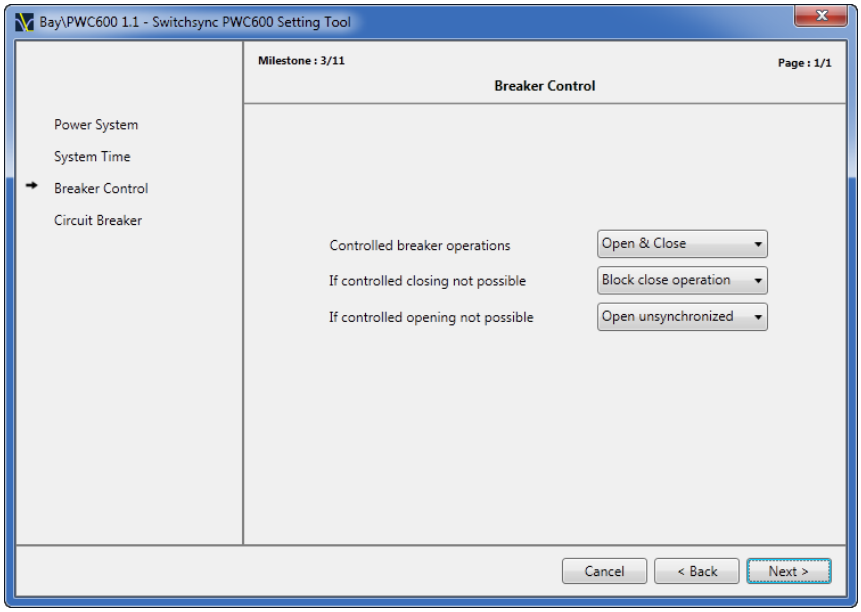


Figure 80: Navigating between steps

All the milestones are not displayed initially. Each milestone appears when the first step related to that milestone is entered.

9.2.4 Setting parameters overview

The Switchsync PWC600 application is configured by setting the parameters categorized under various milestones. A milestone may comprise one or more pages. The sequence of milestones is summarized in Figure 81.

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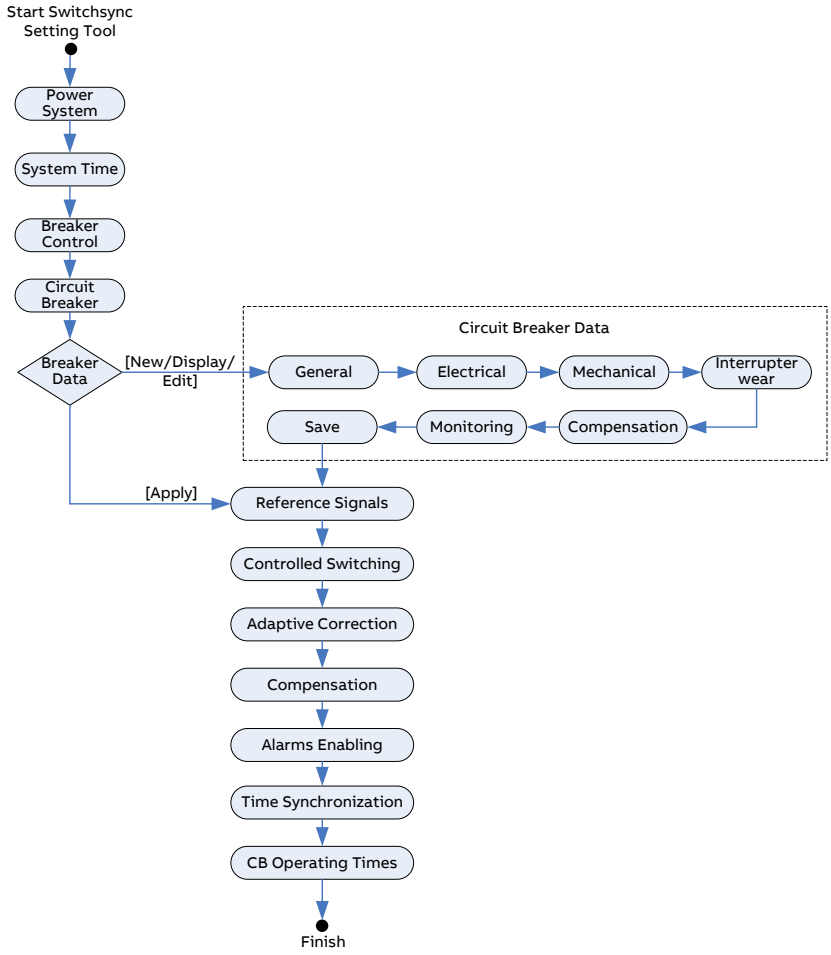


Figure 81: SST workflow overview

Switchsync Setting Tool guides the user through each setting. On moving the focus (through mouse click or the Tab key) to a setting, an explanatory tip is displayed at the bottom of the page.

The same text appears as a tool tip when hovering the mouse pointer over the setting.

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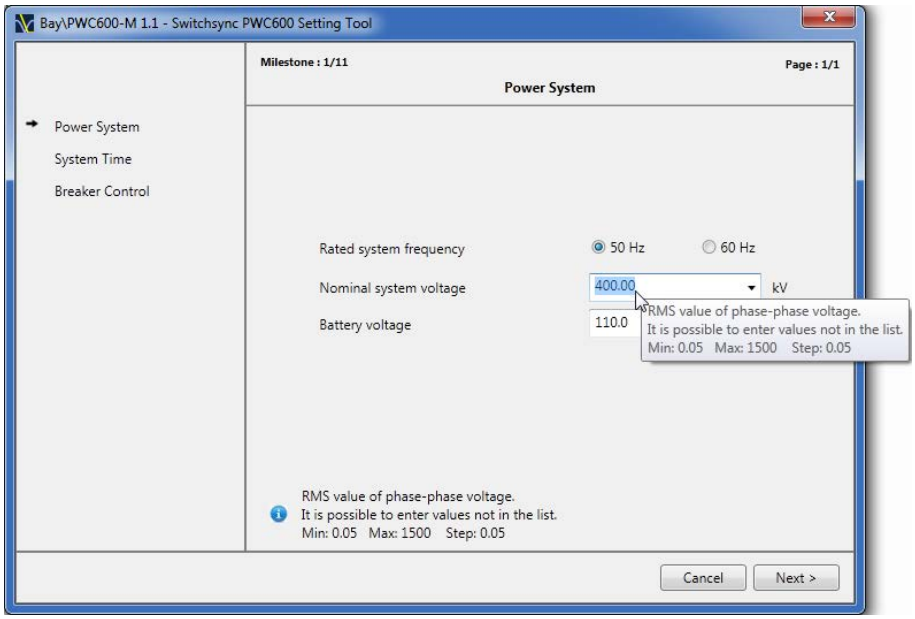


Figure 82: Setting parameters with tooltips

The proposed settings depend on the type of application, model of Switchsync PWC600 and breaker data. They may also depend on the choices entered in earlier steps.

All references to a circuit breaker pole actually designate the system phase to which that pole is connected, e.g. CB pole "L1" refers to the pole connected to system phase L1.

Switchsync Setting Tool supports certain parameter types.

- Numerical parameter type
- String parameter type
- Date/Time parameter type
- MultiChoice parameter type

When entering numerical data, only use a dot (.) for decimal point.

Switchsync Setting Tool checks that the entered value is valid and within the setting range. A red border with “X” symbol is marked around the setting control to indicate error. Move the mouse pointer over the error symbol to display the message. The message describes the error and correct format for the parameter.

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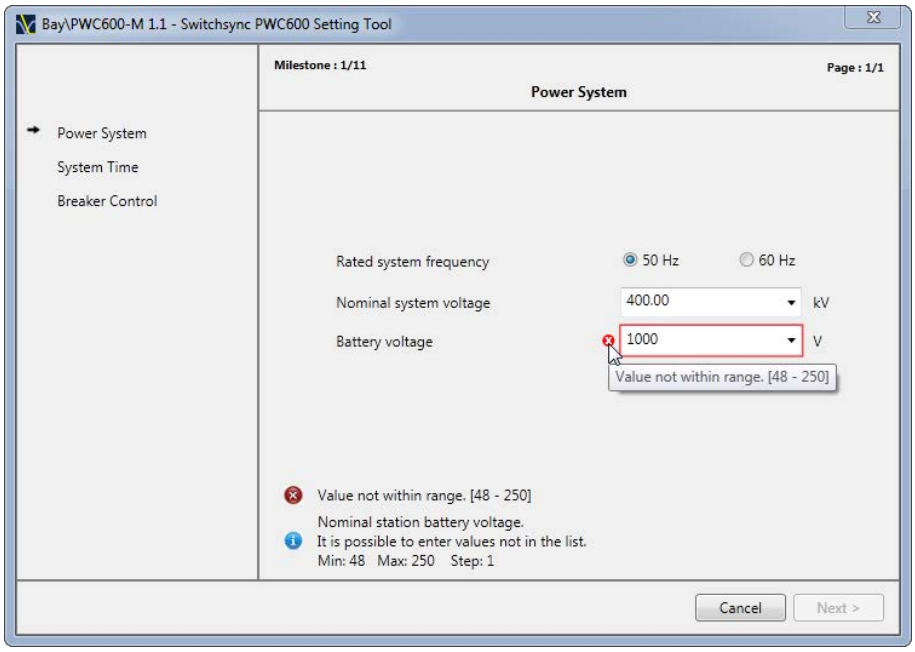


Figure 83: Validation of entered values

On any data validation error or missing data, navigation between the steps with **Next** and **Milestone** is disabled.

9.2.5 Description of setting parameters in SST

This subsection describes all values that can be entered in Switchsync Setting Tool (SST). These are a subset of all parameters accessible through Parameter Setting Tool. For ease of use, SST features internal functions for mapping certain entered values to actual settings of different function blocks. A complete description of all function blocks including their respective settings is given in the Technical Manual.

9.2.5.1 Power system

Basic parameters of the power system and voltage levels where PWC600 is installed.

Table 58: Parameters in SST milestone "Power System", page 1

Parameter	Unit	Description	Remarks
Rated system frequency	Hz	Rated frequency of the power system	
Nominal system voltage	kV	Nominal RMS value of phase-phase voltage in the power system	
Battery voltage	V	Nominal voltage of the station battery that supplies the circuit breaker tripping and closing coils through PWC600.	

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9.2.5.2 System time

Information on time zone and daylight saving time in the location where PWC600 is installed.

Daylight saving time (DST), if observed, always follows certain rules. For example, in Central Europe (CET time zone = UTC+01:00), DST always starts on the last Sunday of March at 2:00 local time (1:00 UTC) and ends on the last Sunday of October at 3:00 local time (1:00 UTC). For locations where DST is not observed, enter the same settings under *Begin* and *End*.

Table 59: Parameters in SST milestone "System Time", page 1, section "Daylight Saving Time"

Parameter	Unit	Description	Remarks
Month / Begin		Month when DST starts	
Month / End		Month when DST ends	
Day of the week / Begin		Weekday of the selected week and month when DST starts	
Day of the week / End		Weekday of the selected week and month when DST end	
Week of the month / Begin		Week of the selected month when DST starts	
Week of the month / End		Week of the selected month when DST ends	
Time (UTC) / Begin	h:min	UTC time when DST starts on the selected day	
Time (UTC) / End	h:min	UTC time when DST ends on the selected day	

Table 60: Parameters in SST milestone "System Time", page 1, section "Time Zone"

Parameter	Unit	Description	Remarks
Time Zone (half hours from UTC)	0.5 h	Time difference between local time and UTC, disregarding daylight saving time	Note that the unit is ½ hours, e.g. for CET (= UTC+01:00) enter 2.

9.2.5.3 Breaker control

Specify which CB operations shall be controlled by PWC600, and what to do if controlled switching is not possible.

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Table 61: Parameters in SST milestone "Breaker Control", page 1

Parameter	Unit	Description	Remarks
Controlled breaker operations		Which CB operations shall be controlled by PWC600? Those operations not included in the selection will be executed unsynchronized i.e. all phases simultaneously at a random system phase angle.	
If controlled closing not possible		In case of conditions that prohibit controlled switching, shall PWC600 block closing commands or execute them without point-on-wave control?	These conditions include missing reference signal or "unstable" CB timing
If controlled opening not possible		In case of missing reference signal or other conditions that prohibit controlled switching, shall PWC600 block opening commands or execute them without point-on-wave control?	These conditions include missing reference signal or "unstable" CB timing

9.2.5.4 Circuit breaker

Specification of the circuit breaker to be controlled by PWC600.

Most ABB breaker models that are suitable for controlled switching are included in a library that is installed as part of the Connectivity Package. Selecting a CB model from the library will automatically populate all breaker related settings in SST.

Breaker models not included in the library can be defined by the user, see Section 9.2.6.

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Table 62: Parameters in SST milestone "Circuit Breaker", page 1

Parameter	Unit	Description	Remarks
Circuit breaker manufacturer		Name of the company that manufactured the circuit breaker	Selecting "ABB" pulls the available models from the CB library. "Other / Custom" gives access to user-defined breakers.
Technology		Limits the list of circuit breaker models to those of the selected technology	Not a setting, just a display filter
Circuit breaker model / type		Name of circuit breaker model to be controlled by PWC600. If the actual CB model is not available in the list, contact ABB for a breaker data file (ABB breakers only) or create a custom breaker type (Section 9.2.6).	Changing this selection will reset all data under the **Compensation** and **Breaker Times** milestones to the default values for the selected CB model.
Nominal control voltage	V	Rated voltage of the circuit breaker's tripping and closing coils	
Circuit breaker data		Select "Apply" to directly apply the data of the selected CB model. Select "Display" to view or "Edit" to modify the data.	"Edit" option is not available for breaker models in the library.

The pages that will be displayed after selecting *Circuit breaker data* = "Display" or "Edit" are described in Section 9.2.6.

9.2.5.5 Reference signals

Specification of the analog voltage and current signals, and CB auxiliary contacts, connected to PWC600 for reference and feedback. Analog signals can be acquired from the hardware inputs on the TRM module or received from an IEC 61850-9-2(LE) compliant merging unit (MU) via dedicated process bus. "Source side" refers to the part of the switch bay that is live when the breaker is open – usually the busbar. "Load side" refers to the part of the switch bay that will be energized by closing the breaker.

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Table 63: Parameters in SST milestone "Reference Signals", page 1

Parameter	Unit	Description	Remarks
Source side voltage input		Specify the origin of the source side voltage signal, which is used as reference for controlled closing (and possibly opening) operations.	By default, MU1 is assigned for receiving primary current values. It may be selected here if the same MU transmits the source voltage samples as well.
Source VT configuration		Single-phase or three-phase configuration of source voltage transformer	Visible only when *Source side voltage input* = "TRM"
Voltage signal connected to first VT input		Which primary phase(s) does the analog signal connected to the first VT input represent – refer to Section 7.3.1	Visible only when *Source side voltage input* = "TRM"
Primary voltage	kV	Rated primary voltage of the source side voltage transformer	Visible only when *Source side voltage input* = "TRM"
Secondary voltage	V	Rated secondary voltage of the source side voltage transformer tap	Visible only when *Source side voltage input* = "TRM"
svID		Sampled values identifier of the selected merging unit, according to the IEC 61850-9-2(LE) specification	Visible only when *Source side voltage input* = "MU1" or "MU2"

Table 64: Parameters in SST milestone "Reference Signals", page 2

Parameter	Unit	Description	Remarks
Load current input		Specify the origin of the load current signal, which can be used for feedback and as reference for controlled opening operations.	
Primary current	A	Rated primary current of the current transformer	Visible only when *Load current input* = "TRM"
Secondary current	A	Rated secondary current of the current transformer tap	Visible only when *Load current input* = "TRM"
svID		Sampled values identifier of the selected merging unit, according to the IEC 61850-9-2(LE) specification	Visible only when *Load current input* = "MU1"

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Table 65: Parameters in SST milestone "Reference Signals", page 3

Parameter	Unit	Description	Remarks
Load side voltage input		Specify the origin of the three-phase load side voltage signal, which can be used for feedback.	
Primary voltage	kV	Rated primary voltage of the load side voltage transformer	Visible only when *Load side voltage input* = "TRM"
Secondary voltage	V	Rated secondary voltage of the load side voltage transformer tap	Visible only when *Load side voltage input* = "TRM"
svID		Sampled values identifier of the selected merging unit, according to the IEC 61850-9-2(LE) specification	Visible only when *Load side voltage input* = "MU2" or "MU3"
Auxiliary contacts connected		Select the auxiliary contacts that are connected to PWC600 in all three phases, to enable evaluation of these signals for feedback and monitoring.	

9.2.5.6 Controlled switching

On the first page, the properties of the load to be switched and of the power system are defined.

Table 66: Parameters in SST milestone "Controlled Switching", page 1

Parameter	Unit	Description	Remarks
Controlled switching application		Basic kind of load to be switched	
Reactor core type / Transformer core type		For inductive loads, specify the design type of the magnetic core	Visible only for "Reactor" or "Transformer" applications
Capacitor bank configuration		Electrical three-phase circuit of the capacitor bank	Visible only for "Capacitor bank" application
(Primary)Winding configuration		For inductive loads, specify the electrical three-phase circuit of the winding to be switched by this CB	Visible only for "Reactor" or "Transformer" applications
Impedance grounding		Type of neutral grounding impedance (inductive or resistive)	Visible only for "Reactor" application with *Winding configuration* = "Y, impedance grounded"
Impedance ratio K = Lneutral / Lphase		Ratio of neutral grounding inductance and phase inductance	Visible only for "Reactor" application, impedance grounded, with *Impedance grounding* = "Inductive"

Table continues on next page

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Parameter	Unit	Description	Remarks
Impedance ratio K = Rneutral / Xphase		Ratio of neutral grounding resistance and phase reactor impedance	Visible only for “Reactor” application, impedance grounded, with *Impedance grounding* = “Resistive”
Secondary or tertiary winding Δ (delta) connected		Specify whether any of the windings not switched by this CB is connected in Δ (delta) circuit.	Visible only for “Transformer” application
Nominal load current	A	RMS value of expected steady-state current in each phase at nominal system voltage. For capacitor and reactor, enter the load current. For transformer, line, or cable, enter the charging current at no-load conditions.	
Source grounding		Specify whether or not the power system is effectively grounded.	
Reference signal for controlled opening		Specify the signal to be used as targeting reference for controlled opening operations.	Disabled for “Transformer” or “Transmission line / cable" application

Based on the information entered above, SST suggests default controlled switching strategies (see Section 5) may be modified by the user, if necessary, on the next pages.

For impedance grounded reactors, an additional instruction page is displayed between pages 1 and 2.

If only controlled opening was enabled on the **Breaker control** milestone, page 2 “Closing strategy” is not displayed.

Table 67: Parameters in SST milestone “Controlled Switching”, page 2, section “Current making targets”

Parameter	Unit	Description	Remarks
L1 / Default value	deg	Suggested target phase angle for current making in L1 phase, relative to positive-going zero crossing of L1 phase-to-ground voltage.	non-editable, value can be selected and copied to clipboard
L1 / Applied value	deg	Target phase angle for current making in L1 phase, relative to positive-going zero crossing of L1 phase-to-ground voltage.	Definition applies even when L1 voltage is not connected to PWC600, as any phase shift from actual reference voltage is taken care of internally.
L2 / Default value	deg	Suggested target phase angle for current making in L2 phase, relative to default current making target in L1.	non-editable, value can be selected and copied to clipboard

Table continues on next page

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Parameter	Unit	Description	Remarks
L2 / Applied value	deg	Target phase angle for current making in L2 phase, relative to applied current making target in L1.	
L3 / Default value	deg	Suggested target phase angle for current making in L3 phase, relative to default current making target in L1.	non-editable, value can be selected and copied to clipboard
L3 / Applied value	deg	Target phase angle for current making in L3 phase, relative to applied current making target in L1.	

Table 68: Parameters in SST milestone "Controlled Switching", page 2, section "Gap voltage peak prior to making"

Parameter	Unit	Description	Remarks
L1 / Default value	pu	Default expected gap voltage peak across L1 circuit breaker pole just prior to the target making instant.	non-editable, value can be selected and copied to clipboard
L1 / Applied value	pu	Expected gap voltage peak across L1 circuit breaker pole just prior to the applied target making instant.	
L2 / Default value	pu	Default expected gap voltage peak across L2 circuit breaker pole just prior to the target making instant.	non-editable, value can be selected and copied to clipboard
L2 / Applied value	pu	Expected gap voltage peak across L2 circuit breaker pole just prior to the applied target making instant.	
L3 / Default value	pu	Default expected gap voltage peak across L3 circuit breaker pole just prior to the target making instant.	non-editable, value can be selected and copied to clipboard
L3 / Applied value	pu	Expected gap voltage peak across L3 circuit breaker pole just prior to the applied target making instant.	

For reactor applications, an additional instruction page is displayed between pages 2 and 3. The guidelines given there need to be observed during commissioning for successful controlled de-energization.

If only controlled closing was selected on the **Breaker control** milestone, page 3 "Opening strategy" is not displayed.

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Table 69: Parameters in SST milestone "Controlled Switching", page 3, section "Target current interruption instants"

Parameter	Unit	Description	Remarks
L1 / Default value	deg	Suggested target phase angle for current interruption in L1 phase, relative to positive-going zero crossing of selected reference signal in L1.	non-editable, value can be selected and copied to clipboard
L1 / Applied value	deg	Target phase angle for current interruption in L1 phase, relative to positive-going zero crossing of selected reference signal (source voltage or current) in L1.	cannot deviate more than 39 degrees from default value but may be shifted by multiples of 180 degrees
L2 / Default value	deg	Suggested target phase angle for current interruption in L2 phase, relative to default current interruption target in L1.	non-editable, value can be selected and copied to clipboard
L2 / Applied value	deg	Target phase angle for current interruption in L2 phase, relative to applied current interruption target in L1.	cannot deviate more than 39 degrees from default value but may be shifted by multiples of 180 degrees
L3 / Default value	deg	Suggested target phase angle for current interruption in L3 phase, relative to default current interruption target in L1.	non-editable, value can be selected and copied to clipboard
L3 / Applied value	deg	Target phase angle for current interruption in L3 phase, relative to applied current interruption target in L1.	cannot deviate more than 39 degrees from default value but may be shifted by multiples of 180 degrees

Table 70: Parameters in SST milestone "Controlled Switching", page 3, section "Target arcing times"

Parameter	Unit	Description	Remarks
L1 / Default value	ms	Default expected time from contact separation instant until current interruption in L1 phase, based on load type and CB properties.	non-editable, value can be selected and copied to clipboard
L1 / Applied value	ms	Expected time from contact separation instant until current interruption in L1 phase.	See Section 4.3.2.2 for details
L2 / Default value	ms	Default expected time from contact separation instant until current interruption in L2 phase, based on load type and CB properties.	non-editable, value can be selected and copied to clipboard
Table continues on next page			

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Parameter	Unit	Description	Remarks
L2 / Applied value	ms	Expected time from contact separation instant until current interruption in L2 phase.	
L3 / Default value	ms	Default expected time from contact separation instant until current interruption in L3 phase, based on load type and CB properties.	non-editable, value can be selected and copied to clipboard
L3 / Applied value	ms	Expected time from contact separation instant until current interruption in L3 phase.	

9.2.5.7 Adaptive correction

Specify how to detect actual switching instants and how to use this information to optimize controlled switching performance. See Section 4.4.2 for details.

If only controlled opening was enabled on the **Breaker control** milestone, most of the controls on page 1 are not displayed.

Table 71: Parameters in SST milestone "Adaptive Correction", page 1

Parameter	Unit	Description	Remarks
Signal for feedback detection		Specify which analog signal is to be used for determining the actual instants of current making and/or current interruption.	Available choices ("Current", "Load voltage") depend on configured feedback signals
Mechanical feedback and monitoring		Specify whether or not status changes of connected CB auxiliary contacts shall be used for monitoring CB status and timing.	Forced to "Disable" when no auxiliary contacts are connected
Coarse threshold / L1	%	Threshold for detecting the presence of the selected feedback signal in L1 phase, in percent of nominal RMS value.	See Section 4.5.1.2 for details on the detection algorithm including recommended threshold values.
Coarse threshold / L2	%	Threshold for detecting the presence of the selected feedback signal in L2 phase, in percent of nominal RMS value.	
Coarse threshold / L3	%	Threshold for detecting the presence of the selected feedback signal in L3 phase, in percent of nominal RMS value.	
Fine threshold / L1	%	Threshold for detecting the start point of the selected feedback signal in L1 phase, in percent of nominal RMS value.	See Section 4.5.1.2 for details on the detection algorithm including recommended threshold values.
Table continues on next page			

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Parameter	Unit	Description	Remarks
Fine threshold / L2	%	Threshold for detecting the start point of the selected feedback signal in L2 phase, in percent of nominal RMS value.	
Fine threshold / L3	%	Threshold for detecting the start point of the selected feedback signal in L3 phase, in percent of nominal RMS value.	
Adaptive correction of electrical making times		Activate adaptive correction of electrical making times, based on actual making instants of selected feedback signal.	Disabled when *Signal for feedback detection* = “None”. See Section 4.4.2.1 for details on adaptive correction.
Adaptive correction of mechanical closing times		Activate adaptive correction of mechanical closing times, based on actual closing instants estimated from CB auxiliary contacts timing.	Disabled when *Mechanical feedback and monitoring* = “Disable”
None		Deactivate adaptive correction for closing in all three phases.	
Adaptive correction factor (beta) / L1		Beta factor for adaptive correction based on the selected electrical or mechanical feedback signals, in L1 phase.	Disabled when *Adaptive correction for closing* = “None”. See Section 4.4.2.1 for details on adaptive correction.
Adaptive correction factor (beta) / L2		Beta factor for adaptive correction based on the selected electrical or mechanical feedback signals, in L2 phase.	Disabled when *Adaptive correction for closing* = “None”
Adaptive correction factor (beta) / L3		Beta factor for adaptive correction based on the selected electrical or mechanical feedback signals, in L3 phase.	Disabled when *Adaptive correction for closing* = “None”

If only controlled closing was enabled on the **Breaker control** milestone, most of the controls on page 2 are not displayed.

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Table 72: Parameters in SST milestone "Adaptive Correction", page 2

Parameter	Unit	Description	Remarks
Signal for feedback detection		Primary signal selected (on page 1) to be used for determining the actual instants of current interruption.	Non-editable, only for reference
Mechanical feedback and monitoring		Selection (on page 1) whether or not status changes of connected CB auxiliary contacts shall be used for monitoring of CB status and timing.	Non-editable, only for reference
Coarse threshold / L1	%	Threshold for detecting the presence of the selected feedback signal in L1 phase, in percent of nominal RMS value.	See Section 4.5.1.2 for details on the detection algorithm including recommended threshold values.
Coarse threshold / L2	%	Threshold for detecting the presence of the selected feedback signal in L2 phase, in percent of nominal RMS value.	
Coarse threshold / L3	%	Threshold for detecting the presence of the selected feedback signal in L3 phase, in percent of nominal RMS value.	
Fine threshold / L1	%	Threshold for detecting the end point of the selected feedback signal in L1 phase, in percent of nominal RMS value.	See Section 4.5.1.2 for details on the detection algorithm including recommended threshold values.
Fine threshold / L2	%	Threshold for detecting the end point of the selected feedback signal in L2 phase, in percent of nominal RMS value.	
Fine threshold / L3	%	Threshold for detecting the end point of the selected feedback signal in L3 phase, in percent of nominal RMS value.	
Limit of arcing time extensions per phase		Maximum allowable number of target arcing time extensions, as consequence of re-ignition or re-strikes detected from primary current.	Disabled when *Signal for feedback detection* = "None". See Section 4.4.2.2 for details on adaptive correction.

9.2.5.8 Compensation

Specify whether and how to compensate deterministic influences of ambient conditions on CB switching times. See Section 4.4.1 for details.

If more than one compensation quantity is activated, PWC600 will add up the individual compensation values to obtain one total compensation value for each CB pole per operation type (Close or Open).

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Table 73: Parameters in SST milestone "Compensation", page 1:

Parameter	Unit	Description	Remarks
Control voltage (battery voltage)		Enable ("1") or disable ("None") compensation of the impact of control voltage on the mechanical operating times of the circuit breaker.	PWC600 measures breaker control voltage on its own supply terminals.
Idle time		Enable ("3") or disable ("None") compensation of the impact of idle time on the mechanical operating times of the circuit breaker. Idle time is the time elapsed since the last CB operation.	PWC600 internally measures CB idle time based on electrical (primary current or load voltage) and/or mechanical (from auxiliary contacts) status feedback.
Temperature		Enable or disable ("None") compensation of the impact of temperature on the mechanical operating times of the circuit breaker. Specify whether temperature is acquired individually for each CB pole ("3") or in a single location applicable to the three poles ("1").	Measured temperature values must be supplied to PWC600 via IEC 61850 GOOSE messages.
Table continues on next page			

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Parameter	Unit	Description	Remarks
Drive pressure		Enable or disable (“None”) compensation of the impact of drive pressure on the mechanical operating times of the circuit breaker. Specify whether pressure is acquired individually for each CB pole (“3”) or in a single reservoir shared by the three poles (“1”).	Measured pressure values must be supplied to PWC600 via IEC 61850 GOOSE messages.
Spring charge		Enable or disable (“None”) compensation of the impact of spring charge on the mechanical operating times of the circuit breaker. Specify whether spring charge is acquired individually for each CB pole (“3”) or in a single drive shared by the three poles (“1”).	Spring charge level is obtained from two binary input signals. Only applicable to breaker models that can be operated with the drive not fully charged, which would impact operating times.
(Additional quantity)		Enable or disable (“None”) compensation of the impact of an additional measured quantity on the mechanical operating times of the circuit breaker. Specify whether that additional quantity is acquired individually for each CB pole (“3”) or in a single location applicable to the three poles (“1”).	Visible only if the additional quantity has been defined in the CB data. Measured values of the additional quantity must be supplied to PWC600 via IEC 61850 GOOSE messages, or computed internally.

According to the selections on page 1, SST will display only those individual compensation pages for which at least one measuring channel is available. The layout and setting names on these pages are identical – the page informs to which compensation quantity it applies. Thumbnail graphics give a quick preview of the compensation curves, which are defined separately for CB closing and opening operations.

Table 74: Parameters in SST milestone “Compensation”, pages 2...7, sections “Close” and “Open”

Parameter	Unit	Description	Remarks
Enable		Enable or disable timing compensation for controlled closing and/or opening, respectively.	
Mutually to all poles / Individually to each pole		Specify whether the same compensation curve shall be applied to all three CB poles, or whether an individual compensation curve is defined for each CB pole.	Visible only when three measuring channels have been enabled on page 1.
(Checkbox underneath thumbnail)		Select compensation curve(s) for editing.	Deactivated when corresponding *Enable* checkbox is unchecked

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With at least one thumbnail checked, clicking the **Edit selected curve** button opens the compensation curve editor for this quantity. If more than one thumbnail is checked, the entered compensation curve will be applied to all these operations and phases.

A compensation curve defines the expected deviation (in milliseconds) of the circuit breaker's mechanical closing or opening time from nominal value, for a given value of the measured quantity. Initial compensation data are copied from the circuit breaker definition, either from the CB library or as defined by the user. Changes made here do not impact the CB library.

Table 75: Parameters in SST "Compensation" pop-up dialog, sections "Compensation range" and "Compensation Curve". Units correspond to the definition of the measured quantity.

Parameter	Unit	Description	Remarks
Upper limit		Upper limit of compensation range, to be shown in the preview graph.	
Lower limit		Lower limit of compensation range, to be shown in the preview graph.	
Type of curve		Select "Chart" for defining a piece-wise linear compensation characteristic. Select "Equation" for defining an algebraic function for defining the compensation characteristic.	
Number of points		Number of data points for "Chart" type characteristic. Each data point consists of a parameter value and associated timing deviation value.	Visible only for "Chart" type compensation curve

Table 76: Parameters in SST "Compensation" pop-up dialog, table of data points in "Chart" type compensation curve. Input values (X1, X2, ...) must be specified in ascending order.

Parameter	Unit	Description	Remarks
X1		Parameter input value of first data point	Physical value of measured parameter, e.g. seconds, centigrades
Y1	ms	CB timing compensation value for parameter input value X1	
X2		Parameter input value of second data point	X2 must be larger than X1
Y2	ms	CB timing compensation value for parameter input value X2	
X3 ... X8		Parameter input values of further data points	Visible only for *Number of points* >2
Y3 ... Y8	ms	CB timing compensation values for parameter input values X3 ... X8	Visible only for *Number of points* >2

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Table 77: Parameters in SST "Compensation" pop-up dialog, list of parameters of "Equation" type compensation curve. "x" is the measured value impacting the switching time.

Parameter	Unit	Description	Remarks
a		Coefficient of first algebraic term in the equation	
b		Coefficient of second algebraic term in the equation	
c		Constant offset in the equation	
d		Coefficient of fourth algebraic term in the equation	
e		Mantissa of exponential term in the equation	
f		Coefficient of exponent of the exponential term in equation	
m		Exponent of first power term in the equation	
n		Exponent of second power term in the equation	

9.2.5.9 Alarms enabling

Specify which conditions should raise a warning or alarm. Refer to Section 4.5.3 on the recommended alarms for different applications.

Table 78: Parameters in SST milestone "Alarms enabling", page 1

Parameter	Unit	Description	Remarks
Unsynchronized switching operation		Enable raising an alarm if the last circuit breaker operation was performed without point-on-wave control.	
Actual switching instant, or CB operating time, out of limit		Enable raising an alarm related to accuracy of controlled switching operations or to operating times of the circuit breaker. Details are selected on subsequent pages.	Checking this item enables display of pages 3-4.
Re-ignition/re-strike		Enable raising an alarm if a re-ignition/re-strike was detected, or if the maximum number of adaptive opening time corrections due to such events was exceeded.	A re-ignition/re-strike is declared if current interruption in a CB pole occurs more than 1/8 power cycle later than expected. Refer to Section 4.5.1.3
Table continues on next page			

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Parameter	Unit	Description	Remarks
Maximum allowed delay time exceeded		Enable raising an alarm if the internal delay time (from detected input command till last output time stamp) has exceeded the set limit.	
Unstable circuit breaker operating characteristics		Enable raising an alarm if the actual (estimated) mechanical operating times of the CB have been fluctuating by more than 10% between the last three operations of the same type (Close or Open).	Activated only if at least one auxiliary contact is connected (**Reference Signals** milestone) and mechanical feedback and monitoring is enabled (**Adaptive Correction** milestone).
Contradicting mechanical and electrical CB position indications		Enable raising an alarm if load current is detected while the auxiliary contacts indicate that the CB is open.	

Table 79: Parameters in SST milestone "Alarms enabling", page 2

Parameter	Unit	Description	Remarks
Loss of reference signal		Enable raising an alarm if any of the primary voltage or current signals, which is to be used as reference for the next controlled switching operation, is below the "dead value" threshold.	See Section 4.5.3
Loss of compensation signal		Enable raising an alarm if any of the external signals, which are used for parameter compensation of CB timing, is lost or the respective sensor is flagged faulty.	Visible only when at least one compensation signal other than *Control voltage* or *Idle time* is activated.
Circuit breaker operation count		Enable raising an alarm if the counted number of mechanical C+O operation cycles of the CB exceeds the set limit.	
Circuit breaker interrupter wear		Enable raising an alarm if the cumulated interrupter wear (in equivalent mechanical operations) of the CB exceeds the set limit.	
Table continues on next page			

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Parameter	Unit	Description	Remarks
Phase L1		Initial value of cumulated interrupter wear (in equivalent mechanical operations) of CB pole L1. This value will be used after clearing CB wear in the IED.	Visible only after clicking **Edit initial interrupter wear**
Phase L2		Initial value of cumulated interrupter wear (in equivalent mechanical operations) of CB pole L2. This value will be used after clearing CB wear in the IED.	Visible only after clicking **Edit initial interrupter wear**
Phase L3		Initial value of cumulated interrupter wear (in equivalent mechanical operations) of CB pole L3. This value will be used after clearing CB wear in the IED.	Visible only after clicking **Edit initial interrupter wear**

Table 80: Parameters in SST milestone "Alarms enabling", page 3. The entire page is visible only when Actual switching instant, or CB operating time, out of limit is checked on page 1.

Parameter	Unit	Description	Remarks
Mechanical closing time		Enable raising an alarm if the actual (estimated) mechanical closing time of the CB is outside the expected range.	Activated only if *Mechanical feedback and monitoring* is enabled in the **Adaptive Correction** milestone.
Mechanical opening time		Enable raising an alarm if the actual (estimated) mechanical opening time of the CB is outside the expected range.	Activated only if *Mechanical feedback and monitoring* is enabled in the **Adaptive Correction** milestone.
Mechanical closing target error		Enable raising an alarm if the difference between actual (estimated) and predicted mechanical closing time of the CB is outside the expected range.	Activated only if *Mechanical feedback and monitoring* is enabled in the **Adaptive Correction** milestone.
Table continues on next page			

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Parameter	Unit	Description	Remarks
Mechanical opening target error		Enable raising an alarm if the difference between actual (estimated) and predicted mechanical opening time of the CB is outside the expected range.	Activated only if *Mechanical feedback and monitoring* is enabled in the **Adaptive Correction** milestone.
Mechanical moving time (close)		Enable raising an alarm if the time between changeover points of two auxiliary contacts in the CB drive during a closing operation is outside the expected range.	Activated only if *Mechanical feedback and monitoring* is enabled in the **Adaptive Correction** milestone.
Mechanical moving time (open)		Enable raising an alarm if the time between changeover points of two auxiliary contacts in the CB drive during an opening operation is outside the expected range.	Activated only if *Mechanical feedback and monitoring* is enabled in the **Adaptive Correction** milestone.

Table 81: Parameters in SST milestone "Alarms enabling", page 4. The entire page is visible only when Actual switching instant, or CB operating time, out of limit is checked on page 1.

Parameter	Unit	Description	Remarks
Closing velocity		Enable raising an alarm if the linear closing velocity of the CB is outside the expected range.	Deactivated: not supported in PWC600 1.1
Opening velocity		Enable raising an alarm if the linear opening velocity of the CB is outside the expected range.	Deactivated: not supported in PWC600 1.1
Initial closing delay time		Enable raising an alarm if the time from CB closing command till changeover of the first auxiliary contact is outside the expected range.	Activated only if *Mechanical feedback and monitoring* is enabled in the **Adaptive Correction** milestone.
Initial opening delay time		Enable raising an alarm if the time from CB opening command till changeover of the first auxiliary contact is outside the expected range.	Activated only if *Mechanical feedback and monitoring* is enabled in the **Adaptive Correction** milestone.
Electrical closing target error		Enable raising an alarm if the deviation of actual making instant from target making instant is outside the expected range.	Activated only if a suitable *Signal for feedback detection* is enabled in the **Adaptive Correction** milestone.
Electrical opening target error		Enable raising an alarm if the deviation of actual interruption instant from target interruption instant is outside the expected range.	Activated only if a suitable *Signal for feedback detection* is enabled in the **Adaptive Correction** milestone.

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Table 82: Parameters in SST milestone "Alarms enabling", page 5. The entire page is visible only when at least one compensation parameter is activated on the Compensation milestone.

Parameter	Unit	Description	Remarks
Battery voltage out of supervision range		Enable raising an alarm if the measured battery voltage is outside the expected range.	Activated only if measurement of *Control voltage (battery voltage)* is enabled under **Compensation**
Idle time out of supervision range		Enable raising an alarm if the measured idle time is outside the expected range.	Activated only if measurement of *Idle time* is enabled under **Compensation**
Temperature out of supervision range		Enable raising an alarm if the measured temperature is outside the expected range.	Activated only if measurement of *Temperature* is enabled under **Compensation**
Drive pressure out of supervision range		Enable raising an alarm if the measured drive pressure is outside the expected range.	Activated only if measurement of *Drive pressure* is enabled under **Compensation**
Spring charge out of supervision range		Enable raising an alarm if the measured spring charge is outside the expected range.	Activated only if measurement of *Spring charge* is enabled under **Compensation**
(Additional quantity) out of supervision range		Enable raising an alarm if the measured additional quantity value is outside the expected range.	Visible only if measurement of a pre-defined additional quantity is enabled under **Compensation**

9.2.5.10 Time synchronization

The real-time clock in PWC600 can be synchronized to a time server using the SNTP or IRIG-B protocols. This internal system time is used for display and for time stamping of events. Here, specify the source for time synchronization of the PWC600 device.

Table 83: Parameters in SST milestone "Time Synchronization", page 1

Parameter	Unit	Description	Remarks
Fine synchronization input		Specify input for time synchronization information	

Table 84: Parameters in SST milestone "Time Synchronization", page 1, section "SNTP Configuration". This section is visible only when Fine synchronization input = "SNTP".

Parameter	Unit	Description	Remarks
Server IP address		IP address of primary time server	
Redundant server IP address		IP address of secondary time server, to be used if primary time server cannot be accessed	optional; if not used leave default value of 0.0.0.0.

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Table 85: Parameters in SST milestone "Time Synchronization", page 1, section "IRIG-B telegram specification". This section is visible only when Fine synchronization input = "IRIG-B".

Parameter	Unit	Description	Remarks
Transmitted time domain		Specify whether the server transmits the time information as local time or UTC.	
Encoding type		Specify which information is included in the IRIG-B telegrams on top of the basic IRIG-B specification: Select "1344" for time quality information according to IEEE 1344. Select "1344TZ" for the synchronization data to override the IED's time zone setting.	
Time zone handling (IEEE 1344)		Select "PlusTZ" if the time server adheres to the IEEE 1344 definition that "Encoded IRIG time + time zone offset = UTC, at all times".	

9.2.5.11 Breaker times

Enter the actual mechanical closing and opening times of each circuit breaker pole. Initial values are taken from the circuit breaker definition, either from the CB library or as defined by the user.



While creating the parameter configuration, the actual CB operating times are often not available. In this case, keep the default values displayed on entering this milestone, and make sure the correct values will be applied before going live.

Table 86: Parameters in SST milestone "Breaker Times", page 1

Parameter	Unit	Description	Remarks
Primary contact / L1	ms	Average time from closing command to primary contact touch in CB pole L1	Actual value to be updated before or at commissioning.
Primary contact / L2	ms	Average time from closing command to primary contact touch in CB pole L2	Actual value to be updated before or at commissioning.
Primary contact / L3	ms	Average time from closing command to primary contact touch in CB pole L3	Actual value to be updated before or at commissioning.
Auxiliary contact NO (52a) / L1	ms	Average time from closing command to closing of 52a (NO) auxiliary contact in CB pole L1	Visible only when "NO/ 52a" is checked under **Reference Signals / Feedback Signals**

Table continues on next page

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Parameter	Unit	Description	Remarks
Auxiliary contact NO (52a) / L2	ms	Average time from closing command to closing of 52a (NO) auxiliary contact in CB pole L2	Visible only when “NO/ 52a” is checked under **Reference Signals / Feedback Signals**
Auxiliary contact NO (52a) / L3	ms	Average time from closing command to closing of 52a (NO) auxiliary contact in CB pole L3	Visible only when “NO/ 52a” is checked under **Reference Signals / Feedback Signals**
Auxiliary contact NC (52b) / L1	ms	Average time from closing command to opening of 52b (NC) auxiliary contact in CB pole L1	Visible only when “NC/ 52b” is checked under **Reference Signals / Feedback Signals**
Auxiliary contact NC (52b) / L2	ms	Average time from closing command to opening of 52b (NC) auxiliary contact in CB pole L2	Visible only when “NC/ 52b” is checked under **Reference Signals / Feedback Signals**
Auxiliary contact NC (52b) / L3	ms	Average time from closing command to opening of 52b (NC) auxiliary contact in CB pole L3	Visible only when “NC/ 52b” is checked under **Reference Signals / Feedback Signals**

Table 87: Parameters in SST milestone “Breaker Times”, page 2

Parameter	Unit	Description	Remarks
Primary contact / L1	ms	Average time from opening command to primary contact separation in CB pole L1.	Actual value to be updated before or at commissioning.
Primary contact / L2	ms	Average time from opening command to primary contact separation in CB pole L2.	Actual value to be updated before or at commissioning.
Primary contact / L3	ms	Average time from opening command to primary contact separation in CB pole L3.	Actual value to be updated before or at commissioning.
Auxiliary contact NO (52a) / L1	ms	Average time from opening command to opening of 52a (NO) auxiliary contact in CB pole L1	Visible only when “NO/ 52a” is checked under **Reference Signals / Feedback Signals**
Auxiliary contact NO (52a) / L2	ms	Average time from opening command to opening of 52a (NO) auxiliary contact in CB pole L2	Visible only when “NO/ 52a” is checked under **Reference Signals / Feedback Signals**
Auxiliary contact NO (52a) / L3	ms	Average time from opening command to opening of 52a (NO) auxiliary contact in CB pole L3	Visible only when “NO/ 52a” is checked under **Reference Signals / Feedback Signals**
Table continues on next page			

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Parameter	Unit	Description	Remarks
Auxiliary contact NC (52b) / L1	ms	Average time from opening command to closing of 52b (NC) auxiliary contact in CB pole L1	Visible only when “NC/ 52b” is checked under **Reference Signals / Feedback Signals**
Auxiliary contact NC (52b) / L2	ms	Average time from opening command to closing of 52b (NC) auxiliary contact in CB pole L2	Visible only when “NC/ 52b” is checked under **Reference Signals / Feedback Signals**
Auxiliary contact NC (52b) / L3	ms	Average time from opening command to closing of 52b (NC) auxiliary contact in CB pole L3	Visible only when “NC/ 52b” is checked under **Reference Signals / Feedback Signals**

9.2.6 Defining or editing a custom circuit breaker

If PWC600 is to be used with a circuit breaker model that is not included in the library, the user can define this breaker model manually in Switchsync Setting Tool. Usually, the circuit breaker manufacturer should provide the information related to controlled switching and monitoring.

9.2.6.1 Initiating of CB model creation or editing

The process of defining or editing a custom CB model is initiated from page 1 of the **Circuit Breaker** milestone in SST.

To create a new custom circuit breaker model:

1. Select *Circuit breaker manufacturer* = “Other / Custom”.
2. Select *Circuit breaker type* = “New Circuit Breaker”.
3. Enter the *Nominal control* voltage of the breaker coils as specified by the manufacturer.
4. Click **Next**.

9.2.6.2 Editing the data

To edit the data of a previously defined custom CB model, or to create a copy of an existing custom CB model:

1. Select *Circuit breaker manufacturer* = “Other / Custom”.
2. From the list under *Circuit breaker type*, select the CB model to be edited.
3. Enter the *Nominal control voltage* of the breaker coils as specified by the manufacturer.
4. Select *Circuit breaker data* = “Edit”.
5. Click **Next**.

9.2.6.3 Viewing the data

To view the data of any circuit breaker model without editing:

1. Select the appropriate *Circuit breaker manufacturer* and *Circuit breaker type / model*.
2. Enter the *Nominal control voltage* of the breaker coils as specified by the manufacturer.
3. Select *Circuit breaker data* = “Display”.
4. Click **Next**.

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9.2.6.4 Circuit breaker definition

The detailed data of the circuit breaker model are entered on several pages in SST. A value must be entered in each field, it is not possible to leave them blank. If actual data are not known keep the default values or contact the CB manufacturer for guidance.

For each value to be entered, a short description is displayed, same as for the other parameters in SST.

The final page of the **Circuit Breaker** milestone confirms saving of the CB data. No information needs to be entered here.

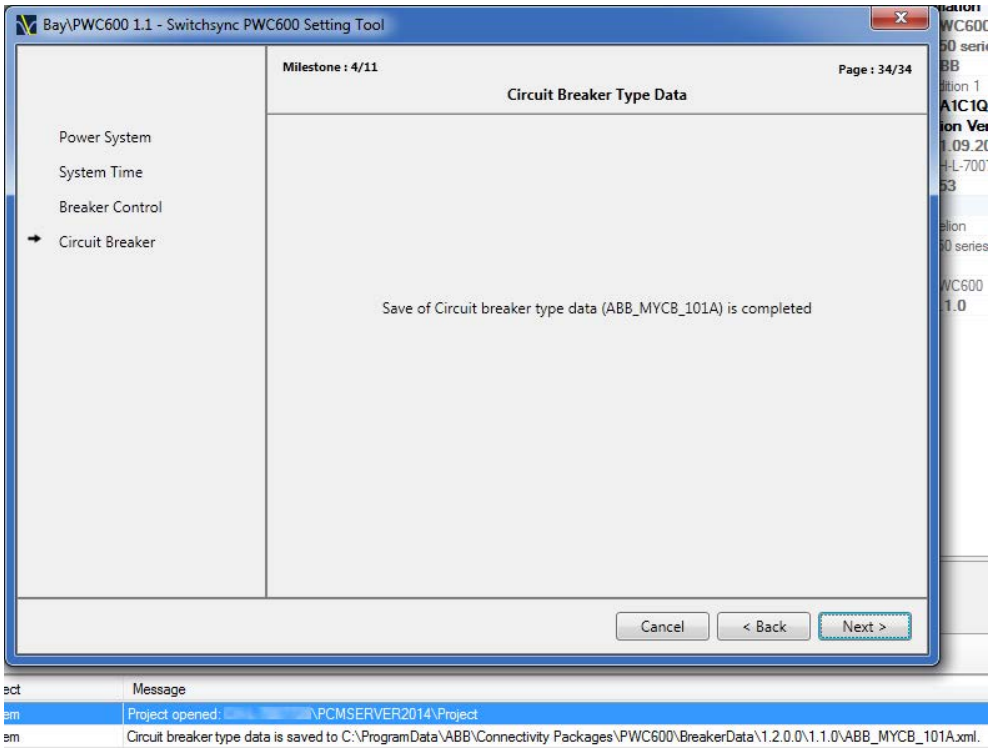


Figure 84: Saving custom circuit breaker data

The entire file path is shown in the **Output** window.

