CSD100 Point-on-Wave Controller

NOT. 200.8713_En

Instruction manual for version 1.5

Submitted by: GE Vernova

Revision No. 1.0

September 12, 2025

GE VERNOVA

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2 CONFORMITY

This product is in conformity with the relevant European Union harmonization legislation:

- Directive 2014/35/EU of the European Parliament concerning electrical equipment designed for use within certain voltage limits (low voltage directive)
- Directive 2014/30/EU of the European Parliament relating to electromagnetic compatibility
- Directive 2011/65/EU of the European Parliament on the restriction of the use of certain hazardous substances in electrical and electronic equipment

This conformity is declared with references to the relevant harmonized standards:

- IEC 60950-1:2006 (2nd Edition) +A1:2009 +A2:2013 +A11:2009 +A12:2011, Information technology equipment – Safety – Part 1: General requirements
- IEC 61010-1:2010 (3rd Edition), Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 1: General requirements
- IEC 60255-27:2013, Measuring relays and protection equipment – Part 27: Product safety requirements
- IEC 61000-6-5:2015, Electromagnetic compatibility (EMC) – Part 6-5: Generic standards – Immunity for equipment used in power station and substation environment
- IEC 60255-26:2013, Measuring relays and protection equipment – Part 26: Electromagnetic compatibility requirements
- CISPR32 / EN55032 (2015-03) relative to conducted and radiated emissions

Custom Tariff number (TARIC code)

Custom Tariff number (TARIC code) of the CSD100 Point-on-Wave controller is 85389091.

Export control classification number (ECCN)

The Export Control Classification Number (ECCN) of the CSD100 Point-on-Wave controller is 1B999.c.

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6 REFERENCES

[1] CIGRE Technical Brochure 262, “Controlled Switching of HVAC Circuit Breakers - Benefits & Economic Aspects”, CIGRÉ Working Group A3.07, December 2004. [1]

[2] CIGRE Technical Brochure 263, “Controlled Switching of HVAC Circuit Breakers - Guidance for Further Applications Including Unloaded Transformer Switching, Load and Fault Interruption and Circuit-Breaker Uprating”, CIGRÉ Working Group A3.07, December 2004.

[3] CIGRE Technical Brochure 264, “Controlled Switching of HVAC Circuit Breakers - Planning, Specification and Testing of Controlled Switching Systems”, CIGRÉ Working Group A3.07, December 2004.

[4] CIGRE Technical Brochure 757, “Guidelines and best practices for the commissioning and operation of controlled switching projects”, CIGRÉ Working Group A3.35, February 2019.

[1] CIGRE publications are available from CIGRE (Conference Internationale des Grands Reseaux Electriques Haute Tension) (International Conference on High Voltage Systems), 21, rue d’Artois, F 75008 Paris, France http://www.cigre.org

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7 SAFETY INSTRUCTIONS

7.1 Warning

This Safety Section and the relevant equipment documentation provide full information on safe handling, commissioning and operating of this equipment. This Safety Section also includes reference to typical equipment label markings.

Before carrying out any work on the equipment the user should be familiar with the contents of this Safety Section and the ratings on the equipment's rating label.

Reference should be made to the external connection diagram before the equipment is installed, commissioned or serviced.

The safety instructions in this section must be followed during all use, maintenance and repair operations performed on the controller.

Non-compliance with the precautions and warnings given in this manual constitutes a violation of the safety standards relating to the normal use of this controller.

GE will not be held responsible for non-compliance with these instructions.

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7.2 Symbols and labels

Throughout this document you may come across the following symbols. These are also represented on the product.



Important: Consult the user manual before using the equipment. Failure to follow and comply with the instructions marked in this manual with this symbol may result in personal injury or damage to the equipment and facilities.



Dangerous and lethal voltages are generated during the operation of this equipment.
Risk of electrical shock.



Protective earth / ground terminal
Identifies any terminal which is intended for connection to an external conductor for protection against electric shock in case of a fault, or the terminal of a protective earth (ground) electrode.



DC voltage



AC voltage



Disposal of Waste Equipment by Users in Private Household in the European Union
Indicates that this product must not be disposed of with your other household waste.



CE marking
Conformity to all applicable European directives

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7.3 General use


The equipment documentation shall be consulted before installing, commissioning or servicing the equipment.


The use of CSD100 and related products described in this manual is restricted exclusively to qualified engineers, accredited to handle low-voltage equipment, or persons instructed by them. CSD100 users must also be qualified to operate High Voltage switching systems.


Personnel undertaking installation, commissioning or servicing work for this equipment should be aware of the correct working procedures to ensure safety.


Personal protective equipment must be worn during all handling operations.


Use this product only for the purposes specified by the manufacturer. If the instructions and warnings are not observed, the safety features of this product may be affected.


CSD100 controller contains electrical and electronic components that may still be charged. The user may suffer electrical shock if precautions and instructions are not followed before handling or opening the relay case.


Observe the necessary safety precautions when handling components that are vulnerable to electrostatic discharge. Users of CSD100 must follow safety recommendations given in the following standards (IEC 61340-5-1 & 61340-5-2, EN 61340-5-1 & 61340-5-2)!


Before any use of CSD100, it must be earthed via the protection earth connection and the housing grounding terminal stud.


Before use, check that all plug-in cable connectors to the CSD100 are securely locked.


Appropriate handling equipment must be used to transport the CSD100.


It is the responsibility of the user to ensure that the equipment is installed, operated and used for its intended function in the manner specified by the manufacturer.


If the equipment is used and protected in a manner not specified by the manufacturer, the safety protection provided by the equipment may be impaired.


The equipment should be operated within the specified electrical and environmental limits.


FAILURE APPLYING THESE INSTRUCTIONS MAY RESULT WITH DEATH OR SERIOUS INJURIES

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7.4 Handling the goods

7.4.1 Transport

On receipt, ensure the correct product has been delivered. Unpack the product immediately to ensure there has been no external damage in transit. If the product has been damaged, make a claim to the transport contractor and notify GE promptly.

7.4.2 Storage

Store the unit indoors in a cool, dry place, free of dust and moisture, in its original packaging. Keep any moisture-absorption bag in the packing. The efficiency of the drying agent is impaired if the unprotected bag is exposed to the surrounding conditions. Before the CSD100 is placed in the box again, warm the drying bag slightly to regenerate the drying agent.

Follow the storage temperature range outlined in the TECHNICAL INFORMATION section.

7.4.3 Unpacking

This product shall be handled with care and should be checked for damage which could have originated during transportation before installation.

When unpacking and installing the unit, take care not to damage any of the parts and make sure that additional components are not accidentally left in the packing or lost. Do not discard any CDROMs or technical documentation. These should accompany the unit to its destination substation.

1. Open the relay package and check that the following items have been delivered:

- CSD100 Point-on-Wave controller
- Mounting kits and screws
- Terminal blocks with labels
- Safety instructions
- Test report
- CE Declaration of conformity

2. Inspect the unit for physical damage.

3. View the nameplate and verify that the correct model has been delivered.

5. For any issue, contact GE as outlined in the For Further Assistance section in chapter 2.

6. Check that you have the latest copy of the CSD100 Point-on-Wave controller documentation

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7.4.4 Lifting

Plan carefully, identify any possible hazards and determine whether the load needs to be moved at all. Look at other ways of moving the load to avoid manual handling. Use the correct lifting techniques and Personal Protective Equipment to reduce the risk of injury. Many injuries are caused by:

- Lifting heavy objects;
- Lifting things incorrectly;
- Pushing or pulling heavy objects;
- Using the same muscles repetitively.

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7.5 Installing, commissioning and servicing

7.5.1 Installation



Follow recommendations provided by the manufacturer to install this product. Procedure for installation of this product is detailed in chapter INSTALLATION, MOUNTING , CABLING



The CSD100 shall be installed in the control room or the relay room of the substation. Its position shall be chosen for easy inspection and easy access to the CSD100 connections.



Use mounting accessories supplied by the manufacturer only.



The CSD100 shall be well lit and properly locked to its housing location.



1 U clearance should be left above and under the device.

7.5.2 Protective earthing



This product is a safety class I product and has protective earthing terminals. There must be an uninterruptible safety earth / ground from the main power source to the product's input wiring terminals, power cord, or supplied power cord set.



Before energizing the equipment, it must be earthed / grounded using the protective conductor terminal, if provided, or the appropriate termination of the supply plug in the case of plug connected equipment



The protective earth conductor connection must not be removed or interrupted since the protection against electric shock provided by the equipment would be lost.



When the protective earth conductor terminal (PCT) is also used to terminate cable screens, etc., it is essential that the integrity of the protective earth conductor is checked after the addition or removal of such functional earth connections. For M4 stud PCTs the integrity of the protective (earth) connections should be ensured by use of a locknut or similar.



The recommended minimum protective earth conductor wire size is 6 mm² unless otherwise stated in the technical data section of the equipment documentation, or otherwise required by local or country wiring regulations.



The protective earth conductor connection must be low-inductance and as short as possible.



All connections to the equipment must have a defined potential. Connections that are pre-wired, but not used, should preferably be grounded when binary inputs and output relays are isolated. When binary inputs and output relays are connected to common potential, the pre-wired but unused connections should be connected to the common potential of the grouped connections.



Whenever it is likely that the protection has been impaired, disconnect the power cord until the ground has been restored.

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7.5.3 Power supply voltage



Do not use power exceeding the device rated power supply voltage.



For safety reasons, variation in the main power supply must not exceed the nominal value by +/- 10%.

7.5.4 Electrical hazards



Terminals exposed during installation, commissioning and maintenance may present a hazardous voltage unless the equipment is electrically isolated.



If working in an area of restricted space, such as a cubicle, where there is a risk of electric shock due to accidental touching of terminals which do not comply with IP20 rating, then a suitable protective barrier should be provided.



If there is unlocked access to the rear of the equipment, care should be taken by all personnel to avoid electric shock or energy hazards.



Any disassembly of the equipment may expose parts at hazardous voltage; also, electronic parts may be damaged if suitable electrostatic voltage discharge (ESD) precautions are not taken.



Removal of the equipment front panel/cover is not allowed and may expose hazardous live parts, which must not be touched until the electrical power is removed.

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7.5.5 Equipment connections

The equipment must be connected in accordance with the appropriate connection diagram.

To ensure that wires are correctly terminated the correct crimp terminal and tool for the wire size should be used. Use appropriate tools for connecting and removing the connectors.

Voltage and current connections shall be made using insulated crimp terminations to ensure that terminal block insulation requirements are maintained for safety.

The clamping screws of all terminal block connectors, for field wiring, using M4 screws shall be tightened to a nominal torque of 1.3 Nm.

The clamping screws of all terminal block connectors, for field wiring, using M3 screws shall be tightened to a nominal torque of 0.6 Nm.

The clamping screws of all terminal block connectors, for field wiring, using M2 screws shall be tightened to a nominal torque of 0.25 Nm.

Watchdog (self-monitoring) contacts are provided in numerical relays to indicate the health of the device. GE strongly recommends that these contacts are hardwired into the substation's automation system, for alarm purposes.

Conductors used for wiring shall meet the requirement of IEC 60228.

Terminals for connection to external circuits shall meet the requirement of IEC 60947-1.

Micro circuit-breaker used for the equipment protection shall meet the requirement of IEC 60947-2 and be installed an easily accessible location. Recommendations for protection levels are delivered in chapter 11.3.1.

Power supply sources disconnecting device shall meet the requirement of IEC 60947-3 and be installed an easily accessible location.

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7.5.6 Current transformer circuits



Before working on CT circuits, these shall be short-circuited.



Do not open the secondary circuit of a live CT since the high voltage produced may be lethal to personnel and could damage insulation. The secondary of the line CT must be shorted before opening any connections to it.



Take extreme care when using external test blocks and test plugs, as hazardous voltages may be exposed. CT shorting links must be in place before inserting or removing test plugs, to avoid potentially lethal voltages.

7.5.7 Insulation and dielectric strength testing



Insulation testing may leave capacitors charged up to a hazardous voltage. At the end of each part of the test, the voltage should be gradually reduced to zero, to discharge capacitors, before the test leads are disconnected.

7.5.8 Pre-energization checklist

Before energizing the equipment, the following should be checked:

- Integrity of the protective conductor (earth) connection;
- Protective miniature circuit breaker rating;
- Voltage rating/polarity (rating label/equipment documentation);
- CT circuit rating (rating label), polarity and integrity of connections;
- Voltage and current rating of external wiring, applicable to the application.

Pre-energization checklist and commissioning procedure are detailed in chapter COMMISSIONING.

7.5.9 Warning about fiber optics communication ports



Fiber-optic communication outputs shall not be viewed directly

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7.5.10 Maintenance and repair



Components may only be adjusted or replaced by qualified, electrically certified staff.



Repair of CSD100 device consists in its replacement only. There are no serviceable subparts within the product enclosure. All servicing must be made with the prior agreement of GE by qualified staff.



To avoid accidents, always disconnect the power supply and any external power sources, and then check that the equipment is off before touching any components. Never replace a live component.

7.5.11 Cleaning and decontamination



The equipment may be cleaned with a sweet and non-fluffy duster (a lint free cloth) softly dampened with clean water, when no connections are energized. Use of detergents or chemical solvents is prohibited.

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7.6 De-commissioning and disposal

7.6.1 General recommendations

All relevant local safety regulations must be followed when dismantling this product.

Under the GE eco-design commitment, CSD100 does not contain any RoHS hazardous substances and then does not need specific management before dismantling.

To optimize end-of-life of CSD100, we recommend separating the metal frame beforehand, which is recyclable, and then extracting printed circuit board and wires to send them to professional waste disposer, like TERRA NOVA, UMICORE or BOLLIDEN, who are specialized in the processing of electrical waste.

7.6.2 De-commissioning



Before decommissioning, isolate completely the equipment power supplies (both poles of any dc supply).



The supply input for the equipment may include capacitors across the supply or to earth. To avoid electric shock or energy hazards, after completely isolating the supplies to the equipment (both poles of any dc supply), the capacitors should be safely discharged via the external terminals prior to de-commissioning.

7.6.3 Disposal



This product must not be disposed of with your other household waste. Instead, it is your responsibility to dispose of your waste equipment by handing it over to a designated collection point for the recycling of waste electrical and electronic equipment. The separate collection and recycling of your waste equipment at the time of disposal helps to conserve natural resources and ensure that it is recycled in a manner that protects human health and the environment. For more information about where you can drop off your waste equipment for recycling, please contact your local city office, your household waste disposal service or the shop where you purchased the product.

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8 GLOSSARY AND LIST OF ABBREVATIONS AND ACRONYMS

The following definitions and acronyms are used in this manual:

Table 1 Glossary and list of abbreviations and acronyms

Term	Definition
Switchgear, Controlgear	
“a” contact Make contact	A control or auxiliary contact which is closed when the main contacts of the mechanical switching device are closed and open when they are open [IEV 441-15-12]
"b" contact Break contact	A control or auxiliary contact which is open when the main contacts of a mechanical switching device are closed and closed when they are open [IEV 441-15-13]
3PO	3-pole operation (gang operation)
3PR	Three-phase reclose
3σ	Circuit breaker operating time scatter
52a	CB position signaling / CB signaling
ϕres	Residual flux
Adaptive control	Closed-loop control (feedback control loop) with automatic modification of the controlling system parameters, to compensate for varying operating conditions and states
Arcing contact	A contact on which the arc is intended to be established. Note – An arcing contact may serve as a main contact; it may be a separate contact so designed that it opens after and closes before another contact which it is intended to protect from injury. [IEV 441-15-08]
Arcing time (of a pole or a fuse)	The interval of time between the instant of the initiation of the arc in a pole or a fuse and the instant of final arc extinction in that pole or that fuse [IEV 441-17-37]
Arcing time (of a multipole switching device)	The interval of time between the instant of the first initiation of an arc and the instant of final arc extinction in all poles [IEV 441-17-38]
ATR	Autotransformer
Auto-reclosing	auto-reclosing (of a mechanical switching device) the operating sequence of a mechanical switching device whereby, following its opening, it closes automatically after a predetermined time [IEV 441-16-10]
Auxiliary contact	A contact included in an auxiliary circuit and mechanically operated by the switching device [IEV 441-15-10]
Auxiliary switch	A switch containing one or more control and/or auxiliary contacts mechanically operated by a switching device [IEV 441-15-11]
Back-to-back capacitor bank	Two capacitor banks in close vicinity
CB	Circuit breaker: mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making,

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Term	Definition
	carrying for a specified duration and breaking currents under specified abnormal circuit conditions such as those of short circuit [IEV 441-14-20]
Closing operation	An operation by which the device is brought from the open position to the closed position [IEV 441-16-08]
Closing operating time	The interval during which the contacts move from the fully open position to the fully closed position (IEEE C37.100).
Closing time (of a mechanical switching device)	The interval of time between the initiation of the closing operation and the instant when metallic continuity is established in all poles (IEEE C37.100).
Controlled switching	Controlling the circuit breaker such that the circuit is made at a predetermined point on the voltage waveform. NOTE — This control action considers that the circuit will be made earlier than the contact touch due to prestrike.
CSD	Controlled switching device
CT	Current transformer
Current chopping	Current interruption before the natural zero current, which causes overvoltage in inductive current switching (as opposite to soft commutation)
Dead tank circuit-breaker (DT)	A circuit-breaker with interrupters in an earthed metal tankCommonly referred as DT [IEV 441-14-25]
DS	Disconnect switch
Effectively earthed neutral system	system earthed through a sufficiently low impedance such that for all system conditions the ratio of the zero-sequence reactance to the positive-sequence reactance (X0/X1) is positive and less than 3, and the ratio of the zero-sequence resistance to the positive-sequence reactance (R0/X1) is positive and less than 1. Normally such systems are solidly earthed (neutral) systems or low impedance earthed (neutral) systems
Fault clearance	Disconnection from the electric power system of a defective item, by automatic or manual operations, in order to maintain or restore supply [IEV 614-02-24]
Grading capacitor	capacitor for installation on high-voltage circuit-breakers to control the voltage distribution across the individual interrupter unit IEC 62146-1, 3.13
GIS	Gas insulated substation
GSUT	Generator step-up transformer
HVAC	High voltage alternating current
HVDC	High voltage direct current
ICT	Inter connection transformer
Idle time	Time interval for which the item is in an idle state (no operation)
IPO	Independent pole operation
IVT	Inductive voltage transformer
Live tank circuit-breaker (LT)	A circuit-breaker with interrupters in a tank insulated from earthCommonly referred as LT [IEV 441-14-26]
Main contact	A contact included in the main circuit of a mechanical switching device, intended to carry, in the closed position, the current of the main circuit. [IEV 441-15-07]

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Term	Definition
	“Permanent contact” notion can be used
Making or breaking unit	Part of a circuit-breaker which in itself acts as a circuit-breaker and which, in series with one or more identical and simultaneously operated making or breaking units, forms the complete circuit-breaker
MAT	Minimum arcing time
NER	Neutral earthing reactor
NGR	Neutral grounding reactor
Non-effectively earthed neutral system	System other than effectively earthed neutral system, not meeting the conditions given in 3.1.128. Normally such systems are isolated neutral systems, high impedance earthed (neutral) systems or resonant earthed (neutral) systems
Opening operation	An operation by which the device is brought from the closed position to the open position [IEV 441-16-09]
Opening time	Interval of time between the specified instant of initiation of the opening operation and the instant when the arcing contacts have separated in all poles
Overvoltage	Any voltage between one phase and earth or between phases having a peak value or values exceeding the corresponding peak of the highest voltage for equipment [IEV 604-03-09]
PH-E	Phase-to-earth
PH-PH	Phase-to-phase
PIR	Pre-insertion resistor (closing resitor)
PIS	Pre-insertion switch
Pole of a switching device	The portion of a switching device associated exclusively with one electrically separated conducting path of its main circuit and excluding those portions which provide a means for mounting and operating all poles together Note – A switching device is called single-pole if it has only one pole. If it has more than one pole, it may be called multipole (two-pole, three-pole, etc.) provided the poles are or can be coupled in such a manner as to operate together. [IEV 441-15-01]
PoW	Point-on-wave
Pre-arcing time	The interval of time between the beginning of a current large enough to cause a breakdown between contacts in approach and the instant of contact touch [IEV 441-18-21]
Pre-insertion time	Duration of the insertion of a closing resistor in a circuit during a closing operation, before main contact touch. Mechanical insertion time and electrical insertion time (including pre-arcing time) can be distinguished.
Prestrike	The initiation of current between the contacts during a closing operation before the contacts have mechanically touched (IEEE C37.100).
PTR	Power transformer
RDDS	“Rate of Decay of Dielectric Strength” of an interrupter. This is the rate that the dielectric strength across the closing contacts is reduced as the contacts come together for a closing operation. This characteristic is important in assessing the pre-strike of the closing arc prior to the mechanical closing of the circuit breaker contacts. (CIGRE Publication 262 to 264).

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Term	Definition
Recovery voltage	The voltage which appears across the terminals of a pole of a switching device or a fuse after the breaking of the current [IEV 441-17-25]
Re-ignition (of an a.c. mechanical switching device)	resumption of current between the contacts of a mechanical switching device during a breaking operation with an interval of zero current of less than a quarter cycle of power frequency [IEV 441-17-45]
Restrike (of an a.c. mechanical switching device)	resumption of current between the contacts of a mechanical switching device during a breaking operation with an interval of zero current of a quarter cycle of power frequency or longer [IEV 441-17-46]
RRDS	Rate of rise of dielectric strength
RRRV	Rate of rise of recovery voltage
Secondary arc	Arc that remains at the faulted point after interruption of the short-circuit current fed by the network
SLD	Single-line diagram
SPR	Single-phase reclose
Switching device	A device designed to make or break the current in one or more electric circuits [IEV 441-14-01]
Synchronous operation (opening or closing)	Operation of a switching device in such a manner that the contacts are closed or opened at a predetermined point on a reference voltage or current wave (IEEE C37.100). NOTE — Synchronous operation applied on multiphase circuits may require that closing or opening of the contacts of each pole be responsive to a different reference.
TRV	“Transient Recovery Voltage” The recovery voltage during the time in which it has a significant transient character
VT	Voltage transformer
Network and digital	
100BASE-TX	100BASE-TX is a type of Ethernet network standard. It stands for: • 100: This indicates a maximum data transfer rate of 100 megabits per second (Mbps). • BASE: This signifies that the signaling is baseband, meaning that the Ethernet communication uses the entire bandwidth of the medium without modulating the signal onto a carrier frequency. • TX: This refers to twisted pair cables, specifically Cat5 or higher, using two pairs (four wires) of the cable for transmission. 100BASE-TX is widely used in local area networks (LANs) and provides a balance of speed and cost-effectiveness for many networking applications.
1000BASE-T	1000BASE-T is another Ethernet network standard, and it stands for: • 1000: This indicates a maximum data transfer rate of 1000 megabits per second (Mbps), or 1 gigabit per second (Gbps). • BASE: This signifies that the signaling is baseband, similar to 100BASE-TX, meaning the Ethernet communication uses the entire bandwidth of the medium without modulating the signal onto a carrier frequency. • T: This refers to twisted pair cables. Specifically, 1000BASE-T uses all four pairs (eight wires) of Cat5e or higher twisted pair cables for transmission.

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Term	Definition
	1000BASE-T is commonly used in local area networks (LANs) to provide gigabit Ethernet speeds over standard copper cabling.
100BASE-FX	100BASE-FX is an Ethernet network standard, and it stands for: • 100: This indicates a maximum data transfer rate of 100 megabits per second (Mbps). • BASE: This signifies that the signaling is baseband, meaning the Ethernet communication uses the entire bandwidth of the medium without modulating the signal onto a carrier frequency. • FX: This refers to fiber optic cables. Specifically, 100BASE-FX uses multimode fiber optic cables for transmission. 100BASE-FX is typically used in scenarios where longer distances or higher resistance to electromagnetic interference are required, such as in larger networks or environments with high electrical noise.
1000BASE-SX	1000BASE-SX is an Ethernet network standard, and it stands for: • 1000: This indicates a maximum data transfer rate of 1000 megabits per second (Mbps), or 1 gigabit per second (Gbps). • BASE: This signifies that the signaling is baseband, meaning the Ethernet communication uses the entire bandwidth of the medium without modulating the signal onto a carrier frequency. • SX: This refers to short wavelength laser over multimode fiber optic cables. It is typically used for short-distance communication, such as within buildings. 1000BASE-SX is commonly used for network connections that require high-speed data transfer over shorter distances, usually up to 550 meters, depending on the quality of the fiber and the setup.
Digital certificate	Asymmetric encryption key system, certified by external entity. Digital certificates are used to establish the identity of a user, device, or server and enable secure communication over networks.
DHCP	Dynamic Host Configuration Protocol (IP address server/provider)
DoS	Denial of service
FW	Firmware
GPS	“Global Positioning System” Satellite-based navigation system that provides location and time information anywhere on or near the Earth, where there is an unobstructed line of sight to four or more GPS satellites.
GMC	“Grand Master Clock”. Primary time source for synchronization. The Grand Master Clock provides the reference time to Slave Clocks, ensuring all devices on the network operate in sync.
HSR	“High-availability Seamless Redundancy” Network protocol designed to provide uninterrupted network communication with zero recovery time. HSR provides redundancy by sending duplicate frames over a ring network topology. Each node in the network has two interfaces, and data is sent in both directions around the ring.
HTML	“Hypertext Markup Language” It is the standard markup language used to create and design documents on the World Wide Web
HTTPS	Secured version of Hyper Text Transfer Protocol to guarantee identification and private/encrypted communications, for web interfaces.
HW	Hardware
IED	“Intelligent electronic device” Components that perform various functions related to monitoring, protection, control, and automation of electrical power systems

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Term	Definition
IP	Internet Protocol
IRIG-B	Inter Range Instrumentation Group (Rate Designation B)
LAN	“Local Area Network”. Network that connects devices within a limited geographic area, such as a home, office, or building.
LC	“Lucent Connector” Type of fiber optic connector used in networking and telecommunications. It is known for its small size and is often used in high-density network applications. Here are some key characteristics of the LC connector: Small Form Factor, Push-Pull Mechanism, Duplex Configuration, High Precision.
MAC	“Media Access Control” In networking, MAC refers to a sublayer of the data link layer (Layer 2) in the OSI model. It is responsible for controlling how devices on a network uniquely identify themselves on the physical medium. Each network interface card (NIC) has a unique MAC address, which helps in routing data to the correct destination within a local network.
MAC address	Unique identifier assigned to a network interface controller for use as a network address in communications within a network segment. MAC addresses are typically assigned by the manufacturer and are used in various network technologies, including Ethernet and Wi-Fi.
PKI	“Public key infrastructure” The complete set of processes required to provide encryption and digital signature services. IEC 27099 IEC 9594-8
PTP	“Precision Time Protocol” Protocol used to synchronize clocks throughout a computer network. Originally defined in IEEE 1588, PTP is designed to provide high precision time synchronization over ethernet.
Private key	Private part of asymmetric key. Stored in a secured way.
Public key	Public part of asymmetric key.
NTP	“Network Time Protocol” Protocol used to synchronize the clocks of computers over a network. NTP is one of the oldest Internet protocols still in use and can synchronize time within milliseconds over the Internet and within microseconds in local area networks.
OS	Operating system
PRP	“Parallel Redundancy Protocol” Network protocol designed to provide seamless failover and high availability in network communications. PRP operates by sending duplicate packets over two separate networks. This ensures that even if there is a failure in one network, the data can still be received through the other, providing high availability and reliability.
RTC	“Real-time clock” Integrated circuit that keeps track of the current time. It is used to maintain an accurate time and date even when the device is turned off (in association with energy storage)..
SHA256	Secure Hash Algorithm (32 bits words)
SW	Software
Syslog	Standard for message logging. Standard protocol used for logging and monitoring system messages in computer networks. It enables the collection, storage, and analysis of log messages from various devices and applications in a centralized manner, facilitating network management and troubleshooting. Syslog provides a standardized format for log messages, making it easier to parse, analyze, and correlate logs from different sources. Syslog operates over the network, typically using UDP port 514, though it can also use TCP for more reliable delivery. Secure versions, like Syslog over TLS, offer encryption for sensitive data. Syslog messages include

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Term	Definition
	severity levels ranging from emergency to debug, allowing administrators to prioritize issues and respond accordingly.
TCP	“Transmission control protocol” It is one of the core protocols of the Internet Protocol Suite and is widely used for managing the transmission of data over networks.
TLS	“Transport Layer Security” Cryptographic protocol designed to provide secure communication over a computer network. TLS is widely used to encrypt the data transmitted between web browsers and servers, ensuring privacy and data integrity.
UDP	“User Datagram Protocol” It is one of the core protocols of the Internet Protocol Suite and is used for transmitting data over a network. Unlike TCP, UDP is a connectionless protocol, which means it does not establish a connection before sending data and does not guarantee delivery, order, or error checking.
UTC	“Coordinated Universal Time”. It is the primary time standard by which the world regulates clocks and time. UTC is not adjusted for daylight saving time and is used as a basis for civil time across the globe. It is maintained by a combination of precise atomic clocks and astronomical observations.
VLAN	“Virtual Local Area Network” Technology used to create distinct broadcast domains within a single physical network infrastructure, allowing for more efficient network management and improved security. VLANs allow network administrators to segment a physical network into multiple logical networks. This segmentation helps reduce broadcast traffic and can improve network performance and security by isolating different groups of devices.
XML	“Extensible Markup Language” widely used format for storing and transporting data in a structured, text-based format that is both human-readable and machine-readable
VPN	“Virtual Private Network” It is a technology that creates a secure and encrypted connection over a less secure network, such as the internet.
IEC 61850	
AP	Access Point
CID file	“Configured IED Description” Specific type of SCL file used to describe the final configuration of an IED. It includes detailed information about the device's capabilities, its communication configuration, and the data it can exchange with other devices in the network. The CID file is essential for ensuring interoperability and seamless communication between various devices within a substation automation system. It helps in the proper configuration and integration of IEDs into the overall substation control system.
CPOW	LN: Point-on-wave switching
DA	“Data attribute” Component of the data model used to describe the functionality and information exchange capabilities of Intelligent Electronic Devices (IEDs) within a substation automation system. Data Attributes are the smallest elements of the data model and represent specific pieces of information associated with a Data Object (DO). These attributes can include measurable quantities, status indicators, settings, and control parameters. Each Data Attribute is defined with a specific type, such as integer, floating-point, or Boolean, and includes metadata such as units, range, and description.
Data model	The data model is a structured representation of the information exchanged between IEDs within a substation automation system. This model facilitates interoperability and standardized communication across different devices

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Term	Definition
	and systems. The data model is organized hierarchically and includes several key components: 1. **Logical Nodes (LNs)**: These are the basic building blocks of the data model, representing specific functions or equipment within the substation. Each Logical Node corresponds to a particular aspect of the substation's operation, such as protection, measurement, or control. Logical Nodes are standardized across devices, ensuring consistent interpretation of data. 2. **Data Objects (DOs)**: Each Logical Node is composed of multiple Data Objects, which represent specific pieces of information or functionality related to the node's purpose. Data Objects serve as containers for related Data Attributes and are essential for defining the node's behavior. 3. **Data Attributes (DAs)**: These are the most granular elements of the data model, representing individual pieces of information associated with a Data Object. Data Attributes can include measured values, status indicators, configuration settings, and control commands. 4. **Logical Devices (LDs)**: Logical Devices are collections of Logical Nodes that together represent a specific piece of equipment or functionality within the substation. Each IED contains one or more Logical Devices, reflecting its role and capabilities. 5. **IEDs (Intelligent Electronic Devices)**: These are the physical devices within the substation that perform various protection, control, and monitoring functions. The data model provides a standardized way to describe the capabilities and communication interfaces of IEDs, ensuring they can interact seamlessly with other devices.
DO	Data objects – provide means to define typed information, for example, position of a switch with quality information and timestamp, contained in logical nodes. Each Logical Node is composed of multiple Data Objects, which represent specific pieces of information or functionality related to the node's purpose. Data Objects serve as containers for related Data Attributes and are essential for defining the node's behavior.
EX	Extended definition (application name space)
GGIO	LN: Generic process I/O
GOOSE	“Generic Object Oriented Substation Event” GOOSE is a communication protocol used for fast and reliable exchange of data between Intelligent Electronic Devices (IEDs) within a substation automation system. They are are transmitted as multicast frames over Ethernet, enabling multiple devices to receive the same message simultaneously.
GoCB	GOOSE Control Block
ICD file	“IED Capability Description” The ICD file is a type of Substation Configuration Language (SCL) file that describes the capabilities and communication interfaces of a specific IED. It provides detailed information about the device's functional capabilities, including its data model, services, and communication protocols.
LCCH	LN: Physical communication channel supervision
LD	“Logical device” Conceptual grouping of Logical Nodes (LNs) within an Intelligent Electronic Device (IED). It serves as an organizational unit that

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Term	Definition
	represents a specific piece of equipment or functionality within a substation automation system.
LGOS	LN: GOOSE subscription
LN	“Logical node” Fundamental building blocks of the IEC 61850 data model, representing specific functions or equipment within a substation automation system. Each Logical Node encapsulates the data and behavior associated with a particular aspect of the substation's operations, such as protection, control, measurement, or monitoring.
LPHD	LN: Physical device
LTMS	LN: Time master supervision
MMS	“Manufacturing Message Specification” MMS is a protocol used for communication in industrial automation and control systems, including substation automation systems. It provides a standard method for exchanging real-time data and supervisory control information between networked devices in a substation. MMS operates over TCP/IP networks and is used to facilitate communication between Intelligent Electronic Devices (IEDs) and control systems. It supports a wide range of functions, including reading and writing data, reporting events, and executing control commands. MMS is an integral part of the IEC 61850 standard, which aims to ensure interoperability and seamless communication in substation and power system automation.
MMXU	LN: Measurement in a 3 phases system
MX	Measurands (analogue value) Type designation used for Data Attributes that represent measured values. These measured values are typically associated with physical quantities like voltage, current, or power, and are part of the data model used by Intelligent Electronic Devices (IEDs) within a substation automation system.
Publisher	Device or component within a substation automation system that sends data to other devices or components using a specific communication protocol. The concept of a Publisher is particularly relevant in the context of the GOOSE and SV communication models.
RDRE	LN: Disturbance recorder function
SCBR	LN: Circuit breaker supervision
SCL	“Substation Configuration Language” SCL is an XML-based language used to describe the configuration of electrical substations and the communication between Intelligent Electronic Devices (IEDs) within those substations. SCL files contain detailed information about the substation's structure, including the arrangement of IEDs, their capabilities, data models, communication protocols, and settings.
SIMG	LN: Insulation medium supervision (gas)
SOPM	LN: Supervision of operating mechanism
ST	Status information. Type designation used for Data Attributes that represent status information. This can include binary status indicators such as open/closed for a circuit breaker
STMP	LN: Temperature supervision
Subscriber	Device or component within a substation automation system that receives data from other devices or components using specific communication protocols. The concept of a Subscriber is particularly relevant in the context of the GOOSE and SV communication models.
Sampled values	

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Term	Definition
9-2LE	The sampled value protocol defined by UCA International Users Group document Implementation Guideline for Digital Interface to Instrument Transformers using IEC 61850-9-2
APDU	“Application Protocol Data Unit” Fundamental unit of communication in network protocols, encapsulating the data that is exchanged between applications across a network. The APDU is part of the OSI model's application layer and plays a critical role in data transmission within substation automation systems. In IEC 61850, APDUs are used in various communication services, such as MMS, GOOSE, and SV, to facilitate reliable and efficient data exchange between IEDs.
APPID	Application identifier. The APPID is used to select ISO/IEC/IEEE 8802-3 frames containing sampled value messages and to distinguish the application association.
ASDU	“Application Service Data Unit” The ASDU encapsulates the sampled data.
MSVCB	Multicast sampled value control block
noASDU	Number of ASDU concatenated into one APDU.
SmpSynch	Synchronization mechanism used in Sampled Values (SV) communication. It ensures that the sampling of analog signals, like current and voltage, is aligned across different devices within a substation automation system. SmpSync involves aligning the sampling instances across multiple devices to a common time reference, typically provided by a Precision Time Protocol (PTP) Grandmaster clock or GPS. This ensures that the sampled data from different devices is consistent and can be accurately compared or combined. By synchronizing the sampling process, SmpSync ensures that the measurements taken by different devices represent the same point in time. This is essential for coherent data analysis, such as calculating power flow or detecting faults.
SmpRate	“Sampling Rate”, parameter used in Sampled Values (SV) communication to define the frequency at which analog signals, such as current and voltage, are sampled and digitized for transmission over a network (number of samples per second)
sps	Samples per second
SV	“Sampled values” Sampled Values are a key component of the IEC 61850 standard, used to facilitate the transmission of digitized analog signals, such as current and voltage measurements, over a communication network within a substation automation system.
SVID	“Sampled values system-wide unique identification” It is a unique identifier used to distinguish between different streams of Sampled Values (SV) being transmitted over a network within a substation automation system.
Other	
AWG	“American wire gauge”. Standardized system used in the United States and Canada to denote the diameter of electrically conducting wire
COMTRADE	Common format for Transient Data Exchange
DI	Digital input (Binary input)
EMC	Electromagnetic compatibility
HMI	Human machine interface
I/O	Input/Output
IEC	International Electrotechnical Commission

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Term	Definition
IEEE	Institute of Electric and Electronic Engineers
LED	Light emitting diode
M12	12 mm circular connector metric thread size
MCB	Miniature circuit breaker
MLS	Multiple load switching
SoE	Sequence of event
UVLO	“Undervoltage Lockout”. Protective feature commonly used in electronic circuits, particularly in power supplies and integrated circuits, to prevent the device from operating below a certain voltage threshold.
Units	
A	Ampere
deg	Degree
degC	Degree Celsius
F	Farad
H	Henry
Hz	Hertz
Mpa	Mega-Pascal (1 Mpa eq. 10 bar)
p.u.	Per unit value
r.m.s.	Root Mean Square
V	Volt
VA	Volt-ampere
VAR	Volt-ampere reactive

Note: other definitions related to Switchgear, Controlgear and fuses are available here:

http://www.electropedia.org/iev/iev.nsf/index?openform&part=441

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9 INTRODUCTION

CSD100 is an Intelligent Electronic Device, more commonly referred to as a Point-on-Wave controller or Controlled Switching Device. CSD100 is the latest Grid Solutions' Controlled Switching Device, benefiting from more than 20 years of expertise and experience implementing such solutions worldwide. It is designed to comply with the latest standards and technical specifications.

The aim of this controller is to reduce high voltage switching transients that would generate equipment stress, power quality disturbance, and, in worst cases, protection system mis operation, during circuit breaker operation.

It is primarily designed to operate independent pole operated circuit breakers (IPO) for both controlled opening and closing operations. CSD100 achieves this by giving open and/or close switching commands to each circuit-breaker pole at the right time, according to a computed sequence.

Table 2 Switching transients summary

Load	Operation	Goal	Definition
Capacitor Banks	Closing	Reduce inrush current	Closing at zero-voltage across CB terminals
	Opening	Reduce restrike probability	Switching out with optimum arcing time
Shunt Reactors	Closing	Reduce current asymmetry and/or pre-strike times	Switching-in at voltage peak or intermediate voltage
	Opening	Prevent CB reignition	Switching-out inside reignition-free window
Power Transformers	Closing	Reduce inrush current	Closing when prospective flux equals residual flux
	Opening	Control residual flux	Switching-out at voltage peak
	Uncontrolled opening (protection trip)	Compute residual flux (from load voltages)	-
Transmission Lines	Closing	Reduce switching overvoltages	Closing at zero-voltage across CB terminals
		Prevent current zero missing	Closing at voltage peak
	Opening	Reduce restrike or reignition risk (line characteristics dependent)	Switching out with optimum arcing time
Transmission cables	Closing	Reduce inrush current and overvoltages	Closing at zero-voltage across CB terminals
		Prevent current zero missing	Closing at voltage peak (compensated cable with compensation > 50%)
	Opening	Reduce restrike probability	Switching out with optimum arcing time

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Figure 1 represents a simplified layout of a controlled switching system installation. For a very minimum configuration, circuit breaker currents and load voltages may not be populated. Contrary, for more functions or in case of more complex substation arrangement, additional information may be connected to the CSD100, from the circuit breaker or its environment (auxiliary switches for mechanical time measurement, temperature, position of adjacent switchgear…).

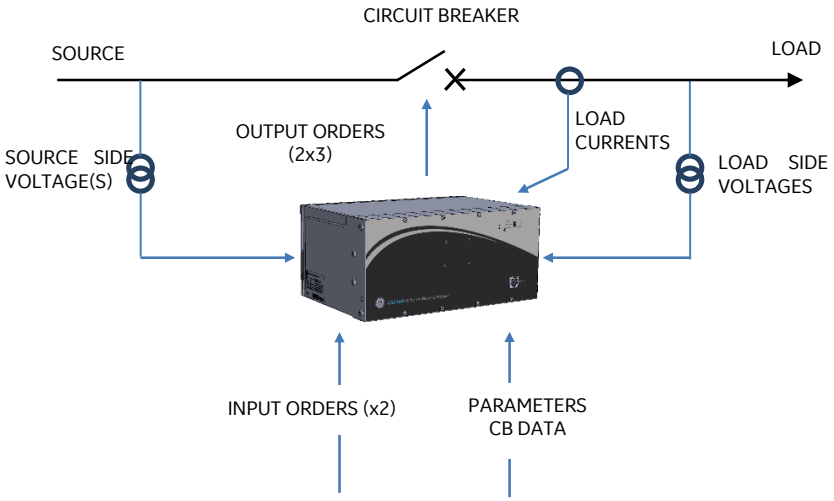


Figure 1 Controlled switching simplified layout

CSD100 is applicable to the following use cases:

- Energizing and de-energizing of shunt reactors: single or three phases (3 or 5 limbs), various neutral position.
- Energizing and de-energizing of capacitor banks (fixed targets or trapped charge management)
- Energizing and de-energizing of power transformers (fixed targets or residual flux management): Yd, Dy, Yy, Dd, measurement of flux (from voltage) either at primary, secondary or tertiary side.
- Energizing, re-closing and de-energizing of uncompensated transmission lines (OHL or underground) with trapped charge management during reclose cycle, single pole or 3 phases reclose (2 phases reclose is also supported).
- Energizing, re-closing and de-energizing of shunt-compensated transmission lines (OHL or underground) with self-learning of line oscillation during reclose cycles, and distinction between healthy and faulty phases.

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Switching targets are pre-set or dynamically computed by the CSD100 for these strategies (modes), and remain accessible for any customization, if needed.

Additional “User modes” (x 4) with customizable targets are available for management of specific or nonstandard loads.

Worth to note, CSD100 is also able to dynamically switch from one strategy to another according to position of adjacent switchgear (up to 4 positions, thus 16 combinations).

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10 PRODUCT DESCRIPTION

10.1 Hardware description

10.1.1 Controller design

CSD100 is a compact form-factor IED integrating several electronic boards in a metal enclosure and designed to achieve controlled switching of HVAC circuit breaker.

It is available off-the-shelf, as a single reference, with universal range I/Os described in Table 3 and Figure 10.

Technical characteristics and ratings of the I/Os are described in section 10.1.6 of this manual.

This all-in-one device integrates all functions of acquisition, operation and communication as described in section 10.2.

Some advanced features / functions of CSD100 require a license key to be unlocked for operation.

10.1.2 Housing

CSD100 shall be installed in the control panel or in the protection panel of the circuit breaker. It can be either front panel mounted (19'' rack) or DIN rail mounted using the appropriate mounting brackets kit delivered with the product as described in section 11.2.

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10.1.3 Controller views

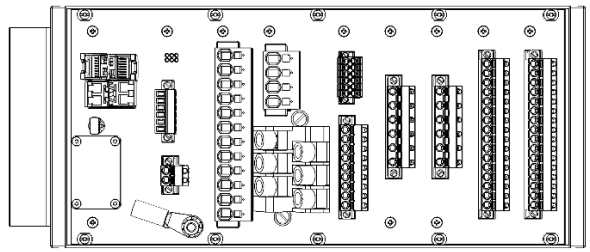


Figure 2 CSD100 rear view

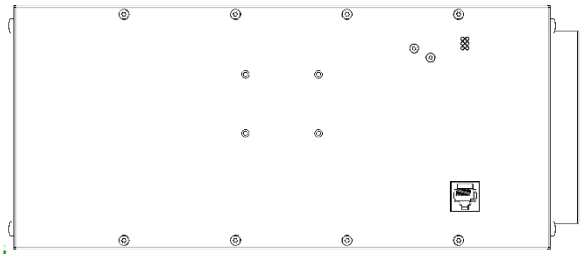


Figure 3 CSD100 front view

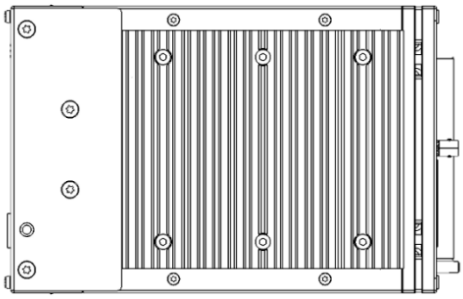


Figure 4 CSD100 left side view

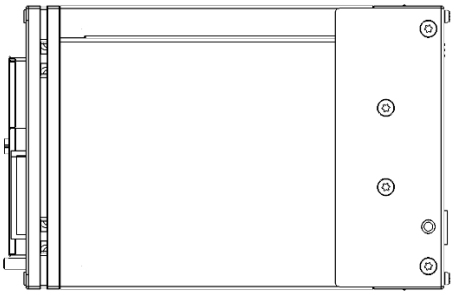


Figure 5 CSD100 right side view

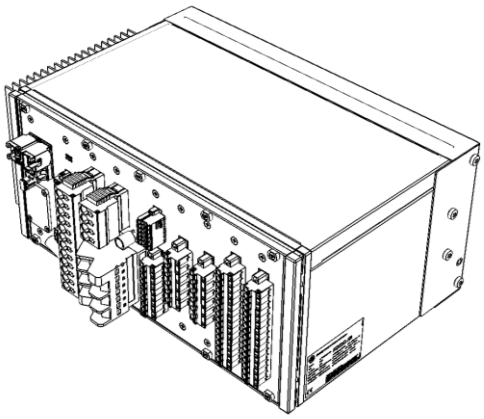


Figure 6 CSD100 3D view

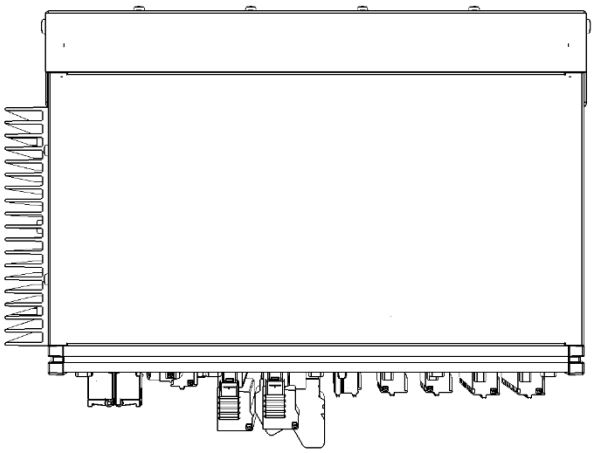


Figure 7 CSD100 top view

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10.1.4 Front panel

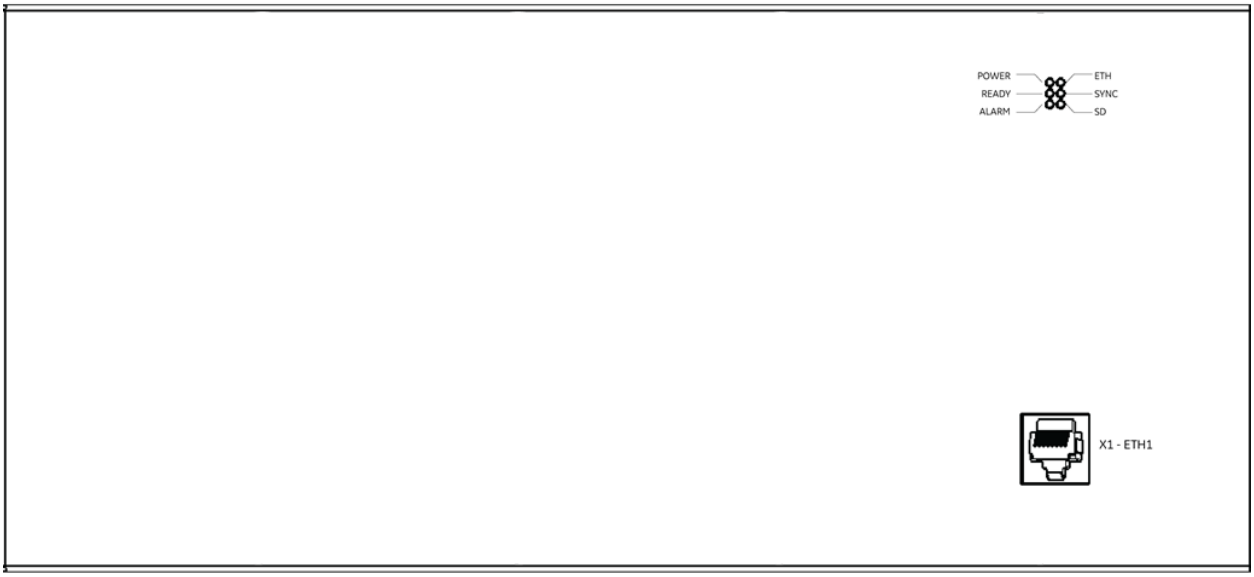


Figure 8 CSD100 front panel

10.1.5 Rear panel

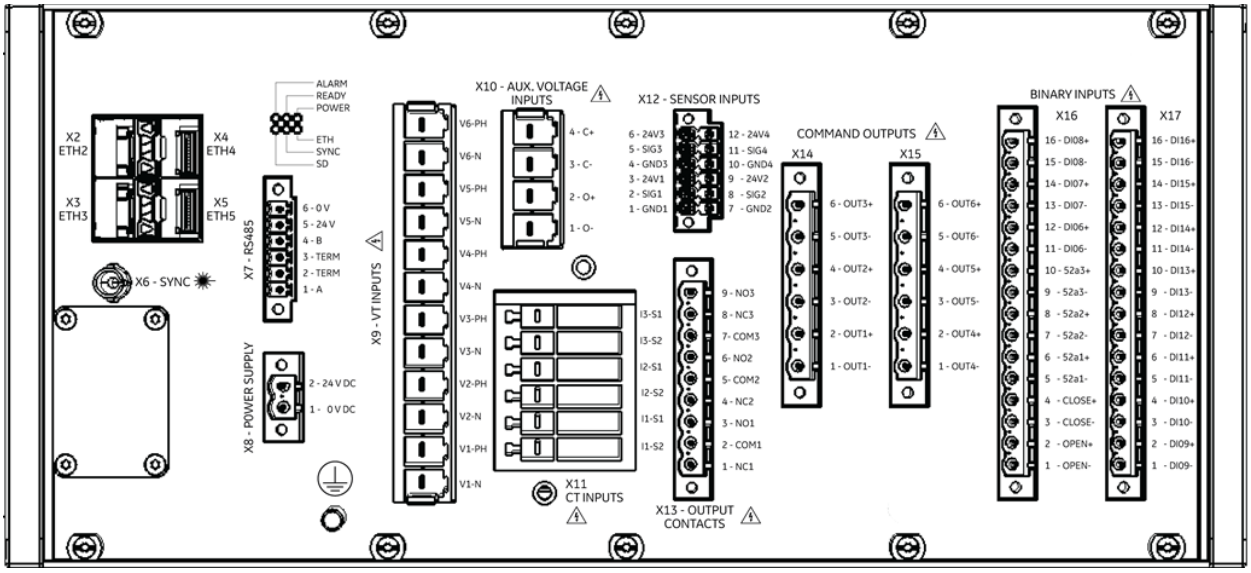


Figure 9 CSD100 rear panel

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10.1.6 Universal range I/Os description

Universal range I/Os are described in Table 3 and Figure 10.

Table 3 CSD100 I/Os description

I/O	Description	Range / Type
100/1000Mbits/s SFP transceiver (x2) Eth. switch.	Process bus, station bus communication (x2) (Contact your vendor for compatible references)	LC optic fiber, or RJ45
SYNC	1 PPS synchronizing input	ST optic fiber
Signaling LEDs	Controller status (x 6)	Bicolored GN-OR
Power supply input	24 V DC power supply	18 - 30 V DC
RS485 serial link	Circuit breaker gas density measurement Hydraulic pressure measurement	Keller transmitter
Isolated AC voltage input (x 6)	Source and load side voltage measurement	0 – 250 V AC
Isolated AC current input (x 3)	Load current measurement (safety plug)	0 – 5 A
Isolated DC voltage input (x 2)	Auxiliary voltage measurement (opening and closing polarities)	0 – 250 V DC
Isolated analogue input (x 4)	Ambient temperature measurement (x 1) Circuit breaker travel measurement (x 3)	4-20 mA or 0-5 V
Output relays (x 3)	WD (x 1) and alarm (x 2) signaling	0 – 250 V DC
Isolated power output (x 6)	Closing order (x 3) + Opening order (x 3) Or closing order / opening order (x 6) for double drive CB type	0 – 250 V DC
Isolated binary input (x 16)	Incoming orders (x 2) 52a signaling (x 6) Multiple load switching (x 4) + Dual switching (x 1) Commissioning mode (x 1) Alarm reset (x 1)	0 – 250 V DC

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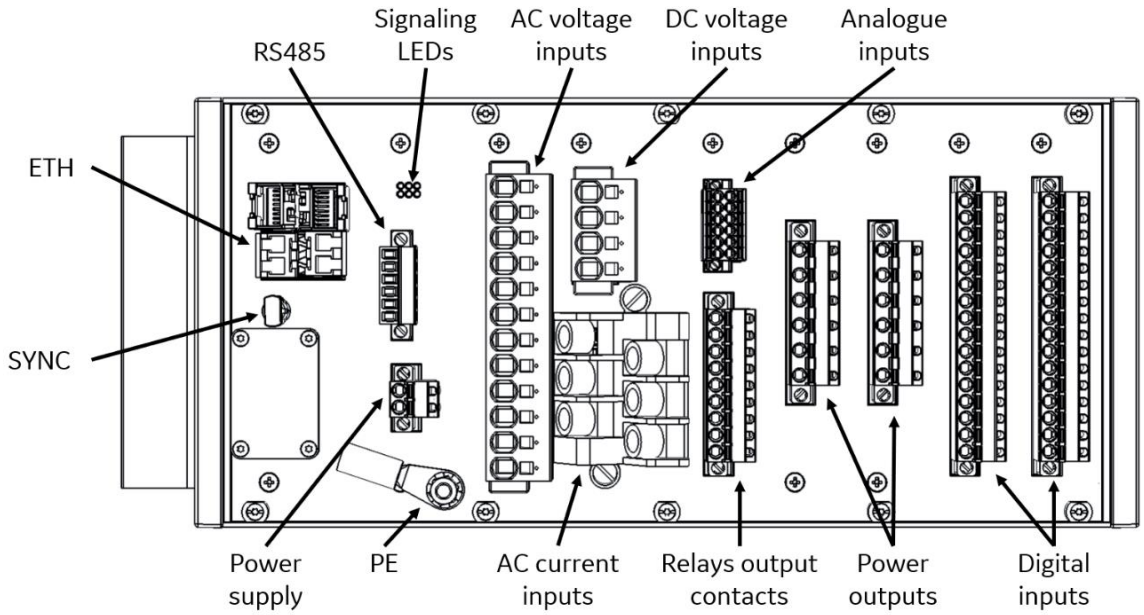
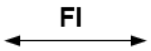
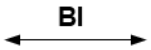
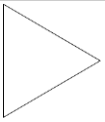
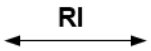
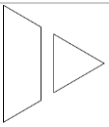
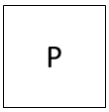
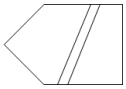
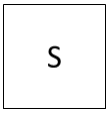
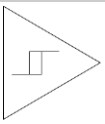
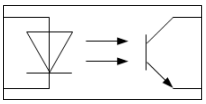
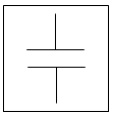


Figure 10 Hardware overview

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10.1.6.1 Symbols used in this section

Table 4 CSD100 I/Os blocks symbols

Description	Symbol	Description	Symbol
Functional insulation according to IEC 60664-1		Filtering	
Basic insulation according to IEC 60664-1		Driver / buffer	
Reinforced insulation according to IEC 60664-1		Isolated driver	
Signal protection		Isolated analogue to digital converter (ADC)	
Signal scaling		Thresholding	
Microprocessor		Opto-isolator	
		Reserve of energy	

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10.1.6.2 RS-485 serial link description

RS485 half-duplex port is used to interface sensors and retrieve non real time (slow changing) data (pressures and temperatures). These sensors are to be multiplexed on the same port and thus require to be beforehand configured at different addresses.

A 24VDC power supply output is also available at the same port to energize these sensors. The current capability of this supply is 250mA and it is protected against overloads.

For communications over long distances (typically >30m), a built-in termination resistor can be activated by additional wire.

Both 24VDC output and RS485 signals are galvanically isolated from chassis frame.

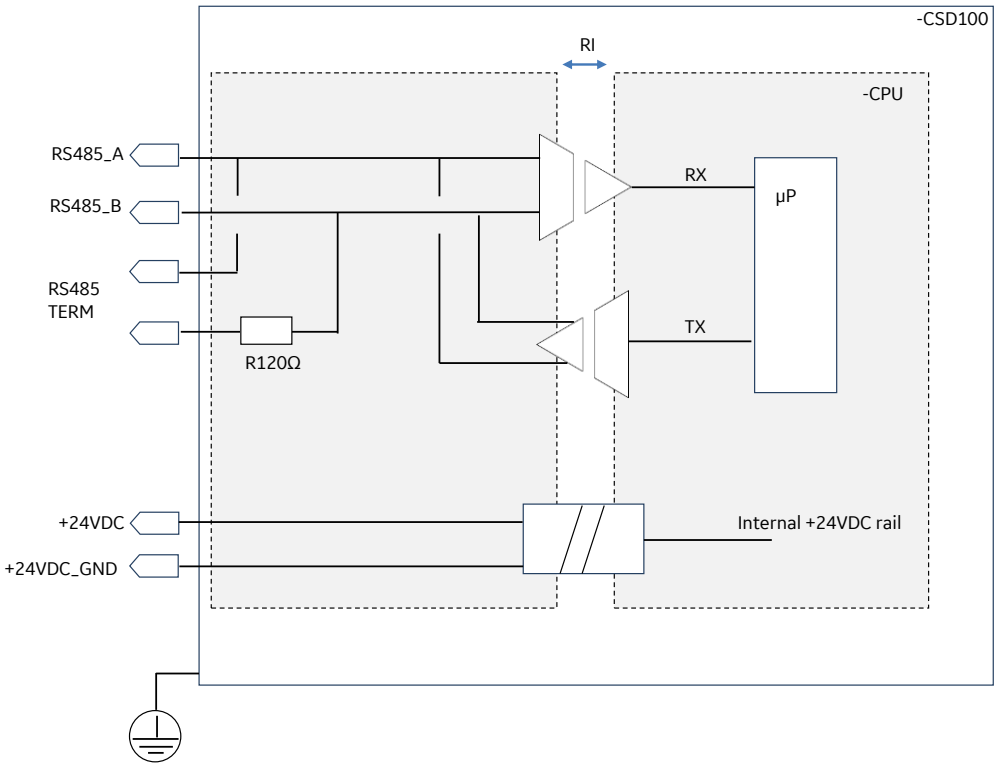


Figure 11 RS485 port description

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10.1.6.3 Power supply input description

An external power supply unit is delivered with CSD100. It accepts voltage in the range of 90VDC to 250VDC and provides galvanic isolation.

Intermediate power supply rail (external PSU output / CSD100 rack input) is regulated 24VDC.

External and internal power circuitries provide:

- Galvanic isolation
- Energy storage (capacitor banks) to cope with short power supply interruptions
- A soft start circuitry.

Overall power consumption is less than 30W.

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10.1.6.4 Voltage transformer input description

When operating controlled switching system, the power systems' voltage measurement is required for synchronizing and monitoring purpose (see 12.1). This section provides a description of the CSD100 voltage transformer inputs.

10.1.6.4.1 Protection, scaling

Voltage transformer inputs are designed as isolated differential inputs.

They are used to step down the voltages originating from the power systems' voltage transformers to levels readable by the unit's electronic circuitry.

They are protected against severe EMC phenomena, resulting from high voltage substation operations, and provide electrical isolation between the unit and the power system.

10.1.6.4.2 Filtering and A/D conversion

- Filtering: EMC and antialiasing
- Analogue bandwidth: [1Hz - 3kHz] (no attenuation)
- A/D conversion rate: 40kHz

10.1.6.4.3 Calibration

Voltage transformer inputs do not require any calibration since designed to operate with an accuracy better than 2 % over the entire operating temperature range.

10.1.6.4.4 Main characteristics

Table 5 AC voltage inputs characteristics

Item	Description	Value
a.c. voltage inputs	Rated voltage, V_n	250 V AC phase to neutral
	Voltage withstand	250 V AC, continuous phase to neutral 300 V AC, 10 s
	Operating range	0 - 250 V AC
	Frequency range	1Hz to 3kHz
	Power consumption at rated voltage and network power frequency	< 0.2 VA
	Accuracy at rated voltage	2%

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10.1.6.4.5 Diagram / Isolation groups

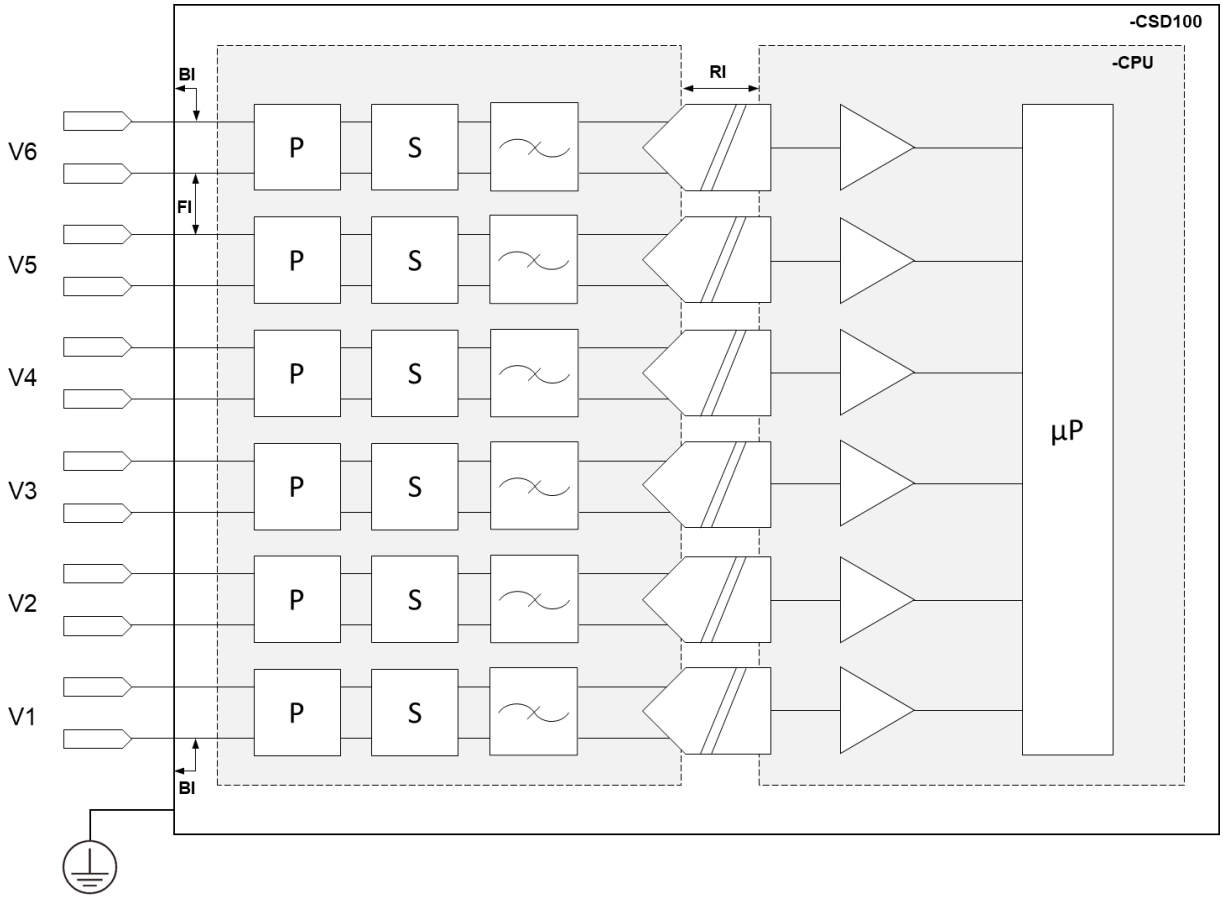


Figure 12 Voltage transformer inputs description

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10.1.6.5 Auxiliary voltage input description

The voltage with which circuit breakers coils are operated may be measured to anticipate for any deviation from nominal, which would impact mechanical times.

10.1.6.5.1 Protection, scaling

DC voltage inputs are designed as fully isolated differential inputs, from channel to frame chassis and from channel to channel.

They are used to step down the voltages originating from the auxiliaries (typically battery system) to levels readable by the unit's electronic circuitry.

They are protected against severe EMC phenomena, resulting from high voltage substation operations, and provide electrical isolation between the unit and the power system.

10.1.6.5.2 Filtering and A/D conversion

- Analogue bandwidth: >100Hz (no attenuation)
- A/D conversion rate: 40kHz

10.1.6.5.3 Calibration

Voltage transformer inputs do not require any calibration since designed to operate with an accuracy better than 2 % over the entire operating temperature range and thanks to components value initial tolerances.

10.1.6.5.4 Main characteristics

Table 6 DC voltage inputs characteristics

Item	Description	Value
d.c. voltage inputs	Rated voltage, V_n	280 V DC phase to neutral
	Voltage withstand	280 V DC, continuous 300 V DC, 10 s
	Operating range	0 - 280 V DC
	Power consumption	< 0.8 W at maximum voltage
	Accuracy at rated voltage	2%

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10.1.6.5.5 Diagram / Isolation

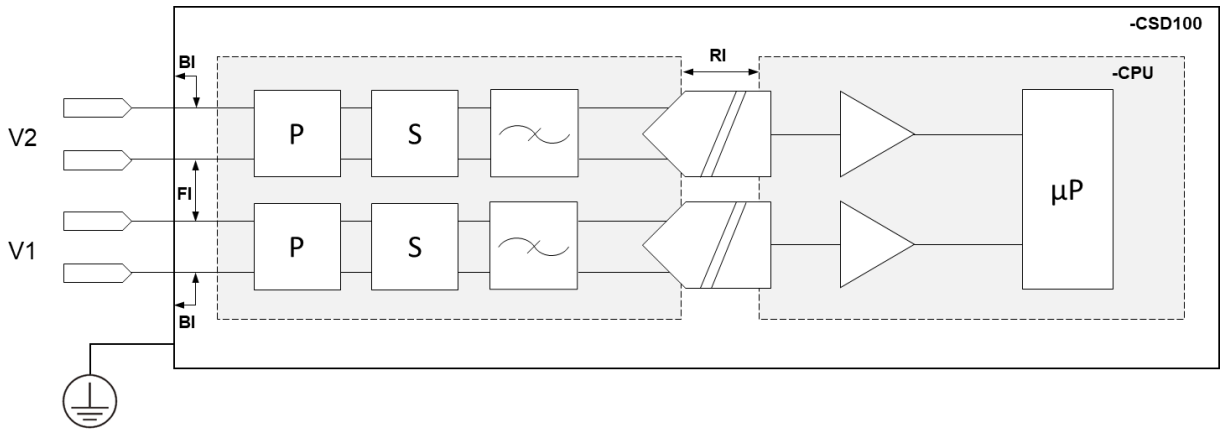


Figure 13 Auxiliary voltage input description

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10.1.6.6 Current transformer input description

When operating controlled switching system, the load current measurement is required for synchronizing (upon opening operations) and monitoring purpose (see 12.1.2). This section provides a description of the CSD100 current transformer inputs.

10.1.6.6.1 Protection, scaling

Current transformer inputs are designed as fully isolated inputs, from channel to frame chassis and from channel to channel.

They are used to step down the currents originating from the power systems' current transformers to levels readable by the unit's electronic circuitry.

They provide electrical isolation between the unit and the power system.

10.1.6.6.2 Transformer Inputs

The current inputs accept either 1 A or 5 A nominal current, without any tapping selection.

10.1.6.6.3 Filtering and A/D conversion

- Analogue bandwidth: [20Hz - 1kHz] (no attenuation)
- A/D conversion rate: 40kHz

10.1.6.6.4 Calibration

Current transformer inputs do not require any calibration since designed to operate with an accuracy better than 3 % over the entire operating temperature range.

10.1.6.6.5 Main characteristics

Table 7 AC current inputs characteristics

Item	Description	Value
Current inputs	Rated current, I_n	1A / 5A (one single option)
	Thermal short-time withstand	20 A, continuous 500 A - 1 s
	Rated frequency	50/60 Hz ±1 %
	Power consumption of measuring inputs	< 0.1 VA at 5 A
	Accuracy at rated current	3 %

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10.1.6.6.6 Diagram / Isolation

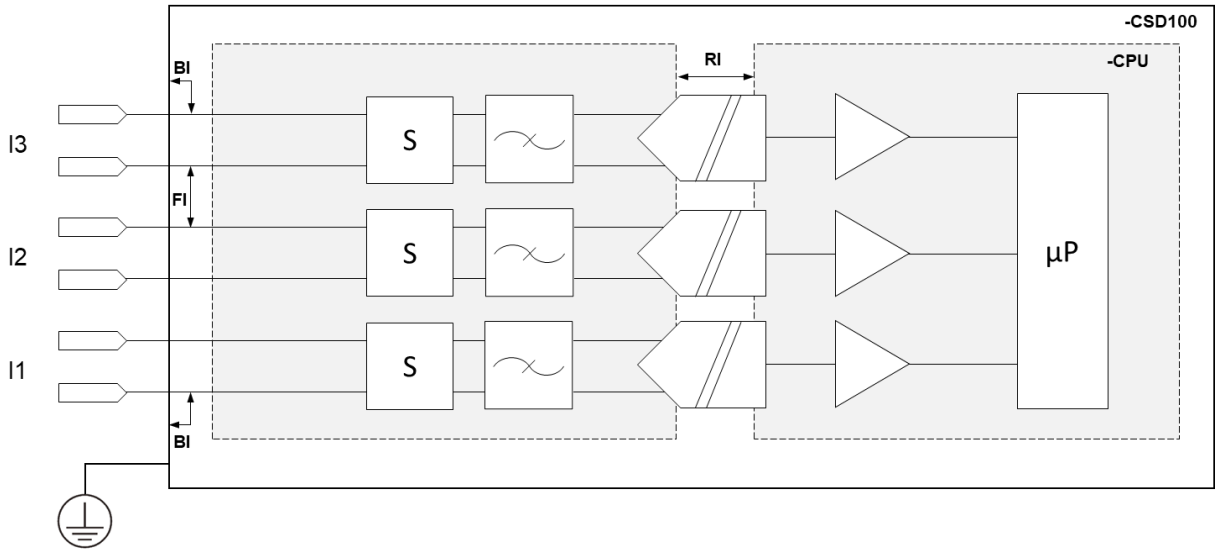


Figure 14 Current transformer input description

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10.1.6.7 Analogue sensors input description

Aim is to measure real time or non-real time data from industrial sensors (travel curve, temperature).

These four low level analogue inputs are either configurable to 4-20mA or ±5V inputs.

4-20mA inputs are compatible with 2-wires or 3-wires sensor types.

10.1.6.7.1 Protection, scaling

Low level analogue sensor inputs are designed as isolated inputs, from channel to frame chassis (but not from channel to channel).

They provide electrical isolation between the unit and the power system.

10.1.6.7.2 Input impedance

In 4-20mA mode, the measuring impedance (shunt) is 25Ω.

In ±5V mode, the input impedance is 1kΩ.

10.1.6.7.3 Filtering and A/D conversion

- Analogue bandwidth : [0Hz - 3kHz] (-3dB)
- A/D conversion rate: 40kHz

10.1.6.7.4 Calibration

Low level analogue inputs do not require any calibration since designed to operate with an accuracy better than 1 % over the entire operating temperature range and thanks to components value initial tolerances.

10.1.6.7.5 +24VDC output

A 24VDC output is provided to feed the sensors and the 4-20mA loops. It is also isolated and protected against overload.