9.2.6.5 Transferring custom CB files

A custom circuit breaker is stored as a separate file on the local computer. Only the relevant data are transferred to the application configuration at the conclusion of SST. The resulting configuration can be written to the IED or archived from another computer. However, re-running SST on a configuration that includes a custom CB requires a copy the CB file to be present on the same computer.

SST stores and reads custom CB files in the following folder: **C:\ProgramData\ABB\Connectivity Packages\PWC600\BreakerData\1.2.0.0**

where “1.2.0.0” is the version number of the PWC600 Connectivity Package, which may be different depending on the installed version.

The **ProgramData** folder is hidden by default. If it is not listed among the folders in the root directory **C:**, showing hidden folders can be enabled in the **Folder Options** of Windows Explorer by navigating to the **View** tab and selecting *Show hidden files, folders, and drives*.

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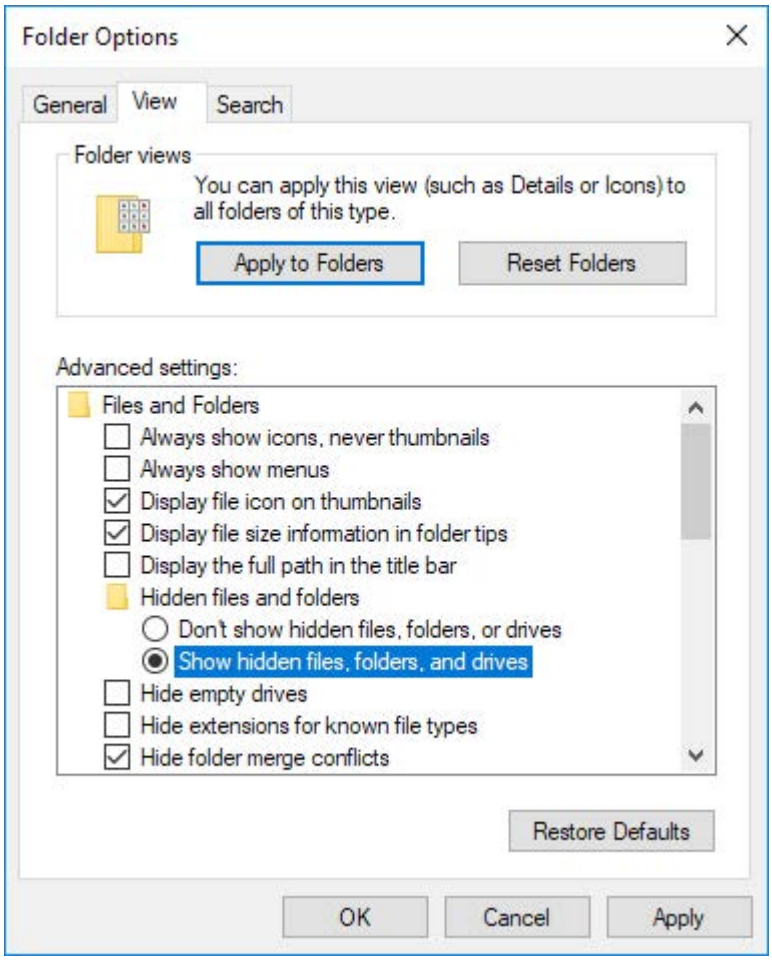


Figure 85: Enable showing of hidden folders in Windows

Transferring an IED configuration containing a custom CB to another computer will not include the CB file. The latter needs to be transferred manually between the corresponding folder on the source computer and destination computer. The same applies when archiving an IED configuration or a PCM600 project.

If the installed Connectivity Package versions are not identical between computers, make sure to copy the files between the folders according to the actual Connectivity Package. However, it is recommended to always use the latest released Connectivity Packages, which can be installed through Update Manager (see Section 8.3.2).

9.2.7 Intermediate saving

It is possible to exit Switchsync Setting Tool (for example, to request additional information which is not available at the moment) before completing all steps, and save the partial configuration.

1. Click **X** or **Cancel** to exit the Switchsync Setting Tool.
2. In the confirmation dialog, click **Yes**.

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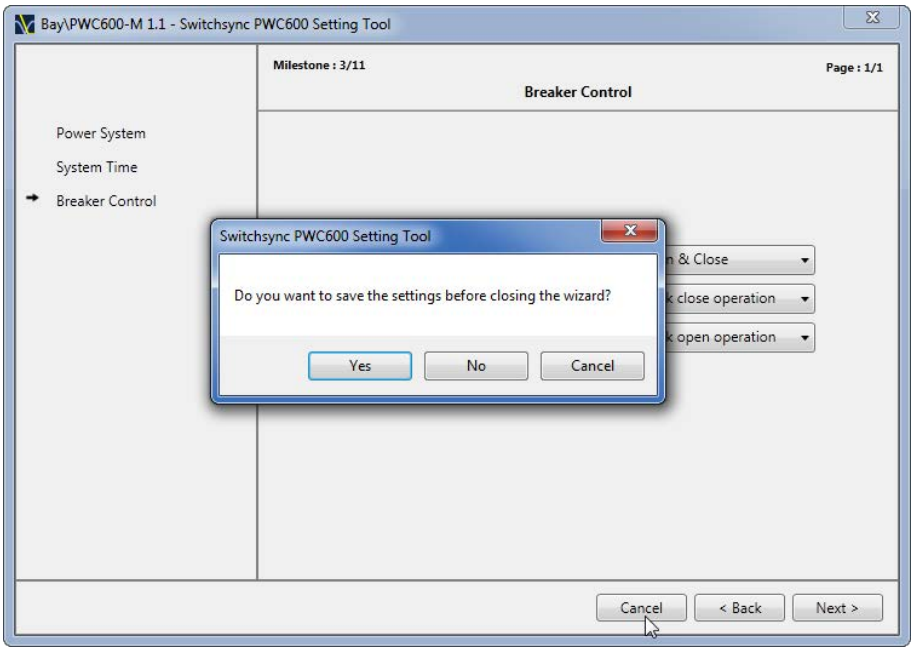


Figure 86: Saving the configuration partially

Switchsync Setting Tool can be started by selecting **Continue with previously saved settings** from the step where it was left earlier.

9.2.8 Completing Switchsync Setting Tool

1. On the final screen of Switchsync Setting Tool, click **Finish** to save the changed parameters to the database.

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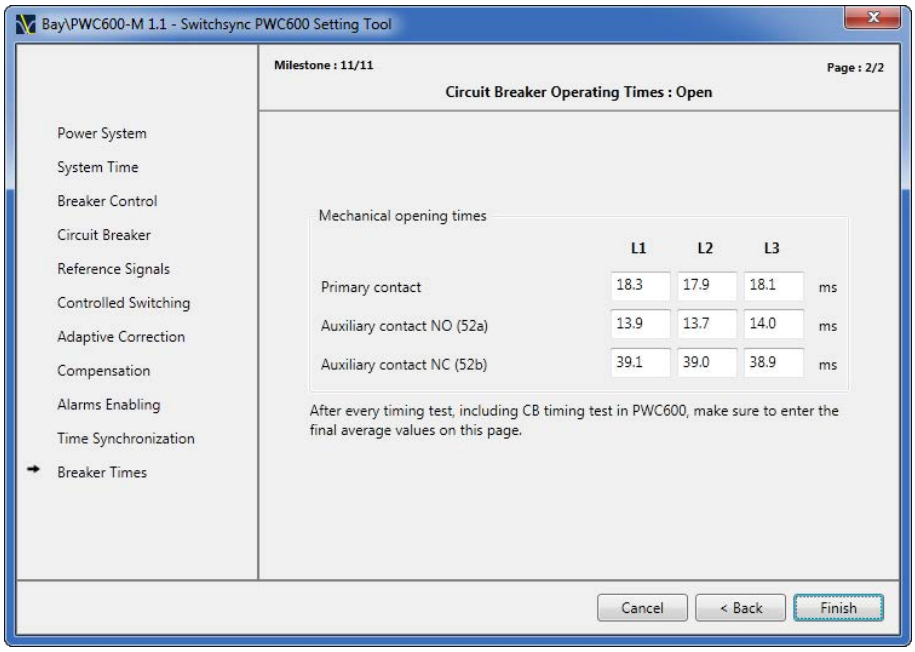


Figure 87: Finishing SST to save the configuration

Finishing SST also copies the names of Substation, Bay, and IED from the plant structure to the TERMINALID function.

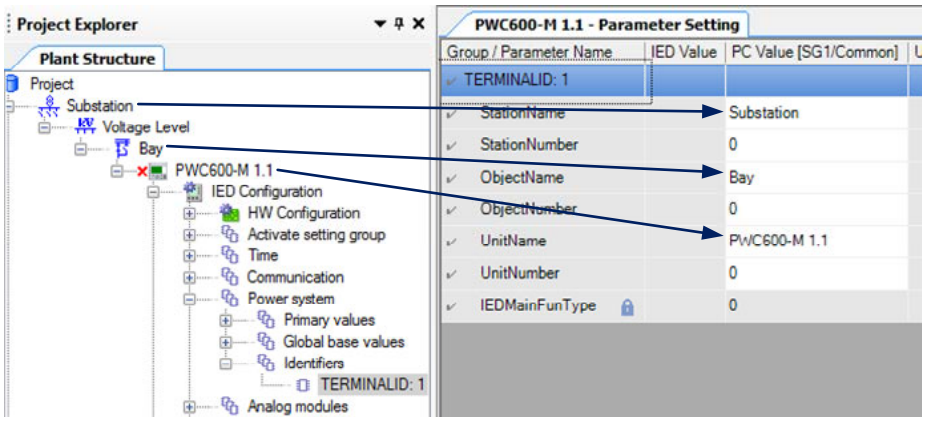


Figure 88: Automatic copying of object identifiers to the TERMINALID function

Switchsync Setting Tool is an offline tool. After completing the steps, the **Finish** operation stores the parameters in the PCM600 database. The parameters must be written to the physical IED with Parameter Setting tool or Common Write, see Section 9.3.

User-defined circuit breaker types are stored as separate files on the local PC and are not part of the saved configuration. If these data should be reused with SST on another PC, they need to be transferred manually. See Section 9.2.6.5.

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9.3 Writing parameters to the IED

Settings and parameters entered or modified through SST are stored locally in the PCM600 database. Writing them to the IED requires online connection to the IED.

On a new IED object, always write the entire software configuration to the IED. See Section 9.5.

1. In **Plant Structure**, right-click the **PWC600** object and select **Parameter Setting**.

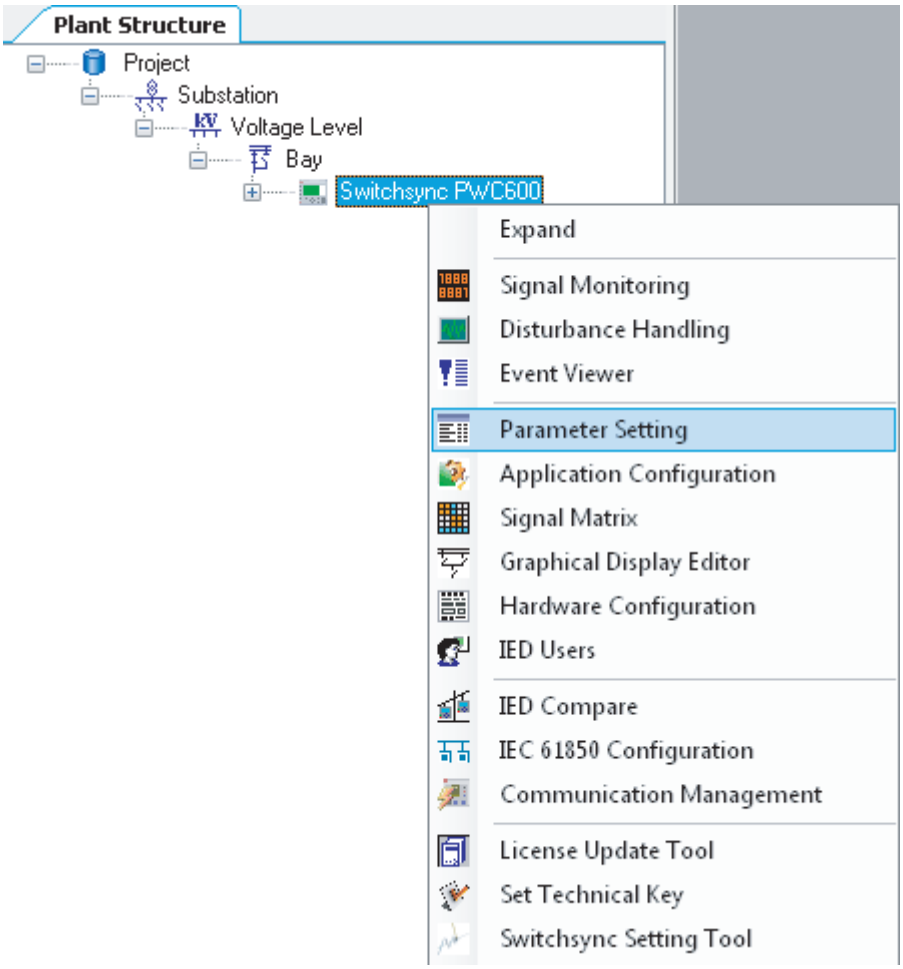


Figure 89: Opening the Parameter Setting tool

2. Click **View/Parameter layer/Advanced parameters** or the corresponding button in the toolbar to enable access to advanced parameters.

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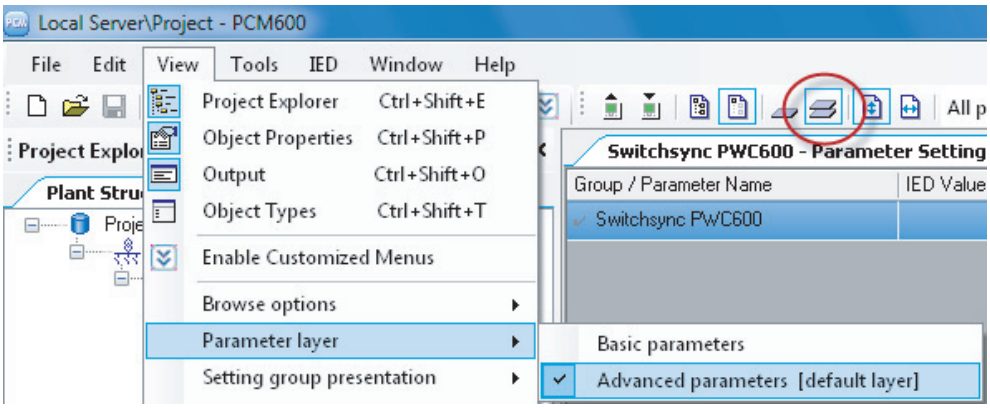


Figure 90: Enabling advanced parameters

3. Click **IED/Write parameters to IED** or the corresponding button in the toolbar to initiate writing parameters to the IED.

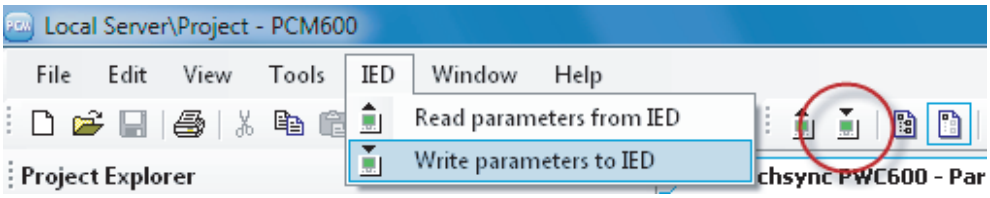


Figure 91: Writing parameters to the IED

4. In the **Write parameters to PWC600** dialog box, select **All parameters** and click **OK**.

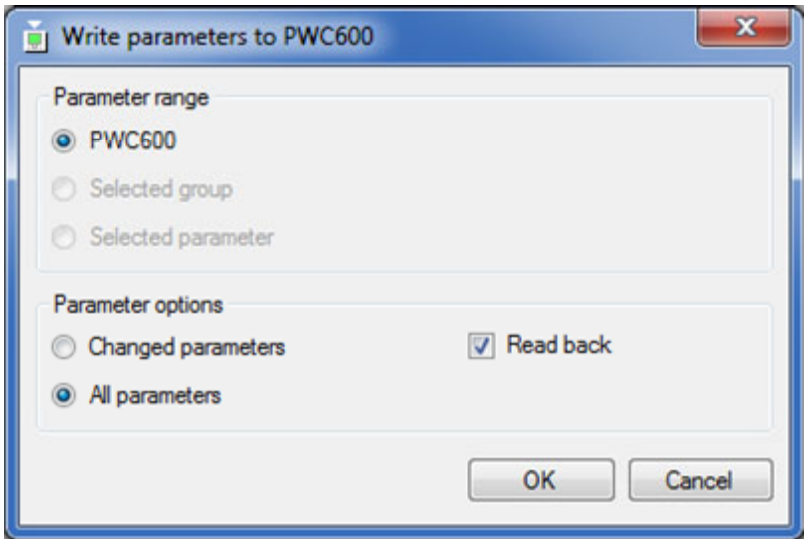


Figure 92: Selecting all parameters

Always select the entire PWC600 object under **Parameter range**. If the IED object does not show up as first option, click **Cancel** and select it in the plant structure, then start again from step 3.

Progress of the writing operation is displayed by a progress bar.

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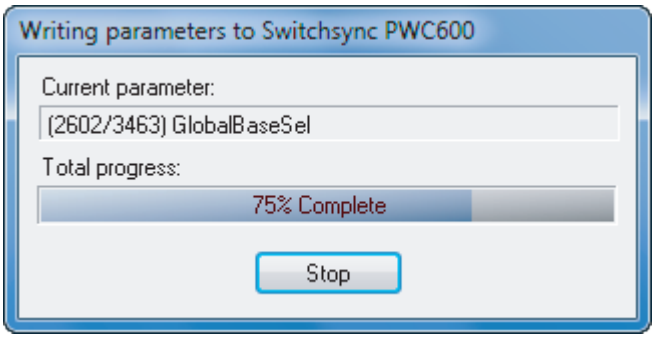


Figure 93: Progress bar

While writing the parameters to its non-volatile memory, the IED replaces the bay name by an animated icon in the bottom right corner of the IED.



Figure 94: LHMI icon

When the bay name is displayed again, then the updated parameters are in use by the application. No restart of the IED is required.

If **Read back** was enabled in the **Write parameters to Switchsync PWC600** dialog box, the Parameter Setting tool automatically reads back all the parameters from the IED after completion of the write operation, displaying a similar progress bar.

5. After writing the parameters to the IED, wait until the animated Write icon on the screen has disappeared and the Ready LED is steadily on before doing any further operation on the IED.

9.4 Modification of the default pre-configuration

9.4.1 Precautions

Switchsync PWC600 is delivered with a default pre-configuration that has been proven to work for different applications. In most cases, changes to this configuration should not be necessary.

Modifying the pre-configuration may cause loss of functionality, in particular with respect to Switchsync Setting Tool.

However, if changes are wanted, the given information must be observed.

Proper functioning of Switchsync PWC600 and associated tools requires specific interaction between certain function blocks. To ensure integrity of these essential connections, some of the pages in Application Configuration are locked.

Do not make any modifications to the locked pages in Application Configuration without approval from ABB.

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In PCM600 Graphical Display Editor (GDE), the Switchsync PWC600 configuration comprises five pages by default. The first three pages **Operation**, **Avg opening times**, and **Avg closing times** are specifically designed for the CB Test mode user interface and do not appear under **Control/Single line diagram**) of the LHMI menu.

The first three default GDE pages (**Operation**, **Avg opening times**, **Avg closing times**) must not be changed, removed or rearranged.

9.4.2 General information for working with PCM600

PCM600 supports online help feature which can be accessed using the **Help** menu in PCM600. Internet connection is not required to access this help. All the tools used for configuring the Switchsync PWC600 application are available in the shortcut menu of the IED or its subordinate tree nodes (child nodes). The tools list is opened by right-clicking the IED or any other tree node. The number of tools listed varies by the tree node.

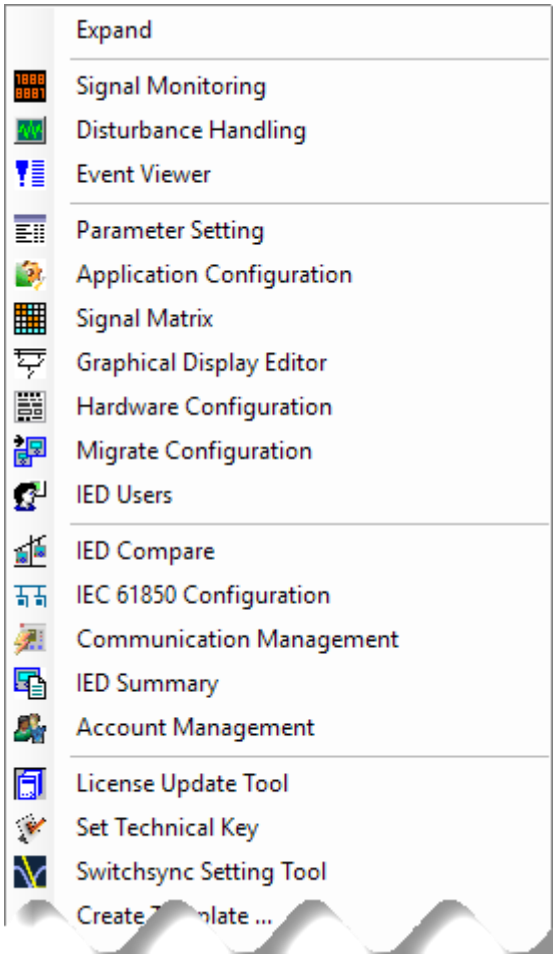


Figure 95: Tools list for PWC600 IED object

The following sections contain specific information required for modifying the default pre-configuration.

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9.4.3 Working with the Application Configuration tool

The Application Configuration tool is a graphical engineering tool for configuring the software application running in an IED. The application can be distributed over several worksheets, each of which includes one or more pages.

The symbol at the top left corner of an application worksheet implies that the page is locked and cannot be modified.

Right-click the IED and click Application Configuration to open the Application Configuration tool.

As an example, the following subsections demonstrate how to add functionality for counting the activations of hardware binary input PIO_3.PBI2, which may represent energization of the pump motor of the CB drive. Reaching the limit of 10000 pump starts shall illuminate LED1 (group 2) yellow; pressing Function Key 2 shall both reset the counter and clear the LED.

9.4.3.1 Adding application worksheets in the configuration

Additional functionality, not included in the default configuration, should be defined on a separate application worksheet.

The order of worksheets has no impact on the functionality.

1. Activate the application worksheet after which a new worksheet is to be inserted by clicking the respective tab.
2. On the main menu, select **Insert/MainApplication**, or click the **Insert MainApplication** button.

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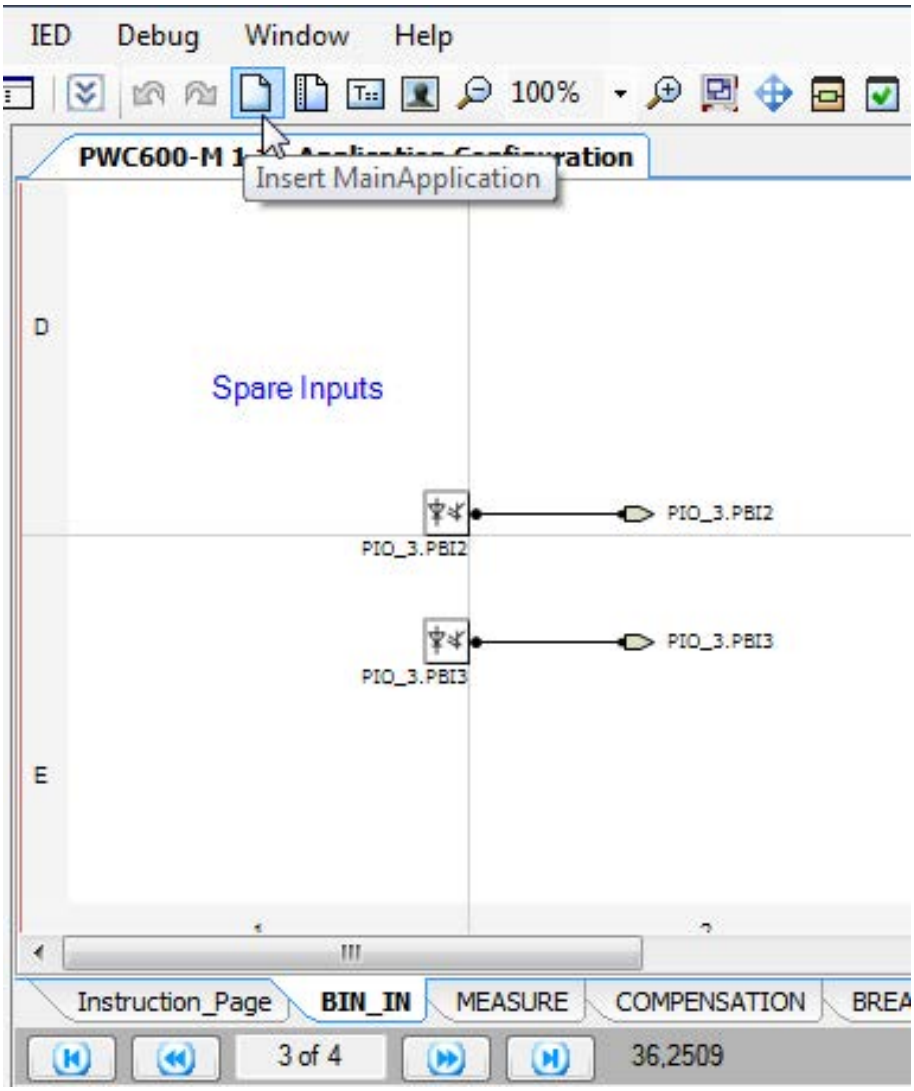


Figure 96: Adding an application worksheet

3. Change the name of the new worksheet by overwriting *Name* in **Object Properties**.

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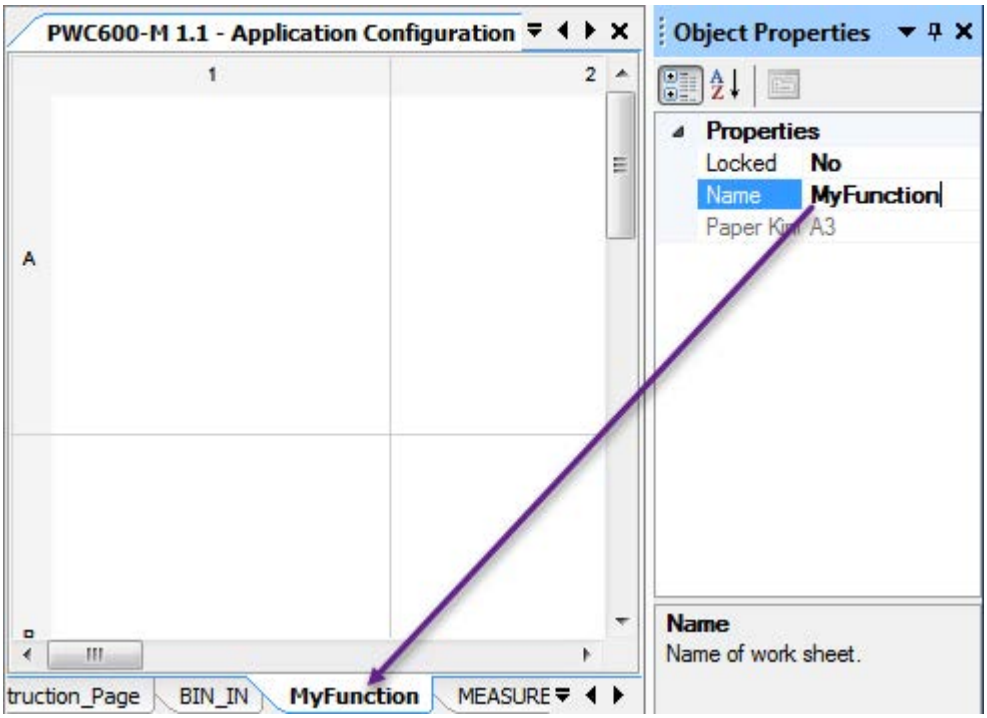


Figure 97: Naming the application worksheet

4. Save the application configuration. The newly added worksheet will appear in the plant structure as a new node under **IED\Application Configuration**.

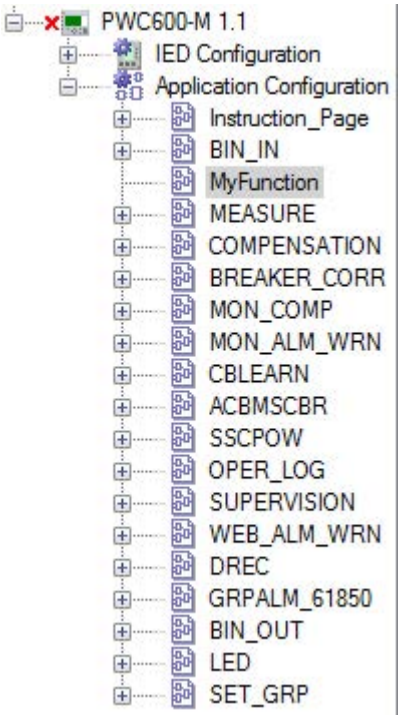


Figure 98: IED application tree structure with new worksheet added

9.4.3.2 Function blocks

Function blocks are the main elements of an application configuration. They are designed for a various number of functions and organized in type groups. The different function block types

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are shown in the Object Types view. Figure 99 presents an overview of the main parts that are relevant for a function block.

- Set user-defined names for function blocks and signals marked with blue text.

  Signals with a user-defined name created in Application Configuration become visible in Parameter Setting only after the IED configuration has been written to the IED and read back into PCM600.

  Characters other than a...z, A...Z, 0...9 and _ are not allowed in user-defined names of signals and function blocks, since they might not display properly in the LHMI. The space character should also be avoided.

- Lock function blocks.
- Set visibility for execution order, cycle time and instance number.
- Manage signals, for example hide, show and rearrange.
- Invert Boolean inputs and Boolean outputs.

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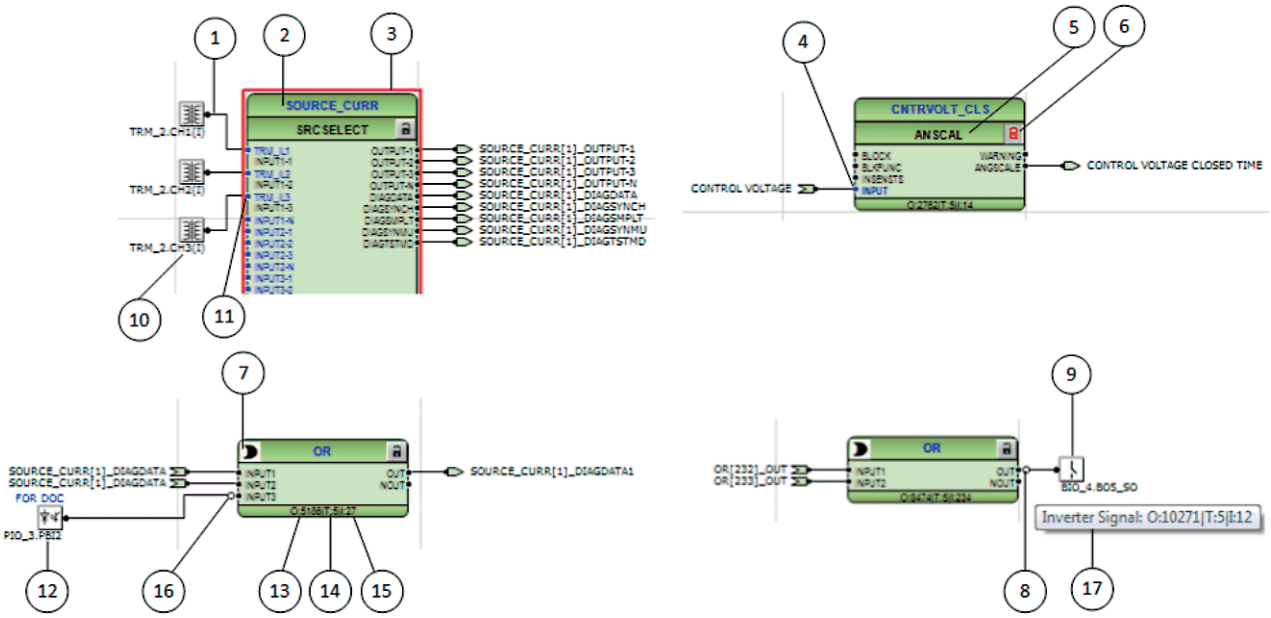
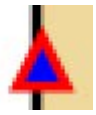


Figure 99: ACT: Function block overview (example)

1 Connection(s)
2 User defined function block name
3 Function block, selected (red)
4 Mandatory signal (indicated by a red triangle if not connected)



5 Function block name
6 Function block, locked (red)
7 ANSI symbol
8 Inverted output
9 Hardware, binary output channel
10 Hardware, analog input channel
11 User defined signal name
12 Hardware, binary input channel
13 Execution order
14 Cycle time
15 Instance number
16 Inverted input
17 Signal description note

Mandatory signals must be connected.

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Function blocks with no outputs connected will not execute in operation and hence may show improper values on the outputs.

9.4.3.3 Adding a function to the application

1. From the main menu select **View/Object Types**, or click the **Object Types** button, to display the list of functions for the selected IED type. (This selection is persistent, PCM600 will remember it in its frame layout.)

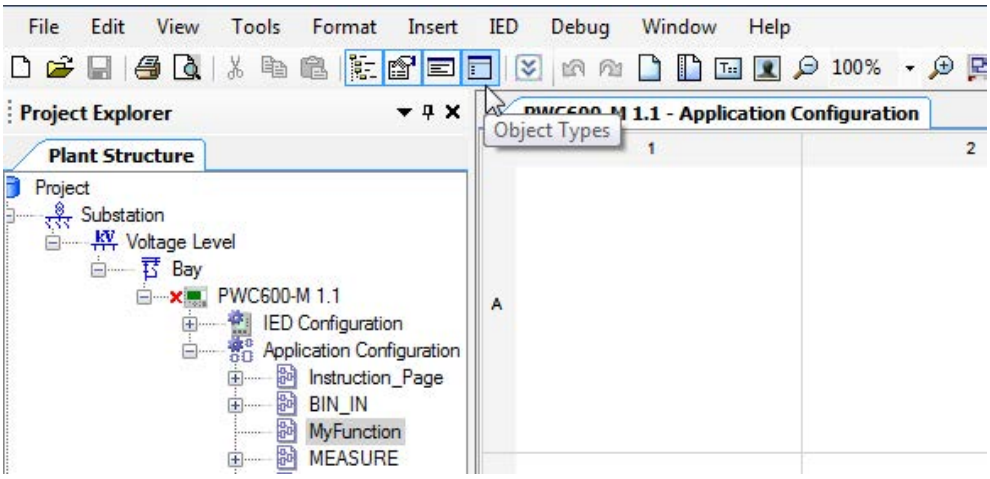


Figure 100: Enabling the function list (Object Types) view

Different function categories are listed under **Object Types**.

All functions available in PWC600 are described in the *Technical Manual*.

2. Select the desired function, and drag and drop it to the worksheet.

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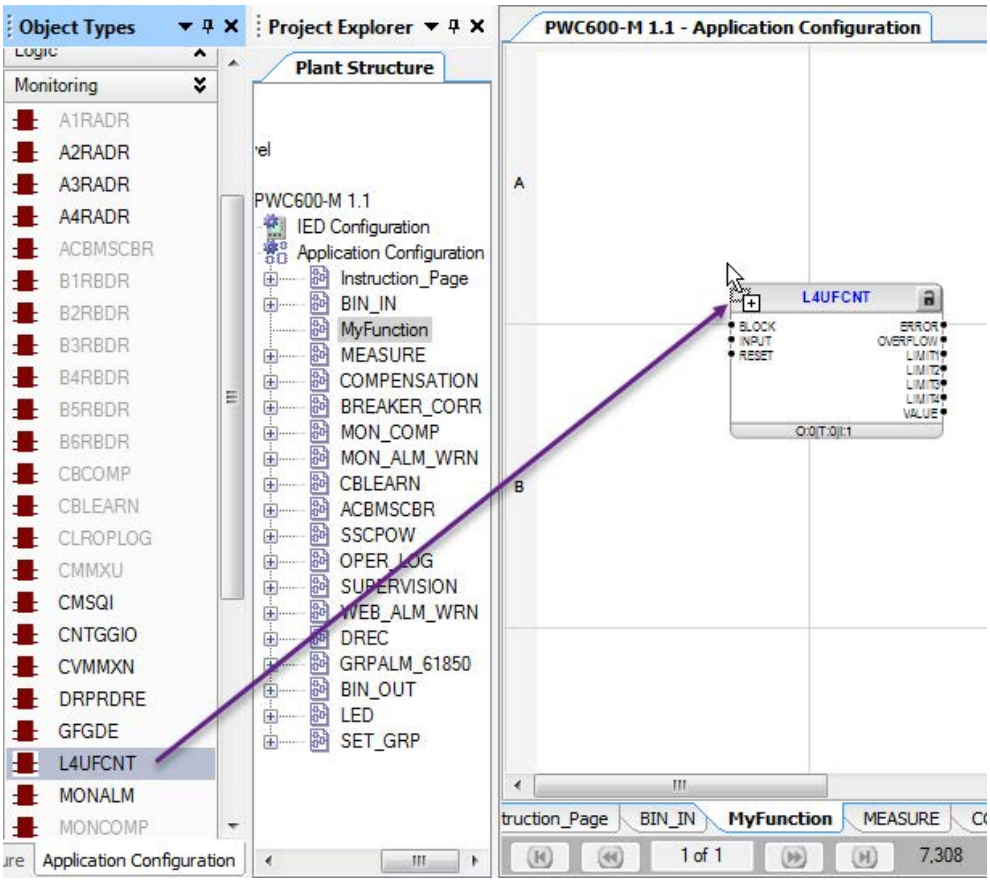


Figure 101: Adding a function to the application worksheet

The Function Block Instance dialog is displayed.

3. If desired, assign a user-defined name by typing it into the *Name* field.
4. Select the appropriate *Execution Order, Instance Number* to match the execution sequence in the application. See below for details. If in doubt use the proposed values.
5. Click **Assign** to create the function block with the specified parameters.

9.4.3.4 Function block execution parameters

Three function block execution parameters determine the runtime execution of the function block within the application configuration.

- Execution order
- Cycle time
- Instance number

Each time a new function block is created these parameters have to be selected from the drop down lists in ACT. Depending on the function block type not all three parameters are selectable. The cycle time may be predefined to one value. The instance number is a counter for the total possible number of function blocks of that type used within an application configuration.

Execution Order and *Instance Number* are a combination that is predefined for each function block within a product. It is possible to select a pair out of the list. Figure 102 shows an example of the dialog for specifying the function block parameters.

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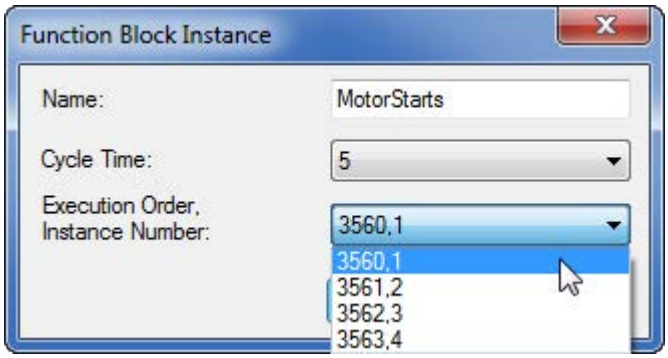


Figure 102: ACT: function block execution parameters

In Switchsync PWC600, the *Cycle Time* is fixed at 5 ms.

A function block that is placed after another function block in the signal flow should have a higher execution order to ensure execution in the proper sequence, see Figure 103.

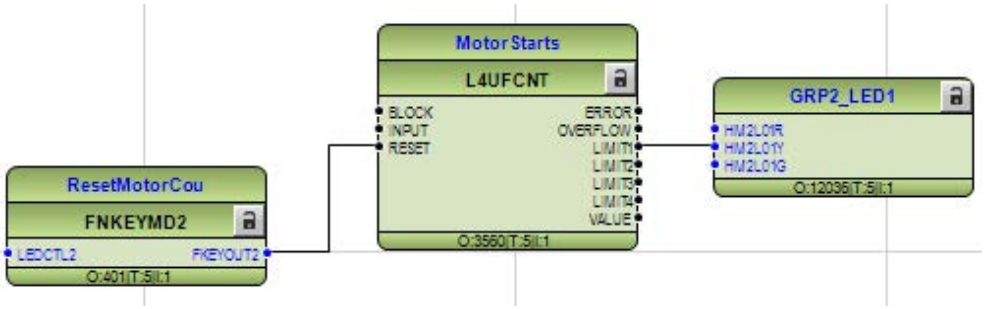


Figure 103: Proper execution order of three function blocks

9.4.3.5 Signals and signal management

Every function block has a set of input and output signals: inputs are arranged on the left edge of the function blocks, outputs on the right edge.

A function block can contain more signals than needed in that application part. A signal that is not used in a particular application can be hidden in the function block view in Application Configuration. It is not necessary to connect all inputs and outputs at a function block. If not connected, the signals always have a default value. The default value can be seen when hovering the mouse pointer over the signal.

Boolean input and output signals may need to be inverted to fulfill the logic. Application Configuration supports adding the inversion logic to a binary signal.

The input signal on logic function blocks can only be inverted if a a logic Inverter function block with a lower execution order in the same cycle time is available. Similarly, the output signal can only be inverted if a logic Inverter function block with a higher execution order in the same cycle time is available. Up to two input signals and two output signals can be inverted in logic function blocks in the same cycle time.

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Even though current is injected to the IED and the IED is connected to PCM600 in online mode, the signal value of TRM and Merging Unit channels in Application Configuration is probably shown as zero.

All signals which are not mandatory, have a default value that is used when not connected.

9.4.3.6 Adding user-defined names

Some function blocks in the IED support assigning names to generic signals, for example, the input signals of LED, event and disturbance handling block (BxRBDR and AxRADR) and alarm handling function block (MONEVG).

1. Right-click the function block and select **Manage signals** to add names to these signals.
2. Enter the name in the **User Defined Name** column for the corresponding signal.
   The maximum number of characters supported for user-defined signal names is 13.

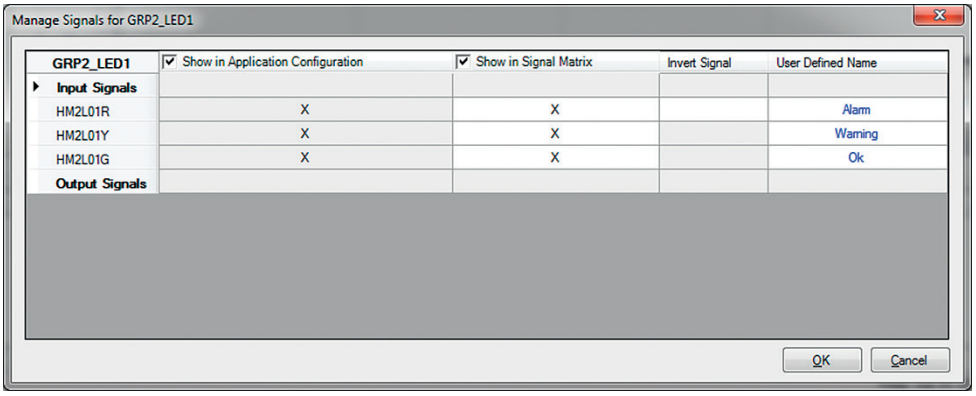


Figure 104: Adding user-defined names for LHMI visualization

For some functions, the list view in Parameter Setting tool also displays the user-defined names assigned to the inputs. To show the changes to the user-defined names in the parameter list view, the application configuration must be written to the IED and then read back from PCM600.

9.4.3.7 Connections and variables

A connection is the link or "wire" between function block outputs and inputs.

Connections can be created by drawing a line between two signals or by linking two signals using variables.

It is possible to search and replace variable names in Application Configuration, by selecting **Edit/Find and Replace** from the main menu.

The signals used in the pre-configuration already have variable names assigned. If signals that are part of a locked worksheet need to be modified, the worksheet first needs to be unlocked.

To connect a function block signal to an existing variable:

1. Right-click the signal name and select **Connect/Existing Variable**.
2. In the **Variable List** dialog, type part of the name in the **Filter** field to reduce the list size.

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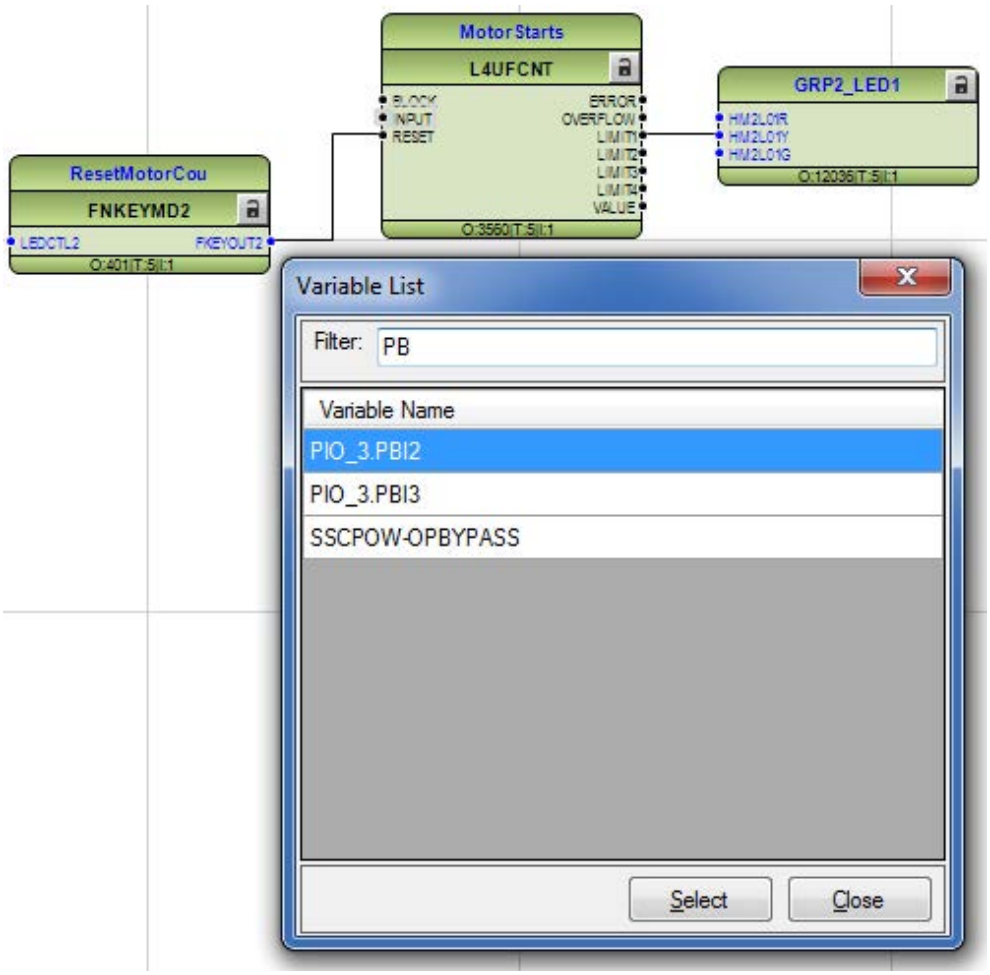


Figure 105: Selecting an existing variable to connect to

3. Select the variable name in the list and click **Select**.

An existing connection is removed by clicking the line and then pressing Delete.

Connection validation

A connection is only useful and possible between two signals of the same data type. Attempting to connect two incompatible signals generates an error message.

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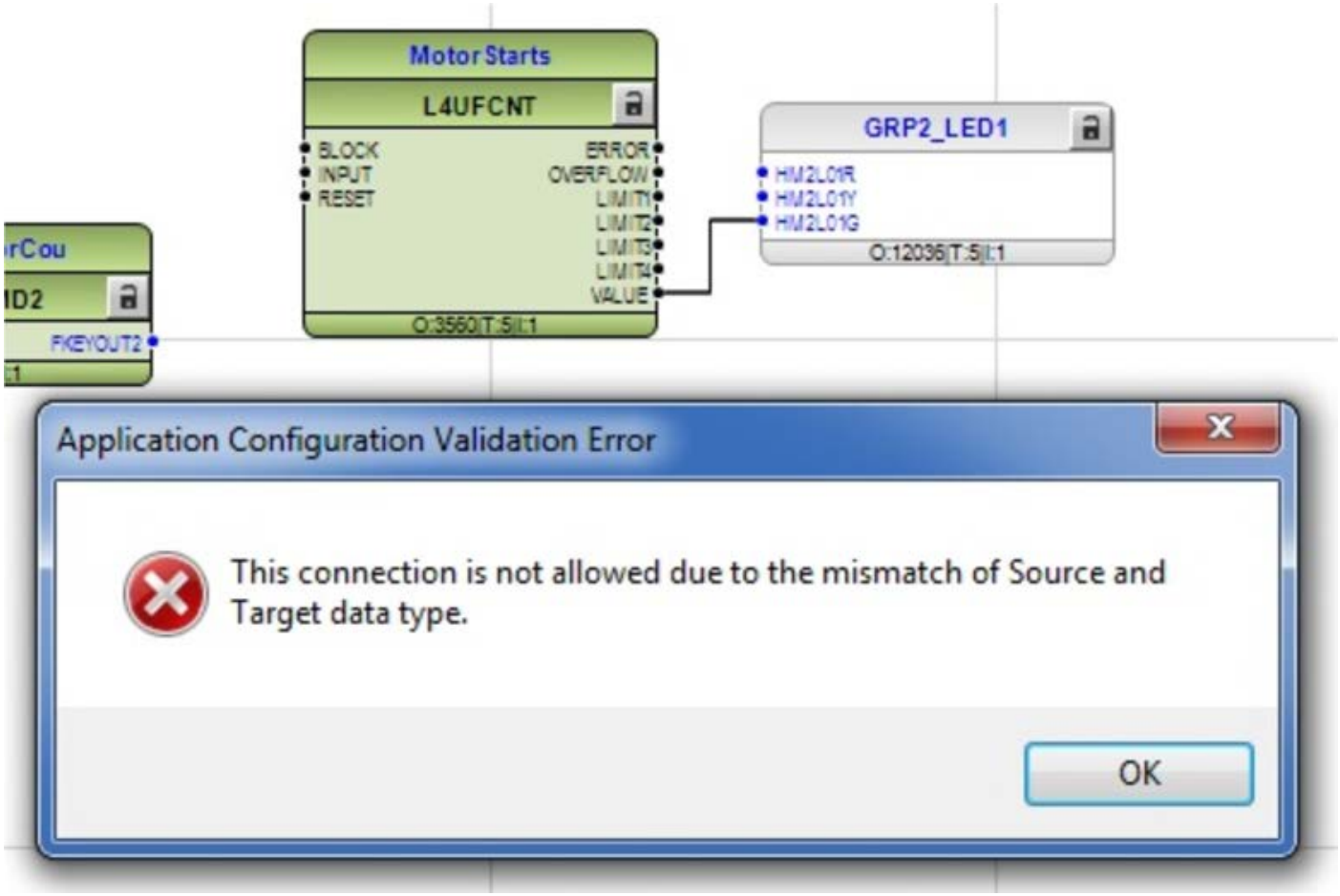


Figure 106: Warning message of signal mismatch for a connection

9.4.3.8 Saving the configuration

After adding or modifying all desired application pages, function blocks, and signal connections make sure to save your work.

- Select **File/Save** from the main menu or click **Save** icon.

Only after saving the application will the newly added function blocks appear in the IED's Application Configuration tree of the plant structure. This is a necessary step before function parameters can be accessed in Parameter Setting tool.

For most functions other than basic logic gates, it is necessary to adjust the settings for achieving proper functionality. This is described in Section 9.4.4 below

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9.4.3.9 Single-phase reference signal

If the reference signal for controlled switching is obtained from a single-phase VT, that VT output must be connected to the L1 source voltage input (see Section 7.3.1). If the measured voltage is not L1 then the connections to the waveform recorder ("disturbance recorder") shall be adjusted accordingly. This is done in ACT on the DREC worksheet. See Figure 107 for an example where the single-phase VT is located in system phase L2.

1. Delete the connections between the "FIRST_VOLT_AIx" variables and the inputs labeled "VSx" on the A1RADR function block.
2. Connect the "FIRST_VOLT_AI1" variable to the "VS" input according to the system phase in which the single-phase VT is located. (In this example, connect it to "VS2" for phase L2.)

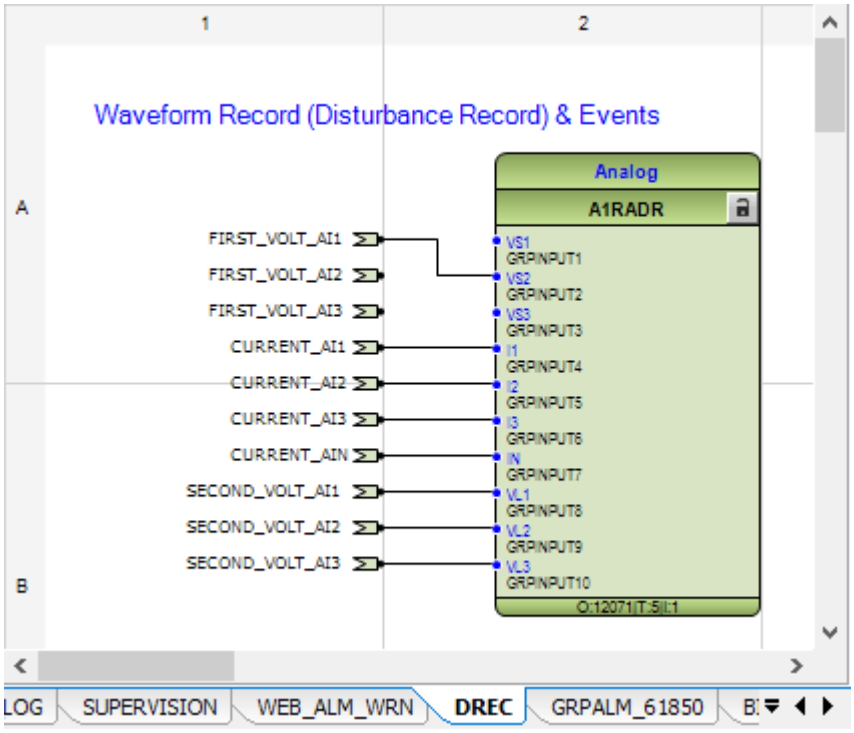


Figure 107: Re-connecting the waveform recorder for a single-phase VT measuring L2 voltage

9.4.3.10 Validation

Validation checks the application configuration on errors about the rules and restrictions defined for doing a MainApplication on three levels.

- During creating the logic while creating a connection or placing a function block.
- On demand by starting the validation.
- When writing the application configuration into the IED.

Validation when creating the application configuration

Validation is made when creating the application configuration, for example:

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- A connection between two input signals or two output signals is not possible.
- A connection between two different data types is not possible, for example a binary output to an analog input.

Validation on demand

To check the validity of an application configuration, click the checkmark icon in the toolbar, or select **IED** / **Validate Configuration** from the main menu.

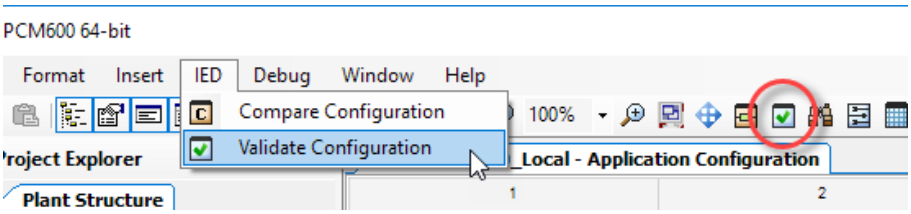


Figure 108: Initiating validation of application configuration

ACT will check the application configuration for formal correctness. Found problems are qualified in:

- Warnings, marked by a yellow warning icon
  - Example: A variable connected to an output signal that is not connected.
  - Example: If the user connects output from higher execution order function to inputs of lower execution order function.
- Errors, marked by a red circle with a cross
  - Example: A mandatory input signal that is not connected.

Warnings will not prevent writing to the IED. Errors have to be corrected before writing the application configuration to the IED. An application configuration can be saved and ACT can be closed with open errors, but not written to the IED, see Figure 109.

These problems are listed in the **Output** View under the tab **ApplicationConfiguration**. Several buttons allow filtering for the types of problems. A double-click in the error or warning row will navigate to the location where the problems was identified.

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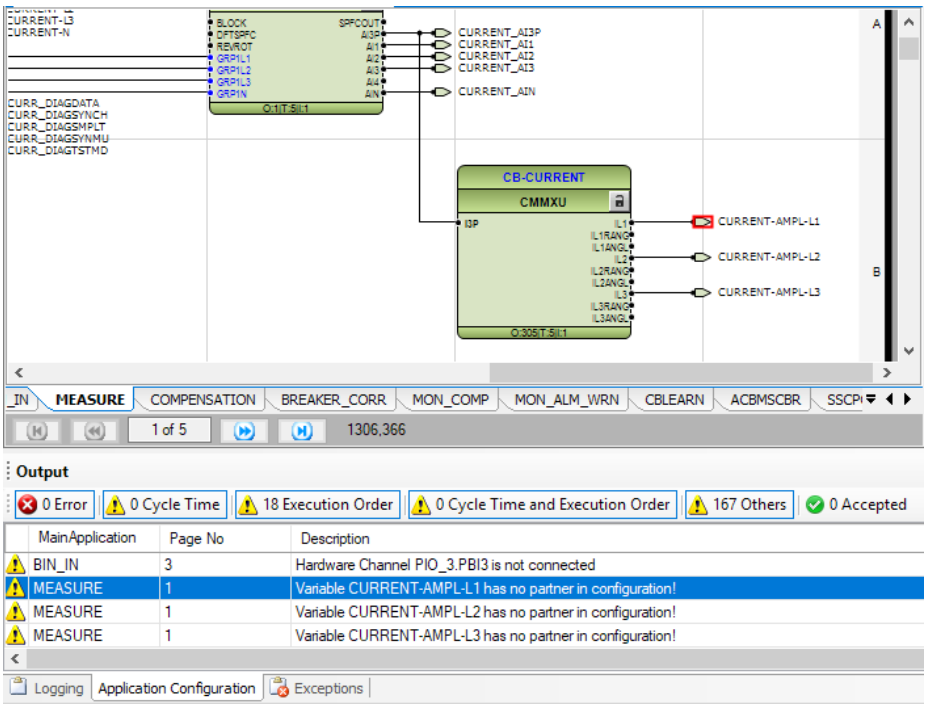


Figure 109: Validation on demand

Manual validation of the Switchsync PWC600 pre-configuration may list some warnings. All warnings referring to the original configuration can be ignored, only warnings for functionality added or modified by the user must be investigated.

Validation when writing to the IED

When writing the application configuration to the IED an automatic validation is performed. The validation is the same as the manually demanded validation. Errors will abort the writing.

9.4.4 Working with the Parameter Setting tool

For a standard application, parameters are configured using Switchsync Setting Tool (SST). In some cases, the parameters which are not handled from SST need to be adjusted manually, which is done in Parameter Setting Tool (PST). This applies in particular after adding function blocks to the pre-configuration.

9.4.4.1 Displaying options

1. Right-click the IED and click **Parameter Setting** to open the Parameter Setting tool.
2. Click to display the advanced and basic parameters, and click to display the parameters of all the child nodes under the selected main node.

The above display options should be applied whenever working in PST on a PWC600 object.

9.4.4.2 Modifying settings

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1. In the Plant structure, navigate to the function block that holds the setting(s) to be accessed.
2. To modify a setting value, click the editable field next to the parameter name under **PC Value [SG1/Common]**.
3. Enter or select the new value. After navigating away from the setting, the changed value is displayed in bold.

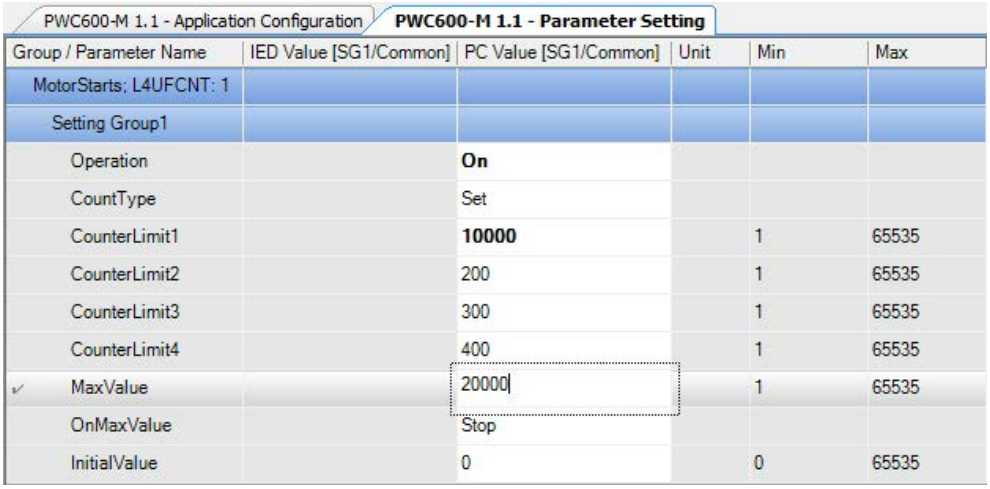


Figure 110: Changing settings in Parameter Setting tool

4. Repeat the previous steps as desired.
5. After completion of the changes, save the entire set of parameters by selecting **File/Save** from the main menu or by clicking **Save** icon.
6. Confirm saving by clicking **Yes** in the pop-up dialog.

9.4.4.3 Enabling setting groups

Setting Groups allow automatic application of different parameter sets based on external signals or conditions or on a setting parameter. Selecting a setting group immediately applies the settings of that group to all settings that support group settings, in all function blocks.

1. Open Parameter Setting tool (PST) on the PWC600 object.
2. In the Plant structure, navigate to **IED Configuration/Activate setting group/SETGRPS:1**.
3. Change the *MaxNoSetGrp* parameter to the number of setting groups to be supported by the application. After navigating away from that parameter, a dialog will pop up instructing the user to restart PST.

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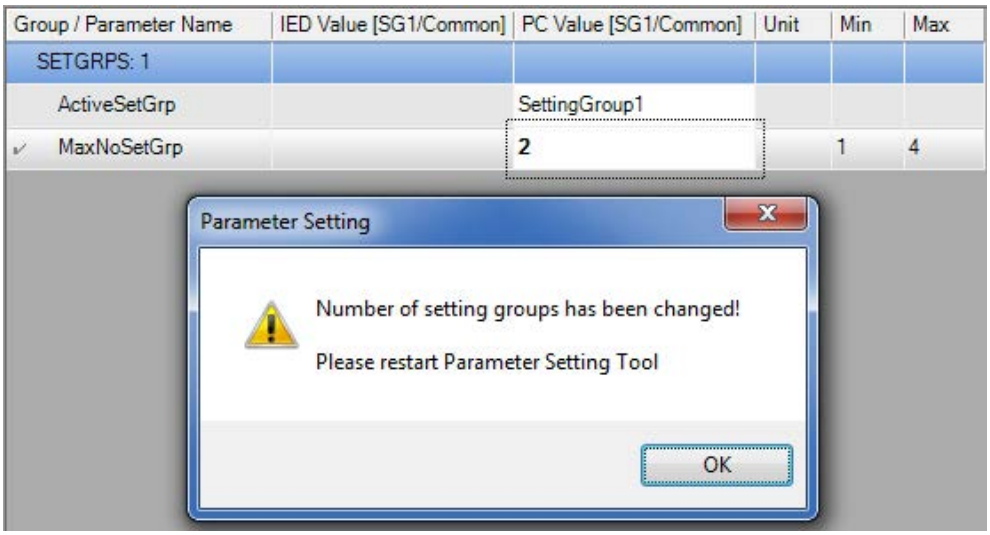


Figure 111: Defining the number of setting groups

4. Click **OK**.
5. Save the parameters by selecting **File/Save** from the main menu or by clicking **Save** icon.
6. Close Parameter Setting tool.
7. If using setting groups for the first time:
   7.1. Re-open Parameter Setting tool on the PWC600 object. It now shows additional columns or subgroup headings for each setting group.
   7.2. Select the preferred presentation of the setting group values from **View/Setting group presentation** in the main menu, or by clicking the corresponding below icon



in the toolbar.

9.4.4.4 Copying setting group values

Initially after enabling more than one setting groups, all groups other than SG1 are populated with default values. However, in the application most setting values need to be identical between setting groups. This is easily achieved by copying setting groups.

1. Open Parameter Setting tool (PST) on the PWC600 object.
2. On the **Edit** menu, click **Copy/paste setting group**.
3. In the pop-up dialog, select the appropriate groups in the **Source group** field and the **Target group** field.
4. Click **OK**. All parameters currently visible in the setting sheet are copied from the source group to the target group. Changed values in the target setting group are shown in bold.



Initially, make sure to select the PWC600 object as top node in the Plant Structure, to assure that all parameters get copied to the target setting group. Later, targeted copying of only a subset of parameters is achieved by selecting the related section of the Application Configuration tree as top node.

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Switchsync Setting Tool (SST) operates only on Setting Group 1, regardless how many setting groups are enabled.

To configure more than one setting group through SST, apply this procedure.

1. Run SST and enter all settings for an intended higher setting group (not 1).
2. Finish SST.
3. Open PST on the PWC600 object.
4. Copy all settings from Group 1 to the intended target group.
5. Save and close PST.
6. Repeat the steps above as necessary for another setting group (not 1).
7. Run SST and enter all settings for Setting Group 1.
8. Finish SST.

9.4.5 Local HMI engineering

LEDs are assigned to signals or groups of signals in the default pre-configuration. The pre-configuration also includes a configured function key and a sample single-line diagram (SLD) for display on the screen. LEDs, function keys, and SLD can be modified following the process described in this section.

9.4.5.1 Local HMI engineering process

The engineering process of the LHMI involves several steps. Figure 112 presents the pre-engineering step, the main steps in the engineering process and the required sequences.

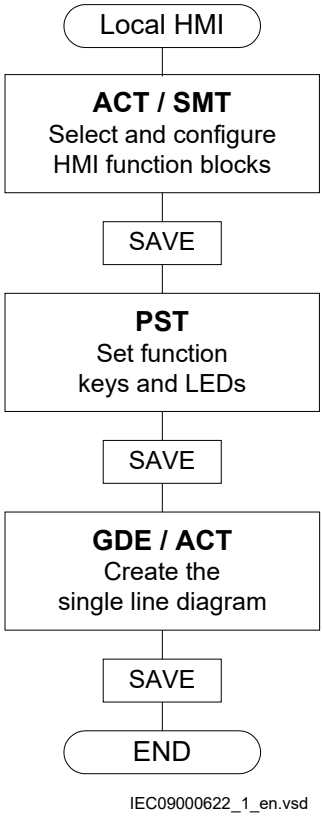


Figure 112: LHMI: Engineering flowchart

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9.4.5.2 LEDs and function keys

- Application Configuration tool with possible assistance of Signal Matrix tool
  - To use the function keys and LEDs on the LHMI, the corresponding special function blocks must be inserted for these operation element groups.
  - The function blocks for the LEDs are organized as a single function block per LED but indexed to the group identification, for example GRP1_LED3 (indication LED 3 in virtual LED group 1).
  - The function blocks for LHMI are visible by default for the Parameter Setting tool.
  - Use the Application Configuration tool to connect the signals from application functions to LED function blocks.
- Parameter Setting tool
  - The operation mode of the function keys and the LEDs is defined in the Parameter Setting tool.
  - The presented text labels on the LCD for LHMI keys and LEDs.
- Graphical Display Editor with assistance of Application Configuration tool, for example
  - Making the single line diagram of the primary process part.
  - Making the dynamic links for the apparatus.
  - Making the dynamic links for measurements.

Application Configuration tool and local HMI function blocks

A set of special function blocks is available for all the operation element groups on LHMI.

See the technical manual for more information about function blocks.

LHMI function blocks that are available in the Application Configuration tool:

- FNKEYMD1 to FNKEYMD5
- LEDGEN
- GRP1_LED1 to GRP1_LED15
- GRP2_LED1 to GRP2_LED15
- GRP3_LED1 to GRP3_LED15

The function blocks for the LEDs are organized in function blocks per LED.

Figure 113 describes the basic LHMI and the operation element groups. These are the 15 LEDs and their text elements on the LCD [A]. The other group is the five function keys with their LEDs and the corresponding text elements on the LCD [B].

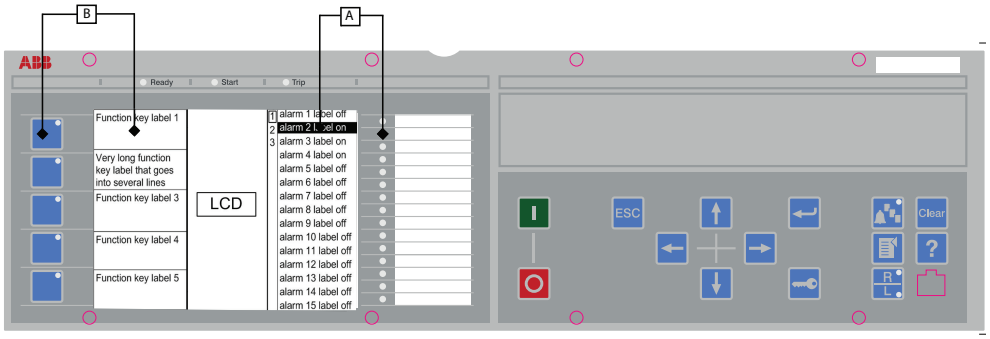


Figure 113: Local HMI: Placement of local HMI operation elements

Function block LEDGEN

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- Handles an external acknowledge signal as source to acknowledge the LEDs.
- Generates an additional pulse for general purposes whenever the LEDs are acknowledged by the operator.
- Generates a pulse whenever a new LED signal occurs. It may be used to trigger some other indication, for example an acoustical alarm.
- Handles the timer *tReset* and *tMax* for the LED operation mode 'LatchedReset-S'.

The LEDGEN function block is a part of the pre-configuration. The RESET input is connected to an OR combination of signals including Function Key 1, an external binary input, a GOOSE receiver, and the trigger signal for the next switching command. This can be modified according to the requirements.

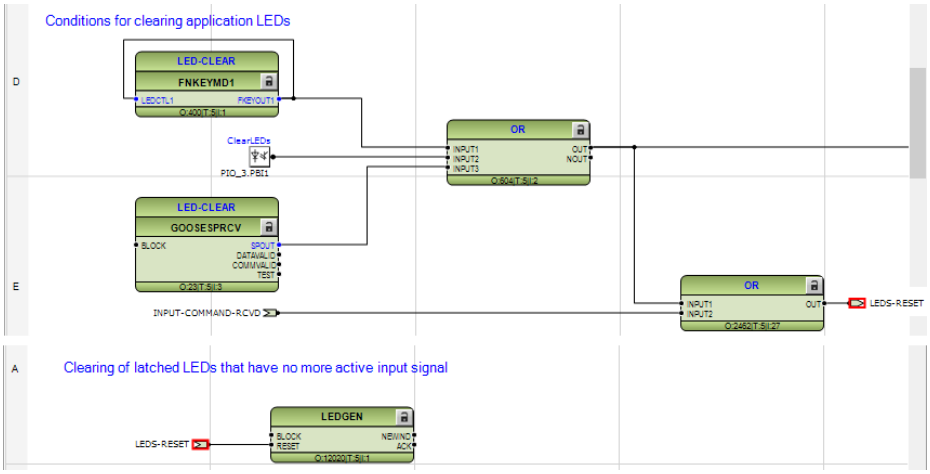


Figure 114: LEDGEN default configuration

Function blocks GRP1_LED1 to GRP3_LED15

- The 15 LEDs on the right side of the LCD can indicate in total 45 alarms, warnings or other signals to the operator. They are organized in three groups 1 to 3.
- LEDs in Group 1, are used in the pre-configuration for specific functions. LEDs in Groups 2 and 3 are not used.
- Each signal group belongs to one function block.
- Each LED illuminates in one of the three colors: RED, YELLOW or GREEN.
- The organization of flashing, acknowledgment and group selection is done directly between the function blocks and the basic LHMI keys, the 'Multifunction' key to toggle between the three groups or the 'Clear' key to acknowledge or reset the LEDs.
- Only the programming of the signals is needed for the LEDs.
- The operation mode of the LEDs is defined in the Parameter Setting tool.

The input signals support naming of signals. The name added to these signals is visible in the LHMI menu **Tests/Function status/Monitoring/HMI/LEDs/All indication LEDs**.

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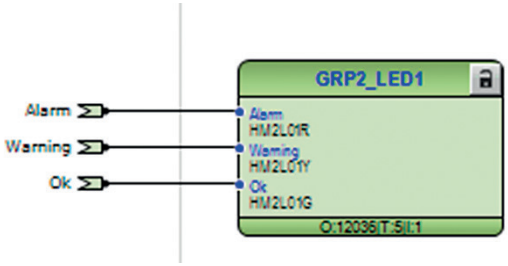


Figure 115: LED connection in Application Configuration for function block signals

The text added to the *Label* settings appears adjacent to the LED according to the active signals connected to the LED input. When no signals are active, text assigned to the *LabelOff* setting is displayed.

In default pre-configuration, no text is assigned to the *LabelOff* settings. Thus, only labels of activated LEDs will be displayed.

The LEDs have several different operation modes, which are explained in the Technical Manual.

Function block FNKEYMD1 to 5

- Every function key has an own FNKEYMD function block.
- The five function keys on the left side of the LCD [B] can be used to process user actions.
- The function block handles the signal for the LED included in the key as input signals.
- The LED signal of the key is independent of the key function and must be programmed to application demands.
- The function block handles the operators command when the key is pressed as output signal.
- The functions are activated whenever a key is pressed the first time. The corresponding text elements, which are configured using the *Label* setting, for the five keys appear on the left side of the LCD. No execution of the function is done at this stage, the first push is used to activate the presentation only.
- The next key push is handled as activate function and the output signal of the function block is set.
- The operation mode of the function key output is defined in the Parameter Setting tool ("Pulsed", "Toggle" or "Off").

Function key 1 is part of the pre-configuration, where it is programmed to clear the active LEDs.

Parameter Setting tool and function block configuration

The operation mode of the function keys and the LEDs must be specified individually in the Parameter Setting tool.

A function key can generate a pulsed or toggle signal or operate as a menu shortcut.

- Pulsed signal
  - Each push activates the output for a configured time.
  - The pulse length can be set in the Parameter Setting tool.
  - The default pulse time is 200 ms.
- Toggle signal

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- Each push changes the state of the signal: OFF-ON-OFF-ON-OFF...
- The default state after power up or reset is OFF.

- Menu shortcut
  - When pressing a key configured for that purpose, the function key panel is hidden and LHMI opens directly in the configured menu.

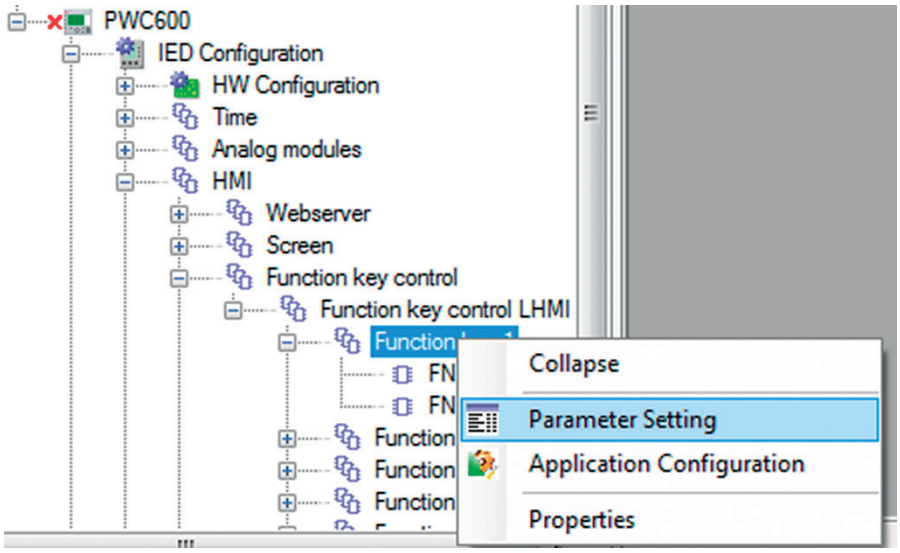


Figure 116: Opening parameter view of the function key function block

Group / Parameter Name	IED Value	PC Value	Unit	Min	Max
Function key 1					
FNKEYMD1: 1					
Mode		Pulsed			
PulseTime				0.001	60.000
LabelOn					18 character(s)
LabelOff					18 character(s)
FNKEYTY1: 1					
Type		Control			
MenuShortcut		Clear			

Off
Toggle
Pulsed

Figure 117: LHMI: function key operation mode

9.4.5.3 Single-line diagram engineering

For the purpose of PWC600, a single-line diagram is a LHMI display screen that presents information in graphical or text form. Certain LHMI elements can also be used for controlling signals in the application. Single-line diagrams are created in Graphical Display Editor (GDE).

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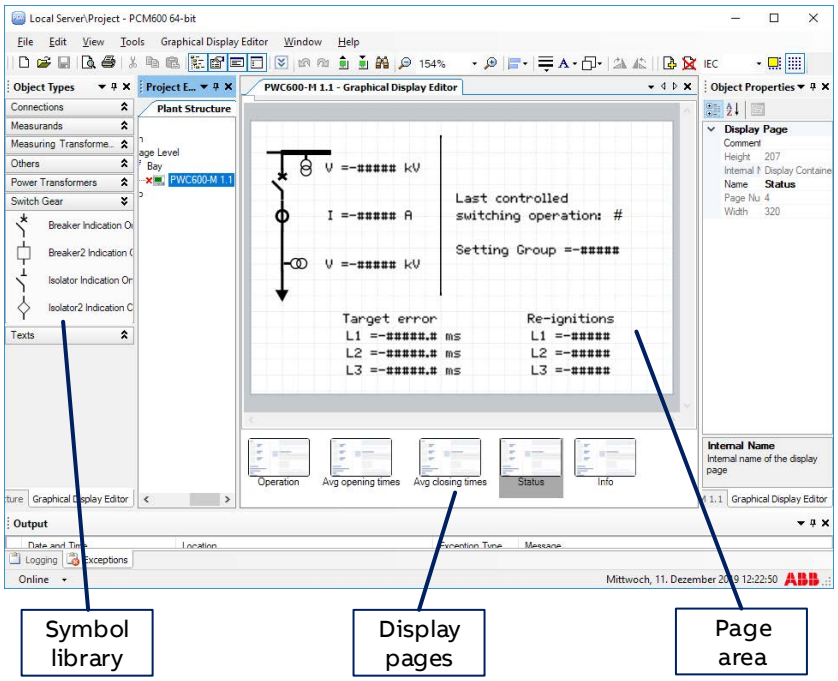


Figure 118: Graphical Display Editor (GDE) opened to PWC600 default single-line diagram

To get started with GDE:

1. In the plant structure, right-click the PWC600 object.
2. From the context menu, select **Graphical Display Editor** to start the tool.

Symbols for populating the SLD can be taken from the library in the **Object Types** frame.

The Switchsync PWC600 pre-configuration includes three pages titled **Operation**, **Avg opening times**, and **Avg closing times**. These pages are used for CB timing test mode and must not be changed.

Page area and sequence order

Rules to handle HMI pages:

- Several single line diagrams can be created for one bay.
- The IED supports one bay.
- The sequence order of the HMI pages in the Graphical Display Editor starts from left to right.
- Measurements and the single line diagram can be shown on the page in any possible order and placement.
- All symbol objects, for example apparatus, text and measurement, on the HMI page must be linked to the correct function block in the application configuration in order to present the correct process values.

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Symbols / page elements

The symbol library window contains drawing symbols or elements to create a single line diagram, measurements and texts on a page. The elements are arranged in groups. Click on a group title to expand the group and show the individual drawing symbols.

The library shows the symbols either in ANSI standard or in IEC standard. The standard is selected by the drop down list box located on top of the display window.

Switchsync PWC600 does not support ANSI symbols. Only IEC symbols are displayed on the LHMI.

- To add an element to the page, drag the symbol from the library and drop it onto the page area.
- To move an element on the page area, click and drag it with the mouse.
- To remove an element from the page, click on it and press the **Delete** key.
- To adapt the properties of an element, click on it and make the desired adjustments in the **Object Properties** pane.

Special symbols for dynamic text

In the Texts group the symbol library contains a set of special symbols to present text that depends on the status of variables. A set of three symbols is valid to present a double point information. The corresponding function block in ACT is VSGGIO.

- *Dynamic Text* or *Indication Button* is used when a position shall be monitored on single line diagram, see Figure 119.
- *Select Button* is used when a function shall be controlled from a single line diagram.

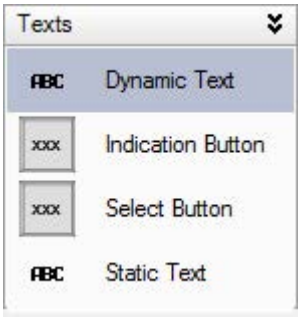


Figure 119: GDE: Dynamic Text symbols

The standard (IEC or ANSI) for the symbols and the selection of the font size for the text elements can be changed using the two selector boxes on top of the page window.

Drawing lines

The line width has to fit to the line width used for the symbols. The standard size is 2. Choose the line width in a selection box placed in the upper area above the page. A line that is not connected to a symbol may be assigned any line width in the range 1...5. Lines can be drawn only between connection points.

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1. Place the apparatus or transformer symbols by drag and drop in a grid box.
2. Place connection symbols by drag and drop in a grid box.
3. Center the mouse pointer over a connection point, indicated by two circles, to start drawing a line.
4. Click and hold the mouse button and move the mouse pointer. Center the mouse pointer over the destination connection point and release the mouse button to finish drawing the line.
5. Draw all line elements that are necessary.

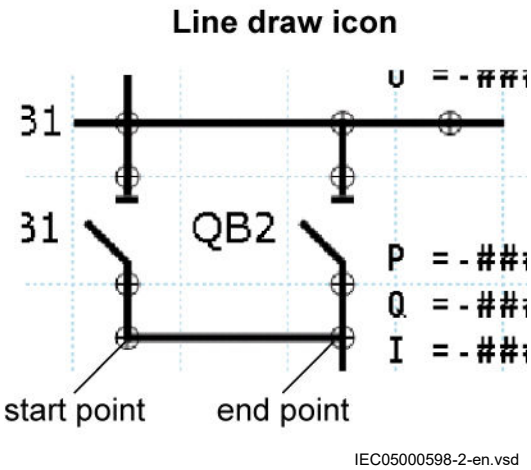


Figure 120: GDE: Drawing a line

Supported single-line diagram symbols

Table 88: Supported symbols

Category	IEC Symbol name	Symbol type	IEC Symbol definitions	ANSI Y32.2/IEEE 315 Symbol definitions	Function block type
Connections	Junction	1			
Connections	Busbar junction	2			
Connections	Earth	10			
Connections	Feeder end	21			
Measuring transformers	Current transformer	5			
Measuring transformers	Voltage transf. 2 windings	6			
Measurands	Measurand	11			CBLEARN CMMXU CMSQI CNTGGIO CVMMXN GFGDE MVGGIO VMMXU VMSQI VNMMXU

Table continues on next page

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Category	IEC Symbol name	Symbol type	IEC Symbol definitions	ANSI Y32.2/IEEE 315 Symbol definitions	Function block type
Others	Capacitor	7			
Others	Surge arrestor	8			
Others	Generator	9			
Others	Reactor	14			
Others	Motor	15			
Others	Coil	18			
Power transformers	Transformer 2 windings	16			
Power transformers	Transformer 3 windings	17			
Power transformers	Autotransformer	23			
Switchgear	Isolator indication only, 00 = Middle position	25			DPGGIO GFGDE
	Isolator indication only, 01 = Open				
	Isolator indication only, 10 = Closed				
	Isolator indication only, 11 = Undefined				
Switchgear	Breaker indication only, 00 = Middle position	26			DPGGIO GFGDE
	Breaker indication only, 01 = Open				
	Breaker indication only, 10 = Closed				
	Breaker indication only, 11 = Undefined				
Switchgear	Isolator2 indication only, 00 = Middle position	33			DPGGIO GFGDE
	Isolator2 indication only, 01 = Open				
	Isolator2 indication only, 10 = Closed				
	Isolator2 indication only, 11 = Undefined				

Table continues on next page

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Category	IEC Symbol name	Symbol type	IEC Symbol definitions	ANSI Y32.2/IEEE 315 Symbol definitions	Function block type
Switchgear	Breaker2 indication only, 00 = Middle position	35			DPGGIO GFGDE
	Breaker2 indication only, 01 = Open				
	Breaker2 indication only, 10 = Closed				
	Breaker2 indication only, 11 = Undefined				
Texts	Static text	0			
Texts	Dynamic text	29			VSGGIO
Texts	Select button, 00 = Middle position	30			VSGGIO
	Select button, 01 = Open				
	Select button, 10 = Closed				
	Select button, 11 = Undefined				
Texts	Indication button, 00 = Middle position	31			VSGGIO
	Indication button, 01 = Open				
	Indication button, 10 = Closed				
	Indication button, 11 = Undefined				
Others	Resistor	39			
Others	Star point	40			
Others	Field winding	41			

Single-line diagram pre-configured signals

Table 89: Pre-configured real-valued signals for mapping to Measurands in GDE

Signal identification	Description
Primary voltage and current	
CB_CURRENT;CMMXU:1.IL1	RMS of CB current in L1 phase
CB_CURRENT;CMMXU:1.IL2	RMS of CB current in L2 phase
CB_CURRENT;CMMXU:1.IL3	RMS of CB current in L3 phase
CB_CURRENT;CMMXU:1.IL1ANGL	Phase angle of current in L1 phase
CB_CURRENT;CMMXU:1.IL2ANGL	Phase angle of current in L2 phase
Table continues on next page	

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Signal identification	Description
CB_CURRENT;CMMXU:1.IL3ANGL	Phase angle of current in L3 phase
FIRST_VOLT;VNMMXU:1.UL1	RMS of first voltage (source voltage) in L1 phase
FIRST_VOLT;VNMMXU:1.UL2	RMS of first voltage (source voltage) in L2 phase
FIRST_VOLT;VNMMXU:1.UL3	RMS of first voltage (source voltage) in L3 phase
FIRST_VOLT;VNMMXU:1.UL1ANGL	Phase angle of source voltage in L1 phase
FIRST_VOLT;VNMMXU:1.UL2ANGL	Phase angle of source voltage in L2 phase
FIRST_VOLT;VNMMXU:1.UL3ANGL	Phase angle of source voltage in L3 phase
SECOND_VOLT;VNMMXU:2.UL1	RMS of second voltage (load voltage) in L1 phase
SECOND_VOLT;VNMMXU:2.UL2	RMS of second voltage (load voltage) in L2 phase
SECOND_VOLT;VNMMXU:2.UL3	RMS of second voltage (load voltage) in L3 phase
SECOND_VOLT;VNMMXU:2.UL1ANGL	Phase angle of second voltage (load voltage) in L1 phase
SECOND_VOLT;VNMMXU:2.UL2ANGL	Phase angle of second voltage (load voltage) in L2 phase
SECOND_VOLT;VNMMXU:2.UL3ANGL	Phase angle of second voltage (load voltage) in L3 phase
Circuit breaker operations monitoring	
TARGET_ERR_L1;GFGDE:31.OUTRL	Target error of last controlled switching operation in L1 phase
TARGET_ERR_L2;GFGDE:32.OUTRL	Target error of last controlled switching operation in L2 phase
TARGET_ERR_L3;GFGDE:33.OUTRL	Target error of last controlled switching operation in L3 phase
Compensation signals	
SPGCH_BN_L1;GFGDE:28.OUTRL	Stored energy level (from binary status) of CB drive in L1 phase
SPGCH_BN_L2;GFGDE:29.OUTRL	Stored energy level (from binary status) of CB drive in L2 phase
SPGCH_BN_L3;GFGDE:30.OUTRL	Stored energy level (from binary status) of CB drive in L3 phase
SPGCH_AN_L1;GFGDE:19.OUTRL	Stored energy level (from analog measurement) of CB drive in L1 phase
SPGCH_AN_L2;GFGDE:20.OUTRL	Stored energy level (from analog measurement) of CB drive in L2 phase
SPGCH_AN_L3;GFGDE:21.OUTRL	Stored energy level (from analog measurement) of CB drive in L3 phase
DRVPRESS_L1;GFGDE:4.OUTRL	Pressure in drive mechanism in L1 phase
DRVPRESS_L2;GFGDE:5.OUTRL	Pressure in drive mechanism in L2 phase
DRVPRESS_L3;GFGDE:6.OUTRL	Pressure in drive mechanism in L3 phase
TEMP_L1;GFGDE:7.OUTRL	Temperature in L1 phase
TEMP_L2;GFGDE:8.OUTRL	Temperature in L2 phase
TEMP_L3;GFGDE:9.OUTRL	Temperature in L3 phase
ADLQTY_L1;GFGDE:13.OUTRL	Measured value of Additional quantity in L1 phase
ADLQTY_L2;GFGDE:14.OUTRL	Measured value of Additional quantity in L2 phase
ADLQTY_L3;GFGDE:15.OUTRL	Measured value of Additional quantity in L3 phase
CNTRL_VOLTAGE;GFGDE:16.OUTRL	Measured battery voltage (supply voltage of IED)
IDLETIME_L1;GFGDE:31.OUTRL	CB idle time since last operation in L1 phase
IDLETIME_L2;GFGDE:32.OUTRL	CB idle time since last operation in L2 phase
IDLETIME_L3;GFGDE:34.OUTRL	CB idle time since last operation in L3 phase
Circuit breaker life monitoring	
OPER_CNT_L1;GFGDE:35.OUTINTRL	Count of mechanical C+O operation cycles in L1 phase
OPER_CNT_L2;GFGDE:36.OUTINTRL	Count of mechanical C+O operation cycles in L2 phase

Table continues on next page

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Signal identification	Description
OPER_CNT_L3;GFGDE:37.OUTINTRL	Count of mechanical C+O operation cycles in L3 phase
ABL_PERCNT_L1;GFGDE:44.OUTRL	Interrupter wear in L1 phase, in % of alarm threshold
ABL_PERCNT_L2;GFGDE:45.OUTRL	Interrupter wear in L2 phase, in % of alarm threshold
ABL_PERCNT_L3;GFGDE:46.OUTRL	Interrupter wear in L3 phase, in % of alarm threshold
REIGN-CNT_L1;GFGDE:10.OUTRL	Count of CB re-ignitions/re-strikes in L1 phase
REIGN-CNT_L2;GFGDE:11.OUTRL	Count of CB re-ignitions/re-strikes in L2 phase
REIGN-CNT_L3;GFGDE:12.OUTRL	Count of CB re-ignitions/re-strikes in L3 phase
IED operation	
ACTIVESETGRP;GFGDE:33.OUTRL	Active setting group

Table 90: Pre-configured double-point signals for mapping to Switchgear in GDE

Signal identification	Description
CB-POS_ALL;DPGGIO:12.POSITION	Consolidated circuit breaker position in the three phases

Signals that are not listed above are also displayed while assigning the signals to the symbols. Ignore these signals, as they do not carry any information to display in operation. For assigning any other analog signals, add a suitable function block as per Table 88. The Measurand supports display of only analog signals.

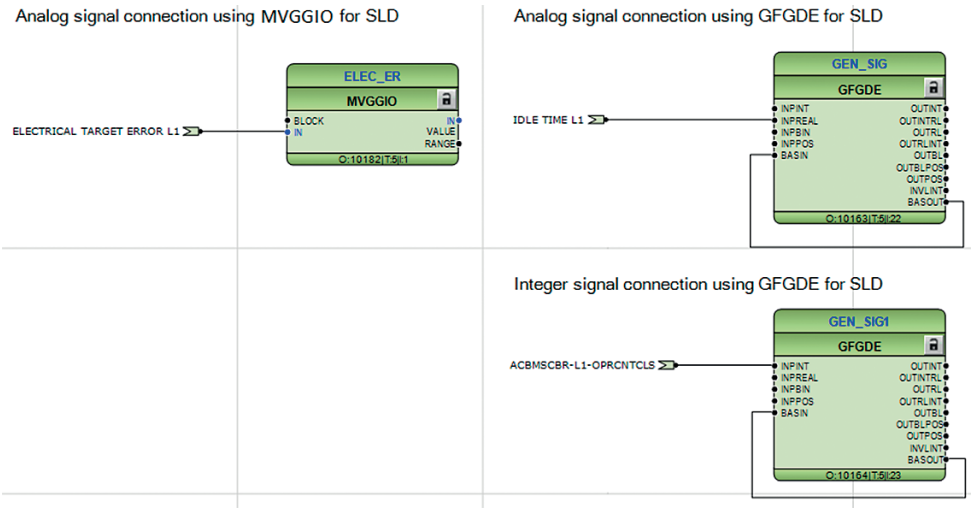


Figure 121: MVGGIO and GFGDE connection in Application Configuration

Phase angles are shown as radians in the single line diagram (GDE measurand) symbols but in degrees in other views on the LHMI.

An integer signal can be converted using the GFGDE function and assigned to a measurand symbol. In this case, the *Digits after decimal point* property should be set to “0”. GFGDE function block *Operation* parameter needs to be set to “On”.

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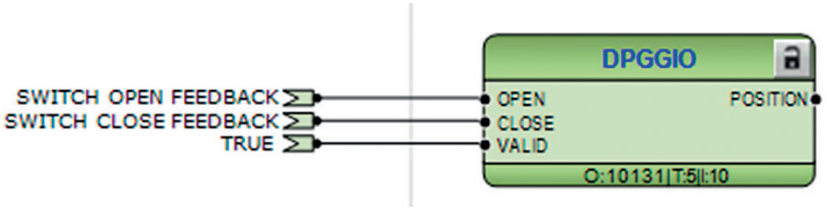


Figure 122: DPGGIO connection in Application Configuration

For MVGGIO and DPGGIO function blocks to work, IEC 61850-8-1 *Operation* needs to be set to “On”. Furthermore, in every GFGDE function block, BASIN must be connected to BASOUT as shown in Figure 121.

Linking process objects

To describe a process object within an IED, it needs to be established in the application configuration, configured with its parameters, and linked to the LHMI display element. Pre-configured signals that are available for LHMI display are listed in Table 89 and Table 90.

To link a display element to an application signal:

1. Right-click the display element and select **Select Input Signal**. A list of engineered switch control application function blocks opens.

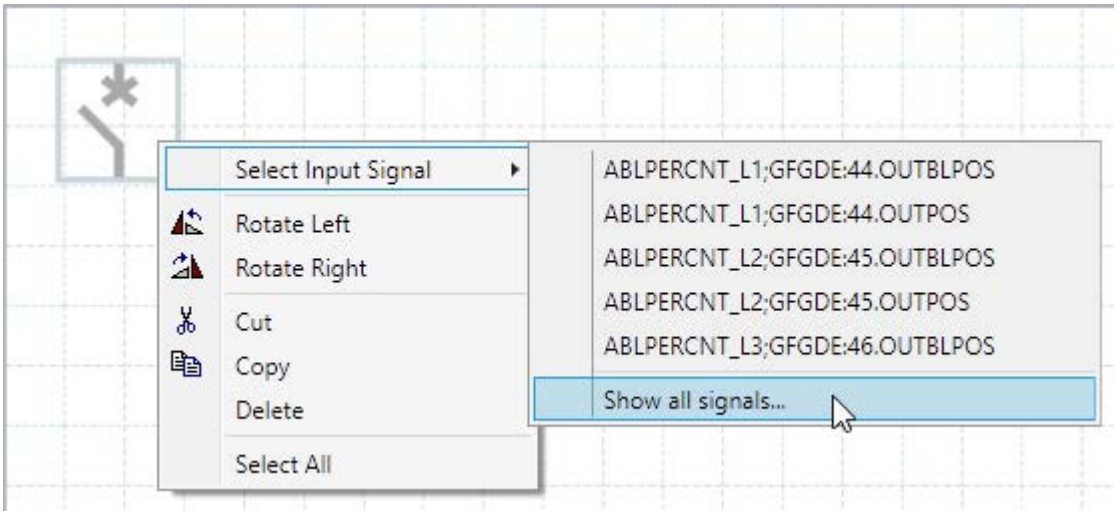


Figure 123: GDE: Input signal selection

2. If the target signal is not included in the initially displayed list, click **Show all signals...**.
3. Select the application function block and output signal that corresponds to the selected element.

Only those apparatus and measurements are shown that are configured in the application configuration.

Values in Measurands are displayed by default in SI units, for example, active power is displayed in W. Modify *Scale Factor* in the **Object Properties** to display values in more readable units (for example MW). Be sure to enter the proper unit symbol in the *Unit Text* field.

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As the measuring function deliver phase angles in radians, use a scale factor of 180/π = 57.3 to display the angle in degrees

Creating a complete HMI display page

1. Draw a sketch of the single line diagram.
2. Place the apparatus, transformer and other symbols that are needed for the single line diagram onto the page area.
3. Add connection points where needed.
4. Link the apparatus symbols with line elements.
5. Adjust the text symbols while writing to north, east, south or west using the **Object Property** window.
6. Place measurements when needed.
7. Edit the name, unit and number of decimals of the measurements.
8. Select each object that has a dynamic link and create the link to the corresponding process object.
9. Check to select the correct function block as function blocks of the same type have different instance numbers.
10. Validate that all links are done.
11. Save the GDE configuration.
12. Repeat the steps for all pages when more than one is needed.
13. Write the display configuration to IED from the Graphical Display Editor tool.

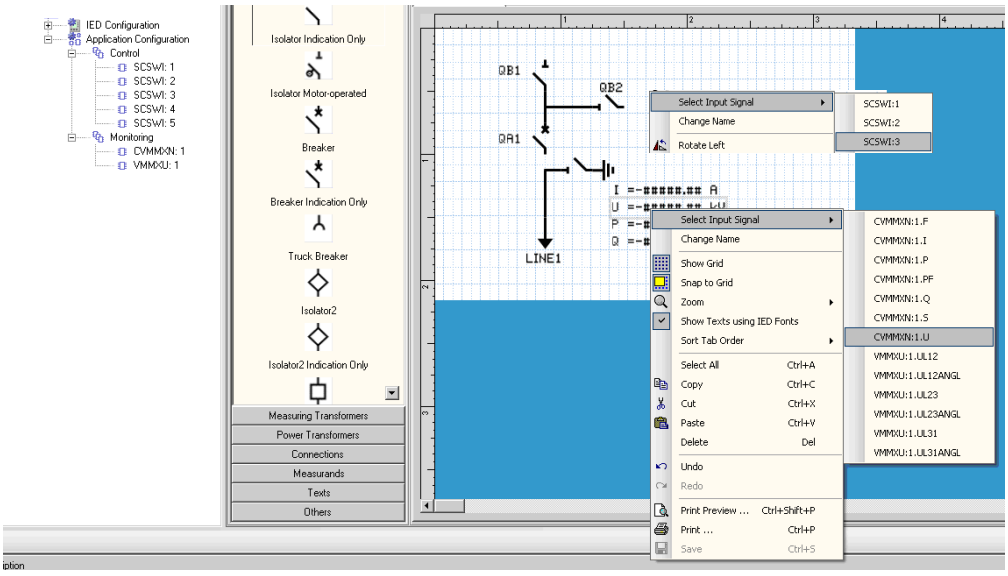


Figure 124: GDE: Establish a dynamic object link

9.4.6 Configuration adjustments for coupled loads

As mentioned in Section 5.1, controlled switching of magnetically or electrically coupled loads may require adjustments that cannot be handled through SST. These modifications need to be done manually in ACT and PST, depending on the load configuration, as described below.