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10.1.6.7.6 Diagram / Isolation

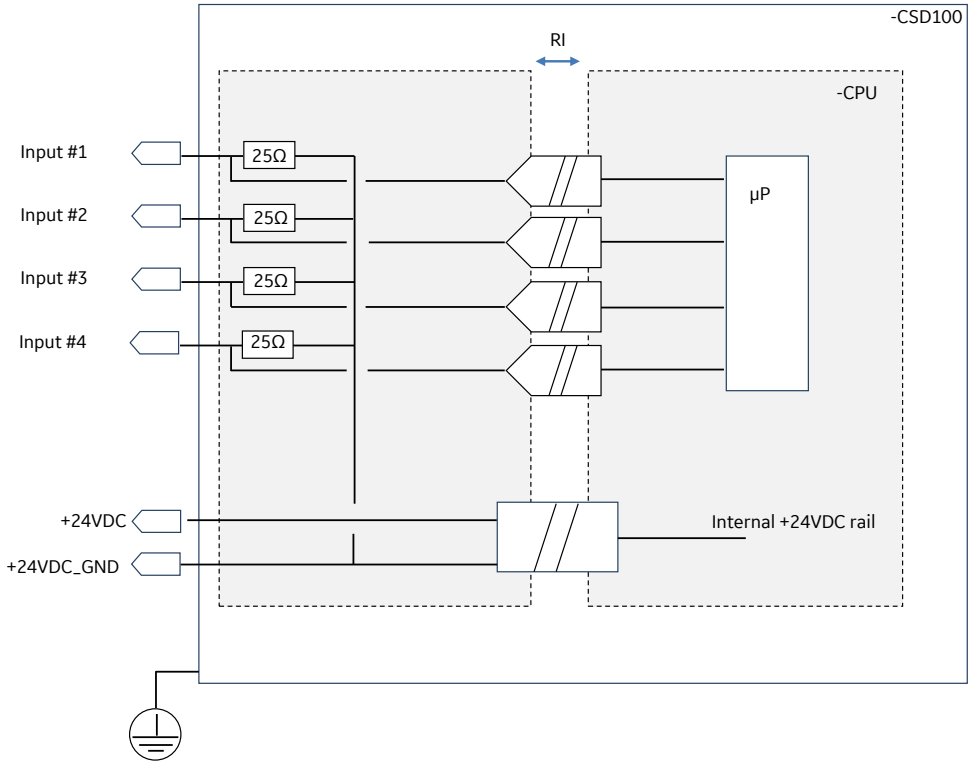


Figure 15 Low level analogue inputs description (4-20mA mode)

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10.1.6.8 Relay output contacts description

Two latching relays (bistable) and one standard relay (monostable) are provided for signaling. For each of them normally closed (NC), normally open (NO) and common (COM) contacts are available on X13 port.

10.1.6.8.1 Main characteristics

Table 8 Relays contacts characteristics

Item	Description	Value
Relay output contacts (monostable)	Dielectric strength between open contacts	1000 V_{rms}
	Dielectric strength between contact and coil	5000 V_{rms}
	Breaking capacity, dc resistive	0.3 A @ 250 VDC
	Breaking capacity, dc inductive	0.1 A @ 250 VDC (L/R = 50 ms)
	Short term withstand	30 A / 1s
Relay output contacts (bistable)	Dielectric strength between open contacts	1000 V_{rms}
	Dielectric strength between contact sets	4000 V_{rms}
	Dielectric strength between contact and coil	5000 V_{rms}
	Breaking capacity, dc resistive	0.45 A @ 250 VDC
	Breaking capacity, dc inductive	0.2 A @ 250 VDC (L/R = 300 ms)
	Short term withstand	30 A / 1s

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10.1.6.8.2 Diagram / Isolation

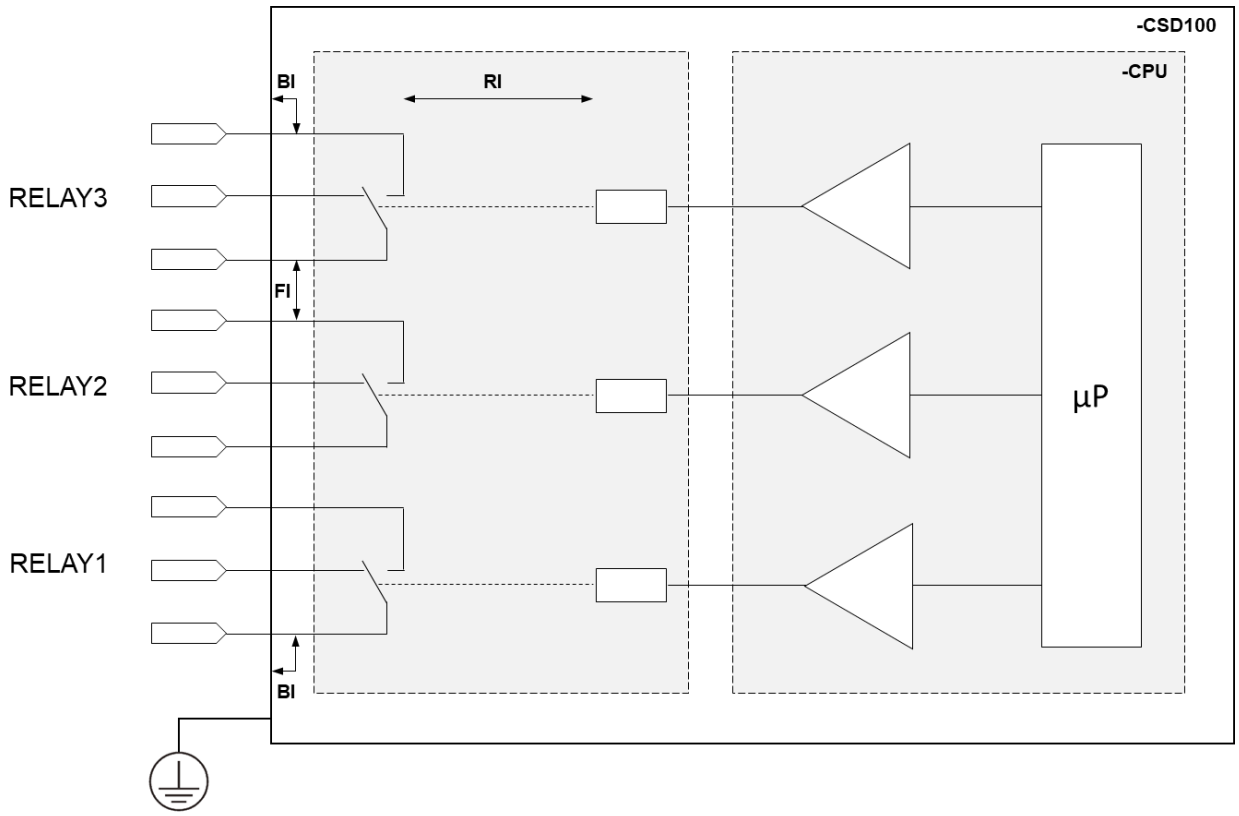


Figure 16 Relay output contact synoptic

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10.1.6.9 Command output description

When operating controlled switching system, high speed reaction of the equipment is required for CB operation purpose. This section provides a description of the CSD100 circuit breaker command outputs.

Six outputs are available with this controller, typically 3 for opening coils and 3 for closing coils.

Command outputs are power transistor types and fully isolated, from channel to chassis frame and from channel to channel. They are functionally equivalent to a potential free contact, with additional restriction of the current flowing direction, imposed by built-in power diode.

They also include a measurement of the flowing current, included in records.

10.1.6.9.1 Performances

- Switching accuracy: <1µs
- Robustness: transistors are 900V rated and protected by varistors to clamp overvoltages at a maximum of 800V during worst conditions (surge test IEC61000-4-5 - 2kV - 1000A)
- Protected against overvoltages from inductive load switching.
- Integrated diode (protected against reverse polarity)
- Built-in current measurement

Table 9 Power outputs characteristics

Item	Description	Value
Power outputs	Rated voltage	250 Vdc
	Maximum continuous current	5 A
	Short duration withstand carry	20A – 1s 35A – 200ms
	Time accuracy	<1µs
Current measurement	Rated current, I_n	12 A
	Analogue bandwidth	From DC to 800Hz (-3dB)
	Sample rate	40 kHz
	Accuracy at rated current	<2%

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10.1.6.9.2 Diagram / Isolation

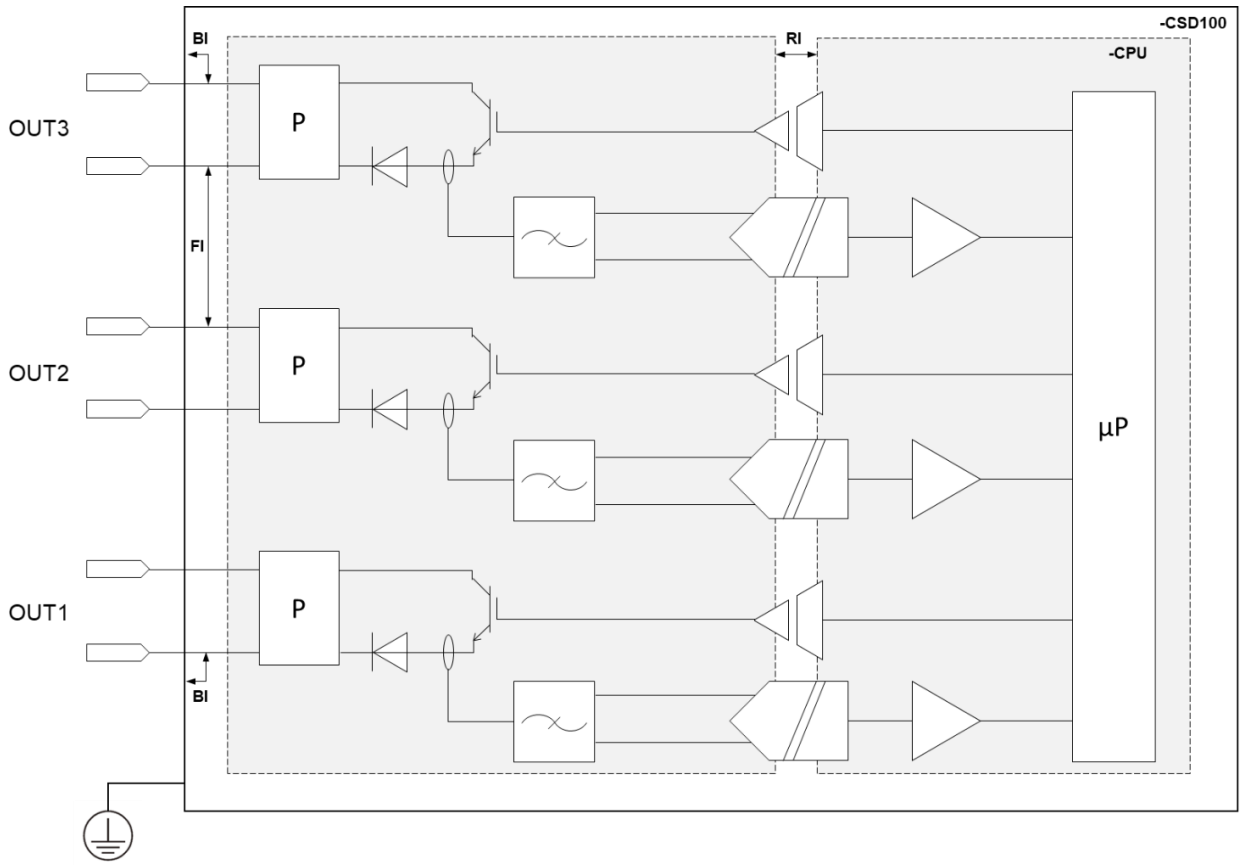


Figure 17 Command output description

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10.1.6.10 Opto-isolated binary input description

When operating controlled switching system, acquisition of binary signals is required for operation purpose. This section provides a description of the CSD100 opto-isolated binary inputs.

Sixteen (16) inputs are available with this controller.

Digital inputs are designed as fully isolated differential inputs, from channel to chassis frame and from channel to channel.

10.1.6.10.1 Main characteristics

- Protected against reverse polarity
- Versatile: directly interfaces to substation voltage levels (48V – 110V – 125V – 220V – 250V)
- No need to program threshold level
- Constant current consumption whatever input voltage level (current source technology)
- Low switching delays:
    - Turn-on <25µs whatever external cable length.
    - Turn-off <150µs with 1nF external capacitor (long cable length)
- Combined hardware + software filtering (“first edge” time stamp).

Table 10 Digital inputs characteristics

Item	Description	Value
Opto-isolated digital inputs	Rated voltage	48 to 250 Vdc
	Operating range	30 to 280 Vdc
	Detection threshold	30 Vdc
	Time resolution	Turn-on <25 µs Turn-off <150 µs*
	Absorbed current (voltage above threshold)	[2.5mA - 3.2 mA] from 40Vdc to 250 Vdc
	Absorbed current (voltage below threshold)	<1µA

* for external capacitor < 1nF (long cable length).

CAUTION: 8 x DI energized simultaneously at maximum ambient temperature

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10.1.6.10.2 Diagram / isolation

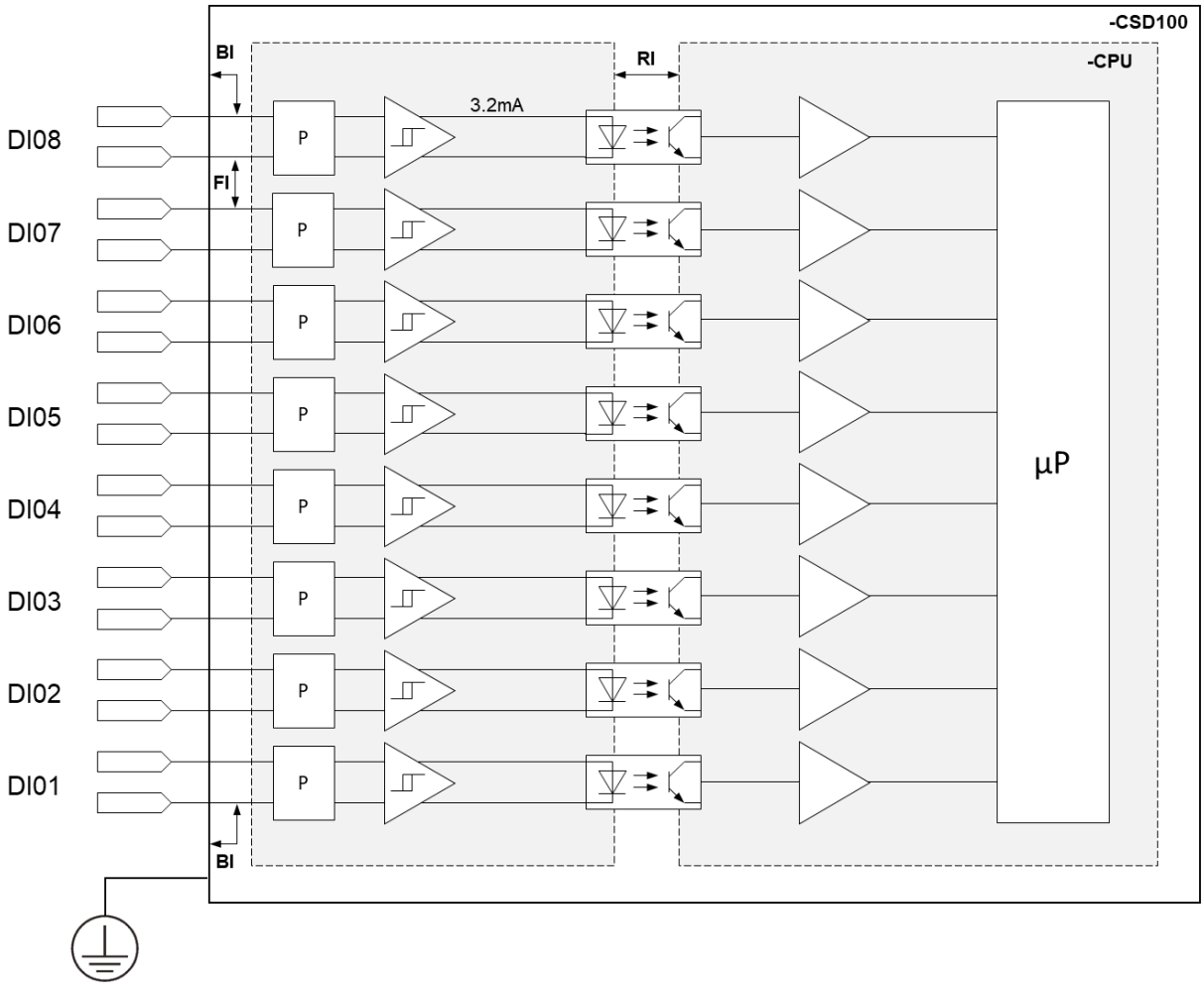


Figure 18 Opto-isolated binary input description

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10.1.7 Connection diagram

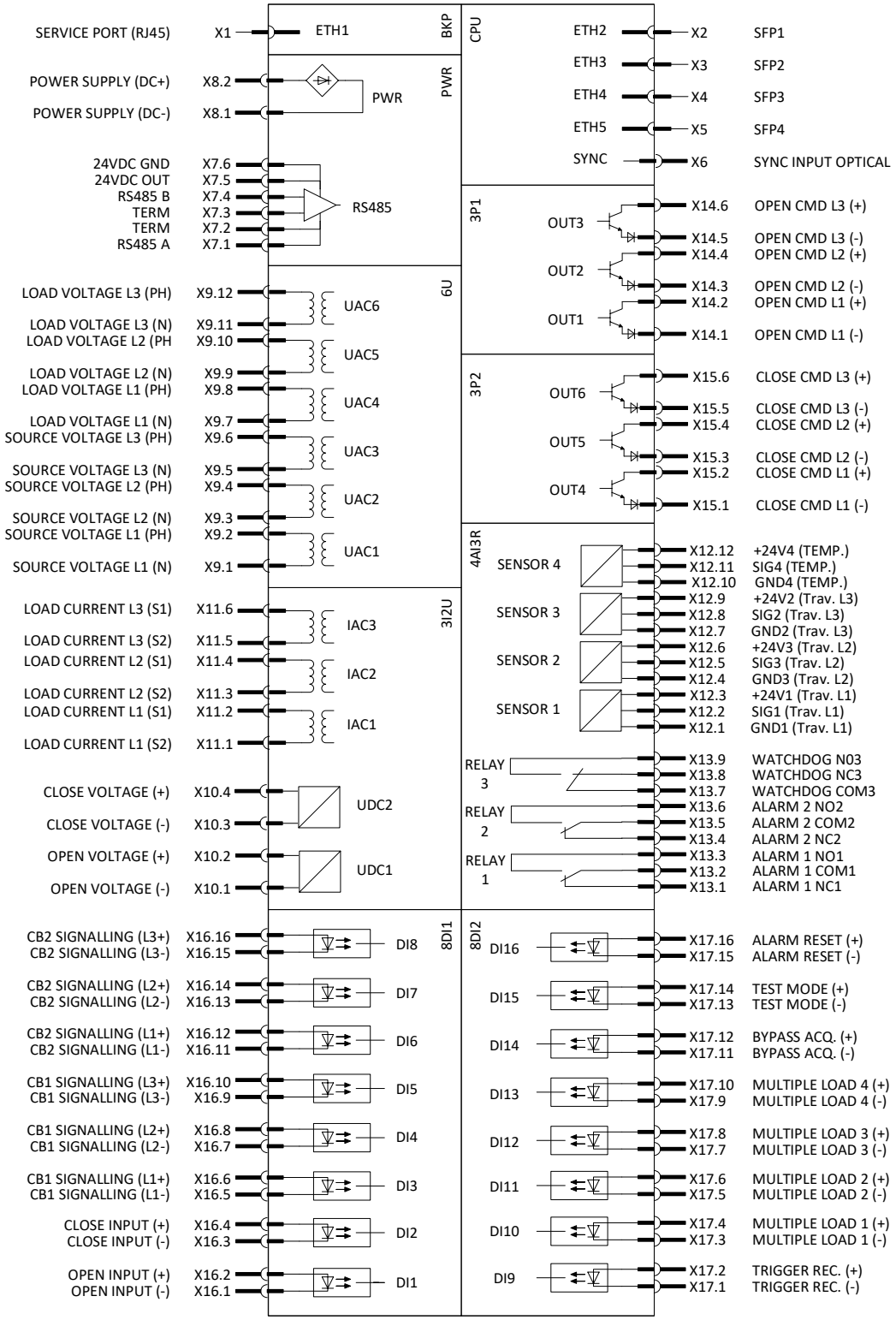


Figure 19 CSD100 connection diagram

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10.1.8 Connection terminals

Each connector is called by an identification index Xi.

Note: to ease maintenance operations (limited to device replacement), the connectors are all removable. Replacement of the device doesn't require any re-wiring work.

Note: product is delivered with spring type connectors, screw type connectors are available on demand.

10.1.8.1 Protective earth

Before any use of CSD100, it must be earthed via the protection earth connection and the housing grounding terminal stud identified by its symbol.

-PE – PROTECTIVE EARTH			
Terminal	**Signal**	**Description**	**Reference**
-PE	-	Equipment protective earth	Insulated crimp ring terminal, M5

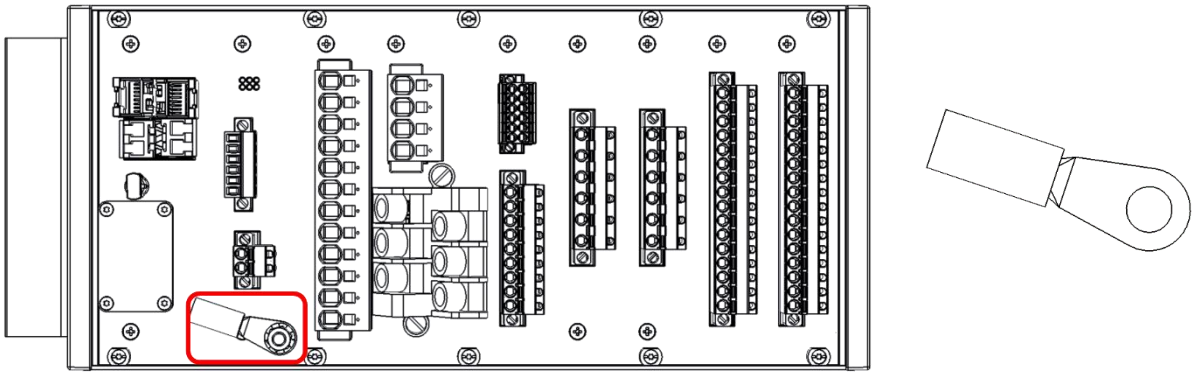


Figure 20 Protective earth connection

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10.1.8.2 Communication ports

Terminal	Signal	Wire type	Reference	Description
-X1	ETH1	RJ45		100m max

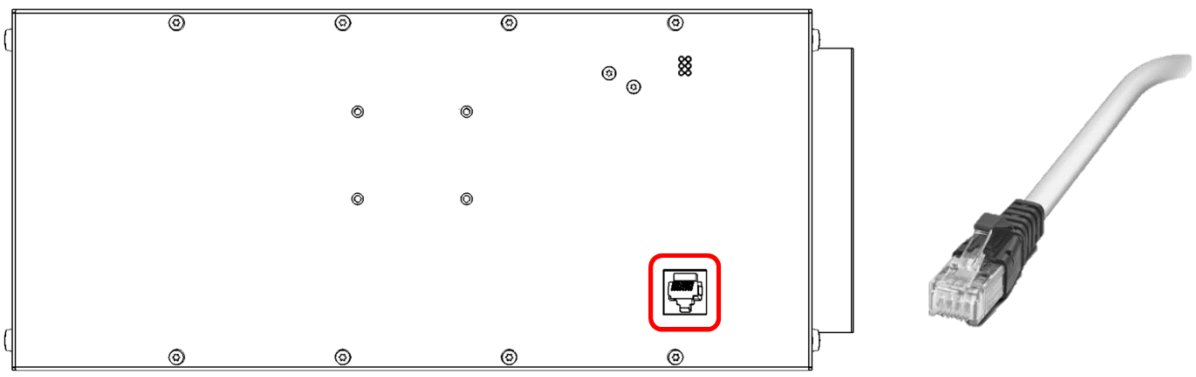


Figure 21 Front side communication port

Terminal	Signal	Wire type	Wire section (max)	Reference	Description
-X6	PPS	ST	Multimode optic fiber, 820nm, simplex, ST connector (input for 1pps)		

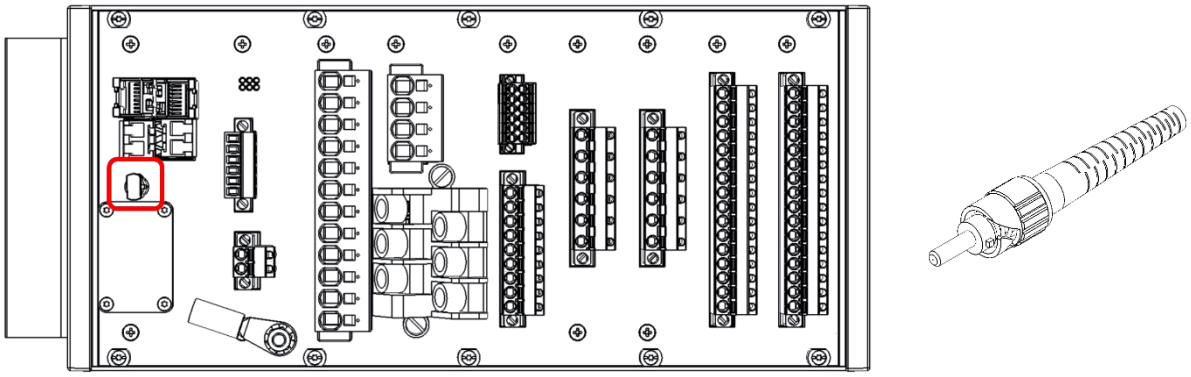


Figure 22 1PPS Sync port

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Terminal	Signal	Wire type	Reference	Description
-X2	ETH2	RJ45	Contact your vendor for compatible reference	10/100/1000BASE-T 100m max
		LC (optic fiber)	Contact your vendor for compatible reference	100BASE-FX, 1000BASE-SX Multimode, monomode, 1310 nm, 850 nm

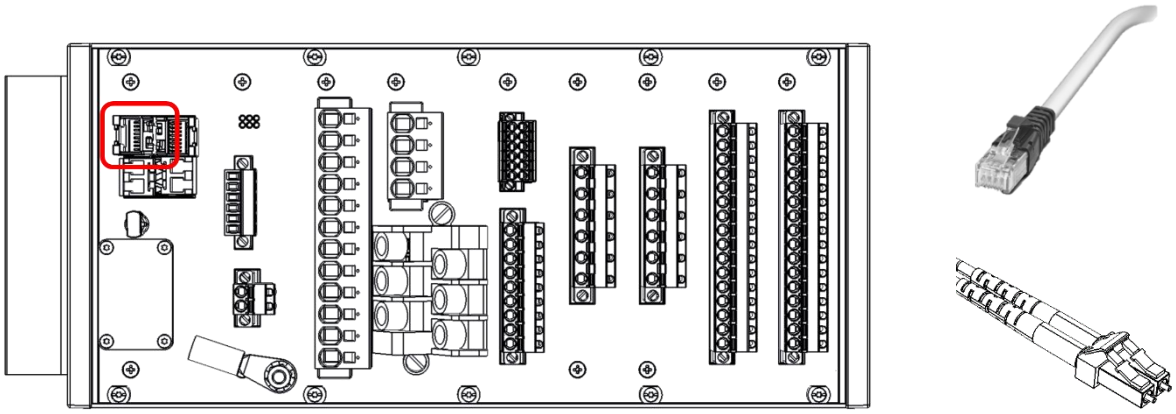


Figure 23 Rear side redundant communication port -X2 (A)

Terminal	Signal	Wire type	Reference	Description
-X4	ETH2	RJ45	Contact your vendor for compatible reference	10/100/1000BASE-T 100m max
		LC (optic fiber)	Contact your vendor for compatible reference	100BASE-FX, 1000BASE-SX Multimode, monomode, 1310 nm, 850 nm

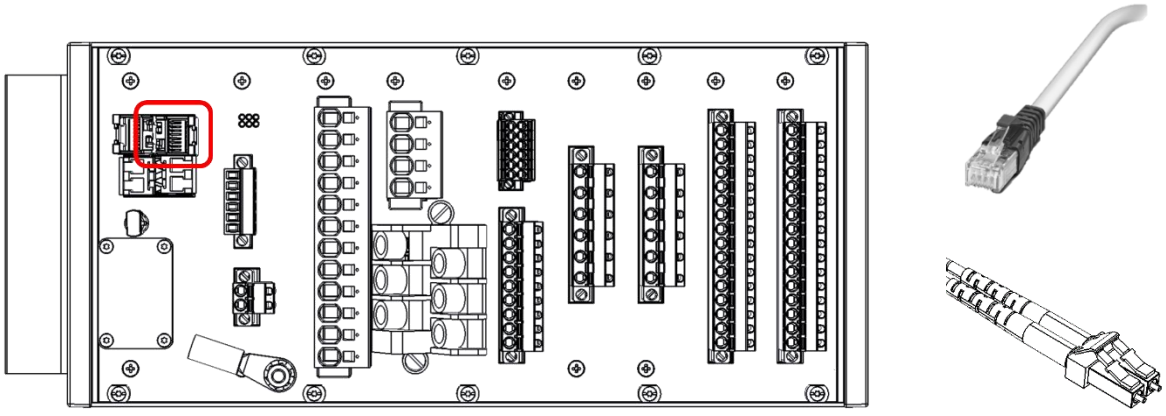


Figure 24 Rear side redundant communication port -X4 (B)

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Terminal	Signal	Wire type	Reference	Description
-X3	Disabled			

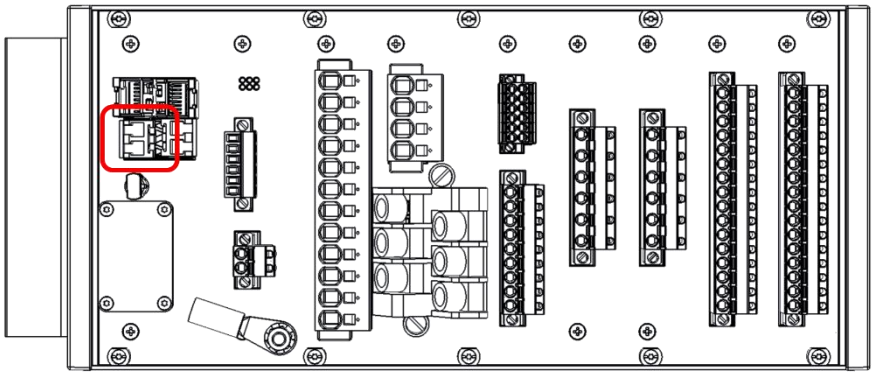


Figure 25 Rear side communication port -X3 (disabled)

Terminal	Signal	Wire type	Reference	Description
-X5	Disabled			

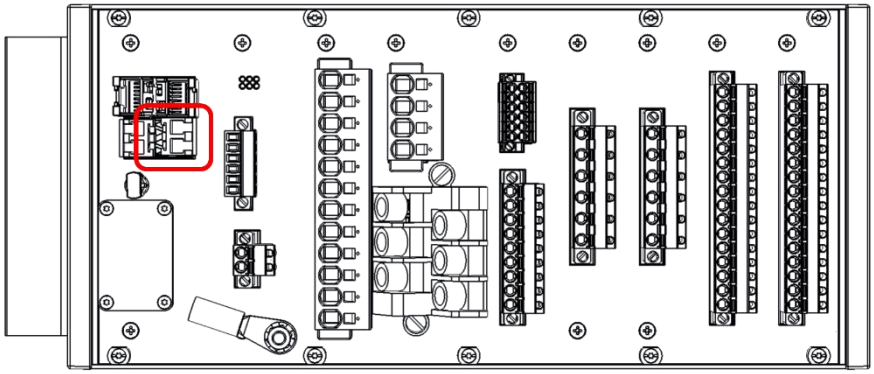


Figure 26 Rear side communication port -X5 (disabled)

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10.1.8.3 RS-485 serial link

RS-485 type serial link is available to communicate with digital transmitters used for circuit breaker gas density monitoring and circuit breaker hydraulic drive pressure.

Table 11 CSD100 RS-485 serial link connection terminals description

-X7 – RS-485 SERIAL LINK			
Terminal	**Signal**	**Description**	**Reference**
-X7:1	A	RS-485 A	Phoenix Contact 1827745 MC 1,5/ 6-STF-3,81
-X7:2	TERM	Termination resistance	
-X7:3	TERM	Termination resistance	
-X7:4	B	RS-485 B	
-X7:5	24V	Digital transmitter power supply positive polarity	
-X7:6	0V	Digital transmitter power supply negative polarity	

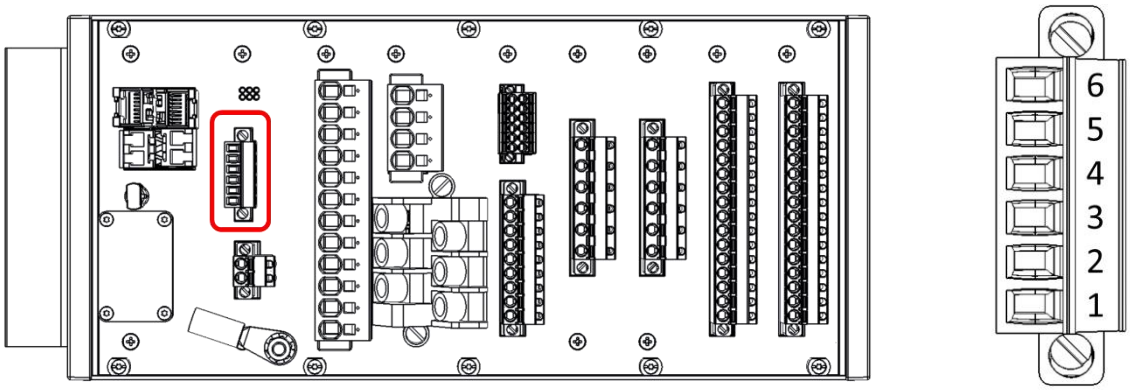


Figure 27 RS485 port connection

Note: Internal termination resistor (120Ω) is activated by applying a short between X7-2 and X7-3.

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10.1.8.4 Power supply input

CSD100 is supplied with a 24 V DC power supply from external power unit (included in delivery).

Table 12 CSD100 power supply input connection terminals description

-X8 – POWER SUPPLY			
Terminal	**Signal**	**Description**	**Reference**
-X8:1	0 VDC	Power supply negative polarity	Phoenix Contact 1873207 FKC 2,5/ 2-STF-5,08
-X8:2	24 VDC	Power supply positive polarity (abs. max. 30VDC)	

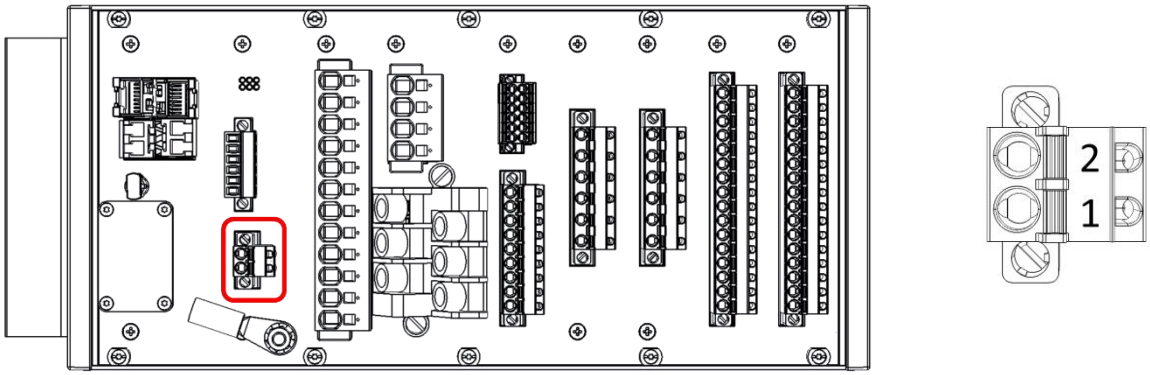


Figure 28 Power supply input connection

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10.1.8.5 Voltage transformers inputs

Six (6) voltage inputs are available to measure the voltage at both sides of the circuit breaker under operation, for synchronizing and monitoring purpose.

Voltage is measured at secondary side of substation voltage transformers.

Table 13 CSD100 voltage transformers inputs connection terminals description

-X9 – VOLTAGE TRANSFORMERS INPUTS			
Terminal	**Signal**	**Description**	**Reference**
-X9:1	V1-N	L1 phase source side voltage, neutral	Phoenix Contact 1718588 SPC 5/12-STCL-7,62
-X9:2	V1-PH	L1 phase source side voltage, phase	
-X9:3	V2-N	L2 phase source side voltage, neutral	
-X9:4	V2-PH	L2 phase source side voltage, phase	
-X9:5	V3-N	L3 phase source side voltage, neutral	
-X9:6	V3-PH	L3 phase source side voltage, phase	
-X9:7	V4-N	L1 phase load side voltage, neutral	
-X9:8	V4-PH	L1 phase load side voltage, phase	
-X9:9	V5-N	L2 phase load side voltage, neutral	
-X9:10	V5-PH	L2 phase load side voltage, phase	
-X9:11	V6-N	L3 phase load side voltage, neutral	
-X9:12	V6-PH	L3 phase load side voltage, phase	

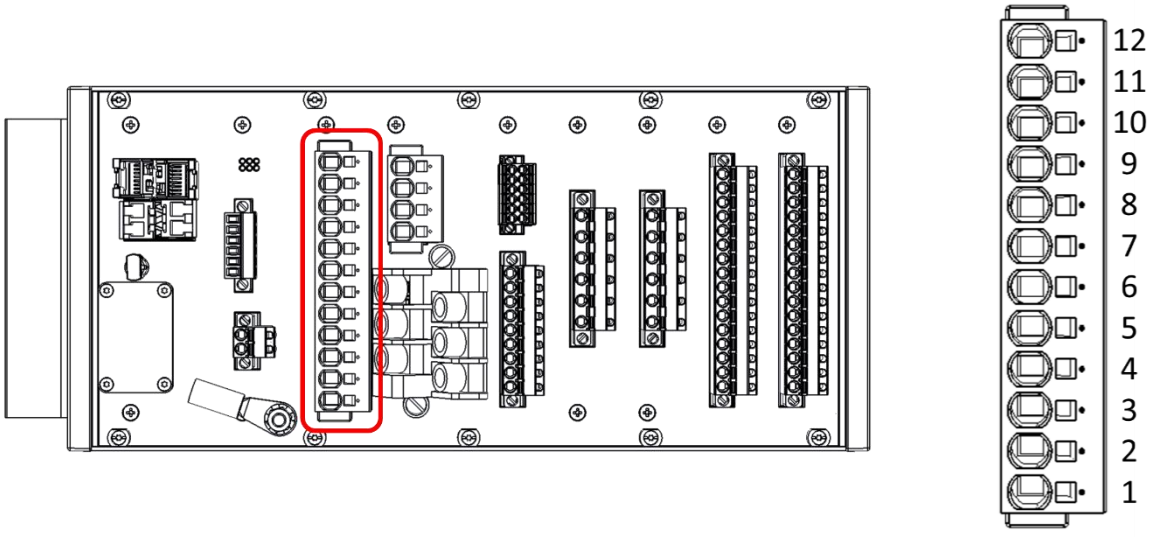


Figure 29 Voltage transformer input connection

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10.1.8.6 Auxiliary voltage inputs

Two (2) voltage inputs are available to measure the voltage from the station auxiliaries (batteries) for compensating functions purpose.

- One input is dedicated to opening polarity monitoring.
- One input is dedicated to closing polarity monitoring.

Table 4 CSD100 auxiliary voltage inputs connection terminals description

-X10 – AUXILIARY VOLTAGE INPUTS			
Terminal	**Signal**	**Description**	**Reference**
-X10:1	DC1- (O-)	Opening channel auxiliary voltage negative polarity	Phoenix Contact 1718504 SPC 5/ 4-STCL-7,62
-X10:2	DC1+ (O+)	Opening channel auxiliary voltage positive polarity	
-X10:3	DC2- (C-)	Closing channel auxiliary voltage negative polarity	
-X10:4	DC2+ (C+)	Closing channel auxiliary voltage positive polarity	

Note: DC1 and DC2 assignment to open or close operations is settable.

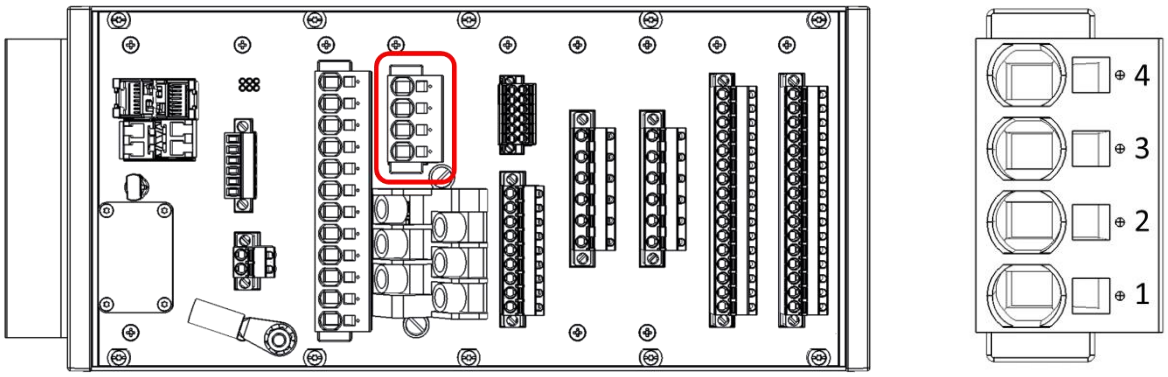


Figure 30 Auxiliary voltage input connection

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10.1.8.7 Current transformers inputs

Three (3) current inputs are available to measure the current at load side of the circuit breaker under operation, for synchronizing (opening operations) and monitoring purpose.

Current is measured at secondary side of installed current transformers, preferably at load side of the circuit breaker.

Table 14 CSD100 current transformers inputs connection terminals description

-X11 – CURRENT TRANSFORMERS INPUTS			
Terminal	**Signal**	**Description**	**Reference**
-X11:1	I1-S2	L1 load side current, S2	Phoenix Contact 1079655 BP 4-3CT
-X11:2	I1-S1	L1 load side current, S1	
-X11:3	I2-S2	L2 load side current, S2	
-X11:4	I2-S1	L2 load side current, S1	
-X11:5	I3-S2	L3 load side current, S2	
-X11:6	I3-S1	L3 load side current, S1	

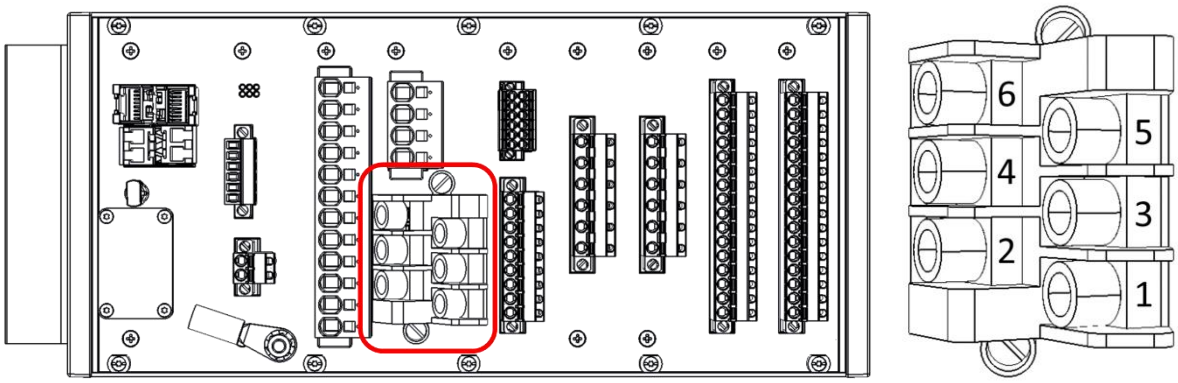


Figure 31 Current transformer input connection

Socket includes “automatic shunt” feature, when unplugged (make before break). It is therefore possible to unplug it on load. In any case, never disconnect, unscrew or cut wires from socket during load condition. Never interrupt high voltage CT secondary loop while on load (risk of death).

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10.1.8.8 Analogue sensors inputs

Four (4) low level inputs are available to measure the signals delivered by analogue transmitters, for monitoring and compensating functions purpose.

One input is dedicated to circuit breaker ambient temperature measurement.

Three inputs are dedicated to circuit breaker travel curve measurement.

Note: input range is settable, signal can be either [4-20] mA type or [0-5] V type.

Table 15 CSD100 analogue sensors inputs connection terminals description

-X12 – ANALOGUE SENSORS INPUTS			
Terminal	**Signal**	**Description**	**Reference**
-X12:1	GND1	Sensor1 measurement reference	Phoenix Contact 1790331 DFMC 1,5/ 6-STF-3,5
-X12:2	SIG1	Sensor 1 signal	
-X12:3	24V1	Sensor 1 power supply, positive polarity	
-X12:4	GND3	Sensor3 measurement reference	
-X12:5	SIG3	Sensor 3 signal	
-X12:6	24V3	Sensor 3 power supply, positive polarity	
-X12:7	GND2	Sensor2 measurement reference	
-X12:8	SIG2	Sensor 2 signal	
-X12:9	24V2	Sensor 2 power supply, positive polarity	
-X12:10	GND4	Sensor4 measurement reference (temperature)	
-X12:11	SIG4	Sensor 4 signal (temperature)	
-X12:12	24V4	Sensor4 power supply, positive polarity (temperature)	

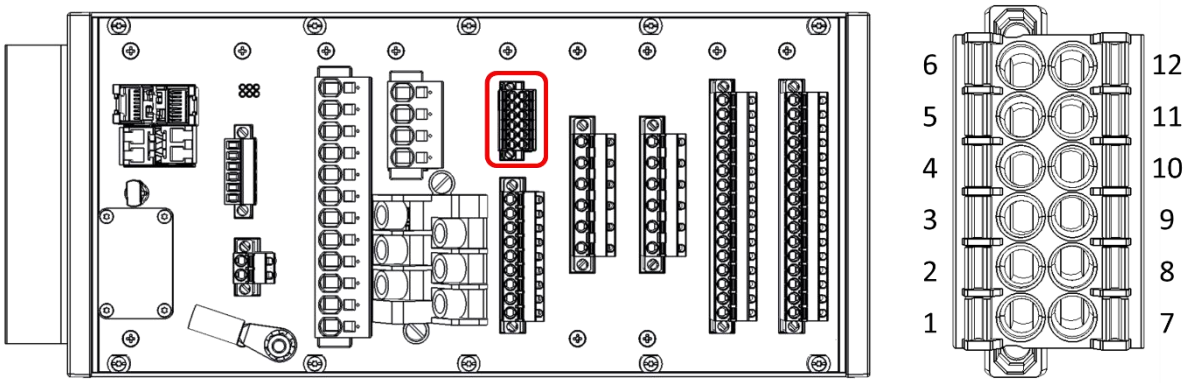


Figure 32 Analogue sensor input connection

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10.1.8.9 Relays output contacts

Three (3) programmable electromechanical output relays deliver the device and application status.

Two types of relays are used for alarm and watchdog purpose:

- Two (2) 7 pins all-or-nothing electromechanical bistable relays (2 coils latching type) designated as “RELAY 1” or “Bist.1, “RELAY 2” or “Bist.2”
- One (1) 5 pins all-or-nothing electromechanical monostable relay (1 coil latching type) designated as “RELAY 3” or “Mon.”

Table 16 CSD100 relays output contacts connection terminals description

-X13 – CONTACT OUTPUTS (RELAYS)			
Terminal	**Signal**	**Description**	**Reference**
-X13:1	NC1	System alarm relay normally closed contact	Phoenix Contact 1873278 FKC 2,5/ 9-STF-5,08
-X13:2	COM1	System alarm relay contact common point	
-X13:3	NO1	System alarm relay normally open contact	
-X13:4	NC2	Application alarm relay normally closed contact	
-X13:5	COM2	Application alarm relay contact common point	
-X13:6	NO2	Application alarm relay normally open contact	
-X13:7	COM3	Watchdog relay contact common point	
-X13:8	NC3	Watchdog relay normally closed contact	
-X13:9	NO3	Watchdog relay normally open contact	

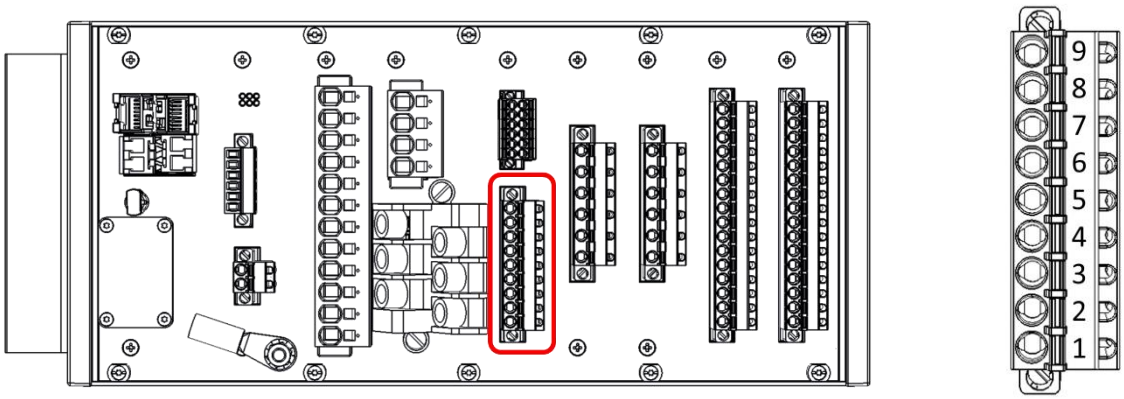


Figure 33 Relays output contact connection

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10.1.8.10 Command outputs 1

This set of three (3) power outputs is dedicated to operating opening operations of the circuit breaker.

Table 17 CSD100 command outputs 1 connection terminals description

-X14 – COMMAND OUTPUTS (IGBT)			
Terminal	**Signal**	**Description**	**Reference**
-X14:1	OUT1-	Phase L1 circuit breaker opening, negative polarity	Phoenix Contact 1939785 GFKC 2,5/ 6-STF-7,62
-X14:2	OUT1+	Phase L1 circuit breaker opening, positive polarity	
-X14:3	OUT2-	Phase L2 circuit breaker opening, negative polarity	
-X14:4	OUT2+	Phase L2 circuit breaker opening, positive polarity	
-X14:5	OUT3-	Phase L3 circuit breaker opening, negative polarity	
-X14:6	OUT3+	Phase L3 circuit breaker opening, positive polarity	

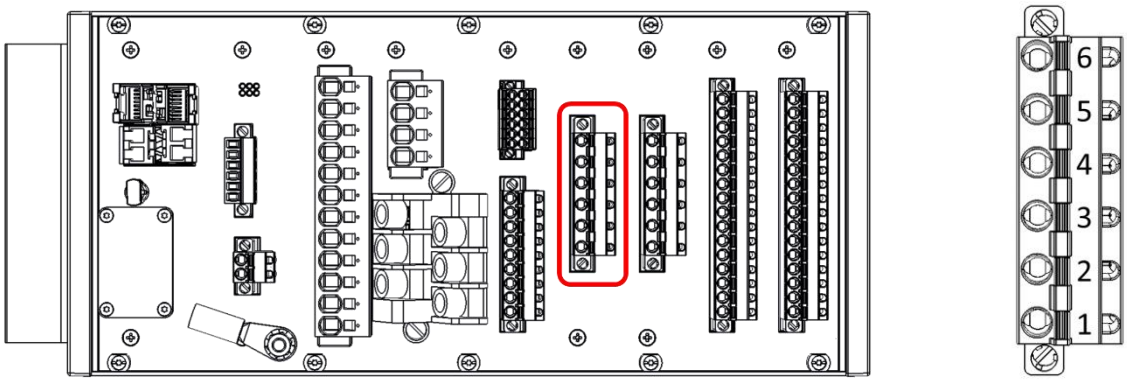


Figure 34 Command output 1 connection

Note: for circuit breaker with double drive where each half pole is operated independently, CSD100 can only operate one type of operation, i.e. closing or opening.

Note: for circuit breaker with double drive where each half pole is operated independently, these outputs drive the opening of the first half pole or the closing of the second half pole.

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10.1.8.11 Command outputs 2

This set of three (3) power outputs is dedicated to operating closing operations of the circuit breaker.

Table 18 CSD100 command outputs 2 connection terminals description

-X15 – COMMAND OUTPUTS (IGBT)			
Terminal	**Signal**	**Description**	**Reference**
-X15:1	OUT4-	Phase L1 circuit breaker closing, negative polarity	Phoenix Contact 1939785 GFKC 2,5/ 6-STF-7,62
-X15:2	OUT4+	Phase L1 circuit breaker closing, positive polarity	
-X15:3	OUT5-	Phase L2 circuit breaker closing, negative polarity	
-X15:4	OUT5+	Phase L2 circuit breaker closing, positive polarity	
-X15:5	OUT6-	Phase L3 circuit breaker closing, negative polarity	
-X15:6	OUT6+	Phase L3 circuit breaker closing, positive polarity	

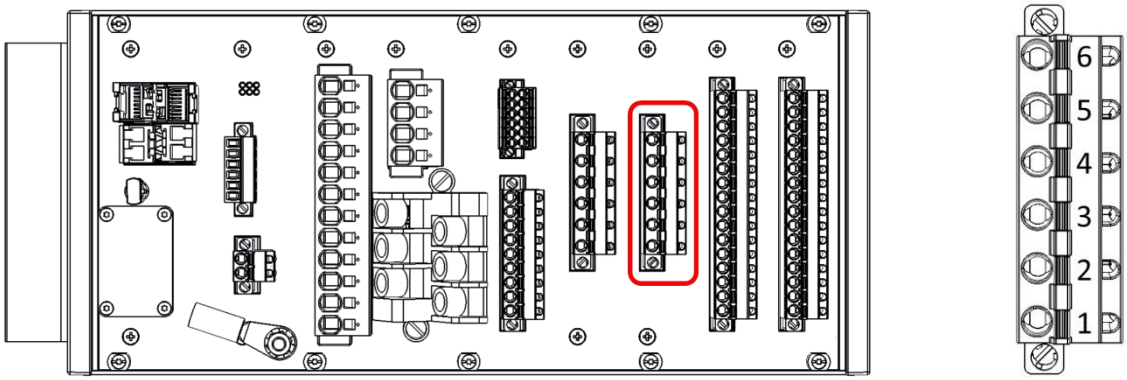


Figure 35 Command output 2 connection

Note: for circuit breaker with double drive where each half pole is operated independently, CSD100 can only operate one type of operation, i.e. closing or opening.

Note: for circuit breaker with double drive where each half pole is operated independently, these outputs drive the opening of the second half pole or the closing of the first half pole.

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10.1.8.12 Opto-isolated binary inputs 1

This set of eight (8) opto-isolated binary inputs is dedicated to receiving incoming orders from the system control and circuit breaker positions (52a signaling).

Table 19 CSD100 opto-isolated binary inputs 1 connection terminals description

-X16 – BINARY INPUTS			
Terminal	**Signal**	**Description**	**Reference**
-X16:1	OPEN-	Opening input order, negative polarity	Phoenix Contact 1873346 FKC 2,5/16-STF-5,08
-X16:2	OPEN+	Opening input order, positive polarity	
-X16:3	CLOSE-	Closing input order, negative polarity	
-X16:4	CLOSE+	Closing input order, positive polarity	
-X16:5	52a1-	Phase L1 circuit breaker 1 signaling, negative polarity	
-X16:6	52a1+	Phase L1 circuit breaker 1 signaling, positive polarity	
-X16:7	52a2-	Phase L2 circuit breaker 1 signaling, negative polarity	
-X16:8	52a2+	Phase L2 circuit breaker 1 signaling, positive polarity	
-X16:9	52a3-	Phase L3 circuit breaker 1 signaling, negative polarity	
-X16:10	52a3+	Phase L3 circuit breaker 1 signaling, positive polarity	
-X16:11	DI06-	Phase L1 circuit breaker 2 signaling, negative polarity*	
-X16:12	DI06+	Phase L1 circuit breaker 2 signaling, positive polarity*	
-X16:13	DI07-	Phase L2 circuit breaker 2 signaling, negative polarity*	
-X16:14	DI07+	Phase L2 circuit breaker 2 signaling, positive polarity*	
-X16:15	DI08-	Phase L3 circuit breaker 2 signaling, negative polarity*	
-X16:16	DI08+	Phase L3 circuit breaker 2 signaling, positive polarity*	

* circuit breaker with double drive

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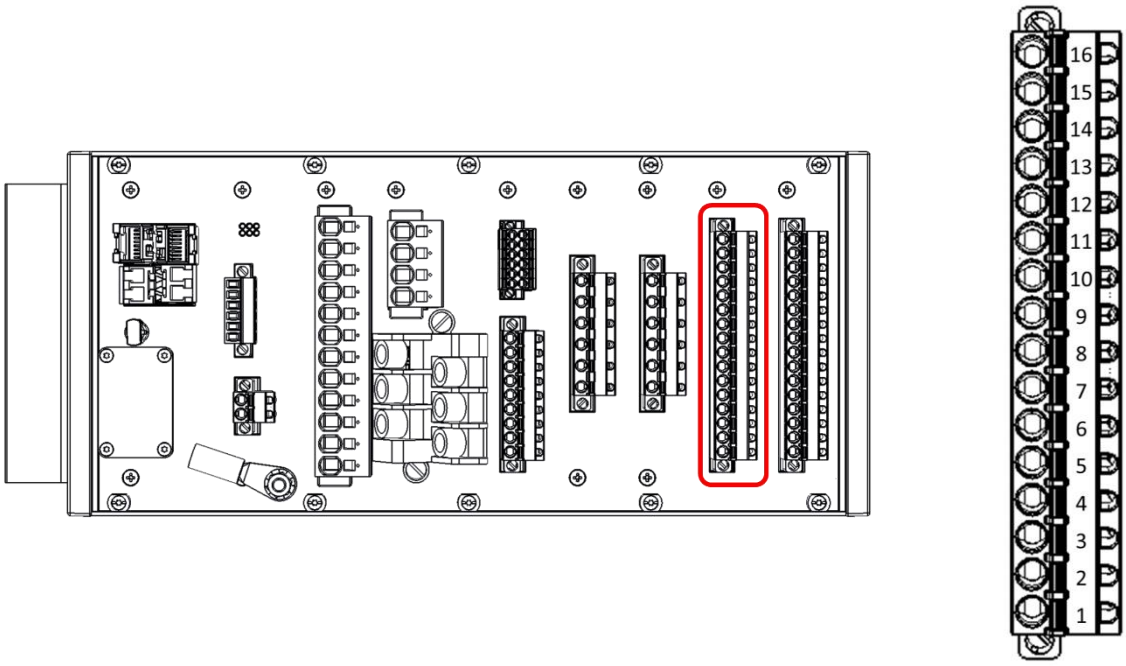


Figure 36 Opto-isolated binary input 1 connection

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10.1.8.13 Opto-isolated binary inputs 2

This set of eight (8) opto-isolated binary inputs is dedicated to receiving information from the system control to

- Operate the circuit breaker in “multiple load switching mode”;
- Operate the circuit breaker in “commissioning mode”;
- Trigger recording on external event;
- Acquisition of bypass position;
- Reset alarms.

Table 20 CSD100 opto-isolated binary inputs 2 connection terminals description

-X17 – BINARY INPUTS			
Terminal	**Signal**	**Description**	**Reference**
-X17:1	DI09-	Recording trigger, negative polarity	Phoenix Contact 1873346 FKC 2,5/16-STF-5,08
-X17:2	DI09+	Recording trigger, positive polarity	
-X17:3	DI10-	Multiple load switching input 1, negative polarity	
-X17:4	DI10+	Multiple load switching input 1, positive polarity	
-X17:5	DI11-	Multiple load switching input 2, negative polarity	
-X17:6	DI11+	Multiple load switching input 2, positive polarity	
-X17:7	DI12-	Multiple load switching input 3, negative polarity	
-X17:8	DI12+	Multiple load switching input 3, positive polarity	
-X17:9	DI13-	Multiple load switching input 4, negative polarity	
-X17:10	DI13+	Multiple load switching input 4, positive polarity	
-X17:11	DI14-	Bypass position measurement, negative polarity	
-X17:12	DI14+	Bypass position measurement, positive polarity	
-X17:13	DI15-	Commissioning mode input, negative polarity	
-X17:14	DI15+	Commissioning mode input, positive polarity	
-X17:15	DI16-	Alarm reset input, negative polarity	
-X17:16	DI16+	Alarm reset input, positive polarity	

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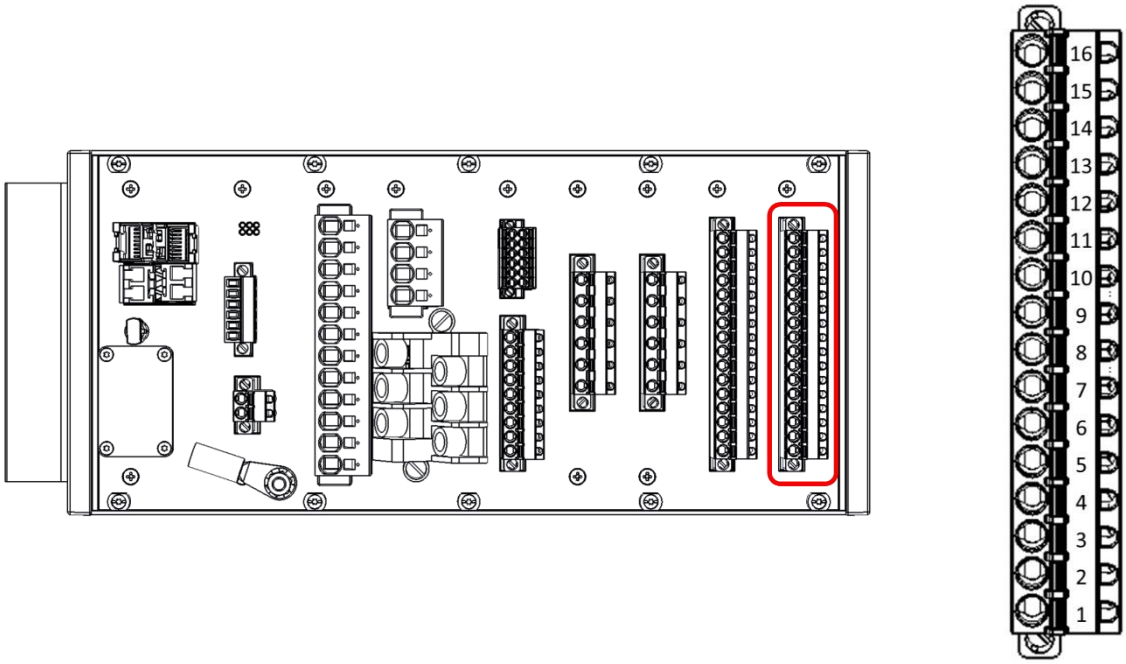


Figure 37 Opto-isolated binary input 2 connection

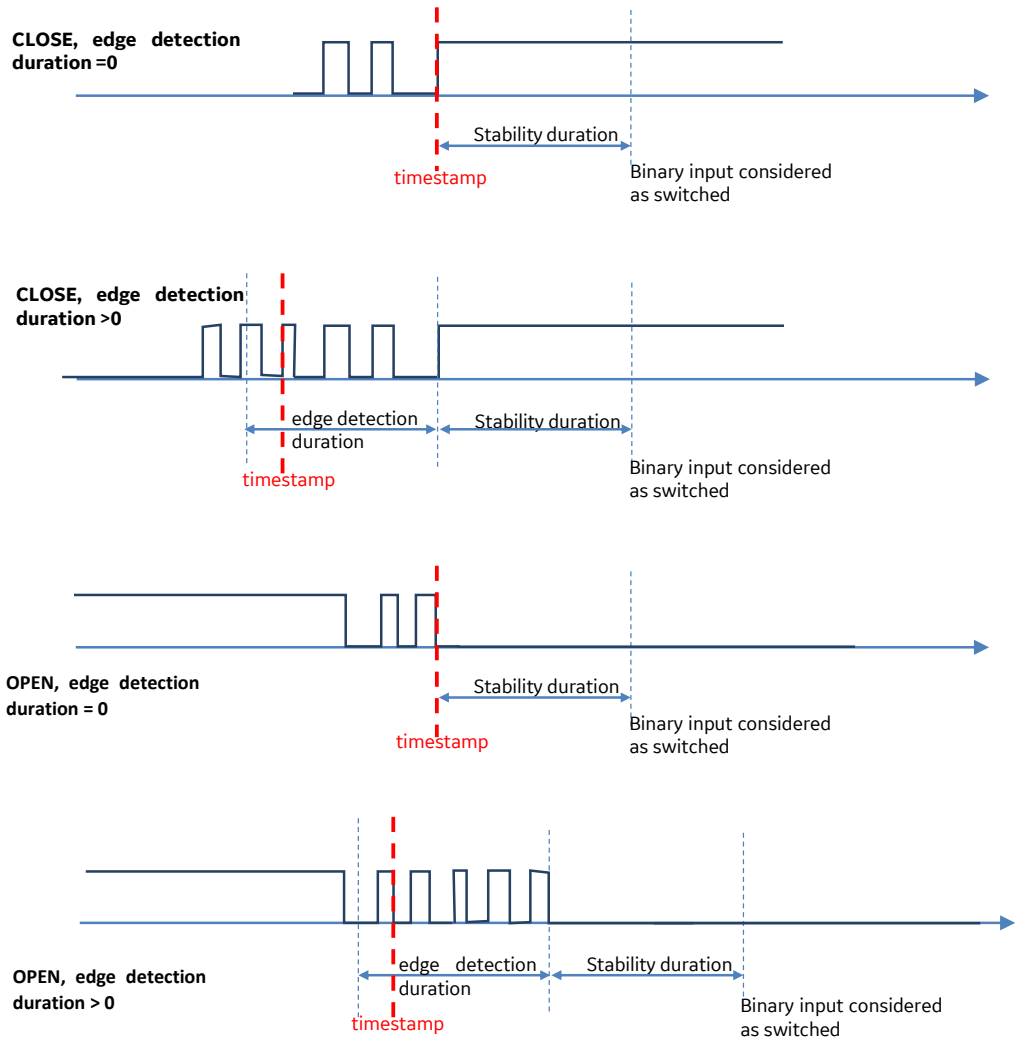
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10.1.8.14 Opto-isolated binary inputs: filtering and debouncing

Binary inputs are filtered and debounced with an advanced processing, involving two steps:

1/ “Stability duration”: from a stable position (0 or 1) the binary input is considered switched only after a settable duration (“stability duration”) in opposite position. Typical value is 2ms.

2/ “First edge detection”: after stability duration processing, the algorithm searches for the first edge before beginning of stability duration, in the limit of “edge detection duration”. Can be set to zero to bypass this step.



Remark: the available settings (“stability duration” and “edge detection duration”, see HMI section), only apply to 52a binary inputs (X16:5 to X16:16). All other inputs are timestamped with 5ms stability duration and 0ms edge detection duration (non-settable).

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10.1.9 Signaling LEDs

Six (6) signaling bicolored green and orange LEDs deliver the equipment status.

Table 21 CSD100 signaling LEDs

Signaling LED	Allocation	Color	Description
LED 1	POWER	Bicolored GN/OR	“Power supply” status
LED 2	READY	Bicolored GN/OR	“Ready to operate” status
LED 3	ALARM	Bicolored GN/OR	Warning and Alarm signaling
LED 4	ETH	Bicolored GN/OR	Ethernet activity
LED 5	SYNC	Bicolored GN/OR	“Time synchronization” status
LED 6	SD	Bicolored GN/OR	“µSD Mode”, reserved for factory diagnosis

GN= green / OR=orange

Note: signaling LEDs are reported at both front and back panel to remain visible whatever the mounting type, DIN rail or front panel.

Note: Refer to section 13.6 for LED animation description.

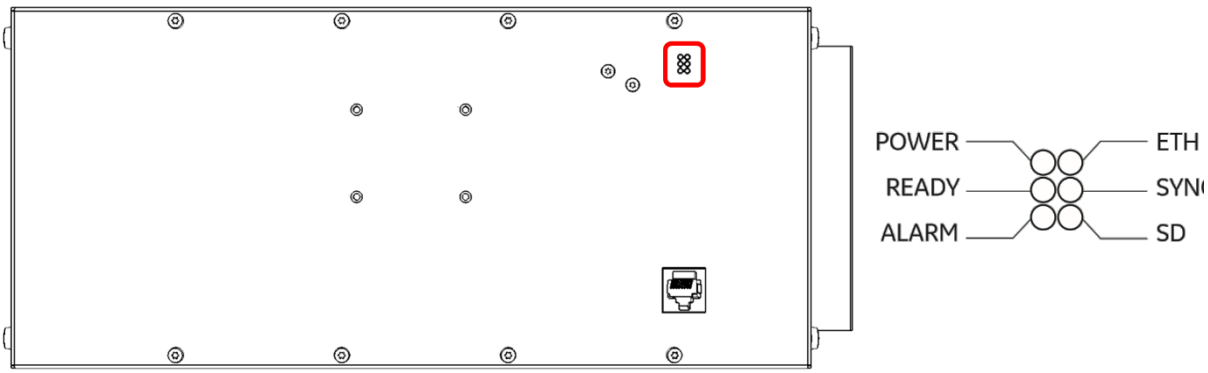


Figure 38 Front panel signaling LEDs

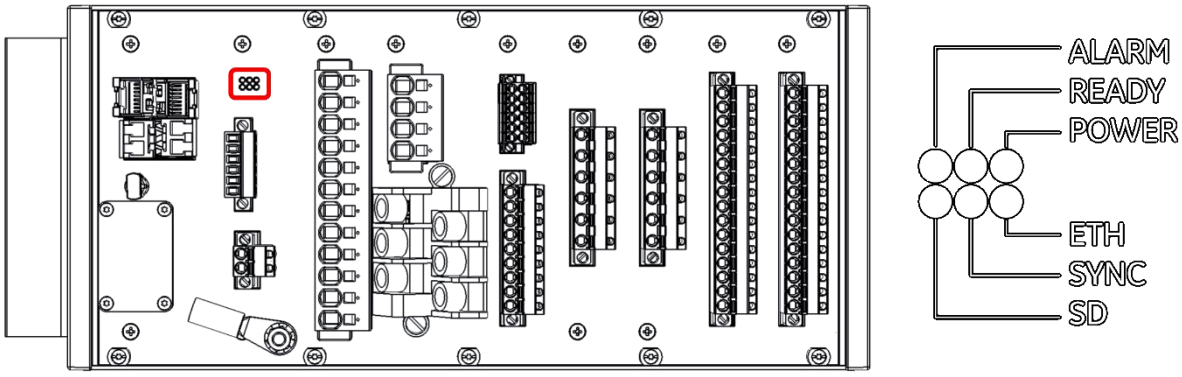


Figure 39 Rear panel signaling LEDs

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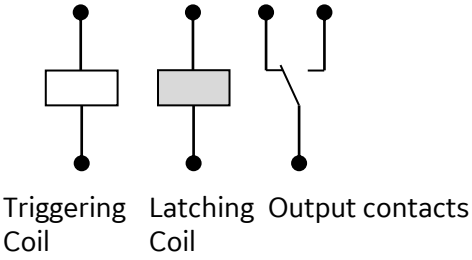
10.1.10 Signaling relays

Note: Detailed description of parameters, alarms and measurements are provided within section 13.

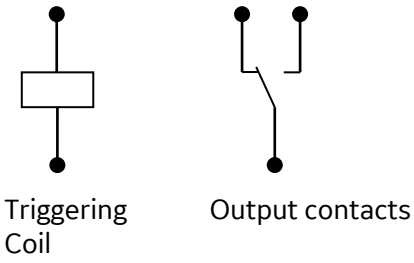
Three (3) programmable electromechanical output relays deliver the device and application status.

Two types of relays are used for alarm and watchdog (“in service” function) purpose:

- Two (2) 7 pins all-or-nothing electromechanical bistable relays (latching type) designated as “RELAY 1” or “Bist.1, “RELAY 2” or “Bist.2”



- One (1) 5 pins all-or-nothing electromechanical monostable relay (standard type) designated as “RELAY 3” or “Mon.”



“**Bist**.” relays are allocated to alarm signaling

“**Mon**.” relay is allocated to CSD100 watchdog function (“in service” function) and interlocking mechanism (switching channel bypass) functions. Relay is energized (inverted position) when the CSD100 is energized and ready to operate.

Technical characteristics of the relays are described in section 17.3.

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The following usage is recommended for wiring scheme:

Table 22 CSD100 signaling relays

Signaling Relay	Allocation	Type	Description
RELAY 1	APPLICATION ALARMS	Bistable (latching)	Operations monitoring & non urgent alarms Release condition NO
RELAY 2	SYSTEM ALARMS	Bistable (latching)	Installation status & urgent alarms Release condition NO
RELAY 3	WATCHDOG	Monostable	Equipment failure, power supply failure, absence of necessary conditions for synchronization (reference waveform)

Note 1: Alarms output relays can be customized individually.

Note 2: Output relays state can be checked from HMI display section.

Note 3: If a fallback strategy is necessary to operate circuit-breaker in degraded mode, then bypassing the CSD100 using an external conventional solution (electromechanical relays) activated by one of the output relays (typically monostable) is necessary.

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10.1.11 External power supply

The following reference is the one recommended by GE to supply the controller with a 24Vdc polarity

Designation	Type	Picture
Power supply	Quint phoenix contact QUINT-PS/1AC/24DC/ 3.5 - 2866747	

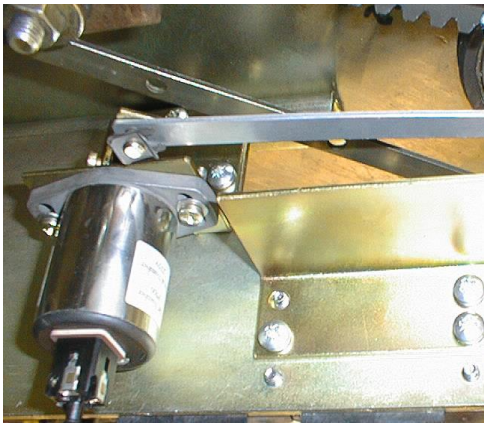
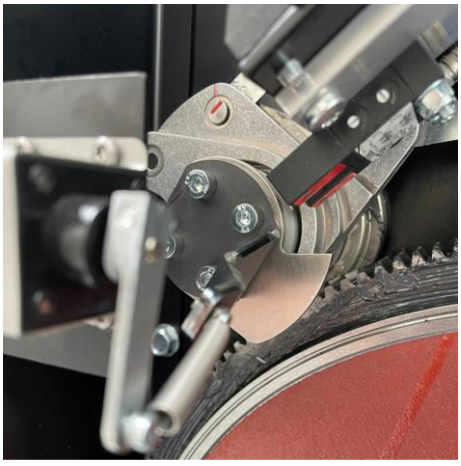
10.1.12 Additional sensors and accessories

Additional sensors for monitoring might be needed depending on the circuit-breaker type and installation conditions (indoor, outdoor, …)

These sensors are not a part of the standard delivery and are available on request.