SST may overwrite some of the setting changes described here. Hence, after every SST run, re-check all the modified settings in PST and restore the desired values if necessary.

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All related function blocks are located under **Application Configuration** in the Plant Structure.

After completing all changes described below, remember to write the entire configuration to the IED, as described in Section 9.5.

9.4.6.1 Coupled load energized from YN end

Remove the alarm checking for actual electrical quantities, and disable the display of electrical target error for closing, in the last phase to close (L2):

1. Open the Application Configuration Tool (ACT) and navigate to MON_ALM_WRN, page 1.
2. On instance 2 of MONALM, delete the connections to the I4L2 and I7L2 inputs.

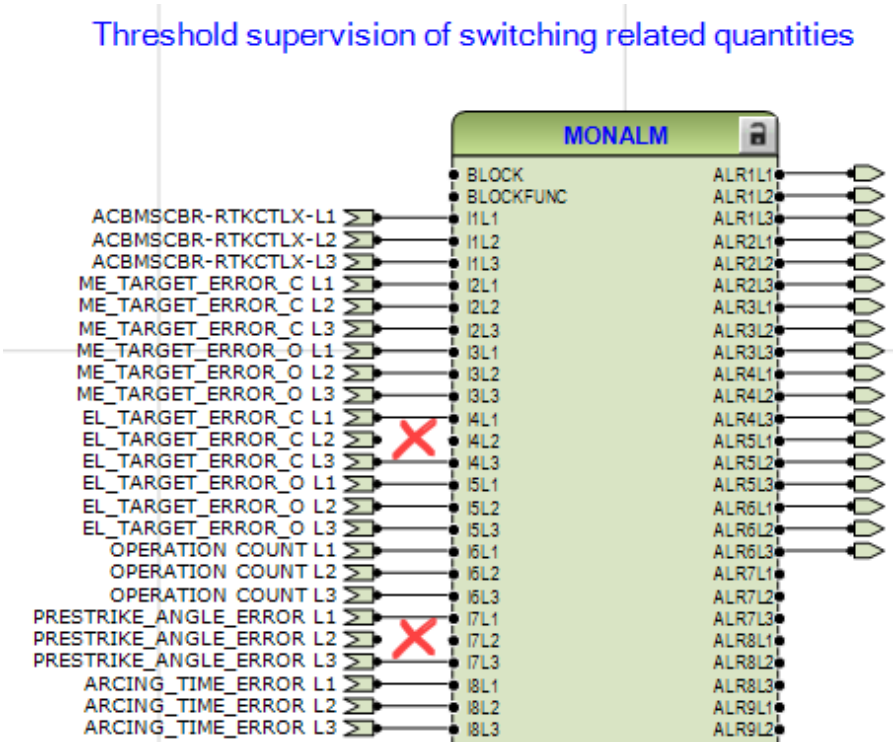


Figure 125: Deleted connection to inputs on MONALM:2

3. Navigate to MON_COMP, page 3.
4. Delete the connection from the variable “ELEC_TARGET_ERROR L2” to the INPREAL input of GFGDE function block “TARGET_ERR_L2”.
5. Draw a connection from the existing variable “EL_TARGET_ERROR_O L2” to the same input.
6. Save and close ACT.

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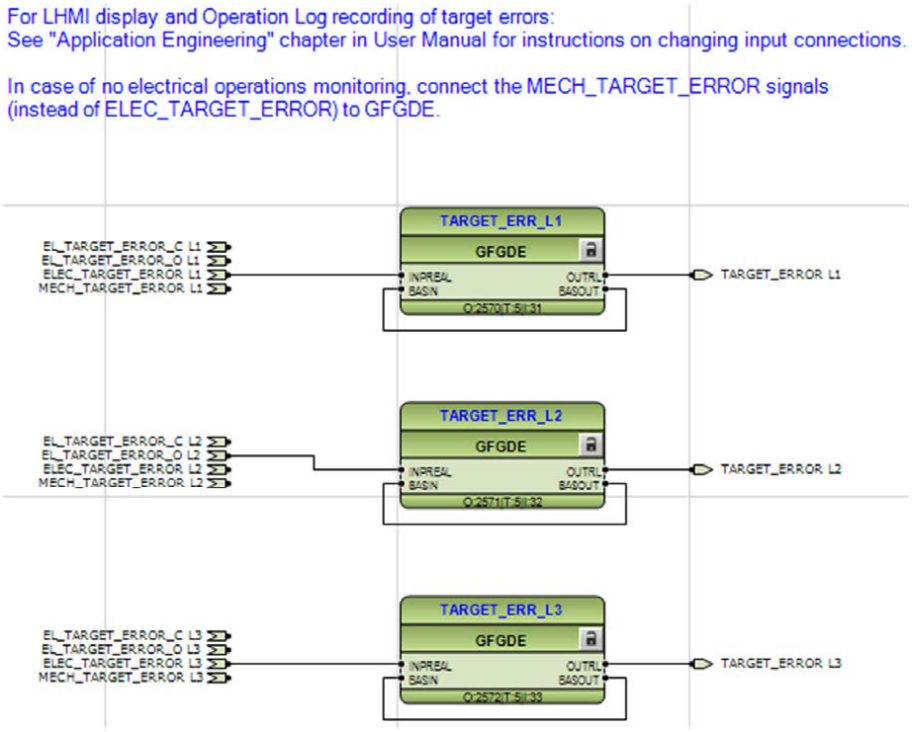


Figure 126: Changed connection for electrical target error in L2

Adjust the settings for adaptive correction and RDDS in the last phase to close (L2):

1. Open the Parameter Setting Tool (PST).
2. Change the settings as per Table 91.
3. Save and close PST.

Table 91: Setting changes for coupled load energized from YN end

Function path in Plant Structure under Application Configuration	Setting name	New value
ACBMSCBR / Monitoring / L2; ACBMSCBR: 2	*BetaAdjustElec*	0.0
	BetaAdjustMech	0.0
	RDDSLX	999.0 kV/ms

9.4.6.2 Ungrounded load

Remove the alarm checking for electrical target error, and disable the display of electrical monitored quantities for closing, in the first phase to close (L1):

1. Open the Application Configuration Tool (ACT) and navigate to MON_ALM_WRN, page 1.
2. On instance 2 of MONALM, delete the connection to the I4L1 and I7L1 inputs(similar as shown inFigure 125).
3. Navigate to MON_COMP, page 3.
4. Delete the connection from the variable “ELEC_TARGET_ERROR L1” to the INPREAL input of GFGDE function block “TARGET_ERR_L1”.
5. Draw a connection from the existing variable “EL_TARGET_ERROR_O L1” to the same input.
6. Save and close ACT.

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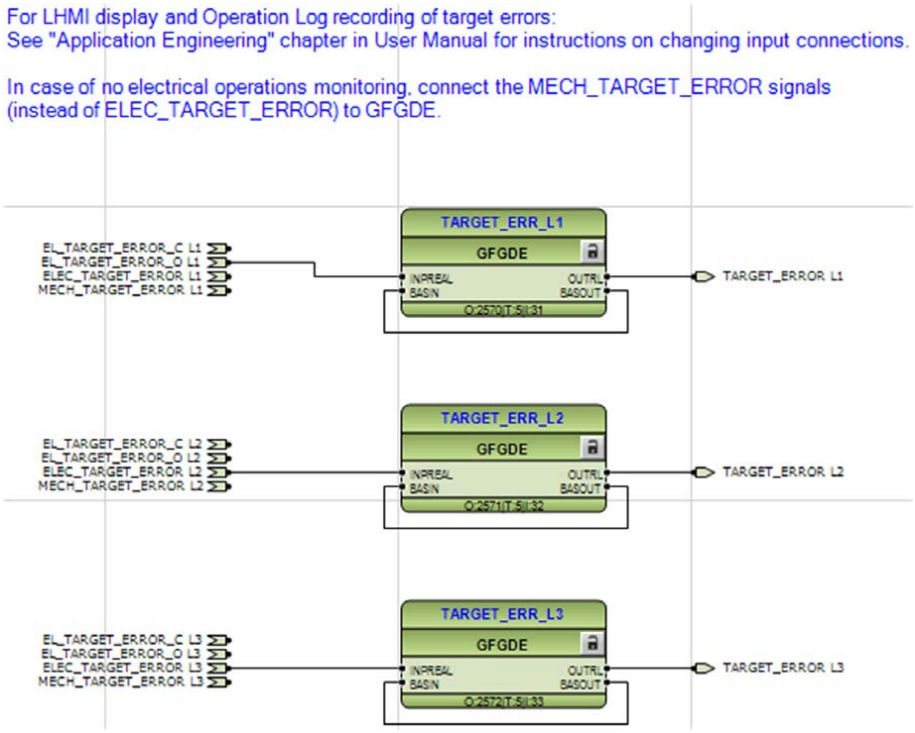


Figure 127: Changed connection for electrical target error in L1

Adjust the settings for adaptive correction and RDDS in the first phase to close (L1):

1. Open the Parameter Setting Tool (PST).
2. Change the settings as per Table 92
3. Save and close PST.

Table 92: Settings changes for any load to be energized from ungrounded end

Function path in Plant Structure under Application Configuration	Setting name	New value
ACBMSCBR / Monitoring / L1; ACBMSCBR: 1	*BetaAdjustElec*	0.0
	BetaAdjustMech	0.0
	RDDSLX	999.0 kV/ms

9.4.6.3 Coupled transformer using load voltage feedback

Remove the alarm checking and display for electrical opening target error, and disable the display of electrical monitored quantities for opening:

1. Open the Application Configuration Tool (ACT) and navigate to MON_ALM_WRN, page 1.
2. On instance 2 of MONALM, delete the connections to the I4L2 and I4L7 inputs, as shown in Figure 125.
3. Navigate to MON_COMP, page 3.
4. Delete the connections to the INPREAL inputs of all three GFGDE function blocks.

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5. Draw a connection from the existing variable “EL_TARGET_ERROR_C L1” to the INPREAL input of GFGDE function block “TARGET_ERR_L1”.
6. Draw a connection from the existing variable “EL_TARGET_ERROR_C L3” to the INPREAL input of GFGDE function block “TARGET_ERR_L3”.
7. Save and close ACT.

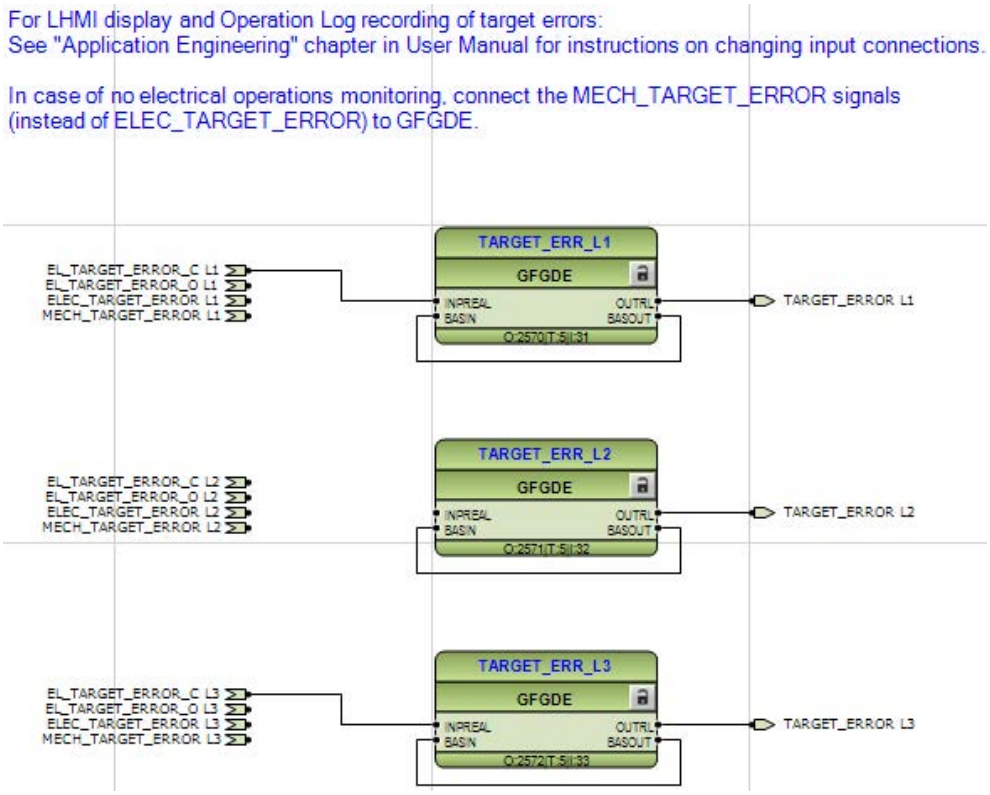


Figure 128: Changed connection for electrical target errors

Adjust the settings for adaptive correction in the last phase to close (L2):

1. Open the Parameter Setting Tool (PST).
2. Change the settings as per Table 93.
3. Save and close PST.

Table 93: Settings changes for coupled transformer using load voltage feedback

Function path in Plant Structure under Application Configuration	Setting name	New value
ACBMSCBR / Monitoring / L2;ACBMSCBR: 2	*BetaAdjustElec*	0.0
	BetaAdjustMech	0.0
	RDDSLX	999.0

9.4.7 Modification of event and waveform record signals

In total, up to 96 binary signals can be configured for creating binary events, which can be accessed either from LHMI, WHMI or the PCM600 Event Viewer tool.

The function blocks for recording binary signals (events) are located in the DREC worksheet; they are named B1RBDR, B2RBDR, B3RBDR, B4RBDR, B5RBDR, and B6RBDR. Each of these function blocks can record up to 16 binary signals.

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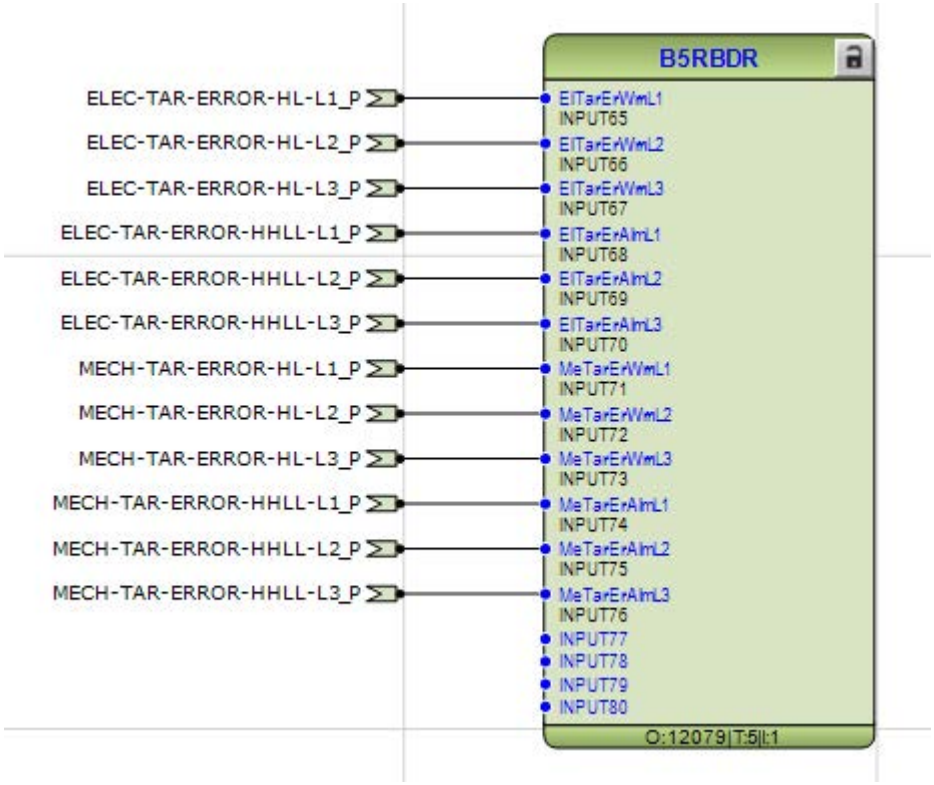


Figure 129: Function block for Event configuration

Current and voltage signals appearing in the waveform record can be configured using A1RADR, A2RADR and A3RADR function blocks. Only A1RADR is used in the default configuration. Other real-valued signals that are generated within the application can be connected to A4RADR. Each of these function blocks allows recording of ten signals.

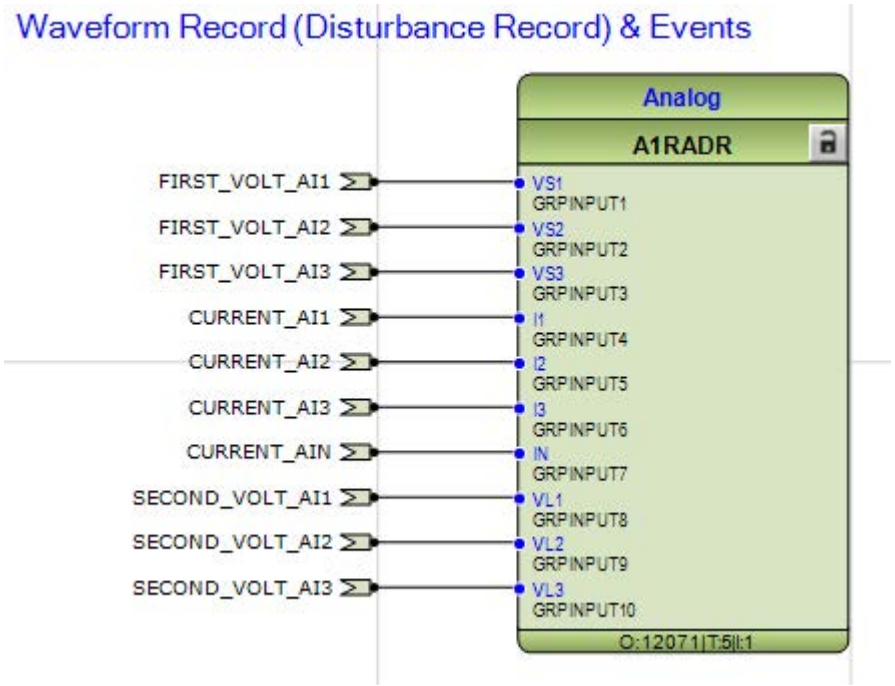


Figure 130: Function block for current and voltage signal recording

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The signals configured in the function blocks BxRBDR and AxRADR appear in the waveform record.

The user-defined name assigned to each input signal in the function block, for example,"ElTarErAlmL1" for INPUT68 in Figure 129, is the event label which appears in the LHMI, WHMI and PCM600 Event Viewer tool. User-defined name assigned to the input in the AxRADR function block appears as the signal name in the waveform record.

The input signals connected to BxRBDR can be configured to trigger a waveform (*TrigDR* = “On”), to activate the Start or Trip LED on the LHMI (*SetLED* selection) and to assign the signal to be a part of snapshot event associated with a waveform record (*IndicationMa*). Additionally, the triggering of the event can be configured for 0-to-1 or 1-to-0 transition of the connected input signal (*TrigLevel*).

Figure 131 shows the parameters for the 81st input of the B6RBDR function. All parameters related to this input are suffixed with the number 81.

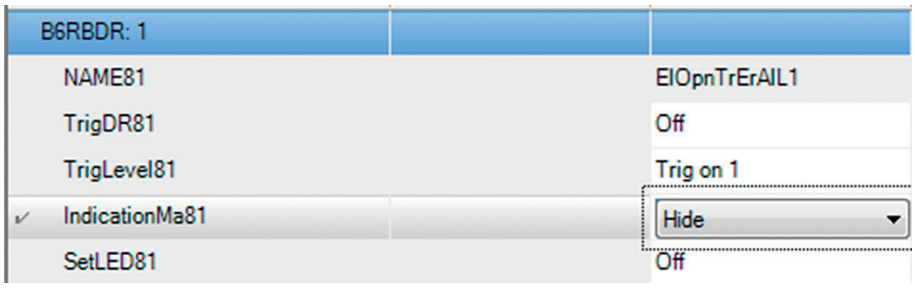


Figure 131: Event recorder function block parameters

To include a connected analog signal in the waveform records, set the corresponding Operation parameter of the AxRADR function to "On". See Figure 132.

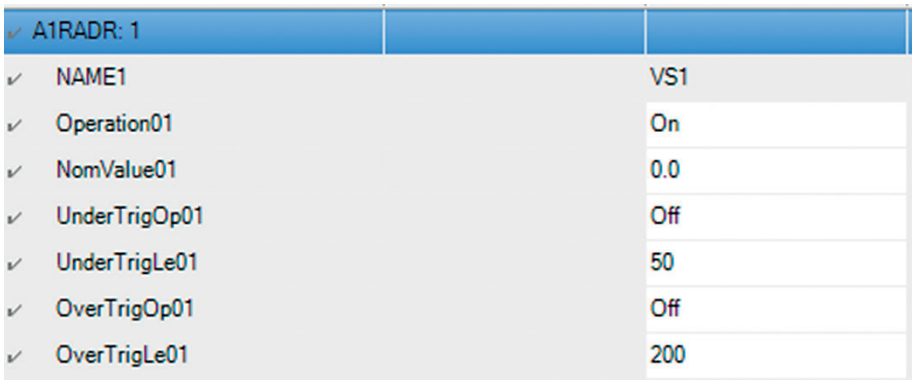


Figure 132: Current and voltage signal recorder function block parameters

9.4.8 Modification of alarm signals

Up to 64 binary signals can be connected for alarm generation. The related function blocks are located on the WEB_ALM_WRN worksheet. Alarms can only be viewed in the WHMI.

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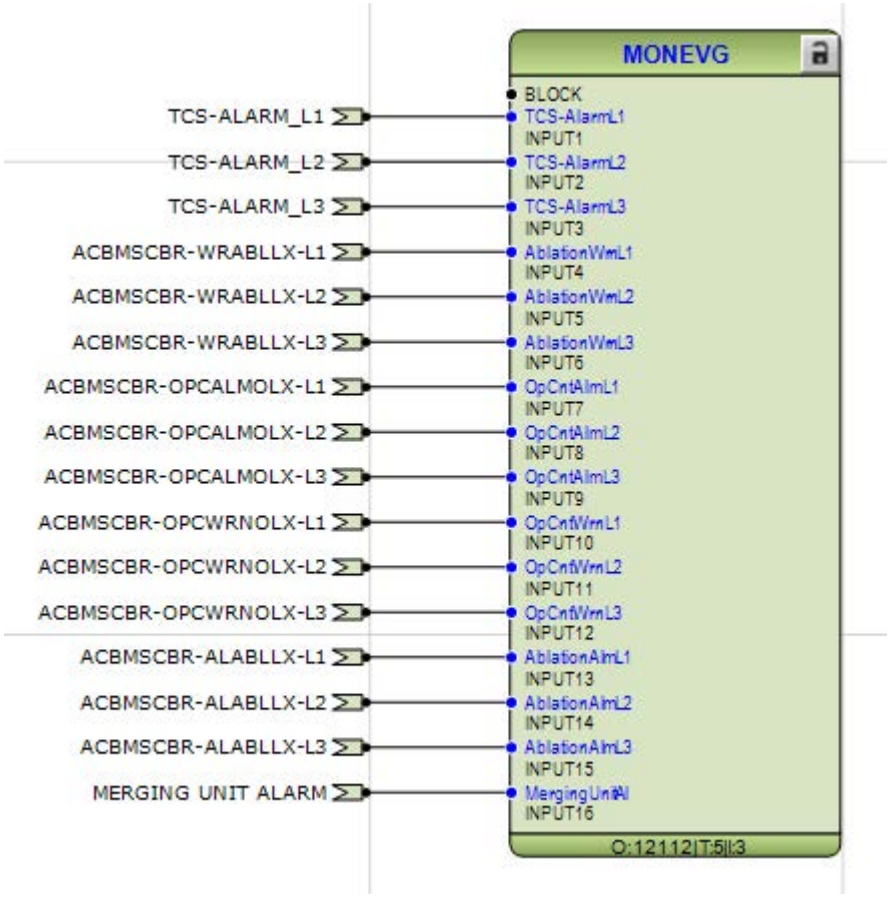


Figure 133: Function block for alarm generation

The name given to each input signal in the function block (for example, "AblationAlmL2" for INPUT14) is the label of the alarm which appears in the WHMI.

The icon for the alarm signals appearing in the WHMI can be configured using the *EventPriority* parameter shown in Figure 134.

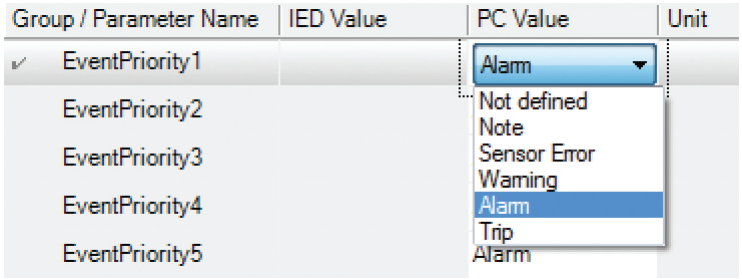


Figure 134: Alarm function block parameters

9.4.9 Modification of operation log input

The data to be included in an operation record are defined by the signals connected to the OPERLOG function blocks in the OPER_LOG worksheet. The default pre-configuration includes all signal connections for storing the relevant data for controlled switching in the operation log. OPERLOG function blocks are arranged in groups of three, where each function instance corresponds to a system phase in the order L1–L2–L3, connected in daisy chain for the control signals. This arrangement must not be changed for the existing OPERLOG function blocks.

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Further OPERLOG instances may be added with or without daisy-chain connection; in the latter case, their data will be assigned to phase L1.

For adding or removing signals from the existing OPERLOG instances (in ACT), the following points shall be considered.

- Only real-valued signals can be connected to OPERLOG inputs.
- Values for unconnected inputs in L2 and L3 will be indicated by a dash “-” in the WHMI view.
- In a three-phase group of OPERLOG function blocks, the signal sources for the L1 instance define the “Description” strings and the units displayed in WHMI. Changing a signal source will sever the internal data link; as a result, the “Description” label will be changed to the user-defined name of the function block input. There is no function for defining different display strings for Description or Unit.
- Removing the signal source for the L1 instance will hide the related data from display in all phases.
- When adding a signal for recording, assign a meaningful name to the OPERLOG input. The maximum length of the name is 13 characters.
- The signal for Electrical target error in each phase is taken from a GFGDE function block (located on MON_COMP page 3), to allow changing the signal source without losing the “Description” string in WHMI display. This flexibility is needed for controlled switching of coupled or ungrounded loads, as described in Section 9.4.6.

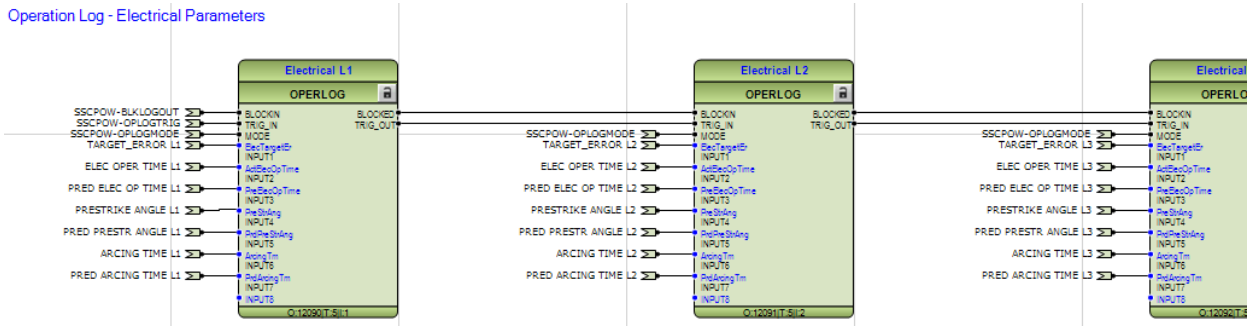


Figure 135: Default connections for operation log

9.4.10 Modification of binary inputs and outputs

Most binary inputs on the PIO and BIO modules are required for various pre-configured IED functions. If certain functions are not used in a specific installation, the respective inputs can be used for other purposes. For example, if no level indication signals are available for the CB drive’s energy storage, BI4…BI9 on BIO_4 can be used for other purposes; or correspondingly PBI1 on PIO_3, if not used for resetting the LEDs. The IED includes two spare binary inputs, which are not used in the pre-configuration.

The binary outputs on the PIO modules are reserved for controlling circuit breaker operations. Some binary outputs on the BIO and PSM modules are pre-configured for signaling. The BIO and PSM modules further include three and six binary outputs, respectively, designed for operating circuit breakers or other switches that are not used in the pre-configuration. They can be connected for signaling purposes if required, even though these contacts have higher current carrying capacity.

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Some spare binary inputs are available in the pre-configuration in the BIN_IN worksheet of Application Configuration in PCM600.

9.4.10.1 Adding binary inputs and outputs to Application Configuration

1. Click **Hardware I/O** under **Object Types** to open the input and output list.
2. Click and drag a **Binary Input** or **Binary Output** to the **Application Configuration** window.

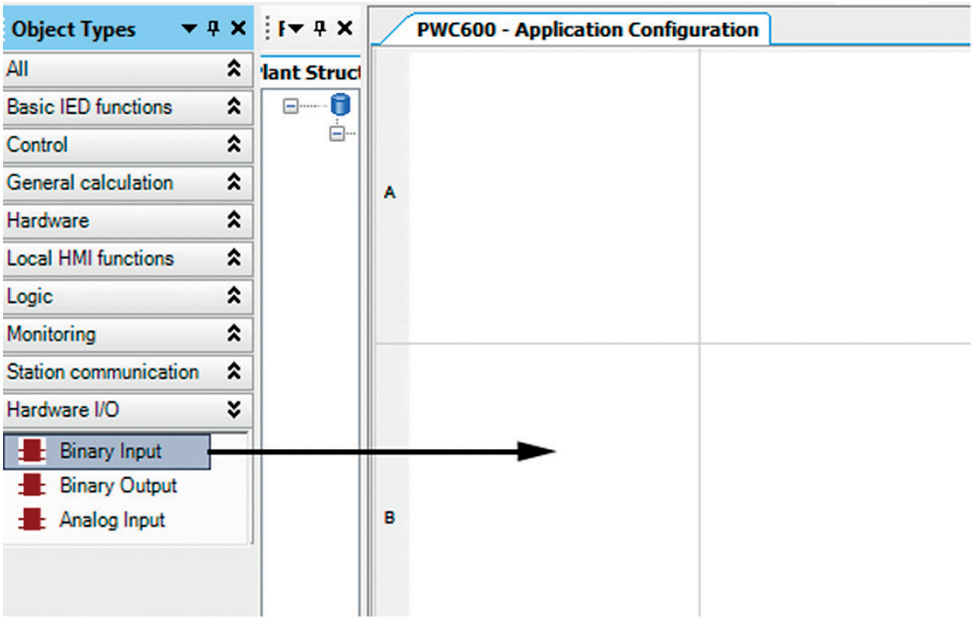


Figure 136: Dragging a binary input to Application Configuration

3. On the **Hardware Module** list, select the module.

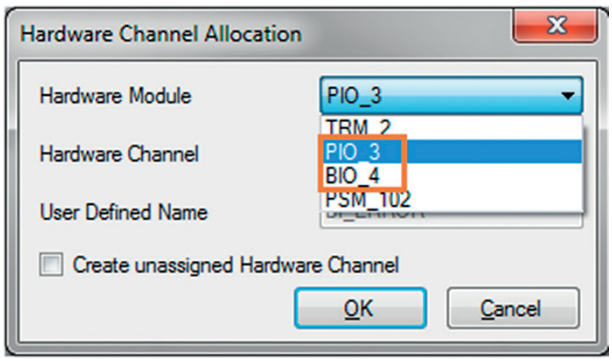


Figure 137: Selecting the hardware modules

4. On the **Hardware Channel** list, select one of the available hardware channels.

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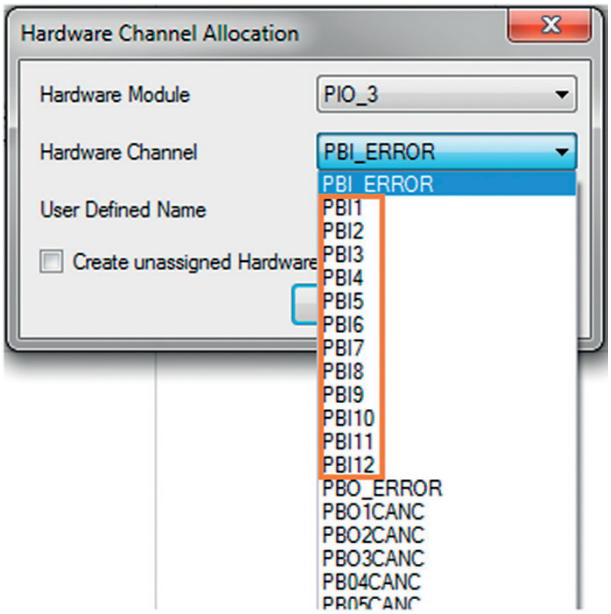


Figure 138: Selecting the hardware channels

5. Optionally, type an application specific name in the **User Defined Name** field.

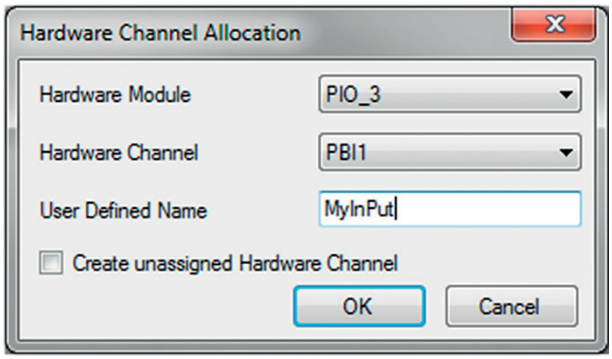


Figure 139: Entering a user-defined name

While adding a binary input, the **Hardware Channel** list also includes the already configured channels. Conversely, while adding a binary output, only channels that are not yet configured appear in the list.

9.4.11 Generic IEC61850 function block configuration

The default pre-configuration contains standard logical node types SSXCBR, SSCPOW, ACBMSCBR, TCSSCBR, CMMXU and VNMMXU. The data objects available on these logical nodes are listed in the MICS (Model Information Conformity Statement) document and in the IEC 61850 communication protocol manual. For transmitting other binary signals, either SPGGIO (single signals) or SP16GGIO (up to 16 signals) can be used. MVGGIO function block is used for transmitting analog signals.

The pre-configuration includes a default IEC 61850 data set comprising many of the indications listed in Section 16.1. This data set may be adjusted according to application requirements. Refer to the *IEC 61850 Communication protocol manual* for guidance.

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9.4.12 Connection of GOOSE close and open commands

If Close and Open commands are given through GOOSE messages from another IED, for example a bay controller, the commands need to be connected to the respective GOOSESPRCV function in the **Goose Receive** tab of the Signal Matrix tool.

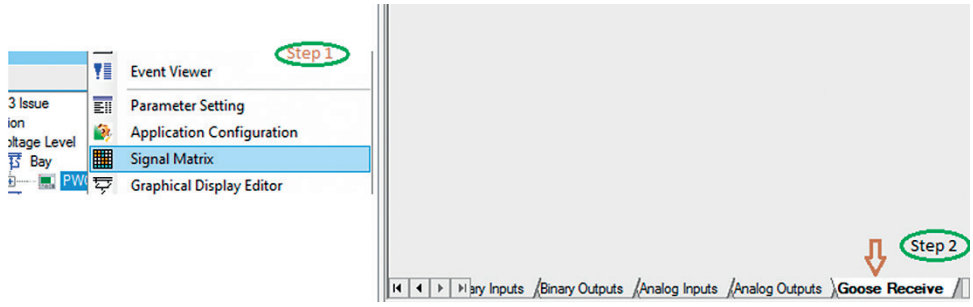


Figure 140: Opening Goose Receive tab of Signal Matrix

Two instances of GOOSESPRCV with user-defined names GOOSE_CLOSE and GOOSE_OPEN are included in the pre-configuration, for CB closing and opening commands respectively.

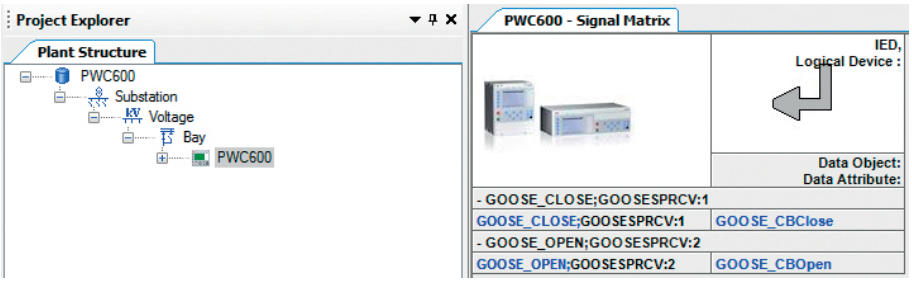


Figure 141: Connecting commands in Signal Matrix

9.4.13 Connection of compensation signals via analog GOOSE

In this version of Switchsync PWC600, analog compensation signals from external sensors can be connected only through analog GOOSE. Figure 142 shows a possible product configuration using ABB RIO600 as an example.

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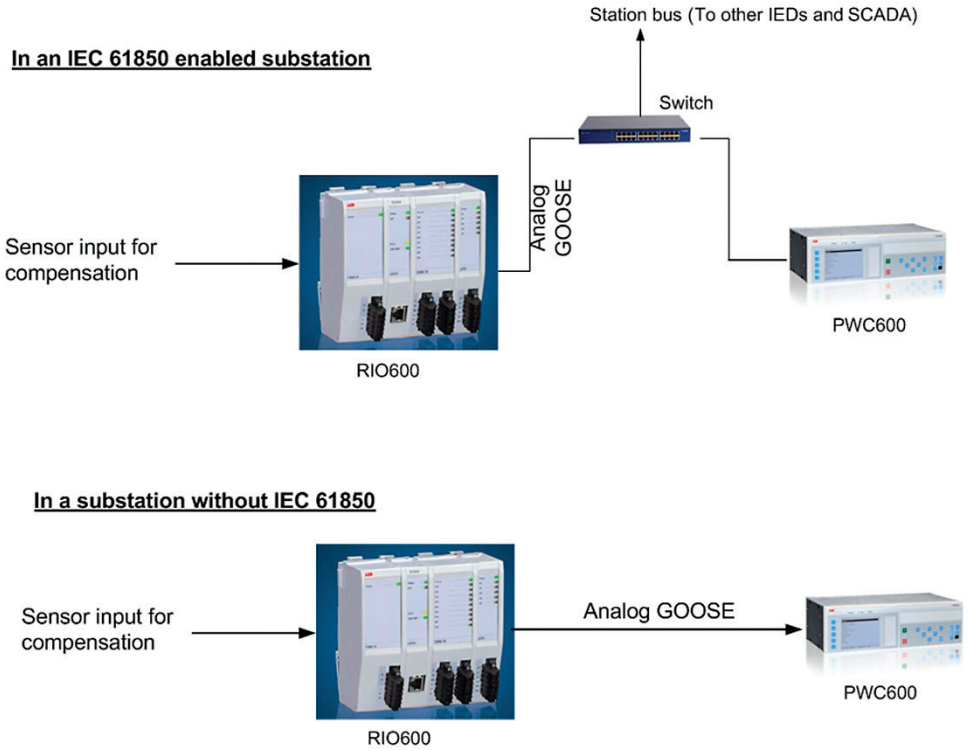


Figure 142: Acquiring analog values via GOOSE communication using ABB RIO600

Some knowledge of IEC 61850 engineering is required for performing this configuration. The function block GOOSEMVRCV, available under the category Station communication of **Object Types**, supports subscribing to analog data over GOOSE. One GOOSEMVRCV function block allows subscribing to one analog value. These functions are available on the COMPENSATION worksheet in Application Configuration.

Figure 143 shows the output and input connection of this function block.

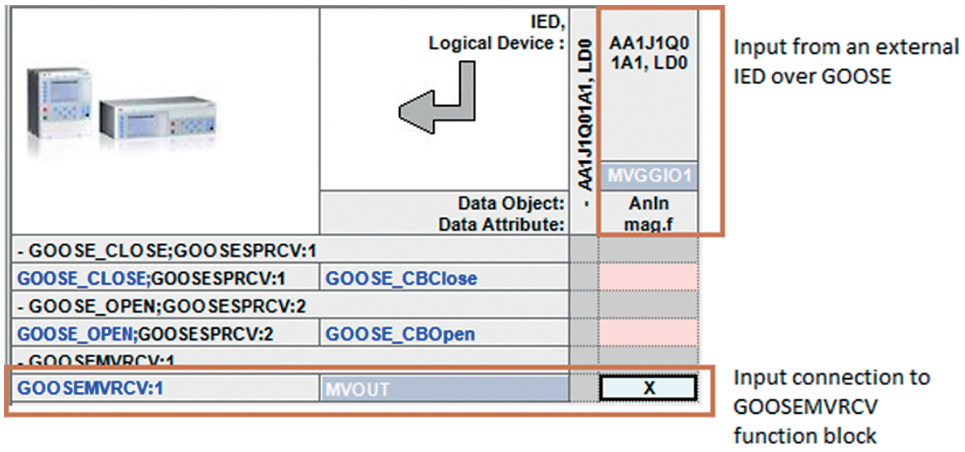


Figure 143: Subscribing to analog GOOSE values in Signal Matrix tool

Refer to the *IEC 61850 Communication Protocol Manual* for guidance.

9.4.14 Implementing setting groups for controlled switching

Setting groups can be used for quickly changing function block settings in service according to pre-defined criteria. The selected settings take effect immediately without the need for

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restarting the IED. Up to four setting groups can be defined, default is one. Section 3.4.2 lists some use cases for setting groups in PWC600.

This section describes implementation of the example given in Section 5.2.4, where setting groups are applied for selecting the appropriate reference signal and switching strategy for two loads connected to the middle (tie) breaker in a 1½ CB arrangement.

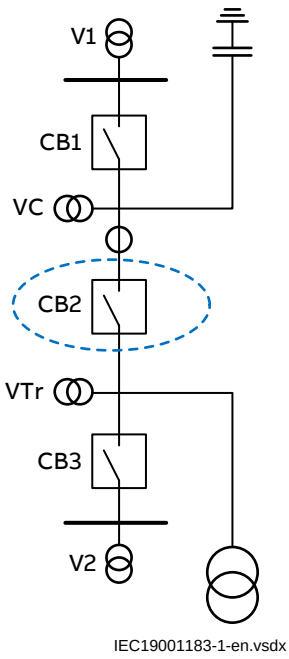


Figure 144: Example SLD of a circuit breaker (CB2) switching two loads

The implementation described here is intended as a guiding example only. For other applications and implementations of setting groups please contact ABB.

The selected criterion for activating the appropriate setting group (SG) is the position of the upper breaker in the diameter, CB1:

- If CB1 is closed, the next CB2 closing will presumably energize the transformer from the upper busbar, hence apply setting group 1 (SG1). The signal from the V1 voltage transformer is used as reference, and operation feedback is taken from auxiliary contacts.
- Otherwise, apply setting group 2 (SG2) for energizing the capacitor. The signal from the V2 voltage transformer is used as reference, and operation feedback is taken from the CB current signal.

This is implemented in three steps, which are described in the following subsections. Only changes from “normal” application (without setting groups) are explained.

9.4.14.1 Hardware connections

The selected Boolean criterion for activation of the individual setting groups can be directly mapped to a binary input signal. Here, input PBI03 is chosen.

1. Connect a binary signal that represents the “closed” status of CB1 to the PBI03 input as described in Section 9.4.10.1. For details on hardware inputs refer to Section 7.3.3.

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To accommodate two different analog reference signals, namely the two busbar VT signals:

1. Connect the output of VT1 to the IED input(s) for the source voltage signal. Both single-phase and three-phase VT signals can be connected.
2. Connect the output of VT2 to the IED input(s) for the load voltage signal. Both single-phase and three-phase VT signals can be connected. A single-phase VT shall be connected to the L1 input, regardless of the system phase it measures.

All other signals are connected to the PWC600 IED as usual.

9.4.14.2 Application configuration

The pre-configuration of PWC600 1.1 already has provisions for implementing setting groups, in the SET_GRP worksheet. Modification of the application configuration is done in the Application Configuration Tool (ACT), see Section 9.4.3.

Activation and reporting of setting groups is handled by the function block ACTVGRP. In most cases, the only required application specific work is mapping the selection criteria to the inputs of this function block.

Here, only setting groups 1 and 2 need to be handled. Setting Group 1 (SG1) is activated by applying a logical 1 to the ACTGRP1 input, and SG2 is activated by applying a logical 1 to the ACTGRP2 input. Thus, the signal on ACTGRP1 must be the Boolean inverse of the signal on ACTGRP2.

1. Add a binary input to the SET_GRP worksheet by dragging a Binary Input object to the workspace.
2. Allocate the desired input by specifying *Hardware Module* = “PIO_3” and *Hardware Channel* = “PBI3”. Adding a *User Defined Name* is optional.

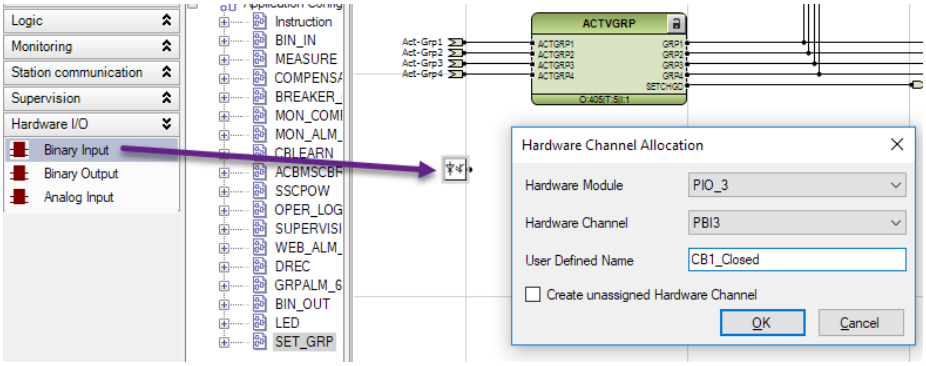


Figure 145: Adding hardware channel for binary input

3. Add an INVERTER function block to the SET_GRP worksheet.
4. Connect the newly added binary input PIO_3.PBI3 to INPUT of the INVERTER.
5. Connect PIO_3.PBI3 to the existing variable **Act-Grp1**. This will activate SG1 whenever CB1 is closed.
6. Connect OUT of the INVERTER to the existing variable **Act-Grp2**. This will activate SG2 whenever CB1 is open.
7. Save the configuration and close ACT.

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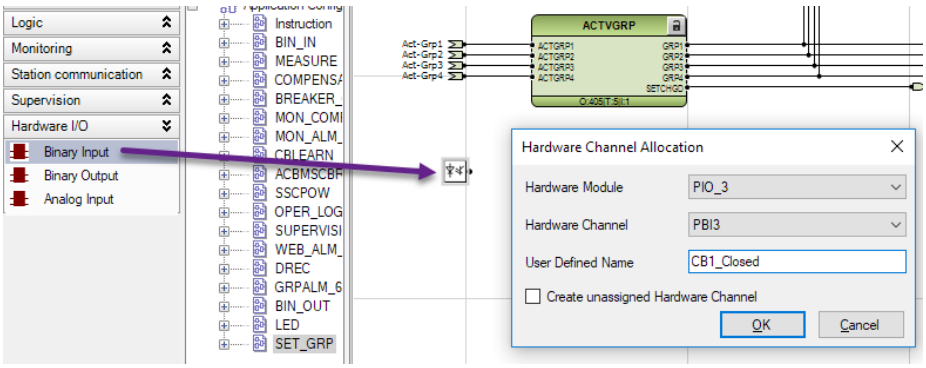


Figure 146: Logic for activating setting groups 1 and 2

Switching between analog reference signals is done through the 3PHSELECT function blocks on the MEASURE worksheet. These connections are part of the pre-configuration, no changes are necessary here.

9.4.14.3 Settings

Adjusting the PWC600 application settings takes several steps in two different tools.

1. In Parameter Setting Tool (PST), set the number of setting groups to 2, as described in Section 9.4.4.3.
2. Run Switchsync Setting Tool (SST) and enter the information corresponding to the setting group with the highest number, in this case SG2 for controlled switching of the capacitor bank. Specifically, consider these points:
   - 2.1. VT specifications are not handled through setting groups. Therefore, on the **Reference Signals** milestone, always enter the VT transformer ratios (for analog inputs on TRM) according to SG1 only. In this example, enter the VT1 primary and secondary voltages on the **Source Voltage Transformer** page and the VT2 voltages on the **Feedback Signals** page. However, for the VT connection information, enter the data for VT2, which will be used as controlled switching reference in SG2.
   - 2.2. On page 1 of the **Controlled Switching** milestone, enter the Nominal load current of that load which actually uses load current feedback for determining CB status and actual switching instants. (In case both loads use current feedback, enter the lower value of the two.) In this example, this is the nominal load current of the capacitor bank only as transformer current is not suitable as feedback signals (see Section 4.5.1).
   - 2.3. Furthermore, if adaptive correction should be based on mechanical feedback (from auxiliary contacts) in any setting group, enable Mechanical feedback and monitoring (**Adaptive Correction** milestone) in all setting groups. This is the case here, as mechanical feedback will be required for transformer switching.
   - 2.4. If adaptive correction for opening operations (based on primary current) should be used in any setting group, enter the same Limit of arcing time extensions per phase value for all setting groups.
3. In PST, copy SG1 to SG2 as described in Section 9.4.4.4.
4. In PST, program the swapping of source and load voltages according to the selected setting group.