Designation	Type	Picture
Ambient temperature sensor	Temperature transducer (RTD100Ω) 4-20mA / 2 wires signal conditioner Range: -50°C/+80°C	

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Designation	Type	Picture
Gas pressure and temperature transmitter (to compute density)	Keller PAA33X series	
Hydraulic pressure sensor	Keller PAA33X series	
Communication cable	RJ45 STP cat.5 cable	-
Travel sensor	4-20mA / 3 wires Range : 90°	
Light barrier (CB signalling)	24V / 3 wires	

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10.2 Functional description

10.2.1 Available operating mode

CSD100 supports the modes described in Table 23.

Table 23 CSD100 operation modes

Operating mode	Description	Comment
Single mode	Operation on a fixed load	11 switching programs available
Multiple load switching (MLS)	Operation on multiple load in complex substation layouts such as 1,5 CB, 1,3 CB, ring configuration or in case of variable load (with variable rate of compensation, moving neutral position…)	CSD100 switches to the appropriate program based on the combination of 4 dedicated digital inputs (16 possible cases)
Dual switching	Manage reversal of the source and load side for synchronization in substation layout with a tie circuit breaker (1,5 CB, 1,3 CB, ring configuration, H configuration)	For example, energizing a line from a transformer or the same transformer from the same line requires to measure the synchronizing voltage at the side already energized
Commissioning mode	Allows to operate each pole of the circuit breaker independently for wiring check and operating time measurement purpose and to operate output relays for alarm signaling testing	Reserved for commissioning and maintenance tasks only. Activated with dedicated wired digital input.
Bypass	Circuit breaker operations are performed randomly and simultaneously through an external bypass circuit switched by the bypass relay	Bypass relay is activated either by CSD100 watchdog, user manual selection or any other logics issued by control command. CSD100 remains capable to record switching traces for performance evaluation purpose. Illustrated in Figure 85

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10.2.2 Circuit breaker type

CSD100 is capable to operate type of circuit breakers described in 12.5.

Table 24 Circuit breaker type

Circuit breaker type	Description	Comment
Single pole operated circuit breaker (IPO)	Independent operation of the three poles of a circuit breaker at optimized switching angle	Traditional mode for controlled switching where each pole is operated at the best angle
Double drive circuit breaker	Capability for independent operation of double circuit breaker with interrupting chambers in series	Only closing or opening operations can be performed in this configuration. Whenever both closing and opening operations are required, 2 x CSD100 per circuit breaker should be installed.
Circuit breaker with pre-insertion resistor	Capability for independent operation of double circuit breaker with pre-insertion switch build using a circuit breaker in parallel with the main interrupting chamber	Allows to set variable pre-insertion time based on system requirements. Only closing operations can be performed in this configuration.
Gang operated circuit breaker (3PO)	Simultaneous operation of the three poles of a circuit breaker simultaneously, wired to a single output of the CSD100 (coil)	One target for the three phases. Degraded mode for controlled switching where a tradeoff between three phases targets has to be defined.

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10.2.3 Synchronizing features

Table 25 Synchronizing features

Item	Description	Comment
System frequency	Selection of the system frequency	50Hz or 60Hz system frequency. Note: synchronizing according to actual measured frequency
Synchronizing on voltage signal	Synchronizing based on measured reference voltage signal, generally source side voltage	Suitable for both controlled closing and controlled opening operations. Whenever voltage signal is used for controlled opening, switching angles are elaborated considering voltage and current signals are in quadrature. Phase to neutral signal wiring recommended.
Synchronizing on current signal	Opening synchronizing based on measured load current	Switching angles are directly related to current signal. Enough r.m.s. current should feed the controller current input, 20mA secondary minimum. CT at the load side of the circuit-breaker recommended.
Synchronizing on differential voltage signal	Reference signal is the voltage difference between source side and load side	With multi-chamber circuit breakers, residual voltage is transmitted from source side to load side through grading capacitors and should be considered for synchronizing
Phase reference for synchronizing	Fixed selection of the phase reference L1, L2 or L3, defining the switching sequence	Automatic selection is possible only when 3 phases of the synchronizing signal are wired to the controller (refer to delay optimization)
Switching delay optimization	Dynamic change of the phase reference to reduce delay introduced by the controller	Applicable when 3 phases of the synchronizing signal wired to the controller. Practically, the controller performs a circular permutation of the predefined switching angles. In all cases, delay introduced by the controller is lower than 1 cycle of power frequency.
Reference signal phase shift	Phase shift between the applied primary voltage at the circuit breaker terminal and the measured secondary voltage.	Applicable for synchronizing on voltage signal. Suitable for applications where voltage divider is located at the secondary side of a transformer or phase to phase voltage signal is wired to the controller voltage input. For example, if measured voltage leads actual pH-E voltage at source side of CB (sync reference) by 30°, this parameter shall be set to +30. For example, if measured voltage lags actual pH-E voltage at source side of CB (sync reference) by 30°, this parameter shall be set to +330 (equivalent to -30°)

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10.2.4 Signaling and feedback

Table 26 Signaling and feedback

Item	Description	Comment
Alarm signaling	2 relays available for signaling urgent and non-urgent alarms	Alarm assignation is customizable
LEDs signaling	6 LEDs available to deliver status of the controller (power supply, ready to operate)	Alarm assignation is customizable for one LED
Switching performance evaluation	Accuracy of the controlled closing and controlled opening operations, within the required tolerance	Measurement performed by 52a triggering accuracy digital input, travel curve measurement, current and voltage inception
Power quality indicators	Voltage dip, peak current	-
Counter	Number of controlled and random operations Number of reignition	Decision making tool

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10.3 Software description

10.3.1 Communication features

10.3.1.1 Communication requirements

Interface : Ethernet RJ45 copper interface (100BASE-TX or 1000 BASE-T) or optical LC interface (100BASE-FX or 1000BASE-SX).

Protocols : TCP/IP – HTTPS

10.3.1.2 Computer requirements

Operating system : Windows, Linux, Android

Software : Standard web browser

Recommended versions:

- Firefox latest version
- Chrome latest version
- Edge latest version
- Brave latest version

10.3.1.3 Point to point access

Maintenance laptop is configured with static (manually set) IP address in the same range as CSD100.

Note: CSD100 also supports dynamic IP address allocation (DHCP).

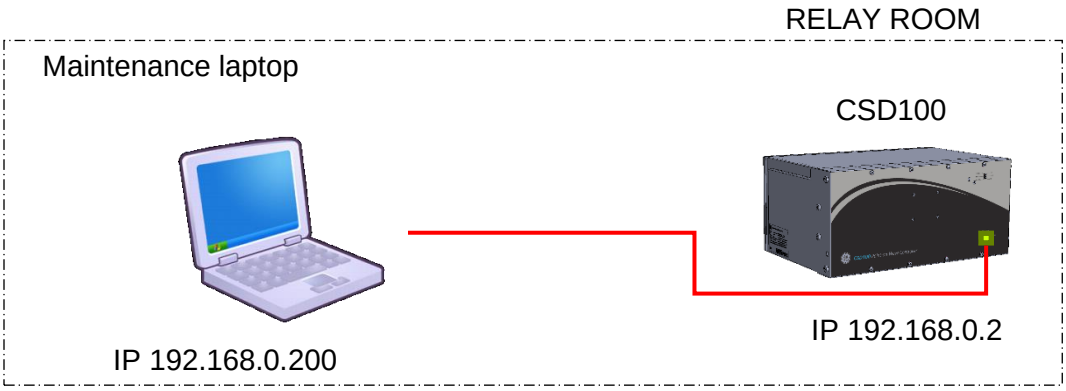


Figure 40 CSD100 point to point access

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10.3.1.4 Remote access

Application computer is configured with static (manually set) IP address in the same range as CSD100 and mask 255.255.255.0. It's connected to CSD100 controllers LAN through an external ethernet switch or by use of internal CSD100 switch, as illustrated below.

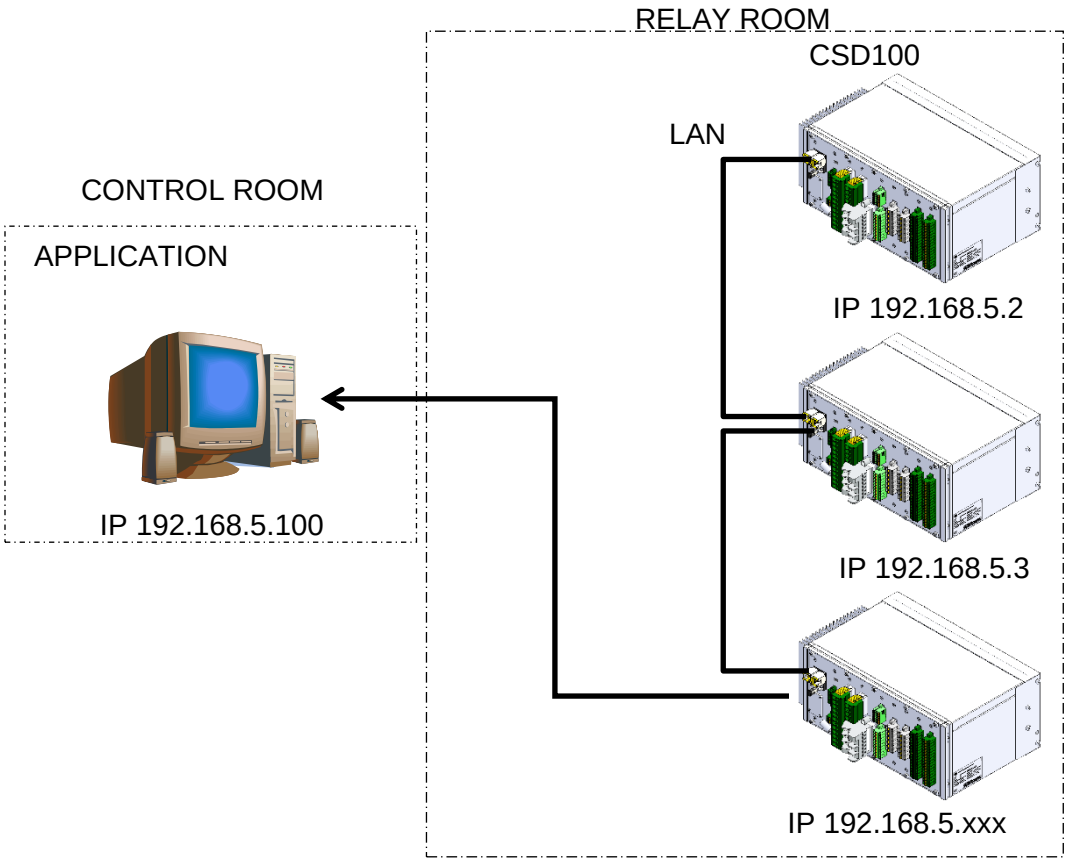


Figure 41 CSD100 remote access

Note: Prior to connecting controllers on the LAN, each device needs to have its IP address customized through the Control Interface and using a point-to-point connection.

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10.3.2 Control interface

The CSD100 has an embedded web server for the Human-Machine interface called **“CSD100 Control Interface”**.

The web server program operates by accepting HTTPS requests from the client, [i.e. laptop fitted with a web browser], and provides an HTTPS response to the client.

The HTTPS response is in HTML document format. Information review, settings adjustments and download of records are possible.

Seven main sections are available to the user through the control interface:

- **“Home”** section summarizes essential information
- **“Measurements”** section gives real-time information about the CSD100 device status and application status;
- **“Settings”** section allows user to set the various parameters needed for controlled switching application;
- **“System”** section allows for management of network related questions, software upgrades, logs, and configuration of users (passwords).
- **“Downloads”** section that allows user to download archives and data from CSD100 device.
- **“Language”** section allows for choosing between a predefined set of languages.

A detailed description of the “CSD100 Control Interface” is provided in section 13.1

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10.3.3 Time synchronization

CSD100 date/time source can come from:

- **Internal clock** (“Local”), as autonomous mode (absence of external synchronization). During power down, date is maintained for 2 weeks. In this mode, the dating drift is less than 0.432 seconds/day (5ppm).
- Ethernet network **SNTP** server (Simple Network Time Protocol) when option is enabled through the control interface. The SNTP server is interrogated every 120 seconds by the CSD100 (non-settable refresh period). Between two requests, timestamps are maintained with internal clock (±50ppm max. inaccuracy, e.g. 50µs/s maximum drift). Therefore, the maximum timestamp error in SNTP mode is 120*50e-6 = ±6ms. This maximum error does not consider the possible inaccuracy from date propagation delay between server and CSD100, which depends on the network topology.
- Ethernet network **PTP** server (IEEE1588) with different profiles available. PTP refresh period is 2 seconds. Therefore, the maximum timestamp error in PTP mode is 2*50e-6 = ±100µs.

When network time is available, internal RTC is regularly updated, to maintain consistency.

Network ports dedicated for time synchronization are rear side ethernet ports.

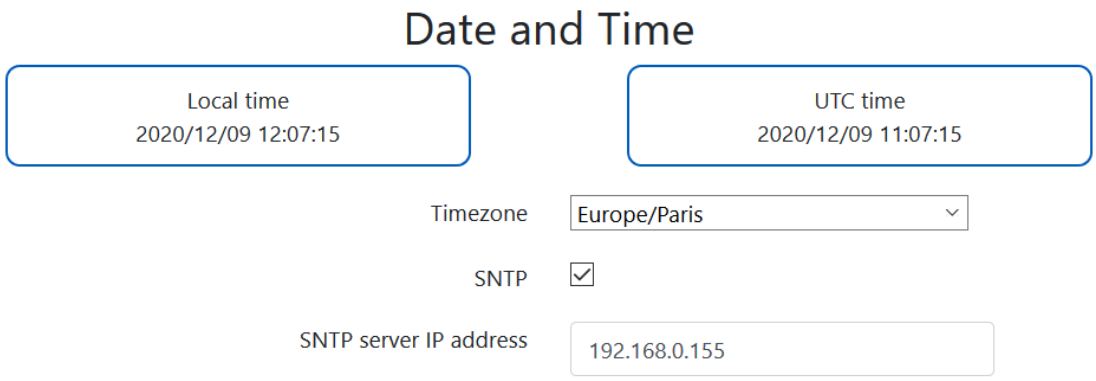


Figure 42 Date and time settings (HMI)

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10.3.4 Cyber security implementation

Refer to section 14 for details about Secure Deployment Guide (SDG).

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11 INSTALLATION, MOUNTING , CABLING

11.1 Lifting, unpacking and inspecting

This product shall be handled with care and should be checked for damage which could have originated during transportation before installation.

11.2 Mounting

Use mounting accessories supplied by the manufacturer only.

Make sure to follow instructions delivered in this document.

11.2.1 Location

CSD100 shall be installed in the control panel or in the protection panel of the circuit breaker.

As described in the following chapters, CSD100 can be either DIN rail mounted, or front panel mounted (19'' rack) using the appropriate mounting brackets kit delivered with the product.

Note: 2 types of mounting brackets kits are delivered with the product.

11.2.2 Case dimensions

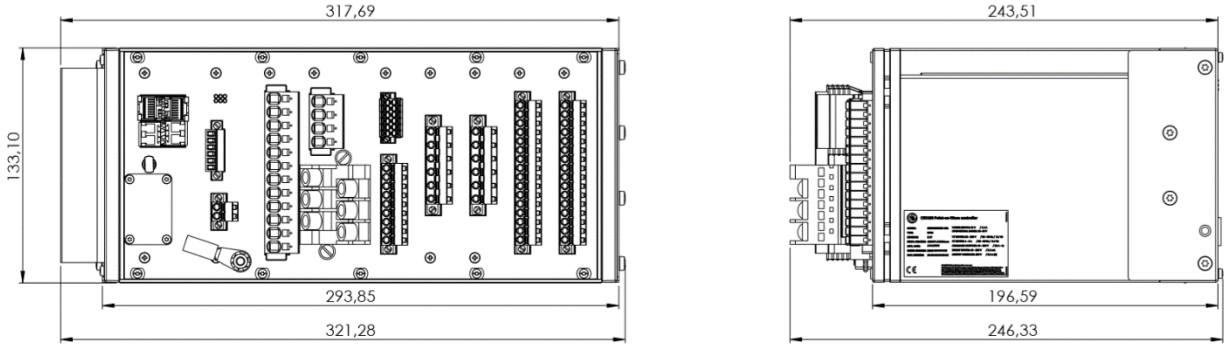


Figure 43 Case dimensions (mm)

11.2.3 Clearance

1 U clearance should be left above and under the device

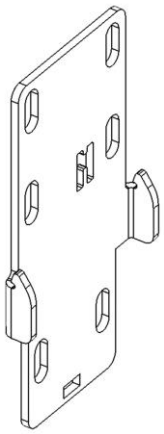
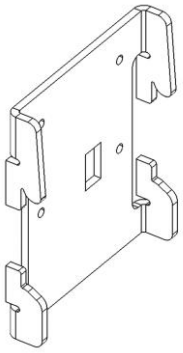
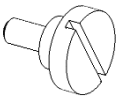
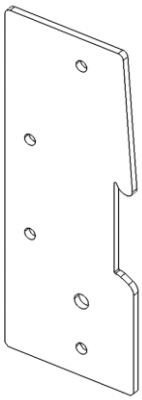
When installed on DIN rail, 25 mm should be left on the sides of the device Left side (heatsink)

Due to high density of wires converging to the CSD100, a minimum of approximately 15cm of clearance shall be dedicated to wiring harness.

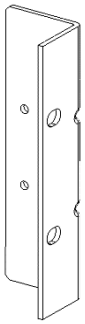
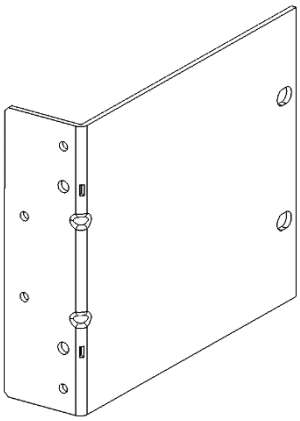
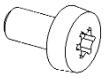
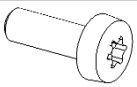
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11.2.4 Mounting kits

Table 27 CSD100 mounting kits parts

Item	Description	Quantity	Picture
DIN rail mounting kit			
01	Compression spring for DIN rail snap lever	1	
02	DIN rail snap lever	1	
03	DIN rail snap lever flange	1	
10	M3 screw for DIN rail snap lever mounting	4	
04	DIN rail side flange	2	

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Item	Description	Quantity	Picture
Front panel (19” rack) mounting kit			
05	Short mounting bracket for rack installation	1	
06	Long mounting bracket for rack installation	1	
Common parts			
07	M4x08 torx screw for DIN rail flanges and rack brackets mounting	4	
08	M4x12 torx screw for DIN rail flanges and rack brackets mounting	4	
09	M4 serrated lock washer	8	

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11.2.5 DIN rail installation

11.2.5.1 Dimensions

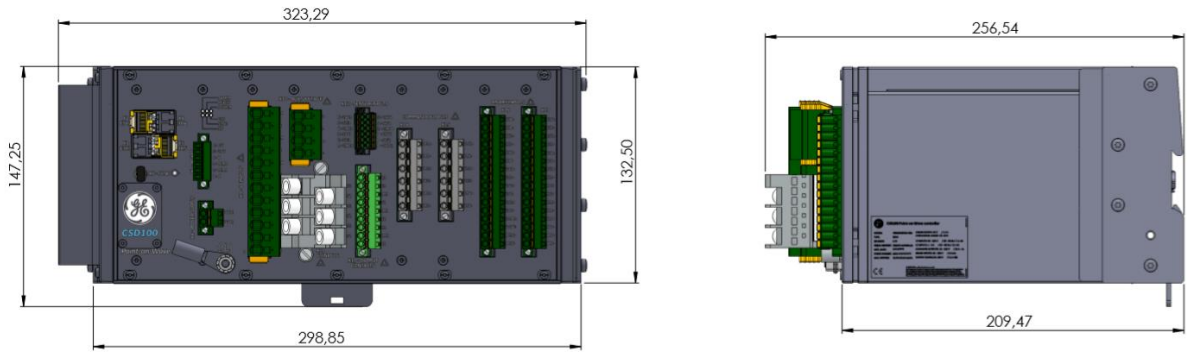


Figure 44 CSD100 DIN rail mounting dimensions (mm)

11.2.5.2 Assembly

11.2.5.2.1 Module pre-installation

The controller is delivered with mounting kits disassembled. Before installing the mounting kits :

Remove installed side screws (x 8) of the front case.

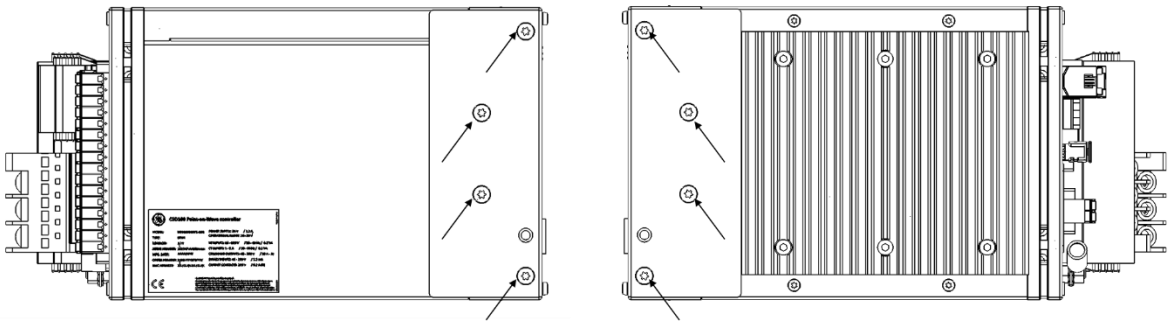


Figure 45 CSD100 side brackets or flanges attachment holes

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11.2.5.2.2 Snap lever assembly

- Insert the spring in the dedicated hole (housing) of the compression lever.
- Insert the compression lever in the fixed part of the kit
- Screw the assembly to the device front panel with four included shoulder bolts. Torque: 0,8 N.m

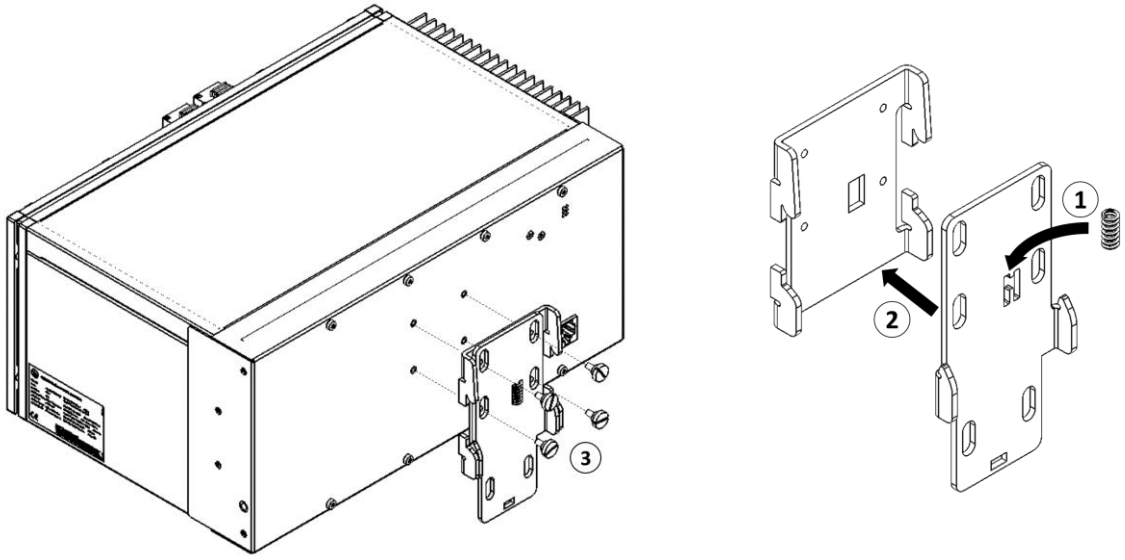


Figure 46 CSD100 DIN rail mounting kit, parts

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11.2.5.2.3 Lateral flanges assembly

Torque: 0,95 N.m

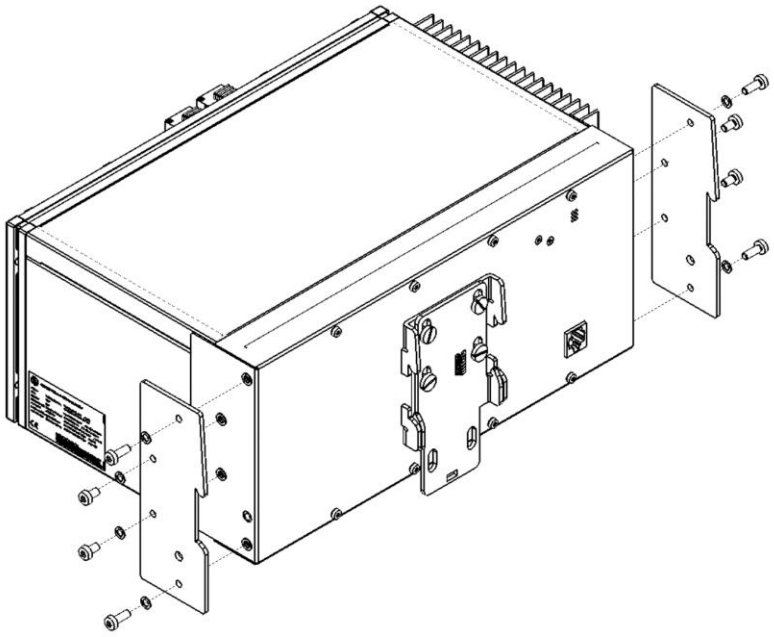


Figure 47 CSD100 DIN rail mounting kit, exploded view

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11.2.5.2.4 Final assembly

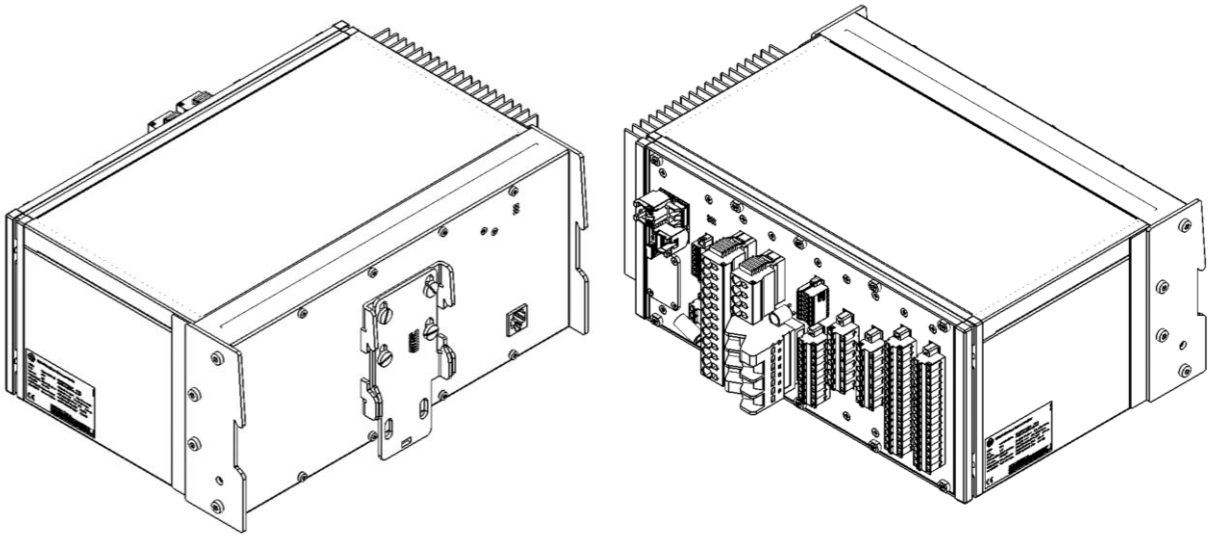


Figure 48 CSD100 DIN rail mounting kit, final assembly

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11.2.5.3 Mounting

Never install a live equipment.

Cabling shall be performed after installation of the equipment on its final location

Use of **steel DIN rail** material is required. Rail height: 15mm or 7.5mm.

- Position the module with the DIN rail guide on the upper edge of the DIN rail.
- Snap in the module with a downward motion until the moving part of the snap lever is fully engaged.
- Once installed, check proper withstand of the module.

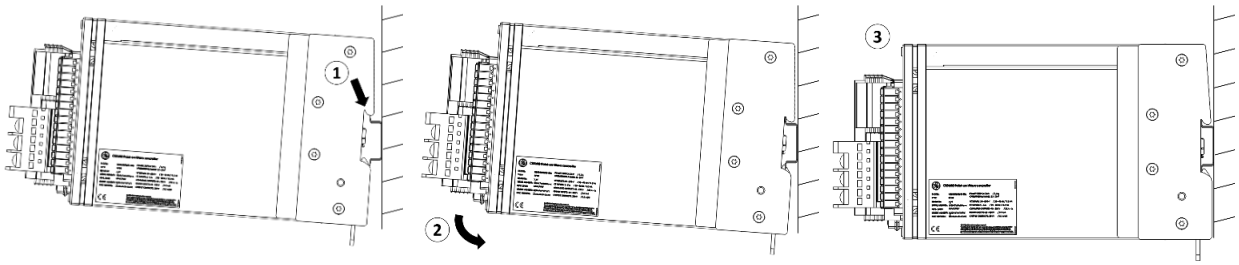


Figure 49 CSD100 DIN rail mounting

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11.2.5.4 Removal

Never replace a live equipment.

Before removal, to avoid accidents, make sure the power supply and any external power sources are switched off and disconnected, connectors are removed and protective earth conductor is unplugged from the equipment case. Then check that the equipment is off before touching any components.

- Pull the snap lever down open with the aid of a screwdriver.
- Slide the module out at the lower edge of the DIN rail.
- Slide the module out at the upper edge of the DIN rail.

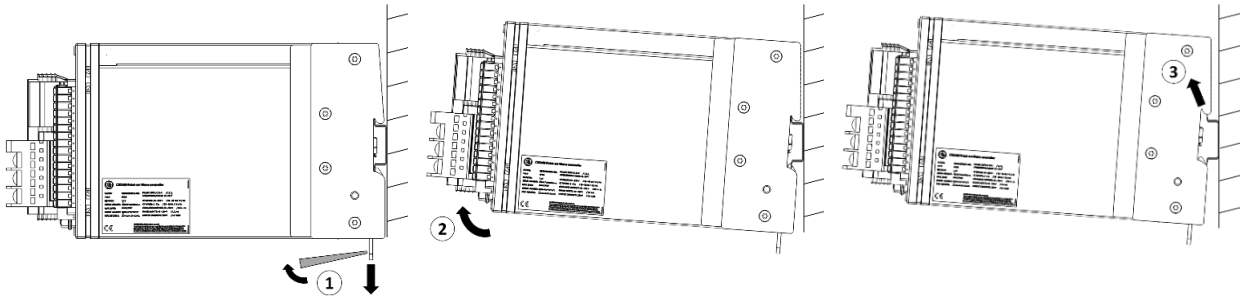


Figure 50 CSD100 DIN rail removal

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11.2.6 Front panel installation (19’’ rack)

11.2.6.1 Dimensions

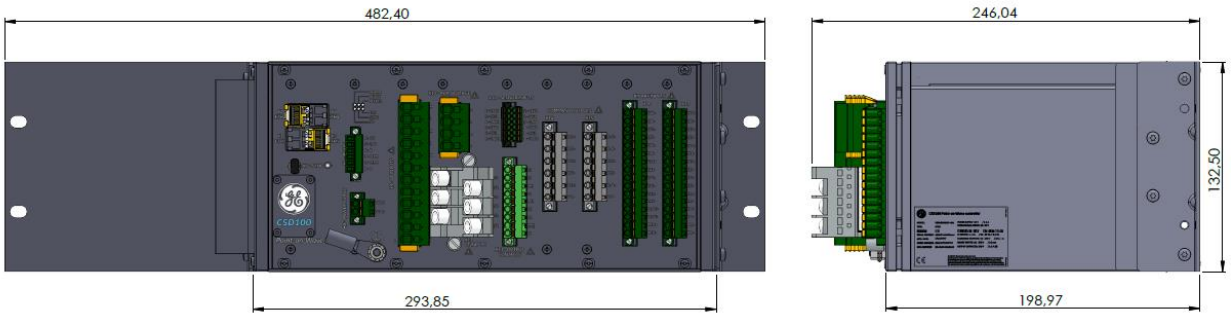


Figure 51 CSD100 front panel mounting dimensions (mm)

11.2.6.2 Assembly

11.2.6.2.1 Module pre-installation

Accessories are included in delivery, as spare parts.

Before installing side brackets or flanges, remove installed side screws (x 8) of the front case.

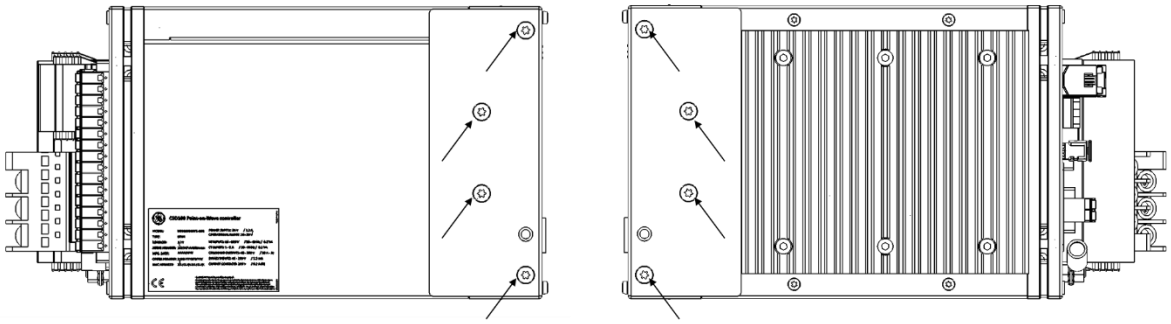


Figure 52 CSD100 side brackets or flanges attachment holes

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11.2.6.2.2 Mounting brackets assembly

Install the mounting brackets

Torque: 0,95 N.m

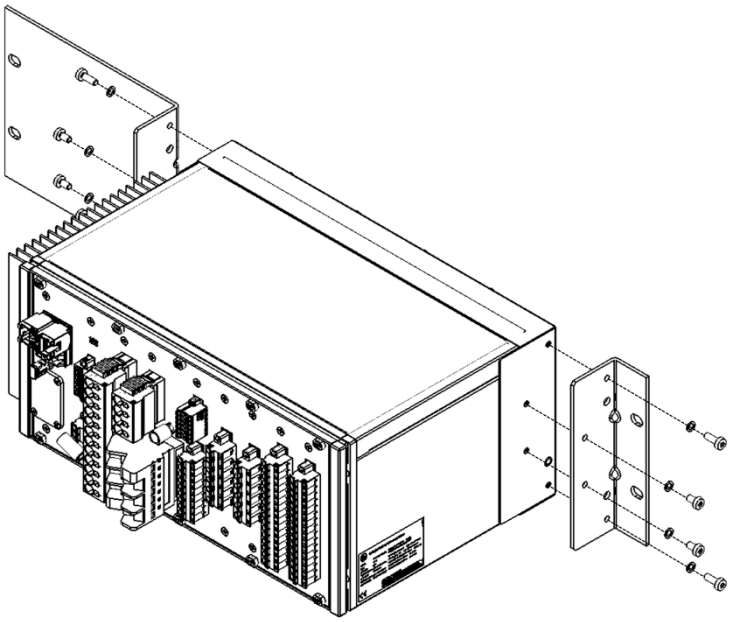


Figure 53 CSD100 side brackets, exploded view

11.2.6.2.3 Final assembly

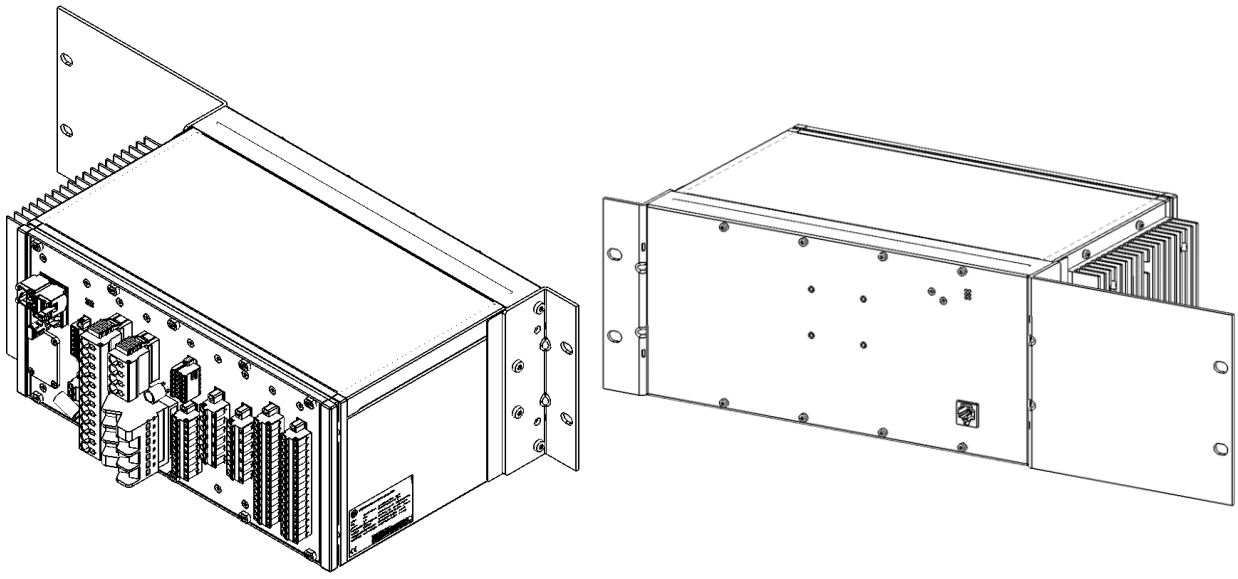


Figure 54 CSD100 front panel mounting (19 inches rack)

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11.2.6.3 Mounting

Never install a live equipment.

Cabling shall be performed after installation of the equipment on its final location

- Position the module on the 19’’ frame
- Safely secure mounting with M6 screw in locked nut, torque 10 Nm
- Once installed, check proper withstand of the module.

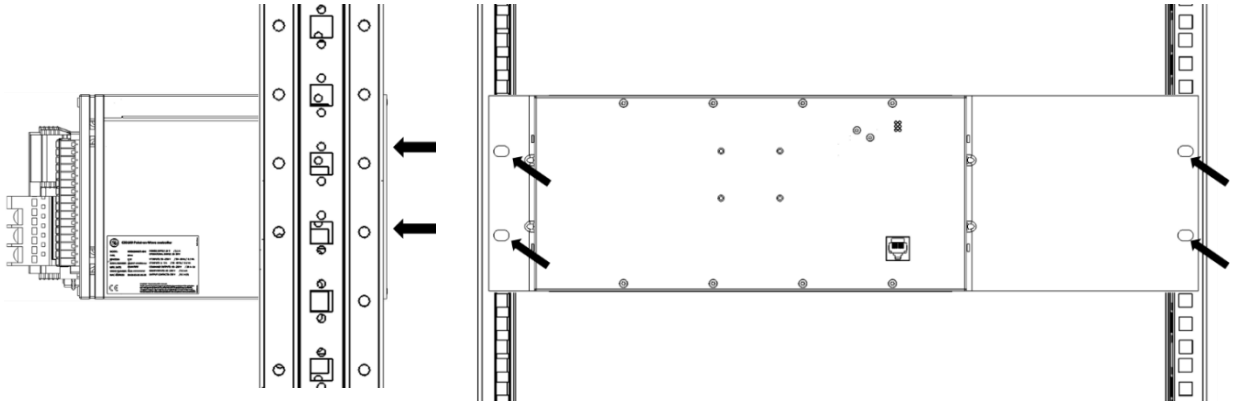


Figure 55 CSD100 rack mounting

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11.2.6.4 Removal

Never replace a live component.

Before removal, to avoid accidents, make sure the power supply and any external power sources are switched off and disconnected, connectors are removed and protective earth conductor is unplugged from the equipment case. Then check that the equipment is off before touching any components.

- Remove the M6 screw
- Safely remove the equipment from its location

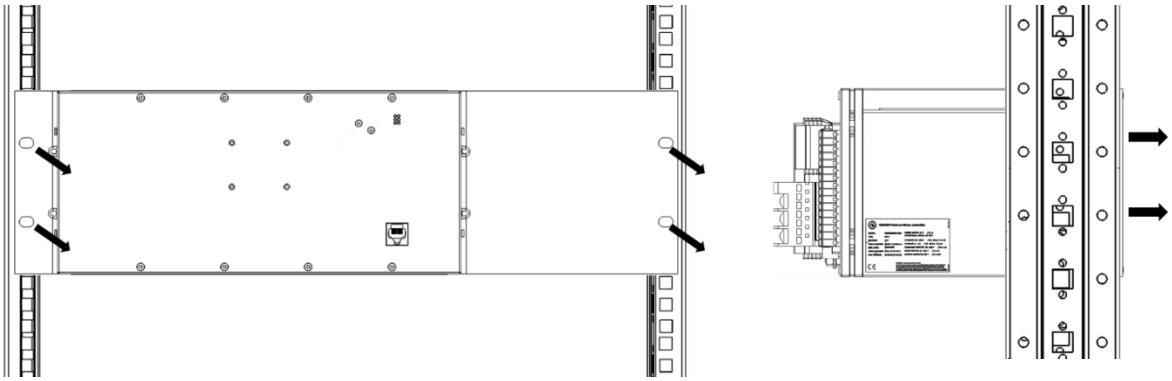


Figure 56 CSD100 rack mounting

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11.3 Cabling / connecting

11.3.1 Interface terminals, equipment and wires compliance



Conductors used for wiring shall meet the requirement of IEC 60228.



Terminals for connection to external circuits shall meet the requirement of IEC 60947-1.



Micro circuit-breaker used for the equipment protection shall meet the requirement of IEC 60947-2 and be installed an easily accessible location.



Recommended protections:

- MCB Power supply: 4A, K or B trip curve
- Command outputs circuits MCB 3P: 10A, Z trip curve
- Relays output contacts circuit MCB 3R: 8A, K trip curve



Whenever required for disconnecting the power supply and any external power sources, disconnecting device shall meet the requirement of IEC 60947-3 and be installed an easily accessible location.



Cabling shall be performed after installation of the equipment on its final location

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11.3.2 Protective earthing

The CSD100 is earthed/grounded by means of the M5 stud designed for this purpose (insert designated PE on Figure 57, connectors side) plus one of the two lateral side earthing holes (M5 bolt).

The recommended minimum protective earth conductor wire size is 6 mm² - AWG10.

Securely lock the bolt. Tightening torque: 4 N.m

Protective earth CSD100 equipment and external power supply must be connected at the same point.

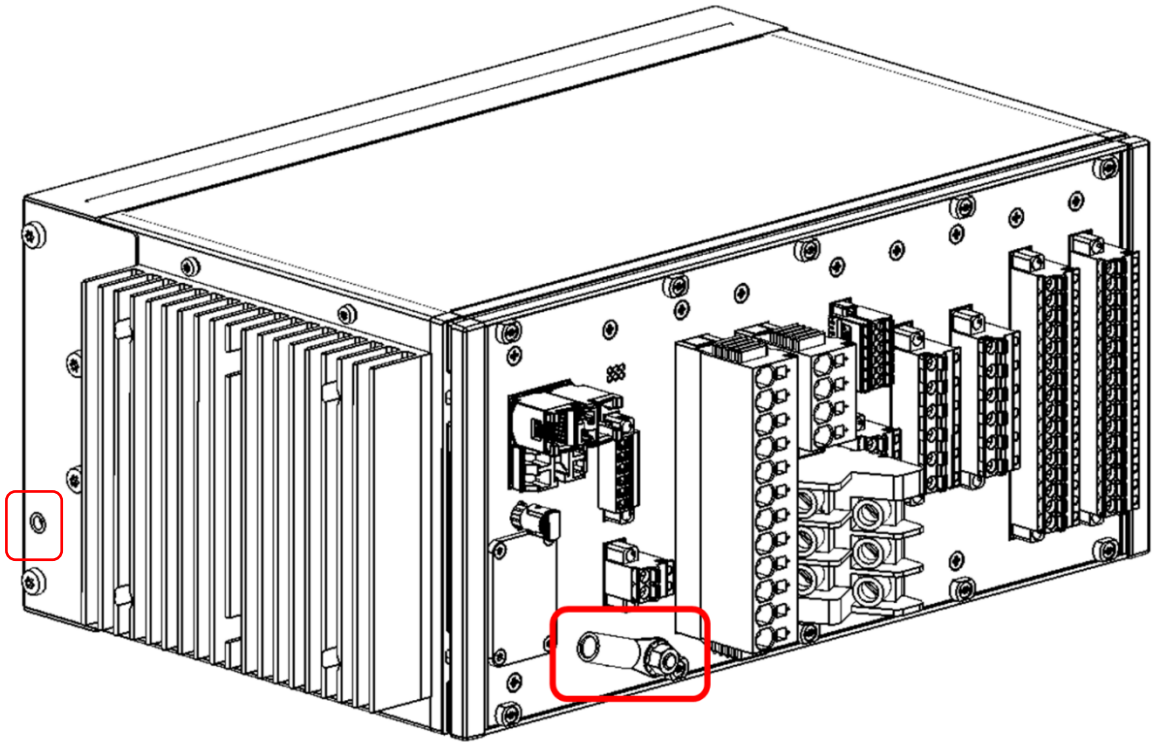


Figure 57 CSD100 protective earth stud

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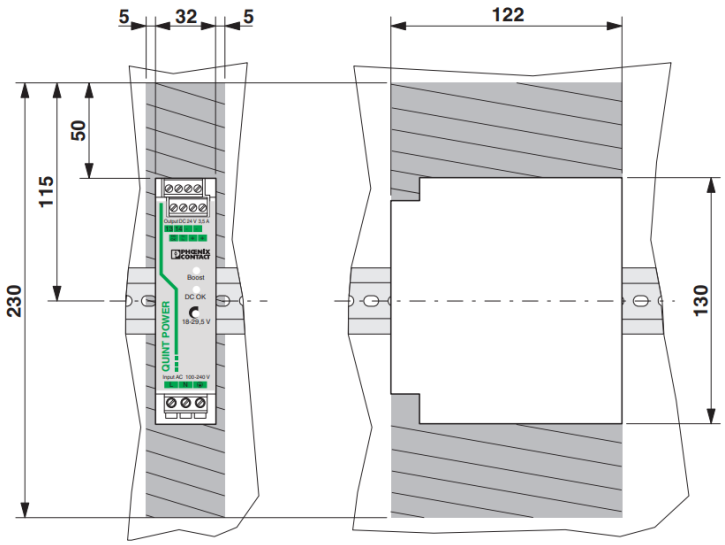
11.3.3 Power supply

CSD100 shall be supply by an external 24V power supply.

Recommended reference is QUINT-PS/1AC/24DC/ 3.5 – 2866747 from PHOENIX CONTACT

For further information, consult www.phoenixcontact.com

2



4

	[mm²]	[mm²]	AWG	L [mm]	[Nm]	[lb in]
Input AC	0,2-2,5	0,2-2,5	20-12	7	0,5-0,6	5-7
Output DC	0,2-2,5	0,2-2,5	20-12	7	0,5-0,6	5-7
Signals	0,2-2,5	0,2-2,5	20-12	7	0,5-0,6	5-7

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7 Mounting/removal

7.1 Normal mounting position

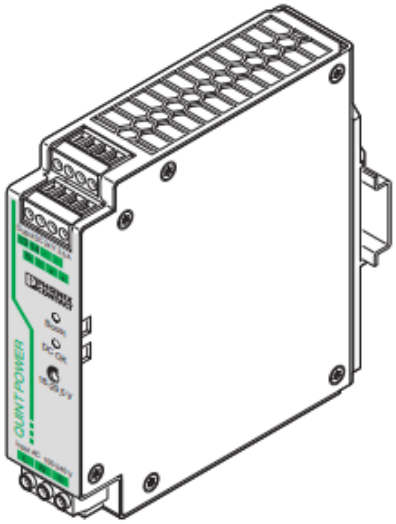


Figure 4 Normal mounting position

7.2 Mounting position rotated 90°

For a mounting position rotated at 90° to the DIN rail, mount the DIN rail adapter (UTA 107) as shown in the figure. No additional assembly material is required. Mounting screws: Torx® T10 (0.8 Nm ... 0.9 Nm tightening torque).

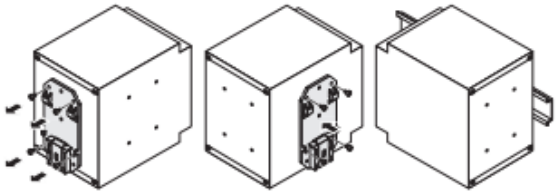


Figure 5 Mounting position rotated 90°

7.3 Mounting on a DIN rail

Position the module with the DIN rail guide on the upper edge of the DIN rail, and snap it in with a downward motion.

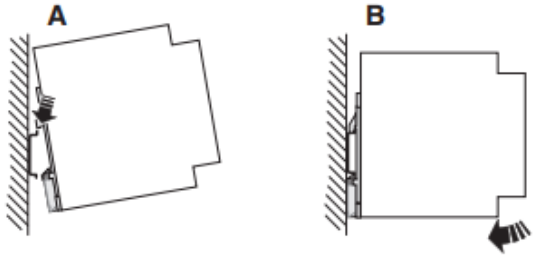


Figure 6 Assembly

7.4 Removal from the DIN rail

Pull the snap lever open with the aid of a screwdriver and slide the module out at the lower edge of the DIN rail.

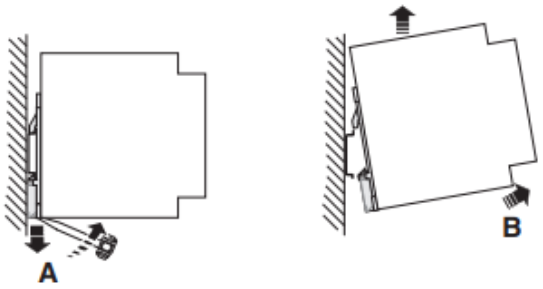


Figure 7 Removal

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11.3.4 Wiring



During operation, hazardous voltages are present in the terminals.



It is strictly prohibited to handle connectors under CSD100 operation.
Connectors must only be handled once the power supply and any external power sources have been switched off and disconnected.



To ensure that wires are correctly terminated the correct crimp terminal and tool for the wire size shall be used.



Use appropriate tools for connecting and removing the connectors.



Follow wiring recommendations provided in sections 11.3.4.1 and 11.3.4.2.

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11.3.4.1 Power supply wiring

Table 28 Power supply wiring recommendation

Terminal block	Wire type	Wire section	Termination	Stripping length	Torque
Input	Stranded conductor	1.5 – 2.5 mm^2 (AWG16 – AWG14)	Insulated crimp bootlace ferrule	7 mm	0.6 Nm
Output	Stranded conductor	1.5 – 2.5 mm^2 (AWG16 – AWG14)	Insulated crimp bootlace ferrule	7 mm	0.6 Nm

11.3.4.2 CSD100 wiring

Table 29 CSD100 wiring recommendation

Terminal block	Wire type	Wire section	Termination	Stripping length	Torque*
-X7	Stranded copper wire conductor	0.2 – 1.5 mm^2 (AWG24 – AWG16)	Uninsulated crimp bootlace ferrule	7 mm	0.25 Nm
-X8	Stranded copper wire conductor	1.5 – 2.5 mm^2 (AWG16 – AWG14)	Uninsulated crimp bootlace ferrule	10 mm	0.6 Nm
-X9	Stranded copper wire conductor	1.5 – 6 mm^2 (AWG16 – AWG10)	Uninsulated crimp bootlace ferrule	18 mm	0.6 Nm
-X10	Stranded copper wire conductor	1.5 – 6 mm^2 (AWG16 – AWG10)	Uninsulated crimp bootlace ferrule	18 mm	0.6 Nm
-X11	Stranded copper wire conductor	2.5 – 6 mm^2 (AWG14 – AWG10)	Insulated crimp ring	8 mm	1.3 Nm
-X12	Stranded copper wire conductor	0.2 – 1.5 mm^2 (AWG24 – AWG16)	Uninsulated crimp bootlace ferrule	7 mm	0.25 Nm
-X13	Stranded copper wire conductor	1.5 – 2.5 mm^2 (AWG16 – AWG14)	Uninsulated crimp bootlace ferrule	10 mm	0.6 Nm
-X14	Stranded copper wire conductor	2.5 mm^2 (AWG14)	Uninsulated crimp bootlace ferrule	10 mm	0.6 Nm
-X15	Stranded copper wire conductor	2.5 mm^2 (AWG14)	Uninsulated crimp bootlace ferrule	10 mm	0.6 Nm
-X16	Stranded copper wire conductor	1.5 – 2.5 mm^2 (AWG16 – AWG14)	Uninsulated crimp bootlace ferrule	10 mm	0.6 Nm
-X17	Stranded copper wire conductor	1.5 – 2.5 mm^2 (AWG16 – AWG14)	Uninsulated crimp bootlace ferrule	10 mm	0.6 Nm

* Screw type terminals option

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11.3.5 Interface cabling

The diagrams in this section are provided as a guideline to help the user identifying CSD100 terminals and do not details interfaces such as interlocks for instance. For contractual scheme, the user should refer to project specific low voltage drawing.

11.3.5.1 RS-485 serial link cabling

For RS-485 serial link cabling, it is recommended to use shielded twisted pairs cable.

M12 5 positions pre-connectorized cables are applicable.

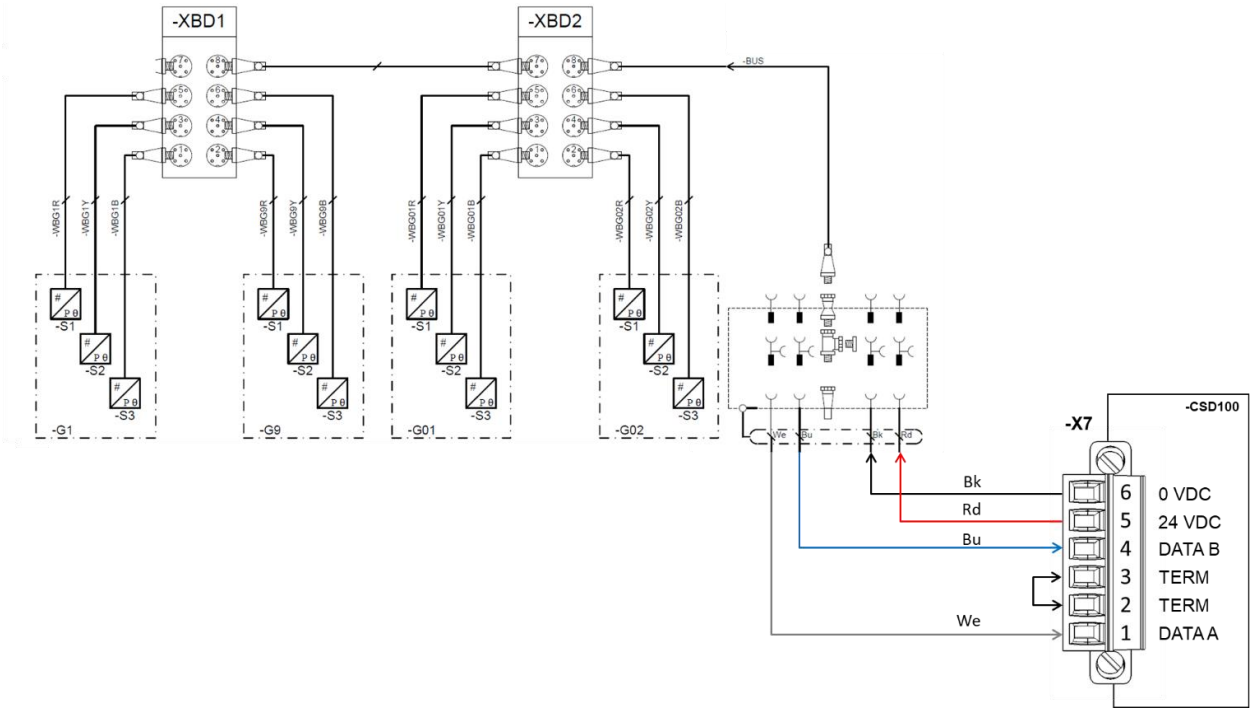


Figure 58 RS- serial link cabling

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11.3.5.2 Power supply input cabling

Power supply module and CSD100 protective earth conductors shall be connected to the same earthing point.

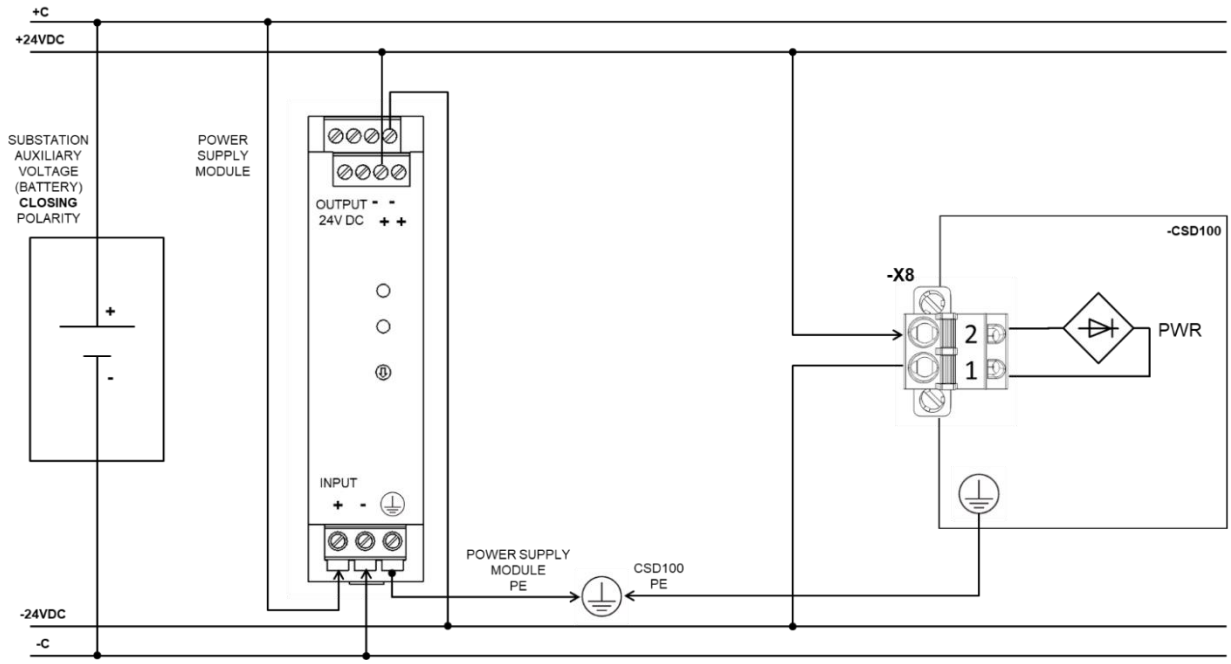


Figure 59 Power supply input cabling

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11.3.5.3 Voltage transformer inputs cabling

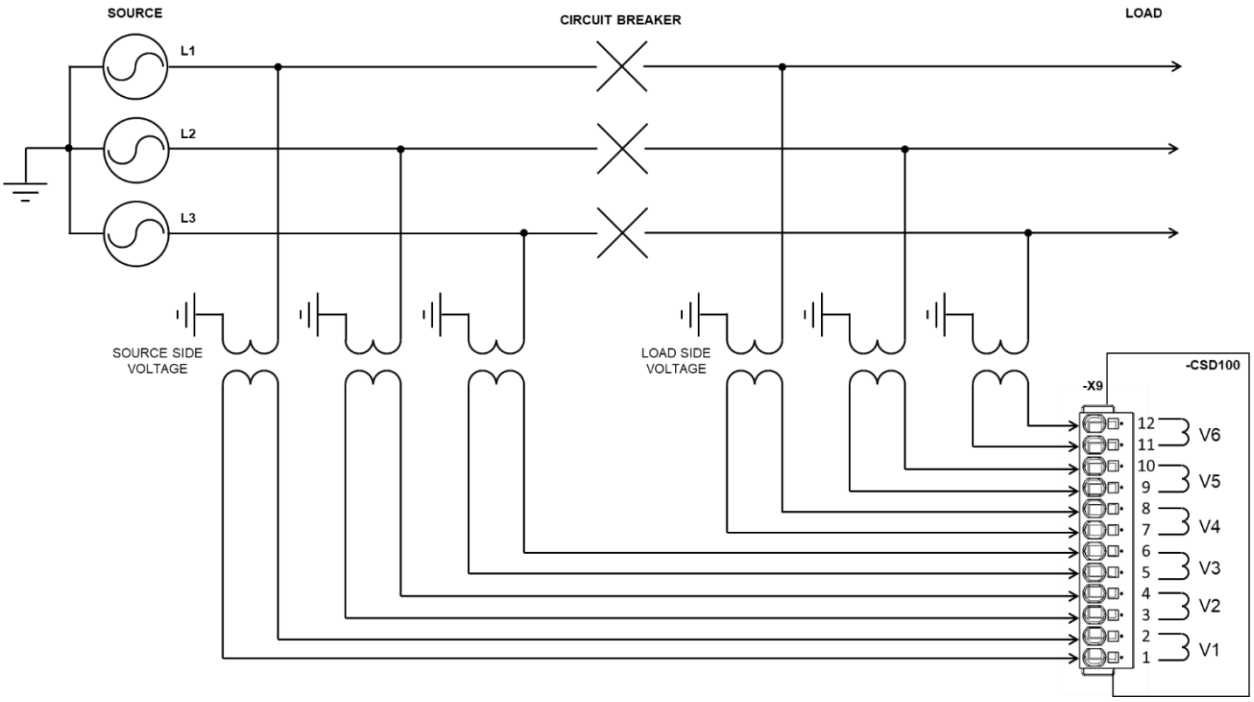


Figure 60 Voltage transformer inputs cabling

In case MCB is used to protect VT circuitry, type B is applicable since CSD100 internal burden is mainly resistive (no switching inrush).

Phase to earth VTs are usually connected. Connecting phase to phase VTs is possible, settings shall be adjusted to compensate for phase shift (source side, synchronizing reference).

Minimal configuration requires a least a single-phase reference VT to be connected (system L1 or L2 or L3, to be connected to respective V1 or V2 or V3 CSD100 input).

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11.3.5.4 Auxiliary voltage inputs cabling

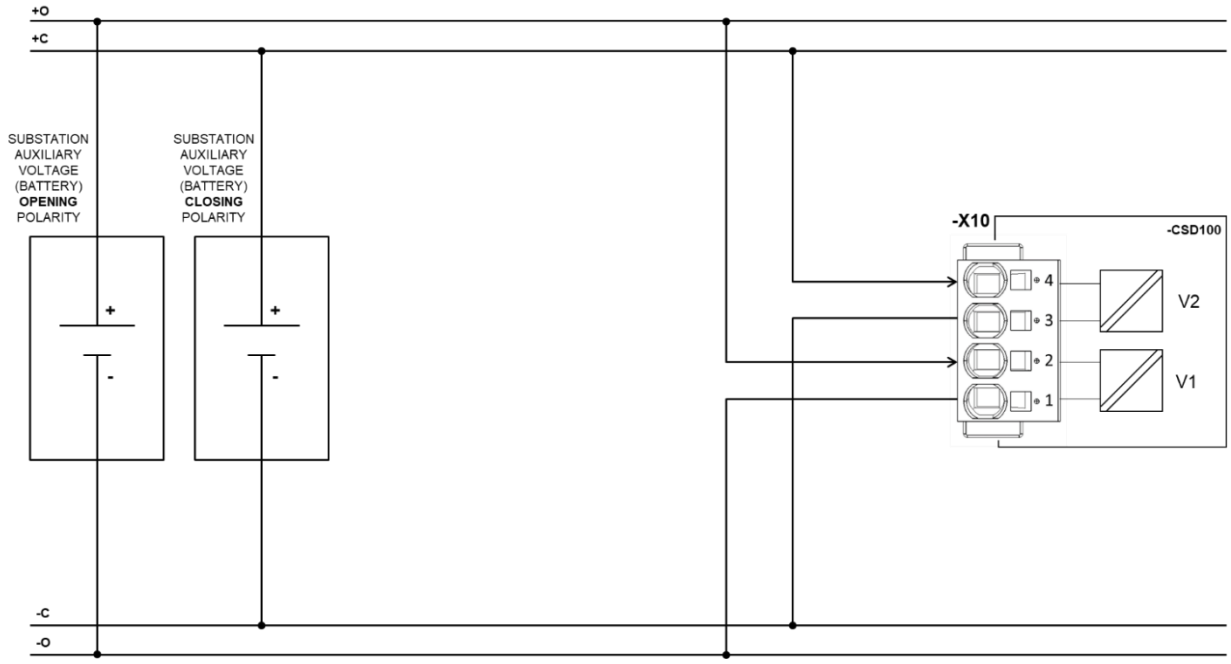


Figure 61 Auxiliary voltage inputs cabling

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11.3.5.5 Current transformer inputs cabling

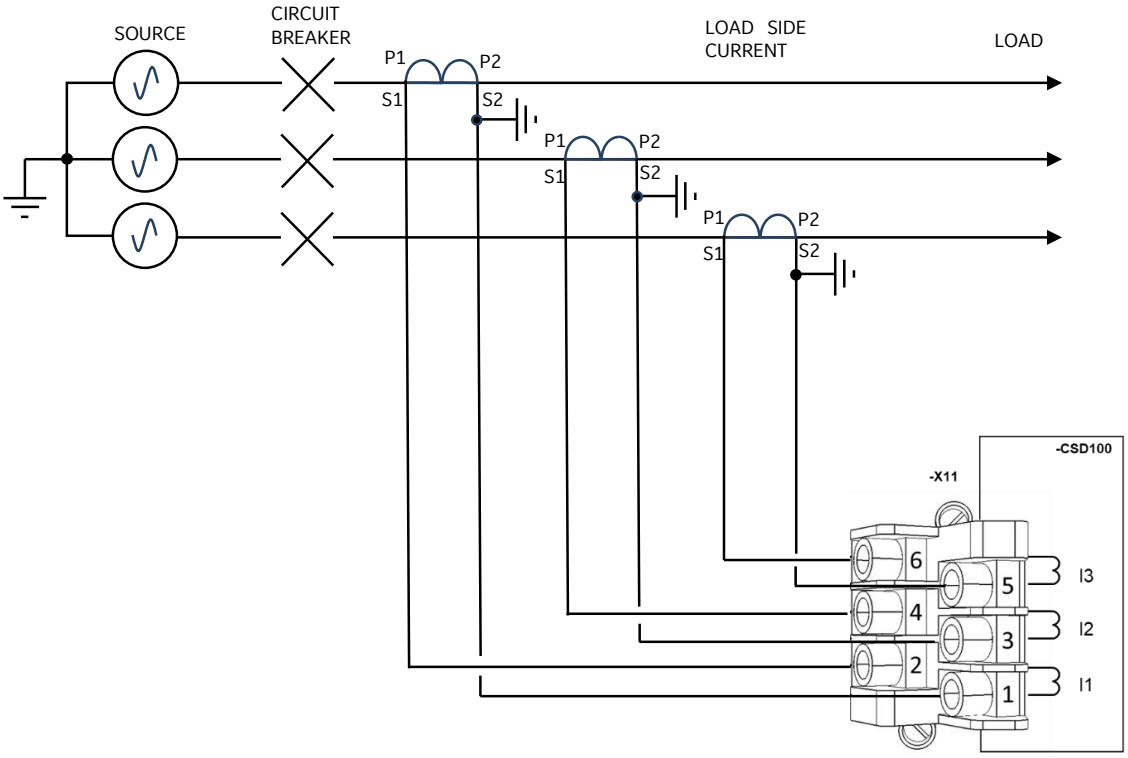


Figure 62 Current transformer inputs cabling

Generally, it is recommended to connect CSD100 to protection core current transformers instead of metering cores, when available. This would avoid possible saturation issues of metering cores. See 12.7.2, 12.8.2, 12.9.2.

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11.3.5.6 Analogue sensors input cabling

For connection of analogue transmitters, it is recommended to use shielded twisted pair cables.

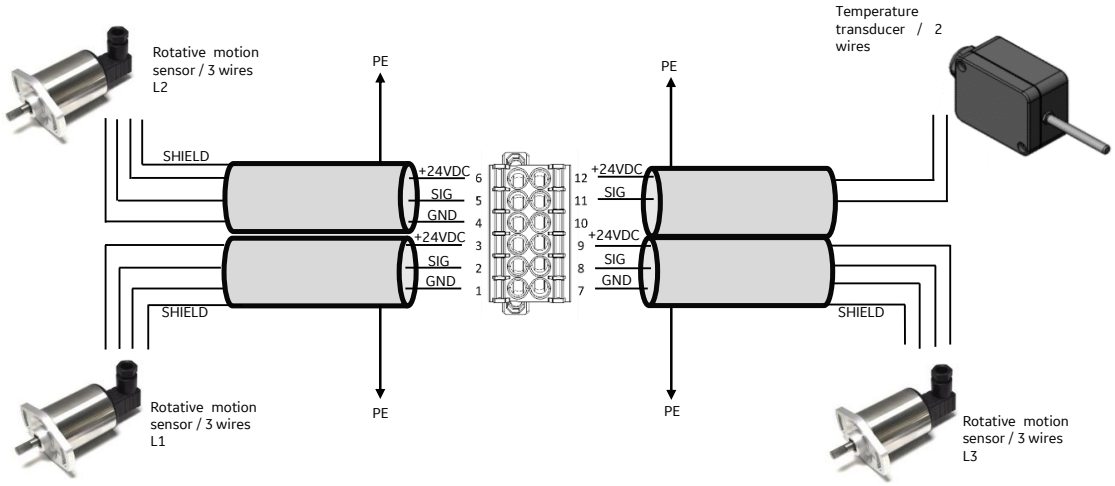


Figure 63 Low level analogue sensors cabling (4-20mA – 3 wires & 2wires)

Connection of cable shield:

- If sensor cable shield is connected to internal electronic reference, cable shield shall be connected to corresponding connector GND.
- If sensor cable shield is galvanically separated from internal electronic reference, cable shield shall be connected to PE, as illustrated in above figure.

For example, temperature sensors usually come with plastic enclosure, without case shield. In that case, the cable shield shall be connected to PE.

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Use case of light barrier

Light barrier installed in circuit breaker drive delivers accurate feedback of the arcing contact position.

It can be wired to analogue sensor input for measurement of circuit breaker operating times.

The use of a 1200 Ω resistor wired in series is then required to adapt input impedance.

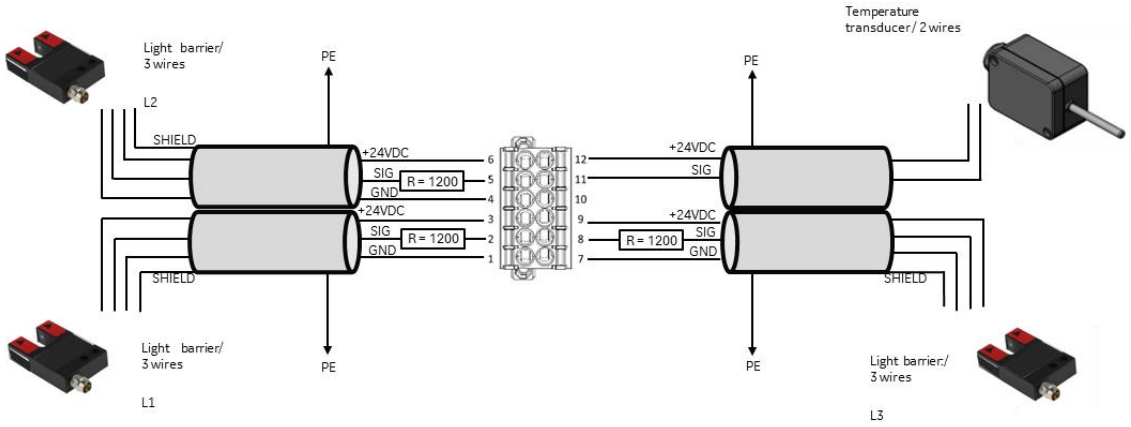


Figure 64 Low level analogue sensors cabling (light barrier)

Alternatively, light barrier can be connected to binary inputs, instead of 52a contacts.

In that case, it is necessary to use voltage shifting device, for instance solid state relays, to increase light barrier output voltage.

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11.3.5.7 Relays output contacts cabling

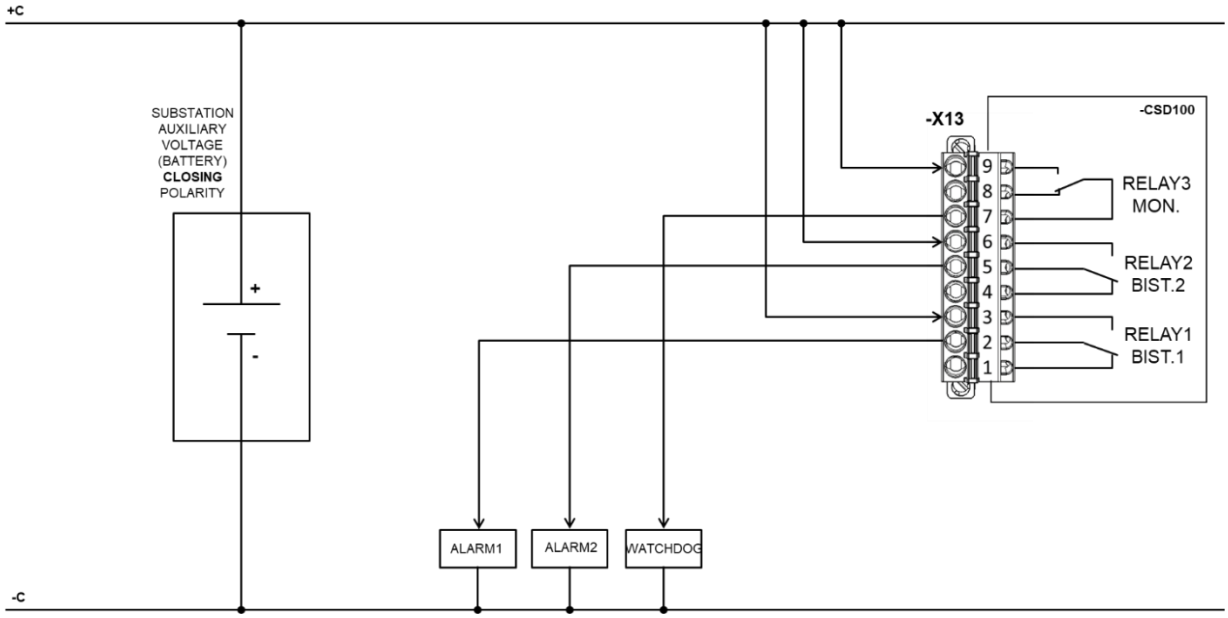


Figure 65 Relays output contacts cabling (monostable position "CSD100 not available for operation")

Watchdog ("in service") contacts X13-7 and X13-9 are connected when CSD100 is healthy and ready to operate (relay is driven in healthy situation).

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11.3.5.8 Command outputs cabling

11.3.5.8.1 IPO circuit breaker with single drive

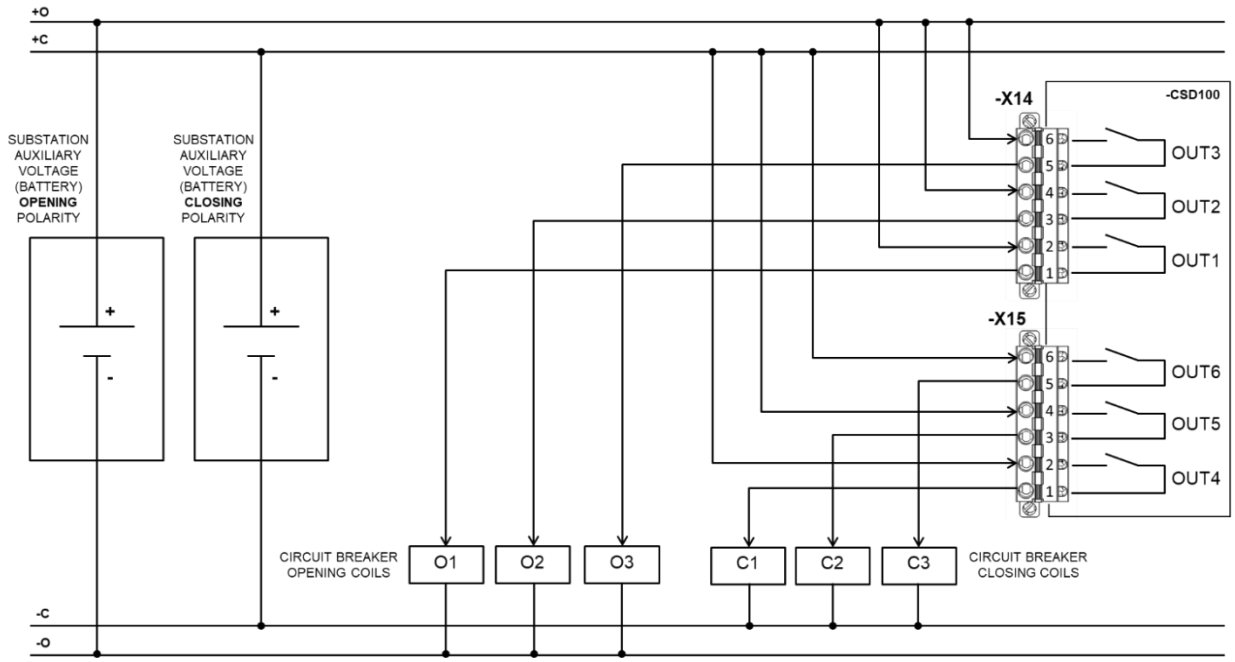


Figure 66 Command outputs cabling – IPO circuit breaker with single drive

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11.3.5.8.2 IPO circuit breaker with double drive – Closing circuit

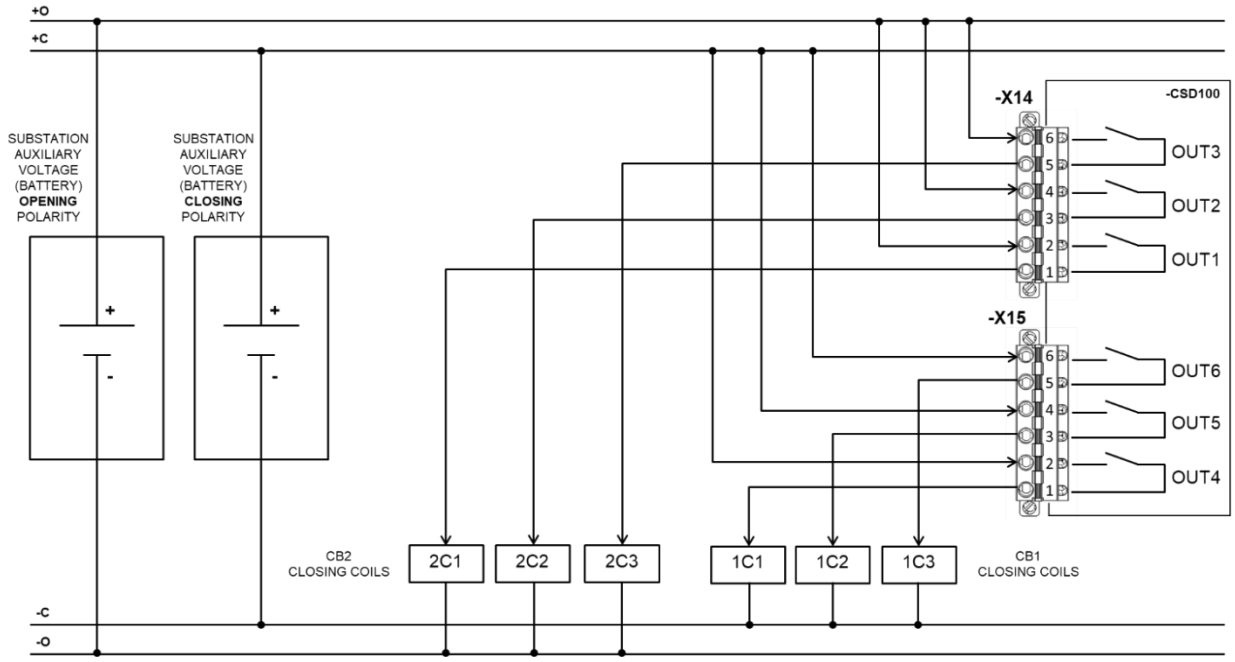


Figure 67 Command outputs cabling – IPO circuit breaker with double drive – Closing circuit

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11.3.5.8.3 IPO circuit breaker with double drive – Opening circuit

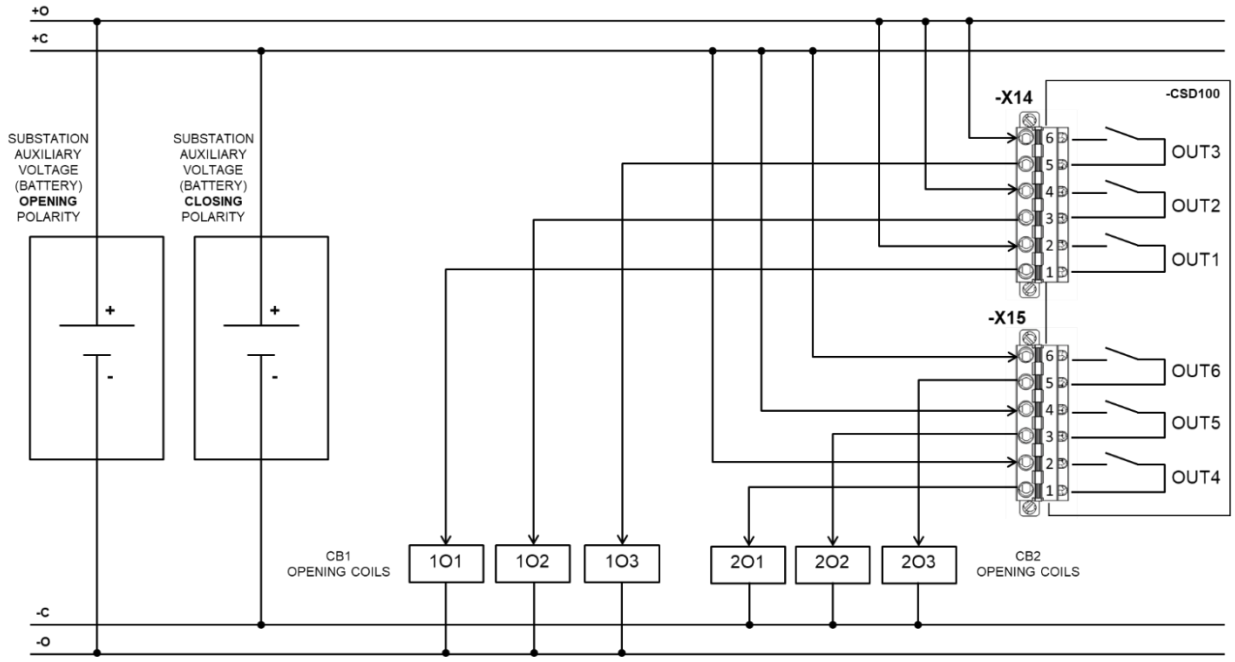


Figure 68 Command outputs cabling – IPO circuit breaker with double drive – Opening circuit

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11.3.5.9 Opto-isolated binary inputs cabling

11.3.5.9.1 Circuit breaker operation input orders

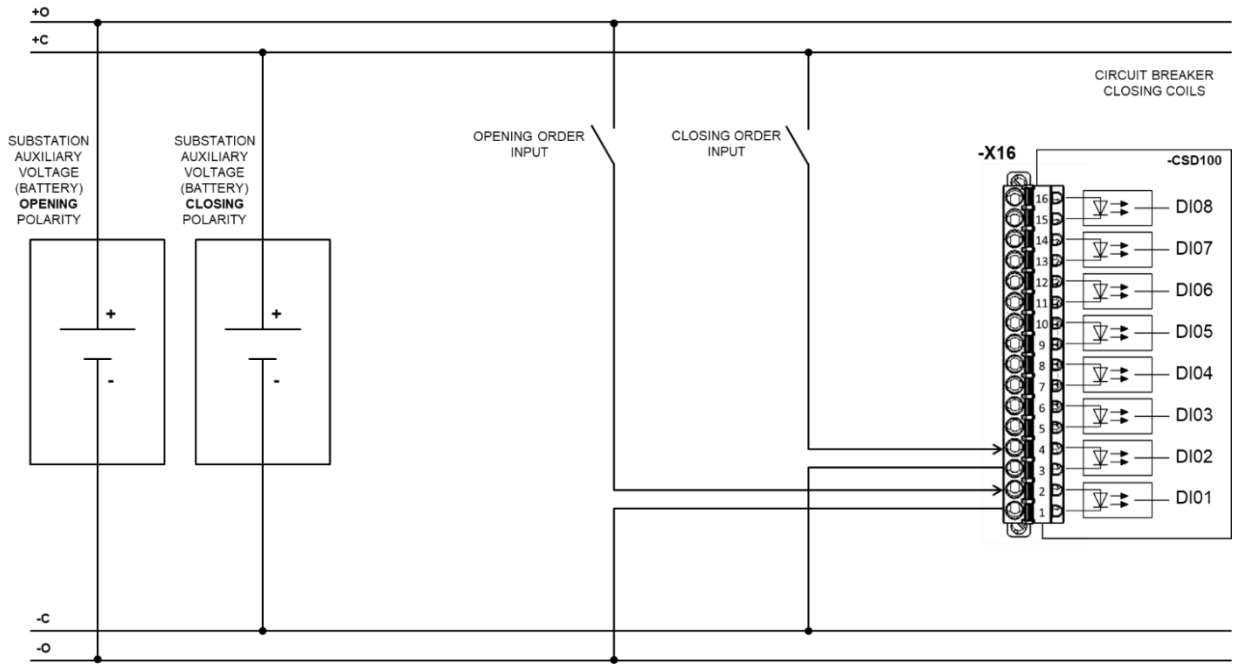


Figure 69 Opto-isolated binary inputs cabling – Circuit breaker operation input orders

Note: Usually, several interlocking contacts are to be inserted in the circuit, upstream (not represented).

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11.3.5.9.2 IPO circuit breaker with single drive signaling

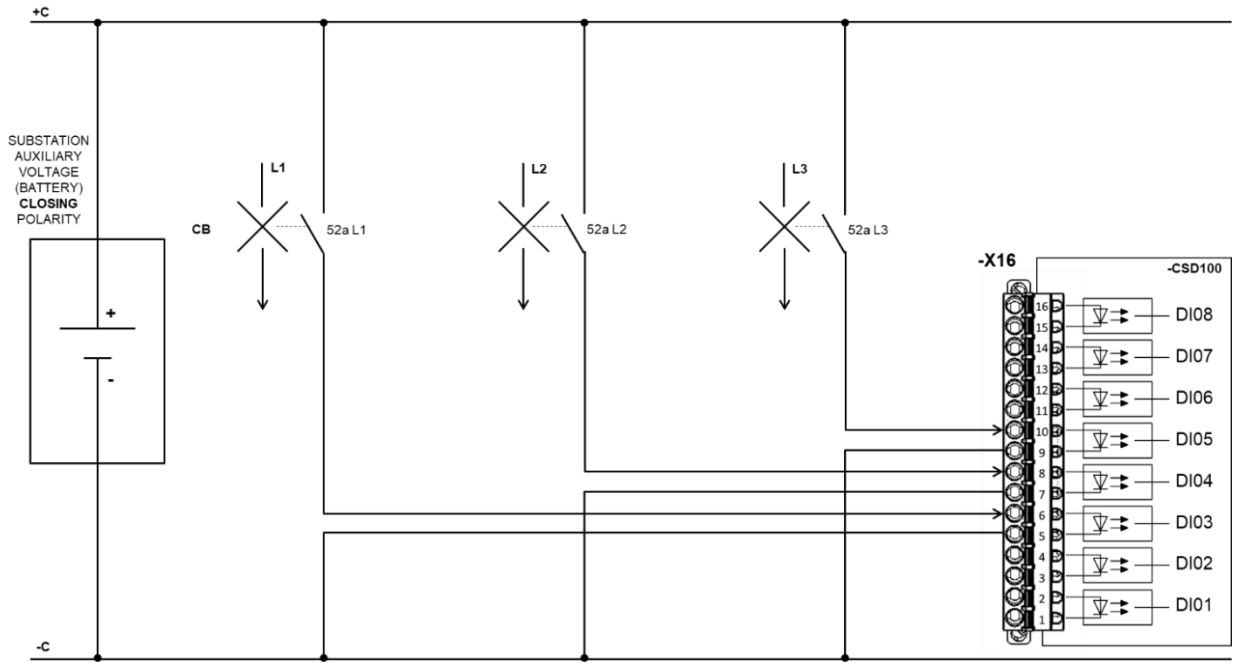


Figure 70 Opto-isolated binary inputs cabling – IPO circuit breaker with single drive signaling

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11.3.5.9.3 IPO circuit breaker with double drive signaling

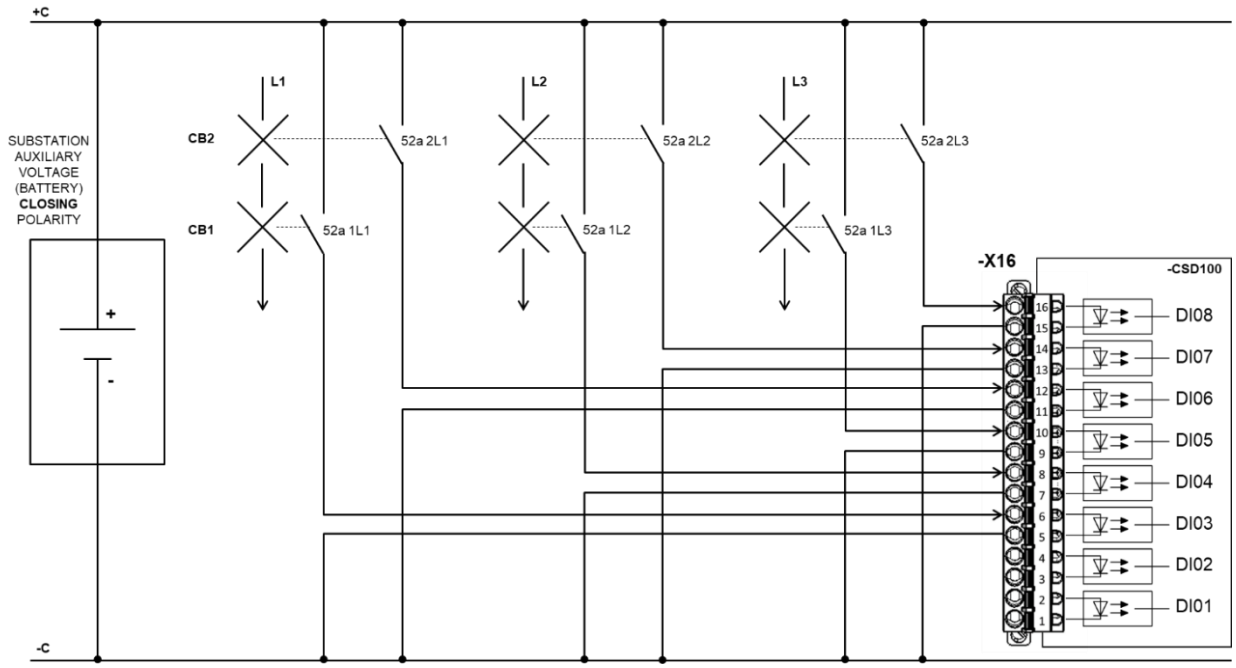


Figure 71 Opto-isolated binary inputs cabling – IPO circuit breaker with double drive signaling

CB1 = first half pole

CB2 = second half pole

52a1Lx = first half pole signaling

52a2Lx = second half pole signaling

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11.3.5.9.4 Operational inputs

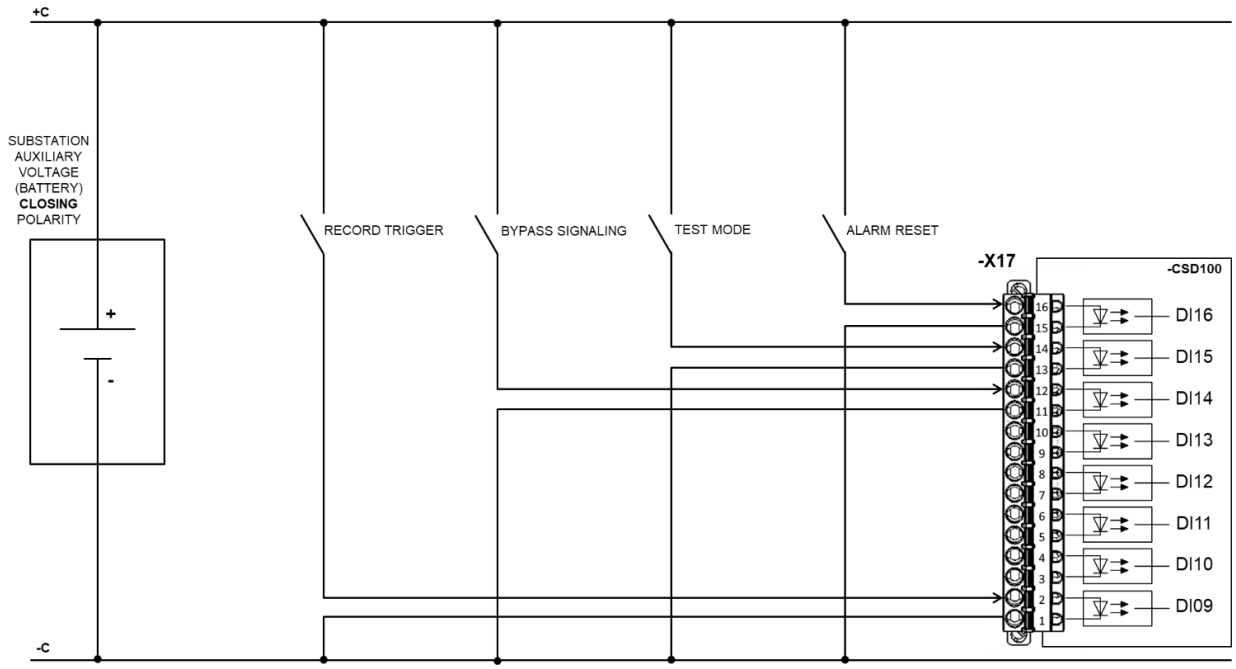


Figure 72 Opto-isolated binary inputs cabling – Operational inputs

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11.3.5.9.5 Multiple load switching mode inputs

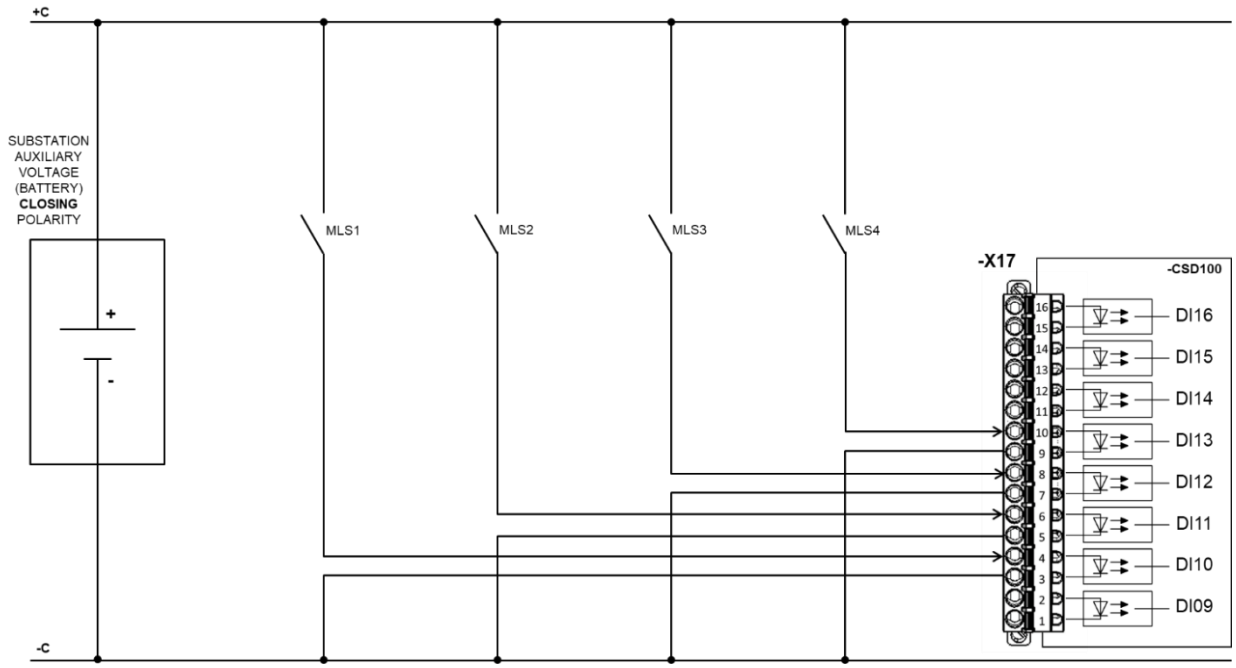


Figure 73 Opto-isolated binary inputs cabling – Multiple load switching mode inputs

MLS = multiple load switching

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12 SWITCHING APPLICATIONS: THEORY, USE CASES, CSD100 FUNCTIONS

12.1 Synchronizing system introduction

In this document, the system sequence (L1, L2, L3) is adopted. It assumes a physical and fixed identification and correspondence with phases and circuit breaker, in the substation.

- L1 open and close commands (coils) must be connected to -X14 and -X15, 1 and 2 positions (OUT1 and OUT4), at the bottom of the connector.
- L2 open and close commands (coils) must be connected to -X14 and -X15, 3 and 4 positions (OUT2 and OUT5), at the middle of the connector.
- L3 open and close commands (coils) must be connected to -X14 and -X15, 5 and 6 positions (OUT3 and OUT6), at the top of the connector.
- If available, L1 source and load voltages must be connected to UAC1 and UAC4 (-X9)
- If available, L2 source and load voltages must be connected to UAC2 and UAC5 (-X9)
- If available, L3 source and load voltages must be connected to UAC3 and UAC6 (-X9)
- If available, L1 current must be connected to IAC1 (-X11 bottom)
- If available, L2 current must be connected to IAC2 (-X11 middle)
- If available, L3 current must be connected to IAC3 (-X11 top)

Reference phase for synchronization can be either L1, L2 or L3. It shall be properly adjusted in the CSD100 parameter set.

Each angle of a usual switching target sequence “α1 / α2 / α3” (for example 90°/30°/150°) is referred to a unique reference synchronization waveform, and α1 corresponds to the reference. Thus, if L2 is connected and used as a reference, α1 target will be applied to L2 physical output, α2 target will be applied to L3 physical output and α3 target will be applied to L1 output. Automatic sequence circular permutation is applied.

The switching sequence rotation, relative to the selected reference phase, is depicted in Table 30.

Table 30 Switching sequence correspondence relative to reference phase

Reference phase	L1 switching angle	L2 switching angle	L3 switching angle
L1	α_1	α_2	α_3
L2	α_3	α_1	α_2
L3	α_2	α_3	α_1

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The reference instant for the switching times / targets is a **zero crossing on the rising slope** of the reference voltage or current. Synchronizing reference is defined as **0 deg**. Each switching angles / targets (expressed in angular degrees) are related to this synchronizing reference.

Switching targets refer to electrical phenomena, i.e. making time (pre-arcing) for closing operations and current interruption for opening operations.

Notes:

- Typical controlled switching operations require a unique phase of the synchronizing system set as a fixed reference;
- Circular permutation is automatically performed by the controller, selecting the correct reference phase through the CSD100 control interface, and there's no need to change the switching targets settings whenever another phase than L1 is set as the reference;
- CSD100 has the capability to select the reference phase automatically when the three phases of the synchronizing system are wired to the controller voltage inputs. The delay introduced by the controller is thus reduced, based on the instant when the incoming order is received by the controller, compared to zero crossings of the synchronizing system.
- Waveforms / switching traces plotted in this section adopt the following chart:
    - L1 : red color
    - L2 : green color
    - L3 : blue color
    - L1-L2 : orange color
    - L2-L3 : cyan color
    - L3-L1 : violet color

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12.1.1 Voltage synchronizing system

For controlled closing operations and controlled opening operations where the current phase shift compared to the system voltage is known and fixed, e.g. case of pure inductive or pure capacitive loads, the synchronizing system (L1, L2, L3) is based on the following phase sequence of the network voltages:

- L1 = reference: $v_A(t) = V_p \times sin(\omega t)$
- L2 = reference – 120 deg: $v_B(t) = V_p \times sin(\omega t - 2\pi/3)$
- L3 = reference – 240 deg: $v_C(t) = V_p \times sin(\omega t + 2\pi/3)$

where

- $V_p = \sqrt{2/3} \times U_r$ is the system PH-E peak voltage and the 1 p.u. value for voltage reference
- U_r is the system PH-PH rated voltage

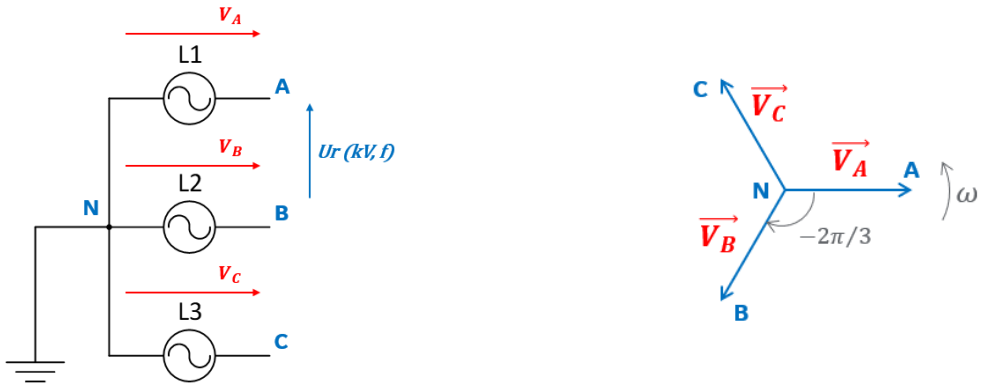


Figure 74 Three-phase voltage system

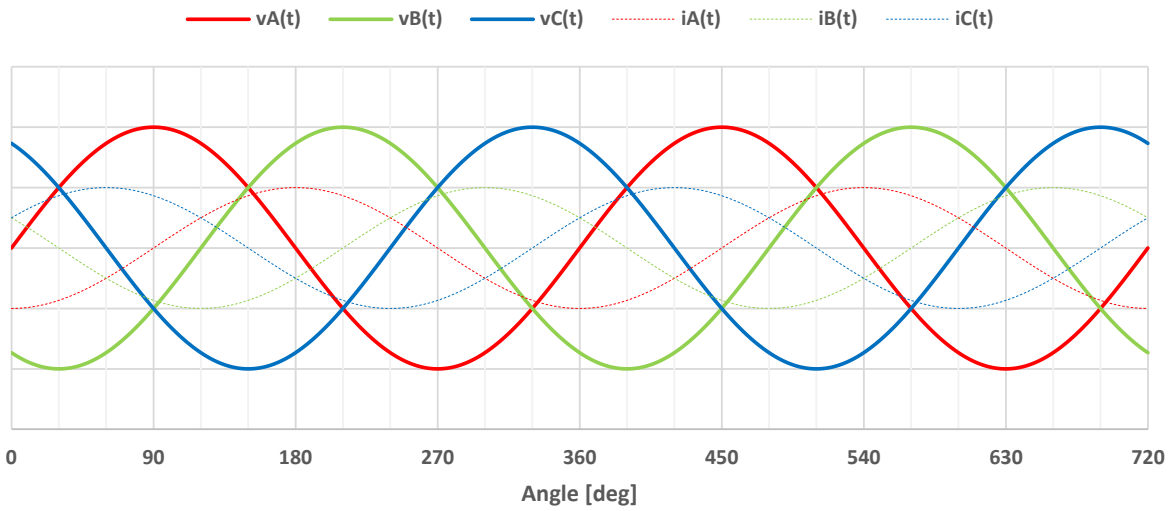


Figure 75 Voltage synchronizing system waveforms

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12.1.2 Current synchronizing system

- For synchronized opening operations related to load current, e.g. where the load current phase-shift compared to the system voltage is not equal to 90 deg or may vary during installation lifetime, the phase reference (L1, L2, L3) is based on the following phase sequence of the network:
- L1 = reference: $i_A(t) = I_p \times \sin(\omega t)$
- L2 = reference – 120 deg: $i_B(t) = I_p \times \sin(\omega t - 2\pi/3)$
- L3 = reference – 240 deg: $i_C(t) = I_p \times \sin(\omega t + 2\pi/3)$

where

- $I_p = \sqrt{2} \times I_r$ is the load peak current and the 1 p.u. value for current reference
- I_r is the load rated current

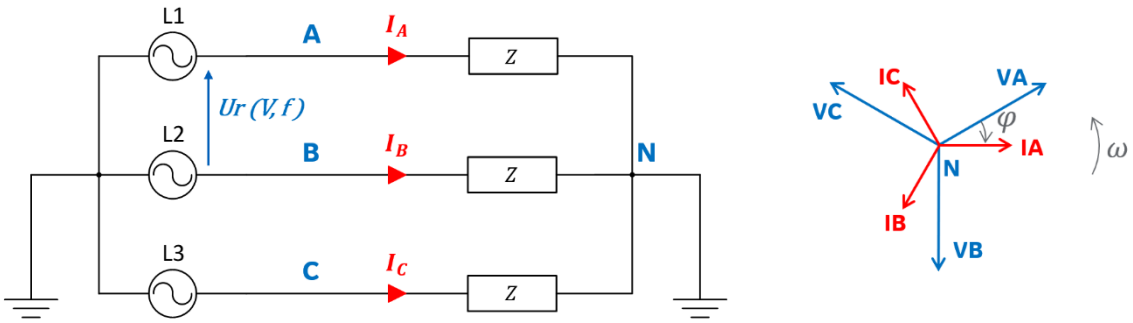


Figure 76 Three-phase current system

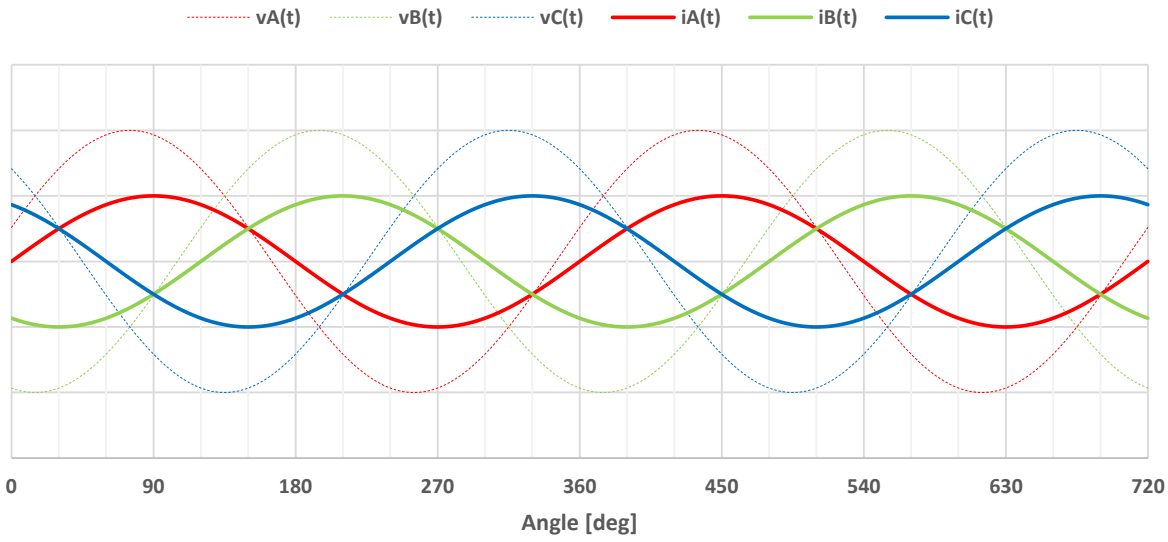


Figure 77 Current synchronizing system traces (example of an inductive load)

Note: load current requires a minimum amplitude to be considered as a consistent synchronizing waveform. A minimum value of 100mA (secondary) is necessary.

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12.1.3 Angle / time correspondence

Table 31 Angle / time correspondence table

Angle	**[deg]**	0	30	60	90	120	150	180	210	240	270	300	330	360
	[rad]	0	$\pi/6$	$\pi/3$	$\pi/2$	$2\pi/3$	$5\pi/6$	π	$7\pi/6$	$4\pi/3$	$3\pi/2$	$5\pi/3$	$11\pi/6$	2π
Time [ms]	**50 Hz**	0	1.67	3.33	5	6.67	8.33	10	11.67	13.33	15	16.67	18.33	20
	60 Hz	0	1.39	2.78	4.17	5.56	6.94	8.33	9.72	11.11	12.5	13.89	15.28	16.67

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12.2 Switching concerns

12.2.1 From random switching to controlled switching

Uncontrolled or random HVAC circuit-breakers operations on high-voltage networks generates electrical transients during switching such as overvoltage, voltage sag, inrush current and harmonics.

These switching transients stress electrical networks equipment and degrade power quality.

Traditional ways to reduce the impact of stresses caused by switching transients have been concentrated on the:

- Use of closing resistors on circuit breakers;
- Use of pre-insertion reactors on some other forms of circuit interrupters;
- Installation of fixed reactors;
- Application of surge arresters on the network.

All these practices result in a calculated damping effect on switching transients; however, the switching remains random with respect to the point on the synchronizing signal waveform and do not address the root cause of the switching transients.

An alternative way to deal with the switching transient phenomena is to act efficiently on root-cause of switching transients. Eliminate random switching and replace such practice by one referred to as, “controlled switching” strategy, or ‘’Point-on-Wave’’ switching.

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Controlled switching consists of issuing switching commands to the circuit breaker at the optimal point on the reference synchronizing signal waveform. Such controlled switching can be done by CSD100. Through its electronics and software, the CSD100 controller effectively sends a switching command to the circuit-breaker poles to operate at the correct instant and thus eliminate or substantially reduce switching transients.

Success of controlled switching operations is conditional on the ability of the CSD100 controller to assess beforehand, the source-side reference voltage (for simple opening and closing operations) or the circuit-breaker current (opening synchronized on current) or the voltage across the circuit breaker open poles (for autoreclose operations) as well as the characteristics and the consistency of the circuit breaker operation under all operating and ambient conditions. The time between the operating signal to the circuit-breaker and operation of the circuit-breaker varies dependent on at least the following:

- Ambient temperature of the circuit breaker;
- Interval since the circuit breaker was last operated;
- Actual control voltage;
- Stored energy level.

An optimal interaction between the CSD100 and the circuit-breaker provides expected results for controlled switching applications.

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12.2.2 Understanding the concern

There are two basic conditions where control of the circuit-breaker is desirable: controlled closing and controlled opening.

12.2.2.1 Closing operations concerns

During controlled closing conditions, eliminating inrush currents and transient overvoltages is desirable:

- The voltage on the circuit elements to be energized is zero. It is desirable to close the circuit when the system voltage is for instance at zero on the voltage waveform (capacitive loads).
- The voltage on the circuit elements to be energized is not at zero. For example, the voltage may be a trapped charge on a transmission line or capacitor bank. In this case it is desirable to close the circuit breaker when the system voltage and the voltage on the element to be energized are at the same voltage.
- In all cases the voltage conditions on each phase must be considered, recognizing that they are approximately 120 electrical degrees apart rotationally.

As a general approach, it is noted that:

- Transmission lines and capacitive loads shall be switched on at voltage continuity condition;
- Inductive loads shall be switched on at current continuity condition;
- Power transformers shall be switched on at magnetic flux continuity condition.

It should also be noted that the optimized switching occurs when the circuit is established across the contacts as they close (pre-arcing) rather than when the circuit-breaker arcing contacts touch, mechanically, when closing, i.e. the circuit is made somewhat before the contacts touch.

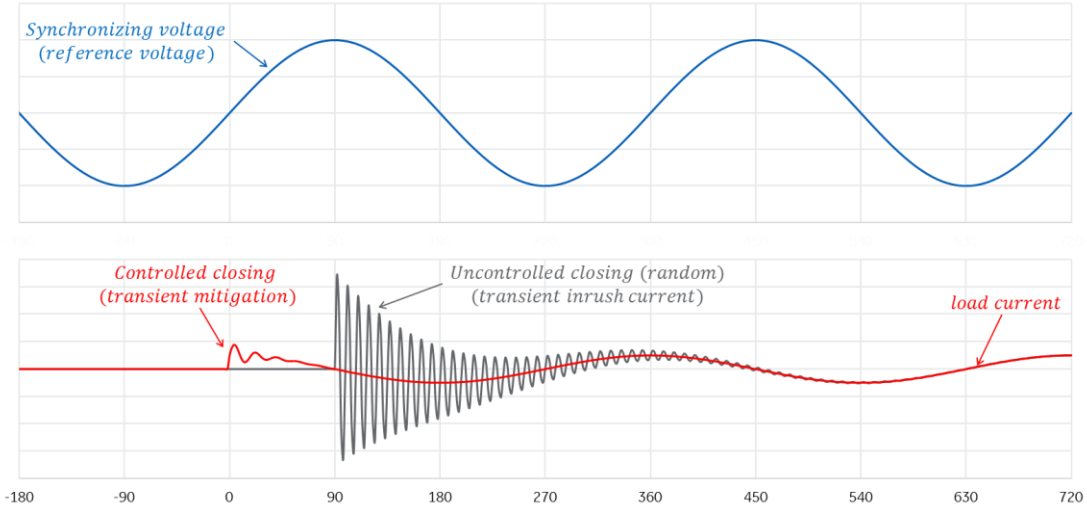


Figure 78 Closing transient mitigation – Example of a capacitive load energizing

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12.2.2.2 Opening operations concerns

During controlled opening conditions (nominal current), the control of arcing time is desirable.

When circuit-breaker contacts separate, an electrical arc is initiated and, in optimal condition, naturally extinguishes at a current zero crossing, forced by the network.

The arcing time varies according to contact separation instant.

HVAC circuit-breakers have an arcing time range where current breaking is guaranteed without harmful transient. Out of this range:

- Long arcing time can lead to current chopping phenomena accompanied with transient overvoltages generated by the large di/dt and with reinforced voltage shift across the circuit breaker (extending arcing time leads to current chopping and consequent overvoltage increase);
- Small arcing time can lead to dielectric re-ignition or restrikes between circuit-breaker contacts since separation gap is insufficient to withstand the recovery voltage.

These conditions may lead to current reignition across the open poles of the circuit breaker, as described in Figure 79.

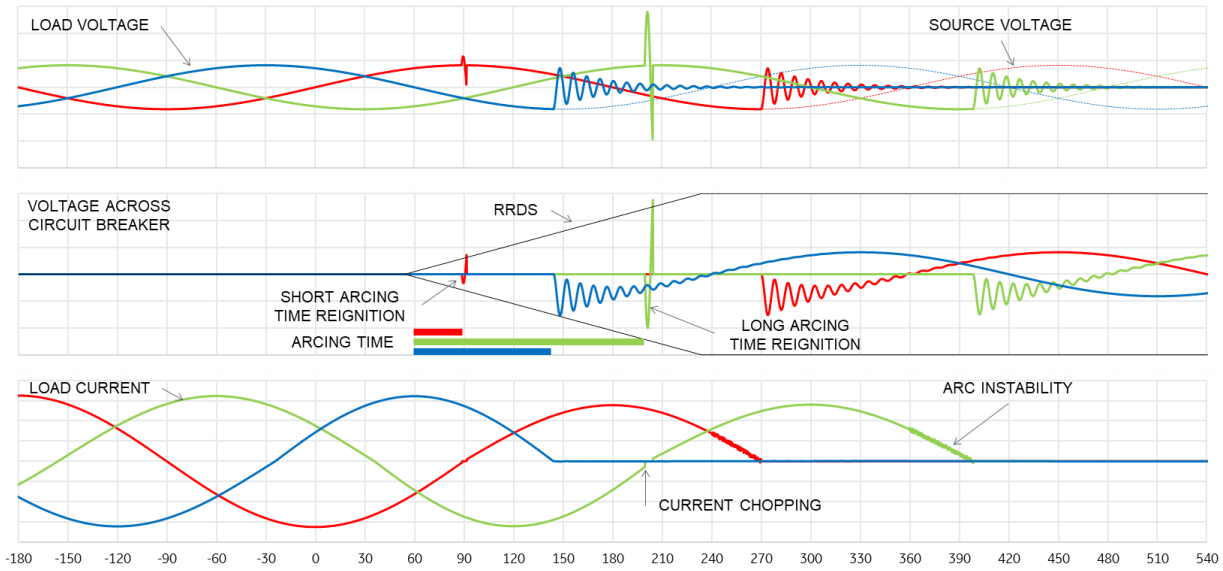


Figure 79 Reignition mechanism

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12.2.2.3 Short summary of load switching concerns

12.2.2.3.1 Shunt Reactor Issue

Small inductive current breaking may lead to the two following situations:

- Too short arcing time doesn't allow withstanding the transient recovery voltage and provokes re-ignition between open poles arcing contact, distance between contacts being insufficient;
- Long arcing time that increases current chopping overvoltage.

12.2.2.3.2 Power transformers under no-load conditions issue

Uncontrolled energizing of no-load power transformer can generate the following conditions:

- High inrush currents, in the range of several times the rated current, that mechanically stress the transformer windings through resulting strong electro-magnetic forces. These inrush currents slowly decay to reach the steady-state magnetizing level after several seconds;
- System r.m.s. voltage sags;
- Temporary harmonic voltages that lead to protection relays undesired operation and tripping operations.

12.2.2.3.3 Capacitor Bank Issue

Uncontrolled energizing of capacitor banks can generate the following conditions:

- High frequency inrush current and voltage depression, depending on capacitor bank size, source impedance and transmission system size.
- Back-to-back energizing as a worst case (proximity of a firstly energized capacitor bank).

12.2.2.3.4 Transmission lines issue

Uncontrolled energizing (or autoreclose) of an unloaded transmission line generates a travelling wave which, when reflected from the open end of the line, provokes over-voltage conditions along the length of the line with a maximum amplitude value at the open-end extremity.

Thus, consequences such as accelerated ageing of the HV equipment (line surge arresters), insulator string flashover can be observed.

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12.2.3 Controlled switching objective summary

Table 32 Controlled switching objective

	Shunt Capacitor Banks	Shunt Reactors	Power Transformer	Transmission Lines
Objective	Limit inrush currents Limit overvoltages	Limit overvoltages Prevent re-ignition	Limit inrush current	Limit overvoltages Or Prevent from current zero missing
Principle	Switching-out for CB medium arcing time Switching-in at zero-voltage across the terminals of CB	Switching-out for CB medium arcing time Switching-in at max-voltage across the terminals of CB	Switching out for minimal residual flux Switching-in at minimal flux difference	Switching-in at zero-voltage across the terminals of CB Or Switching in at voltage peak

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12.3 Controlled switching fundamentals

12.3.1 Switching angles / targets

For most applications of controlled switching, the optimum switching sequence is fixed by network design parameters, the load, and circuit breaker parameters. Therefore, the CSD100 Controller must be programmed with those pre-set corresponding values (refer to section 12.7 to 12.10).

Once programmed with these parameters, the CSD100 Controller proceeds by adding the fixed delay (T_{delay}) between the incoming order from System Control, and the order sent by the CSD100 Controller to the circuit breaker for it to reach the desired point on the network reference voltage waveform. This delay is instantaneously calculated beforehand by the CSD100 Controller.

The optimum switching instant are:

- For opening operations: the actual breaking / interruption of the current through the circuit-breaker contacts. Interruption of current is not instantaneous at circuit-breaker arcing contacts separation; the arcing phenomena must be considered. Arcing time is set depending on the application use of the controller (refer to section 12.5.10).
- For closing operations: the actual making of the current through the circuit-breaker contacts. Because of dielectric characteristics of circuit breakers, pre-arcing occurs before arcing contacts close (mechanically). Pre-arcing time is calculated, depending on network voltages, load type, circuit-breaker design, etc., and programmed into the controller (refer to section 12.5.8).

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12.3.2 Simple operations / duties

12.3.2.1 Controlled switching chart

Controlled switching consists in delaying an operating order, coming randomly from a control device, into a synchronized order to achieve the desired controlled operation, that reduce switching transients effects, as described in Figure 80.

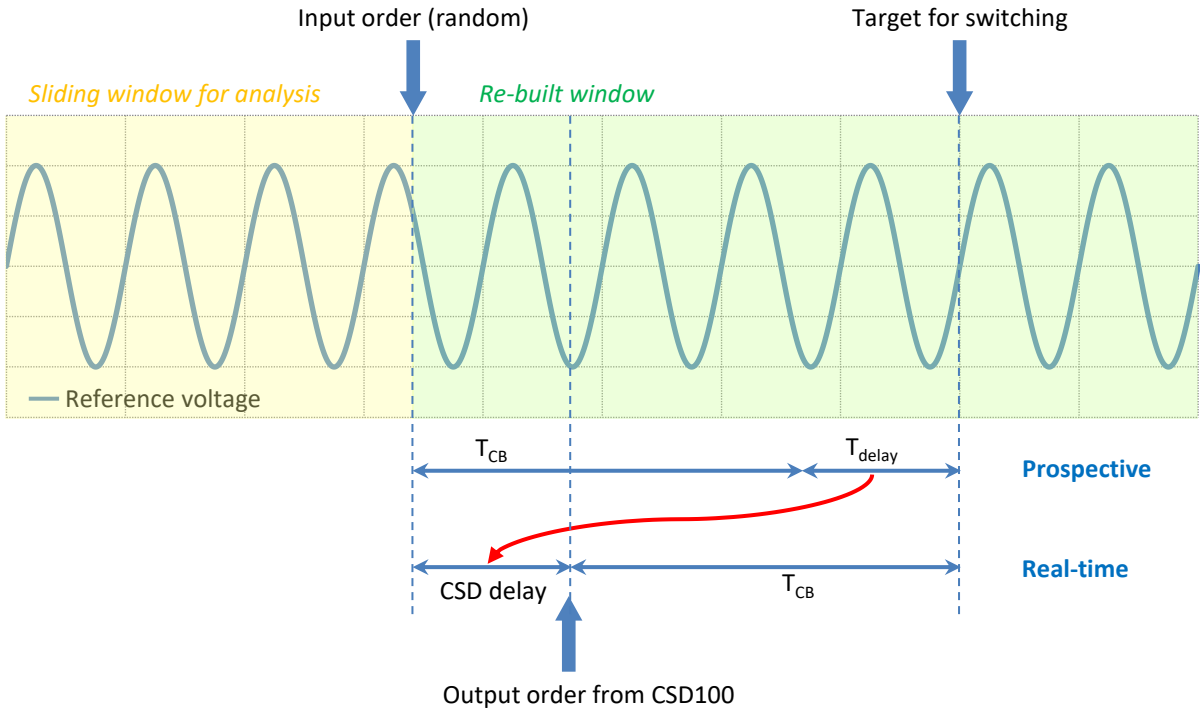


Figure 80 Controlled switching principle chart (1 phase diagram)

After having received a random operating input order from control device, the CSD selects the optimum target time and the desired instant for issuing the circuit breaker operating signal. The CSD does so by monitoring the relevant synchronizing signal (voltage or current) and by forecasting the next zero-voltage / current crossing for synchronization. The targeted instant for circuit-breaker is thus determined.

At the same time, the CSD uses its stored data on the circuit breaker's operating time characteristics and acquired ambient parameters to compute next operating time, and modifies the input order (which would have resulted in a random operation onto the synchronizing signal) into a synchronized operating output order that ensures the circuit breaker's main contacts switching at the pre-determined target.

To summarize, the CSD controller accurately determines the offset (time delay) T_{delay} and uses it to issue an output command to the circuit breaker for it to operate at the exact projected and targeted instant.

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12.3.2.2 Controlled switching sequencing

Controlled switching sequencing is summarized in the following diagram (Figure 81):

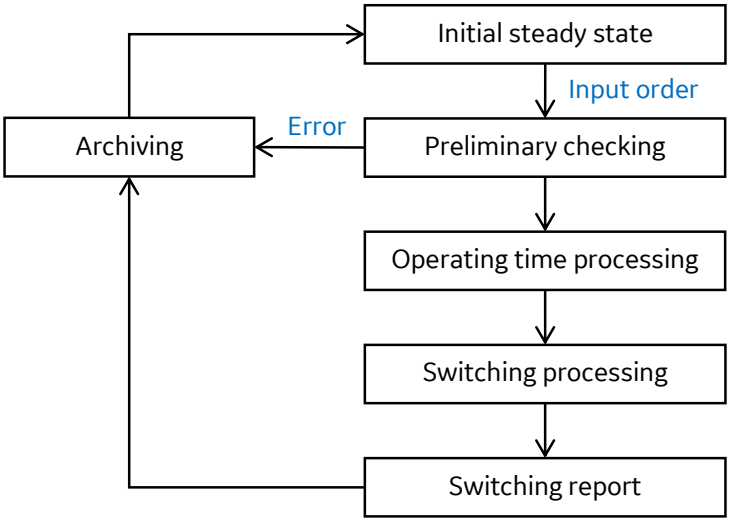


Figure 81 Controlled switching sequencing diagram

Table 33 Controlled switching steps

State machine step	Step description
Initial steady state	Continuous controller status monitoring and alarms updating Continuous analogue and digital data acquisition Synchronizing signal analysis (amplitude and frequency)
Preliminary checking	Operating conditions control Parameters validity control Synchronizing signal control (amplitude & frequency)
Operating time processing	CB compensation time computation CB operating time computation
Switching processing	Synchronizing signal assessment (zero crossing synchronization) Targeted instant for switching determination (according to parameterized shift angles and actual measured frequency) Switching delay T_{delay} computation Switching dates processing and output order issuing
Switching report	Switching status Operating time measurement Alarm processing
Archiving processing	Parameters, measures, switching traces and log files saving

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12.3.2.3 Controlled closing

Figure 82 describes a typical case for controlled closing operation, for a single-phase operation, targeting a voltage peak.

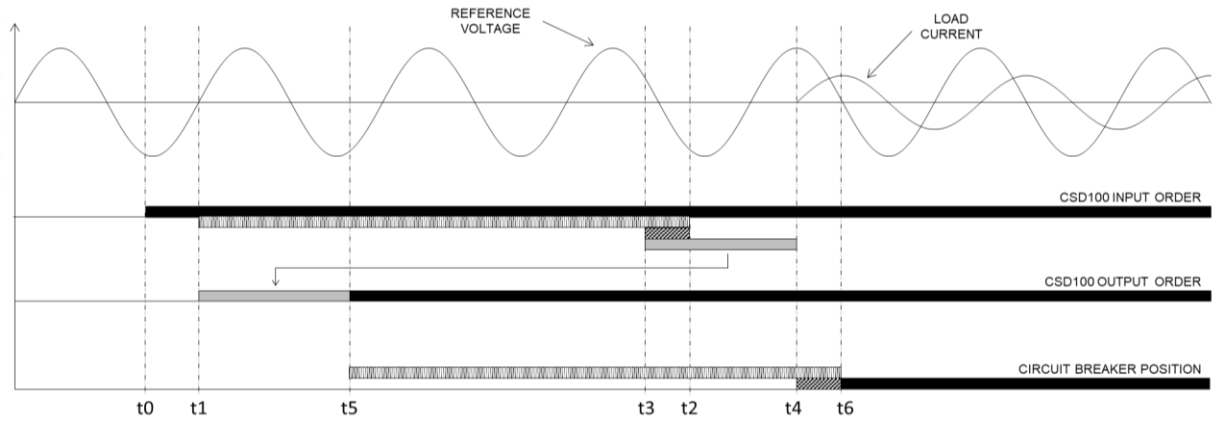


Figure 82 Controlled closing time chart

t0 : closing input order

t1 : synchronization on reference voltage at signal zero crossing rising slope

t2 – t1 : prospective circuit-breaker closing time (set / computed)

t3 – t2 : prospective circuit-breaker prearcing time (set / computed)

t4 : making target

t4 – t3 : time delay to switch at making target

t5 – t0 : time delay introduced by the controller (= (t4 – t3) + (t1 – t0))

t5 : closing output order

t6 – t5 : circuit-breaker closing time (achieved)

t6– t4 : circuit-breaker prearcing time (achieved)

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12.3.2.4 Controlled opening

Figure 83 describes a typical case for controlled opening operation, for a single-phase operation, summarizing an inductive load interruption.

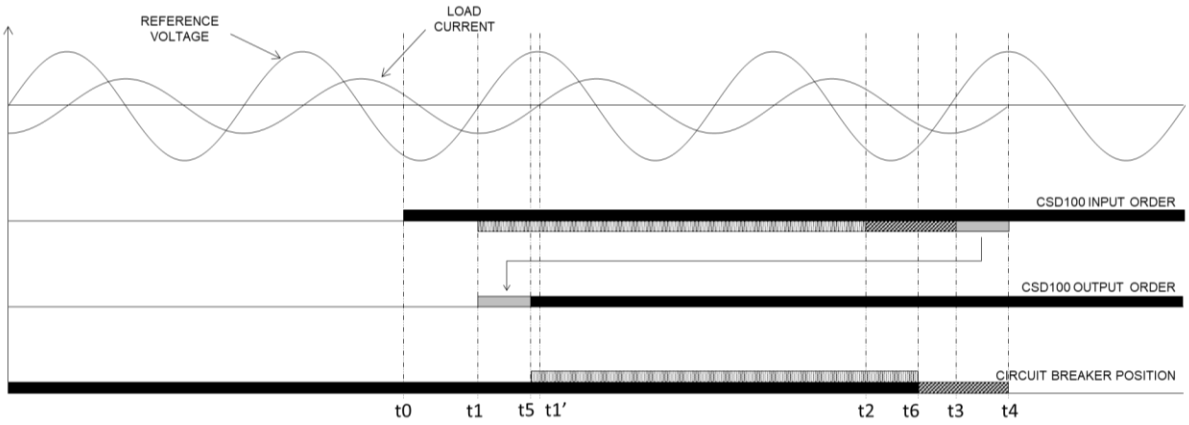


Figure 83 Controlled opening time chart

t0 : opening input order

t1 (t1') : synchronization on reference voltage (load current) at signal zero crossing rising slope

t2 – t1 : prospective circuit-breaker opening time (set / computed)

t3 – t2 : prospective circuit-breaker arcing time (set / computed)

t4 : breaking / interrupting target

t4 – t3 : time delay to switch at breaking target

t5 – t0 : time delay introduced by the controller (= (t4 – t3) + (t1 – t0))

t5 : opening output order

t6 – t5 : circuit-breaker opening time (achieved)

t6– t4 : circuit-breaker arcing time (achieved)

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12.3.3 Fast cycles / combined duties

Transmission line program involves different processing, due to real time constraint from autoreclose cycles:

- If reclose order is received within short delay (timeout to consider reclose operations), reclosing strategies are considered.
- Once reclose order is received, the previously open phase(s) shall be reclosed in a short delay
- Within this delay, strategy and optimum targets shall be computed (this implies fast analysis of line side voltages and individual phase status, healthy or faulty)
- Due to variability of line voltages (free oscillation, trapped charge), targets are not computed with angles by reference to source voltage. They are computed in delay from tripolar order instant.

Refer to section 12.10.4.2 and Figure 208 for more details.

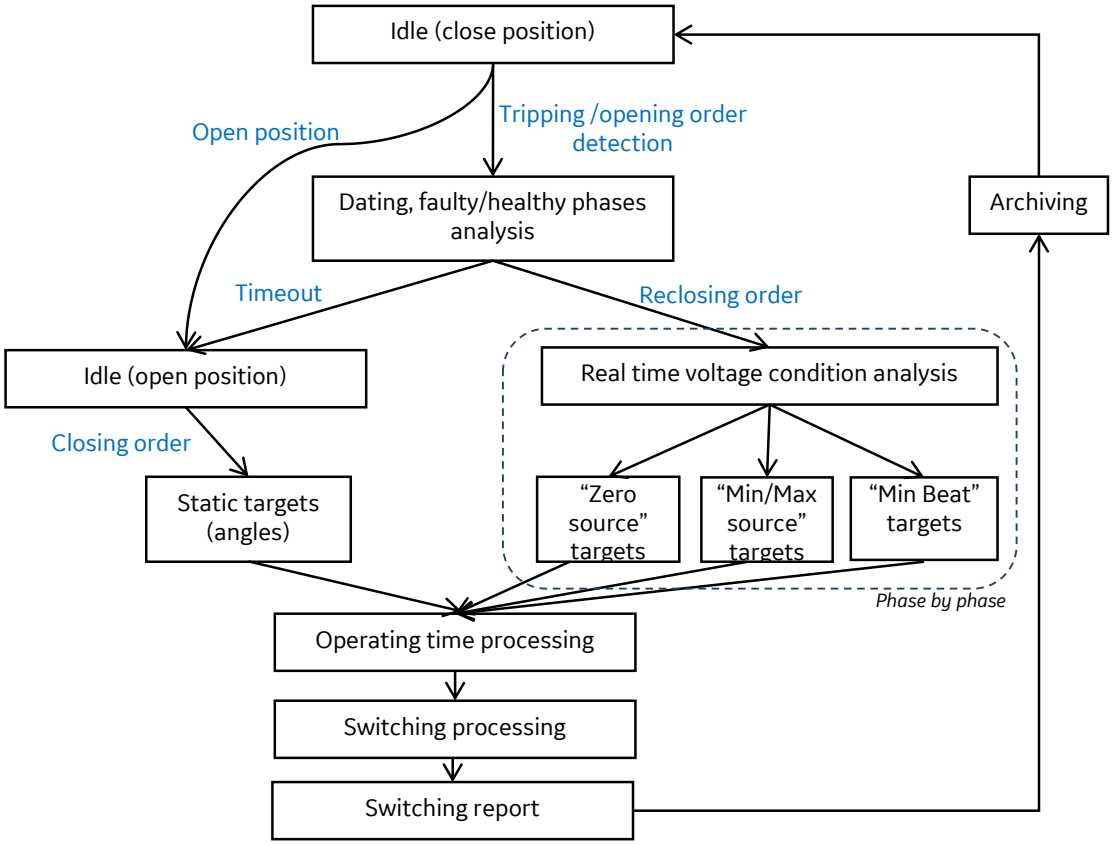


Figure 84 Controlled fast reclosing sequencing diagram

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12.3.4 Controlled switching functional arrangement

12.3.4.1 Typical General Functional Arrangement - Data Acquisition and Checks

The following diagram (Figure 85) gives an overview of the functional arrangement to perform a controlled switching operation. Three independent closing command orders are issued to single pole operated circuit-breaker.

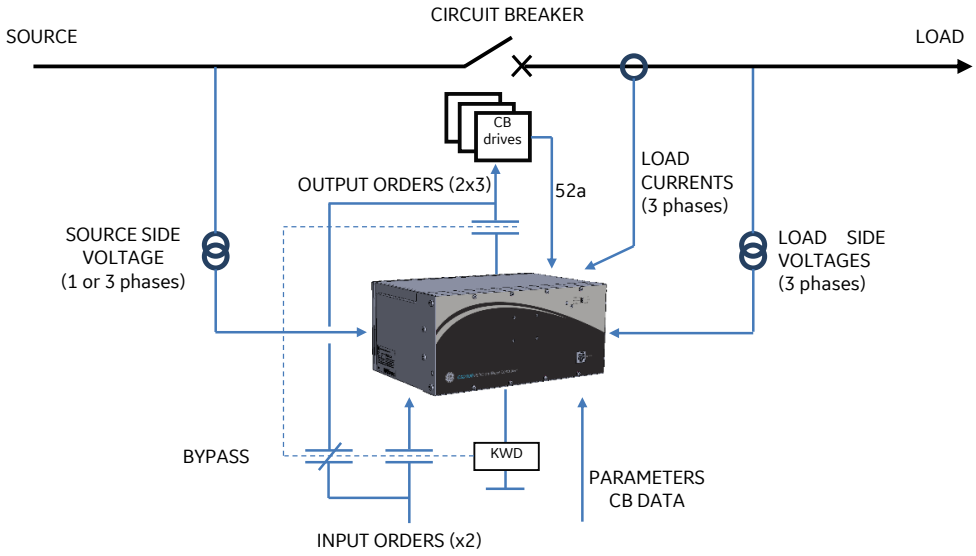


Figure 85 Controlled Switching functional arrangement

The CSD receives and checks the following data from the high voltage installation at the substation:

High voltages quantities:

- **Source voltage U_S**: A single-phase voltage is enough to assess the three phases, assuming that the source is a typical three-phase balanced system.
- **Three phases load voltage U_L**
  - Recommended for all applications (when VTs are available), for monitoring purposes (making times). Each of the three phases is monitored independently since the circuit-breaker poles are operated independently.
  - Mandatory for line reclosing applications and transformer switching with residual flux consideration
- **Three phases load current I_L:** This information provides the controller information on the actual making/breaking time (except for power transformer application) for closing/opening duty, allows detection of reignitions, and discriminates faulty and healthy phase for post-fault clearing reclosing sequence.

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Control signals

- The operating order coming from either the supervisory control board, SCADA system, or the auto-reclose relay.
- The circuit-breaker auxiliary contacts (52a). This provides the information on the main contact position and mechanical operating time of the circuit breaker.

Ambient conditions

The ambient conditions (ambient temperature, time interval since last operation, actual control voltage) and a set of parameters that characterize the network and the circuit-breaker allow the controller to perform a reliable switching operation.

12.3.4.2 Environment adaptation

To accurately perform its task, the CSD100 controller makes necessary adjustments to any information parameter that may be affected by its environment. Those adjustments are to compensate for any parameter value which may be different from those first programmed into the controller. For example, the circuit breaker operating time varies as a function of external factors such as temperature, power supply voltage to operating coils and hydraulic system pressure, for breakers equipped with such a drive mechanism (variation of drive energy).

Variations in all these factors influence the circuit breaker operating time in different and sometimes contradictory ways. In some extreme cases, total deviation from rated operating time can amounts to several milliseconds.

These external factors are monitored continuously. Any compensation to standard / programmed operating parameters is instantaneous.

The hardware used and logic applied for compensations are universal for all CSD100 Controllers.

If the application does not require some inputs, these should be left unconnected with no effect on performance. For instance:

- RS485 hydraulic pressure sensors should only be connected when circuit breakers are equipped with hydraulic operating mechanisms;
- The 3 Load voltage inputs are mandatory for LINE application (fast reclosing purpose) and power transformer flux consideration, but optional for shunt-reactor and shunt capacitor bank applications (monitoring purpose only);
- The 3 Current inputs are mandatory for line reclosing applications (discrimination of faulty phase purpose) or for synchronization based on current waveform (opening operations) but optional for other usages (monitoring purpose only).

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12.4 CSD100 controller features

12.4.1 Available operating mode

CSD100 is ready to operate under the modes described in Table 23.

12.4.2 Circuit breaker type

CSD100 can operate any type of circuit breakers described in Table 24, fitted with spring or hydraulic drive mechanism.

CSD100 is suitable for LT, DT and GIS circuit-breakers.

12.4.3 Synchronizing features

Table 34 CSD100 synchronizing features

Item	Description	Comment
System frequency	Selection of the system frequency	Suitable for system frequency 50Hz or 60Hz Note: synchronizing according to actual measured frequency
Synchronizing on voltage signal	Synchronizing based on measured reference voltage signal, generally source side voltage	Suitable for both controlled closing and controlled opening operations. Whenever voltage signal is used for controlled opening, switching angles are elaborated considering voltage and current signals are in quadrature. Phase to neutral signal wiring recommended.
Synchronizing on current signal	Opening synchronizing based on measured load current	Switching targets are directly related to current signal. A guaranteed minimum current amplitude is necessary. CT at the load side of the circuit-breaker recommended.
Synchronizing on differential voltage signal	Reference signal is the voltage difference between source side and load side	With multi-chamber circuit breakers, residual voltage is transmitted from source side to load side through grading capacitors and should be considered for synchronizing
Phase reference for synchronizing	Fixed selection of the phase reference L1, L2 or L3, defining the switching sequence	This is the basic mode of operation: only one reference voltage is wired to the CSD100. Automatic selection is possible only when 3 phases of the synchronizing signal are wired to the controller (refer to delay optimization)
Switching delay optimization	Dynamic change of the phase reference to reduce input-output delay introduced by the controller	Applicable when 3 phases of the synchronizing signal are wired to the controller. Practically, the controller performs a circular permutation of the predefined switching angles. In all cases, delay introduced by the controller is lower than 1 cycle of power frequency.
Reference signal phase shift	Compensate for possible phase shift between the actual primary voltage at the circuit breaker terminal and the connected reference voltage	Applicable for synchronizing on voltage signal. Suitable for installations where voltage divider is located at the secondary side of a transformer or phase to phase voltage signal is wired to the controller voltage input.

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12.4.4 Compensation features

CSD100 can compensate for any ambient parameters that impact operating time of the circuit breaker.

Compensation functions are listed in the following table:

Table 35 CSD100 compensation features

Compensation feature	Description
Control voltage compensation	Compensation for substation auxiliary voltage (batteries) fluctuations. 2 inputs available for distinction between open end close polarities.
Ambient temperature compensation	Compensation for circuit-breaker ambient temperature variation.
Hydraulic pressure compensation	Compensation for stored energy level (hydraulic drives).
Idle time compensation	Compensation for time elapsed since previous operation.
Adaptive control	Long-term drift compensation (ageing), with operating time measurement feedback

12.4.5 Monitoring features

CSD100 can monitor circuit breaker as well as operations related values.

Monitoring functions are listed in the following table:

Table 36 CSD100 monitoring features

Monitoring feature	Description
Mechanical operation times	From 52a measurement, or travel curve (if sensor installed)
Number of operations	Synchronized and unsynchronized operations (cumulated)
Number of reignitions	Cumulated number of reignitions from opening operations
Making times	Deviation from expected target, from closing operation
Circuit breaker gas density	Supervision of density, which may affect pre-arcing times and RDDS.
Inrush currents	Peak inrush current from closing operation
Source voltage dips	Peak source voltage sag from closing operation
Circuit breaker insulating gas density monitoring	Gas density can be computed for up to 6 independent compartments (3 phases, 2 circuit breakers) from gas pressure and density transmitters connected (multiplexed) to the RS485 port. Supported gas or gas mixtures: dry air, g3, SF6, SF6+CF4, SF6+N2 (gas mixture ratio is settable). A gas alarm is also managed (thresholds and hysteresis are settable).
Electrical wear	Electrical wear is the cumulated “$\int i^2.dt$” computation during circuit breaker arcing time. It is accumulated for each opening operation. Electrical wear alarm and warning are managed with two independent settable thresholds.

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12.4.6 Signaling and feedback

Table 37 CSD100 signaling and feedback

Item	Description	Comment
Alarm signaling	2 relays available for signaling urgent and non-urgent alarms	Alarm assignation is customizable
LEDs signaling	6 LEDs available to deliver status of the controller (power supply, ready to operate)	-
Switching performance evaluation	Accuracy of the controlled closing and controlled opening operations, within the required tolerance	Measurement performed by 52a (NO contacts) triggering accuracy digital input, travel curve measurement, current and voltage inception
Power quality indicators	Voltage dip, peak current	-
Counter	Number of controlled and random operations Number of reignition	Decision making tool

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12.5 Circuit-breaker consideration

Electrical times are the main quality indicators for controlled switching operations.

A distinction between mechanical times (circuit breaker arcing contacts touch / separation) and electrical times (making time / current extinction time) is made.

Mechanical times measurement purpose is to

- Back feed mechanical time compensation function
- Monitor mechanical behavior of the circuit breaker (operations post analysis) with records

Electrical times measurement purpose is to

- Monitor the quality of controlled switching operation (operations post analysis) with records.