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4.1. Navigate to **Application Configuration / MEASURE / Analog modules**.
4.2. In **SOURCE-VOLT; 3PHSELECT:1,** change *InputSelect[SG2]* to “Source2”. This will select the VT signal on the Load Voltage input as controlled switching reference whenever SG2 is active.
4.3. In **LOAD-VOLT; 3PHSELECT:2**, change *InputSelect[SG2]* to “Source1”. This will select the VT signal on the Source Voltage input as load voltage feedback whenever SG2 is active. (Strictly, this setting is not required in the specific example as VT2 does not measure the transformer voltage. However, it is good practice to not assign the same analog input signal for two different purposes at the same time.)
4.4. Save the parameters and close PST.

5. Run Switchsync Setting Tool (SST) and enter the information corresponding to SG1 for controlled switching of the transformer.
6. If desired, open PST and check the relevant settings for SG1 vs. SG2. Specifically, settings for targeting are mostly found in the SSCPOW function block, for feedback evaluation and monitoring in the ACBMSCBR function blocks. Refer to the Technical Manual for details.

Switchsync Setting Tool (SST) operates only on Setting Group 1. Therefore, if any information specifically applying to Setting Groups 2…4 should be changed, either repeat steps 2…5 above or change the values manually in PST.

9.4.15 Activating trip circuit supervision (TCS)

TCS supervises the continuity of a CB Trip or Close coil circuit by continuously injecting a small DC current and checking the resulting voltage. If the voltage falls outside a fixed range, this is interpreted as a fault in the circuit (either short circuit or open circuit) and the function raises an alarm (see Section 16.1).

A PWC600 IED features TCS in three of the power outputs, which are normally not used, on the PSM. The associated software functions are included in the pre-configuration. However, they are deactivated by default in order not to raise an alarm if the functionality is not used.

Section 7.5 explains the two basic hardware circuits for TCS. Depending on the implemented circuit, different adjustments of the pre-configuration are required.

9.4.15.1 TCS with external resistor

The coil circuit is continually supervised regardless of CB status. Hence, the only action required is activating the TCS alarm functionality.

1. Open Parameter Setting Tool (PST) on the IED object.
2. Navigate to **Application Configuration / SUPERVISION / Secondary system supervision**.
3. In all three instances of TCSSCBR, set *Operation* to “On”.
4. Save the settings and close PST.

9.4.15.2 TCS without external resistor

If the circuit breaker’s Trip coil circuit is to be supervised, bear in mind that this circuit is interrupted by a 52a (NO) auxiliary contact whenever the CB is open. Likewise, the Close coil circuit is interrupted by a 52b (NC) auxiliary contact whenever the CB is closed. To prevent

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false alarms, the TCS function needs to be blocked in this situation based on the CB status. Mechanical CB status can be taken from any suitable auxiliary contact. If precision auxiliary contacts are already connected to PWC600 for CB operations monitoring, the signal from one of these contacts can be reused for TCS blocking. Otherwise, another auxiliary contact should be connected to an unused binary input.

The procedure below assumes that a 52b (NC) contact is wired to the PBI7 input on the PIO module, to block false alarm from supervision of the Trip coil circuit.

1. Open Application Configuration Tool (ACT) on the IED object.
2. Navigate to page 1 of the **SUPERVISION** worksheet. (Note that the addition described here can be located on any worksheet. The important part is that an appropriate binary signal will be connected to the TCS blocking inputs.)
3. Add a hardware channel for the selected binary input, in this case PIO_3.PBI7.
4. Connect the selected binary input to the BLOCK input of all three TCSSCBR instances, either through the existing variable “BLOCK-TCS” or by direct connections. (If the “CB is open” information is taken from an internal binary signal, connect this signal accordingly. In that case, omit the preceding step of adding a binary input.)

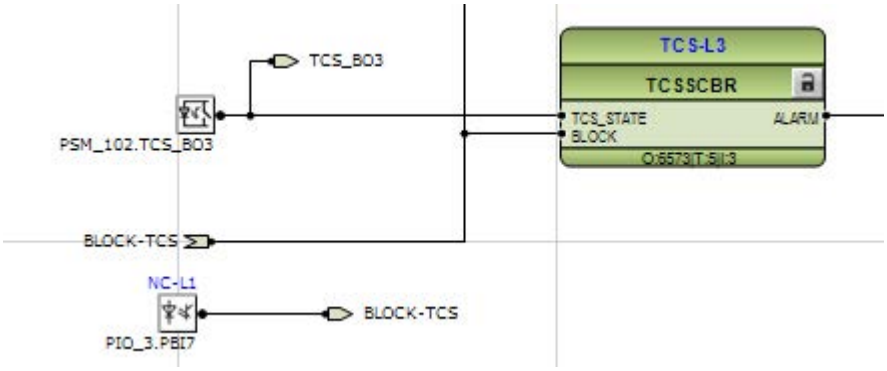


Figure 147: Added blocking signal to prevent false alarms from trip circuit supervision

5. Save the configuration and close ACT.
6. Open Parameter Setting Tool (PST) on the IED object.
7. Navigate to **Application Configuration / SUPERVISION / Secondary system supervision**.
8. In all three instances of TCSSCBR, set *Operation* to “On”.
9. Save the settings and close PST.

9.5 Writing the configuration to the IED

The entire IED configuration must be written to the IED in any of the listed cases.

- The IED is blank, meaning no configuration has been written to it.
- A new IED object has been created in PCM600.
- The application configuration has been modified in ACT or SMT, possibly in PST, SST, or GDE as well. (Changes made in PST or GDE can be written to the IED directly from these tools.)
- The communication configuration has been modified in IEC 61850 Configuration tool (or in an external tool such as IET600).
- The configuration has been migrated to another version.

To write the configuration to the IED:

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1. Ensure that Ethernet connection is established and that the Technical Key is matching between the IED and PCM600.
2. Right click the IED object and select **Write to IED**.

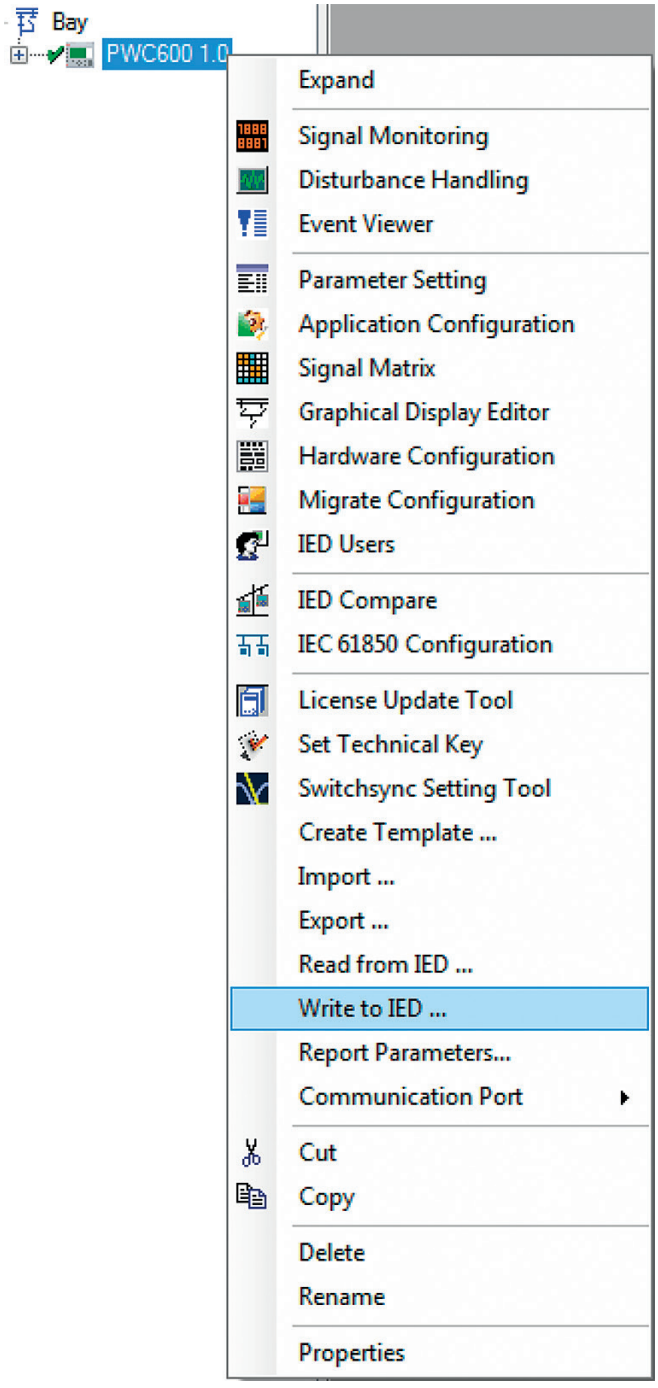


Figure 148: Initiating common write to IED

3. Confirm the operation by clicking **Yes** in the **Read/Write** dialog.
4. Wait until the Status Comment in the **Common Read/Write** frame shows "Success".
5. If the IED reboots, wait until it is operational again and the animated Write icon in the LHMI has been replaced by the Object name.

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On the first connection to an IED, including the first communication attempt after changing the Technical Key, PCM600 may pop up a security warning against installing a non-validated certificate. This certificate must be trusted for communication to work, see Section 8.7.4.

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Section 10 Local HMI

The Local HMI (LHMI) gives access to all information and functions in the IED.
At delivery, logging on is not required and the user has full access until users and passwords are created with PCM600 and written into the IED.

Commands, changing parameter values and resetting indications, for example, are actions requiring password when the password protection is activated. Reading information on the LHMI is always allowed without password.

Utility security policies and practical consideration should always be taken on the feasibility of using passwords. In emergency situations, the use of passwords could delay urgent actions. On the other hand when security issues must be met, the two factors must be seriously considered.

Do not switch off the auxiliary power supply to the IED before 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 to be worn out due to too many writings. As a consequence it may take up to an hour to save changes. If the auxiliary power is interrupted before a change is saved, that change is lost.

10.1 Local HMI elements



Figure 149: Local human-machine interface

The LHMI of the IED contains the following elements:

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

The LHMI is used for setting, monitoring and controlling.

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10.1.1 Display

The LHMI includes a graphical monochrome display with a resolution of 320 x 240 pixels. The character size can vary. The amount of characters and rows fitting the view depends on the character size and the view that is shown.

The display view is divided into four basic areas.

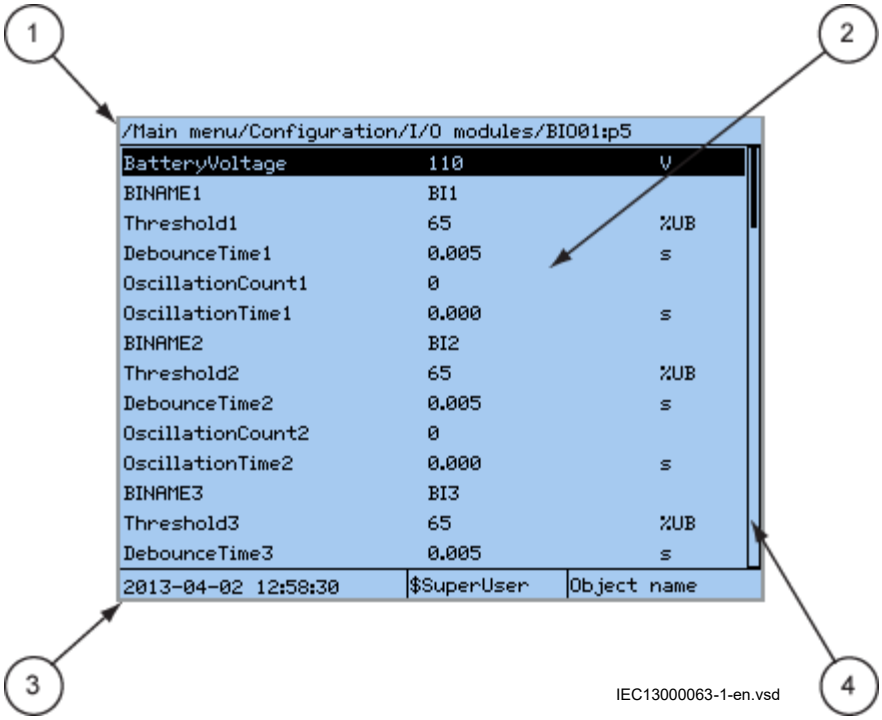


Figure 150: Display layout

1 Path
2 Content
3 Status
4 Scroll bar (appears when needed)

- The path shows the current location in the menu structure. If the path is too long to be shown, it is truncated from the beginning, and the truncation is indicated with three dots.
- The content area shows the menu content.
- The status area shows the current IED time, the user that is currently logged in and the object identification string which is settable via the LHMI or with PCM600.
- If text, pictures or other items do not fit in the display, a vertical scroll bar appears on the right. The text in content area is truncated from the beginning if it does not fit in the display horizontally. Truncation is indicated with three dots.

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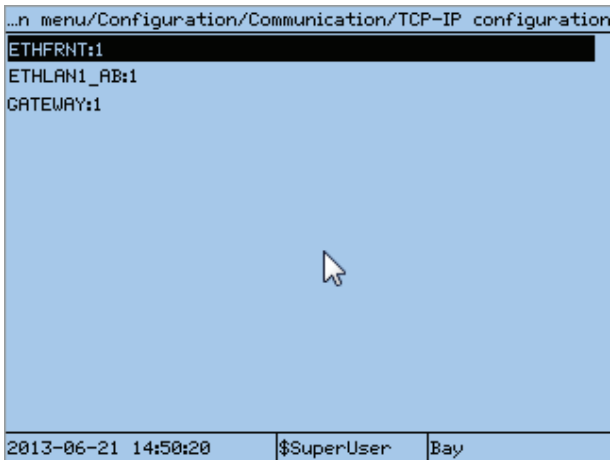


Figure 151: Truncated path

The number following the function name, for example `ETHFRNT:1`, indicates the instance number.

The display is updated either cyclically or based on changes in the source data such as parameters or events.

The function key panel shows on request what actions are possible with the function keys. Each function key has a LED indication that can be used as a feedback signal for the function key control action. The LED is connected to the required signal with PCM600.

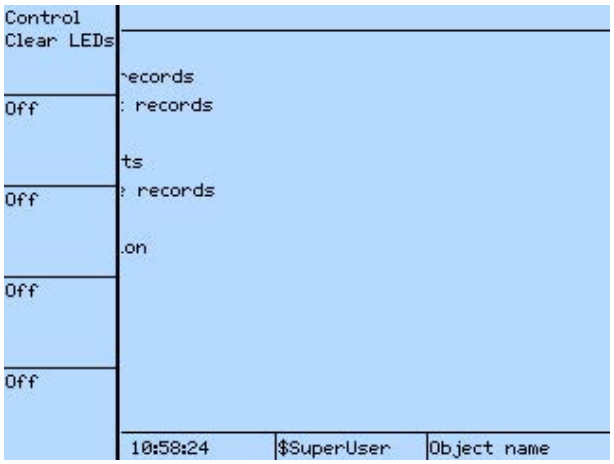


Figure 152: Function key panel

The alarm LED panel shows on request the alarm text labels for the alarm LEDs. Three alarm LED pages are available.

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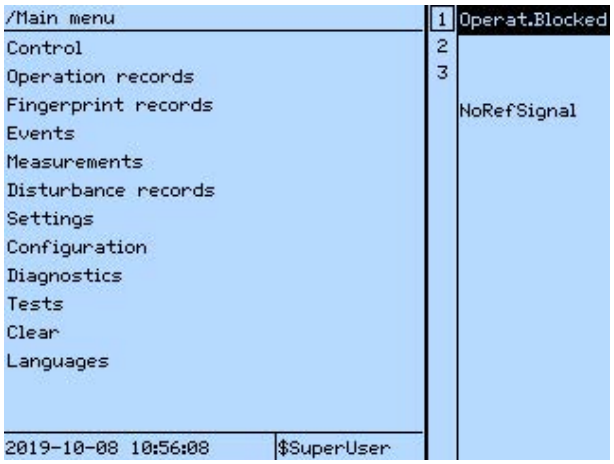


Figure 153: Alarm LED panel

The function key and alarm LED panels are not visible at the same time. Each panel is shown by pressing one of the function keys or the Multipage button. Pressing the ESC button clears the panel from the display. Both the panels have dynamic width that depends on the label string length that the panel contains.

10.1.2 LEDs

The LHMI includes three status LEDs above the display: Ready, Start and Trip. In Switchsync PWC600, only the Ready and Start LEDs are used.

There are 15 programmable alarm LEDs to the right of the screen. Each LED can indicate three states with the colors green, yellow and red. The alarm texts related to each three-color LED are divided into three pages and can be browsed with the Multipage button.

There are 3 separate pages of LEDs available. The 15 physical three-color LEDs in one LED group can indicate 45 different signals. Altogether, 135 signals can be indicated since there are three LED groups. The LEDs can be configured with PCM600 and the operation mode can be selected with the LHMI or PCM600.

In Switchsync PWC600, the functions and operation modes of the LEDs on page 1 are defined in the default pre-configuration.

10.1.3 Keypad

The LHMI keypad contains push-buttons which are used to navigate in different views or menus. The push-buttons are also used to acknowledge alarms, reset indications or provide help.

The keypad also contains five programmable push-buttons (function keys) that can be configured either as menu shortcut or control buttons. The first function key is assigned in the default pre-configuration for resetting the alarm LEDs.

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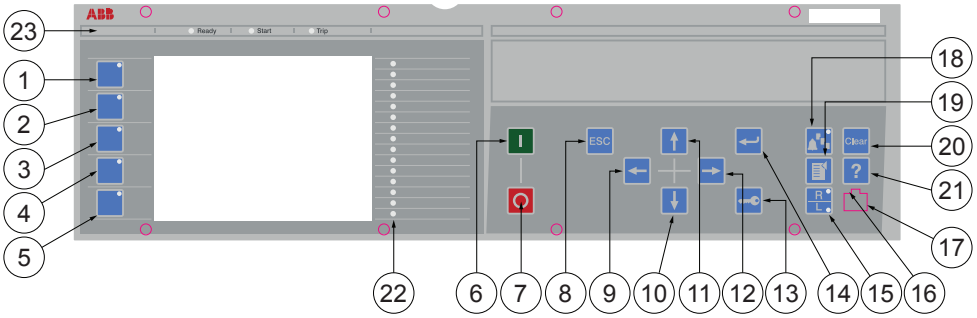


Figure 154: LHMI keypad (IEC variant) with push-buttons and RJ-45 communication port

1...5	Function key
6	Close
7	Open
8	Escape
9	Left
10	Down
11	Up
12	Right
13	User Log on
14	Enter
15	Remote/Local
16	Uplink LED
17	Ethernet communication port (RJ-45)
18	Multipage
19	Main menu
20	Clear
21	Help
22	Programmable alarm LEDs
23	Protection status LEDs

10.1.4 Local HMI functionality

10.1.4.1 Status and alarm indication

Status indicators

The status indicator LEDs are Ready and Start.

Since there are no protection functions available in Switchsync PWC600, the Start and Trip LEDs are not used for application related signalling.

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Table 94: Ready LED (green)

LED state	Description
Off	Auxiliary supply voltage is disconnected.
On	Normal operation
Flashing	IED starting up, or internal fault

Table 95: Start LED (yellow)

LED state	Description
Off	Normal operation.
Flashing	The IED is in Test Mode and functions are blocked. • The indication disappears when the IED is no longer in test mode and blocking is removed.

Alarm indicators

The 15 programmable three-color LEDs are used for alarm and status indication. Individual alarm/status signals are connected to the LED function blocks of Alarm Group 1 in the pre-configuration see Section 16.1.

10.1.4.2 Parameter management

The LHMI can be used to access the IED parameters. Three types of parameters can be read and written.

- Numerical values
- String values
- Enumerated values

Numerical values are presented either in integer or in decimal format with minimum and maximum values. Character strings can be edited character by character. Enumerated values have a predefined set of selectable values.

10.1.4.3 Front port communication

The RJ-45 port in the LHMI enables Ethernet communication with a PC.

- The green uplink LED on the left is lit when an Ethernet connection is established to the port.

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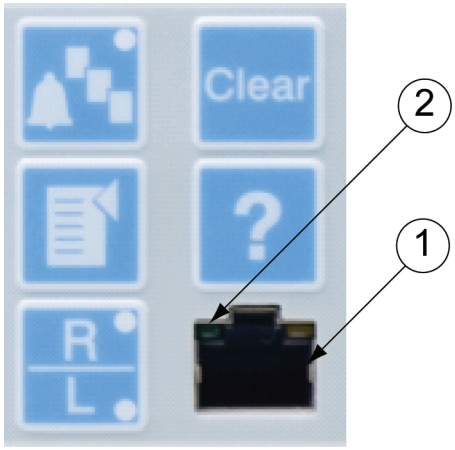


Figure 155: RJ-45 communication port and green indicator LED

1 RJ-45 connector
2 Green indicator LED

When a computer is connected to the IED front port with a crossed-over cable, the IED's DHCP server for the front interface assigns an IP address to the computer if *DHCPServer* = On. The default IP address for the front port is 10.1.150.3.

Do not connect the IED front port to a LAN. Connect only a single local PC with PCM600 to the front port.

10.2 Logging on

When IED users have been defined in PCM600, a user must log on to perform any action other than viewing data.

1. Press to activate the logon procedure.
   The logon is also activated when attempting a password-protected operation.
2. Select the user name by scrolling with and .

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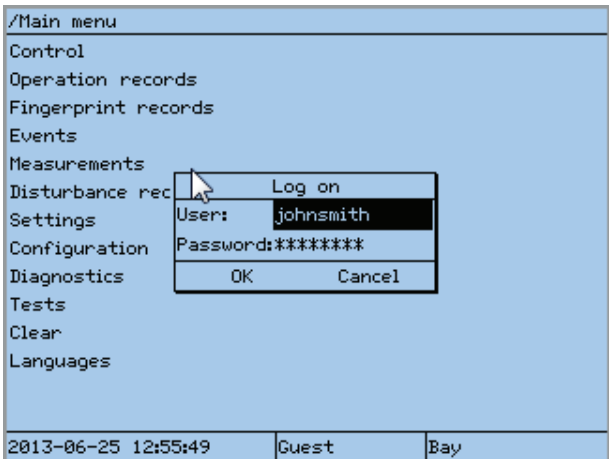


Figure 156: Selecting the user name

3. Enter the password when prompted and select OK.

   - Activate the character to be entered with ← and →.
   - Enter the character with ↑ and ↓.

   Upper and lower case letters are also found by scrolling the 255 characters with ↑ and ↓.

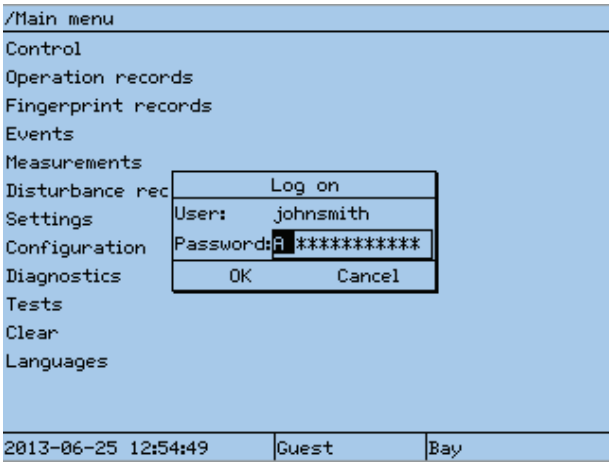


Figure 157: Entering the password

Passwords are case sensitive.

Only characters A - Z, a - z and 0 - 9 shall be used in user names. User names are not case sensitive. For passwords see the Password policies in PCM600.

4. Press ↵ to confirm the logon or ESC to cancel the procedure.
   If the logon fails, a message is displayed on the display.

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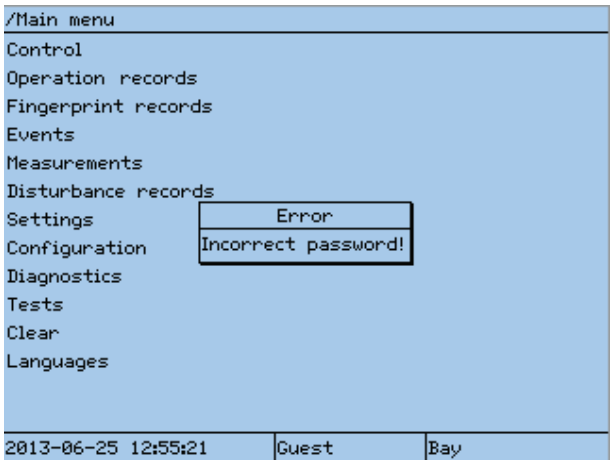


Figure 158: Error message indicating an incorrect password

The logon dialog appears if the attempted operation requires a higher level of user rights.

Once a user is created and written into the IED, logon is possible with the password assigned in the tool. If there is no user created, an attempt to log on causes the display to show a corresponding message.

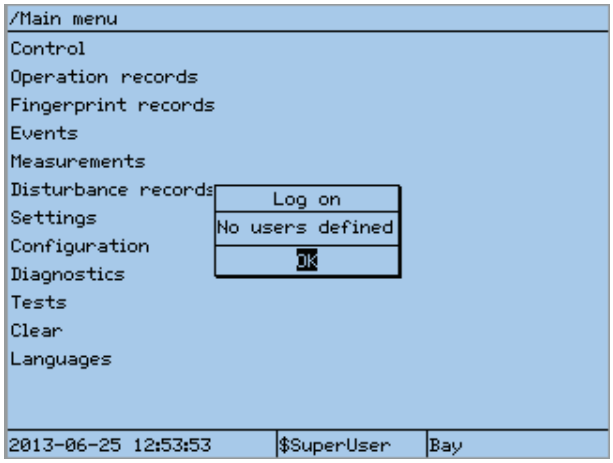


Figure 159: No user defined

10.3 Logging off

The user is automatically logged off after the display timeout. The IED returns to a state where only reading is enabled. Manual logoff is also possible.

1. Press .
2. To confirm logoff, select `Yes` and press .

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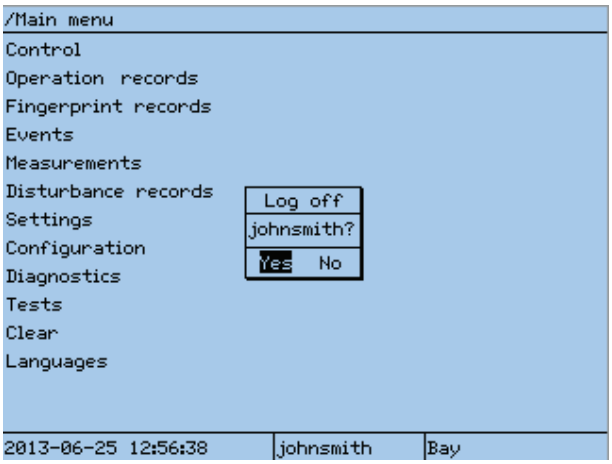


Figure 160: Logging off

- To cancel logoff, press ESC or select No and press ↵.

10.4 Navigating in the menu

Navigate the menus and change the display views on the screen with the keypad.

- To move to the Main menu or default view, press .
- To move up or down in a menu, press or .
- To move down one level in the menu tree, press .
- To move up one level in the menu tree, press .
- To enter setting mode, press .
- To leave setting mode without saving, press ESC.

10.4.1 Menu structure

The Main menu contains main groups which are divided further into more detailed submenus.

- Control
- Operation records
- Fingerprint records
- Events
- Measurements
- Disturbance records
- Settings
- Configuration
- Diagnostics
- Tests
- Clear
- Languages

10.4.2 Scrolling the display

If a menu contains more rows than the display can show at a time, a scroll bar is displayed on the right.

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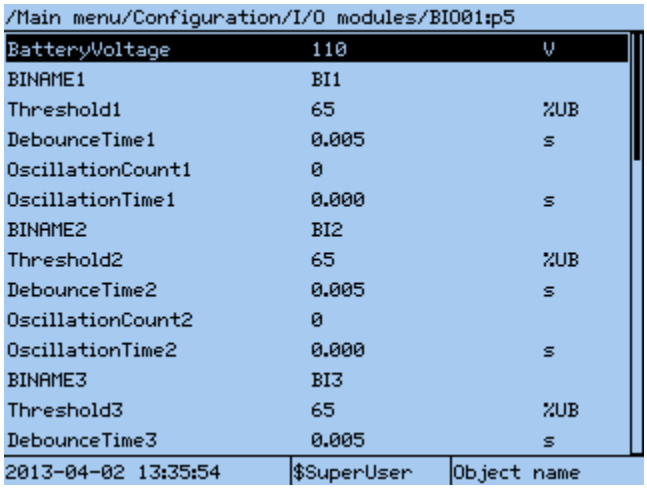


Figure 161: Scroll bar on the right

- To scroll the view upwards, press .
- To scroll the view downwards, press .
- To jump from the last row to the first row, press again.
  - Press to jump from the first row to the last row.

10.4.3 Changing the default view

The default view of the display is **Main menu**. This can be changed according to user preferences.

1. Select **Main menu/Configuration/HMI/Screen/SCREEN:1**, select the parameter *DefaultScreen* and press .
2. Change the default view with or .
3. Press to confirm the selection.

The default pre-configuration includes two graphical display pages named **Status** and **Info**. The text elements on the **Info** page need to be manually modified in Graphical Display Editor for the specific application. The first three pre-defined pages are reserved for circuit breaker timing test mode and must not be changed.

10.5 Identifying the device

The IED information includes detailed information about the device, such as revision and serial number.

1. Select **Main menu/Diagnostics/IED Status/Product identifiers**.
2. Browse the information with and .

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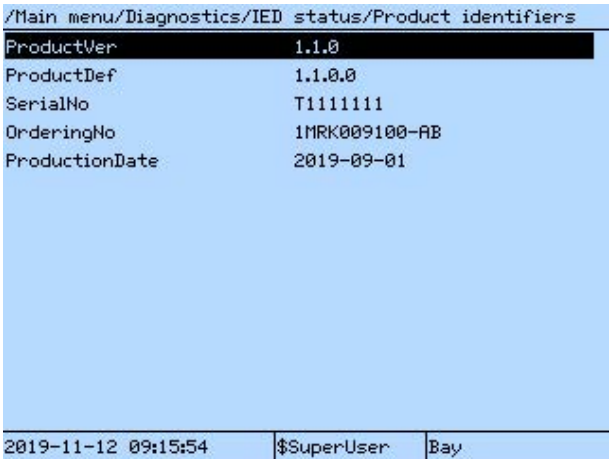


Figure 162: IED information

10.6 Changing the local HMI language

Only one language (English) is supported by this Switchsync PWC600 release. It is not possible to change the LHMI language.

10.7 Settings and configuration parameters

10.7.1 Browsing setting values

1. Select **Main menu/Settings/IED Settings** or **Main menu/Configuration**, and press .
2. If **Settings** was selected in the first step:
   - To change the setting group to be viewed, press to select the setting group number. Then edit the number as explained below. This is possible only when more than one setting group was defined in the configuration.
   - To access the selected setting group, select `Yes` and press .
3. Press or to select No and to exit.

Up to four setting groups are supported in this release of Switchsync PWC600. By default, always use setting group 1.

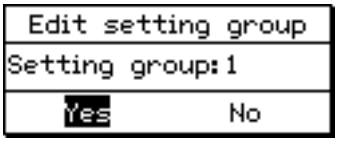


Figure 163: Confirmation to access the selected setting group

4. To browse the settings, scroll the list with and and to select a setting press . To move back to the list, press .

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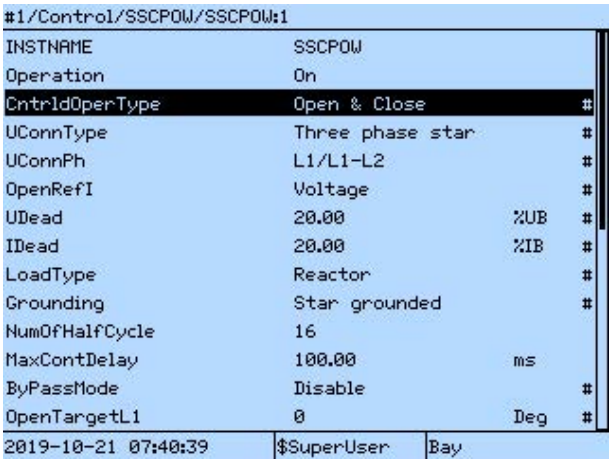


Figure 164: Setting alternatives in the selected setting group

The content of the list depends on the pre-configuration or on the functions configured with PCM600.

The # character to the right indicates that the respective setting is setting-groups controlled. The value shown or edited here applies to the setting group selected above.

10.7.2 Editing setting

- To edit values, log in with the appropriate user rights.
  If the user rights are not sufficient for editing values, the login dialog opens.

10.7.2.1 Editing numerical values

1. Select **Main menu/Settings** and then a setting.
   A small window pops up, wherein initially the last digit of the value is active.
   - When the symbol in front of the value is ↑, the active value can only be increased.
   - When the symbol is ↓, the active value can only be decreased.
   - When the symbol in front of the value is ↕, the active value can either be increased or decreased.

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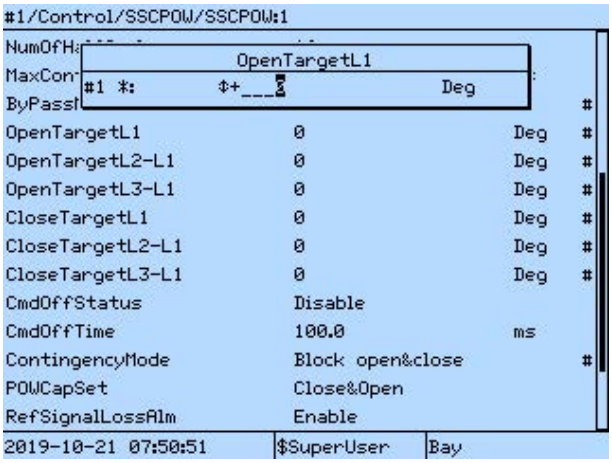


Figure 165: Last digit is active and it can be increased or decreased

2. Press ↑ to increase or ↓ to decrease the value of an active digit.
One press increases or decreases the value by a certain step. For integer values, the change is 1, 10, 100 or 1000 (...) depending on the active digit. For decimal values, the change can be fractions 0.1, 0.01, 0.001 (...) depending on the active digit.

   For parameters with defined steps, digits smaller than the step value cannot be edited.

3. Press ← or → to move the cursor to another digit.
4. To select the minimum or maximum value, select the arrow symbol in front of the value.
   - To set the value to the maximum, press ↑.
   - To set the value to the minimum, press ↓.

   After pressing ↑, the previous value can be restored by pressing ↓ once, and vice versa. Another press of ↓ or ↑ sets the value to the lower or higher limit. The symbol in front of the value is ↕, when the previous value is shown.

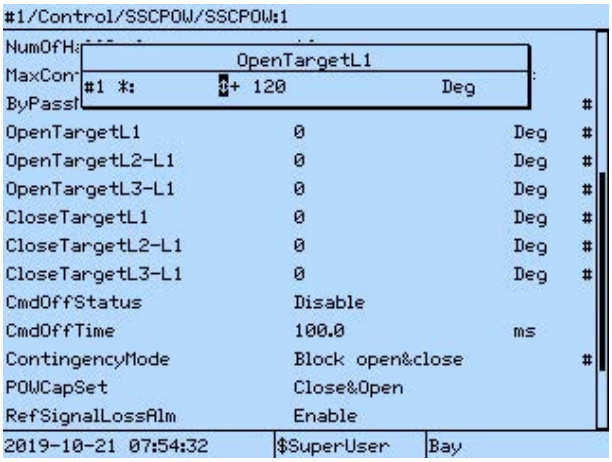


Figure 166: Restoring the previous value

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10.7.2.2 Editing string values

1. Activate the setting mode and select a setting.
   When editing string values, the cursor initially moves to the first character.
2. Press ↑ or ↓ to change the value of an active character.
   One press changes the value by one step.
3. Press ← or → to move the cursor to another character.

- To insert characters or space, press simultaneously ESC and ↵.
- To delete characters, press simultaneously ESC and Clear.

Switchsync PWC600 supports Unicode characters.

10.7.2.3 Editing enumerated values

1. Activate the setting mode and select a setting.
   When editing an enumerated value, the selected value is shown inverted.
2. Press ↑ or ↓ to change the value of an active enumerated value.
   One press changes the enumerated value by one step in the parameter specific order.

10.7.2.4 Changing system time

If there is a need to change the time setting in the LHMI (**Main menu/Configuration/Time/System time/SYSTEMTIME:1**) the change will take effect immediately. To confirm the new setting, press ↵. To remove the change, press ESC.

10.7.3 Saving settings

Editable values are stored in the non-volatile flash memory. Most of the parameter changes take effect immediately after storing, but some parameter changes require application restart. Values stored in the flash memory remain in effect after reboot as well.

1. Press ↵ to confirm any changes.
2. Press ← to move upwards in the menu tree or ☰ to enter the Main Menu.
3. To save the changes in non-volatile memory, select `Yes` and press ↵.

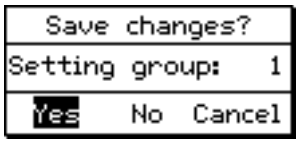


Figure 167: Confirming setting changes

- To exit without saving changes, select `No` and press ↵.
- To return to editing without saving settings, select `Cancel` and press ↵.

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Pressing Cancel in the **Save changes** dialog closes only the **Save changes** dialog box, but the IED remains in editing mode. All the changes applied to any setting are not lost and the user can continue to change settings. To leave the change setting mode, select No or Yes in the **Save changes** dialog.

After changing any parameter marked with !, the IED restarts automatically for the changes to take effect.

10.8 Monitoring

10.8.1 Measured and calculated values

All values show the momentary measurement value and some include demand values calculated from a set period.

1. Select **Main menu/Measurements** to monitor measured and calculated values. The list of IED's basic measurements is shown.
2. Scroll the view with and .
3. Press to show the selected measurements.

10.8.2 Recorded data

The IED is provided with intelligent and flexible functionality that collects different kinds of data. The recorded data give substantial information for analysis of the controlled switching operations.

- Waveform records (disturbance records)
- Events
- Alarms [1]
- Operation records
- Fingerprint records

10.8.2.1 Operation log

To prevent loss of operation data, do not power off the IED within one hour of the last update to the operation log, that is, switching operations. The same applies after clearing the operation log. This time constraint was introduced to minimize the number of write cycles to internal flash memory and cannot be changed.

Viewing the operation log list

1. Navigate to **Main Menu/Operation Records**.
2. Press and to navigate between operation log instances.

[1] Accessible only from WHMI

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Figure 168 shows how the stored operation log instances are displayed.

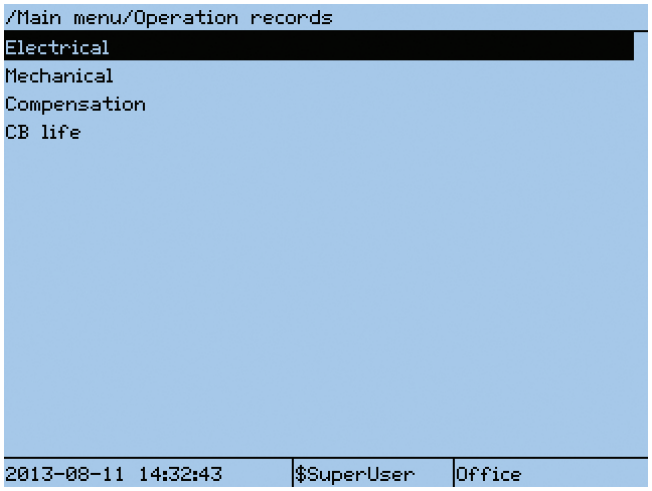


Figure 168: Operation log list view

Viewing operation log records

1. With an operation log instance selected, press → to view the operation records of that instance.
2. Press ↑ or ↓ to navigate between the records.

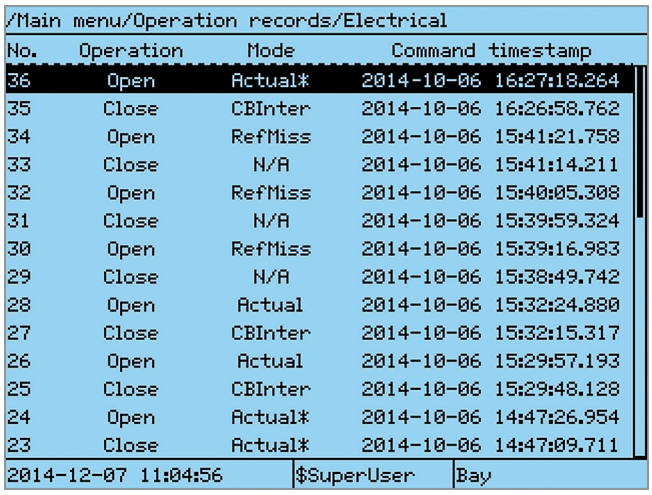


Figure 169: Operation log records view

The latest 100 records are displayed in this view. The newest record is always shown on top of the list.

The full list of operation records can be accessed through the WHMI.

The operation log records view lists the records for all circuit breaker open and close operations along with the command timestamps and mode.

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The operation log records view is not updated dynamically if new records are stored while the view is open. In order to view the new records, return to the operation log instances view and then re-open the operation log records view.

Viewing operation log phase segregated data
From the operation log records view, access the detail data of a selected record as follows:

1. Press ↑ or ↓ to select the record.
2. Press → to view the recorded values.
3. Press ← to exit from the record details view.

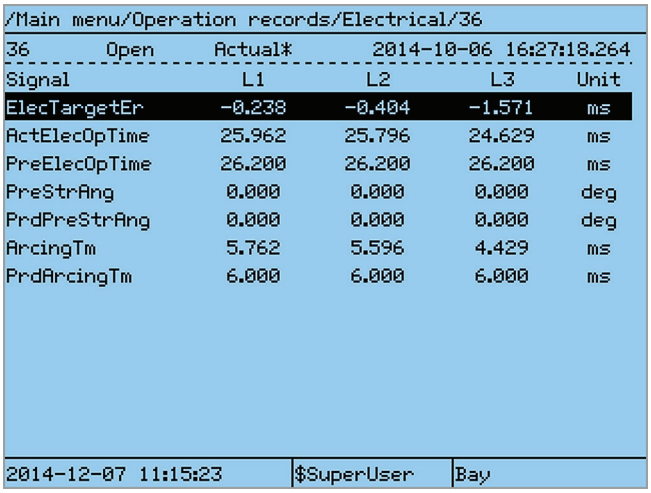


Figure 170: Operation log phase segregated data view

The signal names are the user-defined names of the inputs of the primary instance of OPERLOG. The values listed under L1 column is from the primary instance, L2 and L3 are from the second and third OPERLOG function block in the daisy chain in ACT.

The user defined signal name displayed in the Signal column is limited to 13 characters only. The maximum number of characters to be displayed on the local HMI for phase segregated data view are 26 characters.

10.8.2.2 Waveform records

Creating disturbance recordings
The disturbance recorder records waveforms and binary events associated to a switching operation.

In Switchsync PWC600, controlled switching operations are not initiated due to system disturbances. However, as the function is identical to the implementation in protection relays, the same name is used here.

Normally, a disturbance recording is triggered by a received switching command but the recording can also be triggered manually.

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1. Select **Main menu/Disturbance records**.
2. Select **Manual Trig** with or .
3. Press to execute manual triggering.

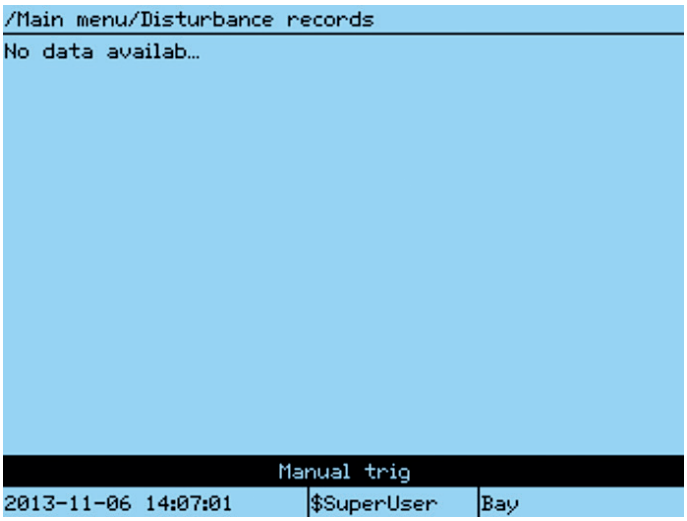


Figure 171: Manual triggering

The disturbance recorder is now triggered and the view is updated to include the new record.

Viewing disturbance recorder data

Read individual disturbance records from the IED with the PCM600 software, or view and download them via WHMI.

To access the general information on a selected disturbance record:

1. Select **Main menu/Disturbance records**.
   All disturbance records are listed.
2. Scroll the view with or .

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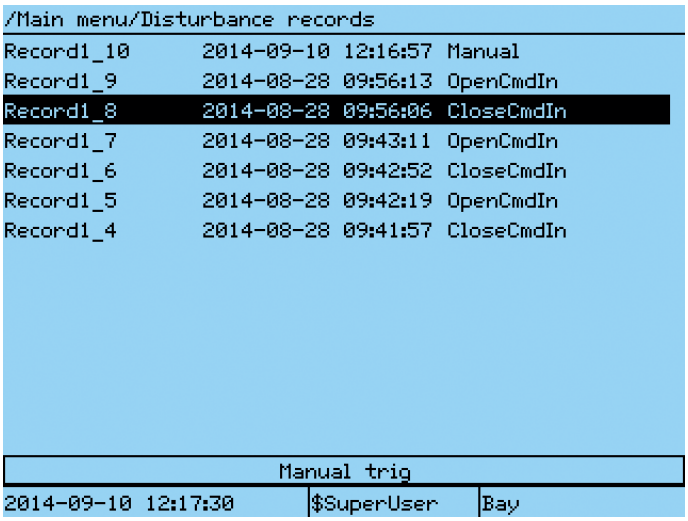


Figure 172: Monitoring disturbance recorder via the LHMI

3. To view a specific disturbance record, press .
A list of detail categories is displayed. In Switchsync PWC600, only the "General information" category is available.

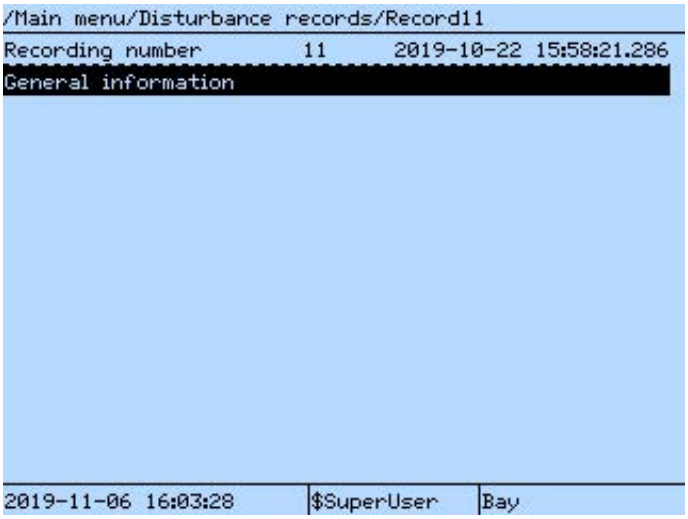


Figure 173: Disturbance record data categories

4. To view the items under this category, press or and then.

Controlling and reading disturbance recorder data
Disturbance recorder data can be managed and read with PCM600.

For more information, see PCM600 documentation.

10.8.2.3 Events

The Events view contains a list of events produced by the application configuration. The events are grouped by day, and each event takes one line. Select the order of events with the setting **Main menu/Configuration/HMI/Screen/SCREEN:1/EvListSrtOrder**.

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1. Select **Main menu/Events**.
2. Press → to open the event list.
   Events are shown grouped by date.
   Time, channel number, signal name and value of the event are shown.
3. Press ↑ or ↓ to scroll the view if it extends beyond the current screen.

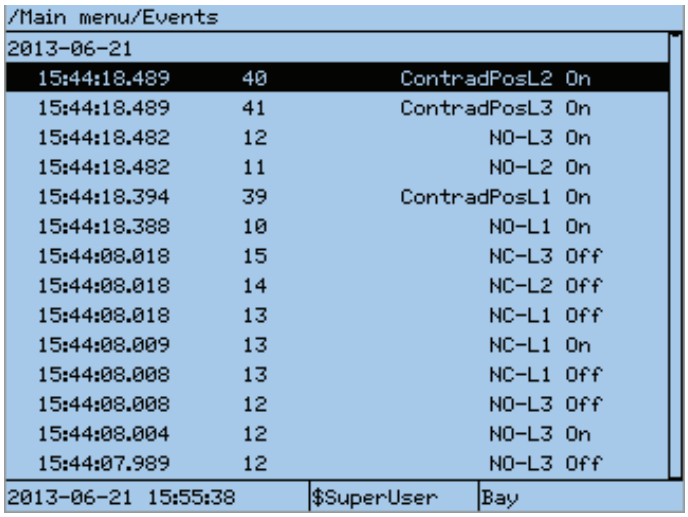


Figure 174: Monitoring events

The event list is not updated dynamically. To update the list, leave the Events menu and then select it again.

10.8.3 Remote monitoring

The IED supports comprehensive remote monitoring.

10.8.3.1 Monitoring the IED remotely

Use the PCM600 tool to operate the IED remotely.

- Read maintenance record and version log.
- Analyze disturbance record data.
- Create disturbance records.
- Monitor IED values.

For more information, see PCM600 documentation.

Remote monitoring is also possible through the WHMI, see Section 11 in this manual.