12.5.1 Circuit-breaker description

A circuit-breaker pole is basically made of:

- An interrupting chamber or multiple interrupting chambers encapsulated in a dielectric fluid or gas and designed to
  - Interrupt normal load current (capacitive, inductive, magnetizing)
  - Interrupt short-circuits current (fault clearing)
  - Carry permanent current
- An operating mechanism designed to
  - Store energy for operation either simple (O, C) or combined (O-CO, CO-CO)
  - Receive electric impulse to trigger operating coils
  - Release mechanism latch (O, C)
- An insulated connecting rod designed to
  - Transmit movement from mechanism to the circuit-breaker contacts encapsulated in the interrupting chamber

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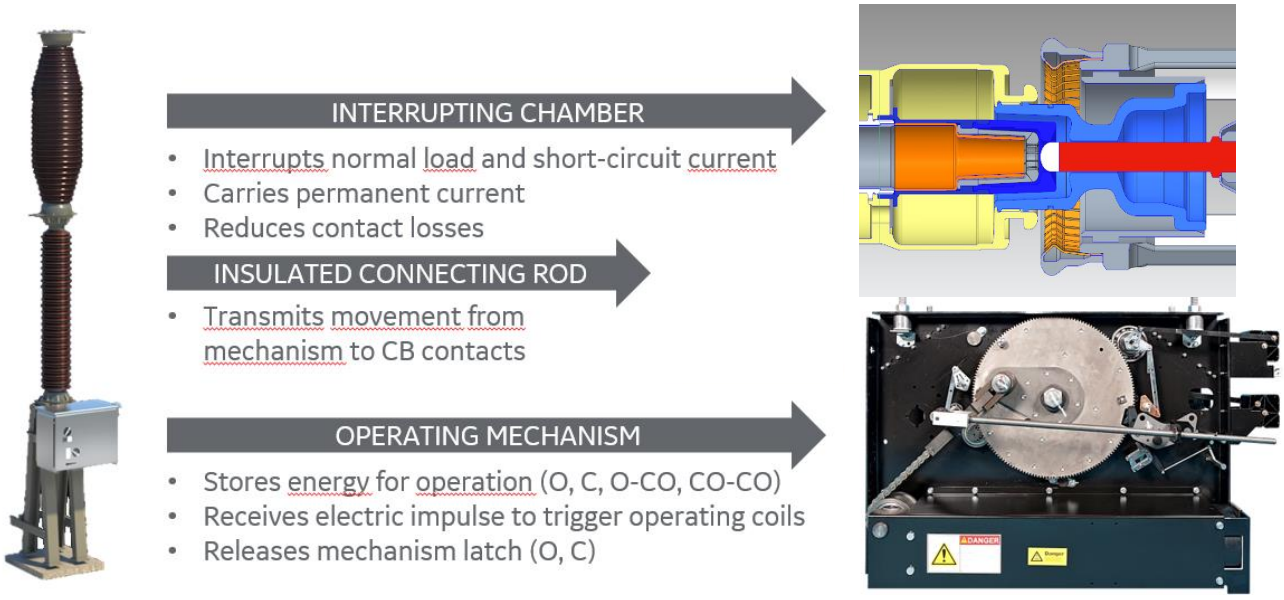
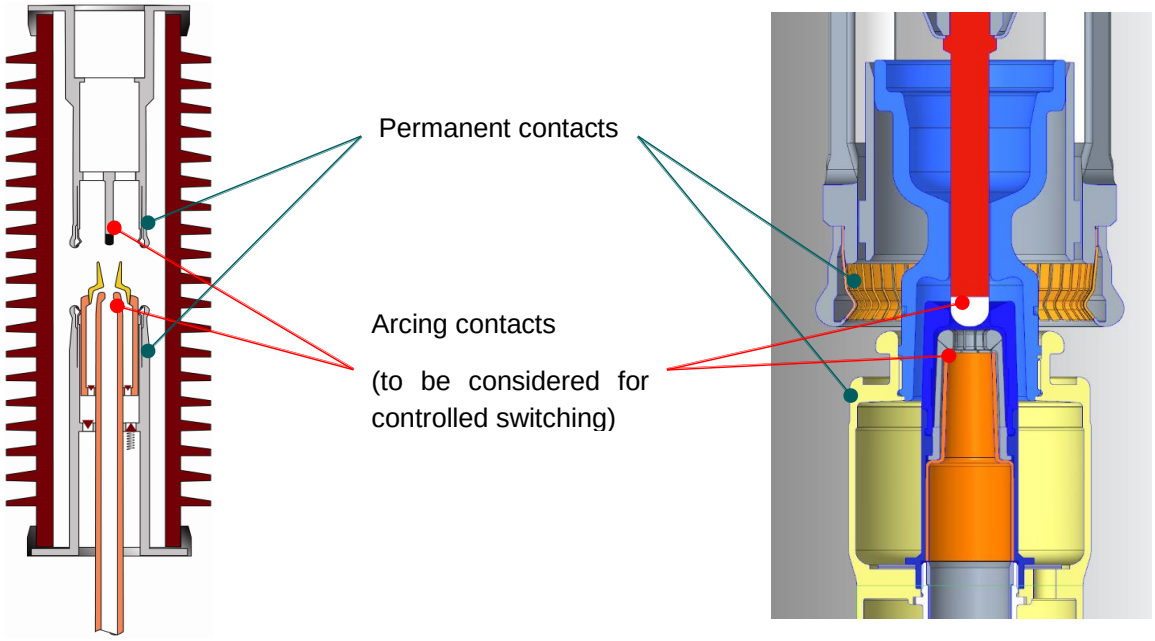


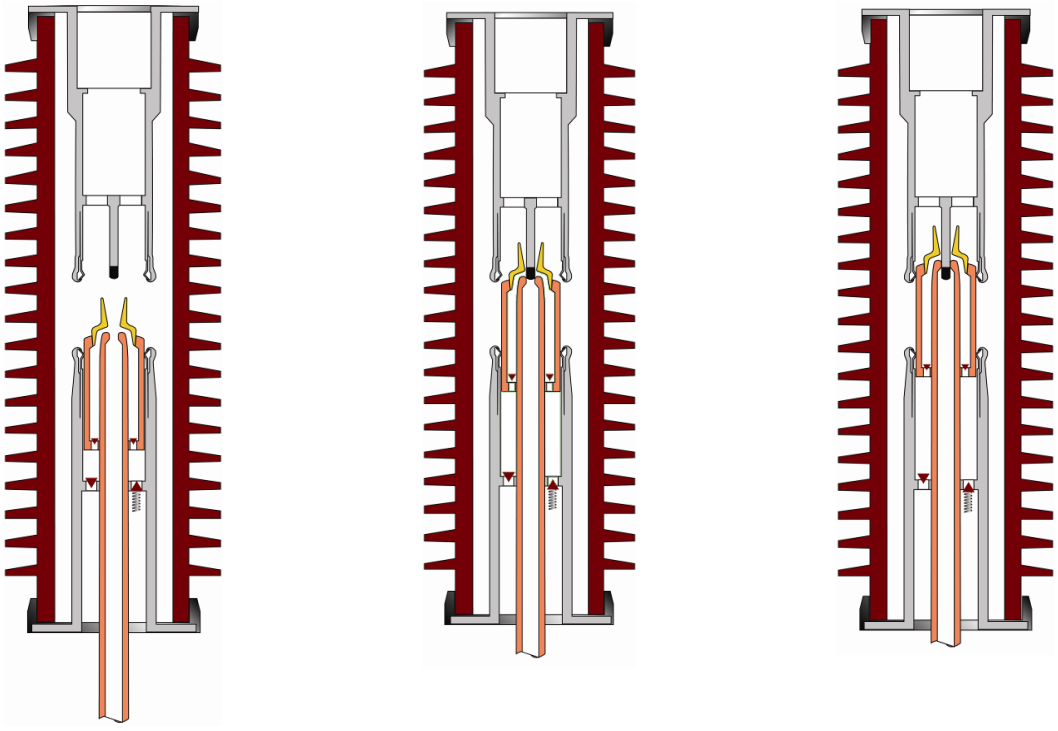
Figure 86 Circuit-breaker description

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12.5.1.1 Circuit-breaker interrupting chamber

Arcing contacts are the contacts considered for synchronizing purposes (last to open and first to close).





Circuit-breaker in open position *Arcing contacts touch* *Circuit-breaker in closed position*

Figure 87 Circuit-breaker positions

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12.5.1.2 Circuit-breaker operating mechanism

Spring mechanism: most common drive type, with one spring dedicated to opening and one spring for closing (usually, closing spring also reloads opening spring, to achieve O-CO standardized cycles). An electrical motor is in charge of reloading closing spring, after operation (this takes a few seconds).

Hydraulic mechanism: typically fitted for higher energy application. A gas accumulator maintained under pressure with a pump and two pressure contacts (two thresholds, this means the level of stored energy is a little variable), drives a hydraulic cylinder for opening and closing operations.

12.5.2 Types of circuit-breakers



3PO: *3 – pole operated (gang operated)*

All 3 poles of the circuit breaker are operated by a single mechanism

IPO: *independent pole operated*

Each pole of the circuit breaker is operated, independently, by its own mechanism

Double drive

Each pole of the circuit breaker is operated, independently, by 2 independent mechanisms

Figure 88 Various types of circuit-breakers

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12.5.3 Circuit-breaker operation

12.5.3.1 Circuit-breaker closing operation

From closing order occurrence (coil energizing) one phase of circuit breaker related signals are depicted in below figure. Load current is measured a few milliseconds before mechanical contact touch (prestrike time).

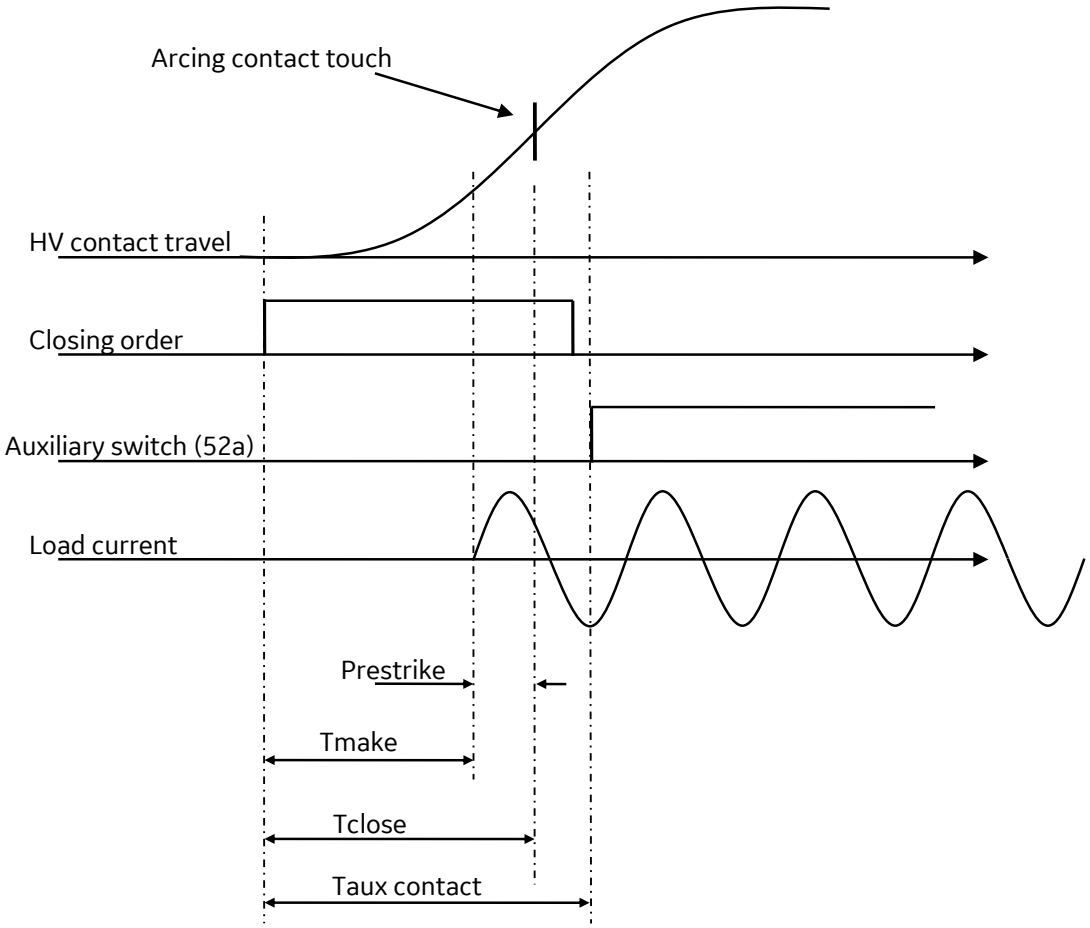


Figure 89 Circuit-breaker closing operation

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12.5.3.2 Circuit-breaker opening operation

From opening order occurrence (coil energizing) one phase of circuit breaker related signals are depicted in below figure. Load current is observed a few milliseconds after mechanical contact touch (arcing time). The coil current is often interrupted upon one of 52a auxiliary contact bloc opening.

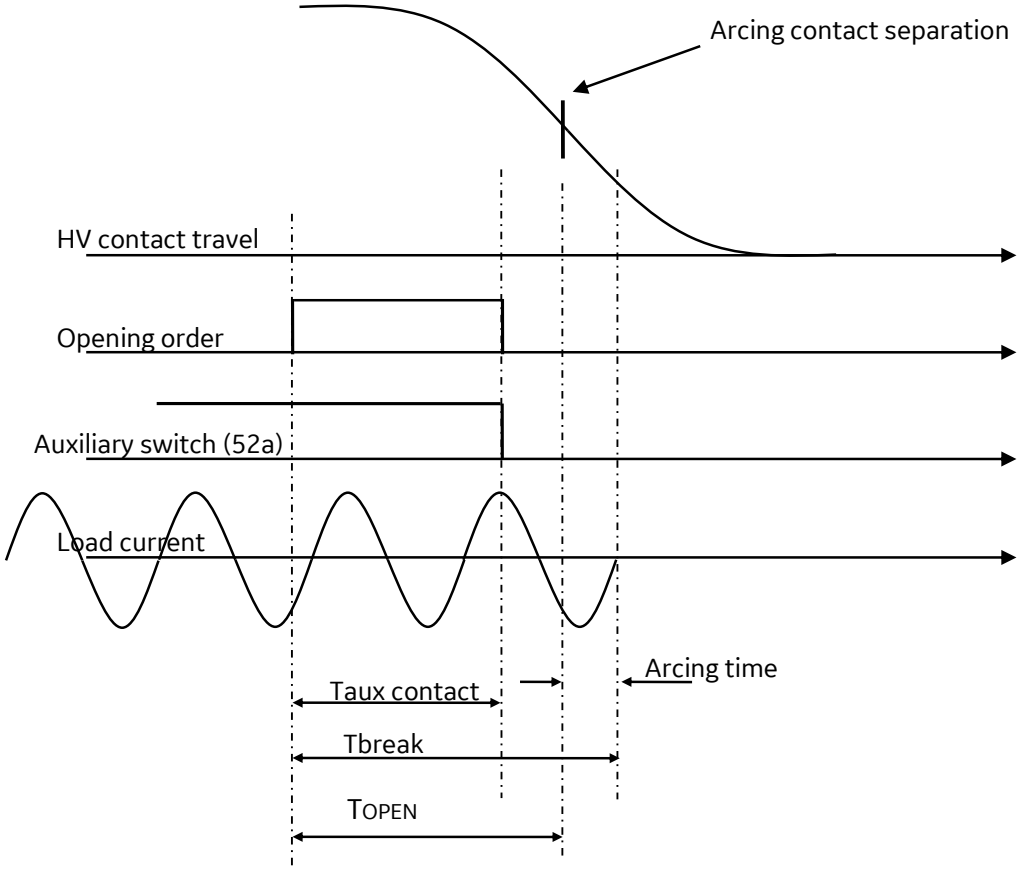


Figure 90 Circuit-breaker opening operation

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12.5.4 Circuit-breaker operating time computation (next operation forecast)

The success of controlled switching is based on two fundamental principles:

- Identification of a target moment for switching, which implies perfect assessment of the synchronizing signal;
- Reliable estimation of the duration of the operation for the device being controlled.

That means it is quite important to anticipate the behavior of the high voltage circuit-breaker being controlled before an order is issued by the synchronizing device.

High voltage circuit breakers typically operate in the range of 15-30ms (opening) or 50-100ms (closing). To guarantee accuracy of contact separation instant (opening) or closing times, it is crucial to anticipate for mechanical operation times (next operation forecast).

The circuit-breaker mechanical operating time is the combination of:

- A fixed nominal / rated value, measured at site during commissioning to consider installation influencing conditions such as the voltage delivered by the auxiliaries, the cables lengths;
- A set of “instantaneous” (“open loop”) compensation values for which knowledge already exists (from type tests and specific tests). These are based on environmental measurements for which mechanical time influence is known;
- An adaptive control value (“closed loop”) with aim to compensate for long term drifts (ageing…). This is based on an operating time measurement feedback, to detect drifts and to compensate for.

Set point operating times is defined as following:

$$T_{setpoint} = T_{rated} + \sum \Delta T_{comp} + \Delta T_{adapt} \qquad (1)$$

Where

- $T_{setpoint}$ Operating time to apply for next controlled switching operation [ms]
- T_{rated} Operating time rated value [ms]
- $\sum \Delta T_{comp}$ Instantaneous compensation delays due to ambient conditions [ms]
- ΔT_{adapt} Adaptive control delay to compensate long term drifts [ms]

Same processing applies both for opening and closing operations.

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12.5.5 Circuit-breaker operating time compensation

One of the challenges in controlled switching lies in the prediction of the duration of the operation, subject to the environment conditions. Ambient temperature, switching device reserve of energy, control auxiliaries' voltage level, dielectric gas density, time elapsed since the last operation, long-term drift are all factors that have an influence.

External influences are considered by the CSD100 Controller's software to optimize the accuracy of switching times. Instantaneous operating time compensations include:

- Ambient temperature compensation;
- Control voltage compensation;
- Stored energy level compensation;
- Idle time compensation.

The following section describes functions and ways to compensate for those external influences.

The total operating time compensation value used by CSD100 software is the sum of these various contributions.

12.5.5.1 Total operating time compensation

Total operating time compensation delay to apply for a switching operation is the sum of all compensation delays computed:

$$\sum \Delta T_{comp} = \Delta T_T + \Delta T_U + \Delta T_P + \Delta T_I \qquad (2)$$

Where

- $\sum \Delta T_{comp}$ Total compensation value
- ΔT_T Ambient temperature compensation value
- ΔT_U Control voltage compensation value
- ΔT_P Hydraulic pressure compensation value
- ΔT_I Idle time compensation value

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Notes:

- This equation is applicable for both closing and opening operations, each compensation law being determined independently;
- A positive value of any individual compensation ΔT_i means this value is added to the rated operating time;
- A negative value of any individual compensation ΔT_i means this value is subtracted from the rated operating time;
- The sum of all instantaneous compensations' delays $\Delta T_T + \Delta T_U + \Delta T_P + \Delta T_I$ is limited to a maximum allowed value that can be set through the control interface;
- Any of the compensation function can be enabled or disabled individually.

Section 13.1.5 describes how to set the various CSD100 parameters to compensate operating times of the circuit-breaker for external ambient influence factors.

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12.5.5.2 Ambient temperature compensation

Circuit-breakers mechanical times may be affected by extreme temperatures. This compensation feature is of importance for outdoor applications with large ambient temperature variation. For indoor applications or outdoor application with a controlled or limited ambient temperature variation, ambient temperature compensation can be disabled.

External temperature is continuously measured by a dedicated CSD100 analogue input. An external sensor with an integrated transducer (2 conductors, auxiliary voltage 24 VDC) and standard output signal [4 – 20] mA is necessary for measuring the temperature polarities (refer to section 11.3.5.6). The transducer power is supplied by the controller internal power source. Temperature is measured for one circuit-breaker from a unique probe, to be installed outdoor, free from parasitic sun effect. Measured value is stored and compared to typical operating time compensation values derived from the circuit breaker's type tests and specific tests.

These time compensation values for circuit breaker operation, are programmed within the CSD100 according to compensation laws set as two independent tables. Two tables of 11 points, from –50°C to +50°C for closing and opening operations, are determined for each circuit breaker family.

CSD100 calculates the additional contribution for operating time compensation according to these compensation tables. Intermediates values are interpolated from the table by the CSD100, according to a linear interpolation between consecutive values.

Table 38 Ambient temperature closing time compensation

Ambient temperature [degC]	-50	-40	-30	-20	-10	0	10	20	30	40	50
Closing time compensation [ms]	ΔT_{TC1}	ΔT_{TC2}	ΔT_{TC3}	ΔT_{TC4}	ΔT_{TC5}	ΔT_{TC6}	ΔT_{TC7}	ΔT_{TC8}	ΔT_{TC9}	ΔT_{TC10}	ΔT_{TC11}

Table 39 Ambient temperature opening time compensation

Ambient temperature [degC]	-50	-40	-30	-20	-10	0	10	20	30	40	50
Opening time compensation [ms]	ΔT_{TO1}	ΔT_{TO2}	ΔT_{TO3}	ΔT_{TO4}	ΔT_{TO5}	ΔT_{TO6}	ΔT_{TO7}	ΔT_{TO8}	ΔT_{TO9}	ΔT_{TO10}	ΔT_{TO11}

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Notes:

- Ambient temperature compensation table is determined for both closing and opening operations;
- If measured temperature is outside [-50°; +50°C] the value at -50°C or +50°C is kept as compensation;
- If measured temperature is out of valid range (min and max parameters) compensation is set to zero.

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12.5.5.3 Control voltage compensation

Circuit breakers actuators (“coils”) have an intrinsic delay (typically 2.5ms) which depends on the voltage value used for actuation. Circuit-breaker operating coils are usually variable reluctance inductive load, with mechanical force proportional to triggering current value, for which rising time is in the order of U_c/L. Thus, control voltage variation has an impact on the operating coil force and consequently on circuit-breaker operating time.

Control voltage measurement, and compensation, is done internally within the CSD100. No additional equipment is necessary.

Control voltages are continuously measured, independently for opening and closing polarities (refer to section 10.1.8.6 and 11.3.5.4), by the CSD100 inputs VDC1 and VDC2. Measured values are stored and compared to typical operating time compensation values derived from the circuit breaker’s specific tests.

These time compensation values for circuit breaker operation, are programmed within the CSD100 according to compensation laws set as two independent tables. Two tables of 4 points, from 70 % to 110 % of the rated opening control voltage and from 85 % to 110 % of the rated closing control voltage, are determined for each circuit breaker family.

CSD100 calculates the additional contribution for operating time compensation according to these compensation tables. Intermediates values are extrapolated from the table by the CSD100 according to a linear interpolation between consecutive values.

Table 40 Control voltage closing time compensation

Control voltage [% rated voltage]	85 %	93 %	100 %	110 %
Closing time compensation [ms]	ΔT_{UC1}	ΔT_{UC2}	ΔT_{UC3}	ΔT_{UC4}

Table 41 Control voltage opening time compensation

Control voltage [% rated voltage]	70 %	85 %	100 %	110 %
Opening time compensation [ms]	ΔT_{UO1}	ΔT_{UO2}	ΔT_{UO3}	ΔT_{UO4}

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Notes:

- Control voltage compensation table is determined for both closing and opening operations;
- CSD100 can compensate for 2 sets of independent auxiliaries, one for opening operation and one for closing operations;
- For opening operations, if the voltage measured value is outside the window [70 %; 110 %] the value at 70 % or 110 % is kept as compensation;
- For closing operations, if the voltage measured value is outside the window [85 %; 110 %] the value at 85 % or 110 % is kept as compensation;
- If the voltage measured value is outside the valid range (min and max parameters) compensation is set to zero.

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12.5.5.4 Hydraulic drive stored energy level compensation

Circuit-breakers with spring operating mechanism drives operate at constant energy value proportional to spring compression rate square value. Stored energy level compensation feature is then not applicable.

For circuit-breakers fitted with hydraulic drives, the stored energy level may vary, due to the difference in pump start/stop pressure switch thresholds, which have an impact on operating time.

Hydraulic pressure is continuously measured by CSD100 digital transmitter input (RS485). An external sensor is necessary for measuring the hydraulic pressures (refer to section 11.3.5.1). The transducer can be powered by the controller internal power source. Measured values are stored in the CSD100 memory bank.

The CSD100 compares those stored hydraulic pressure measured values to typical operating time compensation values derived from the circuit breaker's specific tests.

These time compensation values for circuit breaker operation, are programmed within the CSD100 according to compensation laws set as two independent tables. Two tables of 10 points, from 50 % to 140 % for closing and opening operations, are determined for each circuit breaker family.

CSD100 calculates the additional contribution for operating time compensation according to these compensation tables. Intermediates values are extrapolated from the table by the CSD100 according to a linear interpolation between consecutive values.

Table 42 Hydraulic pressure closing time compensation

Hydraulic pressure [% rated pressure]	50 %	60 %	70 %	80 %	90 %	100 %	110 %	120 %	130 %	140 %
Closing time compensation [ms]	ΔT_{PC1}	ΔT_{PC2}	ΔT_{PC3}	ΔT_{PC4}	ΔT_{PC5}	ΔT_{PC6}	ΔT_{PC7}	ΔT_{PC8}	ΔT_{PC9}	ΔT_{PC10}

Table 43 Hydraulic pressure opening time compensation

Hydraulic pressure [% rated pressure]	50 %	60 %	70 %	80 %	90 %	100 %	110 %	120 %	130 %	140 %
Opening time compensation [ms]	ΔT_{PO1}	ΔT_{PO2}	ΔT_{PO3}	ΔT_{PO4}	ΔT_{PO5}	ΔT_{PO6}	ΔT_{PO7}	ΔT_{PO8}	ΔT_{PO9}	ΔT_{PO10}

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Notes:

- Hydraulic pressure compensation table is determined for both closing and opening operations;
- If the pressure measured value is outside [50%; +140%] the value at 50% or +140% is kept as compensation;
- If the pressure measured value is out of valid range (min and max parameters) compensation is set to zero.

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12.5.5.5 Idle time compensation

Idle time is defined as the elapsed time from the previous operation of the same type to the operation coming, i.e. between two consecutive opening operations or two consecutive closing operations. It affects operating times of circuit-breakers that do not operate frequently, and particularly circuit-breakers fitted with hydraulic operating mechanism.

Elapsed time from previous operation is continuously measured by CSD100, based on the 52a position change measured by the controller binary inputs.

Measured values are stored in the CSD100 memory bank and compared to typical operating time compensation values derived from the circuit breaker's specific tests.

These time compensation values for circuit breaker operation, are programmed within the CSD100 according to compensation laws set as two independent tables. Two tables of 10 points, from 0 h to 168 h for closing and opening operations, are determined for each circuit breaker family.

CSD100 calculates the additional contribution for operating time compensation according to these compensation tables.

Intermediates values are extrapolated from the table by the CSD100 according to a linear interpolation between consecutive values.

Table 44 Idle time closing time compensation

Idle time [hour]	0 h	1 h	2 h	4 h	8 h	16 h	32 h	64 h	168 h	+∞
Closing time compensation [ms]	dT_IC1	ΔT_{IC2}	ΔT_{IC3}	ΔT_{IC4}	ΔT_{IC5}	ΔT_{IC6}	ΔT_{IC7}	ΔT_{IC8}	ΔT_{IC9}	ΔT_{IC10}

Table 45 Idle time opening time compensation

Idle time [hours]	0 h	1 h	2 h	4 h	8 h	16 h	32 h	64 h	168 h	+∞
Opening time compensation [ms]	ΔT_{IO1}	ΔT_{IO2}	ΔT_{IO3}	ΔT_{IO4}	ΔT_{IO5}	ΔT_{IO6}	ΔT_{IO7}	ΔT_{IO8}	ΔT_{IO9}	ΔT_{IO10}

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Notes:

- Influence of idle time on GE's circuit-breakers with spring-spring operating mechanisms is negligible. Idle time compensation feature is then not necessary;
- Idle time compensation table is determined for both closing and opening operations;
- If the idle time exceeds 168 h, the compensation value is fixed and set to the value defined for $+\infty$.

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12.5.6 Circuit-breaker adaptive control

Circuit breakers mechanical times may be affected by long term drifts, due to ageing. Evidence of such drift is a systematic difference between computed mechanical time and measured mechanical time, operation after operation.

The CSD100 is fitted with adaptive control function to compensate for any long-term drift in the operating time of the circuit-breaker. This adaptive control removes a fraction of the difference between previous computed mechanical time and measured mechanical time to the next operation computed mechanical time (forecast). This a recursive process based on a “gradient” type algorithm.

The adaptive control value at step “n”, $\Delta T_{adapt(n)}$, is defined by:

$$\Delta T_{adapt(n)} = \Delta T_{adapt(n-1)} + k * \left(T_{measured(n-1)} - T_{setpoint(n-1)}\right) \quad (3)$$

This is equivalent to following equation:

$$\Delta T_{adapt(n)} = (1 - k) * \Delta T_{adapt(n-1)} + k * \left(T_{measured(n-1)} - T_{rated} - \Delta T_{inst(n-1)}\right)$$

Where:

- $\Delta T_{adapt(n)}$ Adaptive control value computed for upcoming operation [ms]
- $\Delta T_{adapt(n-1)}$ Adaptive control value computed for previous operation [ms]
- $T_{measured(n-1)}$ Previous operating time measured value [ms]
- $T_{setpoint(n-1)}$ Previous operating time computed value [ms]
- k Weighting factor [dimensionless]
- T_{rated} Nominal circuit breaker rated time (fixed) [ms]
- $\Delta T_{inst(n-1)}$ Sum of instantaneous compensation for previous operation[ms]

$\Delta T_{adapt(n-1)}$, $T_{measured(n-1)}$, $T_{setpoint(n-1)}$ values are memorized in non-volatile memory to restart from correct values in case of power supply interruption and can also be set, to initialize the process.

A weighting factor k in the range of 0 to 0.5 (<0.1 recommended) is used for controlling the feed-back loop of the compensation.

Figure 91 illustrates how a systematic error between measured and calculated mechanical time is progressively compensated, depending of the gain k. Practically, k values higher than 0.1 are not recommended, since aim is to compensate for long term drifts (slow process).

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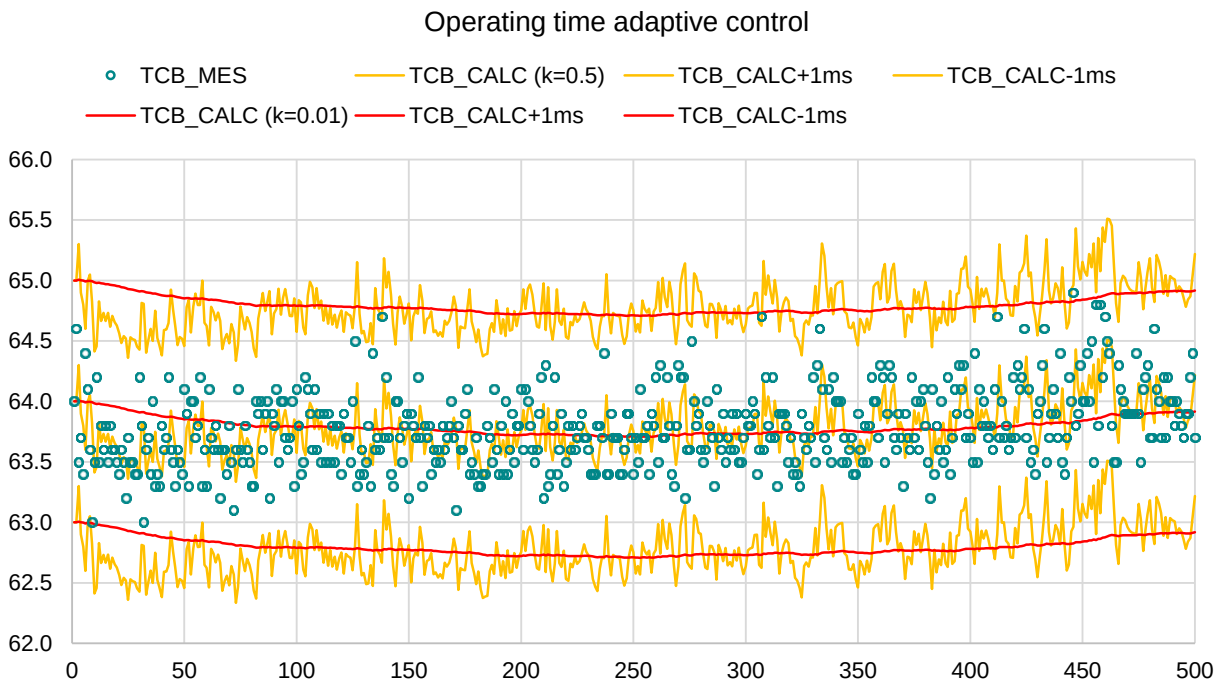


Figure 91 Adaptive compensation feature application

Notes:

- k factor can be set independently for closing and opening operations;
- $\Delta T_{adapt(n-1)}$, $T_{measured(n-1)}$, $T_{setpoint(n-1)}$ values can be initialized or reset through the control interface;
- Computation of ΔT_{adapt} requires the previous operation measured value;
- The adaptive compensation delay ΔT_{adapt} is limited to a maximum allowed value;
- If circuit breaker maintenance period is low enough, it is preferable not to activate this compensation (mechanical times re-measured on a regular basis).
- This compensation should not be activated to compensate for an error in rated mechanical times measurement during commissioning.

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12.5.7 Circuit-breaker operating time measurement

Circuit-breaker operating time measurement is needed for:

- Evaluation of controlled switching operation success (monitoring);
- Feeding of operating time adaptive compensation.

Mechanical time measurements are performed individually for all three (3) phases L1, L2 and L3 of the circuit-breaker under control, and both for closing and opening operations (independently).

12.5.7.1 Operating time measurement methods

Since direct access to main contacts is not possible, operating time measurement is carried out using auxiliary contacts or travel sensors, which reflect the position of the circuit-breaker individual poles. The two following methods are available for operating time measurement purpose:

- The “**Auxiliary switch**” method;
- The “**Travel curve**” method.

The “Auxiliary switch” method consists in dating the instant of circuit-breaker auxiliary contact (type 52a) switching to get back to the main contact switching time, the time shift between main contact and auxiliary contact operating being known and assumed constant.

To simplify the process and to avoid sign errors, CSD100 includes settings for rated main contacts times (opening and closing, 3 phases) as well as rated auxiliary contacts (opening and closing, 3 phases). Thus, time shifts between main and auxiliary contacts are computed (and assumed constant) and automatically affected by the right sign (opening and closing).

The “Travel curve” method consists in dating with accuracy the instant of arcing contacts touch / separation, the travel sensor delivering a projection of the arcing contact travel.

Operating time measurement method is settable individually for opening and closing operations. There isn’t any automatic switching between two methods. Measurement is accepted if it falls within set allowed range ([Min. value; Max. value].

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12.5.7.2 Closing time measurement

12.5.7.2.1 Auxiliary switch method

For each phase the CSD100 measures associated auxiliary contact (used for measurement purpose) closing time "T_{CS}" and get back to circuit-breaker closing time "T_{close}" applying the set auxiliary contact time shift value:

$$T_{close} = T_{CS} - T_{CP_CS}$$

T_{CP_CS} Time shift between main contact and auxiliary contact set value for closing operations measured during commissioning.

Note: during commissioning T_{close} and T_{CS} rated values are measured.

12.5.7.2.2 Travel curve method

Circuit breaker main contacts linear motion is computed from rotative sensors installed in the drives: First, raw information is switched to percentage of travel with user settable static extreme positions (simple linear transform). Then, percentage of travel is transformed into contact travel (mm) with a linear transform, accommodating for possible overtravel.

Finally, the contact touch and separation instants are computed by searching instant of crossing with a settable threshold.

Note: Threshold and stroke information come from circuit breaker type tests or routine tests.

Refer to 12.5.3.1 for illustration.

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12.5.7.3 Opening time measurement

12.5.7.3.1 Auxiliary switch method

For each phase the CSD100 measures associated auxiliary contact (used for measurement purpose) opening time "T_{CS}" and get back to circuit-breaker closing time "T_{close}" applying the set auxiliary contact time shift value:

$$T_{open} = T_{CS} + T_{CP_CS}$$

T_{CP_CS} Time shift between main contact and auxiliary contact set value for opening operations measured during commissioning.

Note: during commissioning T_{open} and T_{CS} rated values are measured.

12.5.7.3.2 Travel curve method

Circuit breaker main contacts linear motion is computed from rotative sensors installed in the drives: First, raw information is switched to percentage of travel with user settable static extreme positions (simple linear transform). Then, percentage of travel is transformed into contact travel with a dedicated linear equation, accommodating for possible overtravel.

Finally, the contact separation instant is computed by searching instant of crossing of a settable threshold.

Note: Threshold and look up table information come from circuit breaker type tests.

Refer to 12.5.3.2 for illustration

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12.5.8 Circuit-breaker pre-arcing phenomena

12.5.8.1 Pre-arcing mechanism

A circuit is energized slightly before the circuit-breaker arcing contacts touch mechanically. During closing operation, as contacts come closer together, dielectric withstand capability of the interrupter contacts is reducing. At some point, voltage conditions exceed contact gap dielectric withstand (crossing of circuit breaker RDDS and circuit-breaker voltage) and breakdown occurs between arcing contacts. This instant is the making time of the circuit and known as the pre-arcing.

Therefore, it is crucial for the CSD100 to anticipate for pre-arcing times. It requires knowledge about the circuit-breaker dielectric characteristic (R.D.D.S.) and the voltage conditions near the targeted switching point. Pre-arcing times are either fixed (dedicated settings) for fixed targets strategies or computed by the CSD100 for variable targets strategies (power transformer with residual flux function).

Figure 92 describes the pre-arcing mechanism that occurs upon circuit-breaker closing operation:

1. The circuit-breaker is open;
2. During closing operation, when the inter-electrode distance is insufficient to support the voltage gradient applied at the circuit-breaker terminals, an arc between arcing contacts is observed. The current starts to pass through the interrupting chamber;
3. On mechanical closure of the arcing contacts, the arc is extinguished;
4. The current pass through the arc contacts until the main contacts close. The main contacts carry the permanent current.

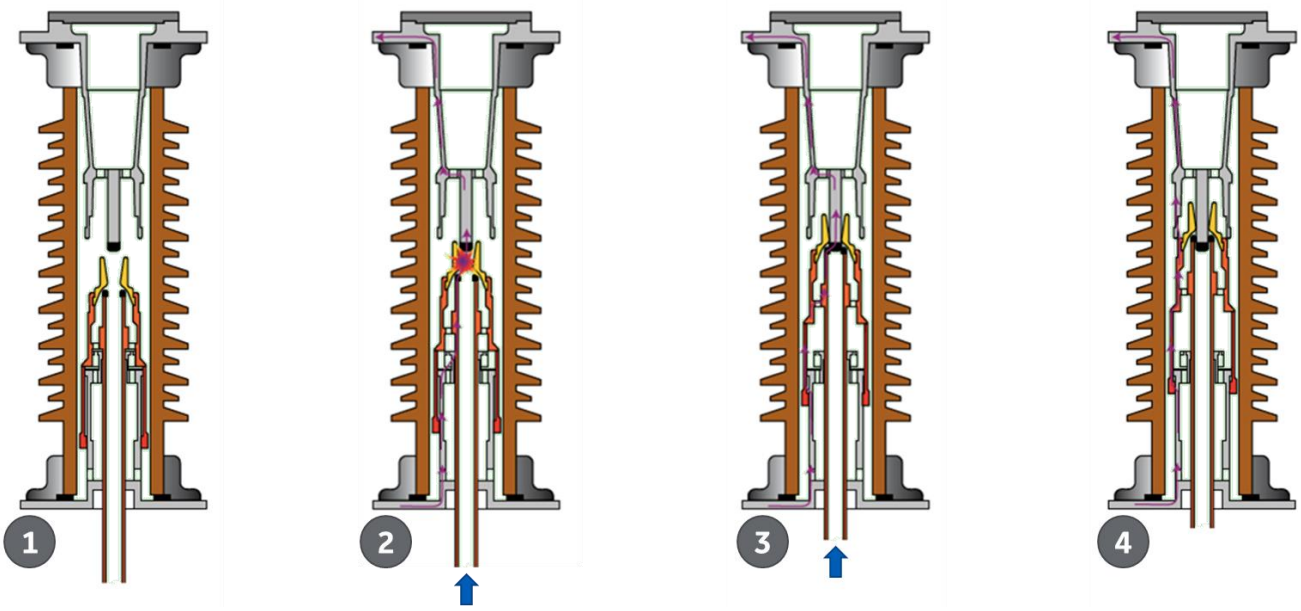


Figure 92 Pre-arcing mechanism in circuit-breaker

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12.5.8.2 Pre-arcing time

Pre-arcing time is defined as the interval of time between the initiation of current flow and the instant when the arcing contacts touch (mechanical closing time of the circuit-breaker) during a closing operation.

Typical values of prearcing times are comprised between some tens or hundreds of microseconds (zero source voltage target with high RDDS circuit-breaker, trapped charge, beat minimum…) to a maximum of about 4ms (peak voltage target with poor RDDS). Any value larger than 4ms is questionable.

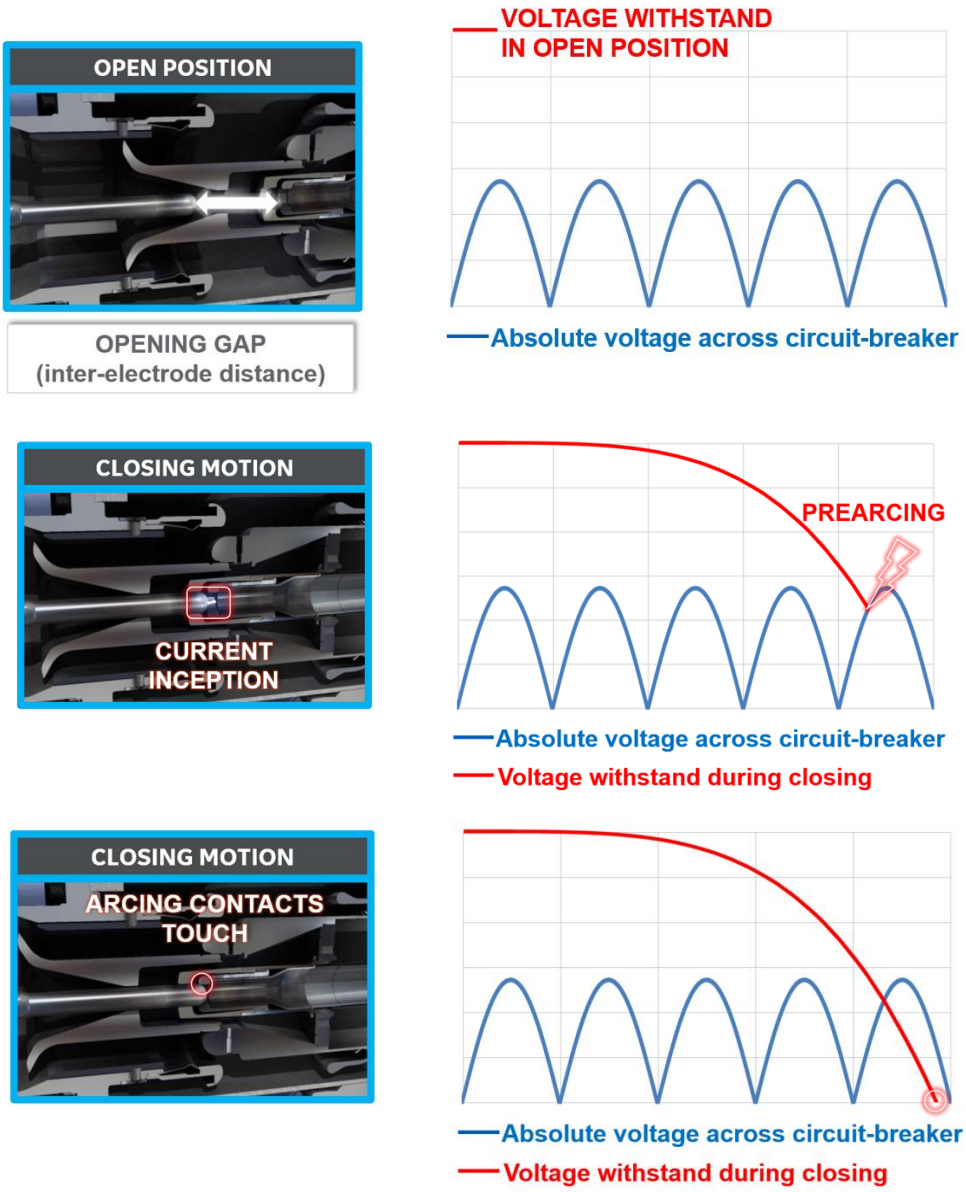


Figure 93 Pre-arcing time illustration

Note: in the following sections, what is called pre-arcing time is the time difference from making target and mechanical contact touch.

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12.5.8.3 Rate of decay of dielectric strength (R.D.D.S.)

RDDS is the dynamic dielectric withstand while main contacts are in approach.

Dielectric performance varies from one circuit-breaker to another. Circuit breaker with R.D.D.S. value in the range of the voltage slope at the zero crossing of the Phase-to-Earth voltage (considered as equal to 1 p.u. R.D.D.S.) are generally applicable for most demanding targets of controlled switching.

The slope of voltage across circuit breaker at zero crossing (to be compared with R.D.D.S.) is typically expressed in kV/ms, is determined from the following equation:

$$Volt.slope\ @\ zero\ crossing\ (R.D.D.S.[1\ p.u.]) = \frac{2\pi \times f \times V_p}{1000} \qquad (4)$$

where

- f System frequency [Hz]
- $V_p = \sqrt{\frac{2}{3}} \times U_r$ System PH-E peak voltage [kV]

Table 46 Typical circuit breaker R.D.D.S. (1 p.u.)

Network system voltage (PH-PH)	145 kV	230 kV	400 kV	550 kV
1 p.u. RDDS (50 Hz)	38 kV/ms	59 kV/ms	103 kV/ms	142 kV/ms
1 p.u. RDDS (60 Hz)	45 kV/ms	71 kV/ms	124 kV/ms	170 kV/ms

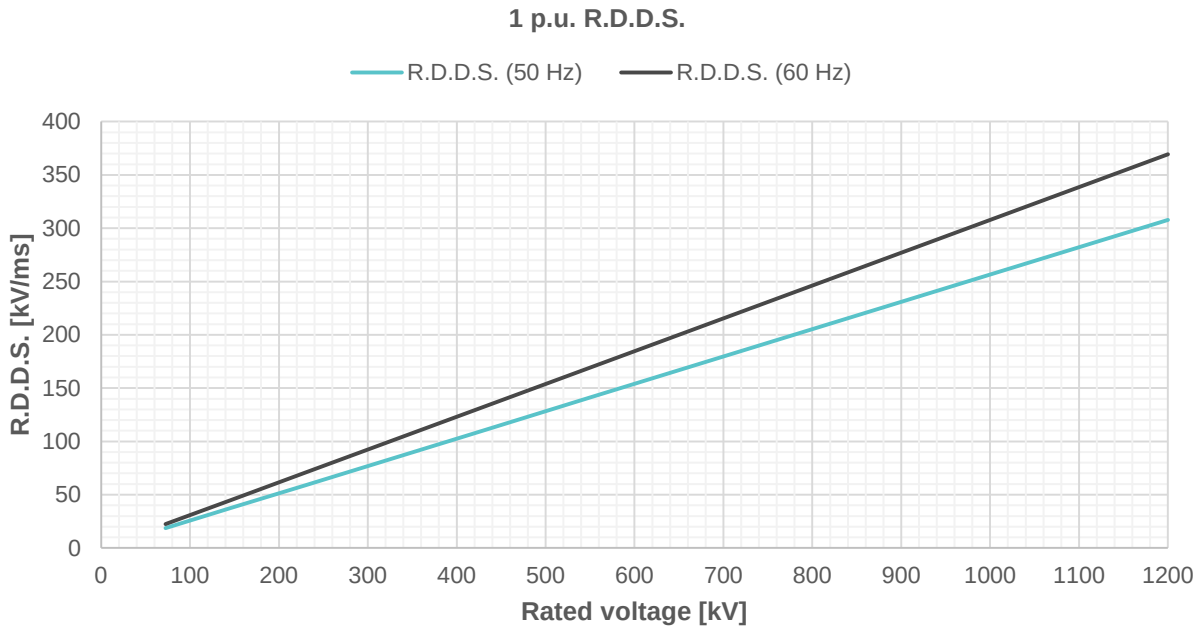


Figure 94 Representation of 1 p.u. R.D.D.S.

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For all **fixed targets** strategies, prearcing computation necessarily includes possible mechanical deviation (closing time scatter) of the circuit breaker, since it can inappropriately advance or delay the actual making time. Thus, prearcing time computation aims to balance consequence of early and late prearcing instants, knowing the statistical mechanical scatter of the circuit breaker.

For **variable target** strategies, prearcing times are computed automatically. On one hand, mechanical scatter defines forbidden target areas. On the other hand, prearcing times for allowed areas are simply computed by dividing targeted voltage level by the circuit breaker RDDS.

Notes:

- For some switching applications where the applied voltage at the circuit-breaker terminals is higher than 1 p.u. (isolated neutral), circuit-breakers with higher rating than the system rated voltage may be considered;

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12.5.8.4 Zero voltage making

12.5.8.4.1 Pre-arcing balance method

As shown in Figure 95 the controller aims slightly after the actual voltage zero to have an equal probability of prestrike at each side of voltage zero. As the risk is higher on the left, pre-arcing time tends to shift to the right. Pre-arcing time parameter value T_{prearc} is determined as follows:

$$T_{prearc} = \frac{V_p}{RDDS} \times sin(\omega \times 3\sigma) \qquad (5)$$

where:

- T_{prearc} Pre-arcing time [ms]
- $V_p = \sqrt{\frac{2}{3}} \times U_r$ Peak voltage at circuit-breaker terminals [kV]
- $\omega = 2\pi \times f$ Network beat [rad/s]
- 3σ Circuit-breaker closing time scatter ($\pm 3\sigma$) [s] (typically expressed in ms)
- $RDDS$ Rate of decrease of dielectric strength [kV/ms]

It is not suitable to target exactly the zero crossing (zero prearcing condition) since the circuit-breaker mechanical scatter and the finite RDDS value introduce a risk of early pre-arcing with preceding voltage alternance.

Notes:

- Use case of capacitor bank (discharged) or line pick-up (energization).
- Peak voltage at circuit-breaker terminals may vary depending on the system neutral position.
- The parameter T_{prearc} corresponds to the necessary target for arcing contact touch move to get equalized risk of pre-strike at both side of this target.

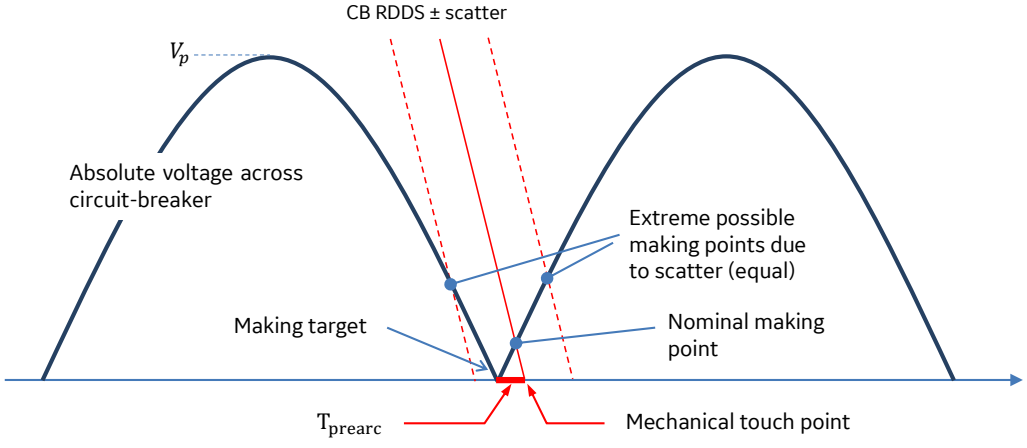


Figure 95 Zero-voltage making characteristic – Pre-arcing balance method

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12.5.8.4.2 Rising slope target method

For some circuit-breaker with small closing time scatter, an alternative consisting in targeting making on the voltage rising slope may produce acceptable results in term of making voltage. Pre-arcing time parameter value T_{prearc} is determined as follows:

$$T_{prearc} = 3\sigma \qquad (6)$$

where

- T_{prearc} Pre-arcing time [ms]
- 3σ Circuit-breaker closing time scatter ($\pm 3\sigma$) [s] (typically expressed in ms)

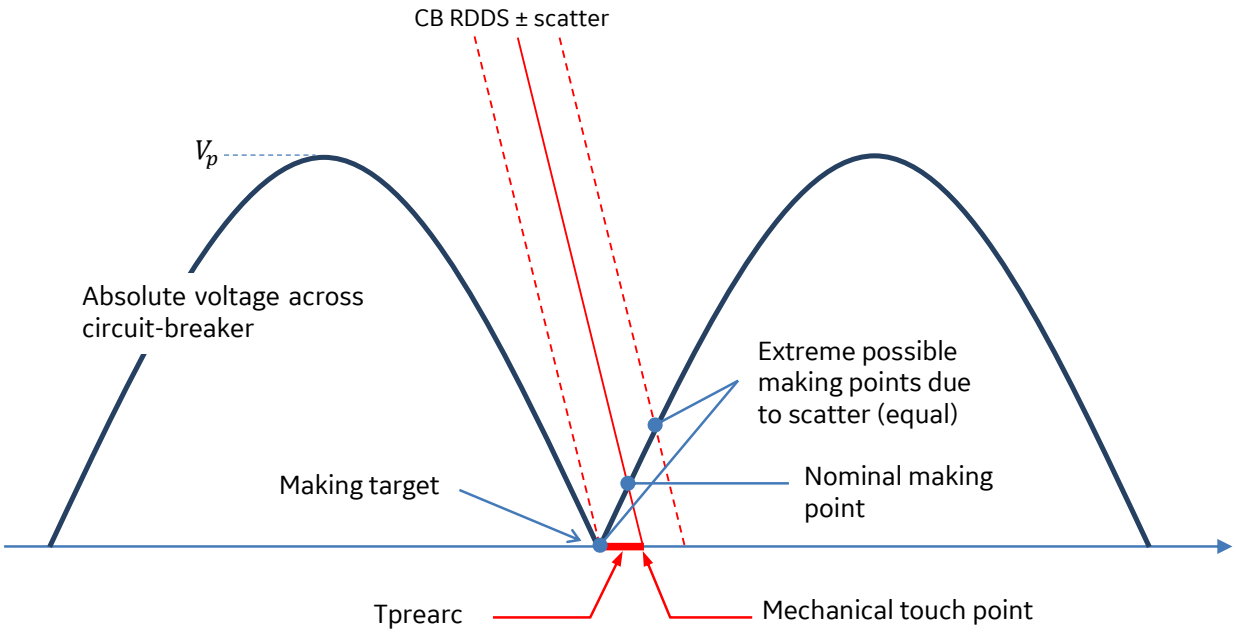


Figure 96 Zero-voltage making characteristic – Rising slope target method

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12.5.8.5 Peak voltage making

12.5.8.5.1 Pre-arcing balance method

As shown in Figure 97 the controller aims slightly before the actual voltage peak in order to have an equal probability of pre-arcing at each side of voltage peak. As the risk is higher on the right, pre-arcing time tends to shift to the left. Pre-arcing time value $\mathrm{T}_{\mathrm{prearc}}$ is determined as follows:

$$\mathrm{T}_{\mathrm{prearc}} = \frac{V_p}{RDDS} \times \cos(\omega \times 3\sigma) \qquad (7)$$

where:

- $\mathrm{T}_{\mathrm{prearc}}$ Pre-arcing time [ms]
- $V_p = \sqrt{\frac{2}{3}} \times U_r$ Peak voltage at circuit-breaker terminals [kV]
- $\omega = 2\pi \times f$ Network beat [rad/s]
- 3σ Circuit-breaker closing time scatter ($\pm 3\sigma$) [s] (typically expressed in ms)
- $RDDS$ Rate of decrease of dielectric strength [kV/ms]

Notes:

- Use case of shunt-reactor switching or power transformer switching with fixed target strategy.
- Peak voltage at circuit-breaker terminals may vary depending on the system neutral position.

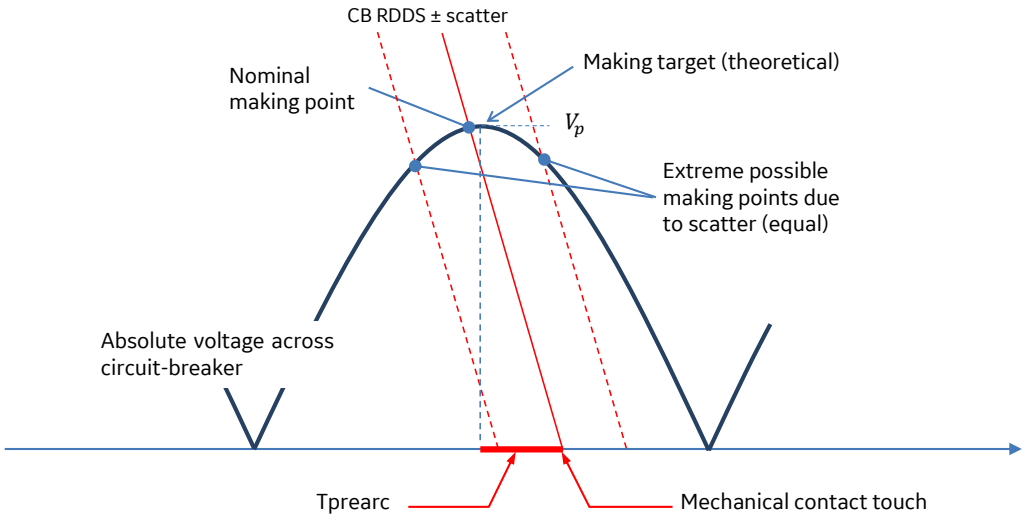


Figure 97 Peak-voltage making characteristic – Pre-arcing balance method

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12.5.8.5.2 Rising slope target method

For some circuit-breaker with large closing time scatter or lower RDDS, an alternative consisting in targeting making on the voltage rising slope may produce acceptable results in term of making voltage. Pre-arcing time parameter value $\mathrm{T_{prearc}}$ is determined as follows

$$T_{prearc}[ms] = \frac{V_p}{RDDS} - 3\sigma \qquad (8)$$

where:

- $\mathrm{T_{prearc}}$ Pre-arcing time [ms]
- $V_p = \sqrt{\frac{2}{3}} \times U_r$ Peak voltage at circuit-breaker terminals [kV]
- 3σ Circuit-breaker closing time scatter ($\pm 3\sigma$) [ms]
- $RDDS$ Rate of decrease of dielectric strength [kV/ms]

Notes:

- Use case of shunt-reactor switching or power transformer switching with fixed target strategy.
- Peak voltage at circuit-breaker terminals may vary depending on the system neutral position.

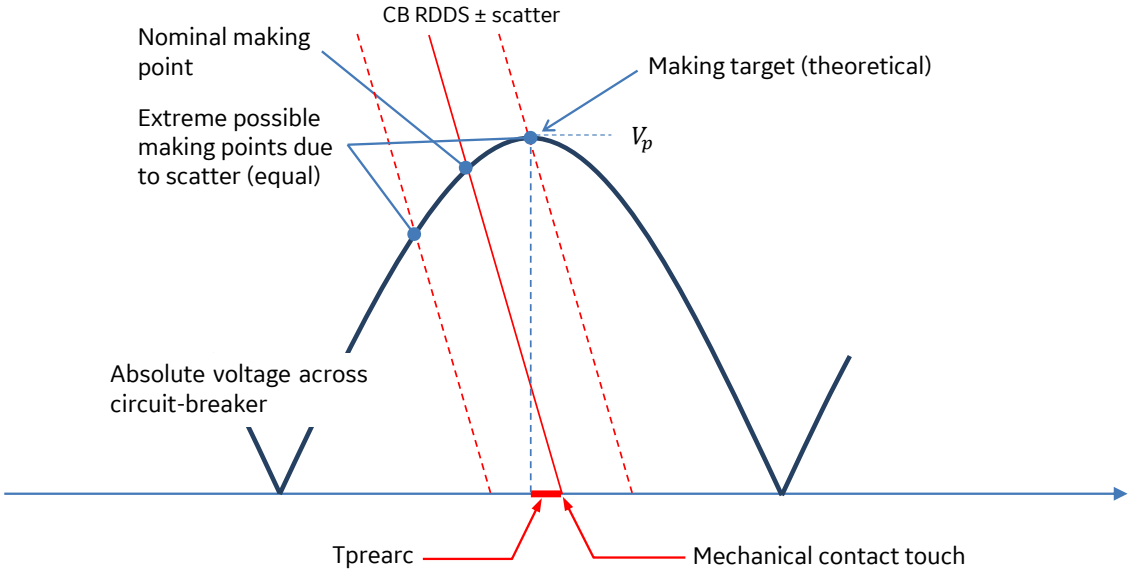


Figure 98 Peak-voltage making characteristic – Rising slope target method

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12.5.8.6 Making at variable angle

For switching applications using variable or non-singular targets, pre-arcing time is computed using the formula:

$$\mathrm{T_{prearc}} = \frac{V_p}{RDDS} \times sin\left(\alpha \times \frac{\pi}{180}\right) \qquad (9)$$

where:

- $\mathrm{T_{prearc}}$ Pre-arcing time [ms]
- $V_p = \sqrt{\frac{2}{3}} \times U_r$ Peak voltage at circuit-breaker terminals [kV]
- α Switching target (angle from previous voltage zero crossing) [deg]
- $RDDS$ Rate of decrease of dielectric strength [kV/ms]

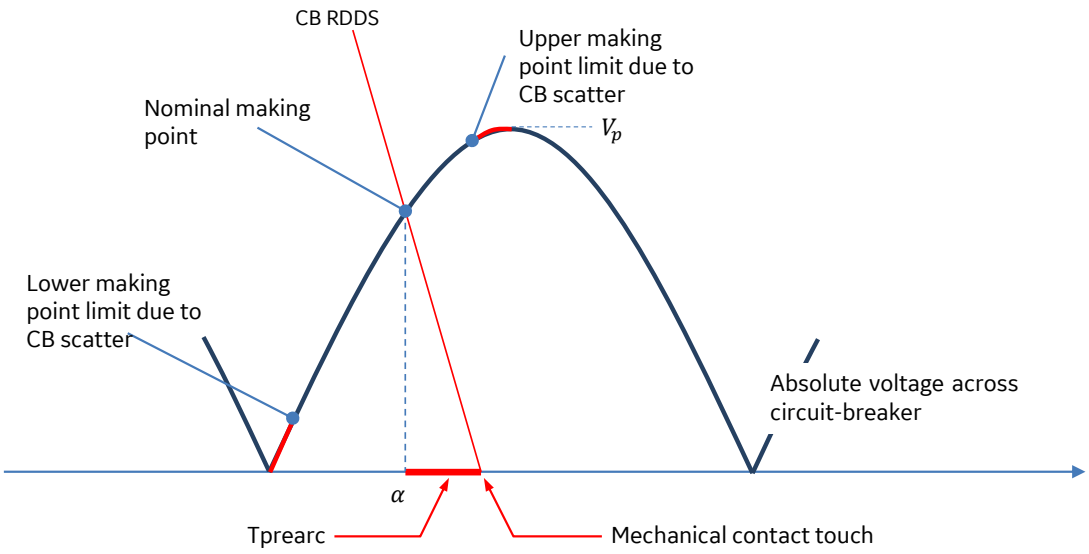


Figure 99 Variable angle making characteristic

Notes:

- Use case of power transformer applications using variable targets, pre-arcing time is automatically computed.
- Peak voltage at circuit-breaker terminals may vary depending on the system neutral position.
- Limit angles, lower making point limit and upper making point limit due to scatter, are defined in 12.9.4.3.5.

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12.5.8.7 Specific consideration for application with d.c. trapped charge

12.5.8.7.1 Application with full d.c. trapped charge

This situation leads to very short pre-arcing times, due to the large time window at reduced voltage.

$$\mathrm{T_{prearc}} = \frac{V_p}{RDDS} \times [1 - \cos(\omega \times 3\sigma)] \qquad (10)$$

where:

- $\mathrm{T_{prearc}}$ Pre-arcing time [ms]
- $V_p = \sqrt{\frac{2}{3}} \times U_r$ Peak voltage at circuit-breaker terminals [kV]
- $\omega = 2\pi \times f$ Network beat [rad/s]
- 3σ Circuit-breaker closing time scatter ($\pm 3\sigma$) [s] (typically expressed in ms)
- $RDDS$ Rate of decrease of dielectric strength [kV/ms]

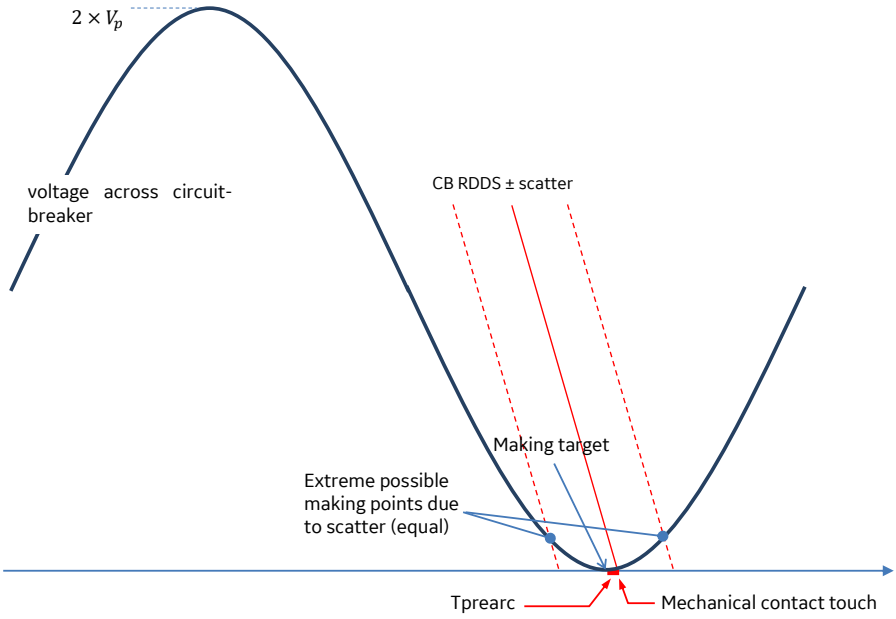


Figure 100 100% d.c. trapped charge making characteristic

Notes:

- Use case of uncompensated transmission line application with CVT (reclosing) or capacitor bank application with immediate closing after controlled opening;
- Peak voltage at circuit-breaker terminals may vary depending on the system neutral position.

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12.5.8.7.2 Application with d.c. trapped charge q

When energizing a load that has kept a d.c. trapped charge q, in p.u., the making target is defined as:

$$Target\ [deg] = 180 \times \left(1 - \frac{1}{\pi} \times \sin^{-1} q\right) \quad (11)$$

$$Target\ [ms] = \frac{1}{\omega} \times (\pi - \sin^{-1} q) \quad (12)$$

Prearcing time, in ms, is thus defined as:

$$T_{prearc} = \frac{V_p}{RDDS} \times sin(\omega \times 3\sigma) \times \sqrt{1 - \left[\frac{q}{cos(\omega \times 3\sigma)}\right]^2} + \frac{1}{\omega} \times \left\{cos^{-1}\left[\frac{q}{cos(\omega \times 3\sigma)}\right] - cos^{-1}(q)\right\} \quad (13)$$

where:

- T_{prearc} Pre-arcing time [ms]
- $V_p = \sqrt{\frac{2}{3}} \times U_r$ Peak voltage at circuit-breaker terminals [kV]
- $\omega = 2\pi \times f$ Network beat [rad/s]
- 3σ Circuit-breaker closing time scatter ($\pm 3\sigma$) [s] (typically expressed in ms)
- $RDDS$ Rate of decrease of dielectric strength [kV/ms]
- q d.c. trapped charge [p.u.]

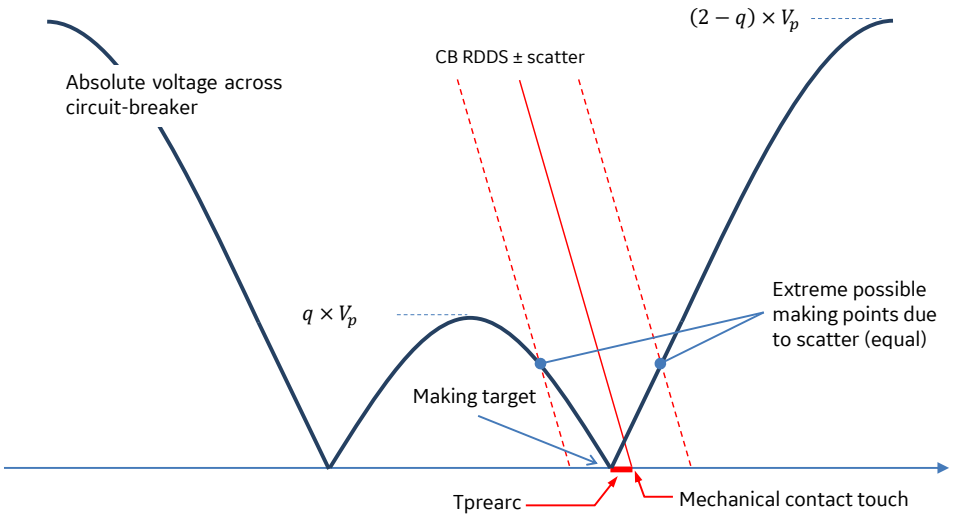


Figure 101 50% d.c. trapped charge making characteristic

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12.5.8.8 Specific consideration for line application with oscillatory trapped charge

When reclosing a shunt-reactor compensated line with a self-oscillating mode at line side (typ. healthy phases), i.e. at voltage beat minimum across the circuit-breaker contacts, a conservative approach consists in applying same prearcing time as for closing at voltage zero since damping of the voltage at line side cannot be predicted with a good accuracy (Figure 102). Prearcing time, in ms, is thus defined as:

$$T_{prearc}[ms] = \frac{V_p}{RDDS} \times sin(\omega \times 3\sigma)$$

or

$$T_{prearc}[ms] = 3\sigma$$

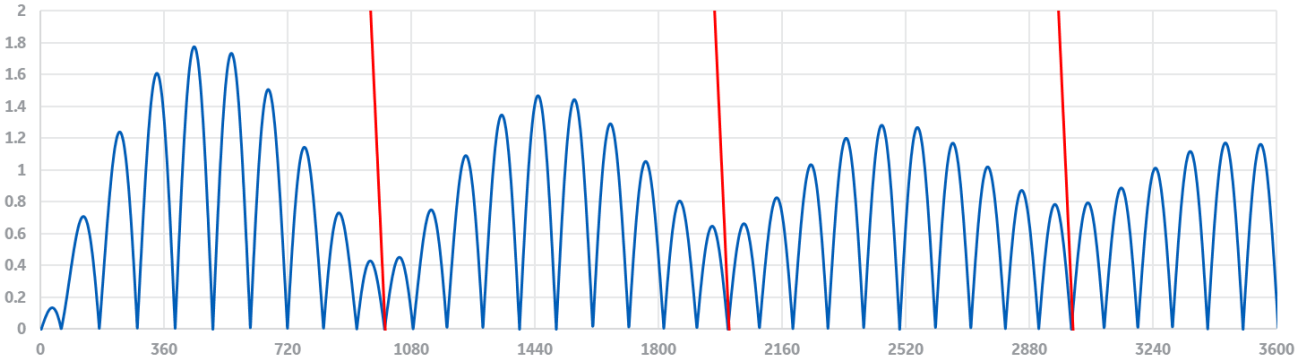


Figure 102 Reclosing at beat-minimum characteristics

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12.5.8.9 Specific consideration for power transformers case (fixed angles strategy)

With fixed target strategy, pre-arcing times must be set. Although peak voltages are targeted, because of various transformer topologies and phase to phase dependence, voltage amplitude and number of circuit breaker poles to be closed at one time may vary, which lead to different input values to the same formula.

$$\mathrm{T_{prearc}} = \frac{V_p}{RDDS} \times \cos(\omega \times 3\sigma) \qquad (14)$$

where:

- $\mathrm{T_{prearc}}$ Pre-arcing time [ms]
- $V_p = \sqrt{\frac{2}{3}} \times U_r$ Peak voltage at circuit-breaker terminals [kV]
- $\omega = 2\pi \times f$ Network beat [rad/s]
- 3σ Circuit-breaker closing time scatter ($\pm 3\sigma$) [s] (typically expressed in ms)
- $RDDS$ Rate of decrease of dielectric strength [kV/ms]

Peak voltage and RDDS values considered for pre-arcing time computation are summarized in below table (switching at fixed angles).

Table 47 Inputs for pre-arcing time computation

Case	Switching side	Prearc inputs	Ph ref	Ph -120°	Ph -240°
1	Star with earthed neutral	Angle	90°	180° + n*180°	180° + n*180°
		Peak voltage Vp	* 1	* √3	* √3
		RDDS	* 1	* 2	* 2
2	Star with isolated neutral Or Delta	Angle	90° + n*180°	0°	0°
		Peak voltage Vp	* 1.5	* √3	* √3
		RDDS	* 1	* 2	* 2
3	Yy with independent core	Angle	90°	30°	150°
		Peak voltage Vp	* 1	* 1	* 1
		RDDS	* 1	* 1	* 1

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12.5.9 Circuit-breaker making time measurement methods

Making times are the exact instants at which voltage is applied to the load and current starts to circulate in the load, usually a few hundreds of microseconds or a few milliseconds before arcing contact touch, due to pre-arcing phenomena. These are the targets for closing operations.

For performance monitoring purpose, CSD100 provides for different methods to assess making times depending on load type and voltage & currents transformers availability on site.

12.5.9.1 Making times from current waveform (“direct threshold” method)

First method (“direct threshold”) is well adapted to loads for which a high current rate of rise is expected, typically capacitive loads. Dating is straightforward (instant at which recorded current waveform crosses a set threshold).

This is the recommended method for capacitor banks and lines.

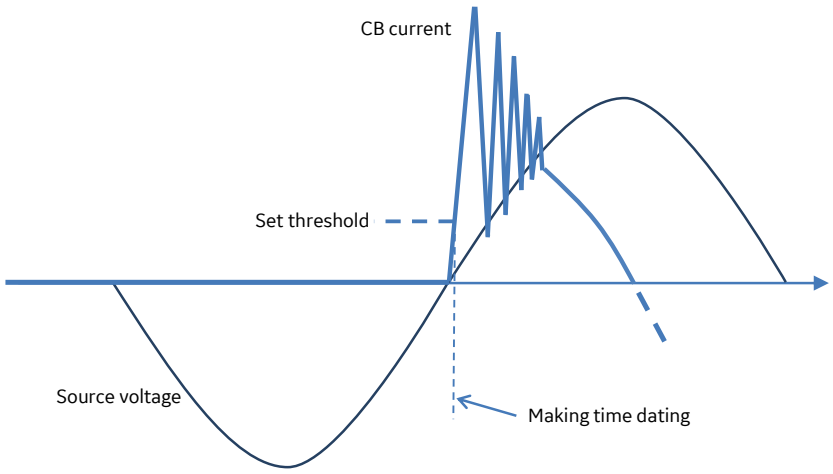


Figure 103 Making times from current waveform (direct threshold method)

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12.5.9.2 Making times from current waveform (“reconstruction” method)

Second method (“reconstruction”) is well adapted to loads for which current establish with sine shape, whatever asymmetry takes place or not. Aim is to compensate for threshold additional delay (detection delay), due to low rate of rise of the current.

This is the recommended method for reactors and inductive loads.

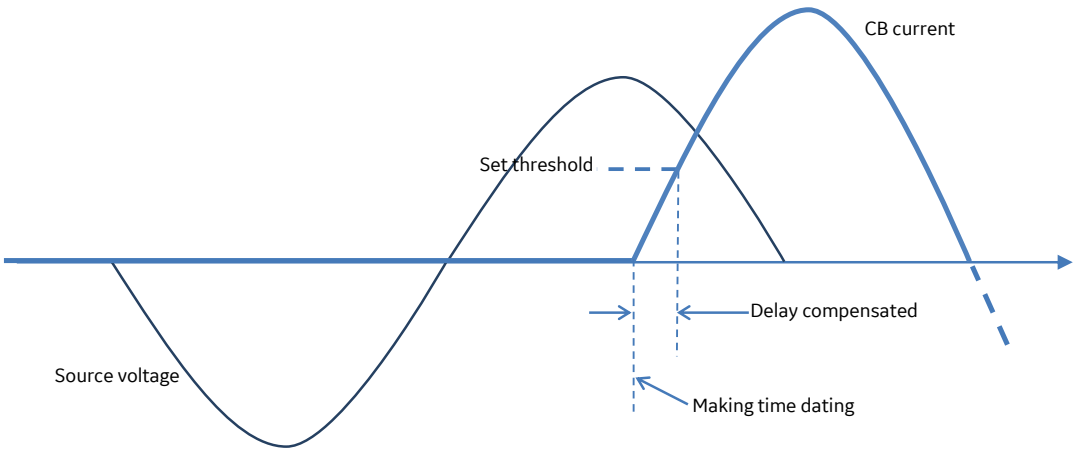


Figure 104 Making times from current waveform (reconstruction method)

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12.5.9.3 Voltage rise method (Making times from load voltage waveform)

When load voltages are available, CSD100 can measure making times from voltage fast variation. This fast variation search is limited to a ±1/4 period time window around the theoretical (expected) making time.

This is the recommended method for power transformers: it is not possible to assess making times from the currents with power transformers because of low magnetizing current amplitude.

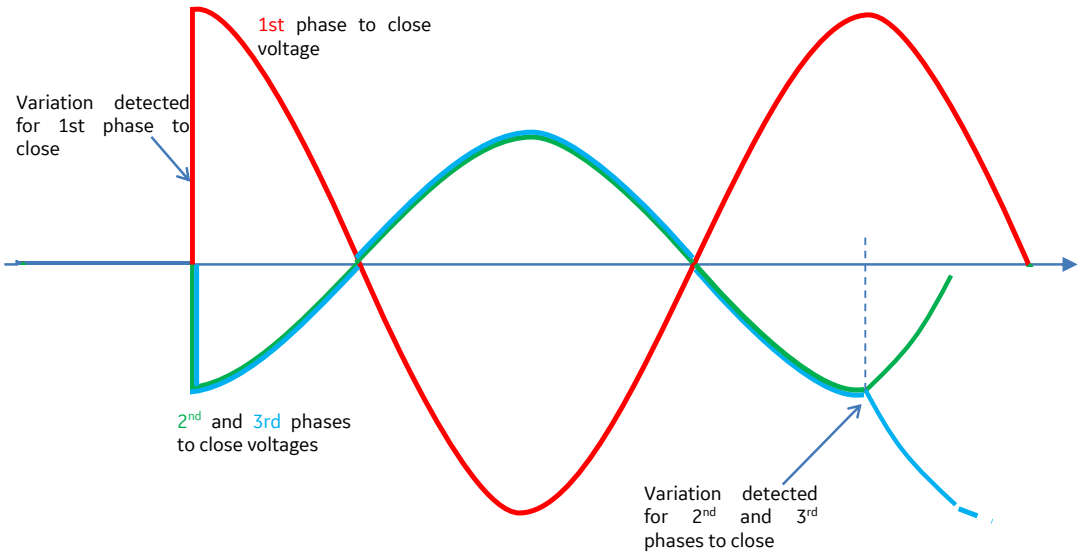


Figure 105 Making times from load voltage waveform (power transformer typical energizing waveforms)

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12.5.10 Circuit-breaker arcing phenomena

12.5.10.1 Definition

Arcing time is defined as the interval of time between the instant of arc initiation (arcing contact separation time or mechanical opening time of the circuit-breaker) and the instant of arc extinction during a breaking operation (instant of current extinction).

- For small inductive current (reactor switching) and capacitive current breaking, where TRV exhibits respectively very steep slope to average slope, the minimum arcing time without re-ignition, typically in the range of 8 to 6ms, should be considered.
- For transformer opening operations, where TRV exhibits low slope, an arcing time in the range of 0.1ms to 1ms should be considered to tend towards transformer demagnetization, provided that proper opening sequence is used.

Note: reactor switching arcing time setting requires attention. The absolute minimum arcing time depends on several values such as circuit breaker filling pressure, circuit breaker velocity, circuit breaker current chopping capability, internal and external stray capacitances, reactor type, reactor neutral grounding. Final arcing time setting is typically chosen as the average between absolute minimum arcing time and half a period of the power network. 8ms is a conservative value for reactor switching.

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12.5.10.2 Arcing mechanism

Figure 106 describes the arcing mechanism that occurs upon circuit-breaker opening operation for load current interruption:

- The circuit-breaker is closed and the load current flows through the main / permanent contacts;
- During opening operation, when the arcing contacts separate, an arc between arcing contacts is established;
- The current pass through the interrupting chamber insulating medium in the form of a conductive gas column, and the arc is cooled down by the circuit-breaker blast and extinguished at current zero crossing;
- The circuit-breaker reaches its open position.

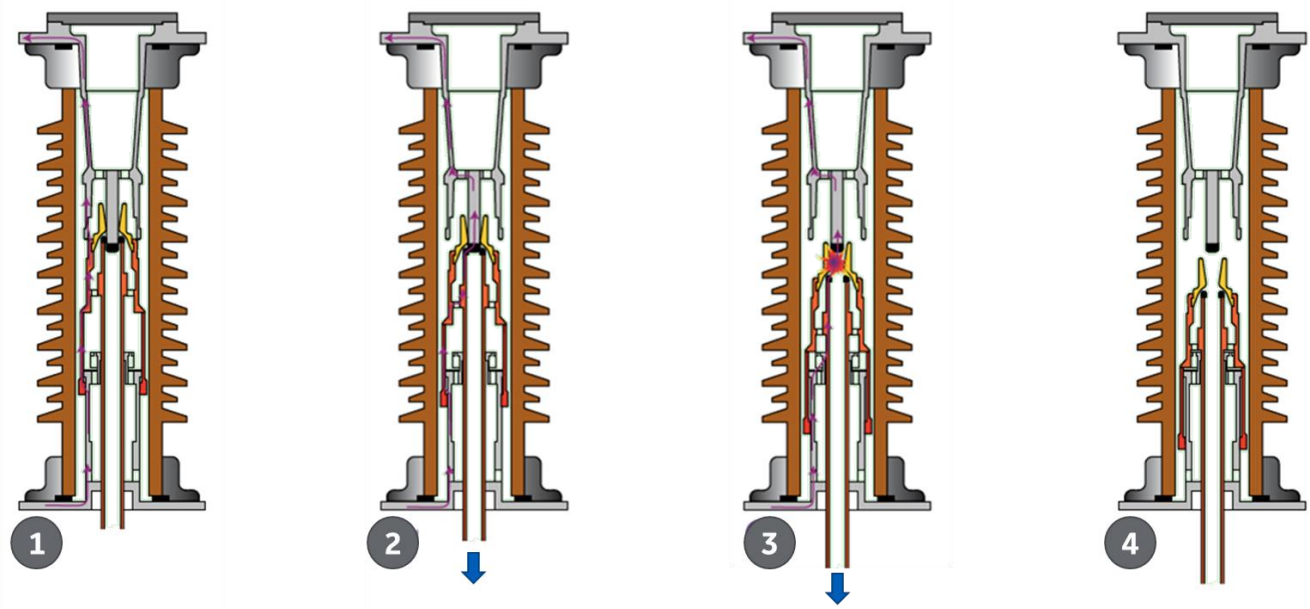


Figure 106 Arcing mechanism in circuit-breaker

Current interruption process is successful if

- Sufficient blast is available from the circuit-breaker interrupting chamber to cool the gas near zero crossing (Thermal regime);
- Inter electrode insulating medium withstands the transient recovery voltage (Dielectric regime)

Otherwise, there's a risk of reignition or restrike

- Thermal reignition / restrike (insufficient blast)
- Dielectric reignition / restrike (insufficient RRDS)

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12.5.10.3 Transient recovery voltage

The recovery voltage is defined as the voltage which appears across the terminals of a pole of a switching device after the breaking of the current.

Transient recovery voltage (T.R.V.) is the recovery voltage during the time in which it has a significant transient character.

Transient recovery voltage is characterized, as described in Figure 107, by:

- Peak value (u_c)
- Time to peak value (t_3)
- Rate of rise of recovery voltage *(RRRV)*

Basically, from a first approach, if the R.R.R.V value is lower than the circuit-breaker R.R.D.S value, the interruption is successful (dielectric regime).

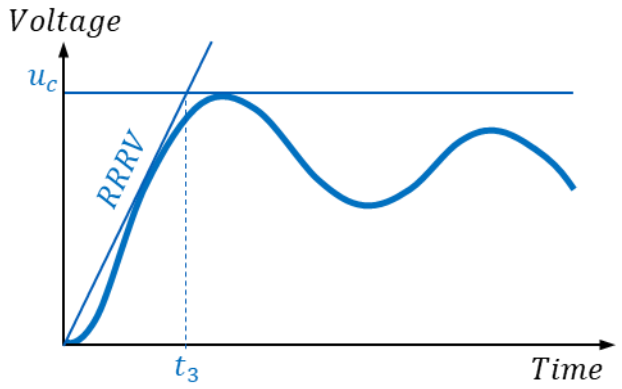


Figure 107 Transient recovery voltage characteristics

Following figures describe the T.R.V. for typical linear load current interruption:

- Figure 108 shows a resistive current interruption T.R.V.
- Figure 109 shows an inductive current interruption T.R.V.
- Figure 110 shows a capacitive current interruption T.R.V.

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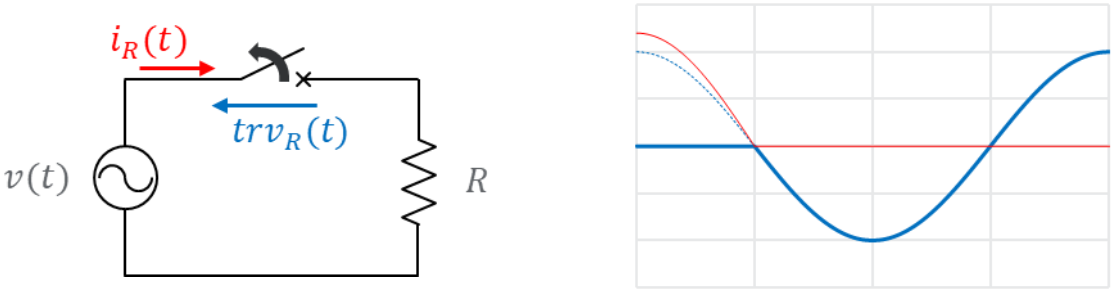


Figure 108 Resistive current interruption T.R.V.

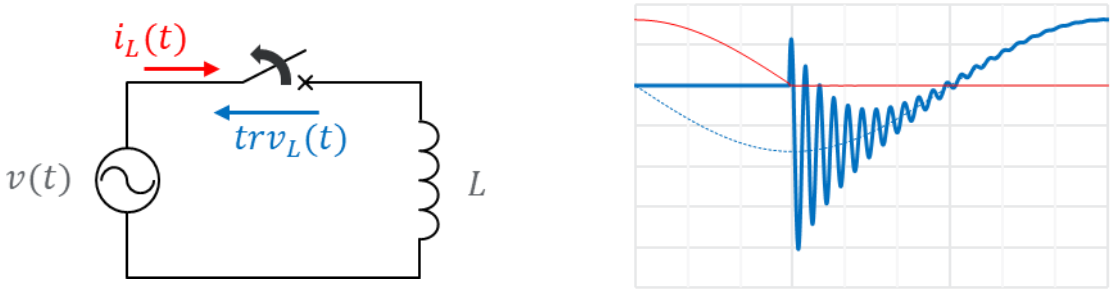


Figure 109 Inductive current interruption T.R.V.

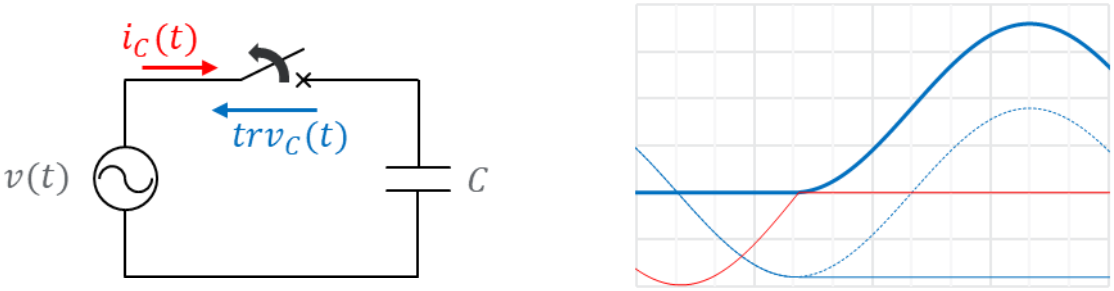


Figure 110 Capacitive current interruption T.R.V.

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12.5.10.4 Current interruption process

Basically, from a first approach, if the R.R.R.V value is lower than the circuit-breaker R.R.D.S value, the interruption is successful (dielectric regime). Otherwise there's a risk of dielectric reignition or restrike.

- Successful interruption: RRDS > RRRV
- Re-ignition or restrike: RRDS < RRRV

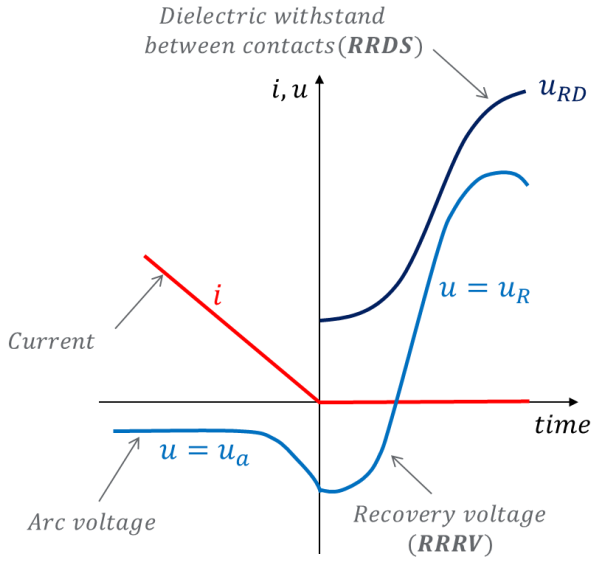


Figure 111 Successful interruption

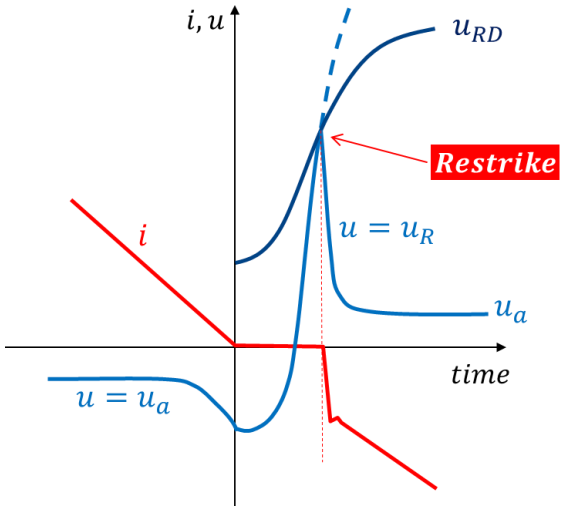


Figure 112 Reignition or restrike

12.5.10.5 Re-ignition and restrike phenomena

Distinction between reignition and restrike is the following:

- Re-ignition occurs before 1/4th period after current interruption
- Restrike occurs after 1/4th period after current interruption

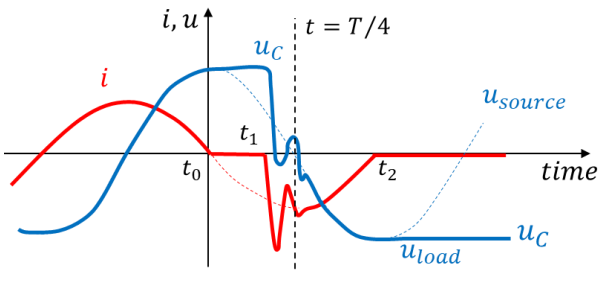


Figure 113 Re-ignition

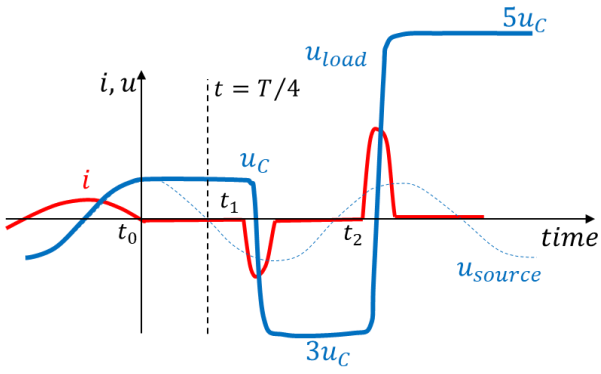


Figure 114 Restrike

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12.5.10.6 Current chopping

In some situations, current is brutally interrupted before its natural zero crossing. This is the current chopping phenomena as described in Figure 115.

Consequence is higher T.R.V. peak value.

This phenomenon is amplified for long arcing time.

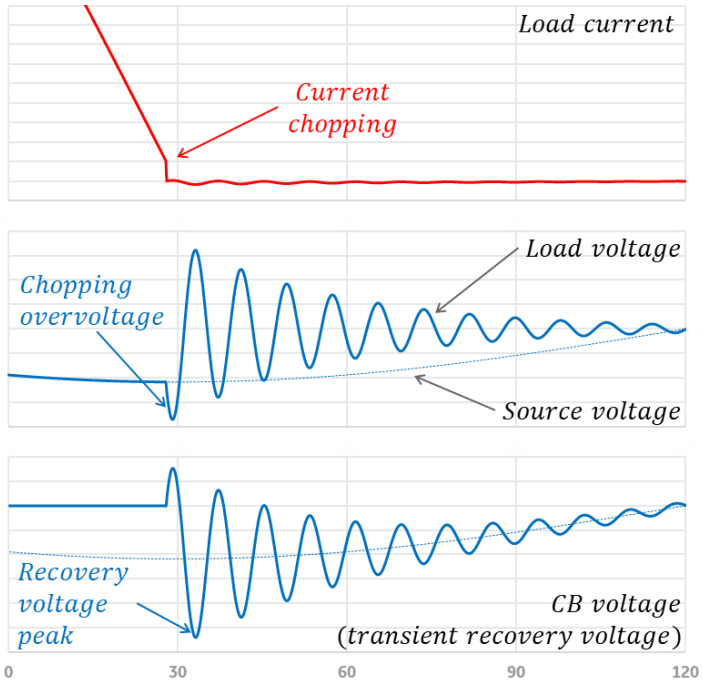


Figure 115 Re-ignition

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12.5.11 Circuit-breaker interrupting time measurement

Arcing times are measured from the prospective instant of contact separation (mechanical time forecast) to the effective current extinction instant, phase by phase. Current extinction detection is carried out in a secured way to cope with low currents (unfavorable signal to noise ratio): 50% automatic threshold and detection delay compensation.

If measured arcing time exceeds half a period, reignition alarm is set.

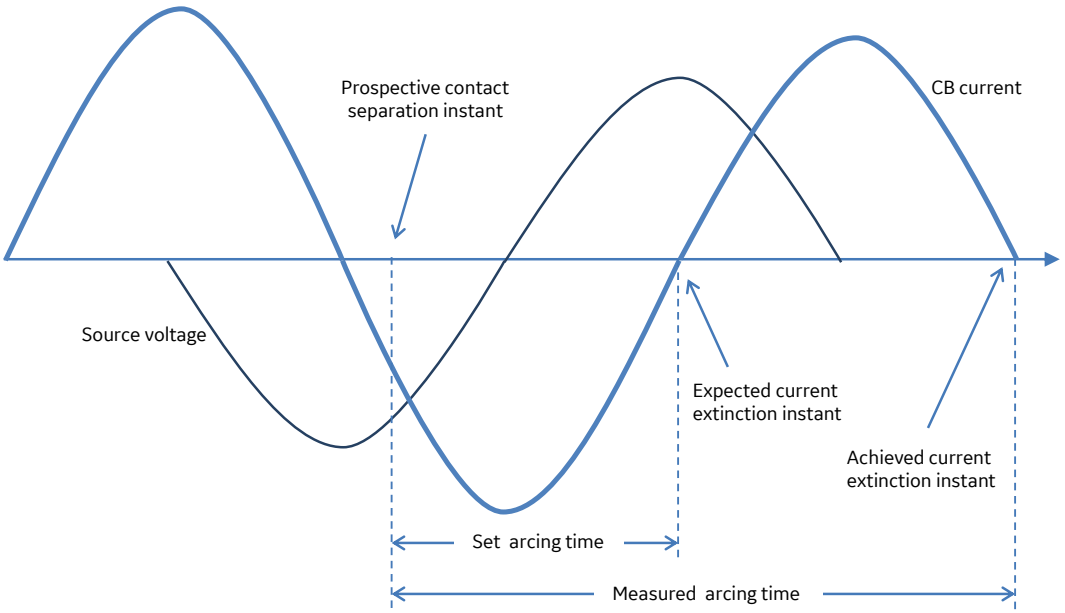


Figure 116 Example of reignition (long arcing time) with inductive circuit: additional half period of current

Note: contact separation instant is not directly measurable during circuit breaker service. There is no significant evidence of contact separation neither on current nor voltage waveforms. Arcing time measurement make use of prospective contact separation instant.

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12.5.12 Circuit-breaker with closing resistor

12.5.12.1 Resistor pre-insertion principle

When using a circuit-breaker with closing resistor, also designated as “pre-insertion resistor” (PIR), the closing time to consider when setting the CSD is the one of the contacts that insert the resistor in the circuit (resistor is “first to close”). This can be either

- The arcing contact of the circuit breaker, for series topology;
- The dedicated pre-insertion switch (PIS), for parallel topology.

In this case, circuit breaker operating time measurement campaign must be adapted to get the relevant timing to set in the controller (“first to close”).

For opening operations, reference is related to arcing contacts only, whatever the pre-insertion principle since only arcing contacts are sized to interrupt normal load and short-circuit currents.

In Figure 117 and Figure 118, following designations are adopted:

- R Closing resistor
- PIS Pre-insertion switch (or Bypass switch)
- CB Interrupting chamber

12.5.12.2 Closing resistor parallel topology

Closing sequence

1. PIS close on resistor (pre-insertion)
2. CB arcing contacts close (bypass of closing resistor, end of “mechanical” pre-insertion time)
3. PIS open

Opening sequence

1. CB arcing contact open

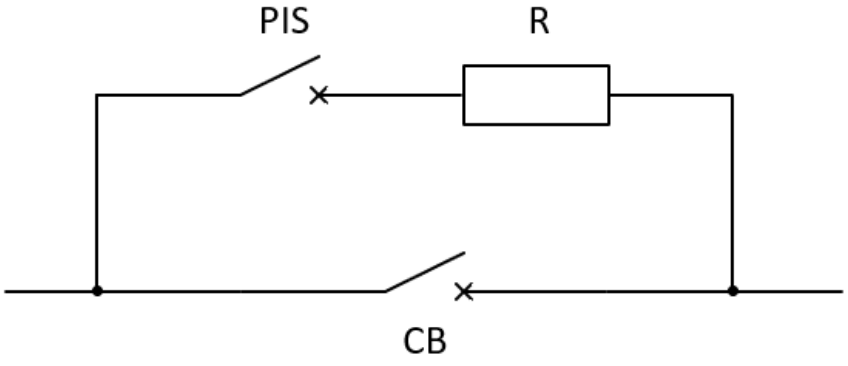


Figure 117 Closing resistor parallel topology

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12.5.12.3 Closing resistor series topology

Closing sequence

1. CB arcing contacts close on resistor (pre-insertion)
2. PIS close (bypass of closing resistor, end of “mechanical” pre-insertion time)

Opening sequence

1. CB arcing contact open
2. PIS open

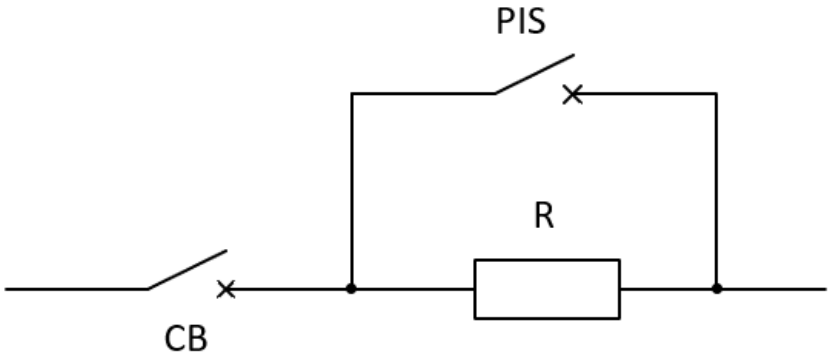


Figure 118 Closing resistor series technology

12.5.12.4 Closing resistor pre-insertion time

Mechanical insertion time is the time difference between instant of “first switch contact touch” (circuit breaker main contacts for series topology or pre-insertion switch for parallel topology) and instant at which resistor is bypassed (“second switch contact touch”).

The electrical insertion time is the mechanical time increased by first switch to close prestrike time and decreased by second switch to close prestrike time.

It is usually larger than mechanical time since voltage conditions across the resistor, when it is time to close second switch, are usually reduced.

Electrical insertion time is the relevant value to assess Pre-insertion resistor(PIR) efficiency when performing transient simulations. Thus, it requires RDDS of first and second switch to be simulated, for most accurate results.

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12.5.13 Circuit-breaker grading capacitors effect

Multi break circuit breakers are sometimes fitted with grading capacitors, to improve voltage repartition between interrupting chambers (RRDS is improved).

Typical values are in the range of 1nF per breaking unit (interrupting chamber).

Thus, circuit breaker being in static open position (ready to close), a small capacitive current is prone to circulate across the circuit breaker, through the load.

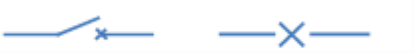
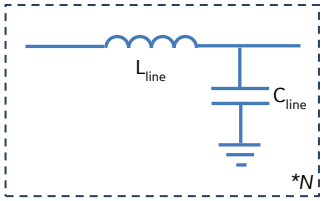
Therefore, if significant voltage is observed at load side before closing, it may be necessary to activate synchronization by reference to differential voltage (source – load), since synchronization targets are slightly shifted.

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12.6 Controlled switching arrangement for various substation layout

In this section, following symbols are used

Table 48 Layout symbols

Description	Symbols
Circuit breaker	
Disconnect switch	
Voltage transformer	
Current transformer	
Shunt reactor	
Capacitor bank	
Transmission line	
Power transformer	

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12.6.1 Single busbar layout

With a single busbar layout, synchronizing voltage is directly accessible from the busbar VT, when available.

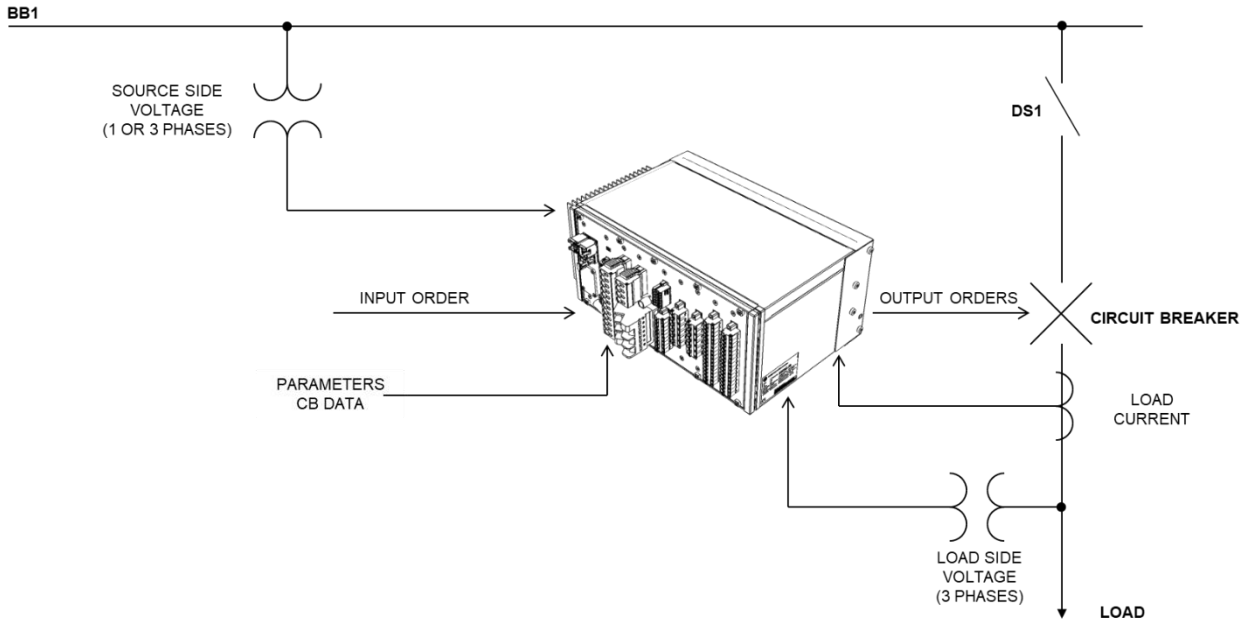


Figure 119 Controlled switching arrangement with single busbar substation layout

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12.6.2 Double busbar layout

With a double busbar layout, synchronizing voltage is accessible from an external voltage selection scheme based on disconnector switch position.

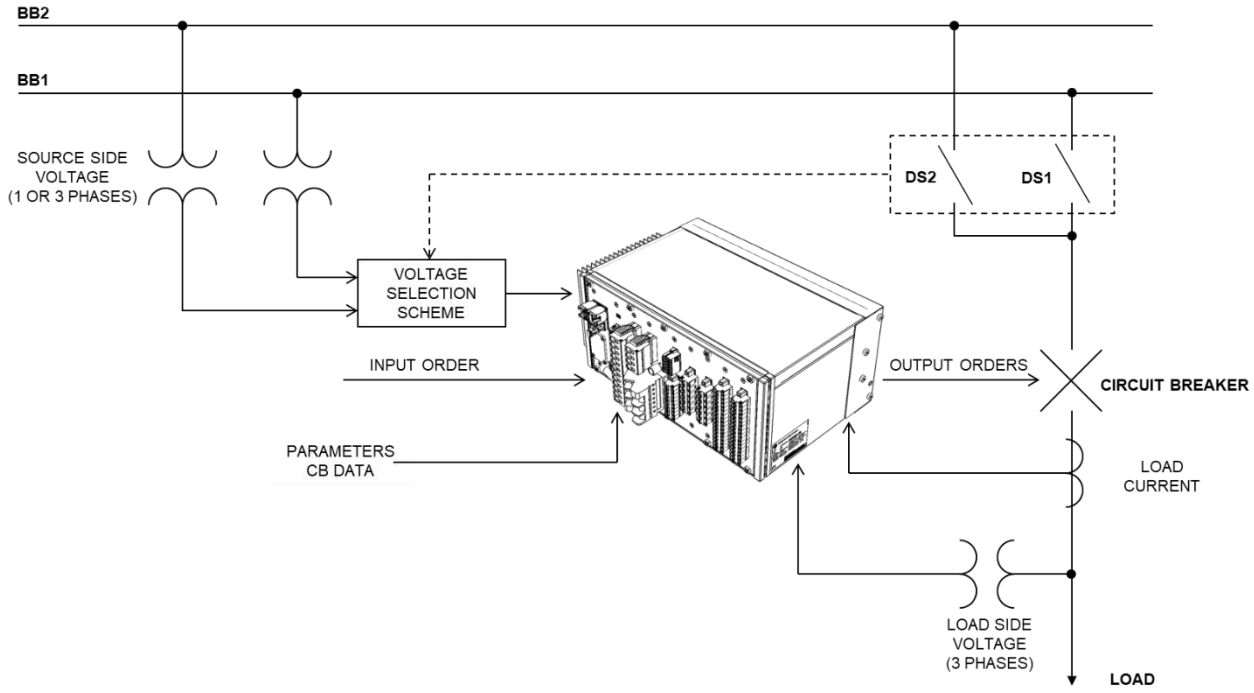


Figure 120 Controlled switching arrangement with double busbar substation layout

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12.6.3 Tie breaker layout

With tie circuit breaker layout, the circuit breaker may be called to switch one or the other side and would require multiple load switching implementation. This concerns following layouts:

- Ring
- 1,5CB
- 1,3CB

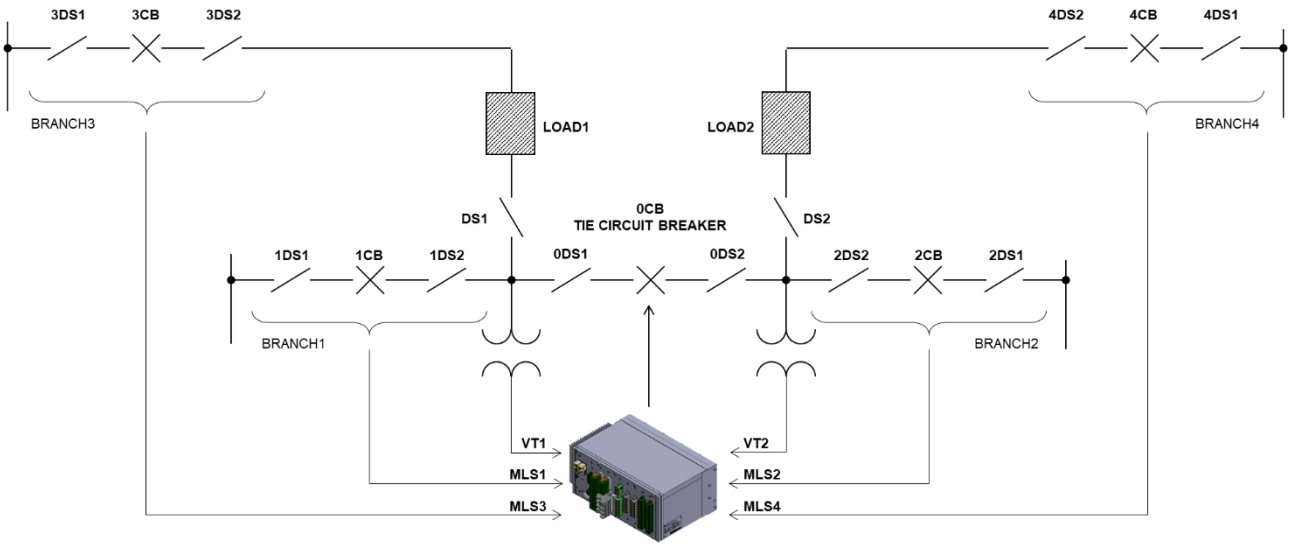


Figure 121 Controlled switching arrangement with tie breaker substation layout

Notes: Use of remote I/O or other communication media may be necessary to transmit information about the position of remote apparatus / devices.

Multiple load switching requires connection of voltages from the three phases at both side of circuit breaker, for correct assessment of load voltages at any time.

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12.7 Shunt reactor switching application

12.7.1 Shunt-reactor switching concerns

Random energizing of shunt reactors produces current asymmetry (Figure 122) that saturates current transformers iron cores and may occasionally lead to protective relay mis-operation. Controlled energizing at each phase respective voltage peak (Figure 123) allows reduction of current asymmetry and improves system reliability.

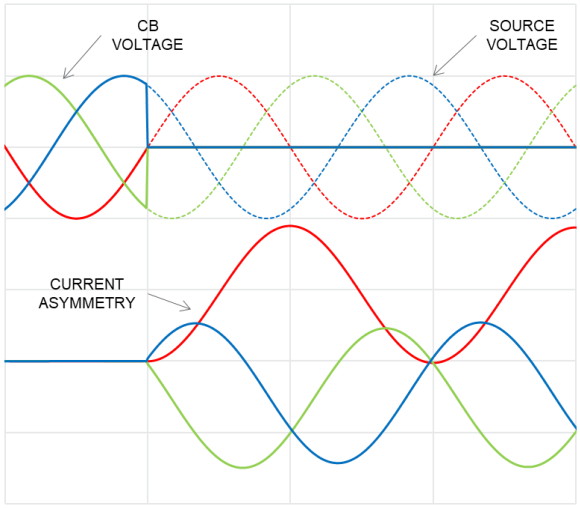


Figure 122 Shunt-reactor random closing

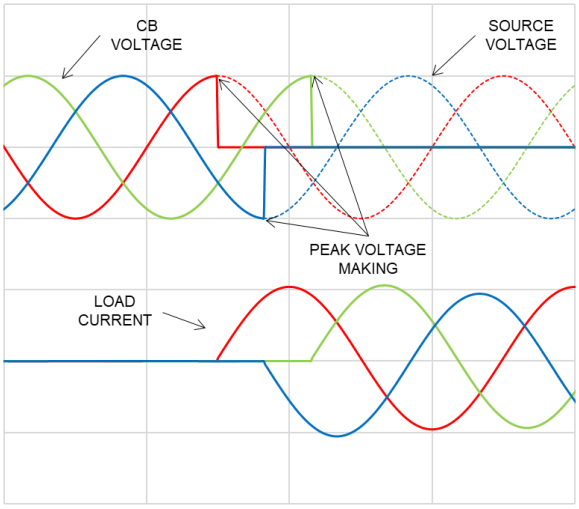


Figure 123 Shunt-reactor controlled closing

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Random opening of shunt reactors statistically leads to current re-ignition in the circuit-breaker interrupting chambers (Figure 124), with consequent steep front overvoltage and accelerated ageing of the circuit-breaker and the shunt-reactor. Controlled opening by optimizing arcing times (Figure 125) and separating arcing contacts within the circuit breaker free-reignition window allows reduction of current reignition probability and increase of equipment lifetime. Contact separation should occur early enough before current zero crossing so that distance between contacts after current interruption is large enough to withstand the transient recovery voltage. Therefore, arcing time control is supported by the CSD100.

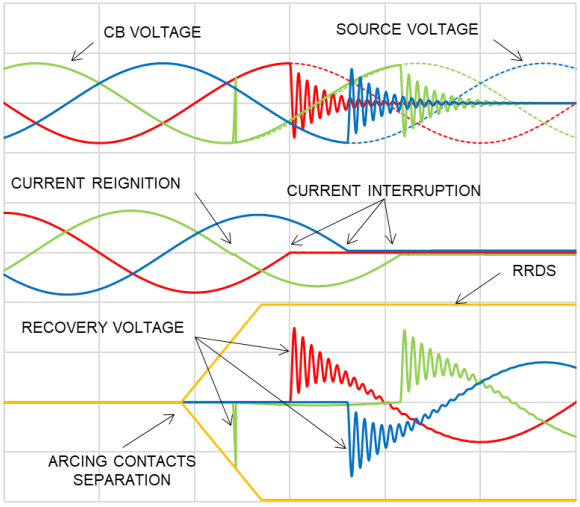


Figure 124 Sunt-reactor simultaneous random opening

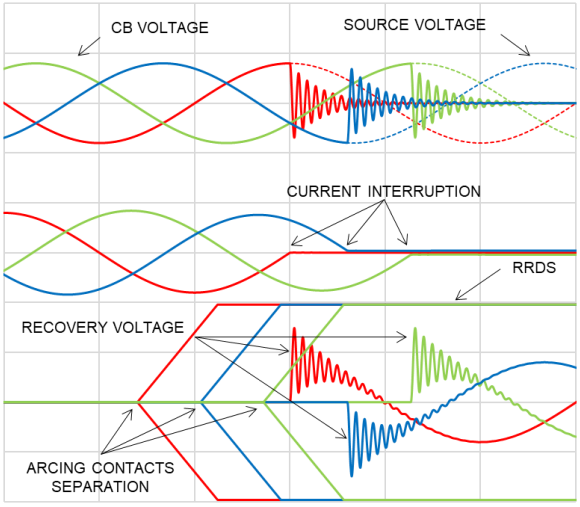


Figure 125 Shunt-reactor controlled opening

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12.7.2 Shunt-reactor controlled switching layout

There is no concern about substation layout for shunt reactor switching. Usually, circuit breaker and reactor are close, which can be considered as a worst case. Indeed, any additional “stray” capacitance from link between circuit breaker and reactor or from surge arrester, voltage transformer… will help to damp the overvoltage from the reactor. From that perspective, GIS substations are favorable.

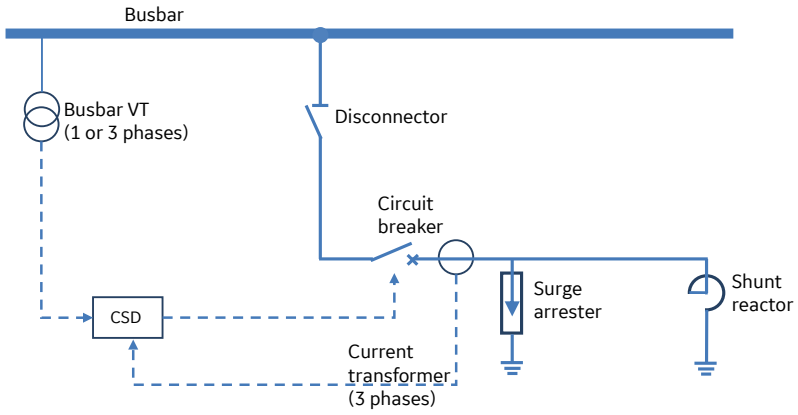


Figure 126 Typical shunt reactor substation layout

For this application, synchronizing reference to be considered

- Source voltage: both synchronized closing and opening operations are based on this voltage reference; load current being considered lagging 90 deg on this pure inductive load;
- Load current: when the “sync on current” option is enabled, synchronized opening is based on this current reference; synchronized closing still refers to source voltage.

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Table 49 Shunt-reactor high voltage signal wiring

Signal wiring	Recommendation
Source voltage	MANDATORY: 1 phase for synchronizing purpose
	ALTERNATIVE: 3 phases may be wired to the controller for automatic selection of synchronizing phase and reduce in / out delay
	VT type / class: 3P protection class or 1.0 metering class (or better) to achieve less than 0.1ms phase displacement in steady voltage condition (50/60Hz)
Load voltage	RECOMMENDED WHEN AVAILABLE: 3 phases If VTs are available at load side, connection to RPH is recommended for closing operations. This helps fine tuning (checking for actual making times, after operation) 1) Making time measurement
	VT type / class: 3PT1, 3PT2 or 3PT3 protection class
Load current	MANDATORY: 3 phases motivation to activate: 1) Synchronized opening operation based on current signal 2) Interrupting time measurement, arcing time measurement and detection of reignition 3) Making time measurement Operating time measurement and compensation by current rise / extinction method (enables to calculate when current making / breaking occurs (reconstruction method) 4) Peak current monitoring upon closing for alarm processing
	CT type / class: Protection class or metering class with nominal primary current higher than two times the rated application current.

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12.7.3 Shunt-reactor description

Shunt reactors may be of different configurations:

- Bank of single-phase air core type reactors;
- Bank of single-phase iron core type reactors;
- Three phase (in a single tank) iron core type reactor with 4 or 5 limbs topology;
- Three phase (in a single tank) iron core type reactor with 3 limbs topology.

Usually, magnetic coupling between reactor phases is null (4 or 5 limbs reactors, bank of single-phase reactors either iron core or air core) or limited (3 limbs reactors). Thus, phase to phase independence shall be considered as the general case. In case of ambiguous situation, please contact GE.



Figure 127 Example of three phase iron core shunt reactor

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12.7.3.1 Shunt-reactor reactive power

Shunt-reactor reactive power Q is defined as:

$$Q = \sqrt{3} \times U_r \times I \qquad (15)$$

where

- Q Shunt-reactor reactive power [VAR] (typically expressed in MVAR)
- U_r System rated PH-PH voltage [V] (typically expressed in kV)
- I Shunt-reactor rated current [A] (typically expressed in A)

12.7.3.2 Shunt-reactor inductance value

Shunt-reactor inductance value is expressed as:

$$L = \frac{U_r^2}{2\pi \times f \times Q} \qquad (16)$$

where

- L Shunt-reactor inductance value [H] (typically expressed in mH)
- Q Shunt-reactor reactive power [VAR] (typically expressed in MVAR)
- U_r System rated PH-PH voltage [V] (typically expressed in kV)
- f System rated frequency [Hz]

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12.7.4 Shunt-reactor controlled closing

Since reactors are generally air core or gapped core type, saturation effect is limited or nonexistent. Therefore, the maximum peak current value that may be observed upon closing is about two times the shunt reactor rated current value and is due to current asymmetry (reactor operated far from ideal current continuity condition).

- Solidly earthed shunt-reactor: Phases are independent from each other and operated at respective voltage peaks;
- Neutral isolated shunt reactor: Two phases shall be closed simultaneously, to allow for current flowing. Target is the peak of source differential voltage. Then, the last phase is closed upon peak of voltage difference between neutral point and source.
- NGR earthed shunt reactor: The ideal switching point of the 2nd phase to operate is slightly anticipated, considering a correction angle, compared to the situation where the reactor neutral connection is solidly earthed.

Following sections introduce closing targets and prearcing times.

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12.7.4.1 Shunt reactor with neutral point solidly grounded (close)

Phases are independent from each other and operated at respective voltage peaks.

Table 50 Solidly grounded shunt-reactor closing program

Switching program	Phase	Angle [deg]	Prearcing time [ms]
React1(*)	L1 (ref)	90	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \cos(\omega \times 3\sigma)$
	L2 (ref - 120 deg)	30	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \cos(\omega \times 3\sigma)$
	L3 (ref + 120 deg)	150	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \cos(\omega \times 3\sigma)$
React1(**)	L1 (ref)	90	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \cos(\omega \times 3\sigma)$
	L2 (ref - 120 deg)	210	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \cos(\omega \times 3\sigma)$
	L3 (ref + 120 deg)	330	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \cos(\omega \times 3\sigma)$

(*) Traditional closing angles.

(**) CSD100 default settings: closing angles set to target making on positive peak values, angles being adjustable using the CSD100 control interface.

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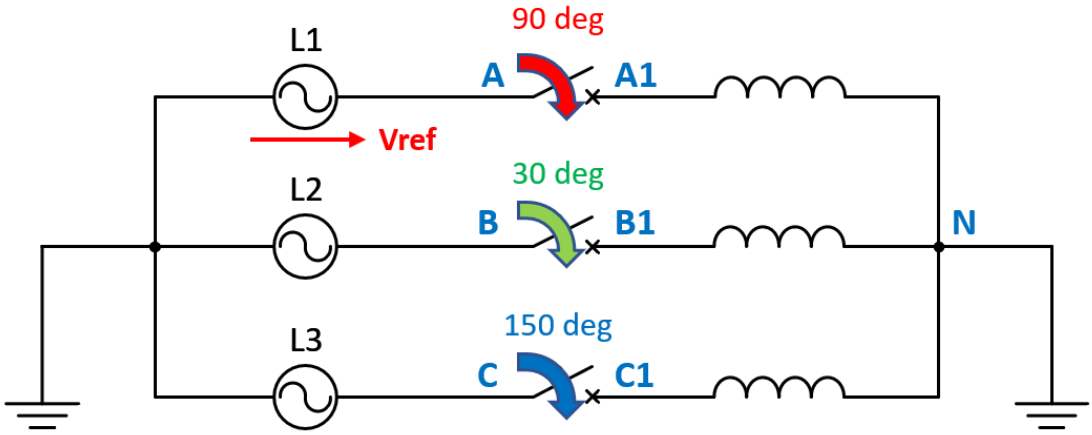


Figure 128 Solidly grounded shunt-reactor closing sequence

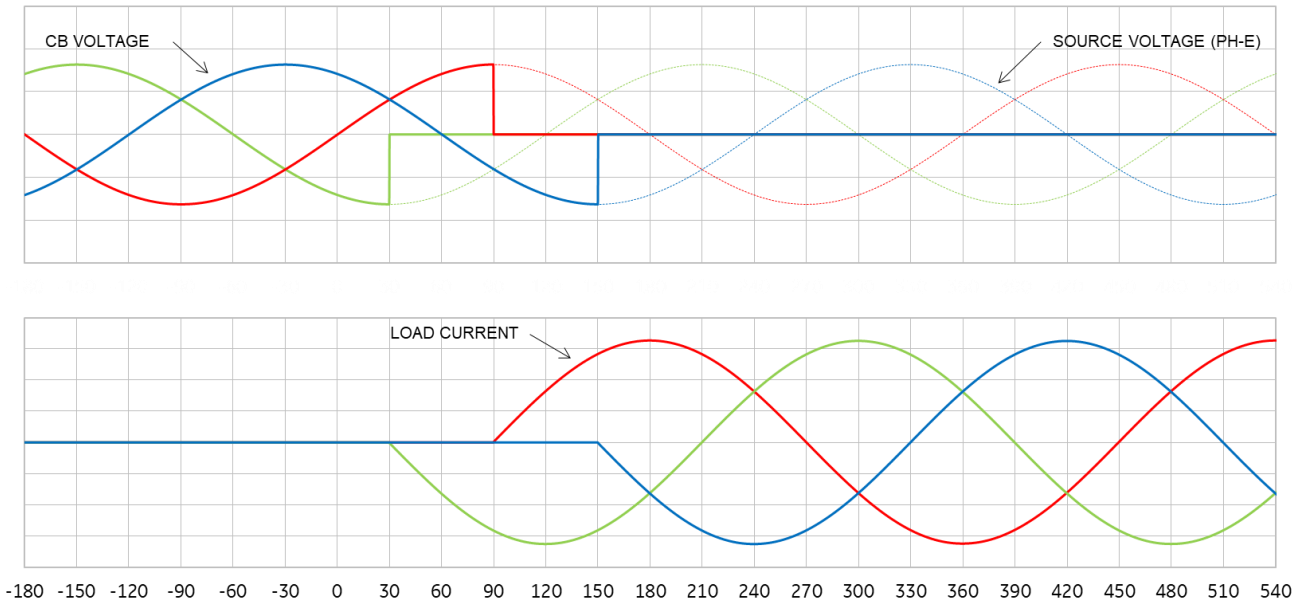


Figure 129 Solidly grounded shunt-reactor closing waveforms

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12.7.4.2 Shunt reactor with neutral point isolated (close)

Two phases shall be closed simultaneously, to allow for current flowing. Target is the peak of source differential voltage.

Then, the last phase is closed upon peak of voltage difference between neutral point and source.

Table 51 Neutral isolated shunt-reactor closing program

Switching program	Phase	Angle [deg]	Prearcing time [ms]
React2 (*)	L1 (ref)	90	$\frac{3}{2} \times \sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \cos(\omega \times 3\sigma)$
	L2 (ref - 120 deg)	0	$\frac{\sqrt{3}}{2} \times \sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \cos(\omega \times 3\sigma)$
	L3 (ref + 120 deg)	0	$\frac{\sqrt{3}}{2} \times \sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \cos(\omega \times 3\sigma)$

(*) CSD100 default settings.

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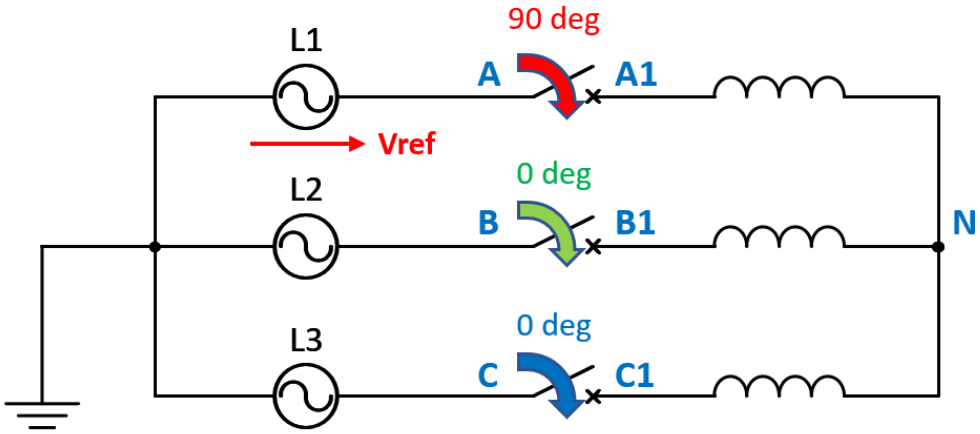


Figure 130 Isolated neutral shunt-reactor closing sequence

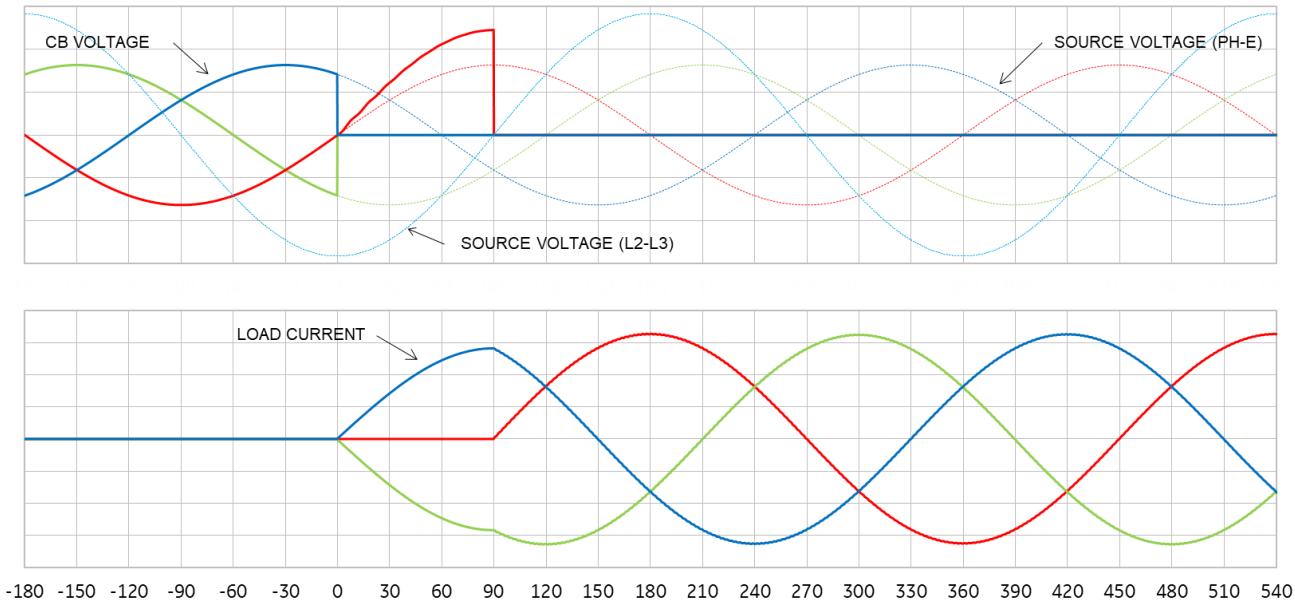


Figure 131 Isolated neutral shunt-reactor closing waveforms

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12.7.4.3 Shunt reactor with neutral point grounded with NGR (close)

When NGR is inserted in earthing circuit, the switching point of the **2nd phase to operate** is slightly anticipated (closing) by a correction angle α , by regard to solidly earthed neutral situation.

The ratio $\delta = L_n/L$ is the key factor to compute corrected sequence (refer to 12.7.6 for details).

Table 52 NGR grounded shunt-reactor closing program

Switching program	Phase	Angle [deg]	Prearcing time [ms]
Case 0.1 < δ < 10 (Narrow sequence, Figure 133)			
User (*)	L1 (ref)	$90 - \alpha$	$\sqrt{1 + \frac{(1+2\delta)\cdot\delta}{(1+\delta)^2}} \times \sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \cos(\omega \times 3\sigma)$
	L2 (ref - 120 deg)	30	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \cos(\omega \times 3\sigma)$
	L3 (ref + 120 deg)	150	$\frac{1+3\delta}{1+2\delta} \times \sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \cos(\omega \times 3\sigma)$
Case 0.1 < δ < 10 (Spread sequence, Figure 135)			
User (**)	L1 (ref)	$270 - \alpha$	$\sqrt{1 + \frac{(1+2\delta)\cdot\delta}{(1+\delta)^2}} \times \sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \cos(\omega \times 3\sigma)$
	L2 (ref - 120 deg)	30	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \cos(\omega \times 3\sigma)$
	L3 (ref + 120 deg)	510	$\frac{1+3\delta}{1+2\delta} \times \sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \cos(\omega \times 3\sigma)$
Case δ < 0.1 (Figure 137)			
Solidly earthed neutral point switching program applies, refer to 12.7.4.1			
Case δ > 10 (Figure 137)			
Isolated neutral point switching program applies, refer to 12.7.4.2			

(*) Any of the user program available with the CSD100, User1, User2, User3 or User4, can be used for that duty. Closing angles are customized according to the NGR value.

(**) Example of spread sequence where last phases closing operations are delayed, minimizing impact of LC transient oscillations, due to the presence of NGR and stray capacitances, generated by previous phases closing operations. Any other closing sequence targeting making at peak PH-E voltage is acceptable.

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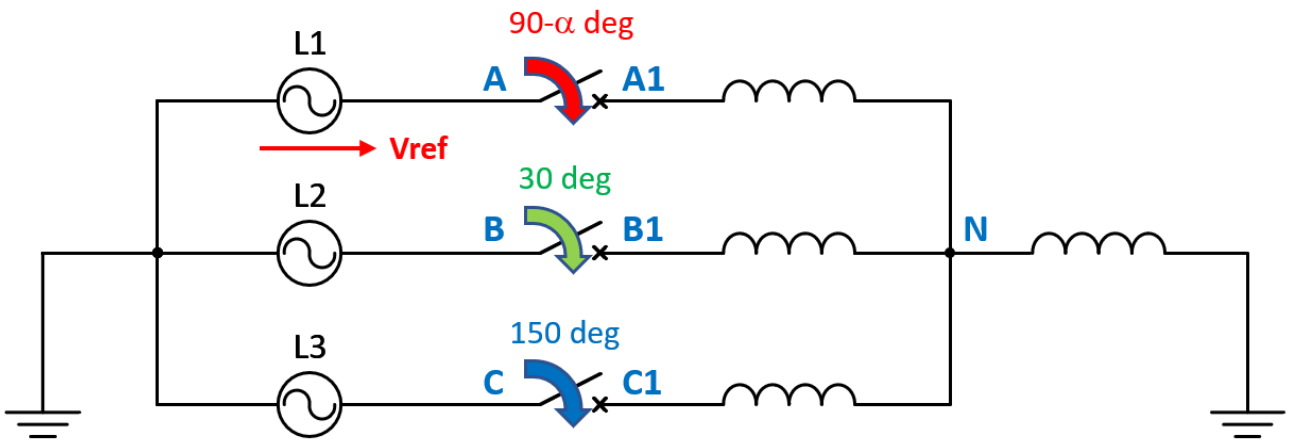


Figure 132 NGR grounded shunt-reactor closing sequence (δ = 1, narrow sequence)

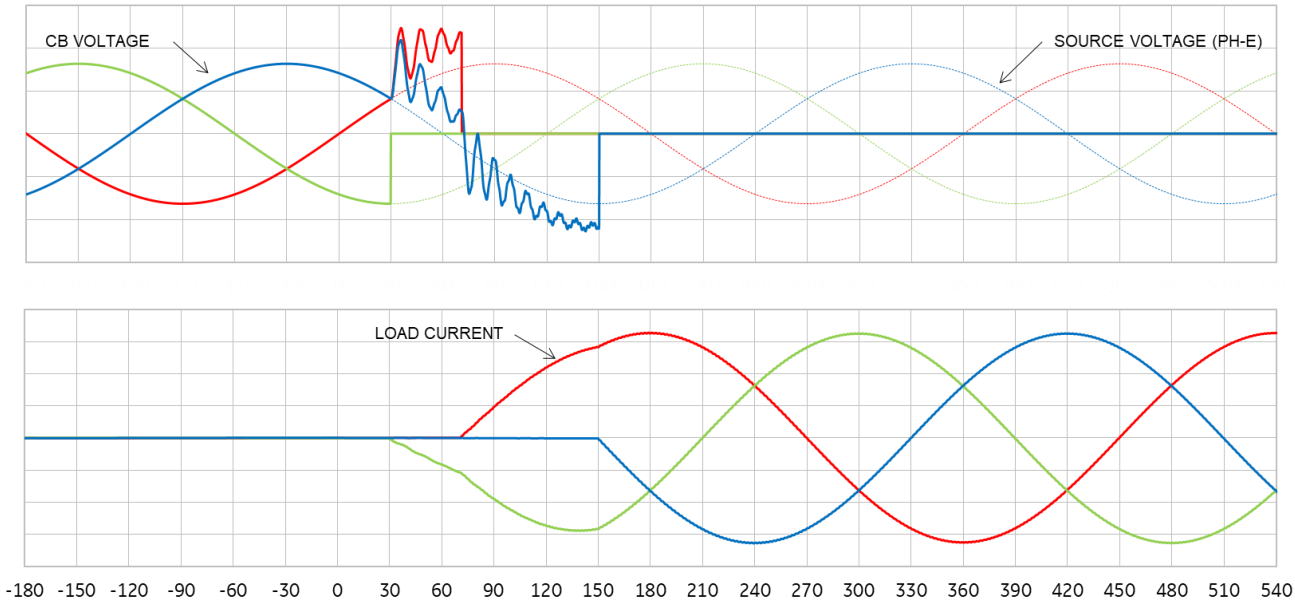


Figure 133 NGR grounded shunt-reactor closing waveforms (δ = 1, narrow sequence)

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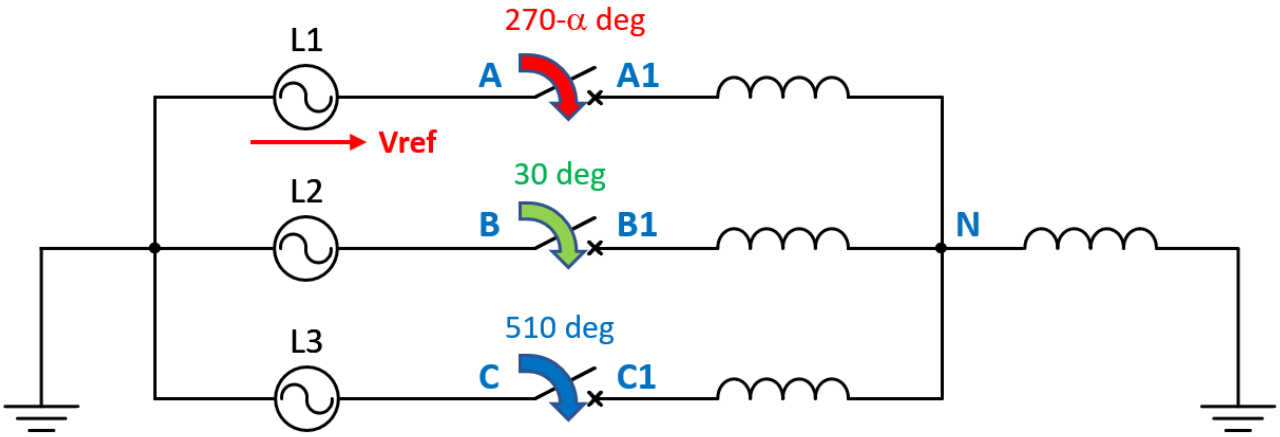


Figure 134 NGR grounded shunt-reactor closing sequence (δ = 1, spread sequence)

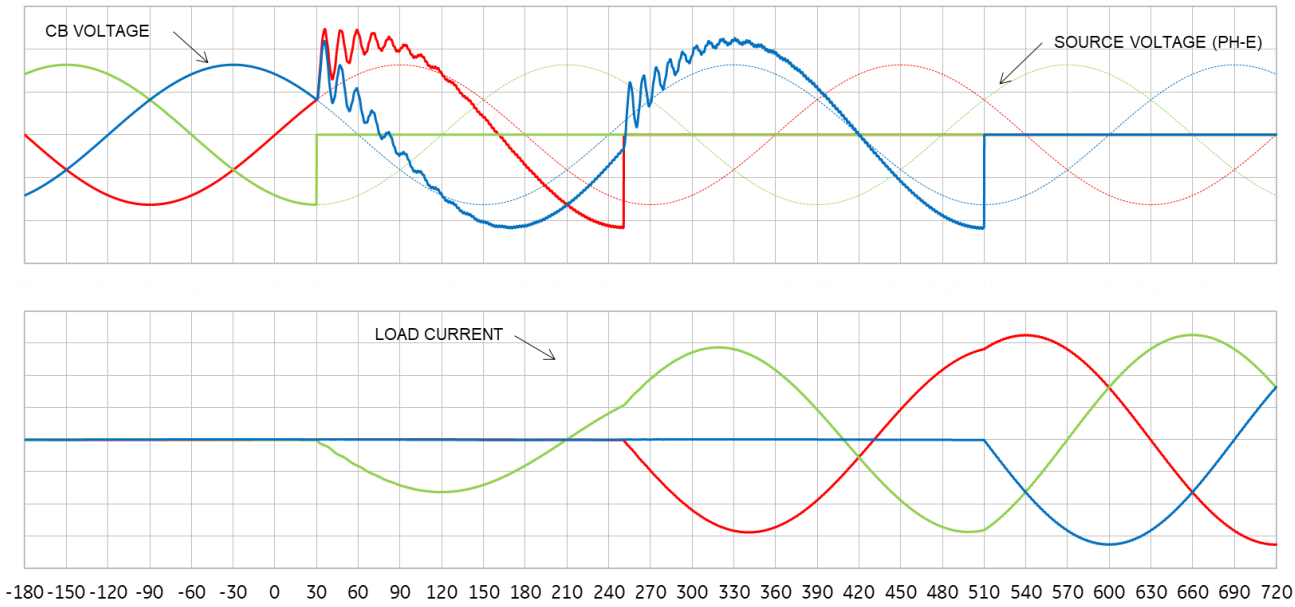


Figure 135 NGR grounded shunt-reactor closing waveforms (δ = 1, spread sequence)

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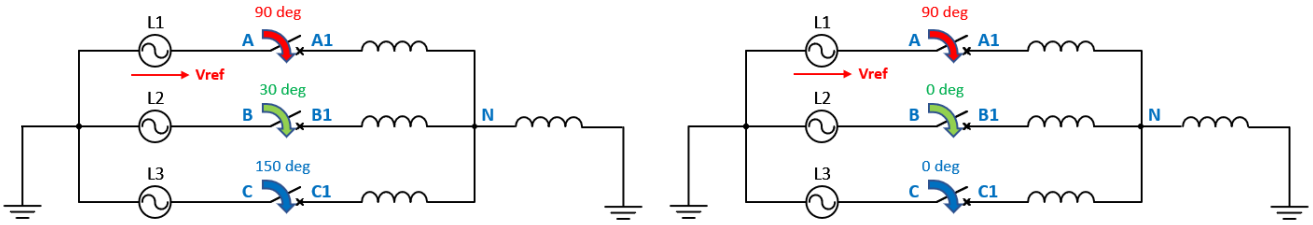


Figure 136 NGR grounded shunt-reactor closing sequence (δ = 0.1 and δ = 10)

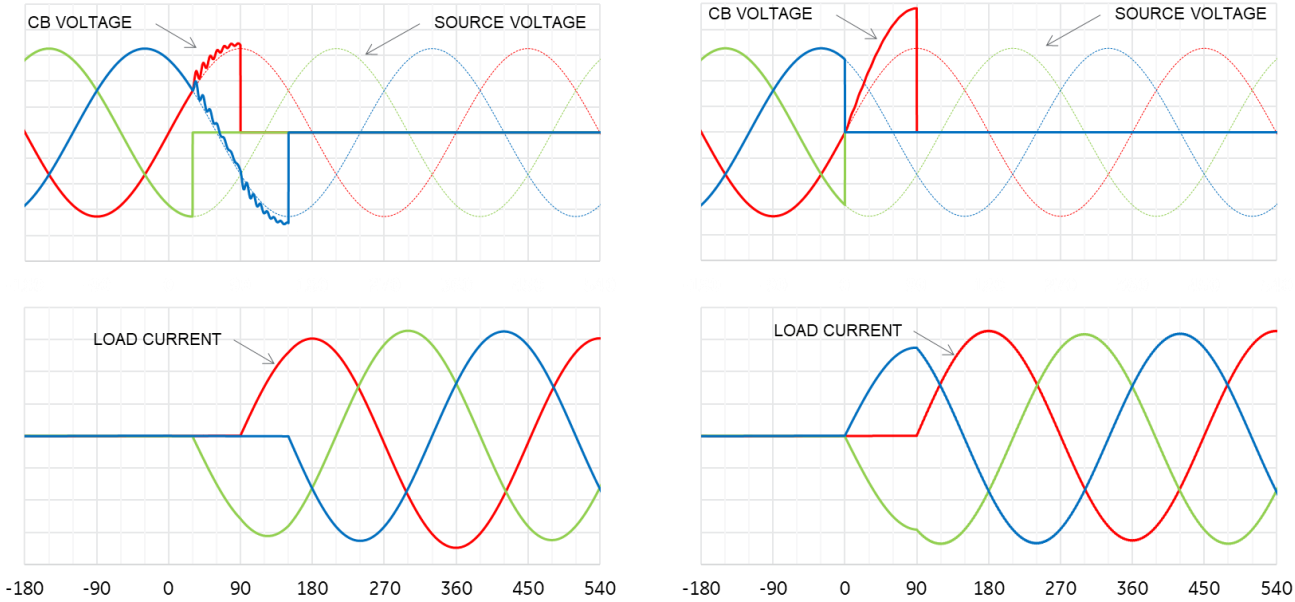


Figure 137 NGR grounded shunt-reactor closing waveforms (δ = 0.1 and δ = 10)

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12.7.5 Shunt-reactor controlled opening

Shunt-reactor controlled opening strategy is dependent of the following characteristics:

- Synchronizing waveform
  - Reference voltage;
  - Reference current;
- Position of the neutral connection
  - Solidly earthed shunt-reactor;
  - Isolated neutral shunt-reactor;
  - NGR earthed shunt reactor.

Duty is to deenergize each reactor phase with an arcing within the free-reignition window, to reduce reignition probability.

Following sections introduce opening targets and arcing times. Interruption targets are referenced to positive going source voltage zero crossing and positive going circuit-breaker current zero crossing.

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12.7.5.1 Shunt-reactor with neutral point solidly grounded (open)

Each pole is opened independently at its respective current zero, corresponding to peak voltage, with intended arcing time.

Opening sequence programmed in CSD100 is described in Table 53 for synchronizing based on voltage signal, and for synchronizing based on current signal.

Table 53 Solidly grounded shunt reactor opening targets

Use case	Switching program		L1 (ref)	L2 (ref - 120 deg)	L3 (ref + 120 deg)
Synchronizing on reference voltage	React1(*)	Angle [deg]	90	30	150
Synchronizing on reference current	React1(*)	Angle [deg]	0	120	60
Synchronizing on reference voltage	React1(**)	Angle [deg]	90	210	330
Synchronizing on reference current	React1(**)	Angle [deg]	0	120	240

(*) traditional settings.

(**) Opening angles can be set to target current interruption on negative current (positive voltage), angles being adjustable using the CSD100 control interface.

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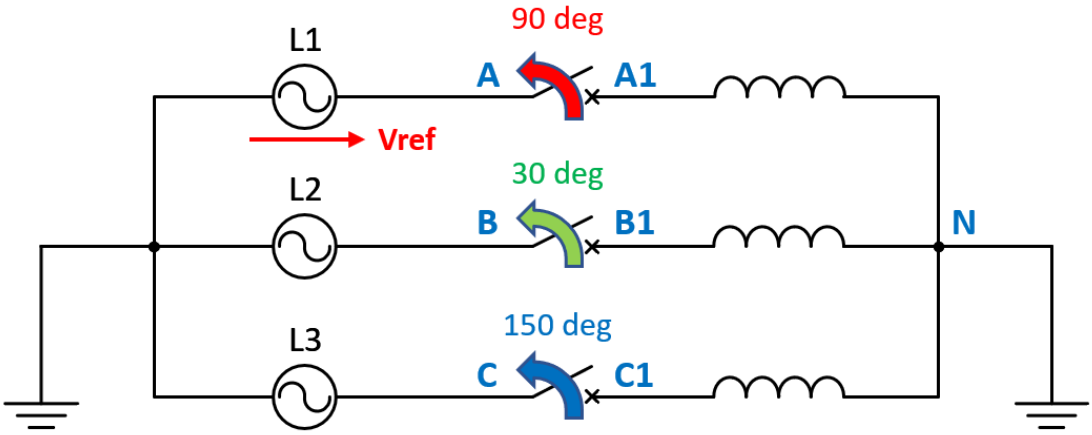


Figure 138 Solidly grounded shunt-reactor opening sequence (reference voltage, narrow sequence)

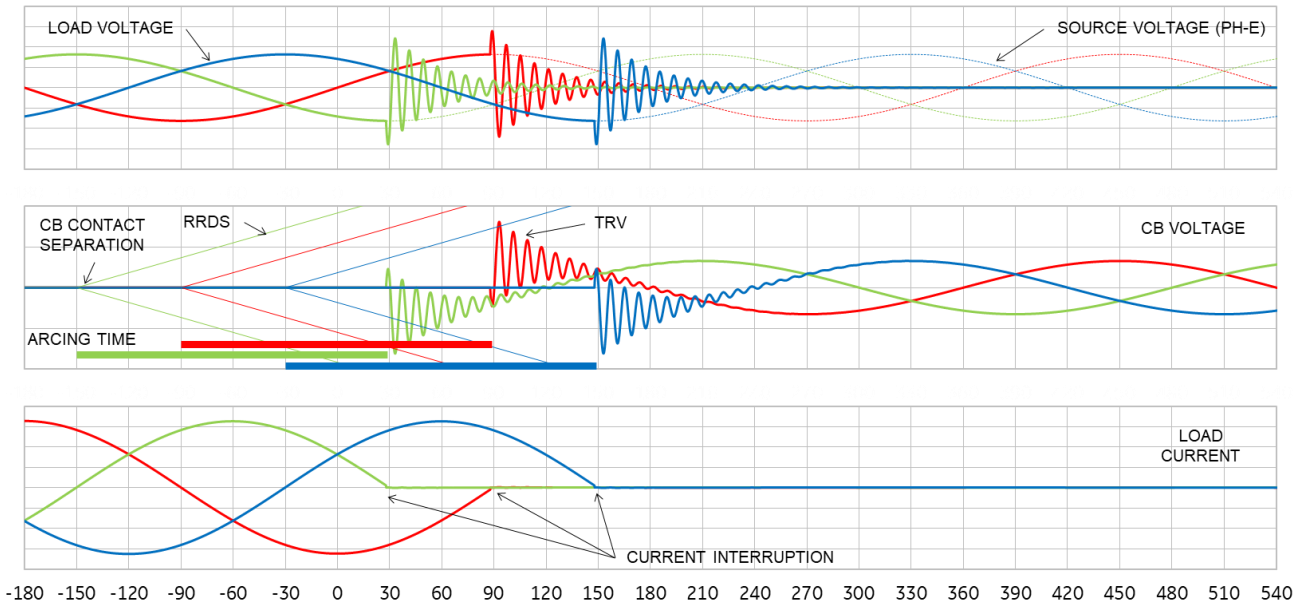


Figure 139 Solidly grounded shunt-reactor opening waveforms (reference voltage, narrow sequence)

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12.7.5.2 Shunt-reactor with neutral point isolated (open)

Under balanced condition, a first pole is opened with intended arcing time as for grounded neutral case. From that instant, in the two remaining poles, current zero crossing coincide; thus, they are operated simultaneously a quarter of period later, or a quarter and a half period later.