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10.8.4 Application indications

Active alarms are indicated by the alarm LEDs and the LED in the Multipage button. The alarms are configured with PCM600. The alarm type and information depend on the application. All alarms and warnings defined in the pre-configuration are listed in Section 16.1.

1. Press to open the alarm view.
2. Press or to move between active alarms in the page, or press to switch between the three alarm pages.
3. Press to open a dialog box that shows more detailed information about the selected alarm.

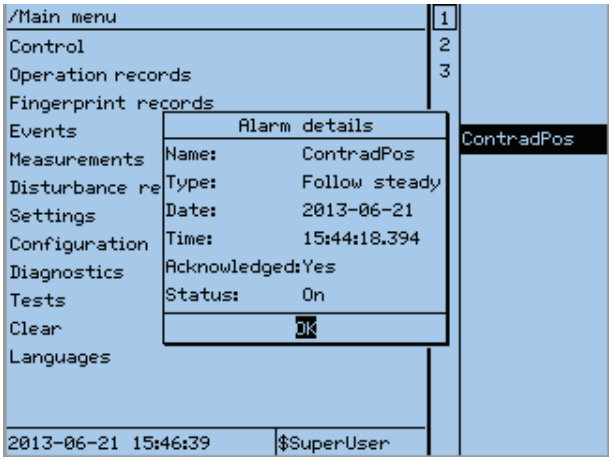


Figure 175: Alarm details

Press or ESC to close the dialog box.

4. Press ESC to close the alarm view.
5. Press Clear to activate the Clear view and to clear alarms.

10.8.5 Internal IED fault

After start-up, the flashing green LED indicates an internal IED fault. The fault messages are found in the LHMI menu.

1. Select **Main menu/Diagnostics/Internal events** or **IED status/General** to view the latest fault indication.
2. Press or to scroll the view.

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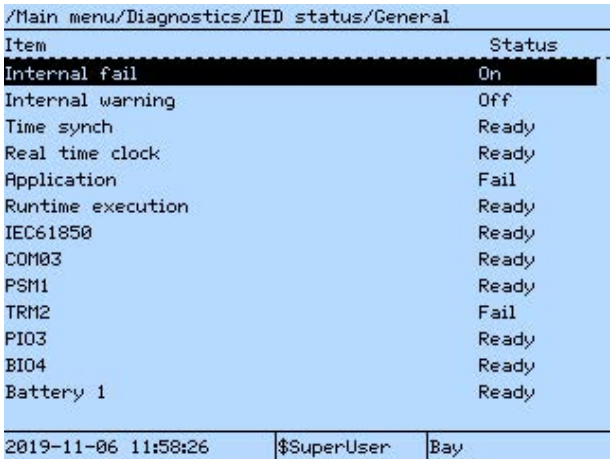


Figure 176: Example of fault indications

The internal event list is not updated dynamically. To update the list, leave the **Internal events** menu and then select it again.

See Section 16.3.1 for details.

10.9 Clearing status information

On the HMI, use the **Clear** menu to reset, acknowledge or clear all messages and indications, including LEDs and latched outputs as well as registers and recordings. Pressing the Clear button activates a view for selecting the reset function. Events and alarms assigned to alarm LEDs can also be cleared with the Clear button.

1. Press Clear to activate the Clear view.
   All items that can be cleared are shown.

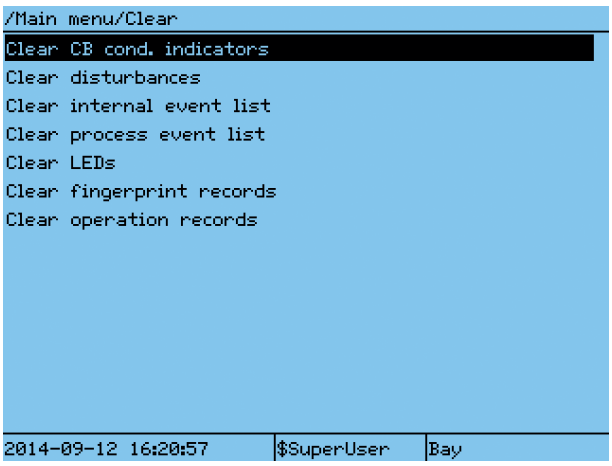


*Figure 177: Contents of **Clear** menu in LHMI*

2. Select the item to be cleared with ↑ or ↓.
3. Press →, select **OK** to confirm the selection or **Cancel** to cancel the selection.
4. To clear other items, repeat the steps.

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In addition to the general procedure above, latched LED indications can be cleared in the default pre-configuration by any of the actions listed below.

- On the LHMI, press Function Key 1 twice, the second time holding it for minimum one second.



Figure 178: Function key 1

- Activate (energize) binary input PBI01.
- Send a "1" value to GOOSESPRCV:3 (LED-CLEAR) via station bus.
- Issue a controlled Close or Open command by activating the corresponding binary input.
- In the IED menu of WHMI, navigate to **Clear/Clear LEDs/All indication LEDs**, enter new value “True”, and click **Write to IED**.

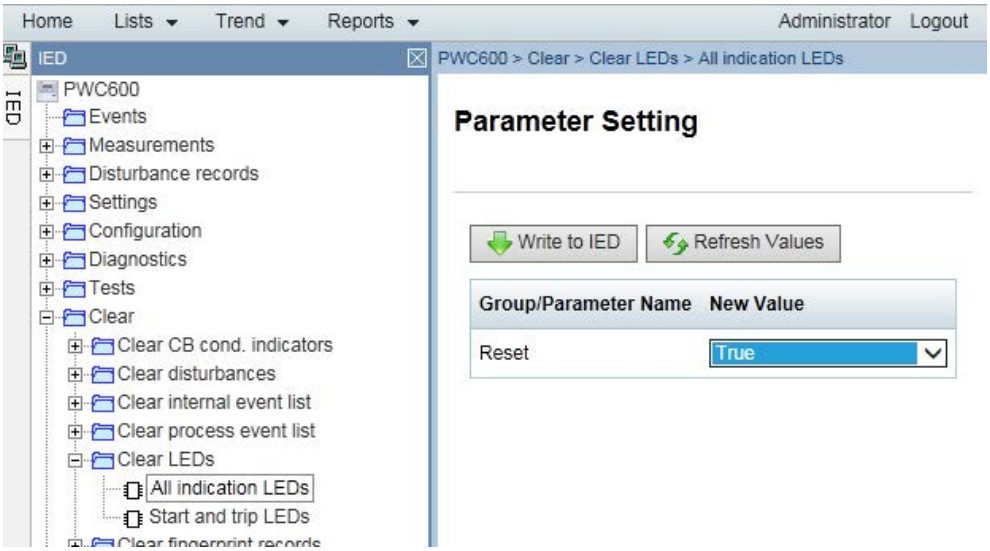


Figure 179: Clear indication LEDs from WHMI

After writing to the IED, the value displayed in WHMI is automatically reset to "False".

10.10 Using the local HMI help

1. Press ? to open the help view.
2. Scroll the text with ↑ or ↓ if the help text exceeds the display area.
3. To close the help, press ESC.

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The help dialog is also closed when the display timeout expires.

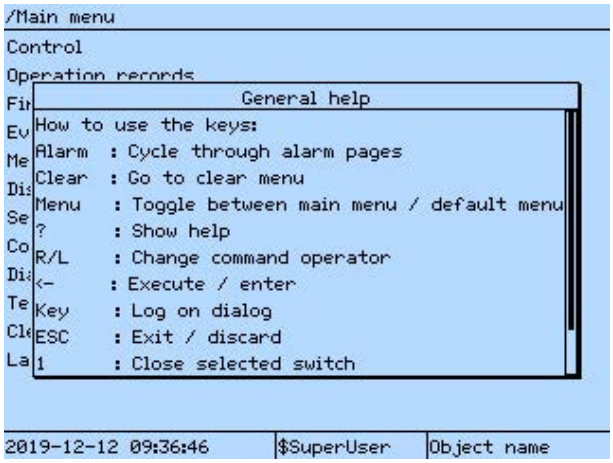


Figure 180: Help menu

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https://manual-hub.com/

Section 11 Web HMI

The Web HMI (WHMI) enables the user to access the IED via a web browser. It has been tested with Google Chrome, Mozilla Firefox, Microsoft Internet Explorer 11, and Microsoft Edge.

WHMI offers several functions.

- Display operation records
- Display waveform records
- Display lists of alarms and events
- Display graphical trend of selected data stored in operation records
- View and edit settings

The WHMI can be accessed locally and remotely.

- Locally by connecting the user's computer to the IED via the front communication port.
- Remotely over LAN/WAN through the rear Ethernet communication port.



For proper display of the WHMI in Internet Explorer, disable *Compatibility View* in the browser's **Tools** menu.

11.1 Logging in



Maximum four concurrent users are supported. Two concurrent sessions with the same user name are allowed, but inactivity timeout is reduced to 30 seconds for the older session (Web server setting is overridden).

1. Connect to the IED by typing “https://” into the browser’s address bar, followed by the IED’s IP address. For example, the default address for the front port is https://10.1.150.3. The authentication dialog is displayed.

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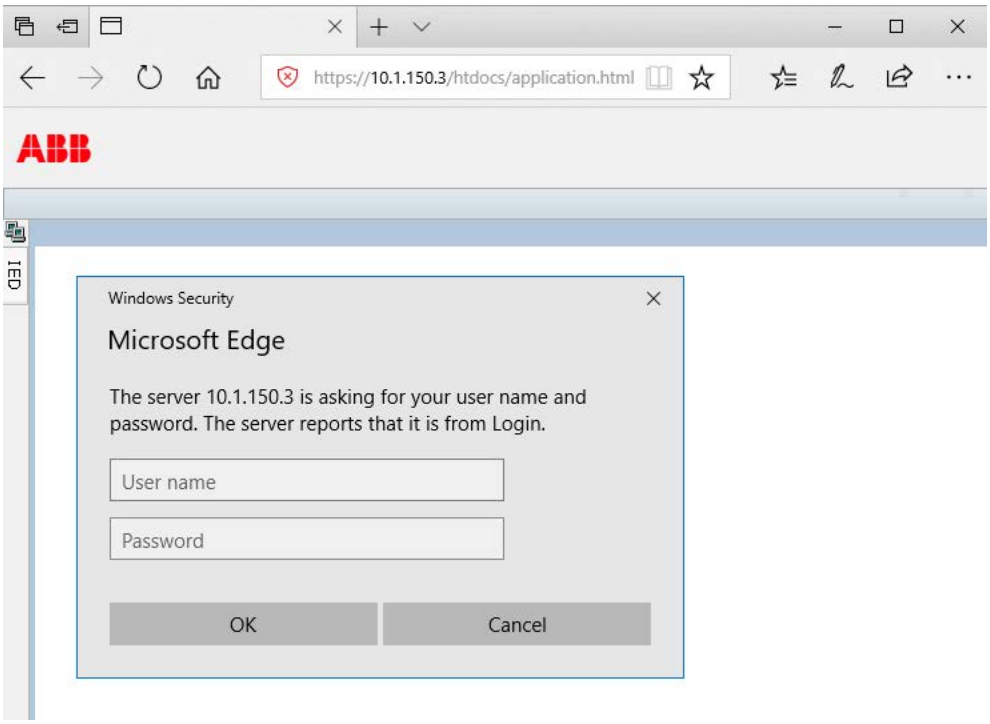


Figure 181: Initial screen after connecting to PWC600

When connecting to an IED for the first time, the browser may warn that the server's security certificate is self-signed and cannot be trusted. The same applies after changing the Technical Key in the IED. This warning is technically correct as PWC600 generates its own certificate (not issued by a trusted certification authority) for secure communication, based on its Technical Key. However, it is not relevant here because there can only be one device with a given IP address in the network. It is necessary to trust this server, or add an exception for it, for accessing the WHMI.

2. If the dialog box for entering user credentials does not open automatically, click the **Login** button .
3. Type the user name and password, and click **OK**.

With no user accounts defined in the IED, enter **Administrator** for both user name and password.

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Figure 182: Entering user name and password

11.2 Home page (Device information)

The Home page shows information on the IED, the load type and the last switching operation. This page can also be accessed from any other page.

- Click **Home** in the main menu.

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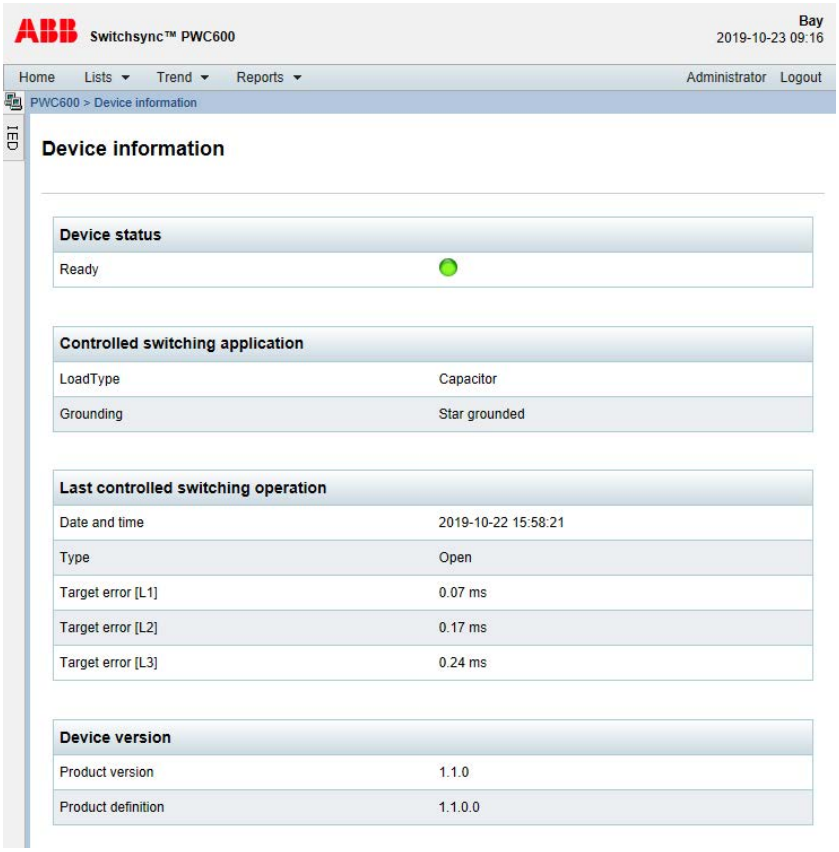


Figure 183: Device information (home page)

The following information is shown on the **Device information** page.

- Device status: The **Ready** icon mimics the status of the **Ready** / **Normal** LED on the LHMI. In normal operation it is steady green.
- Controlled switching application: Load type settings in SSCPOW function.
- Last controlled switching operation: Date and time, type (Open or Close), and accuracy (target errors) of the last CB operation controlled by PWC600. The values are updated every ten seconds. As long as no controlled switching operation has been recorded, only the first row is displayed with no values.
- Device version: Version number and release of the PWC600 firmware.

A value label prefixed by the # symbol indicates a setting/parameter that can be handled by setting groups.

11.3 Menu structure

The main menu is located underneath the product name.

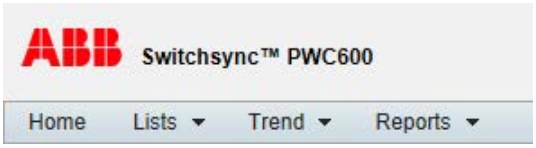


Figure 184: Web HMI main menu

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- **Home**
  Returns to the start page.
- **Lists**
  Contains Operation records, Waveform records (disturbance records), Events, Alarms and Internal Events.
- **Trend**
  Contains Close operations and Open operations. Each has several submenus containing Accuracy, CB times, CB switching, Ambient, Drive energy and Additional.
  Only those items that are available (enabled) in the settings of Switchsync PWC600 are visible in the Trend menu. For example, if only controlled closing is enabled, the Open operations submenu cannot be accessed. Similarly, if the circuit breaker auxiliary contacts are not connected to Switchsync PWC600, no measurements of the mechanical operation properties are available and the CB times and CB switching menu entries are disabled. Furthermore, Trend submenus are enabled only if the data from at least one controlled switching operation are available in the IED's operation log.
- **Reports**
  Contains Status report and Configuration report.

11.4 Warning and error messages

In case the connection between web browser and IED is lost, an error message is shown.

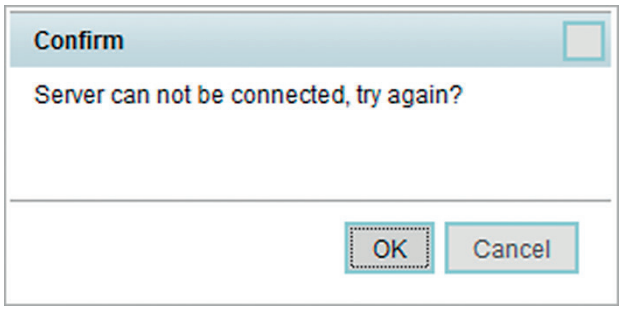


Figure 185: Error message when the connection to server is lost

- Click **OK** to continue using WHMI.
- Click **Cancel** to logout.

When connection to the IED is re-established, it may be necessary to log in again.

11.5 Selecting a list view

The list view contains Operation records, Waveform records, Events, Alarms, and Internal events.

1. Click the **Lists** tab on the menu bar.
   A drop-down list is displayed.

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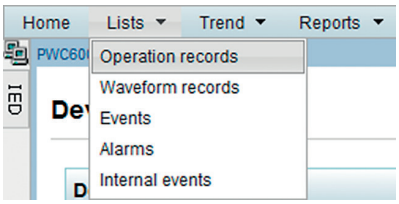


Figure 186: Lists menu

2. Click one of the list items to display the corresponding list.

11.6 Navigating between pages

Most list views can display a limited number of records on a single page. If the maximum number of records per page is exceeded, the information is distributed over several pages. Navigate between the display pages using the control elements on the screen.



Figure 187: Page navigation controls

- Select the **Latest** check box to continuously view the latest records. In this mode, the page is updated every five seconds. No page number is displayed in the **Select page** box.
- Click ⏮ to go to the page containing the latest records. Page number 1 is displayed in the text field and the **Latest** check box is automatically cleared.
- Click ◀ to go to the adjacent page containing newer records. The page number displayed in the text field is decremented and the **Latest** check box is automatically cleared.
- Click ▶ to go to the adjacent page containing older records. The page number displayed in the text field is incremented and the **Latest** check box is automatically cleared.
- Click ⏭ to go to the page containing the oldest records. The number of the last page is displayed in the text field and the **Latest** check box is automatically cleared.
- Enter a page number in the **Select page** box and click **Submit** to directly jump to a specific page of records. The **Latest** check box is automatically cleared.

Navigation controls that cannot be used in a given situation are disabled (dimmed). For example, when the last page is currently displayed, ▶ and ⏭ controls are inactive.

11.7 Operation records

Every switching command received at the command inputs of Switchsync PWC600 triggers an operation record. Each record is stamped with the date, time and the type of operation (Close or Open). This information is displayed in the WHMI **Operation records** view, in the record list on the left, and it is used to identify the individual operation records.

The same list also includes the record-specific information on electrical target errors in each phase. This value is defined as the deviation of the actual (detected) instant of current making or current interruption from the target instant. Color highlighting is used in the record list to indicate controlled switching operation status.

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Table 96: Color highlighting of operation records

Background color	Explanation
Normal (alternating white and light gray)	Successful controlled switching operation
Red	Controlled switching operation where electrical target error is above the limit in one or more phases.

Whenever a waveform record having the same time stamp as the operation record is stored in the IED, a View icon is displayed in the **Waveform record** column as shown below is displayed in the **Waveform record** column.



If no such icon is displayed then no waveform record with the same time stamp is stored in the IED. A common reason is that the maximum number of waveform records (200) has been exceeded and the oldest waveform records have been overwritten.

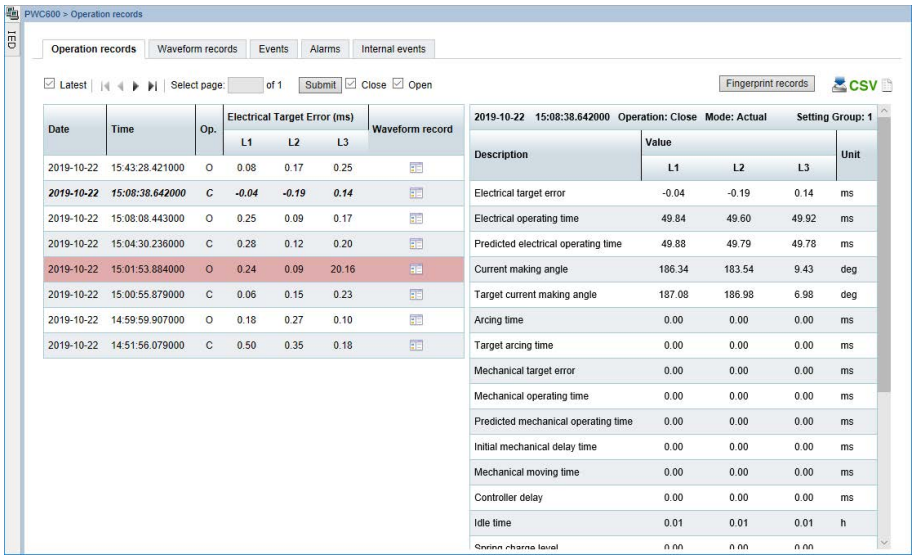


Figure 188: Operation records for Close and Open operations

The right frame of the window contains the recorded data from the selected operation. The top header repeats the record identification data. In addition, it specifies the operation mode, which is an assessment of the switching operation, and the setting group that was active at the time of the recording. The operation modes are defined by the software and cannot be changed by the user.

All data stored in relation to the respective switching operation are listed in tabular form below the header. Most data are stored and displayed per phase. Data not applying to a specific phase are listed in the L1 column.

Certain data, in particular current making angles, are relevant only for Close operations and thus the values are always displayed as zero for Open operations. Other data such as arcing times pertain only to Open operations and are always displayed as zero for Close operations.

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11.7.1 Viewing operation records

The operation records page provides access to detailed data on the past controlled switching operations.

- Select **Lists/Operation records** on the menu bar. Alternatively, when another list is already displayed, click the **Operation records** tab.
  The initial view contains the latest Close and Open records. The left frame shows a list of operations and the right frame gives details of the latest operation. The top-most row in the left frame is displayed in bold.
- To display detail data of another operation record, click the corresponding row in the left frame. The selected record is shown in **bold**.
- To display or to hide the data for Close or Open operations, select or clear the corresponding check box. At least one of the operation types should always be checked.
- Navigate between the pages with the page navigation controls if the list of operation records covers more than one page.
- To view the operation records from the very first operations controlled by this IED, click the **Fingerprint records** button. This will open a new browser window for displaying the fingerprint records in a similar format.



To prevent loss of operation data, do not power off the IED within one hour of the last update to the operation log, that is, switching operations. The same applies after clearing the operation log. This time constraint was introduced to minimize the number of write cycles to internal flash memory and cannot be changed.

11.7.2 Downloading operation records

From the Operation records view, the entire operation log database can be exported to a local CSV file. (A subset of operation records can be exported from the Trend view, see Section 11.11).

1. Click the CSV icon 

to download the file, compressed into a ZIP archive.
2. Depending on the browser's settings, you may need to specify the path and filename. Otherwise, it will be stored as OpLog.zip in the default folder for downloaded files, or opened directly in the app associated with ZIP archives.
3. Unpack the OpLog.zip archive by a suitable tool. The resulting file is named OpLog.csv by default.
4. Open the OpLog.csv file in a spreadsheet program.

The data in the exported file are arranged in blocks according to the OPERLOG function instances in the application configuration. Each block contains identical data for identification of the individual records, only the actual recorded data differ.

11.8 Waveform records

Every switching command received at the command inputs of Switchsync PWC600 triggers the disturbance recorder. It records the sampled voltage and current traces as well as relevant binary signals before and after the trigger event. Only those binary channels that have been On (1) at any time during the recording period are included.

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For controlled switching, switching events are usually not triggered by a system disturbance. Thus, within the context of Switchsync PWC600, disturbance records are called "waveform records" in most places.

By default, Switchsync PWC600 stores waveform records of the latest 200 operations, overwriting the oldest one with the latest one. The waveform records are stored in COMTRADE format, comprising three files with the same name but different extensions (.dat, .cfg and .hdr). These can be viewed online or opened and analyzed by tools such as WaveWin, which is included in the PCM600 installation package. For easy downloading from PWC600, all files comprising one waveform record are packed into a ZIP file.

11.8.1 List of waveform records

- On the main menu, click **Lists/Waveform records**.
  Alternatively, when another list is already displayed, click the **Waveform records** tab.

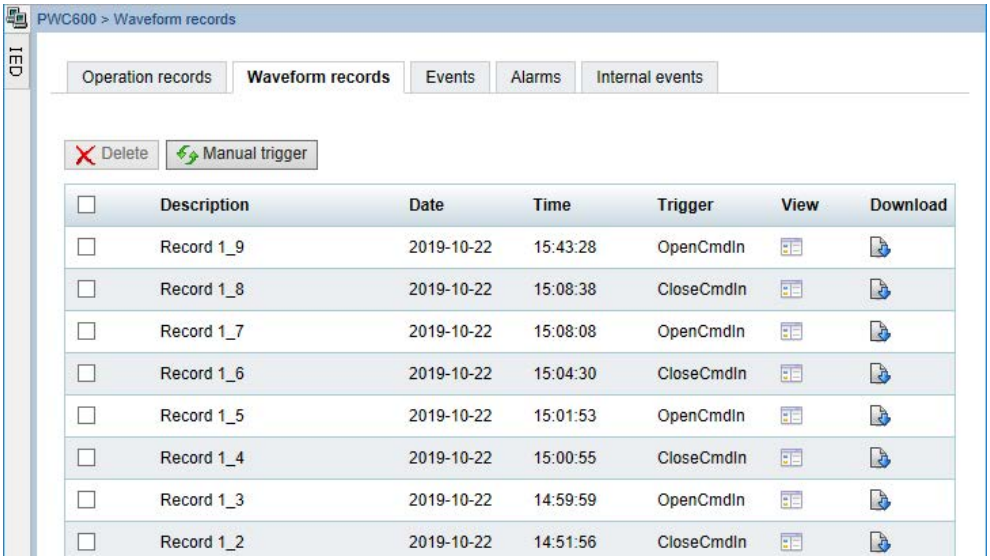


Figure 189: List of waveform records in WHMI

- To view a specific waveform record online, click the corresponding **View** icon.
  The record is opened in the graphical viewer in WHMI.
- To save a waveform record to the local computer, click the corresponding **Download** icon.
  Depending on the settings of the Web browser, one of the alternative actions follows.
  - The downloaded file is opened in the default program for handling ZIP files.
  - The file is stored in the default folder for downloaded files.
  - A file selector dialog opens where the location and name of the ZIP file can be entered.
  - The user is prompted to choose one of the above actions.
- To delete one or more waveform records from the IED, select the corresponding check boxes and click **Delete**. Note that it is not possible to recover files deleted in the IED.
- Click **OK** in the confirmation dialog.



To select or deselect all records at once select the check box in the header of the list.

- To manually initiate a waveform recording, click **Manual trigger**.

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Delete and **Manual trigger** operations are available only to users logged in with Engineer or Installer privileges.

11.8.2 Waveform viewer

Switchsync PWC600 features an online viewer for displaying stored waveform records graphically in the WHMI.

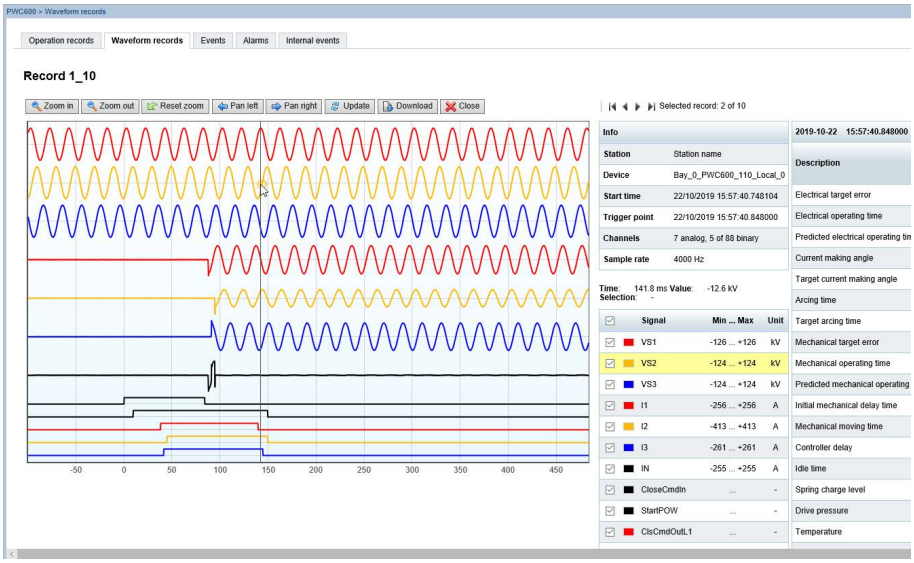


Figure 190: Waveform viewer in WHMI

The waveform viewer can be used only for online display of waveform records stored in the IED. It is optimized for quick assessment of controlled switching operations. For offline viewing and full-featured analysis of waveform records, download the record to the local computer and open it in a COMTRADE viewer such as WaveWin.

The **Info** table provides essential information about the waveform record.

- **Station** and **Device** identify the location of the controlled circuit breaker and Switchsync PWC600, specified by the TERMINALID parameters.
- **Start time** gives the time stamp of the first sample in the record.
- **Trigger point** gives the time stamp of the received switching command that triggered the recording, which is the same as shown in the list of waveform records. All other times within the record are counted relative to this instant.
- **Channels** gives the number of signals that are included in the record. Only those binary channels which have been 1 at any time during the recording period are included, hence the actual number is usually far lower than the maximum.
- **Sample rate** specifies the number of samples per second, same for each channel.

By default, the entire waveform record, containing all signals over the entire recording period, is displayed in the graph area. The horizontal axis displays the time in milliseconds relative to the trigger point, which is the time stamp of the waveform record.

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Each analog channel is auto-scaled individually. The calculated minimum and maximum values of each channel are displayed under **Min ... Max** in the **Signal** list. These values depend only on the recorded data and are arranged symmetrically to zero; they cannot be changed by the user.

If an operation record with matching time stamp is stored in the IED, the detail list of that operation record is displayed to the right of the **Info** table.

11.8.3 Viewing and managing waveform record graphs

1. Click the **View** icon of the requested record in the records list to open the waveform record graph.
2. To hide one or more signals from the graph, clear the corresponding check box in the signal list and click **Update**.



Select or deselect all channels at once by clicking the check box in the header of the signal list.

3. Use the mouse pointer to adapt the view.
   - Position the mouse pointer over the plot area to control the vertical cursor. The current time value of the cursor is displayed dynamically in the **Time** field. When the mouse pointer approaches a signal trace on the graph, it snaps to the nearest actually recorded point, which is marked by a small circle. The corresponding row in the signal list is highlighted in yellow. For analog signals, the primary value of that point is displayed in the **Value** field.
   - Click and drag the pointer within the plot area to select a horizontal range. The length of the selected range together with its limits are displayed in the **Selection** field. Click anywhere inside the plot area to clear the selected range.



While a horizontal range is selected, moving the mouse pointer over the plot area continues to update the **Time** and (if applicable) **Value** fields. No vertical cursor is displayed.

4. Use the available buttons and the mouse pointer to navigate horizontally in the graph.
   - To enlarge the middle of the graph, click **Zoom in**. No horizontal range should be selected.
   - To shrink the middle of the graph, click **Zoom out**.
   - To enlarge the area around the mouse pointer, turn the mouse wheel up (if available). No horizontal range should be selected.
   - To shrink the area around the mouse pointer, turn the mouse wheel down (if available).
   - To enlarge a specific area of the graph, select a horizontal range and click **Zoom in** or turn the mouse wheel (if available) up.
   - To display the full time range of the record, click **Reset zoom**.
   - After zooming in, to move the displayed range along the time axis, click the **Pan left** or **Pan right** buttons.



Vertical zooming is not possible in the online waveform viewer. To enlarge an analog signal vertically, hide as many other signals as possible. Alternatively, download the waveform record to the local system and open it in a COMTRADE viewer such as WaveWin.

5. To save the entire waveform record to the local computer, click **Download**. Depending on the settings of the Web browser, one of the alternative actions follows.

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- The downloaded file opens in the default program for handling ZIP files.
- The file is stored in the default folder for downloaded files.
- A file selector dialog opens for entering the location and name of the ZIP file.
- The user is prompted to choose one of the above actions.

6. To open another waveform record, click the appropriate navigation arrow | ⏮ ◀ ▶ ⏭ |.
7. To close the waveform viewer and return to the list of waveform records, click **Close**.

11.9 Alarms

Alarms are generated by abnormal conditions detected by Switchsync PWC600. Two types of alarms are defined and distinguished under **Alarm type**.

- Warnings report conditions that are not critical but may become critical if not attended to.
- Alarms report conditions that are considered critical and should be attended to at once.

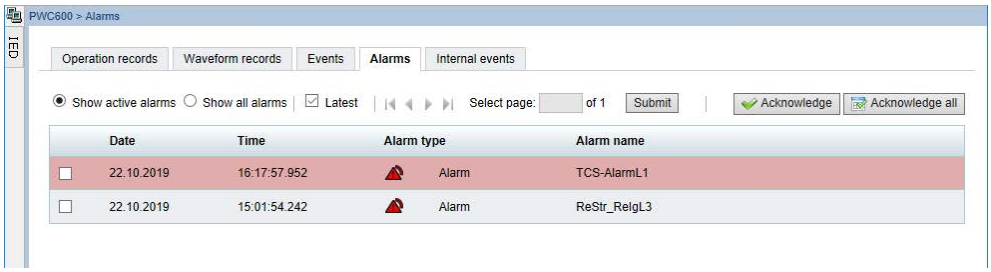


Figure 191: List of active alarms

Initially when raised, any entry in the alarms list is active. The user can acknowledge an alarm. If the original alarm condition is gone, the alarm is removed from the list of active alarms. Otherwise it is still shown although with different background color. The user name and the time stamp of acknowledging are logged for each alarm and can be viewed in the list of all alarms.

No special user privileges are required to acknowledge alarms.

11.9.1 Viewing and acknowledging alarms

- To view only active alarms, click **Show active alarms**.
  This is the default view.
- To view all active and acknowledged alarms, click **Show all alarms**.
- To acknowledge one or more alarms, select the corresponding check boxes and click **Acknowledge**.

To select several adjacent alarms, drag a rectangular selection area over the respective list rows.

- To acknowledge all alarms on the page, click **Acknowledge all**.

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11.10 Events and internal events

The lists of events and internal events contain time-stamped records of status changes of specific binary signals. Events are created by the application and can be configured in ACT. Conversely, internal events are created by the IED's operating software and cannot be modified.

Each entry in the list contains the time stamp of the status change (date and time), the name of the supervised signal and its final value after the status change. The list of events can extend over several display pages, whereas all internal events are displayed on a single page in WHMI.

11.11 Trend graphs

The trend view graphically represents the data logged in operation records for a selected set of signals.

1. Click **Trend** on the menu bar, select the operation type (Close or Open) and the category of trend data to view.
   Only those signal categories can be selected for which data exist in the operation records. If no operation records are stored in the IED, all signal categories are disabled.

   Updating the main menu to reflect a change in available data (for example, after recording the first operation by this IED)can take up to two minutes.

2. Click one of the available tabs to view the trend of the selected data logged in the operation records.
   The content of the list under each tab depends on the application configuration (settings entered in Switchsync Setting Tool). Only those signal category tabs are visible for which data exist in the operation records. When a trend page is opened for the first time, certain data are selected by default. Once the selection is changed, it is preserved for that specific login session, even if the user moves to another page.
   - To view electrical and mechanical target errors, click the **Accuracy** tab. Electrical target errors are shown by default.
   - To view mechanical operating times, initial mechanical delay times and mechanical moving times, click the **CB times** tab. If available, mechanical operating times are shown by default.
   - To view current making angles and arcing times, click the **CB switching** tab. Current making angles are shown by default for Close operations and arcing times for Open operations.
   - To view control voltage, idle time and temperature, click the **Ambient** tab. Idle time is shown by default.
   - To view drive pressure and spring charge levels, click the **Drive energy** tab.
   - To view the additional compensation quantity with the user-defined designations, click the **Additional** tab.
3. To define the signals to be displayed in the trend graph, select the corresponding check boxes in the signal list and click **Apply**.

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The arcing time listed under the **CB switching** tab in the **Trend** (Close operation) page is relevant only for Open operations. Thus, the value is always zero if arcing time is selected. Similarly, the current making angle listed under the **CB switching** tab in the **Trend** (Open operation) page is relevant only for Close operations. Thus, the value is always zero if the current making angle is selected.

4. To export the currently selected trend data to the local computer, click CSV. This works on the selection parameters as entered on the screen, even if the actual graph has not been updated by clicking **Apply**.
5. Click the respective option under **Select view** to change the view mode to time view or equidistant view.
   By default, trend data are shown in the equidistant view.

When the mouse pointer is positioned over the plot area, it controls a vertical cursor. On approaching a signal trace on the graph, it will snap to the nearest actually recorded point (corresponding to a switching operation), which is marked by a small circle. A tool tip displays the signal name, time stamp of the operation and the primary value of that signal.

Trend views are not dynamically updated with addition or deletion of the operation records.

11.11.1 Changing the range of data points in equidistant view

In the equidistant view mode, data points are plotted at equal horizontal spacing, regardless of the actual time difference between them. The horizontal axis labels the record numbers.

Up to 100 data points can be shown in a graph at once; this limit cannot be changed.

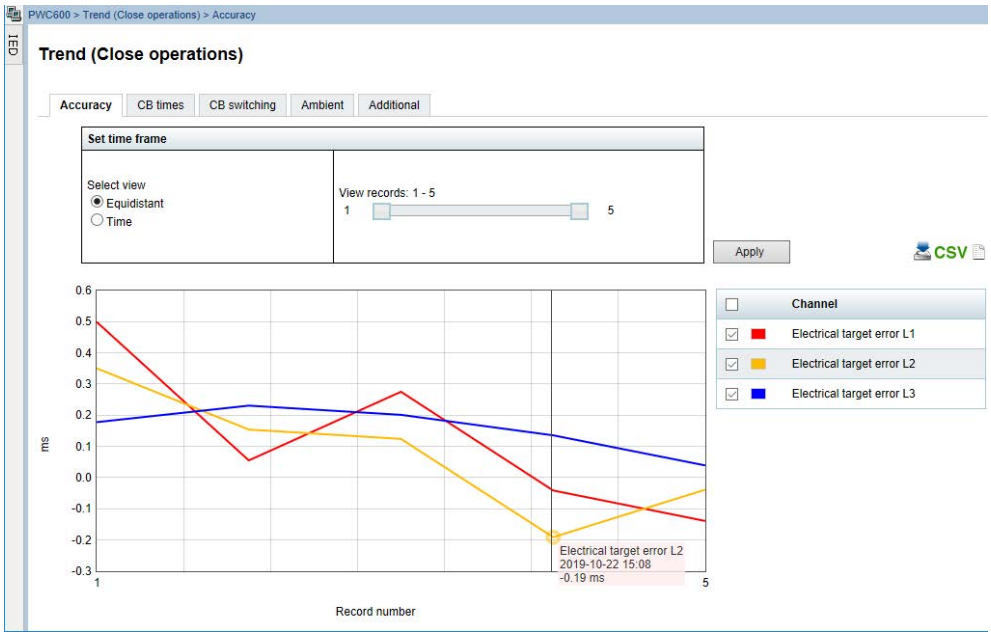


Figure 192: Equidistant trend view

- Drag the sliders on the **View records** bar and click **Apply** to change the range of data points to plot.

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11.11.2 Changing the range of data points in time view

In the Time view mode, data points are plotted at variable horizontal spacing reflecting the actual time difference between them. The horizontal axis labels the time stamps of the records. This is useful for visualizing the impact of time on the viewed quantities.

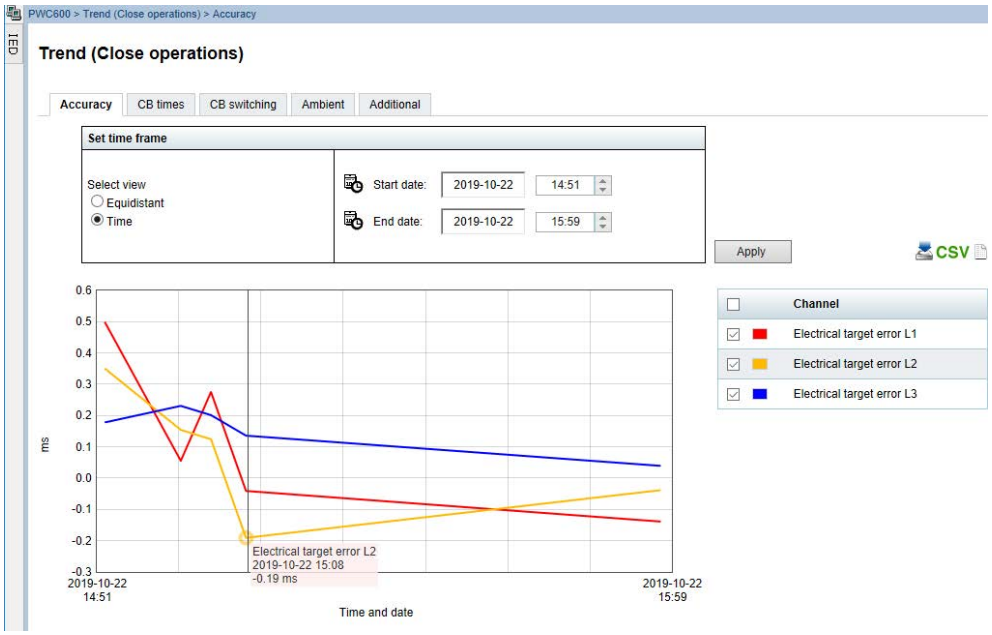


Figure 193: Time view of trend

- Adjust **Start date** and **End date** and click **Apply** to change the range of data points to plot. Up to 250 data points can be shown in a graph at once; this limit cannot be changed. If a larger data range is selected, the Web interface combines adjacent data points automatically and displays their average value as a single point. This condition is flagged by a message text on the screen (Figure 194).

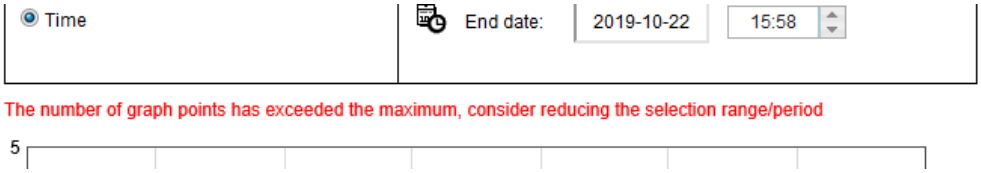


Figure 194: Message for too many data points selected

Click the **Start date** or **End date** box to open a calendar control and select the date with the mouse pointer.

Click the associated up and down buttons to adjust the **Time** fields. Holding the button pressed increases the change rate.

If no data are recorded in the selected interval, an error message is displayed.

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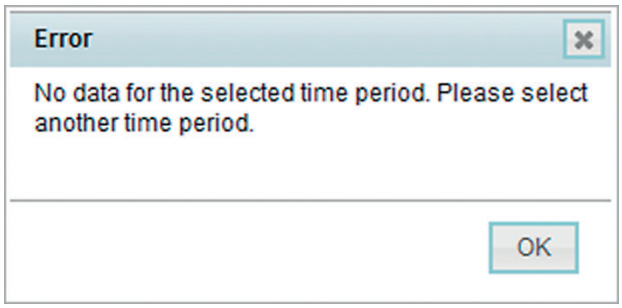


Figure 195: Error message for invalid time period

11.12 Generating reports

Reports are useful in communicating with ABB for troubleshooting an IED.

1. Click **Reports** on the menu bar.
2. Click **Configuration report** to generate a configuration report.
   A new window opens.

Configuration report

Product Information	
Description	**Value**
Device Name	Bay
IED Product Type	PWC600
Product Definition	1.1.0.0
Serial Number	T1111111
Ordering Number	1MRK009100-AB
Production Date	2019-10-10
Front IP Address	10.1.150.3
Rear IP Address	192.168.1.10

Installed Hardware		
Position	**Card**	**Article number**
pCOM	COM03	1KHL178039R0002-G
pPSM	PSM03	1KHL178082R0001-A
p2	TRM01_4I_6U	1KHL178083R0003-A
p3	PIO01	1KHL178089R0004-D
p4	BIO01	1KHL178074R0001-D
pHMI	600LMI01	1KHL160042R0001-G

Figure 196: Configuration report

3. Click **Status report** to generate a status report.
   A new window opens.

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Status report

Product Information	
Description	**Value**
Device Name	Bay
IED Product Type	PWC600
Product Definition	1.1.0.0
Serial Number	T1111111
Ordering Number	1MRK009100-AB
Production Date	2019-10-10
Front IP Address	10.1.150.3
Rear IP Address	192.168.1.10

IED Status	
Item	**Status**
Internal fail	Off
Internal warning	Off
Time synch	Ready
Real time clock	Ready
Application	Ready
Runtime execution	Ready
IEC61850	Ready
COM03	Ready

Figure 197: Status report



To transfer the information from a report to another application, select the report with the mouse, copy it to the operating system's clipboard, and paste it into a text editor or word processor.

11.13 IED menu

Clicking the **IED** tab opens the IED menu, which is similar in structure to the menu on the LHMI. It allows online access to many data and functions that otherwise are available only locally on the IED.

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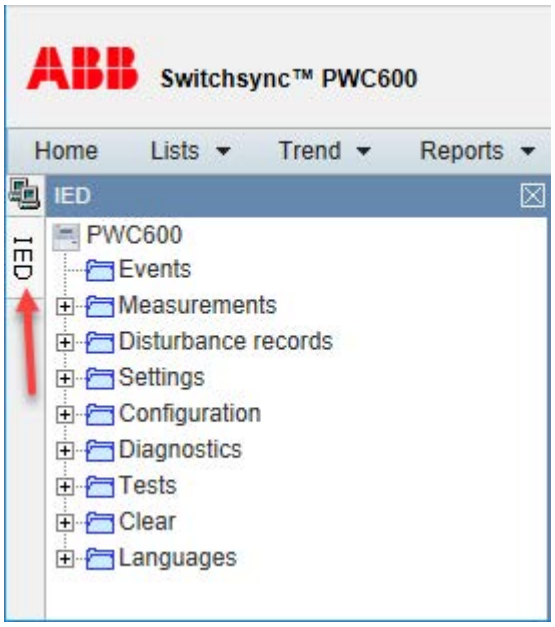


Figure 198: IED menu in WHMI

- Click the [+] icon to expand a menu item.
- Click the [–] icon to collapse a menu item.
- In order to change a parameter/setting value:

1. Navigate to the function instance where the parameter resides (in the appropriate section under **Settings** or **Configuration**, as in the Plant structure in PCM600). The list of all parameters from the currently selected setting group in this function is displayed.

   Under the Settings menu, a parameter name suffixed by the # symbol indicates that this setting/parameter can be handled by setting groups.

2. Click **Enable write** button to make all **New value** fields editable.
3. Change the settings as desired.
4. Click **Write to IED** button to send the new values to the IED.
5. Click **Commit** button to start using the new values in the function.

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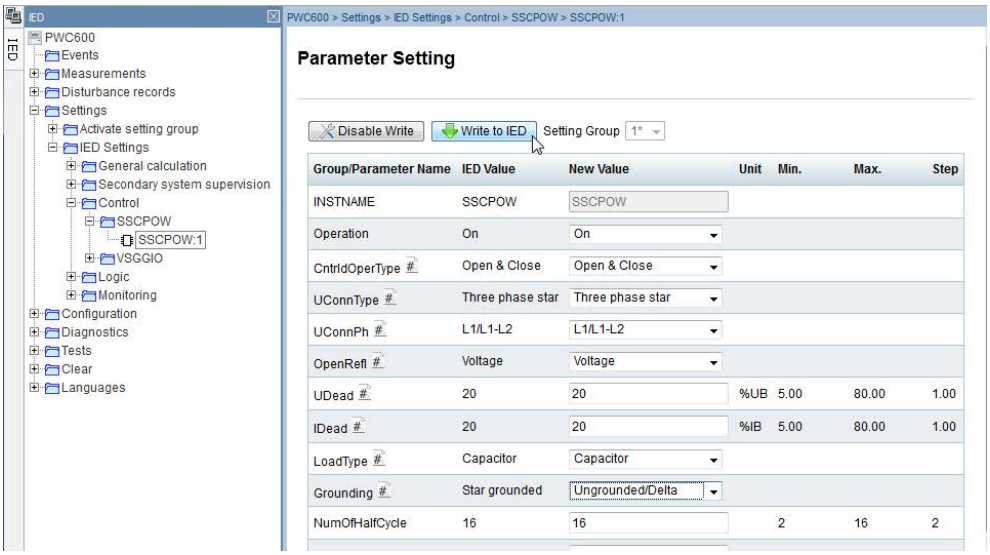


Figure 199: Changing setting values from WHMI

Setting changes made in WHMI are not automatically reflected in PCM600. Therefore, after finalizing the settings in this way, make sure to read the changed settings back into PCM600, from where the entire configuration can be exported or archived.

- Click the [X] icon to close the IED menu.

For further description of the various items in the IED menu refer to Section 10.

11.14 Logging out

- To log out, click **Logout** on the menu bar.



Figure 200: Logout

After a certain period of inactivity, the WHMI user is automatically logged out. This Web client timeout is set in the Web server. The default timeout is 15 minutes.

Always log out properly before closing the browser window. Otherwise, the user session will remain active in the IED until session timeout, which may result in blocking new login attempts.