Opening sequence programmed in CSD100 is described in Table 54 for synchronizing based on voltage signal, and on current signal.

Table 54 Neutral isolated shunt reactor opening targets

Use case	Switching program		L1 (ref)	L2 (ref - 120 deg)	L3 (ref + 120 deg)
Synchronizing on reference voltage					
Narrow sequence	React1	Angle [deg]	90	180	180
Spread sequence (*)	React1	Angle [deg]	90	360	360
Synchronizing on reference current					
Narrow sequence	React1	Angle [deg]	0	90	90
Spread sequence (*)	React1	Angle [deg]	0	270	270

(*) Usual interrupting targets for last phases are extended by half a period, not to impair arcing time of the phase L3 in case of reignition of phase L1. Spread sequence reduces probability of phase L3 reignition in case reignition occurs on phase L1.

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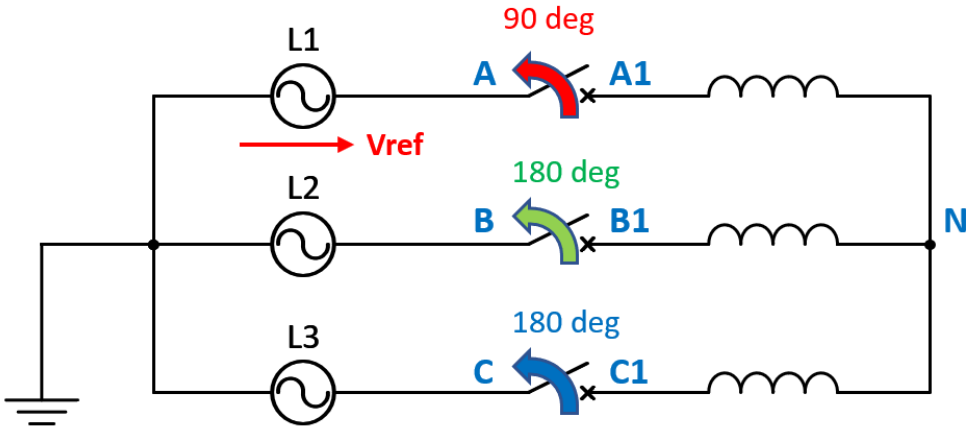


Figure 140 Isolated neutral shunt-reactor opening sequence (reference voltage, narrow sequence)

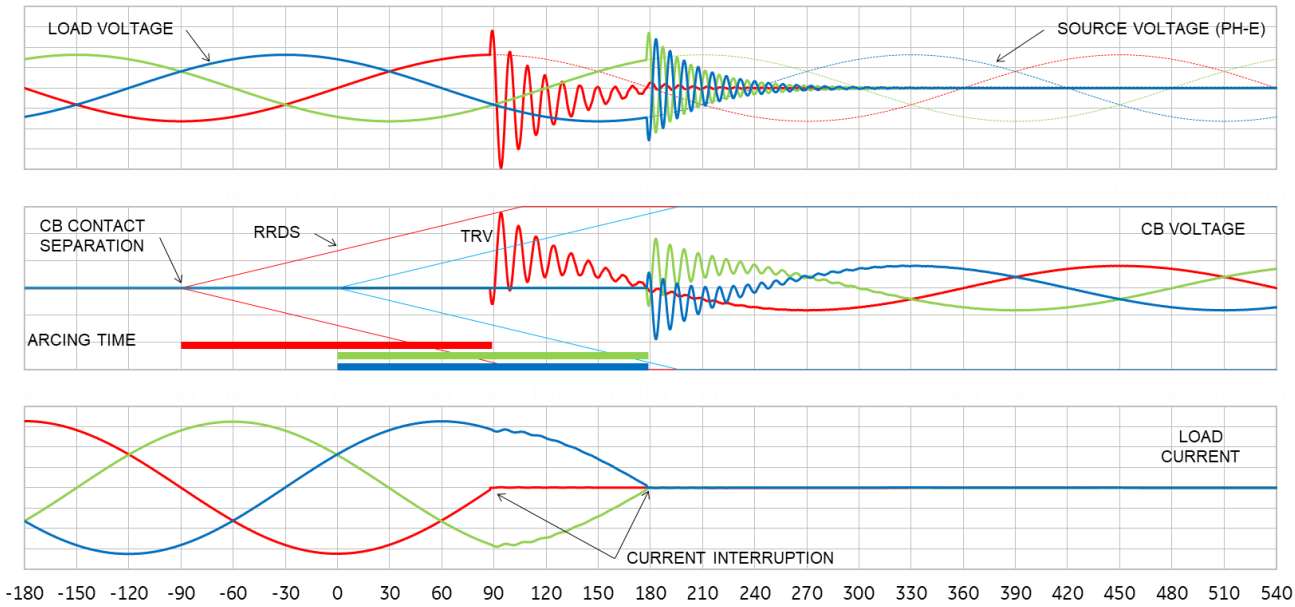


Figure 141 Isolated neutral shunt-reactor opening waveforms (reference voltage, narrow sequence)

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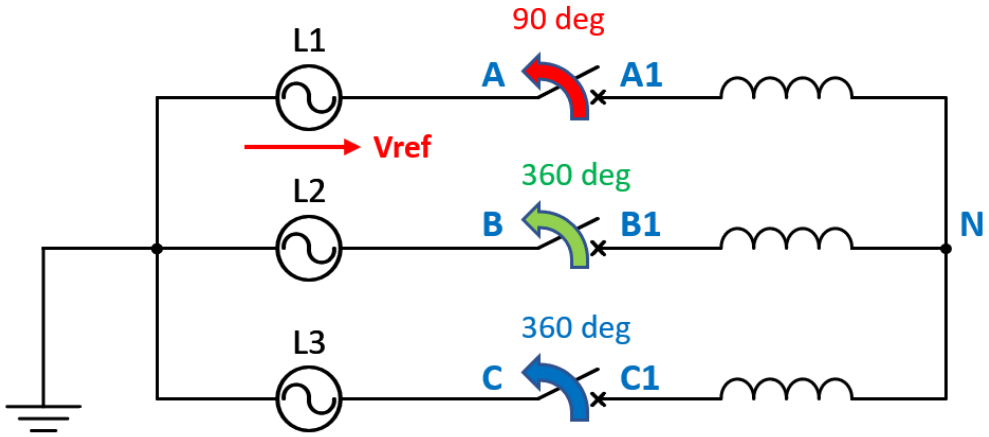


Figure 142 Isolated neutral shunt-reactor opening sequence (reference voltage, spread sequence)

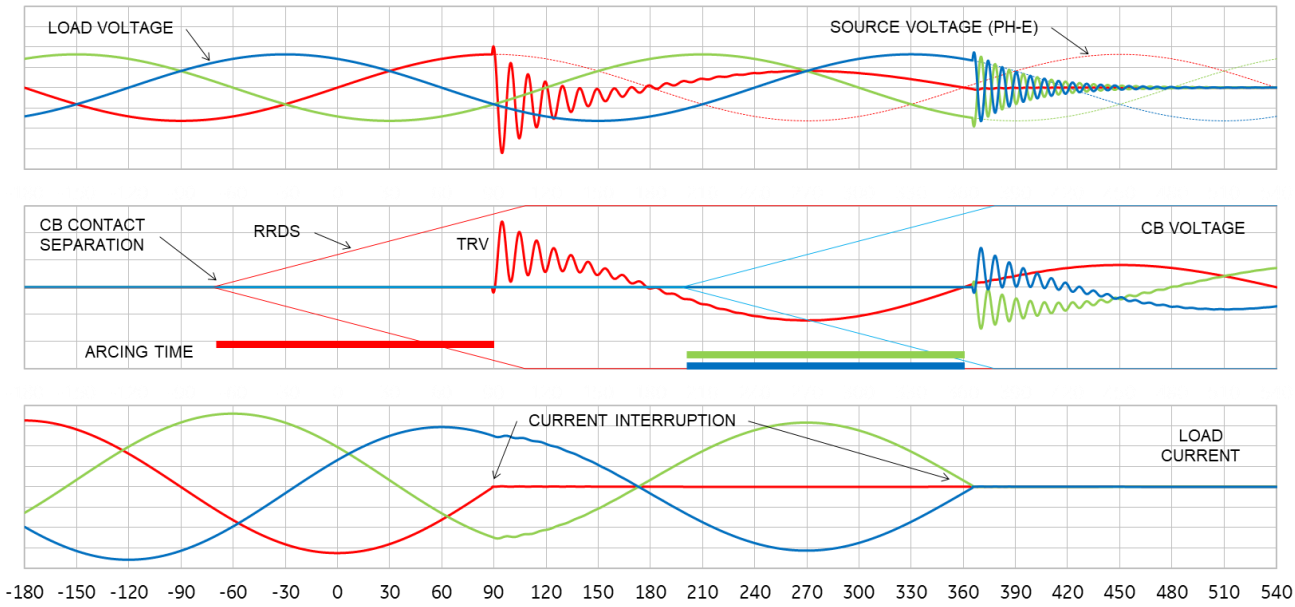


Figure 143 Isolated neutral shunt-reactor opening waveforms (reference voltage, spread sequence)

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12.7.5.3 Shunt-reactor with neutral point grounded with NGR (open)

When NGR is inserted in earthing circuit, the switching point of the **2nd phase to operate** is slightly delayed (opening) by a correction angle α , by regard to solidly earthed neutral situation.

The ratio $\delta = L_n/L$ is the key factor to compute corrected sequence (refer to 12.7.6 for details).

Opening sequence programmed in CSD100 is described in Table 55.

Table 55 NGR grounded shunt reactor opening program

Use case	Switching program		L1 (ref)	L2 (ref - 120 deg)	L3 (ref + 120 deg)
Synchronizing on reference voltage					
0.1 < δ < 10 (Narrow sequence)	User1	Angle [deg]	$90 + \alpha$	30	150
0.1 < δ < 10 (Spread sequence)	User2	Angle [deg]	90	$210 + \alpha$	330
δ < 0.1	Solidly earthed neutral point switching program applies, refer to 12.7.5.1				
δ > 10	Isolated neutral point switching program applies, refer to 12.7.5.2				
Synchronizing on reference current					
0.1 < δ < 10 (Narrow sequence)	User1	Angle [deg]	0	120	$60 + \alpha$
0.1 < δ < 10 (Spread sequence)	User2	Angle [deg]	0	$120 + \alpha$	240
δ < 0.1	Solidly earthed neutral point switching program applies, refer to 12.7.5.1				
δ > 10	Isolated neutral point switching program applies, refer to 12.7.5.2				

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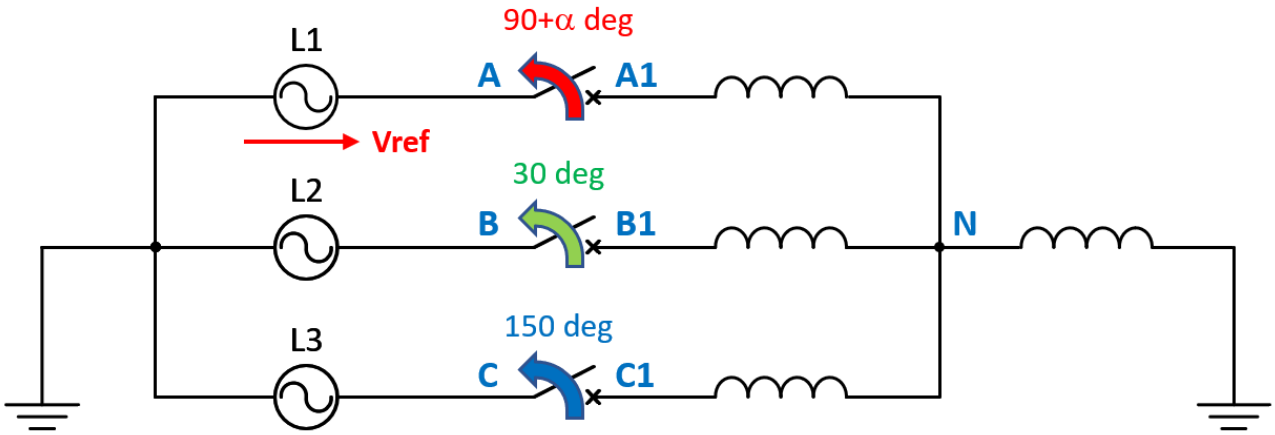


Figure 144 NGR grounded shunt-reactor opening sequence (δ = 1, narrow sequence, voltage reference)

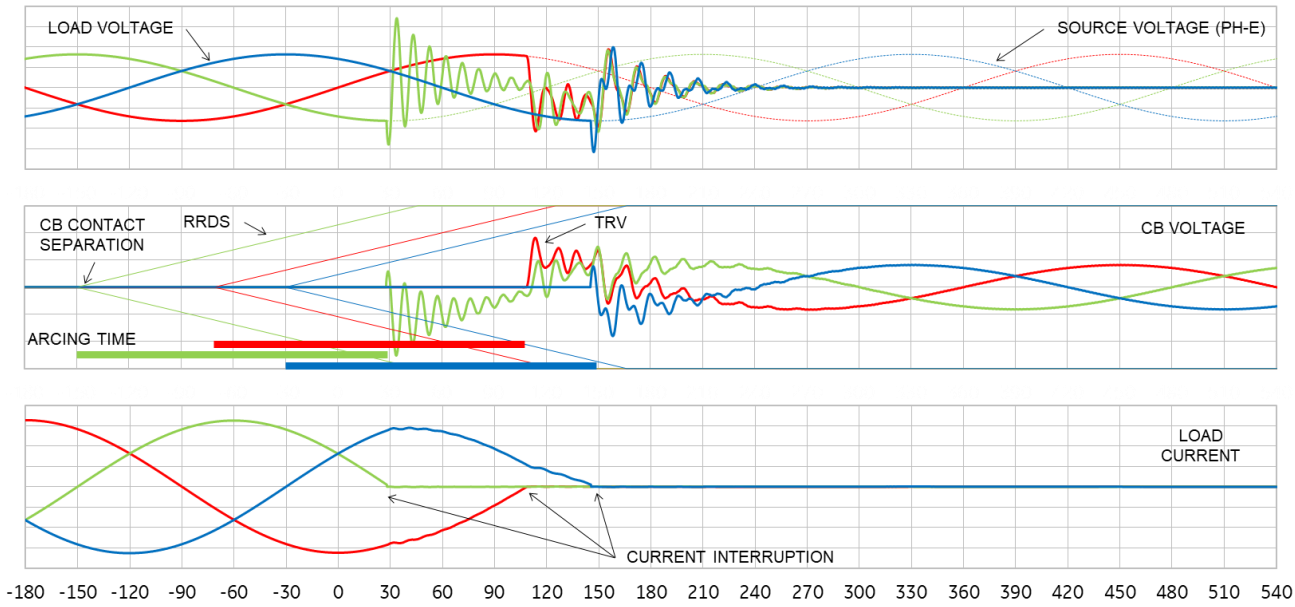


Figure 145 NGR grounded shunt-reactor opening waveforms (δ = 1, narrow sequence, voltage reference)

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12.7.5.4 Arcing time considerations

Due to minimum arcing time (MAT) constraint, the arcing contact separation shall be anticipated by the programmed arcing time, from above mentioned targets. The current interruption process is complex and depends not only on the circuit breaker itself but also on the network and the load. Thus, programmed arcing time (which is set as the minimum applicable arcing time plus margin) may differ from one application to another. Upper limit being half a period of power frequency, **8ms can be considered as a standard value**.

Shunt reactors with ungrounded neutral or NGR grounded neutral enforce higher transient recovery voltage, and thus longer arcing time is required.

Circuit breaker characteristics which impact the minimum arcing time:

- Gas filling pressure
- Velocity
- Value of grading capacitors, if any.
- RRDS characteristic (Rate of Recovery of Dielectric Strength)

Network and load characteristics which impact the minimum arcing time:

- Network frequency
- Reactor rated power
- Load capacitance (reactor stray capacitance)
- Neutral position (grounded, ungrounded, NGR)
- Presence / absence of surge arrester

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Figure 146 illustrates the need for a minimum arcing time (minimum contact separation distance) before network current zero and transient recovery voltage peak (some tens of µs later). Duty for the TRV is not to exceed dielectric withstand (RRDS).

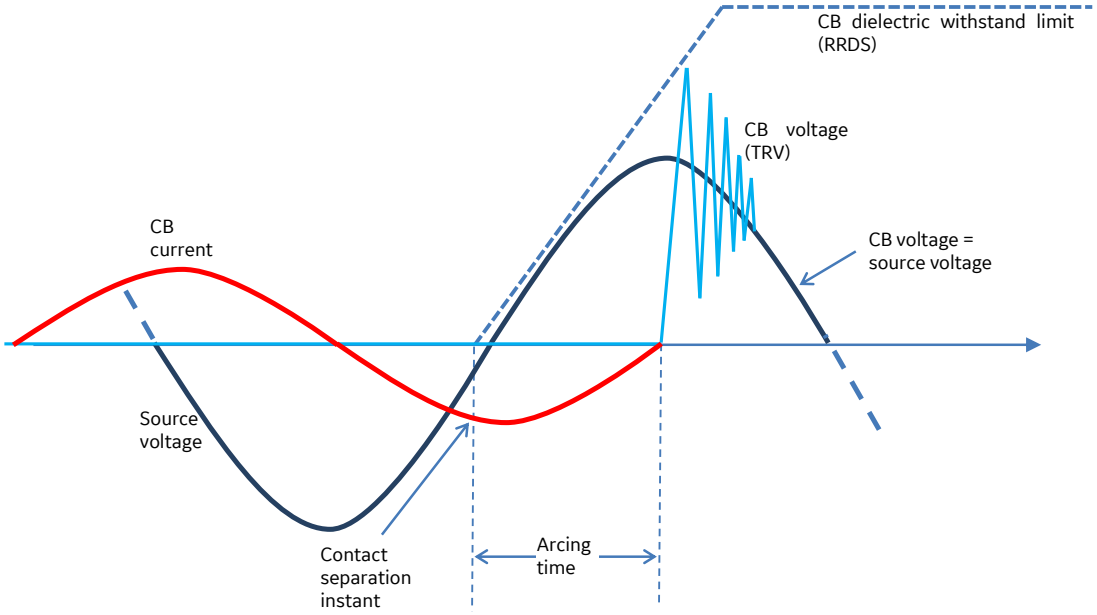


Figure 146 Illustration of shunt reactor de-energization

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12.7.5.5 Detection of reignition

CSD100 is capable to detect and count reignitions, independently for each phase, during opening operations and

- Trigger an alarm when a reignition is detected during last opening operation;
- Trigger an alarm when reignition rate computed by the controller is excessive;
- Trigger an alarm when total number of reignitions is excessive
- Auto-adapt arcing time set value in case total number of reignitions exceed a threshold.

These processing are carried out on a phase by phase basis.

12.7.5.5.1 Detection during last operation

Arcing times are measured from the prospective instant of arcing contact separation (mechanical time forecast) to the effective current extinction instant, phase by phase. Current extinction detection is carried out in a secured way to cope with low currents (unfavorable signal to noise ratio): 50% automatic threshold and detection delay compensation.

If measured arcing time exceeds half a period, reignition alarm is set.

Detection of reignition is possible for:

- Controlled opening operations: arcing contact separation is determined from the instant of circuit breaker coil current raise plus the expected opening time
- Uncontrolled opening operations: arcing contact separation is determined from the auxiliary contact opening plus the time difference between arcing contact opening and rated opening time. Auxiliary contact wiring is required for uncontrolled opening operations reignition detection.

See Figure 116

12.7.5.5.2 Reignition rate alarm

Reignition rate alarm is set if 2 reignitions are observed over a settable number of previous operations (N being settable).

12.7.5.5.3 Adaptive control of arcing time

If total number of reignitions exceeds a settable value, arcing time value can be automatically increased (adaptive control of arcing time).

Table 56 Adaptive control of arcing time

Reignition counter	≤ 2	> 2 & ≤ 5	> 5
Arcing time [ms]	Initial set value	Intermediate value	Final value

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12.7.6 Sequence change when neutral point is grounded with an NGR

When NGR is inserted in earthing circuit, a correction angle α may be introduced in the switching sequence:

The switching point of the **2nd phase to operate** is slightly **anticipated** (closing operations) or **delayed** (opening operations), by regard to solidly earthed neutral situation.

Refer to 12.7.4.3 and 12.7.5.3 for detailed switching sequence.

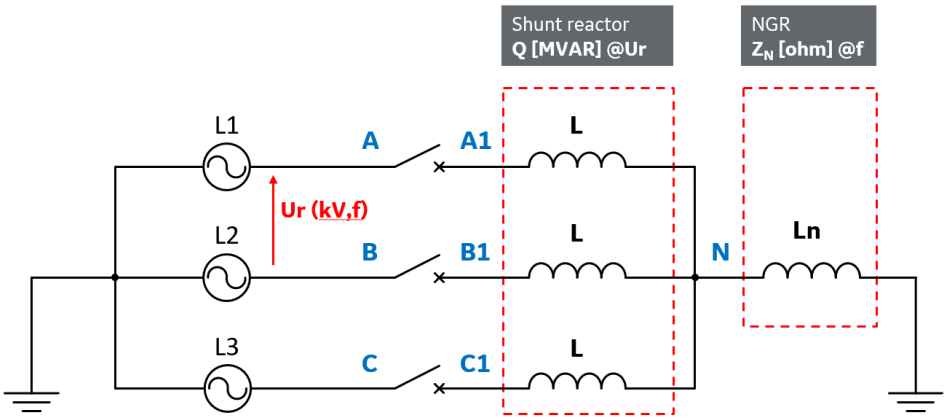


Figure 147 Representation of a shunt-reactor with neutral connection earthed through NGR

Based on the ratio NGR inductance value divided by shunt-reactor single-phase inductance value, the correction angle α is defined as:

$$\alpha = \frac{180}{\pi} \times \tan^{-1}\left(\frac{\sqrt{3} \times \delta}{2 + 3\delta}\right) \qquad (17)$$

where

- α Correction angle [deg]
- $\delta = L_n/L$ NGR inductance value divided by shunt-reactor inductance value
- L Shunt-reactor single-phase inductance value [H] (typ. expressed in mH)
- L_n NGR inductance value [H] (typically expressed in mH)

The ratio δ is computed as following:

$$L[H] = \frac{U_r^2}{2\pi \times f \times Q} \qquad (18)$$

$$L_n[H] = \frac{Z_n}{2\pi \times f} \qquad (19)$$

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From equations (18) and (19), δ is calculated as:

$$\delta = \frac{Z_n \times Q}{U_r^2} \qquad (20)$$

where

- U_r System rated PH-PH voltage [V] (typically expressed in kV)
- Z_n NGR impedance value at rated frequency [ohm]
- Q Shunt-reactor reactive power at rated frequency [VAR] (typ. expressed in MVAR)

Correction angle α, in deg, is plotted in Figure 148 from $\delta = 0.1$ to $\delta = 10$.

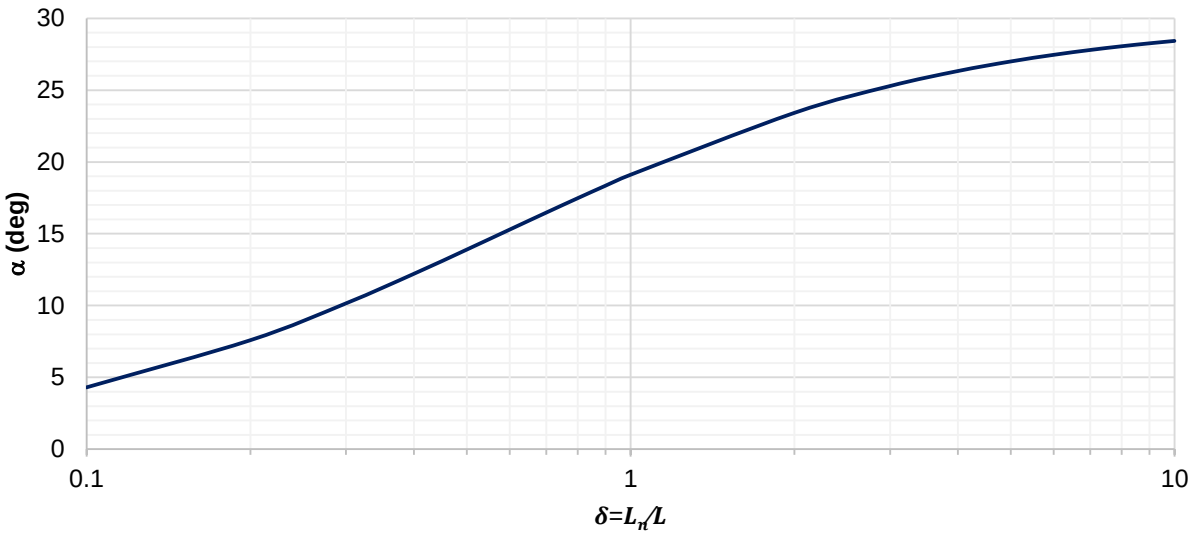


Figure 148 NGR earthed shunt reactor correction angle

Notes:

- For $\delta < 0.1$: shunt-reactor can be considered with neutral connection solidly earthed;
- For $\delta > 10$: shunt-reactor can be considered with neutral connection isolated;
- For $0.1 < \delta < 10$: correction angle α applies to the 2nd operated phase.

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12.7.7 Shunt reactor with switchable neutral point

When the neutral connection is variable, e.g. the neutral point connection is switchable by the mean of a disconnector switch, automatic management of switching program may be performed, using the MLS feature of the controller (refer to 12.11).

For example, Figure 149 describes the case where the neutral point can be either solidly earthed or earthed through an NGR (δ=Ln/L), depending on the position of the earthing disconnector switch:

- when the earthing disconnector switch is in closed position, switching program is set as “Reactor1”, with closing and opening angles corresponding to the sequences described in 12.7.4.1 and 12.7.5.1 ;
- when the earthing disconnector switch is in open position, switching program is set as “User1”, with closing and opening angles corresponding to the sequences described in 12.7.4.3 and 12.7.5.3.

If δ < 0.1, MLS is not necessary and program “Reactor1” is applicable to both switch positions.

If δ > 10, MLS is necessary. “Reactor1” program is applicable when switch is closed and “Reactor2” program is applicable when switch is open.

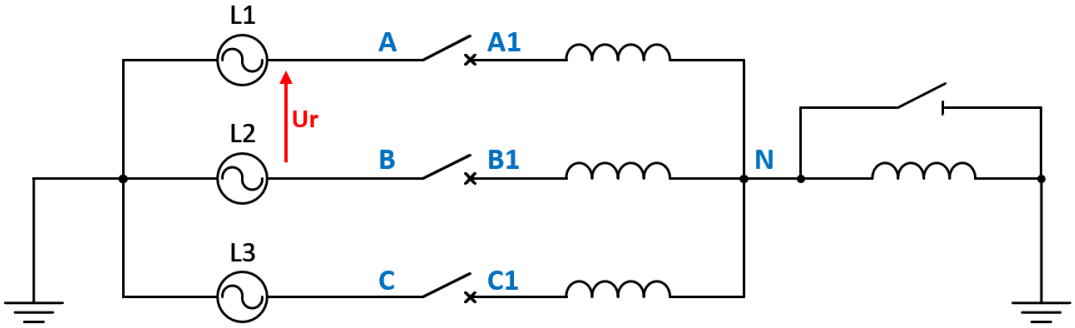


Figure 149 Representation of a shunt reactor with switchable neutral point

Table 57 Switchable neutral shunt-reactor closing program

Use case	MLS1 binary input	Switching program
0.1 < δ < 10	0	“User1”, angles being set for NGR case
	1	“Reactor1”
δ < 0.1	0	“Reactor1”
	1	“Reactor1”
δ > 10	0	“Reactor2”
	1	“Reactor1”

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12.8 Shunt capacitor bank switching application

12.8.1 Shunt capacitor bank switching concerns

A capacitor bank that is randomly energized can generate an inrush current (capacitor charging current), several times the nominal value, at high frequency (several kHz), as well as significant voltage distortion in the network which consequently deteriorates the power quality (Figure 150). Controlled energizing at voltage zero across the circuit-breaker in each phase (Figure 151) reduces the magnitude of inrush currents and the associated voltage disturbances and enhance power quality.

This current is also prone to induce excessive wear of the circuit breaker contacts during prestrike duration.

This phenomenon is particularly severe in the case of the second energization of back-to-back capacitor banks (Figure 152). In this situation, the already energized capacitor tends to reduce source impedance, thus network current limitation is lower and resulting current peak and frequency are higher.

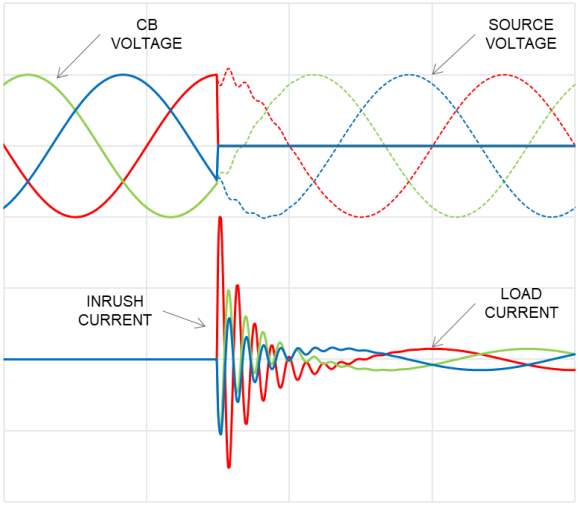


Figure 150 Capacitor bank simultaneous random closing switching trace

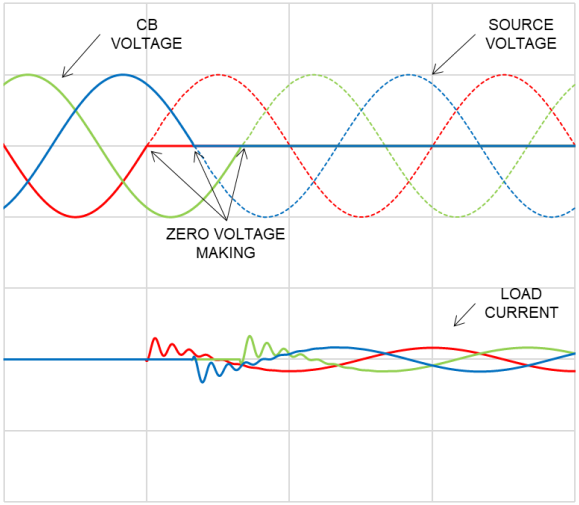


Figure 151 Capacitor bank controlled closing switching trace

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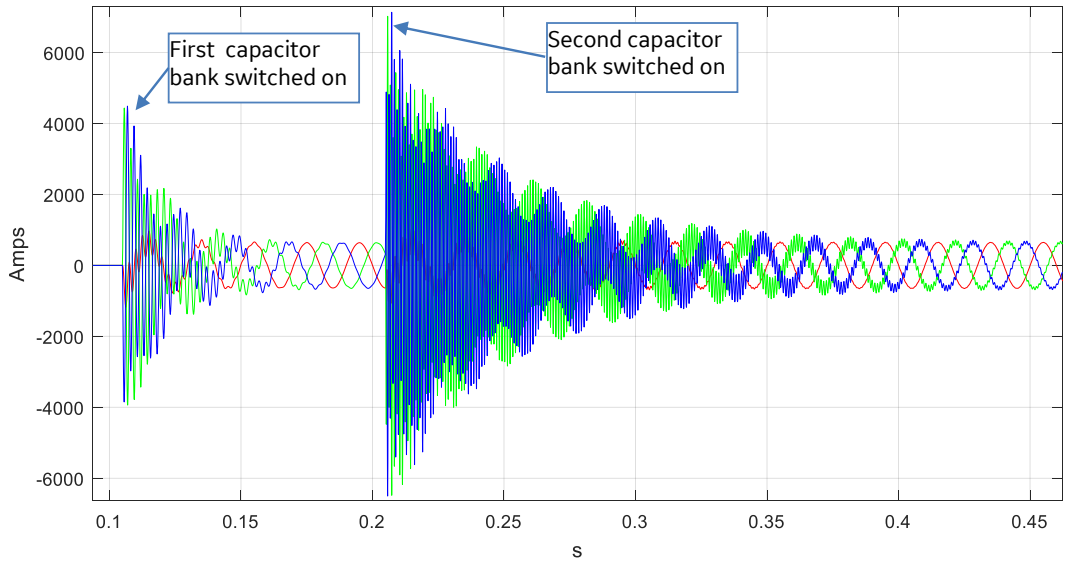


Figure 152 Back-to-Back energization

Notes:

- Since capacitors are specified to discharge their residual voltage within several minutes for safety reasons, CSD100 can energize capacitor banks with consideration of a discharge profile, to improve switching performance. Controlled opening is therefore mandatory to control the trapped charge polarity. Discharge profile is based on elapsed time from previous controlled de-energization. Three sets of targets and prearcing times are provided (full trapped charge, half trapped charge, no trapped charge).
- Controlled closing strategy is applicable for both single bank energizing and back-to-back energizing.

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Controlled opening of capacitor banks allows for a reduction of circuit breaker restrike probability due to short arcing time and insufficient contact gap at current interruption instant. Contact separation should occur early enough before current zero crossing, so that distance between contacts after current interruption is large enough to withstand the transient recovery voltage. Therefore, a minimum arcing time is programmed into the CSD100.

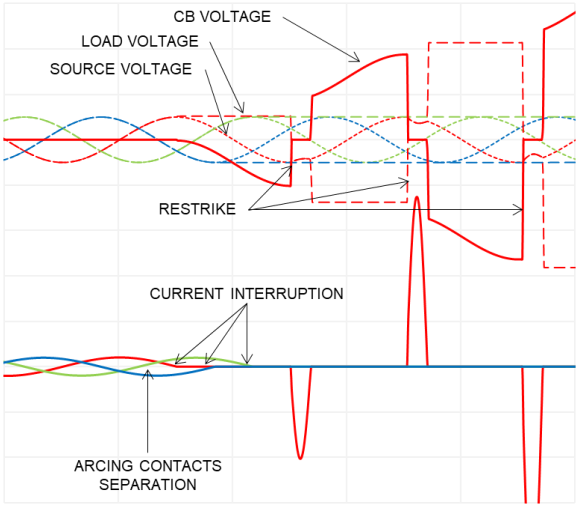


Figure 153 Capacitor bank simultaneous random opening

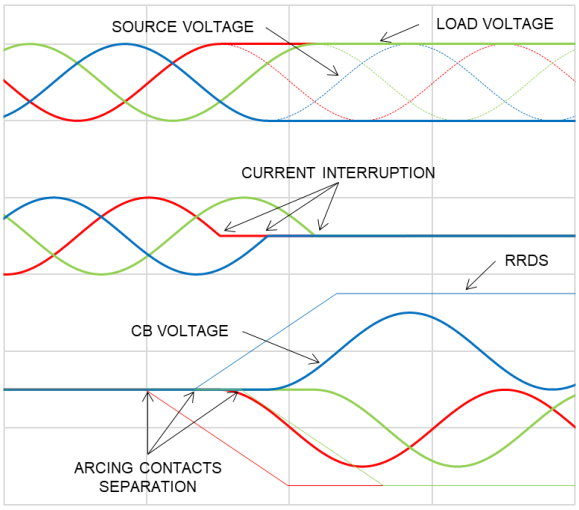


Figure 154 Capacitor bank controlled opening

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12.8.2 Shunt capacitor bank application layout

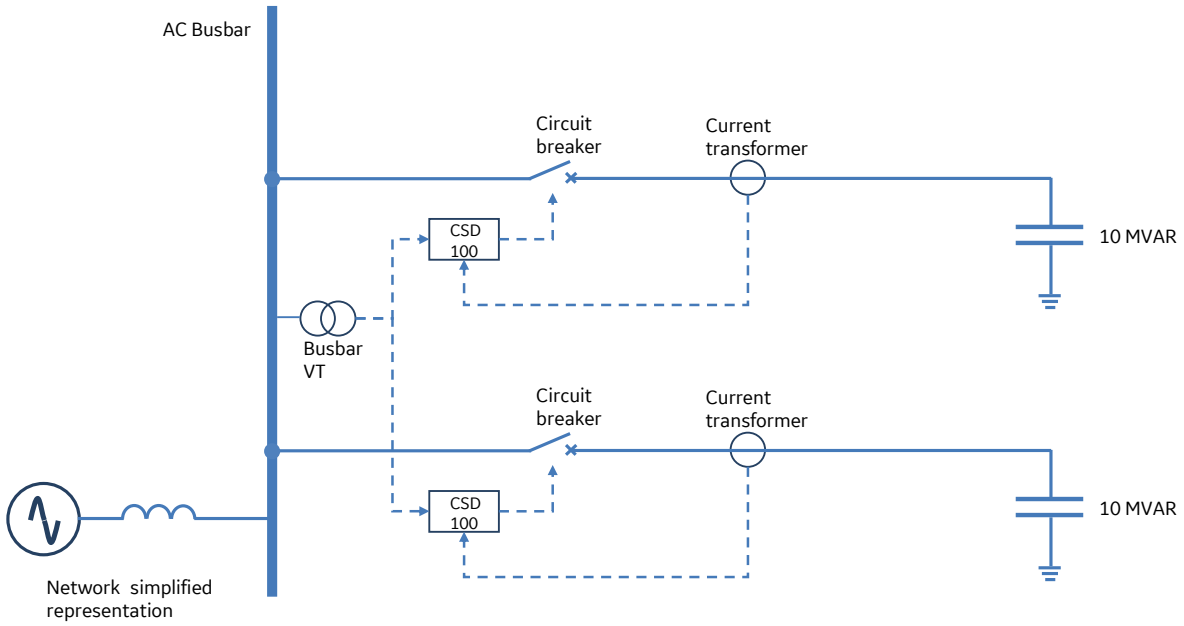


Figure 155 Example of back to back capacitor switching layout (from a single busbar)

For this application, synchronizing reference to be considered

- source voltage: both synchronized closing and opening operations are based on this voltage reference; load current being considered leading 90 deg on this pure capacitive load;
- load current: when the “sync on current” option is enabled, synchronized opening is based on this current reference; synchronized closing still refers to synchronizing voltage.

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Table 58 Capacitor bank signal wiring

Signal wiring	Recommendation
Source voltage	MANDATORY 1 phase for synchronizing purpose
	ALTERNATIVE 3 phases may be wired to the controller for automatic selection of synchronizing phase and reduce in / out delay
	VT type / class: 3P protection class or 1.0 metering class (or better) to achieve less than 0.1ms phase displacement in steady voltage condition (50/60Hz)
Load voltage	RECOMMENDED WHEN AVAILABLE 3 phases If VTs are available at load side, connection to RPH is recommended for closing operations. This helps fine tuning (checking for actual making times, after operation) 1) Making time measurement
	VT type / class: 3PT1, 3PT2 or 3PT3 protection class
Load current	MANDATORY 3 phases motivation to activate: 1) Synchronized opening operation based on current signal 2) Interrupting time measurement, arcing time measurement and detection of reignition/restrike 3) Making time measurement Operating time measurement and compensation by current rise / extinction method (enables to calculate when current making / breaking occurs (reconstruction method) 4) Peak current monitoring upon closing for alarm processing
	CT type / class: Protection class.

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12.8.3 Shunt capacitor bank description

12.8.3.1 Capacitor bank elements

High voltage capacitors are typically made of unitary capacitors with a parallel-serial arrangement.

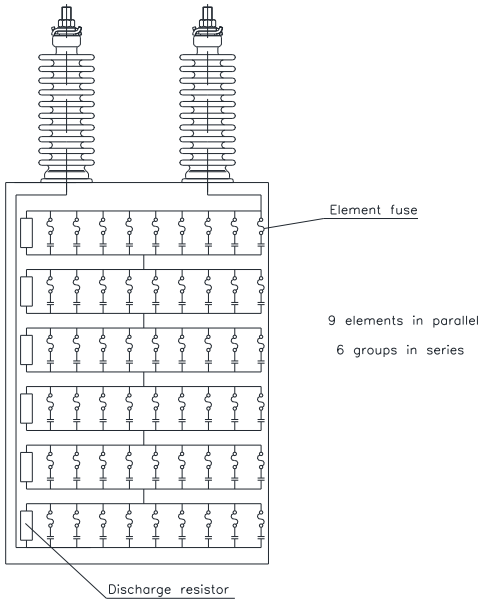


Figure 156 Capacitor bank elements

12.8.3.2 Capacitor bank reactive power

Shunt capacitor bank reactive power is defined as:

$$Q = \sqrt{3} \times U_r \times I_r \qquad (21)$$

where

Q Capacitor bank reactive power [VAR] (typically expressed in MVAR)

U_r System rated PH-PH voltage [V] (typically expressed in kV)

I_r Capacitor bank rated current [A] (typically expressed in A)

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12.8.3.3 Capacitor bank capacitance value

Capacitor bank capacitance value is expressed as:

$$C = \frac{Q}{2\pi \times f \times U_r^2} \qquad (22)$$

where

C Capacitor bank capacitance value [F] (typically expressed in µF)

Q Capacitor bank reactive power [VAR] (typically expressed in MVAR)

U_r System rated PH-PH voltage [V] (typically expressed in kV)

f System rated frequency [Hz]

12.8.3.4 Capacitor bank trapped charge

When deenergizing a capacitor bank, electric d.c. charges accumulate in the capacitor elements. This accumulation of energy, known as “trapped charge”, influences subsequent closing operation, since closing angles must be adapted to close at voltage zero across the circuit-breaker contacts and reduce the energizing transients.

12.8.3.4.1 Trapped charge decay

Capacitor banks are usually fitted with discharge resistors to allow reduction of trapped charge to safe value for operators. Capacitor bank voltage discharge characteristics is defined by:

$$V_c = V_p \times e^{-\tau/RC} \qquad (23)$$

where

- V_c Capacitor voltage (trapped charge) [V] (typically expressed in kV)
- V_p System PH-E peak voltage value [V] (typically expressed in kV)
- C Capacitance value of the capacitor bank [F] (typically expressed in µF)
- R Discharge resistor value [ohm]
- τ Time delay to reach specified residual voltage value [s]

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According to international standards, capacitor bank residual voltage requirements are:

- IEC 60871-1 $V_{res} = 75\ V;\ \tau = 600\ s$
- IEEE Std 18 $V_{res} = 50\ V;\ \tau = 300\ s$

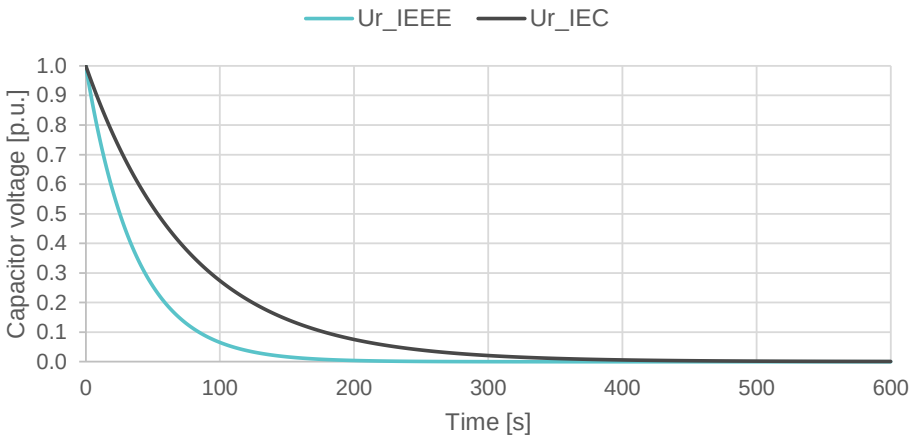


Figure 157 Capacitor bank discharge time requirements

Trapped charge level q, in p.u., is defined as:

$$q = \frac{V_c}{V_p} \qquad (24)$$

12.8.3.4.2 Time to trapped charge half value

Time to trapped charge half value is defined as:

$$t_{50\%} = R \times C \times \ln 2 \qquad (25)$$

where

- $t_{50\%}$: time delay to reach half trapped charge value [s]
- R : discharge resistor value [ohm]
- C : capacitance value of the capacitor bank [F] (typically expressed in µF)

For operation of CSD100, two user settable time limits (timeouts), $t_1 = \frac{1}{2} \times t_{50\%}$ and $t_2 = \frac{3}{2} \times t_{50\%}$ are defined for optimization of energizing sequence:

- When $t < t_1$, the capacitor bank is considered with a trapped charge value q = 1 p.u.;
- When $t_1 < t < t_2$, the capacitor bank is considered with a trapped charge value q = 0.5 p.u.;
- When $t > t_2$, the capacitor bank is considered without any trapped charge.

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12.8.4 Shunt capacitor bank controlled closing

Shunt capacitor bank controlled making angles are dependent of the following characteristics:

- Bank arrangement
  - Wye-connected banks;
  - Delta connected banks;
- Position of the neutral connection
  - Solidly earthed wye-connected capacitor banks;
  - Isolated neutral (wye-connected banks or delta-connected banks);
- Trapped charge level (elapsed time from last open operation).

Duty is to energize each capacitor bank at voltage continuity condition (source side voltage equal to load side voltage).

Usually, trapped charge is considered null (capacitor bank discharged) before energization.

However, trapped charge may be considered in case of early reclose (re-energizing of the bank within the delay to discharge the capacitor elements).

Prearcing time for each phase is also dependent of the same characteristics.

Note: trapped charge consideration is only applicable if previous opening, that fixes the level of trapped charge, is controlled. Otherwise it is mandatory to close with assumption of null trapped charge. Practically, parameters t1 and t2 can be set to zero to force closing without consideration of trapped charge, in any case.

Following sections introduce closing targets and prearcing times.

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12.8.4.1 Solidly earthed capacitor bank controlled closing

Phases are independent from each other and operated at respective voltage continuity condition, which depends on trapped charge presence. Each pole is closed at a zero voltage across the circuit-breaker, considering the trapped charge level at the capacitor terminals.

Table 59 Solidly grounded capacitor bank closing program

Switching program	Phase	Angle [deg]	Prearcing time [ms]
No trapped charge (q=0): $\mathbf{t} > \mathbf{t_2} = \frac{3}{2} \times \mathbf{t_{50\%}}$			
Capa1 (*)	L1 (ref)	180	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \sin(\omega \times 3\sigma)$
	L2 (ref - 120 deg)	120	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \sin(\omega \times 3\sigma)$
	L3 (ref + 120 deg)	240	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \sin(\omega \times 3\sigma)$
Half trapped charge (q=0.5): $\mathbf{t_1} = \frac{1}{2} \times \mathbf{t_{50\%}} < \mathbf{t} < \mathbf{t_2} = \frac{3}{2} \times \mathbf{t_{50\%}}$			
Capa1 (*)	L1 (ref)	150	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \sin(\omega \times 3\sigma) \times \sqrt{1 - \left[\frac{q}{\cos(\omega 3\sigma)}\right]^2} + \frac{1}{\omega} \times \left\{\cos^{-1}\left[\frac{q}{\cos(\omega 3\sigma)}\right] - \cos^{-1}(q)\right\}$
	L2 (ref - 120 deg)	90	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \sin(\omega \times 3\sigma) \times \sqrt{1 - \left[\frac{q}{\cos(\omega 3\sigma)}\right]^2} + \frac{1}{\omega} \times \left\{\cos^{-1}\left[\frac{q}{\cos(\omega 3\sigma)}\right] - \cos^{-1}(q)\right\}$
	L3 (ref + 120 deg)	210	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \sin(\omega \times 3\sigma) \times \sqrt{1 - \left[\frac{q}{\cos(\omega 3\sigma)}\right]^2} + \frac{1}{\omega} \times \left\{\cos^{-1}\left[\frac{q}{\cos(\omega 3\sigma)}\right] - \cos^{-1}(q)\right\}$
Full trapped charge (q=1): $\mathbf{t} < \mathbf{t_1} = \frac{1}{2} \times \mathbf{t_{50\%}}$			
Capa1 (*)	L1 (ref)	90	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times [1 - \cos(\omega \times 3\sigma)]$
	L2 (ref - 120 deg)	30	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times [1 - \cos(\omega \times 3\sigma)]$
	L3 (ref + 120 deg)	150	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times [1 - \cos(\omega 3\sigma)]$

(*) CSD100 default settings.

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Following figures illustrates the switching sequence and the switching traces of solidly earthed capacitor bank controlled closing, with different trapped charges.

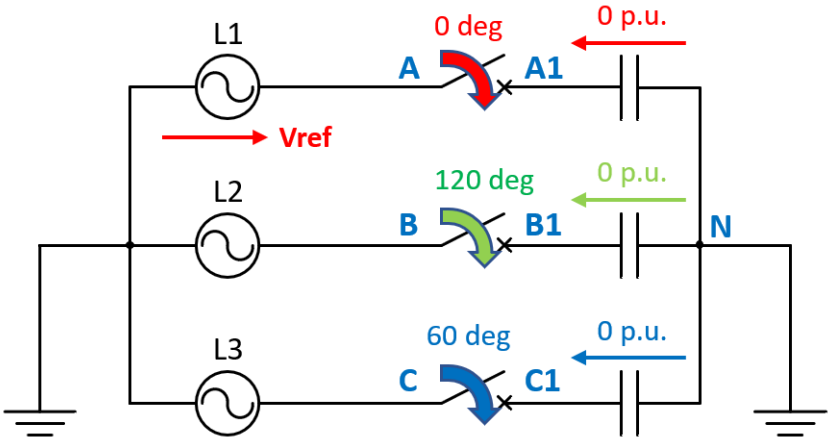


Figure 158 Solidly grounded capacitor bank closing sequence (no trapped charge)

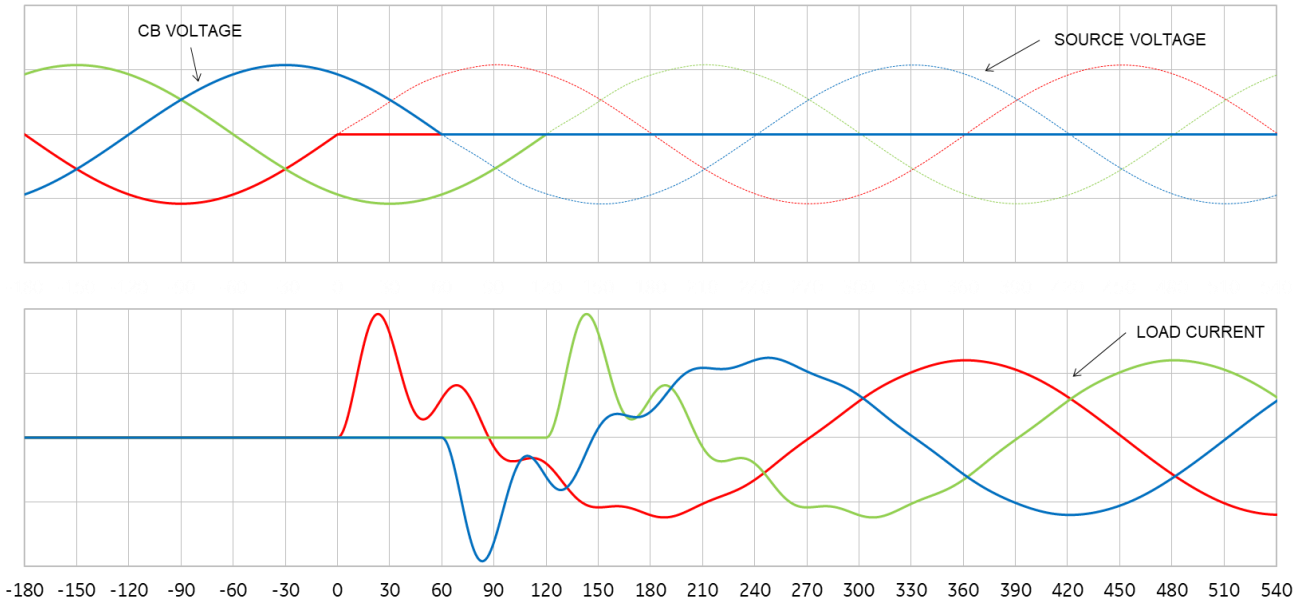


Figure 159 Solidly grounded capacitor bank closing waveforms (no trapped charge)

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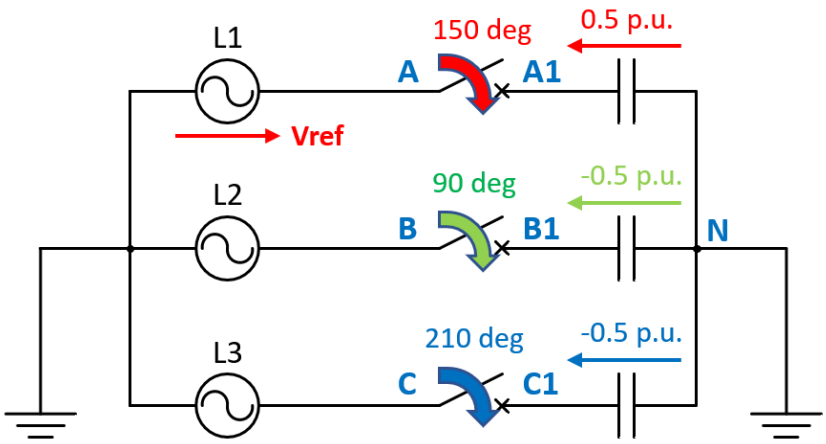


Figure 160 Solidly grounded capacitor bank closing sequence (half trapped charge)

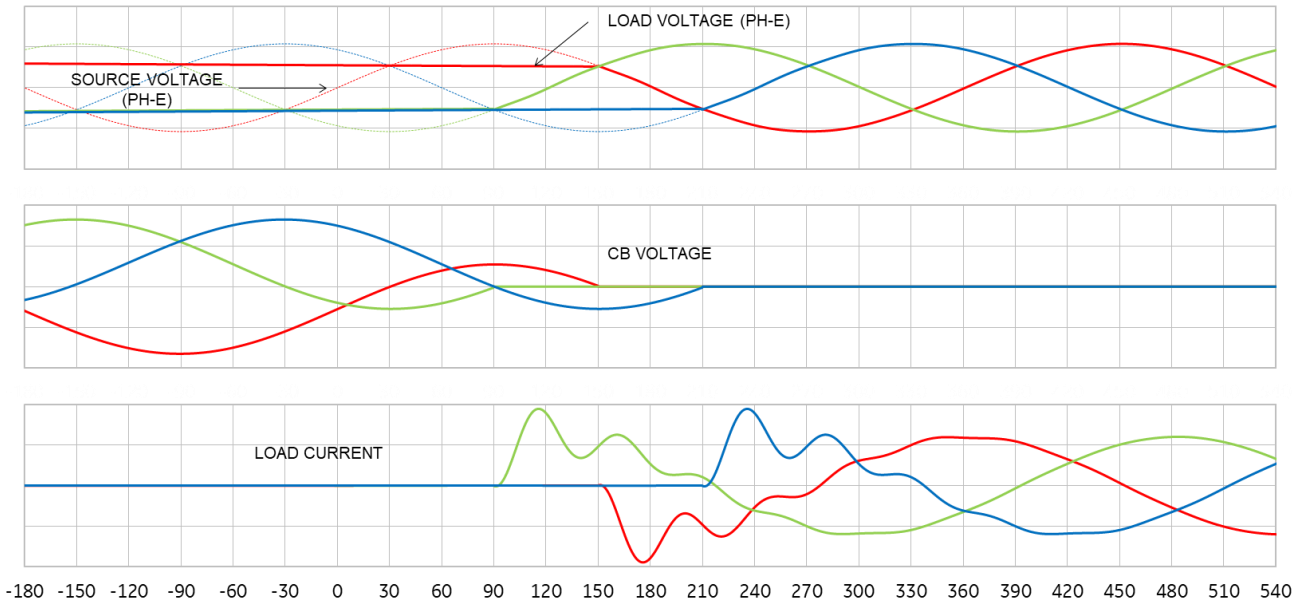


Figure 161 Solidly grounded capacitor bank closing waveforms (half trapped charge)

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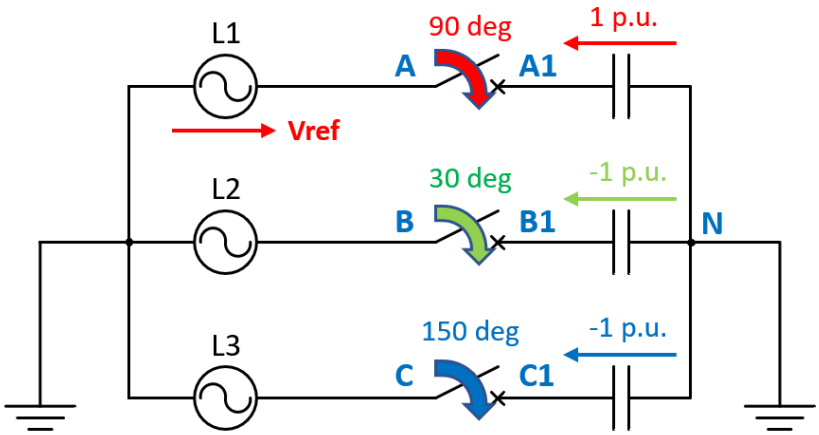


Figure 162 Solidly grounded capacitor bank closing sequence (full trapped charge)

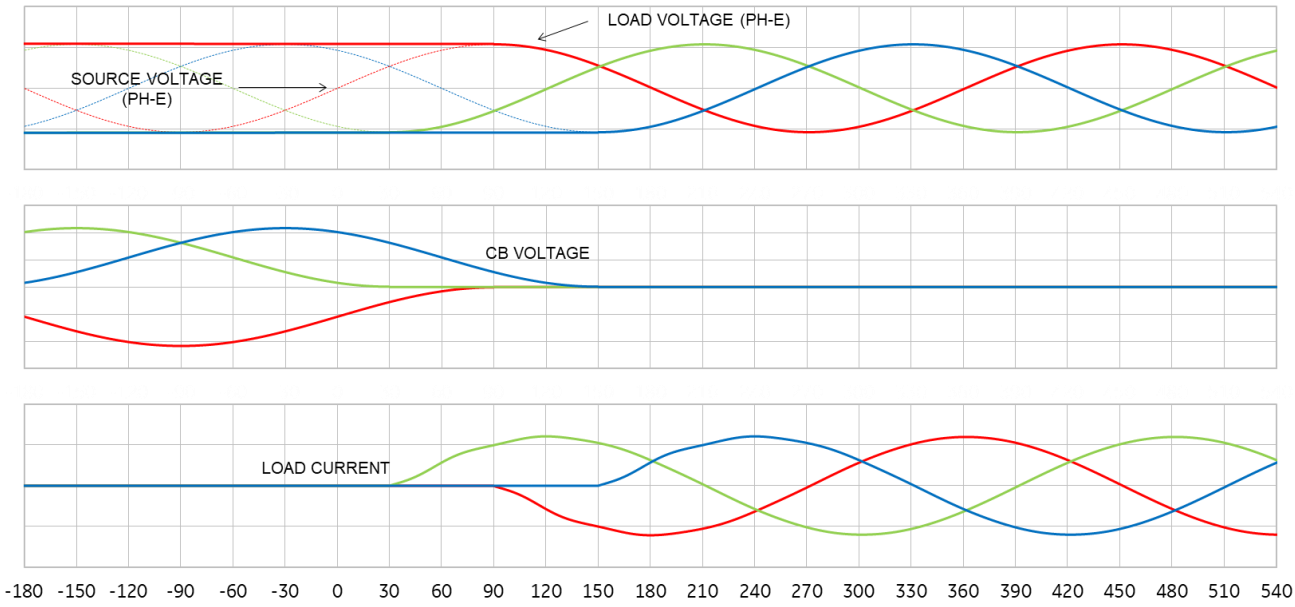


Figure 163 Solidly grounded capacitor bank closing waveforms (full trapped charge)

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12.8.4.2 Isolated neutral capacitor bank controlled closing

Two first phases are closed simultaneously, to allow for current flowing. Target is either a zero crossing of source differential voltage (absence of trapped charge) or a voltage level corresponding to the sum of trapped charge of the two capacitor banks connected in series through the neutral point. Then, the last phase is closed either upon a zero crossing of voltage difference between neutral point and source voltage (absence of trapped charge) or a voltage level corresponding to the trapped charge of this capacitor bank.

Note: Practically, from switching perspective where the voltage across the circuit-breaker is considered, the energizing sequence is similar whatever the capacitor bank arrangement, wye or delta-connected.

Table 60 Isolated neutral capacitor bank closing program

Switching program	Phase	Angle [deg]	Prearcing time [ms]
No trapped charge (q=0): $\mathbf{t} > \mathbf{t_2} = \frac{3}{2} \times \mathbf{t_{50\%}}$			
Capa2 (*)	L1 (ref)	180	$\frac{3}{2} \times \sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \sin(\omega 3\sigma)$
	L2 (ref - 120 deg)	90	$\frac{\sqrt{3}}{2} \times \sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \sin(\omega 3\sigma)$
	L3 (ref + 120 deg)	90	$\frac{\sqrt{3}}{2} \times \sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \sin(\omega 3\sigma)$
Half trapped charge (q=0.5): $\mathbf{t_1} = \frac{1}{2} \times \mathbf{t_{50\%}} < \mathbf{t} < \mathbf{t_2} = \frac{3}{2} \times \mathbf{t_{50\%}}$			
Capa2 (*)	L1 (ref)	390	$\frac{3}{2} \times \sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \sin(\omega 3\sigma) \times \sqrt{1 - \left[\frac{q}{\cos(\omega 3\sigma)}\right]^2} + \frac{1}{\omega} \times \left\{\cos^{-1}\left[\frac{q}{\cos(\omega 3\sigma)}\right] - \cos^{-1}(q)\right\}$
	L2 (ref - 120 deg)	120	$\frac{\sqrt{3}-1}{4} \times \sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS}$
	L3 (ref + 120 deg)	120	$\frac{\sqrt{3}-1}{4} \times \sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS}$
Full trapped charge (q=1): $\mathbf{t} < \mathbf{t_1} = \frac{1}{2} \times \mathbf{t_{50\%}}$			
Capa2 (*)	L1 (ref)	450	$\frac{3}{2} \times \sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times [1 - \cos(\omega 3\sigma)]$
	L2 (ref - 120 deg)	180	$\frac{1}{2} \times \sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS}$ OR $\frac{\sqrt{3}}{2} \times \sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times [1 - \cos(\omega 3\sigma)]$
	L3 (ref + 120 deg)	180	$\frac{1}{2} \times \sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS}$ OR $\frac{\sqrt{3}}{2} \times \sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times [1 - \cos(\omega 3\sigma)]$

(*) CSD100 default settings.

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Following figures illustrates the switching sequence and the switching traces of isolated neutral capacitor bank controlled closing, with different trapped charges.

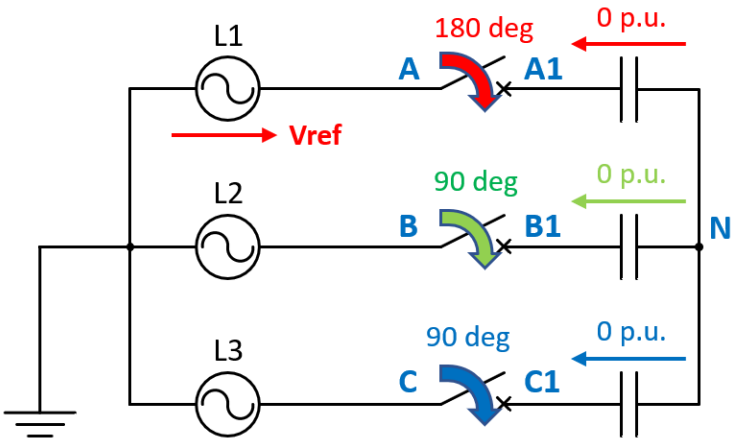


Figure 164 Isolated neutral capacitor bank closing sequence (no trapped charge)

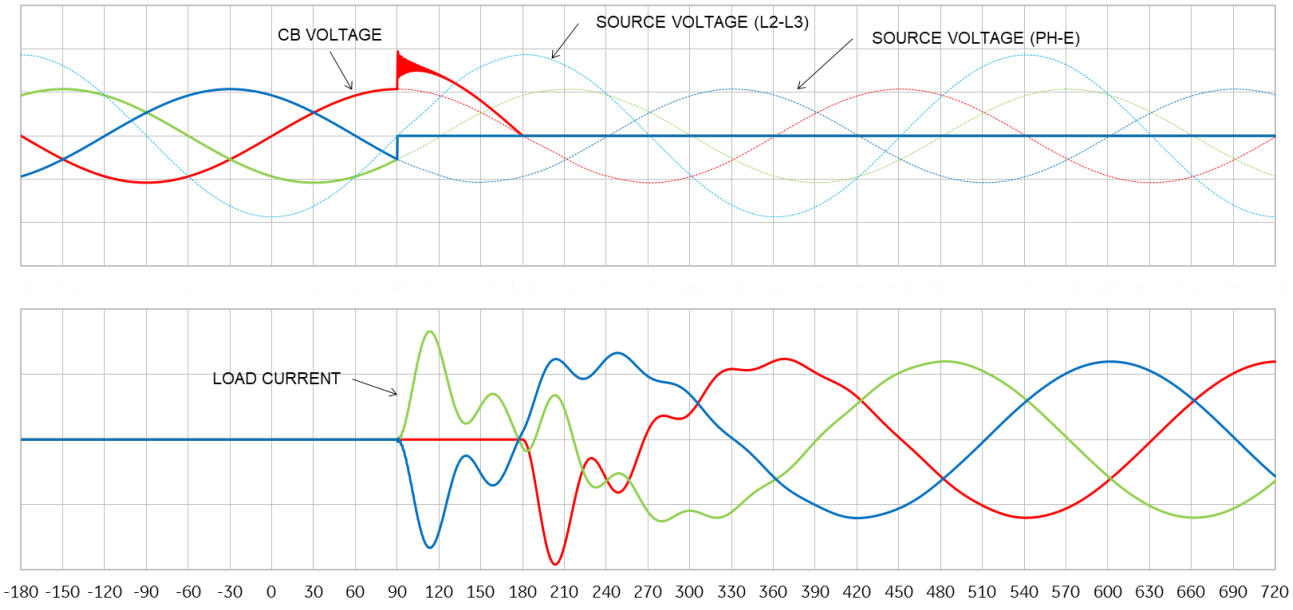


Figure 165 Isolated neutral capacitor bank closing waveforms (no trapped charge)

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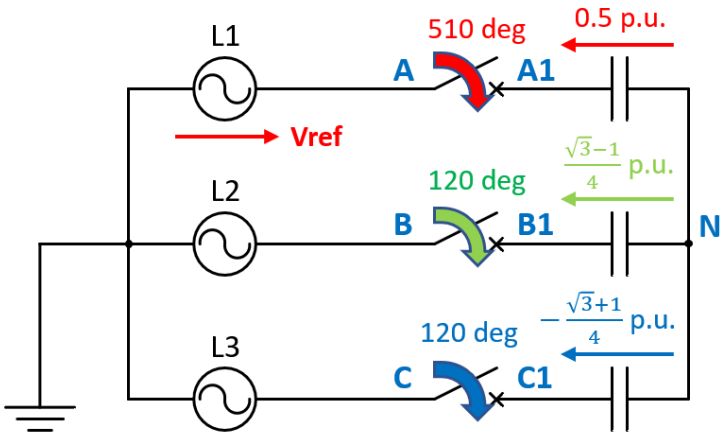


Figure 166 Isolated neutral capacitor bank closing sequence (half trapped charge)

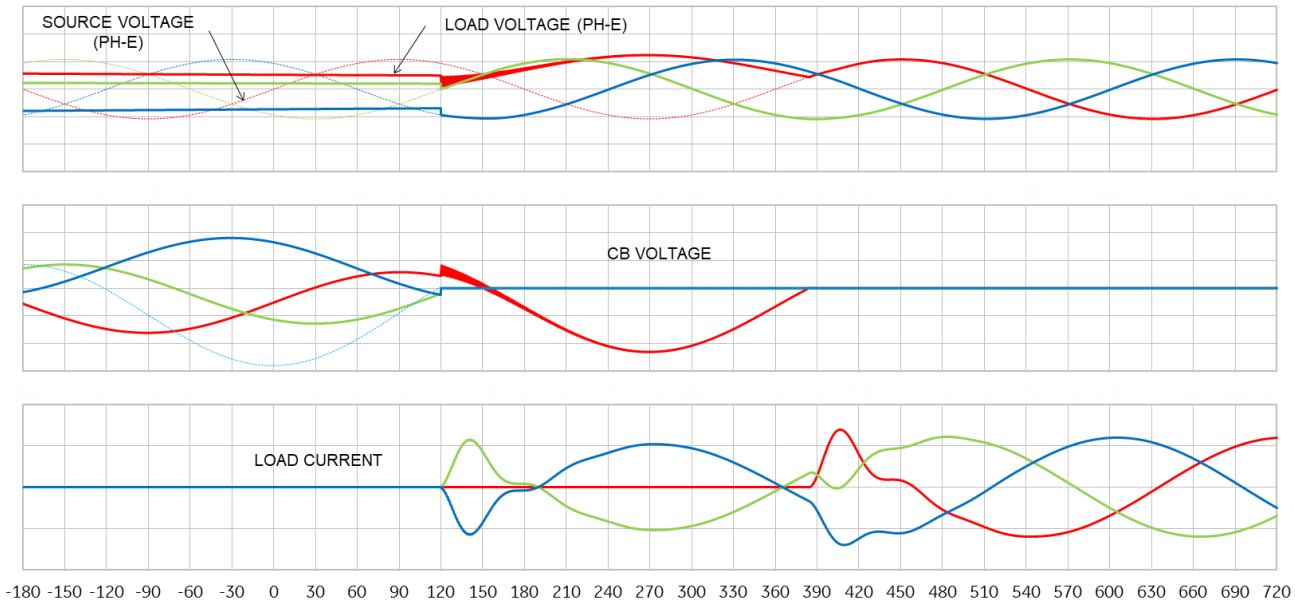


Figure 167 Isolated neutral capacitor bank closing waveforms (half trapped charge)

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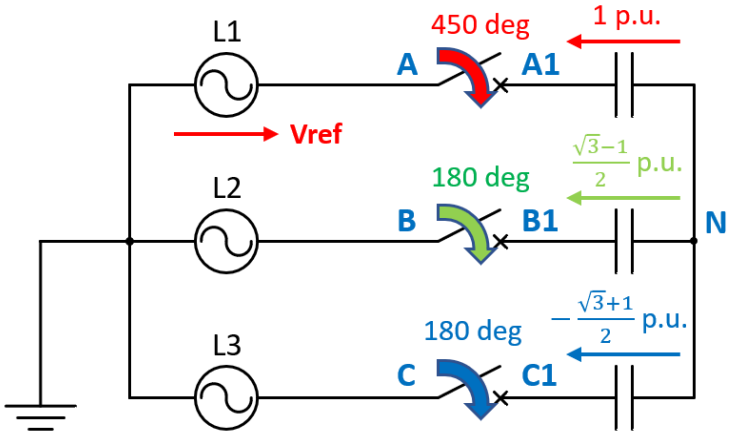


Figure 168 Isolated neutral capacitor bank closing sequence (full trapped charge)

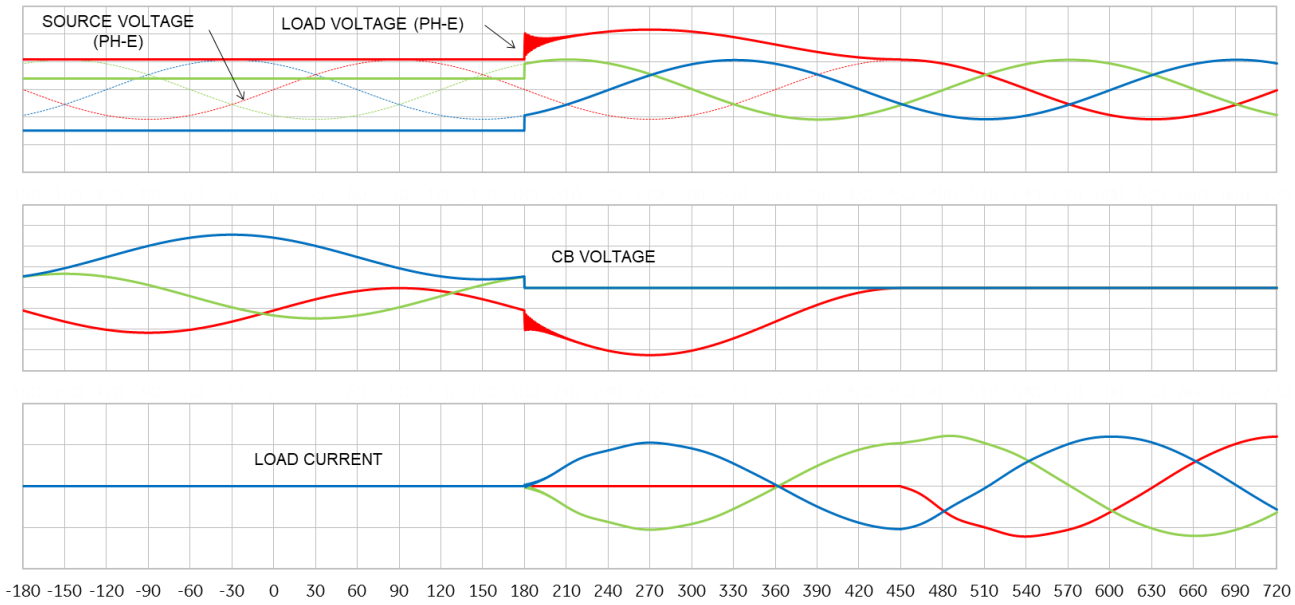


Figure 169 Isolated neutral capacitor bank closing waveforms (full trapped charge)

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12.8.5 Shunt capacitor bank controlled opening

Shunt capacitor bank controlled opening strategy is dependent of the following characteristics:

- Synchronizing waveform
  - Reference voltage;
  - Reference current;
- Bank arrangement
  - Wye-connected banks;
  - Delta connected banks;
- Position of the neutral connection
  - Solidly earthed wye-connected capacitor banks;
  - Isolated neutral (wye-connected banks or delta-connected banks);
- The desired resulting trapped charge levels to prepare subsequent controlled closing.