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Section 12 Commissioning

All work described in this section will be performed inside the control room or in the field kiosk where PWC600 is installed. No work is foreseen to be carried out in the switchyard unless otherwise noted.

If any errors are detected and corrected in wiring, or the circuit breaker is re-adjusted during the commissioning, all related tests should be repeated.

The entire proposed test procedure follows the guidelines given by CIGRÉ Working Group A3.35 (controlled switching).

12.1 Commissioning checklist

Before starting commissioning at site, ensure that the following items are available.

- Single-line diagram including locations of connected measuring devices (CTs and PTs) within the bay or the station
- Specification and design configuration of the equipment to be switched
- Specifications of connected current and voltage transformers (ratio, accuracy class, burden)
- Circuit diagram showing connections of the Switchsync PWC600 IED and the controlled circuit breaker
- Routine test results for individual poles of the circuit breaker
- Equipment for primary or secondary injection of voltage and current
- Equipment for measuring loop resistance and earthing resistance
- Equipment for measuring insulation resistance
- If CB timing test is to be performed: cables and accessories for connecting the circuit breaker's primary contacts to the designated binary inputs of Switchsync PWC600
- Intended switching duty and setting targets with expected results
- PC with PCM600 installed along with the latest connectivity packages corresponding to the IEDs to be tested
- Project data file (.pcmp) or IED configuration files (.pcmi) containing the configured IED objects, which are the output of the application engineering process
- Administrator rights on the PC to set up IP addresses if necessary
- RJ-45 Ethernet cable (CAT 5, crossover)
- Product documentation

12.2 Preparations

Before starting any work other than live commissioning, the switch bay must be taken out of service and the CB must be isolated. All required measures for the protection of persons and equipment must be taken. This may include wearing personal protection equipment if working directly next to live high voltage equipment.

Roles and responsibilities during the on-site work shall be clearly defined, e.g. the commissioning engineer handles PWC600 (and the CB if necessary), whereas all switching operations are initiated by a plant operator.

Before commencing live switching operations, protection systems must be tested and operational. It is advisable to temporarily adjust relay settings such that they will tolerate voltage and current transients caused by non-ideal controlled switching.

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12.3 Checking 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 could be done in a number of ways, from energizing a whole cubicle to energizing a single IED.
- Set the IED's system time in **Main menu/Configuration/Time**, if no time synchronization source is configured.
- Check the self-supervision function in **Main menu/Diagnostics/Internal events** or **Main menu/Diagnostics/IED status/General** menu in local HMI to verify that the IED is functioning properly.
- Write the application configuration to the IED, as described in the Section 9.5.

12.4 Checking CT circuits

- Ensure that the wiring is in strict accordance with the supplied connection diagram.
- Perform a primary injection test to verify the current ratio of the CT, the correct wiring up to the Switchsync PWC600 IED and correct phase sequence connection (L1-L2-L3 or L1-L3-L2).
- Measure CT secondary loop resistance 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.
- Check the earthing 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.
- Check the insulation resistance.



CT and VT connectors on the IED are pre-coded, and the CT and VT connector markings are different. For more information, see the Section 7.3.1.

12.5 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 check must be performed as close to the IED as possible.

The primary injection test verifies the VT ratio and the wiring all the way from the primary system to the IED. 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.

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12.6 Checking binary input and output circuits

12.6.1 Binary input circuits

Preferably, disconnect the binary input connector from the binary input cards. Check that both input level and polarity of all connected signals are in accordance with the IED specifications and the wiring scheme.

12.6.2 Binary output circuits

Preferably, disconnect the binary output connector from the binary output cards. Check that both load and polarity of all connected signals are in accordance with the IED specifications and the wiring scheme.

12.6.3 Circuit breaker control wiring

As further proof of the correctness of the wiring it is suggested to execute individual mechanical operations of each CB pole from PWC600.

If the circuit breaker control has a function that acts on pole discrepancy that function needs to be disabled during this test.

Circuit breaker timing test mode (Section 12.8.2) also controls each CB pole individually and provides a graphical user interface. If it is possible to connect the CB's main contacts to the PWC600 IED it is recommended to use that feature.

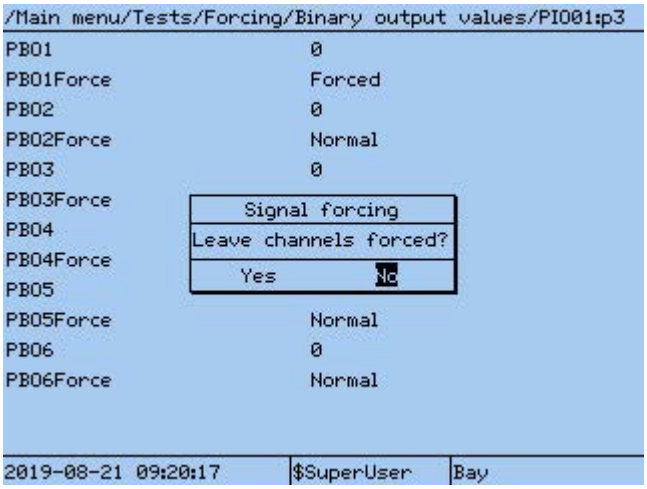
Operation of a single CB pole can be initiated from the LHMI.

1. Navigate to **Main menu/Tests/IED test mode/TESTMODE:1**.
2. Set *TestMode* to "On".
3. Press **Left/Enter** to save the changes. The "Start" LED starts flashing slowly to indicate active IED Test Mode.
4. Navigate to **Main menu/Tests/Forcing/Binary output values/PIO01:p3**. All CB control outputs (*PBO1...6*) are normally off (0) with the respective *PBOxForce* set to "Normal".
5. Manually activate any CB control output by changing its *PBOx* value to 1. (See Section 7.4.1 or the PWC600 wiring diagram for the default function assignment of each PBO).

   Forced changes on a binary output take effect immediately, without the need for explicit saving. If the corresponding *PBOxForce* has been "Normal" before it is automatically changed to "Forced".

6. Turn off the same output by changing its *PBOx* value to 0.
7. Check the circuit breaker whether the intended pole has performed the intended operation.
8. Repeat steps 5...7 for the other circuit breaker poles and the operation types (Close/Open) for which the control signals are connected to PWC600.
9. Exit the Forcing menu by pressing the **Left** key.
10. In the **Signal forcing** dialog box, select No and press **Enter** to end all output forcing.

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11. Navigate to **Main menu/Tests/IED test mode/TESTMODE:1**.
12. Set *TestMode* to `Off`.
13. Save the changes. The “Start” LED is switched off and the IED resumes normal operation.

12.7 Checking optical connections

- Check that the Tx and Rx optical connections are correct.
- Check the 9-2 LE optical connection and PPS connection in case the current or voltages are received from an IEC 61850-9-2(LE) merging unit.

An IED equipped with optical connections requires a minimum clearance 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.

12.8 Circuit breaker operating times

For accurate controlled switching, Switchsync PWC600 needs to know the mechanical operating times of the controlled circuit breaker, that is, the times from switching command to primary contact touch/separation. By default, it takes these from the type data of the CB model selected in SST. However, actual operating times of each circuit breaker pole should be used. These can be entered manually, or acquired by Switchsync PWC600 itself.

12.8.1 Entering operating times manually

If the actual mechanical operating times of the circuit breaker are available from recent commissioning tests, they can be entered directly in the Switchsync Setting tool.

1. In PCM600, open the Switchsync Setting tool for the IED.
2. Select **Start new session** and click **OK**.
3. In the list of milestones in the left frame, click the last item **Breaker Times**.

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The entire list of milestones is displayed only when the IED has been configured previously through the Switchsync Setting tool. If the Breaker Times milestone is not visible, enter the missing information as described in Section 9.2.

4. Enter the actual mechanical closing times of each circuit breaker pole.
   For values that are unknown, leave the default values.

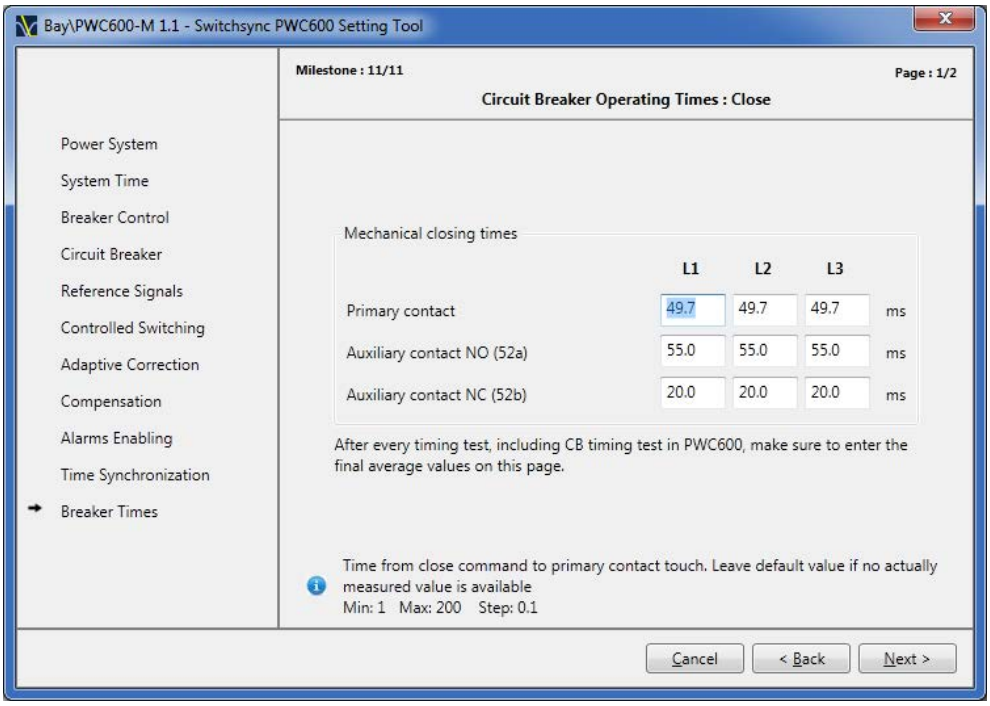


Figure 201: Entering actual circuit breaker operating times for close operations

The fields for entering auxiliary contact times are displayed only when auxiliary contacts are connected and enabled by corresponding settings under the **Reference Signals** milestone.

5. Click **Next**.
6. Enter the actual mechanical opening times of each circuit breaker pole.
   For values that are unknown, leave the default values.
7. Click **Finish**.
8. Write the settings to the IED, as described in Section 9.3.

The values entered here are applied only when in function block CBLEARN the parameter *AvgSetSet* is set to the default value *SetOPisDefaultValues*.

When different operating time values have been entered for the circuit breaker, reset the CB adaptive correction and the "CB unstable" evaluation in all three phases.

1. From the LHMI main menu, navigate to **Clear/Clear CB cond. indicators/Clear adaptive comp/ACBMSCBR:1**.
2. Press → followed by ↵.
3. Repeat the above two steps for ACBMSCBR:2 and ACBMSCBR:3.
4. Repeat the above procedure for the three instances of **Clear/Clear CB cond. indicators/ Clear unstable mode/ACBMSCBR:x**.

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12.8.2 Circuit breaker timing test mode

Circuit breaker test mode is a user interface for the commissioning engineer, which automatically acquires the operating times of the main contacts and auxiliary contacts (optionally). It is, however, not recommended in already live substations, where electromagnetic fields may interfere with the measurements.

For mechanical switching operations, Switchsync PWC600 is inserted into the circuit breaker control circuits. During every controlled operation it measures the mechanical closing and opening times of each circuit breaker pole. After each operation, the results are presented to the operator to accept or reject them. When sufficient number of accepted results are available, they are averaged for each pole and made available internally for use in subsequent controlled switching operations.

In addition to the primary contacts, the timing of auxiliary contacts - preferably one at the start and one at the end of the motion - can be acquired and used for monitoring the circuit breaker operations.

12.8.2.1 Electrical connections

Circuit breaker test mode utilizes the electrical connections that are already in place for point-on-wave control of the circuit breaker.

- Close and/or open command inputs (BI)
- Command outputs to close and/or trip coils (PBO)
- Optionally, inputs (PBI) from auxiliary contacts NO (52a) and/or NC (52b)

Certain additional connections are needed for applying the circuit breaker test mode.

- Each primary contact must be connected via a DC supply to PBI.

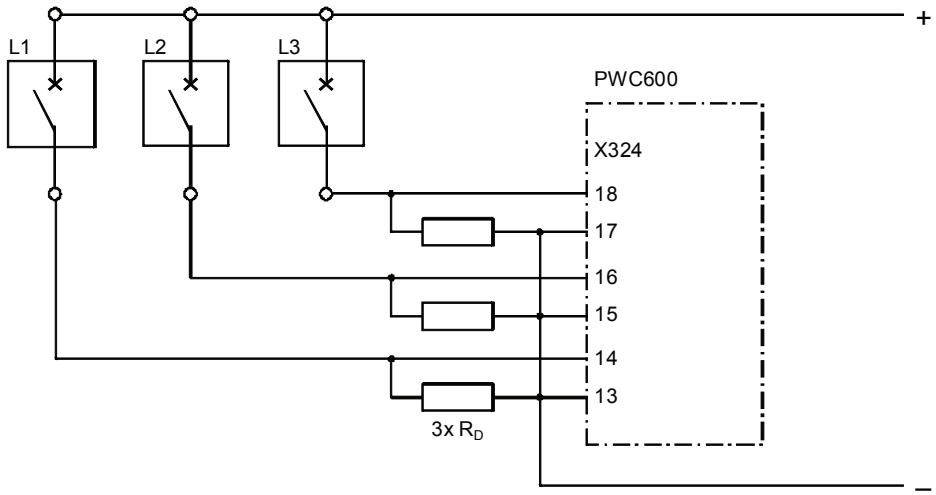


Figure 202: Temporary wiring for DC measurement

These connections are only temporary. The corresponding inputs are otherwise assumed as unused in Switchsync PWC600.

R_D are discharge resistors, which are defined in the binary inputs section. They can be installed permanently or temporarily.

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The contacts and the operation types for which timing is measured are defined by the options selected in Switchsync Setting Tool:

- **Breaker Control/Controlled breaker operations**
- **Reference Signals: Feedback Signals/Auxiliary contacts connected**

12.8.2.2 LHMI navigation

After establishing and verifying all electrical connections as specified above, activate the circuit breaker test mode from the PWC600 LHMI.

1. From the main menu, navigate to **Tests/CB test mode**.

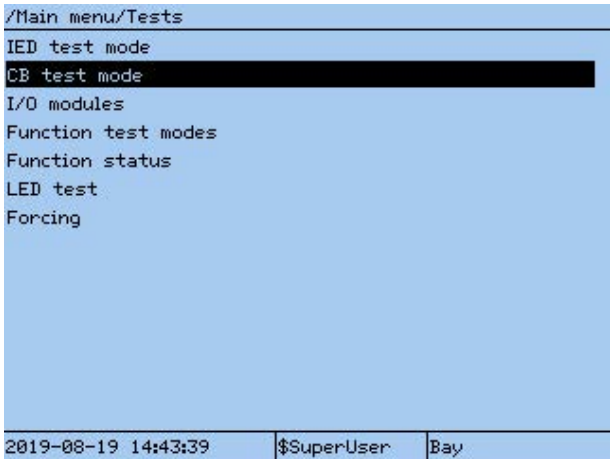


Figure 203: CB test mode menu

Switchsync PWC600 should not be in IED test mode while running CB test mode.

2. Select **Enter CB test mode**. A confirmation dialog box is opened to enter CB test mode.

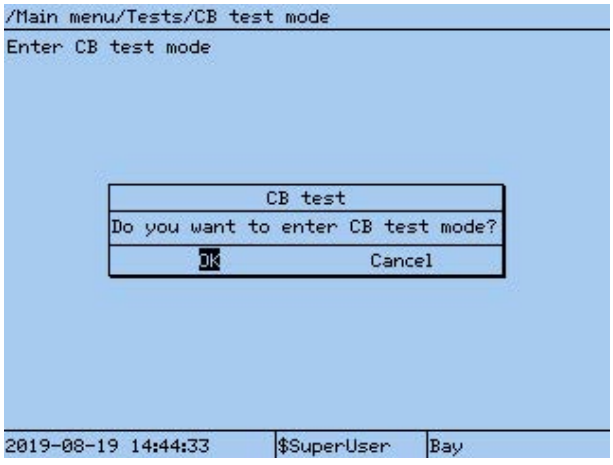


Figure 204: CB test mode activation dialog

3. With OK selected, press the **Enter** key.
CB test mode operation page opens.

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LED_15 flashes continuously whenever Switchsync PWC600 is in circuit breaker test mode.

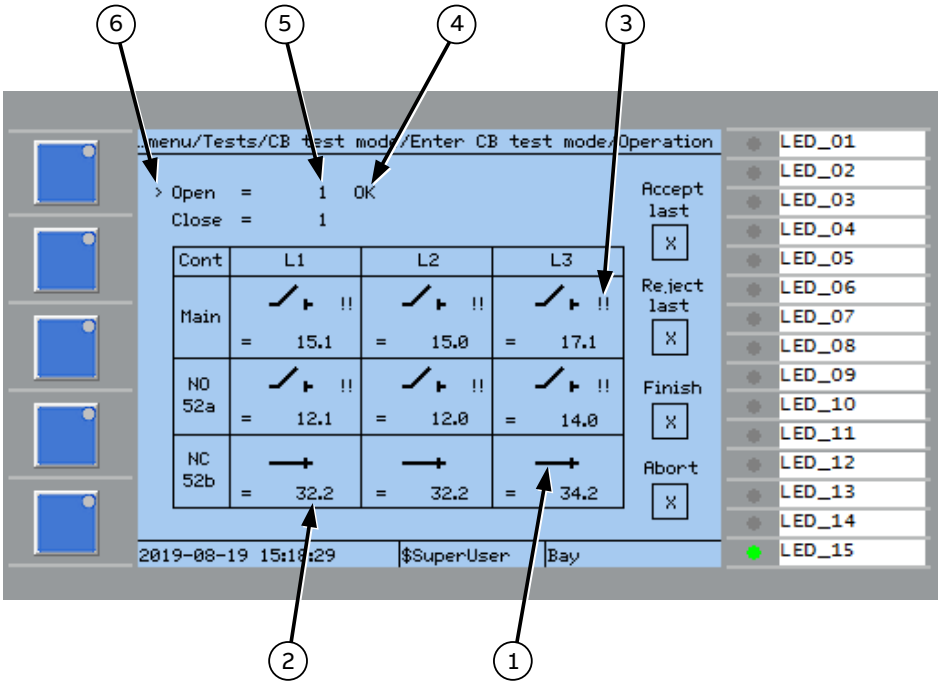


Figure 205: CB test mode operation page

1 Position of the contact
2 Measured timing of last operation
3 Symbol for warning on inaccuracy or wiring error
4 Status of the last operation:
Ok = Successful
Failed = Error in contact wiring
5 Count of operations
6 Indication which operation was last

Reject last, **Accept last**, **Finish**, **Abort** are "soft buttons" for manual intervention. Select a soft button by pressing or until it is highlighted. A selected soft button is operated by pressing the **Close** button followed by on the front panel.

CB test mode will remain active, even when navigating back to the main menu, until terminated by **Finish** or **Abort**.

The averaged opening and closing times are presented on additional display pages, which are accessed using the on the LHMI.

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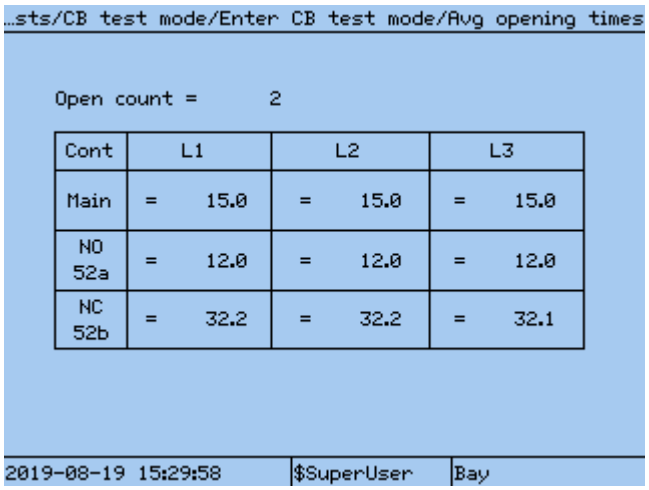


Figure 206: CB test average opening times

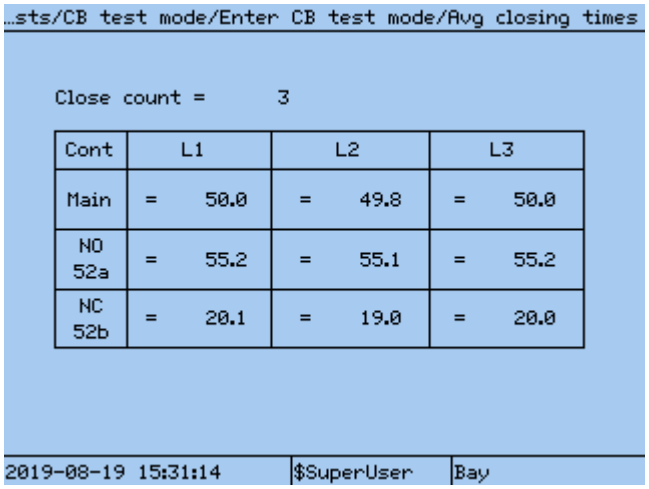


Figure 207: CB test average closing times

When Switchsync PWC600 is configured only for controlled opening operations, controlled closing operations are disabled. This is indicated by a text "Disabled" next to the Close count in **Avg closing times** page. Similarly, when Switchsync PWC600 is configured only for controlled closing operations, the controlled opening operations are disabled. This is indicated by a text "Disabled" next to the Open count in **Avg opening times** page.

To exit the CB test mode display pages (**Operation**, **Avg closing times**, **Avg opening times**) press . Note that by doing this, CB test mode is still active. To re-enter the CB test mode user interface repeat the steps described above.

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12.8.2.3 Circuit breaker contact status

In circuit breaker test mode, PWC600 checks the status of all connected CB contacts for plausibility. Initially, it assumes that the breaker is open, where the contacts should correspond to Table 42.

Table 97: Expected status of contacts when CB is open

Contact	L1	L2	L3
Main	Open	Open	Open
NO (52a)	Open	Open	Open
NC (52b)	Closed	Closed	Closed

After closing the breaker, the contacts should correspond to Table 43.

Table 98: Expected status of contacts when CB is closed

Contact	L1	L2	L3
Main	Closed	Closed	Closed
NO (52a)	Closed	Closed	Closed
NC (52b)	Open	Open	Open

Only those contacts that are connected to the PWC600 IED, and configured accordingly, are considered in checking breaker status.

If any contact does not comply with the expected status PWC600 assumes a static wiring problem, which it flags by displaying an error indicator on the screen and by activating LED 13.

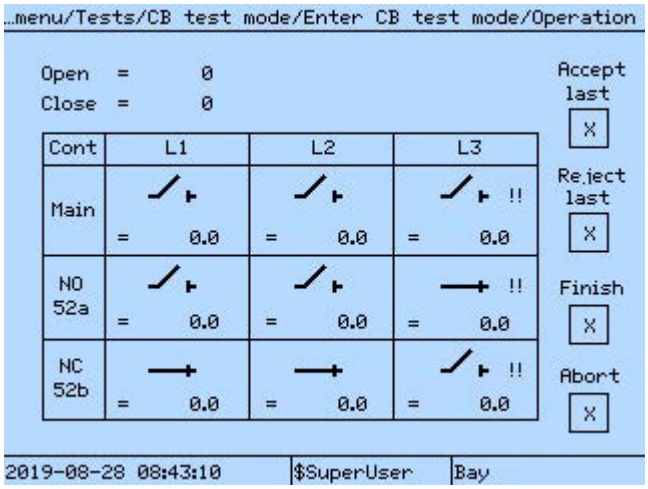


Figure 208: CB test mode indicating wiring error in phase L3

During switching operations in CB test mode, PWC600 further checks whether only contacts of the same CB pole change status within the expected time from the command. For this purpose, the switching output commands are staggered by few hundred milliseconds between phases. With that, the function can detect wires swapped between phases, which will also be indicated by on-screen error display and LED 13.

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12.8.2.4 Operation

After entering CB test mode and verifying that no static wiring errors are detected, execute several CB operations through external switching commands. Assuming the breaker is initially open, and that both Close and Open commands are wired through PWC600:

1. Issue a CB Close command to PWC600 and wait until all three CB poles are closed. The display is updated with the automatic evaluation of the operation.
2. Check for error indications “!!” on the screen and for activation of LEDs 13 or 14, and assess the plausibility of the displayed switching times. PWC600 will flag an error in case of invalid contact status (wiring error) or switching times outside the expected range.
3. When the closing operation is deemed successful, the measured switching times will be included in the average by either of these actions:
   - Explicitly accept the operation results by selecting and activating **Accept last** on the screen, as described above. This will clear the display of the last measured values to indicate readiness for the next operation.
   - Implicitly accept the operation results by issuing the next CB operation command.

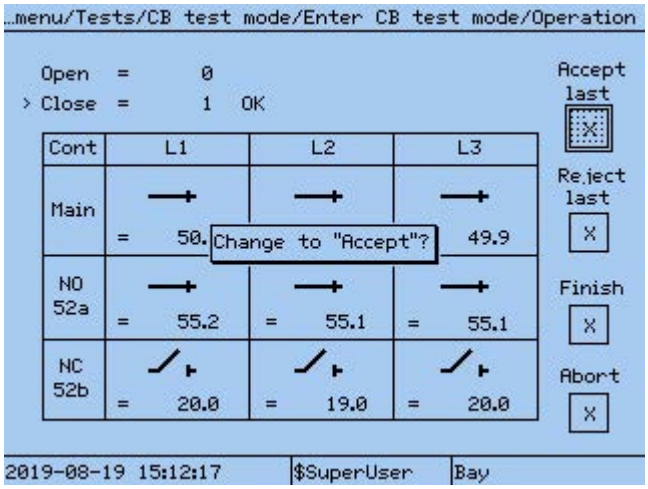


Figure 209: Accepting last switching operation results through soft button

4. In case of switching times out of range or of other errors:
   - Reject the operation, i.e. exclude it from averaging, by selecting and activating **Reject last** on the screen as described above. This will clear the display of measured values.
   - Analyze and remedy the issue.

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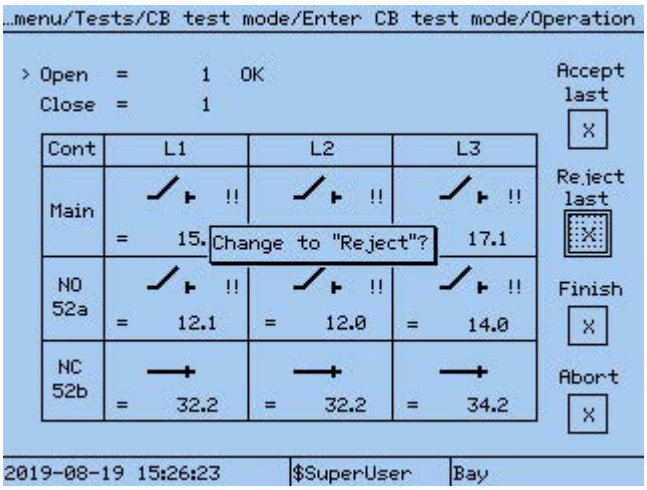


Figure 210: Rejecting last switching operation through soft button

5. Issue a CB Open command to PWC600 and wait until all three CB poles are open.. The display is updated with the automatic evaluation of the operation.
6. Apply the same analysis and resulting actions as for a closing operation.
7. Repeat the above procedure several times. Minimum five C+O cycles are recommended for obtaining meaningful statistics.

12.8.2.5 Concluding circuit breaker test mode

When a sufficient number of successful switching operations has been acquired:

1. Select and activate **Accept last** to include the last operation in the averaging.
2. Navigate to the **Avg opening times** and **Avg closing times** pages, as described above.
3. Write down the final average operating times for later reference.
4. Return to the **Operation** page.
5. Select and activate **Finish**.

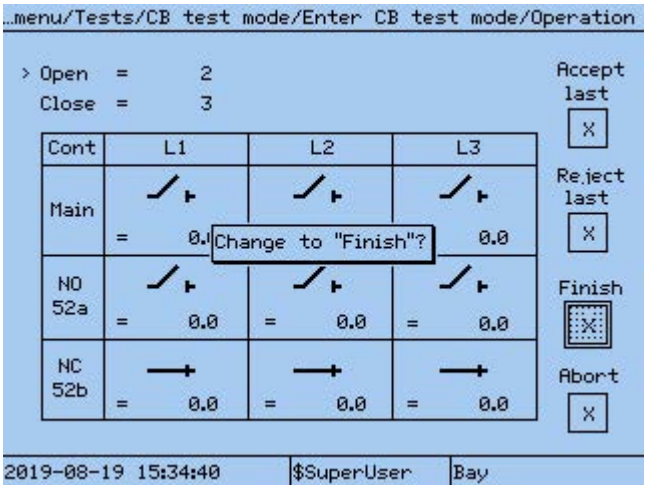


Figure 211: Finishing CB test mode from LHMI

6. Once the Finish command has been given, the function deactivates circuit breaker test mode and LED 15 stops flashing.

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To prevent loss of the learned CB operating times, do not power off theIED within one hour of finishing circuit breaker timing test mode.

Make sure to remove the temporary connections from the circuit breaker'smain contacts after completion of the timing test.

12.8.2.6 Applying the acquired operating times from CB test mode

By default, the manually entered CB operating times are applied even after completing CB test mode. To apply the learned operating times, they should be entered in SST according to the procedure described in Section 12.8.1.

If no record of the learned averages is available, they can be read from the IED:

1. From the LHMI main menu, navigate to **Settings/IED Settings/#1/Monitoring/ CBLEARN/ CBLEARN:1**.
2. Scroll towards the end of the settings list and change *AvgSetSel* to “SetOPisCalcAvgValues”.
3. Navigate back to the main menu and save the changes.
4. Navigate to **Tests/Function status/Monitoring/CBLEARN/CBLEARN:1/Outputs**.
5. Write down the values of the output signals listed in below table. These are the calculated average operating times from the CB timing test.
6. Navigate to **Settings/IED Settings/#1/Monitoring/CBLEARN/ CBLEARN:1**.
7. Change *AvgSetSel* to “setOpisDefaultValues”.
8. Enter the calculated average operating times in SST.

Table 99: CB operating times, output signals from CBLEARN function

Signal name	Description
OPTIMNOL1	Time from trip command to NO (52a) contact opening in L1 phase
OPTIMNOL2	Time from trip command to NO (52a) contact opening in L2 phase
OPTIMNOL3	Time from trip command to NO (52a) contact opening in L3 phase
OPTIMNCL1	Time from trip command to NC (52b) contact closing in L1 phase
OPTIMNCL2	Time from trip command to NC (52b) contact closing in L2 phase
OPTIMNCL3	Time from trip command to NC (52b) contact closing in L3 phase
OPTIMPRIL1	Time from trip command to primary contact separation in L1 phase
OPTIMPRIL2	Time from trip command to primary contact separation in L2 phase
OPTIMPRIL3	Time from trip command to primary contact separation in L3 phase
CLTIMNOL1	Time from closing command to NO (52a) contact closing in L1 phase
CLTIMNOL2	Time from closing command to NO (52a) contact closing in L2 phase
Table continues on next page	

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Signal name	Description
CLTIMNOL3	Time from closing command to NO (52a) contact closing in L3 phase
CLTIMNCL1	Time from closing command to NC (52b) contact opening in L1 phase
CLTIMNCL2	Time from closing command to NC (52b) contact opening in L2 phase
CLTIMNCL3	Time from closing command to NC (52b) contact opening in L3 phase
CLTIMPRIL1	Time from closing command to primary contact touch in L1 phase
CLTIMPRIL2	Time from closing command to primary contact touch in L2 phase
CLTIMPRIL3	Time from closing command to primary contact touch in L3 phase

12.9 Live switching

The suitable operating procedures to be adopted depend on the application and type of operation.

During live commissioning, the success of every controlled switching operation shall be assessed based on data from operation records and waveform records. Both types of data are most easily accessed through the Web interface (WHMI). Operation records can also be viewed on the LHMI. Waveform records can be downloaded from WHMI or through the Disturbance Handling tool in PCM600 and viewed in WaveWin or a similar COMTRADE viewing tool on the PC.

The following subsections give guidelines per application type.

12.9.1 Capacitor bank

1. Perform a controlled closing operation, and confirm that low inrush peak is observed in individual phase currents.
   Target errors (that is, deviation of actual switching instants from target instants) shown in the operation record should not exceed tolerable limits.
2. If so configured, perform a controlled opening operation and confirm that no re-strike has been detected.
   Again, target errors should not exceed tolerable limits.
3. Perform at least three further switching operations and validate consistency in controlled switching performance.

12.9.2 Shunt reactor

1. If so configured, perform a controlled closing operation, and confirm that a low amount of asymmetry is observed in individual phase currents.

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Target errors (that is, deviation of actual switching instants from target instants) shown in the operation record should not exceed tolerable limits.
2. Perform a controlled opening operation and confirm that no re-ignition has been detected.
3. In case the reactor core is magnetically coupled, or the neutral point is grounded through a reactor or resistor, evaluate the length of the last half cycle in each phase and adjust the target interruption instants accordingly (in SST).
4. Perform at least three further switching operations and validate consistency in controlled switching performance.

12.9.3 Power transformer

1. In case of mechanical feedback used for adaptation, prior to live switching, confirm the consistency of adaptation feedback with five no-load operations. If load voltage feedback is used for adaptation, special arrangements are needed in case of coupled transformers. Refer Section 5.2.5 for more details.



Ensure that the breakers on other windings of the transformer are kept open during controlled opening or closing operation.

2. Perform a controlled closing operation using the default controlled switching strategyas proposed by SST.
   The result of this first energization is not relevant as the residual flux in the transformer is unknown.
3. Perform a controlled opening operation.
4. Perform another controlled closing operation.
   Evaluate the inrush current peaks both in positive and negative cycles for individual phases. Target errors (that is, deviation of actual switching instants from target instants) shown in the operation record should not exceed tolerable limits. If the current peak levels are within acceptable limits skip the next step.
5. To further reduce inrush currents adjust the energization targets for individual phases manually, based on relative current peaks for individual phases with respect to full load current of the transformer, taking into account core design and connection configuration. Refer to Section 5.1.6.
6. Perform a controlled opening operation, followed by another controlled closing operation, and check the inrush peaks.
   If inrush is found to be within limits, perform further three operations to check consistency in mitigation effect.

If adaptive correction of mechanical operating times has been disabled at the commencement of live switching, it should be re-enabled as soon as satisfactory controlled switching performance has been achieved.

12.9.4 Transmission line or power cable

In case of transmission lines, it is advised to bypass the overvoltage protection or set it to a higher level during commissioning, until the desired overvoltage mitigation has been ascertained.



Ensure that the remote-end breaker is open during the live switching tests of the line from the end with Switchsync PWC600.

For validating performance in discharged condition of the transmission line, ensure that the line has been de-energized for several minutes, so that any trapped charge has decayed to insignificant levels prior to energization.

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1. Perform a controlled closing operation, and confirm that each phase is energized near its source voltage zero.
   Target errors (that is, deviation of actual switching instants from target instants) shown in the operation record should not exceed tolerable limits.
2. If so configured, perform a controlled opening operation and confirm that no re-strike has been detected.
3. Perform at least three further switching operations and validate consistency in controlled switching performance.

For controlled energization of lines in presence of trapped charges, the line shall be re-energized through an autoreclosing relay with the remote-end breaker open (possibility of highest level of TOV). For this, the controlled energization should be preceded by de-energization of the line.

It is recommended to measure the voltage signals at both the local and the receiving end of the line, as the overvoltage is highest at the open remote end of the line due to travelling wave phenomena.

For uncompensated power cables, apply the same procedure as for discharged transmission lines. For highly shunt-compensated power cables or transmission lines, the controlled energization strategy is a compromise between reduction of switching overvoltages and achieving symmetrical inrush currents to avoid missing zeros. The optimal controlled energization targets need to be obtained for each installation individually, see Section 5.1.7.

12.10 Concluding commissioning

When commissioning of Switchsync PWC600 has been successfully completed:

1. From PCM600, export the current project or the relevant IED objects, which contain all the latest adjusted data, to the local PC.
2. In PCM600 Event Viewer, download the latest events and export them to an Excel file.
3. Using the WHMI in Switchsync PWC600, export the list of operation records to a local CSV file.
4. Using the WHMI or PCM600 Disturbance Handling tool, download all waveform records (disturbance records) to local files.



Make sure to store all files in a backup-protected location for later reference.

5. If some of the commissioning operations were unsuccessful due to non-optimal settings, clear the Fingerprint records in LHMI at **Clear/Clear fingerprint records/SSCPOW:1**.
6. Remove all external test equipment and cabling used during commissioning.
7. Document the final settings and results in the commissioning report.

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Section 13 IED operation

13.1 Start-up

13.1.1 Checking 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 could be done in a number of ways, from energizing a whole cubicle to energizing a single IED.

Set the IED's system time in **Main menu/Configuration/Time**, if no time synchronization source is configured.

Check the self-supervision function in **Main menu/Diagnostics/Internal events** or **Main menu/Diagnostics/IED status/General** menu in local HMI to verify that the IED is functioning properly.

13.1.2 IED start-up sequence

The following sequence is expected when the IED is energized.

- Within a few seconds after power-up, the green Ready LED starts flashing and the ABB logo displayed on the screen.
- 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.

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

13.2 Normal operation

After successful commissioning of Switchsync PWC600, no interaction with the IED is required in service.

After one or more controlled switching operation(s), it may be of interest to view the related operation records and waveform records to assess the performance. This is most conveniently done in WHMI.

If the LHMI indicates a warning or error by a yellow or red LED on the LHMI (see Section 16.1), investigate and remedy the cause of the problem. Then clear the LEDs as necessary.

13.3 Controlled switching operations

A controlled switching operation can be initiated by a signal on the respective binary input or via IEC 61850 GOOSE message from another IED.

The internal waveform recorder is used to record up to 200 controlled switching operations. In addition to the waveform record, key data of each switching operation are stored in the operation log.

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13.3.1 Switching operation mode

Switchsync PWC600 classifies every CB switching operation by assigning an operation mode, see Table 100. This is an automatic assessment of the conditions and success of the operation, based on internal and external signals. Interpretation of the operation mode should consider the following points.

- If multiple conditions are applicable, the mode with the lowest number in the order column is declared as operation mode.
- Contingency is declared under any of the following conditions:
  - Circuit breaker status is faulty, intermediate or unstable.
  - Reference signal is lost.
  - Synchronous switching is externally blocked.
- The circuit breaker is considered to be electrically closed under the following conditions:
  - For capacitor and reactor loads, if *FeedbackSig* is set to "Current": When the current RMS is greater than both the *CloseDead* and *OpenDead* thresholds.
  - For any load type, if *FeedbackSig* is set to "Load voltage": When the load voltage RMS is greater than both the *CloseDead* and *OpenDead* thresholds.

  Otherwise the circuit breaker is considered to be electrically open.
- A circuit breaker is considered to be mechanically closed if the normally open contact (52a) is closed and the normally closed contact (52b) is open. It is considered to be mechanically open if the normally open contact (52a) is open and the normally closed contact (52b) is closed. Mechanical status can be derived using one or two status inputs per phase (Table 101).

Table 100: Operation log modes

Order	Mode	OpLog Mode Enum	Description of conditions
1	Blocked	1451	• Block inputs for a particular command are high when the command is received or • There exists a contingency and the contingency mode is selected to block a particular type of operation.
2	RefMiss	1448	• When the command is received, there is no proper reference signal available. (Reference for Close operation is always voltage and for Open operations, this can be voltage or current).
3	External	1444	• When a CB operation is detected to be initiated externally (that is, the command is not issued from PWC600, but mechanical and / or electrical circuit breaker status change has been detected).
4	N/A (Not available)	1457	• When neither electrical nor mechanical feedback is available.
5	BlkReAtm	1465	• When a command is cancelled (refer point 6) and no more attempts are allowed, and the command is subsequently blocked.
6	Cancel	1446	• If there are time synchronizing issues, the PIO card may reject to operate the output commands issued by the AFL. When rejecting commands, PIO card generates Cancel commands. See Time synchronization section for more details on time sync issues.

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Order	Mode	OpLog Mode Enum	Description of conditions
7	Redundant	1473	• If a close command is received when the circuit breaker is already monitored in closed position. • If an open command is received when the circuit breaker is already monitored in open position.
8	Failed	1474	• When a command is issued and no feedback of mechanical or electrical status change is detected within 300 ms (irrespective of the system frequency) from the time the output command is issued by the IED.
9	CBInter with alarm	1456	• When the mode 1450 has electrical target error detected above the specified limits.
10	CBInter	1450	• After the CB operation is expected to have been completed, the circuit breaker is monitored to be electrically closed and mechanically open, or vice versa.
11	CBUnstable with alarm	1455	• When the mode 1449 has electrical target error detected above the specified limits.
12	CBUnstable	1449	• When the mechanical operating times are inconsistent (varying by 10% over previous operating time) for two consecutive operations. • Close operations are compared to close operations only, and likewise for open operations. • This mode is declared for the first time when detected, all further operations are declared as either bypassed or blocked (according to *ContingencyMode*) till the CBUnstable condition is reset.
13	Bypassed	1443	• When the command is bypassed.
14	Uncontrolled Switching	1464	• An uncontrolled switching is monitored.
15	Reduced accuracy with alarm	1453	• When the mode 1442 has electrical target error detected above the specified limits.
16	Reduced accuracy	1442	• A reduced accuracy is monitored.
17	Actual operation with alarm	1452	• When the mode 1441 has electrical target error detected above the specified limits.
18	Actual	1441	• When a controlled switching operation is monitored to have taken place as expected. An operation is actual when the circuit breaker is either electrically or mechanically monitored to have operated once the command is issued within 300ms. • The operation is declared actual when none of the above oplog modes are generated or none of the above conditions prevail.

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Table 101: Mechanical status detection

Configured circuit breaker auxiliary contact	NO (52a)	NC (52b)	Mechanical status
Both NO and NC are available	Closed	Open	Closed
	Open	Closed	Open
	Closed	Closed	Faulty
	Open	Open	Unknown
Only NO is available	Closed	NA	Closed
	Open	NA	Open
Only NC is available	NA	Open	Closed
	NA	Closed	Open

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Section 14 Requirements on external equipment

14.1 Circuit breaker

To achieve good controlled switching results, the controlled circuit breaker must exhibit stable and predictable switching behavior, as required by the application. Detailed values need to be agreed with the manufacturer.

14.2 Current transformers

The current transformer ratio is selected based on the power system data, for example, maximum load. Optimal accuracy of controlled switching operations can be achieved when the phase displacement does not exceed ±1 electrical degree at nominal current.

For controlled switching of capacitor banks or shunt reactors, measuring cores should be used to properly render the nominal load current. CTs of accuracy class 1 (IEC) / 1.2 (ANSI) or better are recommended.

For controlled switching of power transformers or transmission lines or cables, protection cores should be used to prevent saturation. CTs of accuracy class 3P (IEC) / C (ANSI) or better are recommended.



For loads of type power transformer, transmission line, or power cable, the application setting for nominal load current needs to be set to the expected charging current under no-load conditions.

14.3 Voltage transformers

In most cases, inductive or capacitive voltage transformers can be used.

For measuring the voltage on a power transformer, inductive VTs are preferred as they usually have better accuracy in rendering the switching transients.

For optimal accuracy of controlled switching operations, the phase displacement should not exceed ±1 electrical degree at nominal voltage. VTs with a measuring core of class 1 or better are recommended.

Capacitive voltage transformers (CVTs) should fulfil the requirements according to IEC 61869-5 standard regarding ferro-resonance and transients. Switchsync PWC600 has effective filters for these transients, which gives secure and correct operation with CVTs.

14.4 Non-conventional instrument transformers and merging units

Accuracy requirements for non-conventional instrument transformers (NCITs) are essentially the same as for conventional CTs and VTs, considering the entire signal chain.

Merging units with a digital interface must comply with IEC 61850-9-2(LE), which is a globally agreed implementation proposal for the IEC 61850-9-2 standard.

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14.5 SNTP server

The SNTP server to be used is connected to the local network, not more than 4-5 switches or routers away from the IED. The SNTP server is dedicated for its task, or at least equipped with a real-time operating system (not a PC with SNTP server software). The SNTP server should be stable, that is, either synchronized to a stable source like GPS, or local without synchronization. Using a local SNTP server without synchronization as primary or secondary server in a redundant configuration is not recommended.

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Section 15 Maintenance

15.1 IED maintenance

Switchsync PWC600 IEDs are essentially maintenance free. The normal maintenance practice for similar types of IEDs should be followed.

The IED has limited capacity data related to switching operations: It can store the last 200 operation records and the last 200 waveform records. If the entire history of switching operations is to be preserved the user should read out the data regularly, before any of the above limits is reached, and save them in an appropriate backup location.

15.2 Optimizing accuracy for circuit breaker changes

The operating properties of the circuit breaker may change when any relevant part of the circuit breaker (i.e. mechanism, linkage, interrupter) is overhauled or exchanged. The same may apply after maintenance on the breaker e.g. lubrication of the mechanical linkage. Therefore, the following steps shall be performed to optimize the accuracy of subsequent controlled switching operations and to re-initialize the appropriate monitoring functions.

1. Measure the mechanical operating times in each pole of the circuit breaker, at least for those operations (close or open) that are controlled by PWC600.
2. Enter the new mechanical closing time and opening time values as described in Section 12.8.
3. Reset adaptive correction by navigating to **Main menu/Clear/Clear CB cond. indicators/ Clear adaptive comp/ACBMSCBR:x** and confirming by **OK** on each phase (instance) that was modified. See Figure 212:

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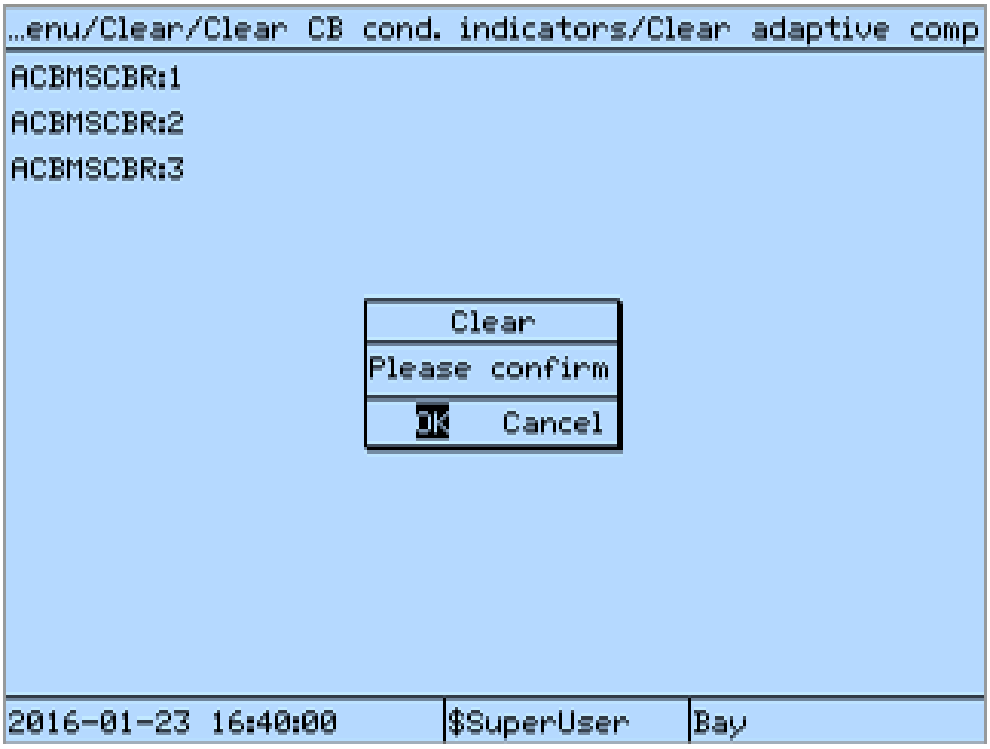


Figure 212: Clearing adaptive correction values from LHMI

4. Reset the evaluation of unstable CB timing by navigating to **Main menu/Clear/Clear CB cond. indicators/Clear unstable mode/ACBMSCBR:x** and confirming by **OK** on each phase (instance) that has been modified.
5. Reset the adaptive correction of target arcing times (triggered by detected re-ignitions) by navigating to **Main menu/Clear/Clear CB cond. indicators/Clear restrike correction/ ACBMSCBR:x** and confirming by **OK** on each phase (instance) that has been modified.
6. If the interrupter was overhauled or exchanged, additionally perform the following.
   6.1. Reset the cumulated interrupter wear by navigating to **Main menu/Clear/Clear CB cond. indicators/Clear CB wear/ACBMSCBR:x** and confirming by **OK** on each phase (instance) that has been modified.
   6.2. Reset the re-ignitions counter by navigating to **Main menu/Clear/Clear CB cond. indicators/Clear restrike count/ACBMSCBR:x** and confirming by **OK** on each phase (instance) that has been modified.
7. If the interrupter or the drive was overhauled or exchanged, (as per specification of the CB manufacturer) additionally perform the following.
   7.1. Reset the counter of CB operations by navigating to **Main menu/Clear/Clear CB cond. indicators/Clear operation count/ACBMSCBR:x** and confirming by **OK** on each phase (instance) that has been modified.
8. In some cases, e.g. when installing a PWC600 IED on a different circuit breaker, it may be desirable to fully erase all data from the previous installation and start fresh. The respective delete options can be accessed in **Main menu/Clear**.

Clearing actions are effective immediately after confirming by **OK**. However, it may take up to one hour before the empty database is permanently saved to non-volatile memory. Hence, after any clearing activity, make sure that the PWC600 IED will remain powered on for at least another hour.

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Section 16 Troubleshooting

16.1 Application diagnostics

The pre-configuration of Switchsync PWC600 provides diagnostic information by several means.

- LEDs on the local HMI
- Hardware binary outputs
- Entries in the Event Log
- Alarms to be viewed in WHMI
- IEC 61850 data objects

All diagnostic conditions and possible indication channels as defined in the pre-configuration are described in Table 102.



Generation and indication of diagnostic information can be controlled by settings or by the application configuration in the Application Configuration tool.

Table 102: Diagnostic information generated by default pre-configuration of Switchsync PWC600

LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
1 (red)	-	-	CloseBlocked	LD0 \ SP16GGIO1 \ Ind	Close commands are blocked	Closing operations are blocked i.e. will not be executed. This situation may be caused by a contingency condition or by a blocking signal to SSCPOW.	Fleeting signal
1 (red)	-	-	OpenBlocked	LD0 \ SP16GGIO1 \ Ind	Open commands are blocked	Opening operations are blocked i.e. will not be executed. This situation may be caused by a contingency condition or by a blocking signal to SSCPOW.	Fleeting signal
2 (yellow)	-	-	CloseByPass	LD0 \ SP16GGIO1 \ Ind2	Controlled close operations bypassed	Closing operation is bypassed i.e. will not be executed under point-on-wave control. This situation may be caused by a contingency condition or by the *ByPassMode* setting.	Transient or fleeting signal
2 (yellow)	-	-	OpenByPass	LD0 \ SP16GGIO1 \ Ind2	Controlled open operations bypassed	Opening operation is bypassed i.e. will not be executed under point-on-wave control. This situation may be caused by a contingency condition or by the *ByPassMode* setting.	Transient or fleeting signal
3 (red)	BIO:4	-	BlockCommands		CB operations blocked	Further CB switching commands are blocked as a consequence of	Persistent signal. Can be manually reset by clearing the restrike correction value

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
						exceeding the maximum permissible number of re-ignition corrections in one pole.	or by setting *MaxReStrikeCorr* to 0.
3 (yellow)	-	ReStr_RelgL1 ReStr_RelgL2 ReStr_RelgL3	ReStr_RelgL1 ReStr_RelgL2 ReStr_RelgL3	LD0 \ SP16GGIO1 \ Ind4	Re-strike / Re-ignition detected	In the last controlled Open operation, re-strike or re-ignition has been detected in one or more phases. Note: Re-ignition is defined as current flowing for more than 1/8 power cycle after the target interrupting instant.	Transient signal
4 (red)	BIO:5	-	-	SS_1 \ SSCPOW1 \ UnCtlSw	Unsynchronized switching operation	The circuit breaker was operated without point-on-wave control, either because of *ByPassMode* setting or due to a contingency situation that was set for bypassing in *ContingencyMode*. Note: Contingency conditions include reference missing and circuit breaker unstable.	Transient signal
4 (yellow)	BO:9	-	NoRefSignal	SS_1 \ SSCPOW1 \ LosRefSig	Reference signal lost	RMS value of selected reference signal (source voltage or breaker current, depending on settings and on CB status) below threshold for valid signal	Fleeting signal

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
5 (red)	BIO:5	-	ElTarErAlmL1 ElTarErAlmL2 ElTarErAlmL3	LD0 \ SP16GGIO2 \ Ind	Electrical target error alarm	For every controlled switching operation, electrical operating time (viz. making time for closing, interrupting time for opening) is predicted; electrical target error is defined as the difference between actual (measured) electrical operating time and predicted electrical operating time. The alarm is generated whenever this error exceeds a set limit.	Transient signal
5 (yellow)	-	-	ElTarErWrnL1 ElTarErWrnL2 ElTarErWrnL3	LD0 \ SP16GGIO2 \ Ind2	Electrical target error warning	For every controlled switching operation, electrical operating time (viz. making time for closing, interrupting time for opening) is predicted; electrical target error is defined as the difference between actual (measured) electrical operating time and predicted electrical operating time. The warning is generated whenever this error exceeds a set limit.	Transient signal

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
6 (red)	BIO:5	-	MeTarErAlmL1 MeTarErAlmL2 MeTarErAlmL3	LD0 \ SP16GGIO2 \ Ind3	Mechanical target error alarm	For every controlled switching operation, mechanical operating time is predicted; mechanical target error is defined as the difference between actual (measured) mechanical operating time and predicted mechanical operating time. The alarm is generated whenever this error exceeds a set limit.	Transient signal
6 (yellow)	-	-	MeTarErWrnL1 MeTarErWrnL2 MeTarErWrnL3	LD0 \ SP16GGIO2 \ Ind4	Mechanical target error warning	For every controlled switching operation, mechanical operating time is predicted; mechanical target error is defined as the difference between actual (measured) mechanical operating time and predicted mechanical operating time. The warning is generated whenever this error exceeds a set limit.	Transient signal
7 (red)	BIO:8	UnstableL1 UnstableL2 UnstableL3	UnstableL1 UnstableL2 UnstableL3	LD0 \ ACBMSCBR1 \ UnstOpChr LD0 \ ACBMSCBR2 \ UnstOpChr	Unstable operating times	The mechanical operating times of three consecutive controlled switching operations of the same type (close	Persistent signal, reset from Clear menu

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
				LD0 \ ACBMSCBR3 \ UnstOpChr		or open) deviate by more than ±10%. This is a contingency condition that will cause either bypassing or blocking of further controlled switching operations. Note: This condition may occur after setting or learning different CB operating times without clearing Unstable mode.	
7 (red)	BIO:8	MechClsTimAlm	-	LD0 \ ACBMSCBR1 \ OpTmAlm LD0 \ ACBMSCBR2 \ OpTmAlm LD0 \ ACBMSCBR3 \ OpTmAlm	Mechanical closing time alarm	The circuit breaker's mechanical closing time exceeds a set alarm level	Transient signal
7 (red)	BIO:8	MechOpnTimAlm	-	LD0 \ ACBMSCBR1 \ OpTmAlm LD0 \ ACBMSCBR2 \ OpTmAlm LD0 \ ACBMSCBR3 \ OpTmAlm	Mechanical opening time alarm	The circuit breaker's mechanical opening time exceeds a set alarm level	Transient signal
7 (red)	BIO:8	InitClsDelAlm	-	LD0 \ SP16GGIO2 \ Ind5	Initial mechanical closing delay alarm	Initial closing delay time is defined as the time from outgoing Close command until the 52b (NC) auxiliary contact of the CB goes off. This alarm is generated whenever the initial closing delay time	Transient signal

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
						exceeds a set alarm limit.	
7 (red)	BIO:8	InitOpn DelAlm	-	LD0 \ SP16GGIO2 \ Ind7	Initial mechanical opening delay alarm	Initial opening delay time is defined as the time from outgoing Open command until the 52a (NO) auxiliary contact of the CB goes off. This alarm is generated whenever the initial opening delay time exceeds a set alarm limit.	Transient signal
7 (red)	BIO:8	MechM ovClsAl m	-	LD0 \ SP16GGIO2 \ Ind9	Mechanical close moving time alarm	Mechanical moving time during closing is defined as the time from 52b (NC) auxiliary contact going off until 52a (NO) auxiliary contact going on. This alarm is generated whenever the mechanical moving time exceeds a set alarm limit.	Transient signal
7 (red)	BIO:8	MechM ovOpnA lm	-	LD0 \ SP16GGIO2 \ Ind11	Mechanical open moving time alarm	Mechanical moving time during opening is defined as the time from 52a (NO) auxiliary contact going off until 52b (NC) auxiliary contact going on. This alarm is generated whenever the mechanical moving time exceeds a set alarm limit.	Transient signal

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
7 (yellow)	BIO:7	MechClsTimWrn	-	LD0 \ SP16GGIO2 \ Ind13	Mechanical closing time warning	The circuit breaker's mechanical closing time exceeds a set warning level	Transient signal
7 (yellow)	BIO:7	MechOpnTimWrn	-	LD0 \ SP16GGIO2 \ Ind14	Mechanical opening time warning	The circuit breaker's mechanical opening time exceeds a set warning level	Transient signal
7 (yellow)	BIO:7	IntClsDelWrn	-	LD0 \ SP16GGIO2 \ Ind6	Initial mechanical closing delay warning	Initial closing delay time is defined as the time from outgoing Close command until the 52b (NC) auxiliary contact of the CB goes off. This warning is generated whenever the initial closing delay time exceeds a set warning limit.	Transient signal
7 (yellow)	BIO:7	IntOpnDelWrn	-	LD0 \ SP16GGIO2 \ Ind8	Initial mechanical opening delay warning	Initial opening delay time is defined as the time from outgoing Open command until the 52a (NO) auxiliary contact of the CB goes off. This warning is generated whenever the initial opening delay time exceeds a set warning limit.	Transient signal
7 (yellow)	BIO:7	MechMovClsWrn	-	LD0 \ SP16GGIO2 \ Ind10	Mechanical close moving time warning	Mechanical moving time during closing is defined as the time from 52b (NC) auxiliary contact going off	Transient signal

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
						until 52a (NO) auxiliary contact going on. This warning is generated whenever the mechanical moving time exceeds a set warning limit.	
7 (yellow)	BIO:7	MechMovOpn Wrn	-	LD0 \ SP16GGIO2 \ Ind12	Mechanical open moving time warning	Mechanical moving time during opening is defined as the time from 52a (NO) auxiliary contact going off until 52b (NC) auxiliary contact going on. This warning is generated whenever the mechanical moving time exceeds a set warning limit.	Transient signal
8 (red)	BIO:8	CntVolt Alm	-	LD0 \ SP16GGIO1 \ Ind7	Control voltage out of alarm limit	Control voltage to the drive (supply voltage of the IED) has crossed a set alarm level.	Fleeting signal
8 (red)	BIO:8	TempAlm	-	LD0 \ SP16GGIO1 \ Ind9	Temperature out of alarm limit	Temperature has crossed a set alarm level.	Fleeting signal
8 (red)	BIO:8	DrvPres Alm	-	LD0 \ SP16GGIO1 \ Ind11	Circuit breaker drive pressure out of alarm limit	Circuit breaker drive pressure has crossed a set alarm level.	Fleeting signal
8 (red)	BIO:8	AddnQty Alm	-	LD0 \ SP16GGIO1 \ Ind13	Additional measured quantity out of alarm limit	The additional measured quantity has crossed a set alarm level.	Fleeting signal
8 (yellow)	BIO:7	Lossof CompSig	LossOfCompSig	SS_1 \ SSCPOW1 \ LosCSig	Loss of compensation signal or sensor fault	Any sensor has failed which is used for compensation of	Fleeting signal

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
						circuit breaker operating times.	
8 (yellow)	BIO:7	IdleTimWrn	-	LD0 \ SP16GGIO1 \ Ind6	Idle time out of warning limit	Idle time since the last CB operation has crossed the set warning limit.	Fleeting signal
8 (yellow)	BIO:7	CntVoltWrn	-	LD0 \ SP16GGIO1 \ Ind8	Control voltage out of warning limit	Control voltage to the drive (supply voltage of the IED) has crossed a set warning level.	Fleeting signal
8 (yellow)	BIO:7	TempWrn	-	LD0 \ SP16GGIO1 \ Ind10	Temperature out of warning limit	Temperature has crossed a set warning level.	Fleeting signal
8 (yellow)	BIO:7	DrvPresWrn	-	LD0 \ SP16GGIO1 \ Ind12	Circuit breaker drive pressure out of warning limit	Circuit breaker drive pressure has crossed a set warning level.	Fleeting signal
8 (yellow)	BIO:7	AddnQtyWrn	-	LD0 \ SP16GGIO1 \ Ind14	Additional measured quantity out of warning limit	The additional measured quantity has crossed a set warning level.	Fleeting signal
9 (red)	BIO:8	OpCntAlmL1 OpCntAlmL2 OpCntAlmL3	-	LD0 \ ACBMSCBR1 \ OpCntAlm LD0 \ ACBMSCBR2 \ OpCntAlm LD0 \ ACBMSCBR3 \ OpCntAlm	Number of circuit breaker operations above alarm limit	The number of circuit breaker close+open operation cycles exceeds the set alarm limit.	Persistent signal. Can be manually cleared only after resetting operation count or increasing alarm level.
9 (red)	BIO:8	AblationAlmL1 AblationAlmL2 AblationAlmL3	-	LD0 \ SP16GGIO1 \ Ind15	Circuit breaker interrupter wear alarm	The circuit breaker's main contacts are monitored for electrical wear (contact erosion, nozzle ablation) from the primary current signals. Whenever the cumulated interrupter wear exceeds the set	Persistent signal. Can be manually cleared only after resetting ablation value or increasing alarm level.

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
						limit, this alarm is generated.	
9 (yellow)	BIO:7	OpCnt WrnL1 OpCnt WrnL2 OpCnt WrnL3	-	LD0 \ ACBMSCBR1 \ OpCntWrn LD0 \ ACBMSCBR2 \ OpCntWrn LD0 \ ACBMSCBR3 \ OpCntWrn	Number of circuit breaker operations above warning limit	The number of circuit breaker close+open operation cycles exceeds the set warning limit.	Persistent signal. Can be manually cleared only after resetting operation count or increasing warning level.
9 (yellow)	BIO:7	Ablatio nWrnL1 Ablatio nWrnL2 Ablatio nWrnL3	-	LD0 \ SP16GGIO1 \ Ind16	Circuit breaker interrupter wear warning	The circuit breaker's main contacts are monitored for electrical wear (contact erosion, nozzle ablation) from the primary current signals. Whenever the cumulated interrupter wear exceeds the set limit, this warning is generated.	Persistent signal. Can be manually cleared only after resetting ablation value or increasing warning level.
10 (red)	BIO:6	TCS-AlarmL 1 TCS-AlarmL 2 TCS-AlarmL 3	TCS-AlarmL1 TCS-AlarmL2 TCS-AlarmL3	LD0 \ TCSSCBR1 \ TrCctAlm LD0 \ TCSSCBR2 \ TrCctAlm LD0 \ TCSSCBR3 \ TrCctAlm	Trip circuit supervision alarm	The impedance of the supervised coil circuit is outside the permissible range.	Fleeting signal
10 (yellow)	BIO:6	Contra dPos	ContradPosL1 ContradPosL 2 ContradPosL 3	LD0 \ ACBMSCBR1 \ CntrPos LD0 \ ACBMSCBR2 \ CntrPos LD0 \ ACBMSCBR3 \ CntrPos	Contradicti ng mechanical and electrical positions	Electrical and mechanical status of circuit breaker do not agree, in particular current is flowing while auxiliary contacts indicate circuit breaker open. Note: Relevant only if auxiliary contacts are connected and load current can be trusted for determining the	Fleeting signal

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
						electrical status (hence valid only for reactor and capacitor loads).	
11 (red)	PSM:9	MaxTimeExceed	-	SS_1 \ SSCPOW1 \ TmExc	Maximum allowed delay time for operation exceeded	Controller delay is calculated as the time from command received until release of the command for the last pole to be operated. This warning is generated whenever the controller delay time exceeds the set alarm limit.	Transient signal
11 (yellow)	PSM:9	-	TimeSynchErr	LD0 \ SP16GGIO3 \ Ind	Time synchronization error	Time synchronization (hardware or software) source is lost.	Fleeting signal
12 (red)	PSM:8	MerginUnitAl	MUCurrData	-	Discrepancy in sample sequence from merging unit for current	Sample sequence needs to be realigned with the merging unit transmitting the primary current. This signal is raised for two seconds before the application is restarted automatically.	Fleeting signal
12 (red)	PSM:8	MerginUnitAl	MUSrcVolData	-	Discrepancy in sample sequence from merging unit for source voltage	Sample sequence needs to be realigned with the merging unit transmitting the source voltage. This signal is raised for two seconds before the application is restarted automatically.	Fleeting signal
12 (red)	PSM:8	MerginUnitAl	MULodVolData	-	Discrepancy in sample sequence	Sample sequence needs to be realigned with the	Fleeting signal

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
					from merging unit for load voltage	merging unit transmitting the load voltage. This signal is raised for two seconds before the application is restarted automatically.	
12 (red)	PSM:8	MerginUnitAl	MUCurrSynMU	-	Merging unit for current not synchronized	Merging unit for primary current is not synchronized to its time master, as indicated by quality flag in data stream.	Fleeting signal
12 (red)	PSM:8	MerginUnitAl	MUSrcVolSynMU	-	Merging unit for source voltage not synchronized	Merging unit for source voltage is not synchronized to its time master, as indicated by quality flag in data stream.	Fleeting signal
12 (red)	PSM:8	MerginUnitAl	MULodVolSynMU	-	Merging unit for load voltage not synchronized	Merging unit for load voltage is not synchronized to its time master, as indicated by quality flag in data stream.	Fleeting signal
12 (red)	PSM:8	MerginUnitAl	MUCurrSynch	-	Hardware synchronization of bad quality or lost	Time quality of the hardware synchronization with the merging unit for primary current is outside the set limit, or the 1PPS signal is lost. Note that synchronization after re-connection of 1PPS may take several minutes.	Fleeting signal
12 (red)	PSM:8	MerginUnitAl	MUSrcVolSynch	-	Discrepancy in sample sequence from merging unit for	Time quality of the hardware synchronization with the merging unit for source voltage is outside the set limit, or	Fleeting signal

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
					source voltage	the 1PPS signal is lost. Note that synchronization after re-connection of 1PPS may take several minutes.	
12 (red)	PSM:8	MergingUnitAl	MULodVolSynch	-	Discrepancy in sample sequence from merging unit for load voltage	Time quality of the hardware synchronization with the merging unit for load voltage is outside the set limit, or the 1PPS signal is lost. Note that synchronization after re-connection of 1PPS may take several minutes.	Fleeting signal
12 (red)	PSM:8	MergingUnitAl	MUCurrSmpLt	-	Samples from current merging unit lost	More than one sample from the merging unit for primary current has been lost or has been marked as invalid, over-flown or failed; the affected samples have been substituted.	Fleeting signal, active for min. 1 second
12 (red)	PSM:8	MergingUnitAl	MUSrcVolSmpLt	-	Samples from source voltage merging unit lost	More than one sample from the merging unit for source voltage has been lost or has been marked as invalid, over-flown or failed; the affected samples have been substituted.	Fleeting signal, active for min. 1 second
12 (red)	PSM:8	MergingUnitAl	MULodVolSmpLt	-	Samples from load voltage merging unit lost	More than one sample from the merging unit for load voltage has been lost or has been marked as invalid, over-flown or failed; the	Fleeting signal, active for min. 1 second

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
						affected samples have been substituted.	
12 (green flashing)	-	-	MUCurrTestMd	-	Merging unit for current in Test Mode	Merging unit for primary current is operating in Test Mode, as indicated by quality flag in data stream.	Fleeting signal
12 (green flashing)	-	-	MUSrcVolTstMd	-	Merging unit for source voltage in Test Mode	Merging unit for source voltage is operating in Test Mode, as indicated by quality flag in data stream.	Fleeting signal
12 (green flashing)	-	-	MULodVolTstMd	-	Merging unit for load voltage in Test Mode	Merging unit for load voltage is operating in Test Mode, as indicated by quality flag in data stream.	Fleeting signal
13 (red)	-	-	TimeOut	-	CB timing test mode timeout	During CB timing test, a switching command is issued for each CB pole individually. If the expected status changes of main and auxiliary contacts are not detected within the set time this alarm is generated.	Transient signal
13 (red)	-	-	OperationFail	-	CB timing test mode failed operation	CB operation was not properly completed in all phases during CB timing test	Transient signal
13 (red)	-	-	CommandError	-	CB timing test mode command error	During CB timing test, after issuing the switching command for a particular pole, either the pole doesn't operate or another pole operates instead.	Transient signal

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
						Note: details of command error can be seen in the CMDERCD output of CBLEARN.	
13 (red)	-	-	WiringError	-	CB timing test mode wiring error	Static wiring error (unexpected status of any primary or auxiliary contact while CB is idle) or dynamic wiring error (command was issued to one pole but another pole operated) detected during CB timing test. Note: details of wiring error can be seen in the WIERCD output of CBLEARN.	Transient signal
14 (red)	PSM:7	Discrep Trip	DiscrepTrip	LD0 \ SP16GGIO1 \ Ind3	Pole discrepancy trip	In CB timing test mode, pole discrepancy trip is issued if a command is not completely executed (i.e. correct status feedback is not received for all three breaker poles) within the expected time. During normal operation, pole discrepancy trip would be issued only in case of internal processing error.	Transient signal
15 (yellow flashing)	-	-	CBTestModActv	LD0 \ SP16GGIO3 \ Ind3	CB test mode active	Circuit breaker timing CB test mode was activated: switching operations are no more point-on-wave controlled; instead, all	CB test mode can be exited only by activating "Finish" or "Abort" on the CB test mode LHMI screen.

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
						switching commands will be electrically staggered between the three poles by a set interval, for acquisition of CB operating times.	
-	PIO:1 PIO:2 PIO:3	-	ClsCmdOutL1 ClsCmdOutL2 ClsCmdOutL3	-	Synchronous closing command output	Status of the precision binary outputs for CB closing commands	Transient signal
-	PIO:4 PIO:5 PIO:6	-	OpnCmdOutL1 OpnCmdOutL2 OpnCmdOutL3	-	Synchronous opening command output	Status of the precision binary outputs for CB opening commands	Transient signal
-	-	MaxReStrReig	MaxReigCorrL1 MaxReigCorrL2 MaxReigCorrL3	LD0\SP16GGIO1\Ind5	Maximum re-ignition correction reached	After detecting a re-ignition during the last controlled opening operation, the limit of adaptive correction of opening times has been reached. If another re-ignition should be detected in the same CB pole, further CB operations will be blocked. Note: The number of re-ignitions detected in each CB pole is included in the operation records.	Transient signal
-	-	-	NO-L1 NO-L2 NO-L3	-	Circuit breaker auxiliary contact 52a (NO)	Status of 52a (NO) auxiliary contact in circuit breaker drive.	Change-over contact (On when CB is closed)
-	-	-	NC-L1 NC-L2 NC-L3	-	Circuit breaker auxiliary	Status of 52b (NC) auxiliary contact in circuit breaker drive.	Change-over contact (On when CB is open)

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
					contact 52b (NC)		
-	-	-	Prim-L1 Prim-L2 Prim-L3	-	Circuit breaker primary contact	Status of primary contact in circuit breaker, used during offline testing in CB timing test mode	Change-over contact from CB
-	-	-	StartPOW	-	Point-on-wave operation in progress	Controlled switching command has been received and is being processed. This signal remains active from detection of a valid switching command until all output commands to the CB have been switched off.	Fleeting signal
-	-	-	BlockOperLog	-	Operation record logging blocked	Operation log is prevented from recording any information	Fleeting signal
-	-	-	ClrOpRec	-	Clear operation records	Command has been received for clearing database of operations records.	Transient signal
-	-	-	ClrFpRec	-	Clear fingerprint records	Either a command for clearing the database of fingerprint records was received, or the settings for MONCOMP function have been altered, which would invalidate the existing fingerprint records.	Transient signal
-	-	-	FaultCurrL1 FaultCurrL2 FaultCurrL3	-	Fault current detected	Measured RMS current exceeds the set fault current level	Fleeting signal

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
-	-	-	CloseCmdIn	-	Close command input (hardwired)	Input command from binary input to initiate controlled closing operation. Note: This signal will trigger a waveform record.	Fleeting signal
-	-	-	OpenCmdIn	-	Open command input (hardwired)	Input command from binary input to initiate controlled opening operation. Note: This signal will trigger a waveform record.	Fleeting signal
-	-	-	CloseCmdGIn	-	Close command input through GOOSE	Input command from GOOSE signal to initiate controlled closing operation. Note: This signal will trigger a waveform record.	Fleeting signal
-	-	-	OpenCmdGIn	-	Open command input through GOOSE	Input command from GOOSE signal to initiate controlled opening operation. Note: This signal will trigger a waveform record.	Fleeting signal
-	-	-	SpChOCOBlk	-	CB operating capability: CO (OCO blocked)	Level of stored energy in CB drive has dropped below the OCO operation capability, and OCO operations are blocked. Only a CO operation cycle is permitted.	Fleeting signal
-	-	-	SpChCOBlk	-	CB operating capability: O (CO blocked)	Level of stored energy in CB drive has dropped below the CO operation capability, and CO operations are	Fleeting signal

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
						blocked. Only an O operation is permitted.	
-	-	-	CmdCancel	-	Command processing internally cancelled	Controlled switching command cannot be executed due to processing error.	Transient signal
-	-	-	Clear_LEDs	-	Manual clearing of alarm LEDs	A user has manually cleared the active indication LEDs, either locally through Function Key 1 or remotely through a binary input or a GOOSE message.	Fleeting signal
-	-	-	Ext.Operation	-	External CB operation	Detected a CB switching operation (status change) that was not initiated by PWC600 in response to an input command. Note: This signal will trigger a waveform record.	Transient signal
-	-	-	SetGrpChanged	LD0 \ SP16GGIO3 \ Ind2	Setting group changed	The active setting group was changed, either because of occurrence of a user defined condition or by changing the *ActiveSetGrp* parameter.	Transient signal
-	-	-	-	LD0 \ DRPRDRE1 \ RcdMade	Waveform recording made	A waveform record has been captured and stored and is ready for downloading	Transient signal
-	-	-	-	SetGrp2Active SetGrp3Active	Active setting group	Setting group 2 / 3 / 4 is active	Fleeting signal

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LED	Binary output	Alarm (WHMI)	Events	IEC 61850 data object[1)]	Description	Explanation	Transition behavior
				SetGrp4Active			
Transient signals are generated during an operation and remain high for less than 100 milliseconds. LED indications of most transient signals are latched. Fleeting signals remain active for as long as the actuating conditions prevails. Once these conditions are no more present, the signals reset automatically. Persistent signals remain active until they are manually cleared by the user.							

1) The data shall be read as <Logical device><Instance number>\<Logical node type><Instance number>\<Data object name> for logical devices other than LD0. For logical device LD0, the data shall be read as LD0\<Logical node type><Instance number>\<Data object name>.

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16.1.1 Resetting persistent signals

As mentioned in Table 102, certain diagnostic signals from the application are persistent, meaning they will not disappear automatically. These signals must be cleared manually from LHMI or WHMI.

1. In LHMI, navigate to **Main menu/Clear/Clear CB cond. indicators**.
2. Select the indication to be cleared, see Table 103.
3. Click **OK** to confirm.

Table 103: Resetting persistent indications

Indication	Menu path for clearing	Remarks
Circuit breaker interrupter wear warning (AblationWrnLx) or alarm (AblationAlmLx)	**Clear/Clear CB cond. indicators/ Clear CB wear/ACBMSCBR:x**	Clearing will set the counter of cumulated interrupter wear (ablation) to *InitialCumAblLX*. Therefore, this should be done only after overhaul or exchange of the CB interrupter.
Number of circuit breaker operations above warning limit (OpCntWrnLx) or alarm limit (OpCntAlmLx)	**Clear/Clear CB cond. indicators/ Clear operation count/ ACBMSCBR:x**	Clearing will set the CB operation counter to 0 ms. Therefore, this should be done only after overhaul or exchange of the CB pole.
BlockCommands	**Clear/Clear CB cond. indicators/ Clear restrike correction/ ACBMSCBR:x**	Clearing will reset the re-ignition correction to 0. Therefore, this should be done only after the conditions leading to unwanted CB re-ignitions have been remedied.
Unstable circuit breaker operation characteristics (UnstbOperLx)	**Clear/Clear CB cond. indicators/ Clear unstable mode/ ACBMSCBR:x**	To be repeated for each CB pole (instance x) that has exhibited unstable operating times. This indication shall be cleared only after the CB problems leading to this condition have been remedied, or after setting / learning different nominal operating times.

In Table 103, x refers both to the CB pole (L1/L2/L3) and to the instance number of the corresponding function block (ACBMSCBR:1/2/3). Indications have to be cleared in each function block instance individually.

16.2 Fault tracing

16.2.1 Identifying hardware errors

1. Check which module has an error.
   - Check the general IED status in **Main menu/Diagnostics/IED status/General** for a faulty hardware module.
   - Check the history of changes in internal event list in **Main menu/Diagnostics/ Internal Events**.
2. Inspect the IED visually.

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- 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.
   - 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.

16.2.2 Identifying runtime errors

1. Check the error origin from **Main menu/Diagnostics/IED status/General**.
2. Reboot the IED and recheck the supervision events to see if the fault has cleared.
3. In **Main menu/Diagnostics/IED status/General**, the status on all items should show `Off` or `Ready`.
4. In case of persistent faults, contact ABB for corrective actions.

16.2.3 Identifying communication errors

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

- Check the IEC 61850 communication status in internal event list in **Main menu/ Diagnostics/IED Status/General**.
- In case of persistent faults originating from IED's internal faults such as component breakdown, contact ABB for repair or replacement actions.

16.2.3.1 Checking communication link operation

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

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/Test/ Function status/Communication/DOSFRNT:1/Outputs**.
   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 X1 via the LHMI in **Main menu/Tests/ Function status/Communication/DOSLAN1:1/Outputs**.
   The X1 communication port on the rear side of the IED is for optical Ethernet via LC connector.
   2.1. Check that the LINKUP value is 1, that is, the communication is working. When the value is 0, there is no communication link.

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16.2.3.2 Checking merging unit status

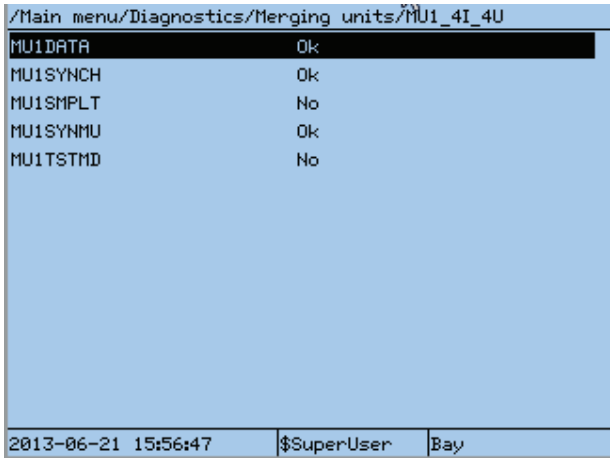


Figure 213: Merging unit status in normal operation

- Check the status of merging unit via the LHMI in **Main menu/Diagnostics/Merging units/MUx_4I_4U**.

x stands for the merging unit function block instance. See Table 102 for explanations of the indication signals.

The configured LED or binary output indication will be activated only if the corresponding merging unit is used in the application.

16.2.3.3 Checking time synchronization

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

Note that the time synchronization source has to be activated. Otherwise the value is always `Ready`.

16.2.4 Running the display test

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

- Select **Main menu/Tests/LED test** and press .
- Press 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.

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16.3 Indication messages

16.3.1 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/Diagnostics/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** screen and then entering it again. The current status of the internal fault signals can also be checked via the LHMI in **Main menu/Diagnostics/IED status/General**.

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 an internal fault appears, contact ABB. Make sure to include the fault indication status data and internal event listings in the request.

Table 104: 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 CPU 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 slot number is displayed at the end of the fault indication.
Internal Fault COM-Error	A COM card error has occurred. The slot number is displayed at the end of the fault indication.
Internal Fault PSM-Error	A PSM card error has occurred. The slot number is displayed at the end of the fault indication.
Internal Fault PIO-Error	A PIO card error has occurred. The slot number is displayed at the end of the fault indication.
Internal Fault BIO-Error	A BIO card error has occurred. The slot number is displayed at the end of the fault indication.

16.3.2 Warnings

The warning message associated with the fault is found in the internal event list in the LHMI menu **Main menu/Diagnostics/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/Diagnostics/IED status/General**.

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

Table 105: Warning indications

Warning indication	Additional information
Warning IEC 61850 Error	An IEC 61850 action such as reading the configuration file, startup etc. was not successfully completed.

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16.3.3 Additional indications

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

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

Table 106: Additional indications

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

16.4 Correction procedures

16.4.1 Changing and setting the password

The password can only be set with PCM600.



For more information, see the Cyber security deployment guideline.

16.4.2 Identifying IED application problems

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

- Check that the function is on.
- Check that SettingGroup1 is activated.
- Check the blocking.
- Check the mode.
- Check the measurement values.
- Verify any modifications to the default pre-configuration.
- Check the channel settings.

16.4.2.1 Inspecting the wiring

The physical inspection of wiring connections often reveals the wrong connection for phase currents or voltages. However, even though the phase current or voltage connections to IED terminals might be 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/Analog primary values** or **Analog secondary values**.
- Check that the phase information and phase shift between phases is correct.
- Correct the wiring if needed.
  - Change the parameter *Negation* in **Configuration/Analog modules/ 3PhaseAnalogGroup/SMAI_20_n:1** (n= the number of the SMAI used).

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Changing the *Negation* parameter is not recommended without detailed knowledge of its effects, unless expressly instructed by ABB.

  - 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/Tests/I/O 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. An activated input signal is indicated with a yellow-lit diode.
- Measure output contacts using the voltage drop method (see Figure 214) 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.

- Measure output circuits of precision binary outputs using the voltage drop method (see Figure 214).
  The load should be dimensioned to draw continuous current of 100 mA DC or less.

  Precision binary outputs are polarity-sensitive. Observe correct polarity of the test circuit. AC supply cannot be used for testing the precision binary inputs or outputs.

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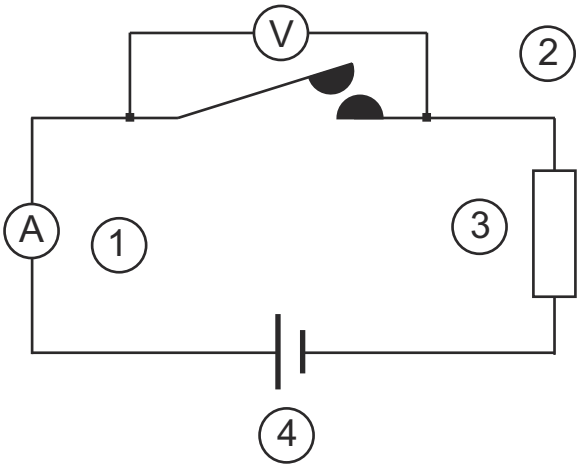


Figure 214: Testing output contacts using the voltage drop method

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

- To check the status of the output circuits via the LHMI, select **Main menu/Tests/I/O modules** and then navigate to the board with the actual binary output to be checked.

  Forcing is possible on all the output contacts available on PSM02/03, BIO01 and PIO01 hardware modules.

- Test and change the output state manually.
  1. To set the IED to test mode, select **Main menu/Tests/IED test mode/TESTMODE:1** and set the parameter *TestMode* to *On*. The Start LED flashes continuously to indicate active IED test mode.
  2. To operate or force the output to operate, select **Main menu/Test/Forcing/Binary output values** and navigate to a specific module in the list.
  3. Select BOn_PO or PBOn to be operated/forced and use ↵ and ↑ or ↓ to operate the actual output.
     Each binary output 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 IED is no longer in test mode.

For relay contact outputs (on BIO and PSM cards), 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 milliohms range. As a result, practically the full voltage is available at the load.

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Section 17 Technical data

17.1 Dimensions

Table 107: Dimensions of the IED - 3U full 19" rack

Description	Value
Width	442 mm (17.40 inches)
Height	132 mm (5.20 inches), 3U
Depth	249.5 mm (9.82 inches)
Weight box	10 kg (<22.04 lbs)

17.2 Power supply

Table 108: Power supply

Description	600PSM02	600PSM03
U_{aux}nominal	48, 60, 110, 125 V DC	110, 125, 220, 250 V DC
U_{aux}variation	80...120% of U_n (38.4...150 V DC)	80...120% of U_n (88...300 V DC)
Maximum load on auxiliary voltage supply	35 W for DC	
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 U_{aux}	
Resolution of the voltage measurement in PSM module	1 bit represents 1 V (+/- 1 VDC)	1 bit represents 2 V (+/- 1 VDC)

17.3 Measuring inputs

Table 109: Measuring inputs

Description	Value
Frequency	
Rated frequency f_r	50 or 60 Hz
Operating range	f_r ± 10%
Sampling frequency	4000 S/s at 50 Hz 4800 S/s at 60 Hz
Current inputs	
Rated current I_r	1 or 5 A[1)]
Operating range	0 – 500 A
Table continues on next page	

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Description	Value
Thermal withstand	500 A for 1 s *) 100 A for 10 s 40 A for 1 min 20 A continuously
Dynamic withstand	1250 A one half wave
Burden	< 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 U_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) Phase currents or residual current

17.4 Binary inputs

Table 110: 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 111: Precision binary inputs

Description	Value
Operating range	Maximum input voltage 300 V DC
Rated voltage	33...288 V DC
Current drain	0...0.5 mA
Power consumption/input	<0.15 W
Threshold voltage	15...221 V DC (parametrizable in the range in steps of 1% of the rated voltage)

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17.5 Signal outputs

Table 112: Signal outputs and IRF output

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 U <48/110/220 V DC	≤0.5 A/≤0.1 A/≤0.04 A

17.6 Power outputs

Table 113: Power output relays without TCS function (not used in default pre-configuration)

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 U <48/110/220 V DC	≤1 A/≤0.3 A/≤0.1 A

Table 114: Power output relays with TCS function (not used in default pre-configuration)

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 U <48/110/220 V DC	≤1 A/≤0.3 A/≤0.1 A
Control voltage range	20...250 V DC
Current drain through the supervision circuit	~1.0 mA
Minimum voltage over the TCS contact	20 V DC

Table 115: Precision binary outputs

Description	Value
Rated switching voltage	33...288 V DC
Continuous carry (resistive)	0.5 A DC
DC make and carry ton <1 s (single shot, toff >600 s) L/R <10 ms Usw ≤50 V	10 A DC
Table continues on next page	

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Description	Value
DC make and carry ton <1 s (single shot, toff >600 s) L/R <10 ms Usw >150 V	6 A DC
Impedance in On state	≤0.5 Ω
Impedance in Off state	≥100 kΩ

17.7 Data communication interfaces

Table 116: Ethernet interfaces

Ethernet interface	Protocol	Cable	Data transfer rate
100BASE-TX (front port)	TCP/IP	CAT 5 S/FTP or better	100 MBit/s
100BASE-FX (rear Ethernet ports)	TCP/IP	Fibre-optic cable with LC connector	100 MBit/s

Table 117: Fibre-optic communication links

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 118: Supported station communication interfaces and protocols

Protocol	Ethernet
	100BASE-FX LC
IEC 61850-8-1	●
HTTPS	●
● = Supported	

Table 119: 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	DNP3.0 (not used in Switchsync PWC600)	Shielded twisted pair cable Recommended: DESCAFLEX RD-H(ST)H-2x2x0.22mm^2, Belden 9729, Belden 9829

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Table 120: IRIG-B

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

Table 121: 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 IEDs supported on the same bus	32	-
Max. cable length	925 m (3000 ft)	Cable: AWG24 or better, stub lines shall be avoided

Table 122: Optical serial port (X9) and PPS synchronization input (X10)

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

1) Maximum allowed attenuation caused by fibre

17.8 Enclosure class

Table 123: Degree of protection of rack-mounted IED

Description	Value
Front side	IP 40
Rear side, connection terminals	IP 20

Table 124: Degree of protection of the LHMI

Description	Value
Front and side	IP40

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17.9 Ingress protection

Table 125: Ingress protection

Description	Value
IED front	IP 54
IED rear	IP 21
IED sides	IP 42
IED top	IP 42
IED bottom	IP 21

17.10 Environmental conditions and tests

Table 126: 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
Altitude	up to 2000 m
Transport and storage temperature range	-40...+85ºC

Table 127: 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

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17.11 Electromagnetic compatibility tests

Table 128: 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 ports	1 kV line-to-earth	
• Other ports	2 kV line-to-earth, 1 kV line-to-line	
• Power supply	4 kV line-to-earth, 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	1000 A/m	IEC 61000-4-9, level 5
Damped oscillatory magnetic field	100 A/m, 100 kHz and 1 MHz	IEC 61000-4-10, level 5
Power frequency immunity test		IEC 60255-22-7, class A IEC 61000-4-16
• Common mode	300 V rms	

Table continues on next page

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Description	Type test value	Reference
• 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
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 • Conducted, RF-emission (mains terminal) 0.15...0.50 MHz 0.5...30 MHz • Radiated RF-emission, IEC 30...230 MHz 230...1000 MHz	 <79 dB(µV) quasi peak <66 dB(µV) average <73 dB(µV) quasi peak <60 dB(µV) average <40 dB(µV/m) quasi peak, measured at 10 m distance <47 dB(µV/m) quasi peak, measured at 10 m distance	EN 55011, class A IEC 60255-25 ANSI C63.4, FCC

17.12 Insulation tests

Table 129: Insulation tests

Description	Type test value	Reference
Dielectric tests: • Test voltage	 2 kV, 50 Hz, 1 min 1 kV, 50 Hz, 1 min, communication	IEC 60255-5 ANSI C37.90-2005
Impulse voltage test: • 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	IEC 60255-5 ANSI C37.90-2005
Insulation resistance measurements • Isolation resistance	 >100 M'Ω, 500 V DC	IEC 60255-5 ANSI C37.90-2005
Protective bonding resistance • Resistance	 <0.1 'Ω (60 s)	IEC 60255-27

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17.13 Mechanical tests

Table 130: Mechanical tests

Description	Reference	Requirement
Vibration response tests (sinusoidal)	IEC 60255-21-1	Class 1
Vibration endurance test	IEC 60255-21-1	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

17.14 Product safety

Table 131: Product safety

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

17.15 EMC compliance

Table 132: EMC compliance

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

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Section 18 Glossary

Names of function blocks, IEC 61850 logical nodes, data objects, data attributes etc. are not listed here. Refer to the respective section of this document or to the relevant part of the standard.

AC	Alternating current
ACT	Application configuration tool within PCM600
ACSI	Abstract communication service interface, as defined in IEC 61850-7-2
A/D converter	Analog-to-digital converter
AI	Analog input
ANSI	American National Standards Institute
AP	Access point for digital communication
AR	Autoreclosing
AWG	American Wire Gauge standard
BI	Binary input
BIO	Binary input/output module
BO	Binary output
BRCB	Buffered report control block
BS	British Standards
CAN	Controller Area Network. ISO standard (ISO 11898) for serial communication
CB	Circuit breaker
CCITT	Consultative Committee for International Telegraph and Telephony. A United Nations-sponsored standards body within the International Telecommunications Union.
CCVT	Capacitive Coupled Voltage Transformer
CDC	Common data class
CET	Central European Time zone
CID	Configured IED description file as per IEC 61850-6
Class C	Protection Current Transformer class as per IEEE/ ANSI
CMT	Communication Management tool in PCM600
CO cycle	Close-open cycle
COM	Communication module
COMTRADE	Standard format according to IEC 60255-24
CPU	Central processing unit
CRC	Cyclic redundancy check
CSV	Comma-separated values
CT	Current transformer
CVT	Capacitive voltage transformer

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DA	Data attribute
DARPA	Defense Advanced Research Projects Agency (The US developer of the TCP/IP protocol etc.)
DC	Direct current
DHCP	Dynamic Host Configuration Protocol
DI	Digital input
DNP	Distributed Network Protocol as per IEEE Std 1815-2012
DO	Data object
DR	Disturbance recorder
DRAM	Dynamic random access memory
DSP	Digital signal processor
DST	Daylight Saving Time
DTT	Data type template section in the SCL description file of a station or IED
DVD	Digital versatile disc
EHV	Extra high voltage
EIA	Electronic Industries Association
EMC	Electromagnetic compatibility
EMI	Electromagnetic interference
EN	European standard
ESD	Electrostatic discharge
FAT	Factory Acceptance Test
FC	Function constraint
GDE	Graphical display editor within PCM600
GIS	Gas-insulated switchgear
GoCB	GOOSE control block
GOOSE	Generic object-oriented substation event
GPS	Global positioning system
GSAL	Generic security application
GSE	Generic substation event
HMI	Human-machine interface
HSAR	High speed autoreclosing
HTTPS	Hypertext transfer protocol secure
HV	High-voltage
HVDC	High-voltage direct current
HW	Hardware
ICD	IED capability description file as per IEC 61850-6
IEC	International Electrical Committee
IEC 60044-6	IEC Standard, Instrument transformers – Part 6: Requirements for protective current transformers for transient performance
IEC 61850	Substation automation communication standard
IEC 61850-8-1	Communication protocol standard for station bus

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IEC 61850-9-2(LE)	Communication protocol standard for sampled values
IEEE	Institute of Electrical and Electronics Engineers
IEEE 802.12	A network technology standard that provides 100 Mbits/s on twisted-pair or optical fiber cable
IEEE 1686	Standard for Substation Intelligent Electronic Devices (IEDs) Cyber Security Capabilities
IED	Intelligent electronic device
IID	Instantiated IED Description as per IEC 61850-6
Instance	When several occurrences of the same function are available in the IED, they are referred to as instances of that function. One instance of a function is identical to another of the same kind but has a different number in the IED user interfaces. The word "instance" is sometimes defined as an item of information that is representative of a type. In the same way an instance of a function in the IED is representative of a type of function.
IP	1. Internet protocol. The network layer for the TCP/IP protocol suite widely used on Ethernet networks. IP is a connectionless, best-effort packet-switching protocol. It provides packet routing, fragmentation and reassembly through the data link layer. 2. Ingression protection, according to IEC standard
IP 20	Ingression protection, according to IEC standard, level 20
IP 40	Ingression protection, according to IEC standard, level 40
IP 54	Ingression protection, according to IEC standard, level 54
IRF	Internal failure signal
IRIG-B	InterRange Instrumentation Group Time code format B, standard 200
ITU	International Telecommunications Union
LAN	Local area network
LCD	Liquid crystal display
LD	Logical device in IEC 61850
LED	Light-emitting diode
LHMI	Local human-machine interface
LN	Logical node in IEC 61850
MCB	Miniature circuit breaker
MICS	Model implementation conformance statement, for IEC 61850
MMS	Manufacturing Message Specification
MU	Merging unit
MVB	Multifunction vehicle bus. Standardized serial bus originally developed for use in trains.
NC	Normally closed auxiliary contact
NCC	National Control Centre
NCIT	Non-conventional instrument transformer
NO	Normally open auxiliary contact
OCO cycle	Open-close-open cycle
PBI	Precision Binary Input for accurate detection of contact changeover

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PBO	Precision Binary Output for time-controlled release of a circuit breaker pole
PC	Personal computer
PCM	Pulse code modulation
PCM600	Protection and control IED manager
PICS	Protocol implementation conformance statement, for IEC 61850
PIO	Precision input/output module
PIXIT	Protocol implementation extra information for testing, for IEC 61850
PoW	Point on wave
PPS, 1PPS	One pulse per second, time synchronization interface
Process bus	Bus or LAN used at the process level, that is, in near proximity to the measured and/or controlled components
PSM	Power supply module
PST	Parameter setting tool within PCM600
PT ratio	Potential transformer or voltage transformer ratio
PWC	Point-on-wave controller
RBAC	Role-based access control (role-based security)
RISC	Reduced instruction set computer
RJ-45	Registered jack 45, commonly used as plug connector for electrical Ethernet
RMS value	Root mean square value
RS422	A balanced serial interface for the transmission of digital data in point-to-point connections
RS485	Serial link according to EIA standard RS485
RTC	Real-time clock
RTU	Remote terminal unit
Rx	Receive line
SA	Substation Automation
SBO	Select-before-operate
SCADA	Supervision, control and data acquisition
SCD	System configuration description file as per IEC 61850-6
SCL	System configuration language in IEC 61850
SCS	Station control system
SCT	System configuration tool according to standard IEC 61850
SMT	Signal matrix tool within PCM600
SMS	Station monitoring system
SNTP	Simple network time protocol – is used to synchronize computer clocks on local area networks. This reduces the requirement to have accurate hardware clocks in every embedded system in a network. Each embedded node can instead synchronize with a remote clock, providing the required accuracy.
SPO	Single-pole operated (circuit breaker), i.e. one drive for each pole.
SST	Switchsync Setting Tool within PCM600

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Starpoint	Neutral point of transformer or generator
SVC	Static VAr compensation
SW	Software
TC	Trip coil
TCS	Trip circuit supervision
TCP	Transmission control protocol. The most common transport layer protocol used on Ethernet and the Internet.
TCP/IP	Transmission control protocol over Internet Protocol. The de facto standard Ethernet protocols incorporated into 4.2BSD Unix. TCP/IP was developed by DARPA for Internet working and encompasses both network layer and transport layer protocols. While TCP and IP specify two protocols at specific protocol layers, TCP/IP is often used to refer to the entire US Department of Defense protocol suite based upon these, including Telnet, FTP, UDP and RDP.
TICS	Tissue implementation conformance statement, for IEC 61850
TPO	Three-pole operated (circuit breaker), i.e. one drive for three poles
TPZ, TPY, TPX, TPS	Current transformer class according to IEC
TRM	Transformer module
TRV	Transient recovery voltage
Tx	Transmit line
UAC	User Account Control in Microsoft Windows operating systems
UHV	Ultra high voltage
UMT	User management tool
Unicode	Universal standard for text encoding
URCB	Unbuffered report control block
UTC	Coordinated Universal Time. A coordinated time scale, maintained by the Bureau International des Poids et Mesures (BIPM), which forms the basis of a coordinated dissemination of standard frequencies and time signals. UTC is derived from International Atomic Time (TAI) by the addition of a whole number of "leap seconds" to synchronize it with Universal Time 1 (UT1), thus allowing for the eccentricity of the Earth's orbit, the rotational axis tilt (23.5 degrees), but still showing the Earth's irregular rotation, on which UT1 is based. The Coordinated Universal Time is expressed using a 24-hour clock, and uses the Gregorian calendar. It is used for aeroplane and ship navigation, where it is also sometimes known by the military name, "Zulu time." "Zulu" in the phonetic alphabet stands for "Z", which stands for longitude zero.
VT	Voltage transformer
WAN	Wide area network
WHMI	Web human-machine interface
XML	Extensible markup language

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