Duty is to deenergize each capacitor bank phase with an arcing time long enough to reduce restrike probability, and to control the polarity of the trapped charge to prepare subsequent closing operation, in case the capacitor bank is reenergized before the capacitor elements are discharged.

Following sections introduce opening targets and arcing times. Interruption targets are referenced to positive going source voltage zero crossing and positive going circuit-breaker current zero crossing.

Notes:

- When synchronizing opening operations with reference to the circuit-breaker current, attention shall be paid to the current flow direction through the CSD100 current inputs. Current shall be leading voltage by 90 deg (for a pure capacitive load), otherwise the effective trapped charge polarity resulting from opening operation is impaired and of opposite sign to the expected one;
- Switching angles are set to obtain same trapped charge whatever the synchronizing signal (reference voltage or reference current).

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12.8.5.1 Solidly earthed capacitor bank controlled opening

Phases are independent from each other and operated at respective natural current zero crossing. As current is leading voltage by 90° (capacitive circuit), the recommended sequence is 90°/30°/150° (Ref phase / Phase -120° / Phase -240°), this sequence being referred to a positive going source voltage zero crossing. This opening sequence leaves a trapped charge of +1pu / -1pu / -1pu (L1 / L2 / L3).

Subsequent closing operation, described in 12.8.4.1, is set accordingly.

Table 61 Solidly grounded capacitor bank opening program

Use case	Switching program		L1 (ref)	L2 (ref - 120 deg)	L3 (ref + 120 deg)
Synchronizing on reference voltage					
Solidly grounded capacitor bank	Capa1 (*)	Angle [deg]	90	30	150
		Trapped charge [p.u.]	+1	−1	−1
Synchronizing on reference current					
Solidly grounded capacitor bank	Capa1 (*)	Angle [deg]	180	120	240
		Trapped charge [p.u.]	+1	−1	−1

(*) CSD100 default settings.

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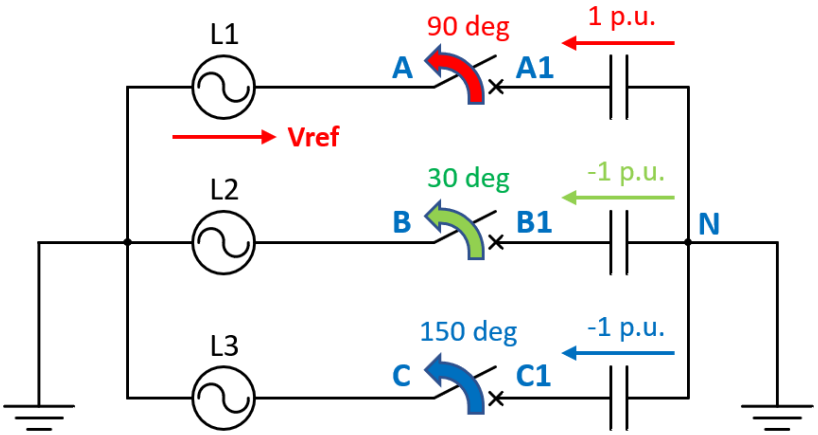


Figure 170 Solidly grounded capacitor bank opening sequence (voltage reference)

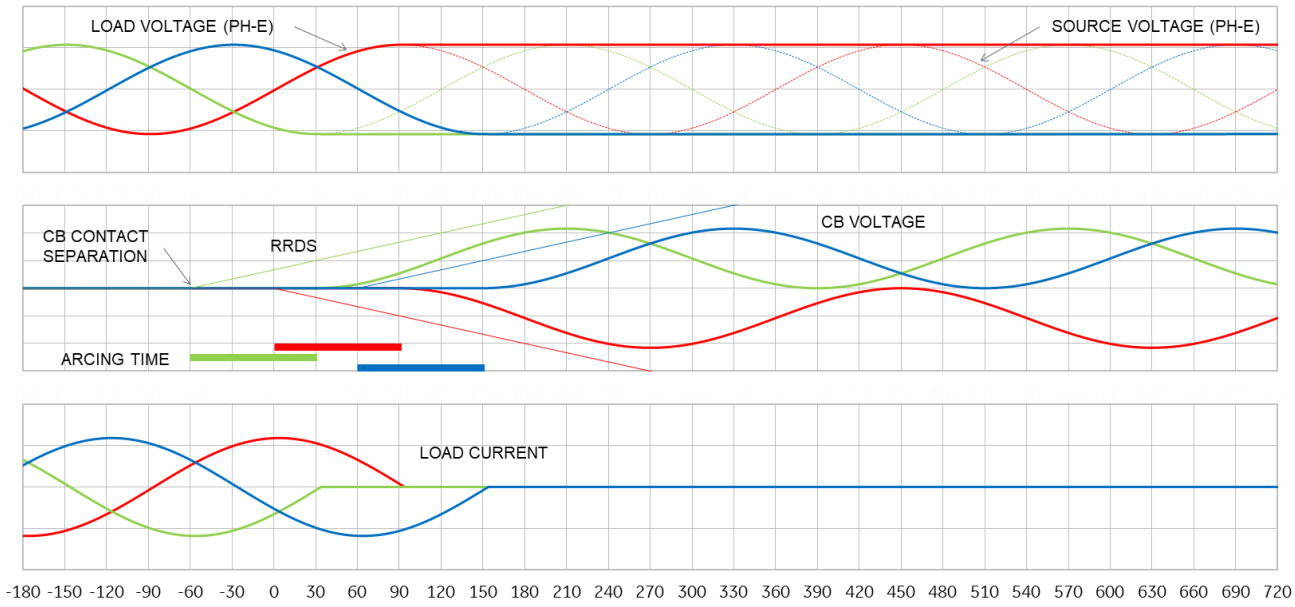


Figure 171 Solidly grounded capacitor bank opening waveforms (voltage reference)

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12.8.5.2 Isolated neutral capacitor bank

Wye and delta coupled capacitor banks are deenergized using the exact same sequence and lead to same trapped charges, when considering phase-to-earth voltages.

Recommended sequence is 90°/180°/180° (Ref phase, Phase -120°, Phase -240°), by reference to a source reference voltage.

Reference phase is first interrupted at 90° (voltage peak, similarly to solidly grounded situation) which leaves a +1 p.u. trapped charge in corresponding capacitor bank (star isolated). For delta arrangement current continues to circulate and therefore first target is not important (it may be programmed earlier). From that instant, last phases currents become equal and opposite in sign, and next zero crossing is a quarter of a period later. At the same time, neutral voltage starts to increase (DC shifted), to reach a trapped charge voltage of 0.5pu a quarter of period later, when Phase -120° and Phase -240° currents are interrupted.

Therefore, the trapped charge voltage on last phases will be the difference between source voltage at 180° (respectively +√3/2 p.u. and -√3/2 p.u.) and the neutral voltage (0.5 p.u.), as illustrated in below figures.

Trapped charge voltages (phase to earth, not to distinguish between Wye and delta situation) are:

- $+1$ p.u. for phase L1
- $+\left(\sqrt{3}-1\right)/2$ p.u. for phase L2
- $-\left(\sqrt{3}+1\right)/2$ p.u. for phase L3

Subsequent closing operation, described in 12.8.4.2, is set accordingly.

Table 62 Neutral isolated capacitor bank opening program

Use case	Switching program		L1 (ref)	L2 (ref - 120 deg)	L3 (ref + 120 deg)
Synchronizing on reference voltage					
Isolated neutral Wye-connected or Delta connected	Capa2 (*)	Angle [deg]	90	180	180
		Trapped charge PH-E [p.u.]	$+1$	$+\frac{\sqrt{3}-1}{2}$	$-\frac{\sqrt{3}+1}{2}$
Synchronizing on reference current					
Isolated neutral Wye-connected or Delta connected	Capa2 (*)	Angle [deg]	180	270	270
		Trapped charge PH-E [p.u.]	$+1$	$+\frac{\sqrt{3}-1}{2}$	$-\frac{\sqrt{3}+1}{2}$

(*) CSD100 default settings.

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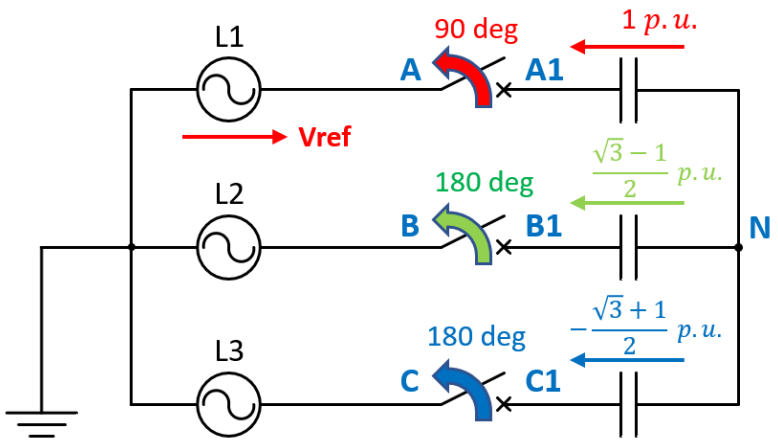


Figure 172 Isolated neutral capacitor bank (wye connected) opening sequence (voltage reference)

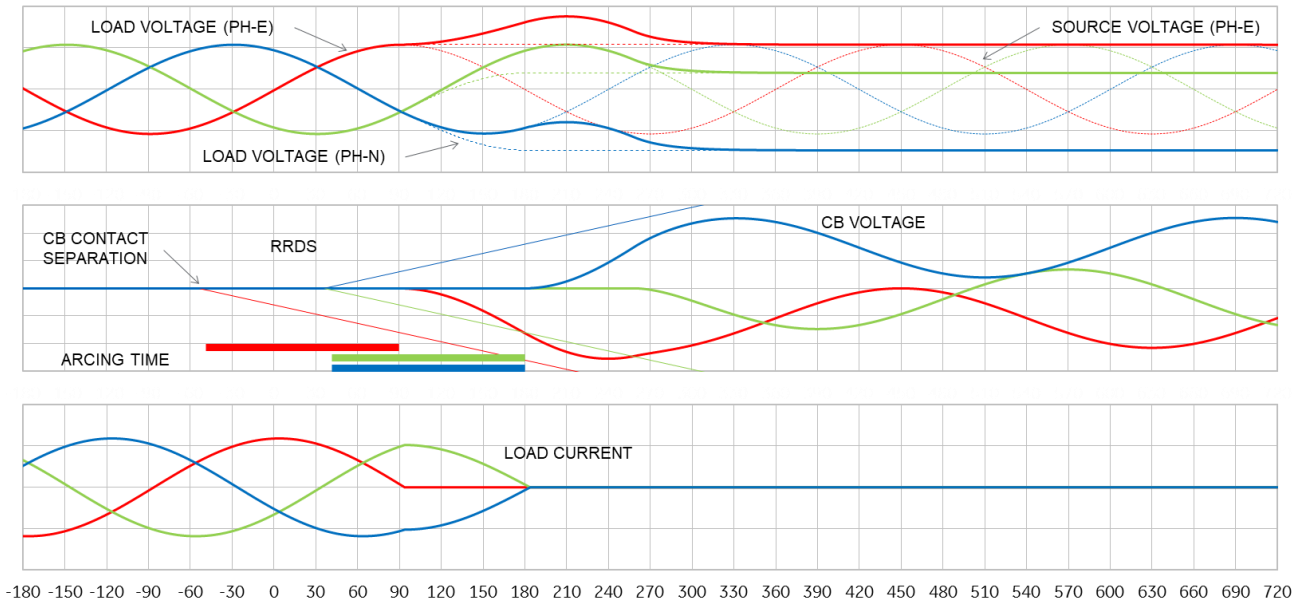


Figure 173 Isolated neutral capacitor bank (wye-connected) opening waveforms (voltage reference)

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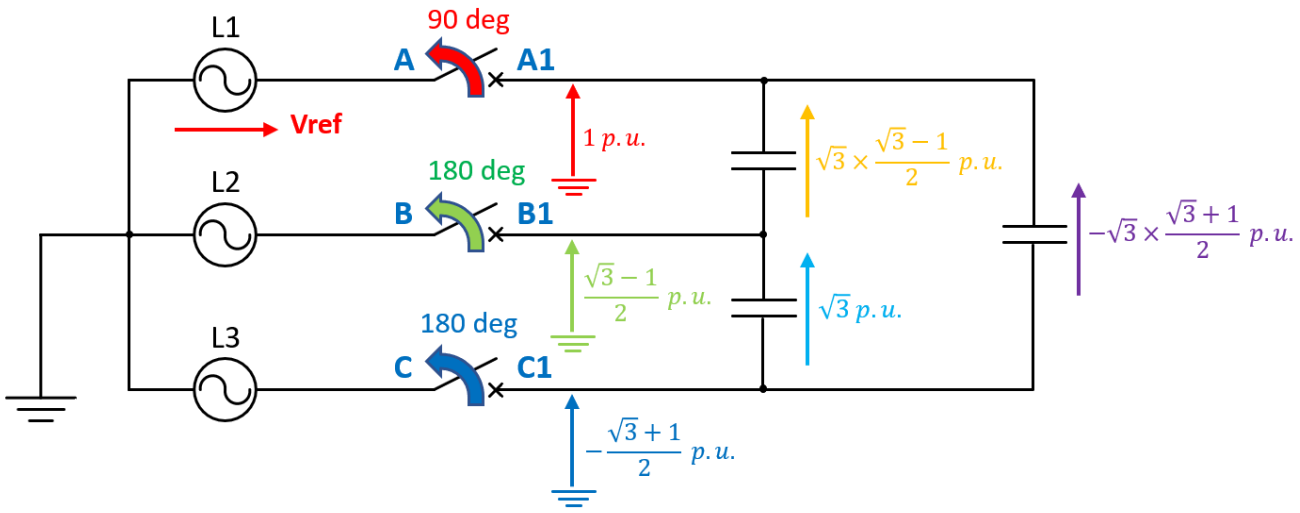


Figure 174 Isolated neutral capacitor bank (delta connected) opening sequence (voltage reference)

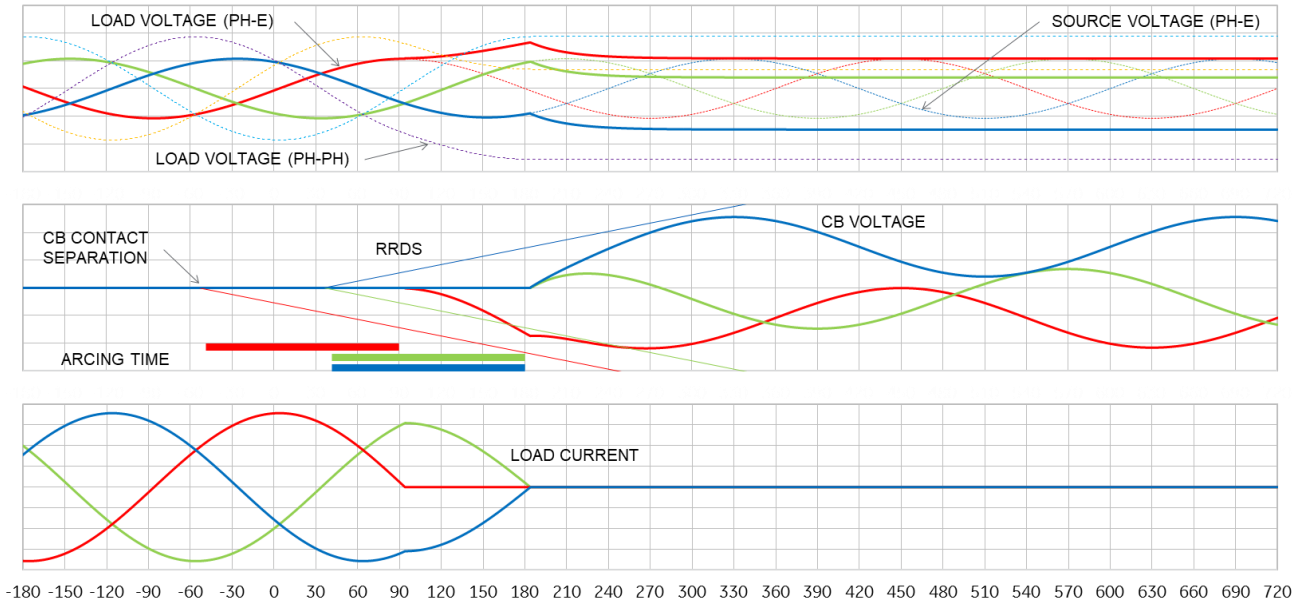


Figure 175 Isolated neutral capacitor bank (delta-connected) opening waveforms (voltage reference)

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12.8.5.3 Arcing time consideration

Due to minimum arcing time (MAT) constraint, the main contact separation shall be anticipated by the programmed arcing time, from above mentioned targets, **6ms being considered as a standard value**.

Transient recovery voltage exhibits moderate slope: circuit breaker voltage is mainly sinusoidal but biased by load voltage trapped charge.

Below figure illustrates the need for a minimum arcing time (minimum contact separation distance) before network current zero and transient recovery voltage peak. Duty for the TRV is not to exceed dielectric withstand (RRDS).

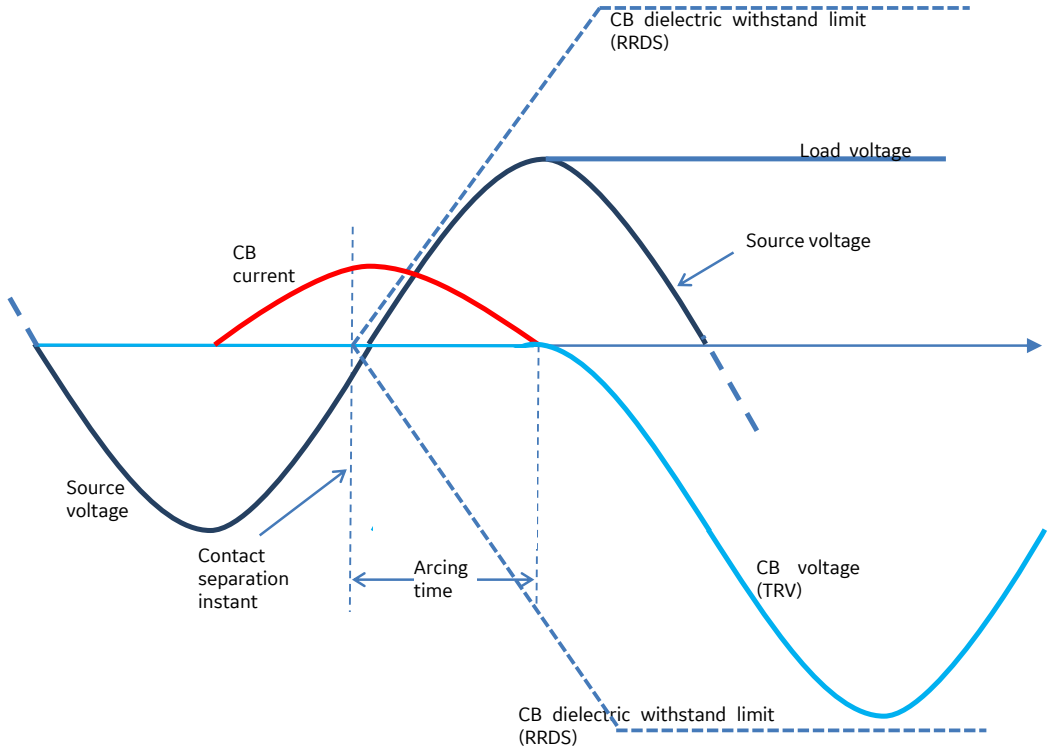


Figure 176 Illustration of capacitor bank de-energization

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12.8.6 Shunt capacitor bank with switchable neutral point

When the neutral connection is variable, e.g. the neutral point connection is switchable by the mean of a disconnector switch, management of closing angles is performed using the MLS feature of the controller detailed in 12.11.

For example, Figure 177 describes the case where the neutral point can be either solidly earthed or isolated, depending on the position of the earthing disconnector switch:

- When the earthing disconnector switch is in closed position, switching program is set as “Capa1”, with closing angles corresponding to the sequence described in 12.8.4.1 and 12.8.5.1;
- When the earthing disconnector switch is in open position, switching program is set as “Capa2”, with closing angles corresponding to the sequence described in 12.8.4.2 and 12.8.5.2.

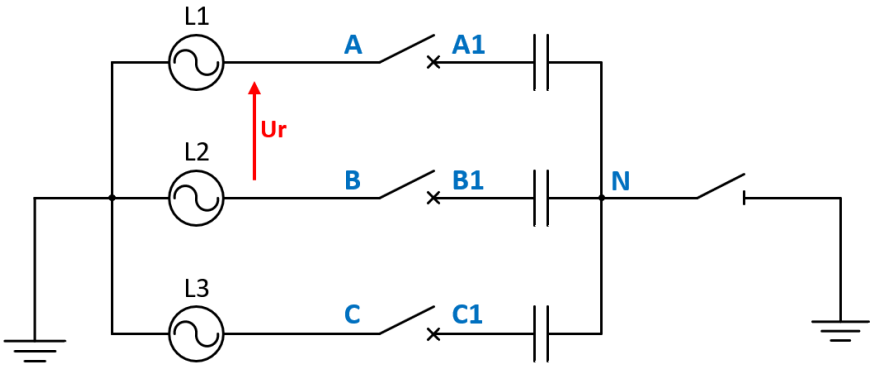


Figure 177 Capacitor bank with switchable neutral point

Table 63 Switchable neutral capacitor bank switching program

Use case	MLS1 binary input	Switching program
Neutral isolated	0	“Capa2”
Neutral solidly earthed	1	“Capa1”

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12.9 Power transformer switching application

This section describes the strategy used for controlled switching of no-load power transformer.

Energization: The general principle is to switch on each winding at flux continuity condition, either residual (first winding) or dynamic (subsequent windings). Flux matching instant is targeted, when prospective flux equals:

- magnetic core residual flux for first winding to close
- dynamic flux imposed by winding already energized for remaining windings to close

De-energization of unloaded transformers creates much less transient than opening of reactors. Switching overvoltages coming from magnetizing current interruption are small, the transient recovery voltage being damped by distributed capacitances of the power transformer. Controlled opening duty is to control transformer core residual flux (practically, null residual flux is expected), thanks to natural current chopping of magnetizing current (actual arcing times are very short)

Note: Ideal switching sequence cannot be achieved for bank of single-phase transformers with isolated neutral, phase shifting transformer (PST), transformer with zig-zag winding, and transformer with a capacitor bank solidly connected to the tertiary winding.

In full no load condition, switch off allows for accurate control of the residual flux in some cases, particularly when zero residual flux condition is looked for. In any case, this is a good practice, to prepare for next energization.

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12.9.1 Power transformer switching concerns

Random energizing of power transformers from the grid, generates strong inrush currents due to iron core turning into saturation and has a direct influence on power quality, such as voltage dip, and the overall electrical transmission system reliability, particularly when connected to a weak transmission system or during restoration phase.

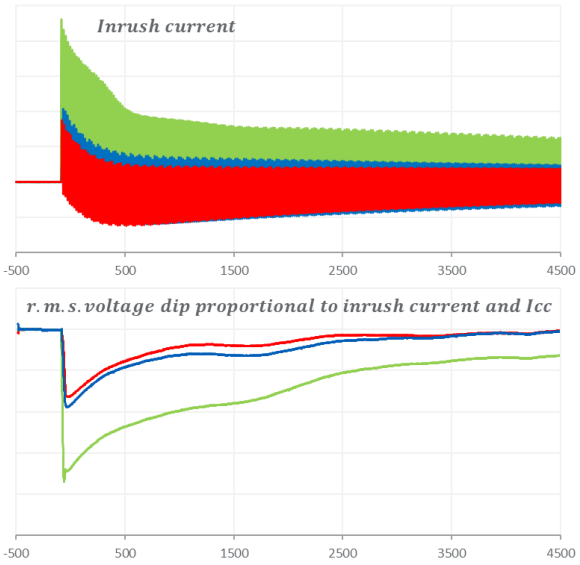


Figure 178 Inrush current (~2000A) and voltage dip (-4%) caused by transformer energizing

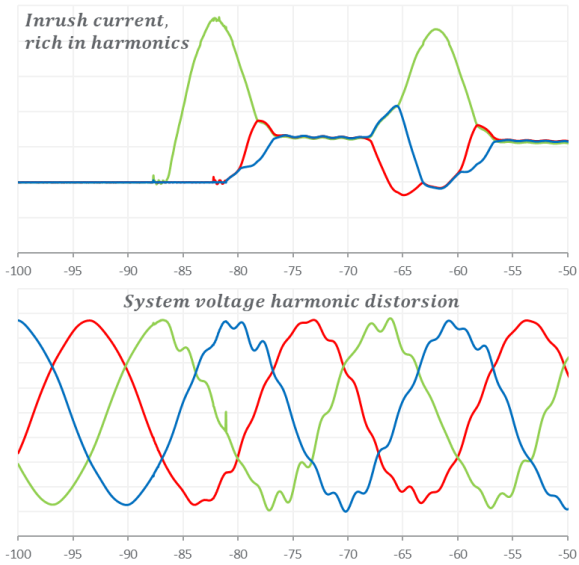


Figure 179 System voltage harmonic distorsion caused by transformer energizing

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Taking into consideration the residual flux inside the power transformer iron core and computing the circuit breaker closing targets accordingly, controlled closing technique allows a significant reduction of inrush current (Figure 181).

Residual flux level is computed by the CSD100, whatever the previous de-energizing condition. Each winding flux is practically obtained from integration of the voltage measured at power transformer terminals, either HV, LV or TV side, considering the windings coupling and vector group.

Purely inductive voltage transformers are favorable since their accuracy towards very low frequencies is better.

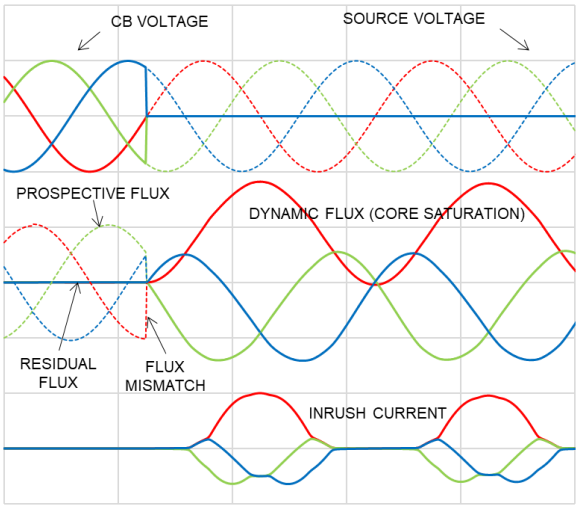


Figure 180 Power transformer random closing

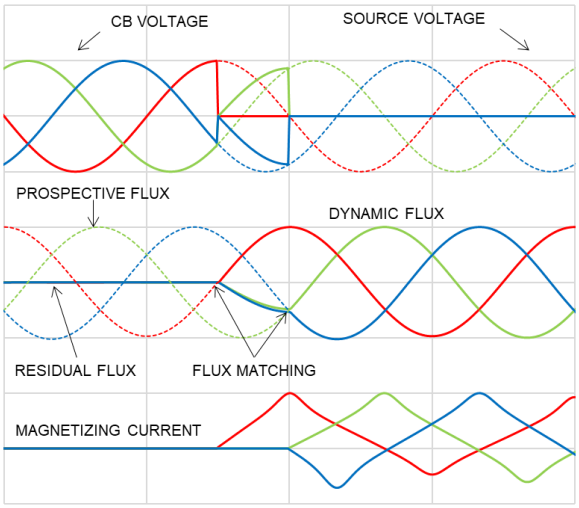


Figure 181 Power transformer controlled closing

For many applications, controlled opening allows control of residual flux level in the power transformer iron core to prepare subsequent closing operation by targeting fixed angles.

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12.9.2 Substation layout considerations

Best results are obtained with full no-load condition, or very light load. Non negligible loads (located either at primary, secondary or tertiary side) regarding power rating of the power transformer will generally impair switching performances, since ideal targets for the power transformer and ideal targets for the additional load might not be the same.

When residual flux is considered, it is computed from power transformer voltage information. The voltage transformers shall be connected in the immediate vicinity of the power transformer for optimal performances.

Example with cable length between transformer and circuit breaker:

In this arrangement, power transformer and HV cable are energized at same time, but ideal targets are different for transformer and cable. It is still recommended to give priority to the power transformer targets with below additional remark and justification:

- As power transformer saturation last for a longer time than cable inrush charging current, it is optimal to give priority to power transformer strategy.
- It is recommended to insert dead half periods between first phase to close and subsequent phases to close, to allow for transitory oscillation (resonant circuit) to damp.

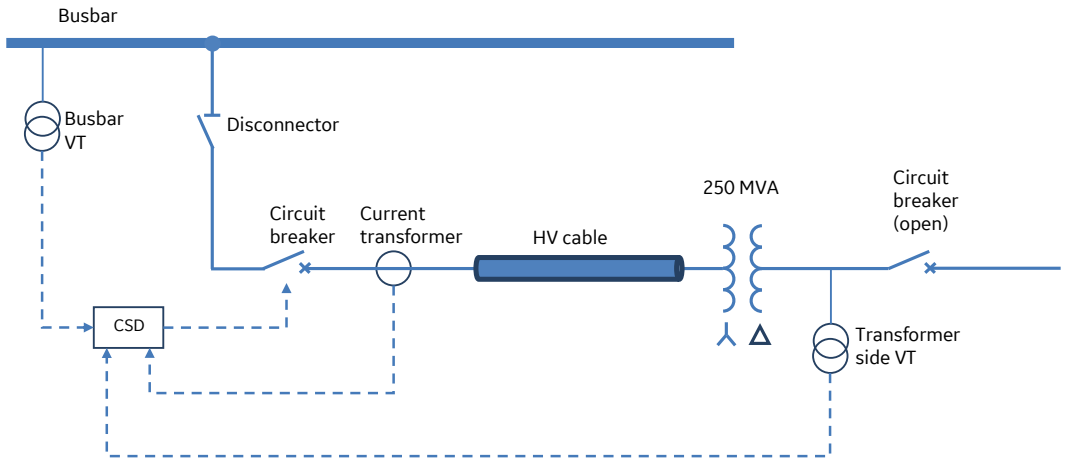


Figure 182 Power transformer application with HV cable stray capacitance

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Example with converter poles (dual HVDC transformers with energization of two transformers in parallel):

In this arrangement, optimal performances can be achieved since power transformer primary sides are of same nature. Thus, targets are the same for both transformers.

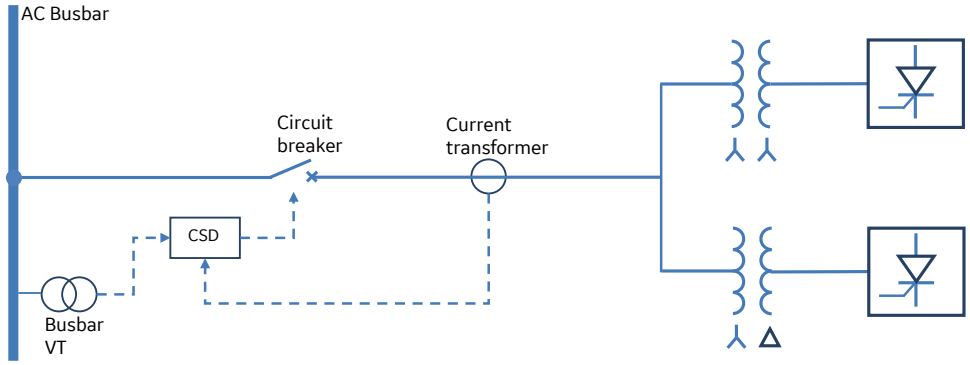


Figure 183 HVDC power transformer application

Example with multi chamber circuit breaker equipped with grading capacitors.

In this arrangement, residual voltage due to capacitive current flowing through grading capacitors deserves attention: if residual voltage exceeds 15~20% of nominal voltage, synchronization according to voltage difference between source and load shall be activated. If power transformer is an ICT (interconnecting transformer) the residual voltage may also come from the circuit breaker located at the other side, if fitted with grading capacitors.

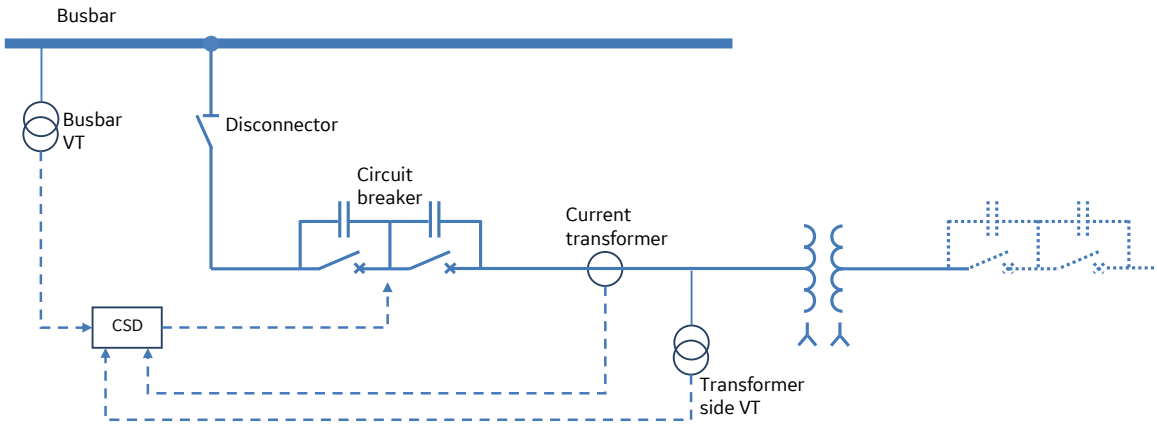


Figure 184 Multi chamber circuit breaker fitted with grading capacitors

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Table 64 Power transformer signal wiring

Signal wiring	Recommendation
Source voltage	MANDATORY 1 phase for synchronizing purpose or 3 phases if voltage dips to be measured
	ALTERNATIVE 3 phases may be wired to the controller for automatic selection of synchronizing phase and reduce in / out delay
	VT type / class: 3P protection class or 1.0 metering class (or better) to achieve less than 0.1ms phase displacement in steady voltage condition (50/60Hz)
Load voltage	MANDATORY FOR FLUX MODE, HIGHLY RECOMMENDED IN ANY CASE 3 phases (1 phase could be sufficient for residual flux computation in some cases) If VTs are available at load side, connection to RPH is recommended for closing operations. This helps fine tuning (checking for actual making times, after operation) 1)Making time measurement 2)Residual flux estimation
	VT type / class: 3PT1, 3PT2 or 3PT3 protection class
Load current	MANDATORY 3 phases motivation to activate: 1) Synchronized opening operation based on current signal 2) Interrupting time measurement, arcing time measurement and detection of reignition 3) Making time measurement Operating time measurement and compensation by current rise / extinction method (enables to calculate when current making / breaking occurs (reconstruction method) 4) Peak current monitoring upon closing for alarm processing
	CT type / class: Protection class.

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12.9.3 Power transformer types

12.9.3.1 Magnetic core – phase to phase dependence

Two magnetic core families of transformers are considered for transformer controlled switching application with CSD100:

- Transformers with independent magnetic cores (no flux sharing between windings)
- Transformers with shared magnetic core (flux is shared between windings)

This consideration extends to any voltage sharing mean, comprising delta coupled windings, and ultimately address the question of phase-to-phase dependence.

12.9.3.1.1 Transformer with independent core

Transformer considered with independent core (phase to phase independence):

- Bank of single-phase transformers without any winding coupled in delta
- Shell-type transformer without any winding coupled in delta (considering that the flux from the first closed winding mainly returns through non-wrapped legs)

12.9.3.1.2 Transformer with shared cored

Transformer considered with shared core:

- Transformer with delta coupling at either primary, secondary or tertiary side, whatever the type of transformer
- 3-phase transformers with 3 limbs
- 3-phase transformers with 4 or 5 limbs (considering that the flux from the first closed winding mainly returns through wrapped legs)
- Bank of single-phase transformers with at least one winding system (primary, secondary, tertiary) coupled in delta

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12.9.3.2 Neutral connection

This section refers to the connection of the transformer neutral point at switching (circuit breaker) side.

12.9.3.2.1 Grounded transformers

Case of transformer with star coupled windings (considered as switching side) with solidly grounded neutral or neutral grounded with reactor (NGR or NER).

Depending on applied switching strategy (fixed angle or consideration of residual flux, refer to 12.9.4), the first phase is closed, either on a voltage peak (consideration of residual flux absence), or on the angle corresponding to the measured residual flux value.

This first closing operation forces a flux in all legs, either directly through the multi-limbed cores of the transformer, or through windings coupled in delta. Particularly, the resulting flux in second and third phase is of opposite sign and half value of the first phase one. Closing of remaining two phases occurs simultaneously when the induced flux in the remaining cores reaches its steady-state prospective value, i.e. one quarter of a cycle (modulo 180°) later, which corresponds to phase-to-phase peak voltage instant.

12.9.3.2.2 NER (NGR) grounded transformers

From a switching perspective, NER (neutral earthed resistor / reactor) grounded transformers shall be considered as solidly grounded.

Therefore, the same switching angles than those applied to solidly grounded transformers are applicable.

12.9.3.2.3 Ungrounded transformers

Switching side (circuit breaker side) windings are connected in delta, or in star with floating neutral point.

General consideration:

With an isolated neutral, closing of one phase makes no sense because no current flows.

With consideration of residual flux absence, two phases (Ref-120° and Ref-240°) are closed first simultaneously, when voltage difference is maximum and prospective flux null.

With consideration of residual flux measured value, winding/leg with highest residual flux value is energized first (delta) or two windings/legs with highest absolute difference of residual fluxes values are energized first (star isolated), by closing simultaneously the two poles of the circuit breaker surrounding this winding(s), when phase-to-phase voltage match residual flux target.

In any case, third phase is then closed at the next voltage peak at its terminals (plus user settable number of half periods) when the flux resulting from the first closing is equivalent to prospective flux.

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Example of transformer with delta coupled windings at switching side.

In Figure 174, residual flux absolute value being maximum for the 1st limb of the transformer, switching sequence is

- Closing CB_a and CB_b simultaneously at Va-Vb angle corresponding to the residual flux measured value
- Closing CB_c at the next voltage peak at its terminals (plus user settable number of half periods)

Similarly:

- If residual flux absolute value is maximum for the 2nd limb of the transformer, switching sequence is:
  - Closing CB_b and CB_c simultaneously at Vb-Vc angle corresponding to the residual flux measured value
  - Closing CB_a at the next voltage peak at its terminals (plus user settable number of half periods)
- If residual flux absolute value is maximum for the 3rd limb of the transformer, switching sequence is:
  - Closing CB_c and CB_a simultaneously at Vc-Va angle corresponding to the residual flux measured value
  - Closing CB_a at the next voltage peak at its terminals (plus user settable number of half periods)

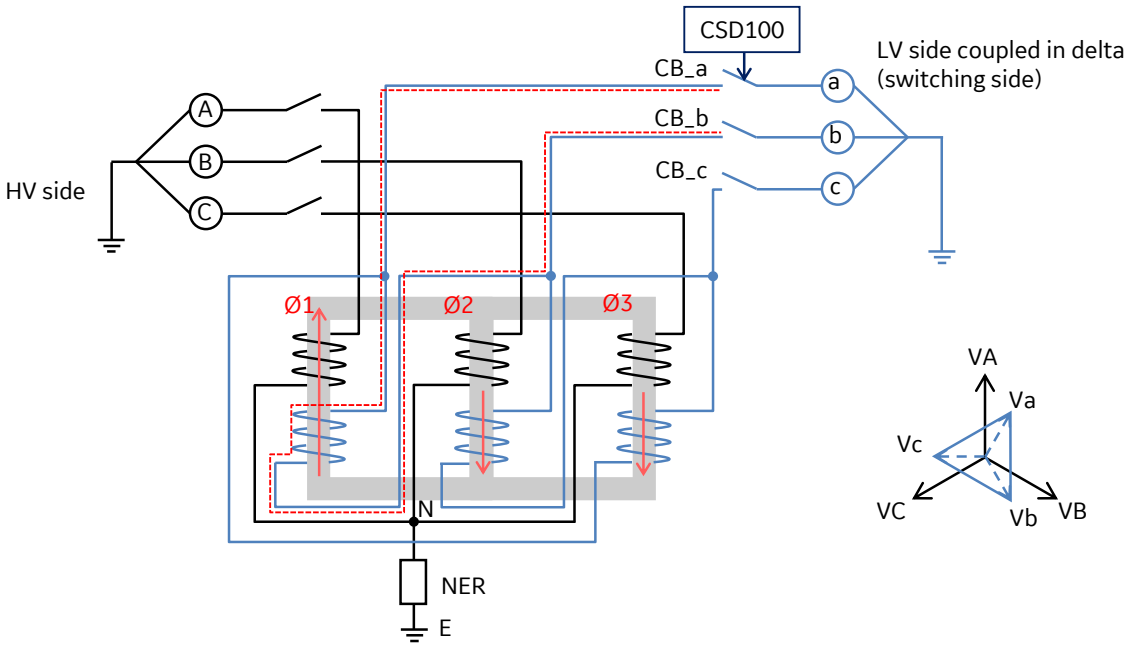


Figure 185 Example of delta winding arrangement (Ynd1) and switching sequence

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Example of transformer with star coupled windings at switching side, with isolated neutral

In Figure 175, the highest absolute difference of residual fluxes is | Ø1- Ø3| and switching sequence is:

- Closing CB_A and CB_C simultaneously at VA-VC angle corresponding to the residual flux measured value
- Closing CB_B at the next voltage peak at its terminals (plus user settable number of half periods)

Similarly:

- If the highest absolute difference of residual fluxes is | Ø1- Ø2|, switching sequence is:
  - Closing CB_A and CB_B simultaneously at VA-VB angle corresponding to the residual flux measured value
  - Closing CB_C at the next voltage peak at its terminals (plus user settable number of half periods)
- If the highest absolute difference of residual fluxes is | Ø2- Ø3|, switching sequence is:
  - Closing CB_B and CB_C simultaneously at VB-VC angle corresponding to the residual flux measured value
  - Closing CB_A at the next voltage peak at its terminals (plus user settable number of half periods)

Third phase is then closed 1 quarter of period later (modulo 180°), at the voltage peak at its terminals, when the flux resulting from the first closing is equivalent to prospective flux.

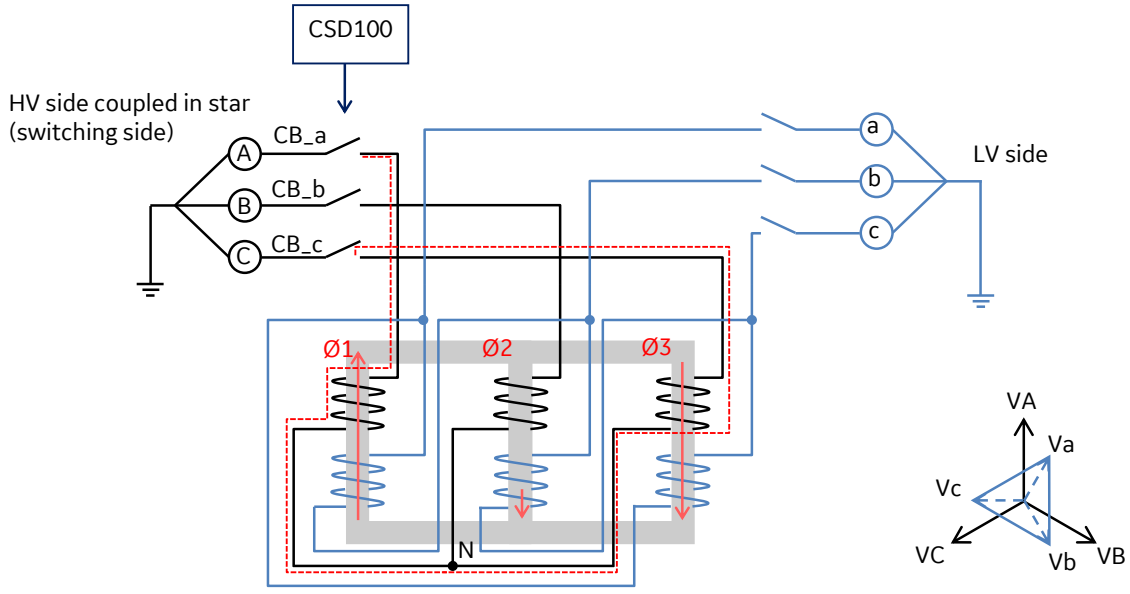


Figure 186 Example of transformer winding arrangement (Yd1) and switching sequence

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12.9.3.3 Grounded transformer banks with independent core (phase to phase independence)

Depending on applied switching strategy (refer to 12.9.4), since there is no inter-phase coupling, each pole is closed:

- at its own respective peak voltage resulting in a phase sequence of 120 degrees between each one (hypothesis of residual flux absence)
- at the angle corresponding to the measured residual flux value for each phase.

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12.9.4 Power transformer switching strategies

When performing transformer controlled energizing operations, the methods considered are:

- Energizing at fixed angles
  - without any consideration of residual flux level
  - with consideration of a known residual flux level (usually null) fixed by a previous controlled de-energizing.
- Energizing at variable angles taking into consideration residual flux measured value by the aid of the CSD, whatever the previous de-energizing condition.

Optimal transformer switching operations are carried out in no load conditions. However, if multi chambers circuit breakers are equipped with grading capacitors (either at primary or secondary), these capacitors allow for a small capacitive current to circulate in windings. This may lead to significant variation of residual flux.

In this peculiar case, energization at fixed angles is the only method applicable.

12.9.4.1 De-energizing

De-energizing of unloaded power transformers is not a concern for circuit breakers or for adjacent network. As no load “small” magnetizing current can be chopped by the circuit breaker, without excessive transient recovery voltage, contact separation can occur at any time. Practically, controlled de-energization aims to control the level of residual flux, and leave the power transformer core with as low as possible residual flux. For that purpose, current is chopped near zero flux condition (voltage peaks), with anticipated very short arcing time (<1ms). A narrow sequence is used.

Table 65 Power transformer opening program – De-energizing

Use case	Switching program		L1 (ref *)	L2 (ref - 120 deg)	L3 (ref + 120 deg)
Star Neutral grounded	Transfo1	Angle [deg]	270°	210°	150°
Delta or Star Neutral isolated	Transfo2	Angle [deg]	90°	180°	180°
Yy independent core	User	Angle [deg]	270°	210°	150°

* Ref: zero crossing of reference voltage, with positive dv/dt

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12.9.4.2 Energizing at fixed angles

12.9.4.2.1 No consideration of residual flux

Energizing a power transformer at fixed switching angles, when transformer core residual flux value is not appraised, is typically achieved at relevant peak voltage, when prospective flux for first closed phase is null and equals to dynamic flux for remaining ones. To avoid switching under the worst condition, i.e. closing the first phase at the time where residual and prospective flux gap is high and with an opposite polarity, this strategy is adopted as the minimum requirement.

The switching sequence depends on winding arrangement and neutral position.

12.9.4.2.2 Consideration of a known residual flux

Residual flux level is fixed by a previous controlled de-energizing or external influencing factors (gradual voltage reduction, core demagnetization or core magnetization).

Controlled opening of circuit-breakers feeding power transformers serves as a good support to prepare subsequent closing operation. Depending on the load current, residual flux level can be fixed, on recurrent basis during de-energizing, to a certain predictable amount. Particularly, demagnetization of iron core can be achieved through a proper sequence. When the transformer is under no-load condition, the ability of gas circuit-breaker to chop transformer magnetizing / no-load current without any re-ignition nor restrike issue (thanks to moderate TRV) gives the opportunity to control the residual flux level inside the transformer magnetic core. Interruption of magnetizing current can be controlled with a good accuracy. Subsequent energizing sequence can be achieved at fixed angles corresponding to the expected residual flux level.

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12.9.4.2.3 Switching angles

Table 66 Power transformer closing program – Energizing at fixed angles

Use case	Switching program		L1 (ref *)	L2 (ref – 120 deg)	L3 (ref + 120 deg)
Star Neutral grounded	Transfo1	Angle [deg]	90°	180° + n*180°	180° + n*180°
		CB voltage [p.u.]	1	$\sqrt{3}$	$\sqrt{3}$
		CB R.D.D.S [p.u.]	1	2	2
Delta or Star Neutral isolated	Transfo2	Angle [deg]	90° + n*180°	0°	0°
		CB voltage [p.u.]	1.5	$\sqrt{3}$	$\sqrt{3}$
		CB R.D.D.S [p.u.]	1	2	2
Yy independent core	User	Angle [deg]	90° + k*180°	30° + m*180°	150° + n*180°
		CB voltage [p.u.]	1	1	1
		CB R.D.D.S [p.u.]	1	1	1

* Ref : zero crossing of reference voltage, with positive dv/dt

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12.9.4.3 Energizing at variable angles taking into consideration residual flux level

First winding energizing point is directly derived from the level of residual flux (expressed in per unit scale). From a positive slope voltage zero crossing reference, targets may fall in the [0-90°] or [180°-270°] (respectively negative and positive residual fluxes).

- Ørespu > 0 : target $\alpha = 3\pi/2 - \text{asin}(Ørespu)$
- Ørespu < 0 : target $\alpha = \text{asin}(Ørespu) + \pi/2$

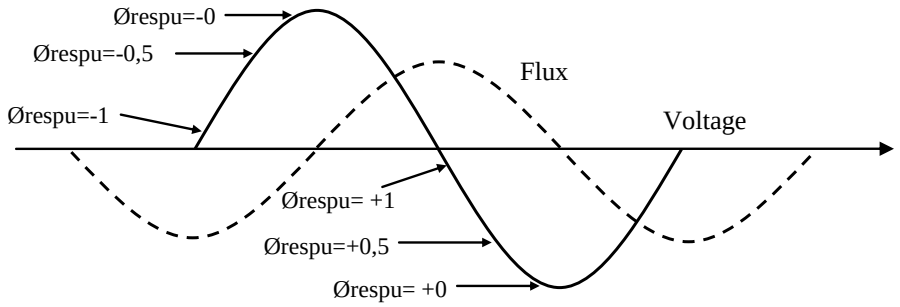


Figure 187 Targets for first winding, according to residual flux

12.9.4.3.1 Residual flux computation

Residual flux level is computed by the CSD100, at the time of transformer de-energization, whatever the de-energizing condition, i.e. controlled opening, random opening, protection tripping, or de-energizing by another circuit-breaker (low voltage side for instance).

CSD100 permanently monitors transformer voltages. As soon as de-energization is detected (r.m.s. voltages falls below set threshold), residual flux estimator is activated. This process is independent from switching and circuit breaker control.

Each winding / core flux is computed from integration of the voltage measured at transformer terminals (refer to Table 38 for voltage correspondence); either HV or LV / TV side, taking into account the windings coupling and transformer vector group.

First step is therefore to compute voltages across the windings from the measured voltages (usually phase to ground voltages).

Then, voltages are permanently integrated (“on the fly”), whatever transformer status (energized or not).

When de-energizing is detected, the flux is sampled and memorized at the exact time of flux stabilization.

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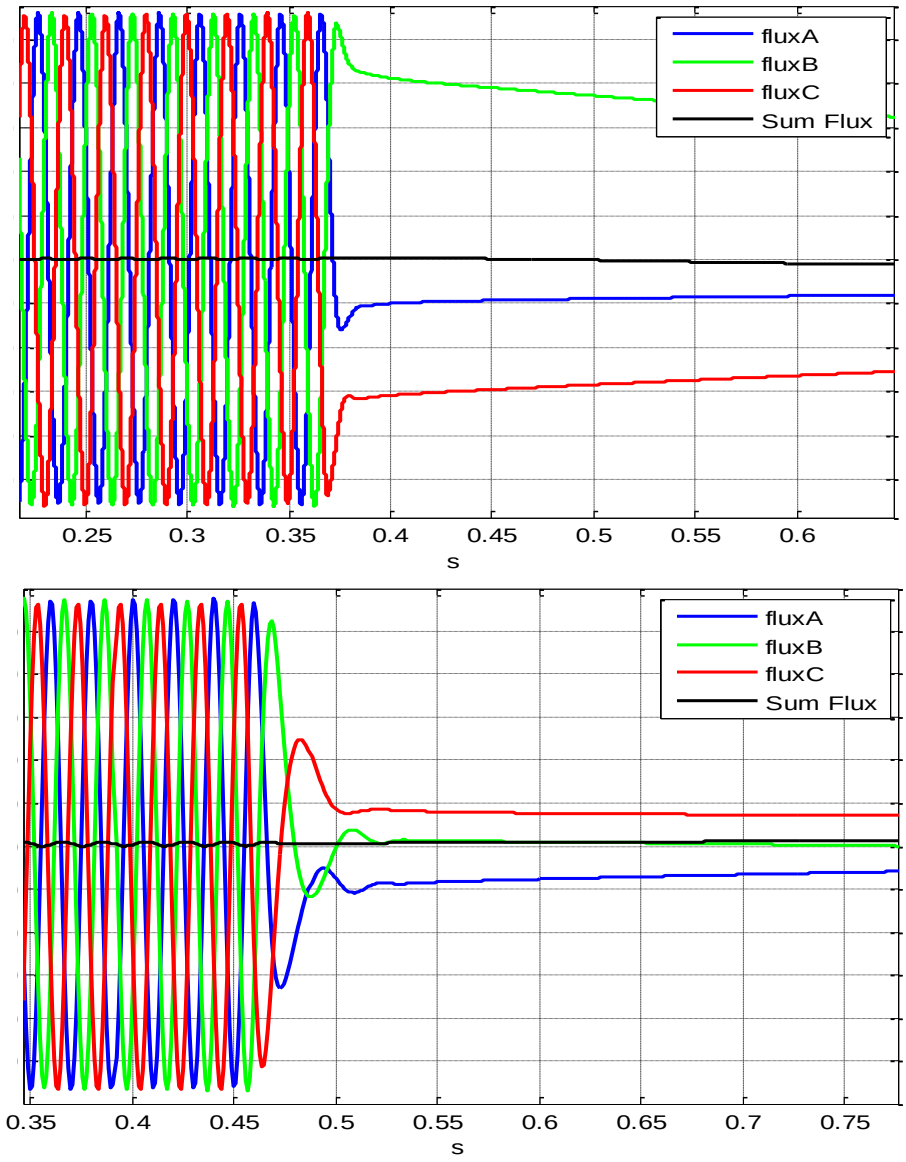


Figure 188 Fluxes waveforms captured upon de-energization: un-controlled opening VS controlled opening (field records)

Final residual flux value is given in relative value (p.u., per unit) and not in Weber. Therefore, the nominal flux value (when transformer is fully energized) is necessary. This value is not obtained from the set voltage level at measuring side, but from the measured and computed flux value far before de-energization (between 30 and 36 periods before de-energizing is detected, depending of power frequency).

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12.9.4.3.2 Recommended voltage transformers for residual flux computation.

Table 67 Recommended voltage transformers for residual flux computation

VT type	Applicability
Purely inductive (wound type)	Recommended
Purely capacitive or RC divider	Applicable, if it can deliver adequate power to CSD100 voltage input without excessive phase shift. CSD100 voltage input is resistive (650kΩ) and capacitive (4,7nF). Power consumption is less than 0.2VA, worst case (250VAC).
Capacitive voltage transformer (“CVT”) made of high voltage capacitive divider and inductive transformer across low voltage capacitor (plus tuning reactor).	Applicable, with expected degraded performances. Computed residual flux values are usually lower than actual values, typically by a factor of two, but residual flux value sign is correctly computed. Expected level of performance is between residual flux value consideration from purely inductive VTs and non-consideration of residual flux (null residual flux hypothesis).

Measurement of phase-to-earth (phase-to-ground) or phase-to-neutral voltage at transformer terminals is required for integration.

12.9.4.3.3 Residual flux management

Residual flux value is memorized in a non-volatile memory of the CSD100 even after shutdown / restart or reset (including setting change) of the device.

In case the transformer energization duration is lower than 10 seconds (opening operation immediately following closing operation, CO cycle), residual flux values computation is not possible and residual flux values are automatically reset to zero, hence avoiding any flux computation error.

Residual flux values can also be set manually using the CSD100 control interface. Particularly, it is recommended to reset manually residual flux values:

- Before first transformer energization
- After transformer maintenance campaign
- After CSD100 replacement (if the previous value has been lost)

Note: demagnetization of the transformer core using external device is advised before first transformer energization or after transformer maintenance

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12.9.4.3.4 Switching (energizing) angles

General principle is to energize first the winding supporting highest level of residual flux, to minimize flux difference for other windings. Two remaining ones are energized according to the sequence used for switching at fixed angles.

Table 68 Power transformer closing program – Energizing at variable angles

Use case	Switching program		L1 (ref *)	L2 (ref - 120 deg **)	L3 (ref + 120 deg)
Star Neutral grounded	Transfo1	Angle [deg] (res flux < 0)	$90 + \sin^{-1}(\varphi_r) * 180/\pi$	180° + n*180°	180° + n*180°
		Angle [deg] (res flux > 0)	$270 - \sin^{-1}(\varphi_r) * 180/\pi$	180° + n*180°	180° + n*180°
		CB voltage [p.u.]	1	$\sqrt{3}$	$\sqrt{3}$
		CB R.D.D.S [p.u.]	1	2	2
Star / Delta Neutral isolated	Transfo2	Angle [deg] (res flux < 0)	$90 + \sin^{-1}(\varphi_r) * 180/\pi$	$90 + \sin^{-1}(\varphi_r) * 180/\pi$	330°+n*180°
		Angle [deg] (res flux > 0)	$270 - \sin^{-1}(\varphi_r) * 180/\pi$	$270 - \sin^{-1}(\varphi_r) * 180/\pi$	330°+n*180°
		CB voltage [p.u.]	1.5	$\sqrt{3}$	$\sqrt{3}$
		CB R.D.D.S [p.u.]	1	2	2
Yy independent core	Transfo1	Angle [deg] (res flux < 0)	$90 + \sin^{-1}(\varphi_r) * 180/\pi$	$30 + \sin^{-1}(\varphi_r) * 180/\pi$	$150 + \sin^{-1}(\varphi_r) * 180/\pi$
		Angle [deg] (res flux > 0)	$270 - \sin^{-1}(\varphi_r) * 180/\pi$	$210 - \sin^{-1}(\varphi_r) * 180/\pi$	$330 - \sin^{-1}(\varphi_r) * 180/\pi$
		CB voltage [p.u.]	1	1	1
		CB R.D.D.S [p.u.]	1	1	1

* Phase with max absolute value of residual flux

** For isolated neutral Ref and Ref-120° controls winding with highest absolute residual flux value

φ_r : residual flux (p.u.)

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12.9.4.3.5 Limit angles / allowed switching zone

It is worth to note that, for a known value of residual flux, two theoretical targets correspond to the favorable switching angle to energize the transformer, as illustrated on below figure. Practically, only one target (“Target 1”) is relevant for effective switching, due to CB closing time scatter and limited RDDS.

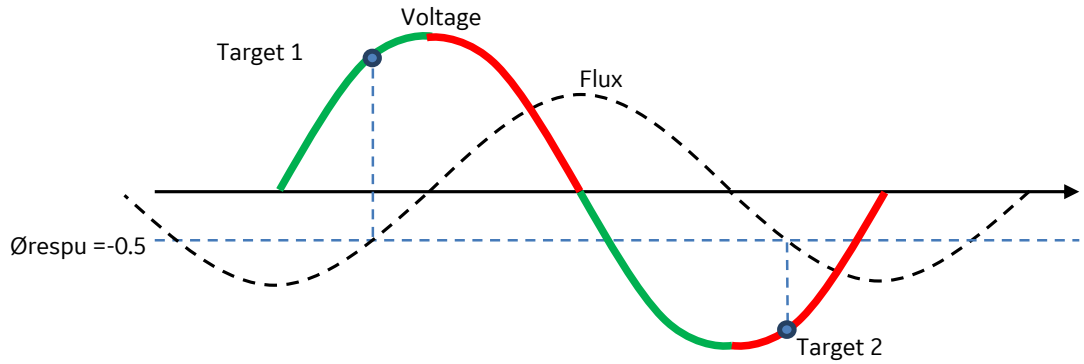


Figure 189 Example of residual flux and corresponding targets possibilities

The area [0° .. 90°] ∪ [180°..270°] shown in above figure is further slightly reduced to allowed target area: [0°+ε_1 .. 90°-ε_2] ∪ [180°+ε_1 .. 270°-ε_2].

Minimum and maximum allowed switching angles are defined and computed by the CSD100 based on:

- Network rated frequency
- Network rated voltage
- Circuit-breaker RDDS
- Circuit-breaker closing time scatter

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Effective computed angles are therefore corrected to bring them to achievable switching targets (below figure).

- Angles in zone 1 are brought to the minimum value of the allowed switching zone (reduce the risk of prestrike to previous voltage alternance).
- Angles in zone 2 are not corrected as they are within the allowed switching zone (reduce the risk of prestrike to following decreasing part of voltage);
- Angles in zone 3 are brought to the maximum value of the allowed switching zone.
- Angles in zone 4 are not allowed

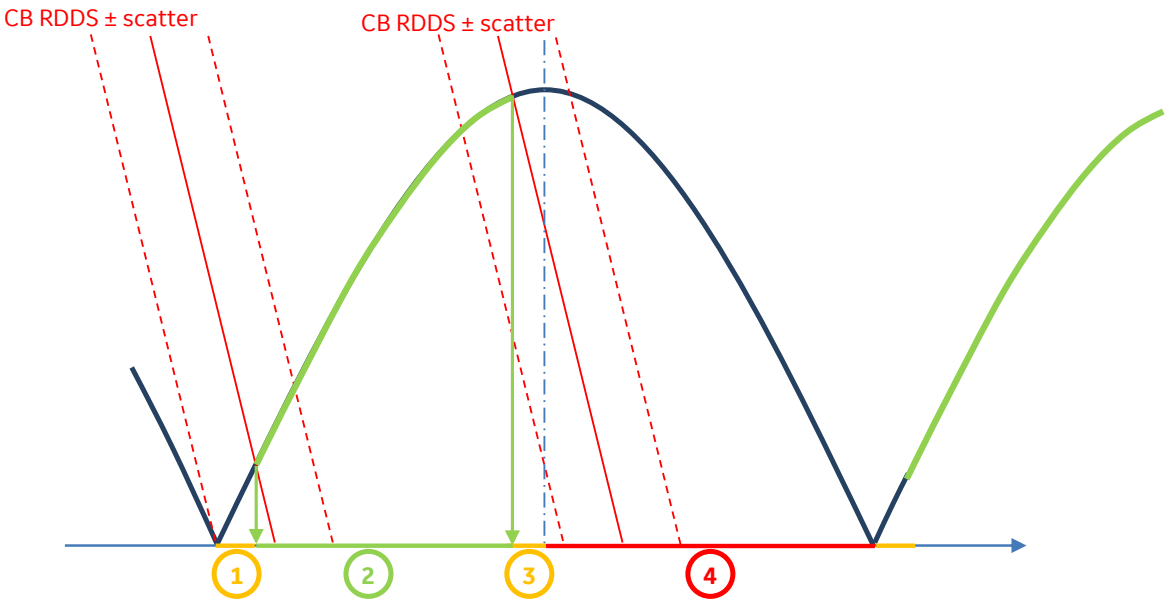


Figure 190 Transformer switching angles correction

12.9.4.3.6 Pre-arcing time computation

As soon as closing is carried out according to residual flux computed value, pre-arcing times are automatically computed, from set system voltage level at switching (circuit breaker) side, circuit breaker RDDS and circuit breaker scattering.

Refer to 12.5.8.9 for details.

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12.9.4.4 Fixed targets, variable targets and automatic switching between them

In transformer mode, user can choose between three sub modes of operation (refer to HMI manual).

- CB is systematically closed with fixed targets
- CB is systematically closed according to memorized residual flux values (first winding).
- Automatic selection between two previous modes, with prioritization to fixed targets mode. Criterion is explained below.

Automatic selection combines the advantages of “energizing at fixed angles” and “energizing at variable angles” methods. The global strategy, described by Figure 191, consists in prioritizing controlled closing at fixed targets as soon as the previous opening is identified as “controlled” (therefore, mastering the level of residual flux to a known value, usually null). In the event of previous opening operation is identified as uncontrolled (case of protection tripping: de-energization is detected without opening order), the fall back scheme consists in closing with consideration of the computed residual flux at the time of de-energizing.

When the de-energizing date, measured by the CSD100, and the last opening date from the last opening operation controlled by the CSD100 are close enough (for example closer than 100ms), previous de-energizing operation is declared as “controlled”.

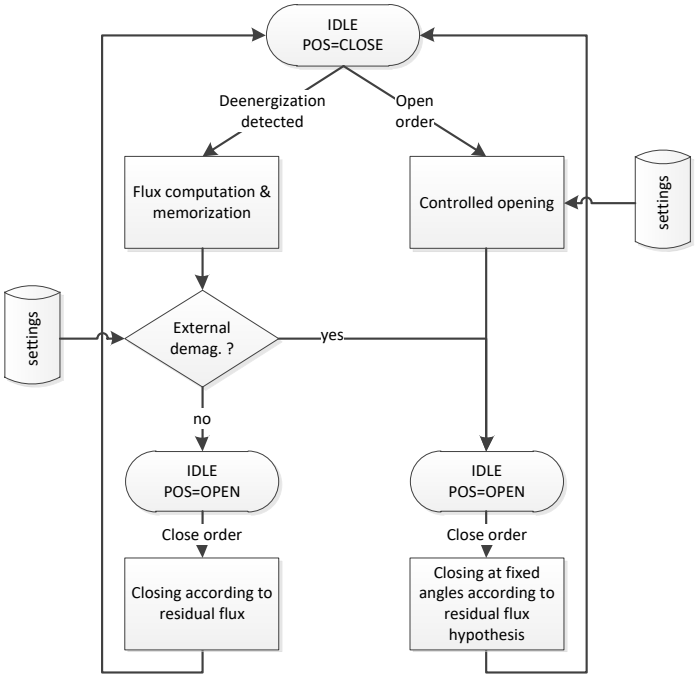


Figure 191 Transformer switching algorithm decision tree

The timeout setting which adjusts the discrimination between controlled and random opening is user settable. The recommended value is 75 milliseconds (default value).

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12.9.4.5 Summary of switching principle

Table 69 Summary of power transformer switching principle

NEUTRAL	OPERATION	CONTROLLED SWITCHING
GROUNDED	CLOSING	The first phase is closed at a voltage peak when residual flux is assumed null or at the voltage corresponding to the residual flux level. This first closing enforces a flux in all cores either directly through the multi-limbed cores of the transformers, or through secondary delta side voltage coupling. Particularly, the flux resulting in second and third phase is of opposite sign and half value of the first phase one. Closing of remaining two phases should occur simultaneously when the induced flux in the remaining cores reaches its steady-state prospective value, e.g. 1 quarter of a cycle later. Closing of these two remaining phases may be delayed for additional half-period(s) in the case voltage oscillations due to first phase closing are produced at other phases terminals (except in the case of independent cores).
	OPENING	Each pole is open independently at its respective current 0 (peak voltage), with a very short arcing time. No-load magnetizing current is chopped at arcing contacts separations. Aim is to target demagnetization of the transformer or residual flux control.
ISOLATED	CLOSING	With an isolated neutral, closing of one phase makes no sense because no current flows. With consideration of residual flux absence, two phases are closed first simultaneously, when voltage difference is maximum and prospective flux null. With consideration of residual flux measured value, winding/leg with highest residual flux value is energized first (delta), by closing simultaneously the two poles of the circuit breaker surrounding this winding, when phase to phase voltage match residual flux target. Third phase is then closed one quarter of period later, at the voltage peak of its respective voltage terminals, when the flux resulting from the first closing is equivalent to the prospective flux. Closing of this remaining phase may also be delayed for additional half-period(s) (except in the case of independent cores)
	OPENING	A first pole is opened with very short arcing time, the remaining poles operates simultaneously a quarter of the period later.

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12.9.5 Application overview

12.9.5.1 Voltage measurement requirement for integration and flux estimation

Requirement for application of “Energizing at variable angles taking into consideration residual flux level” method is described in Figure 192.

At source side, one phase is required to measure phase-to-earth voltage. This reference voltage is used for global synchronization purpose. However, if voltage dips to be measured, the three voltages at source side are required.

At transformer side, three phases are required to measure phase-to-earth (or phase-to-neutral) voltage. This set of voltages is used for residual fluxes estimation by integration of the relevant signals. However, it is also recommended to connect these three voltages to the CSD100 (when available), even if residual flux estimation is not used (fixed targets). Doing so, records inspection allows visualizing actual making time instants during closing operations, to monitor circuit breaker operations.

Note 1: Voltage at transformer terminals can be measured either at HV side, LV side or TV winding. Phase corrections relative to transformer vector group are performed by the CSD100 who is set with the characteristics of the transformer to be switched.

Note 2: Inductive (wound type) voltage transformers are recommended to measure voltage at transformer terminals.

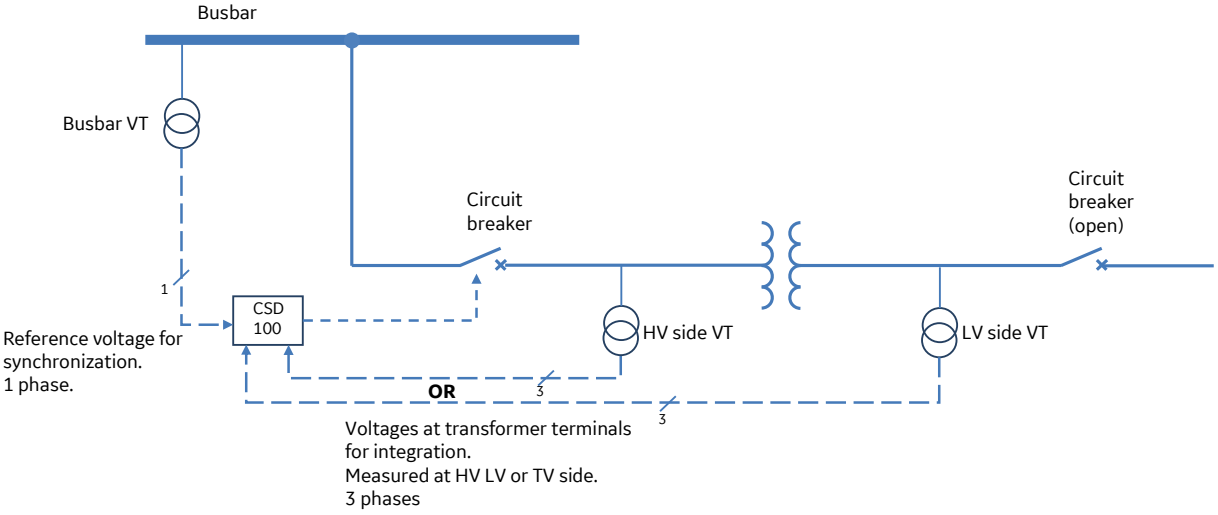


Figure 192 Transformer application installation overview

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12.9.5.2 Influence of vector group and measurement side for integration

Figure 193 provides an example of a controlled switching application arrangement. The transformer is a 3-phase, 3-limb, Yd1 type, earthed at switching side through a neutral earthing reactor (NER). The circuit breaker to control the energization of the transformer is located at the HV side of the transformer. In this example:

- VA, VB, VC and VN are referring to phase-to-earth voltage at HV side
- Va, Vb, Vc and Vn are referring to phase-to-earth voltage at LV side

Depending on the side of the transformer from which the voltages for integration purpose are measured, the set of voltages to compute the residual flux in each leg of the magnetic core (winding voltage) at the time of de-energization are (automatically selected by CSD100, for information purpose only):

- VA-VN / VB-VN / VC-VN when voltage is measured at HV side of the transformer
- Va-Vb / Vb-Vc / Vc-Va when voltage is measured at LV side of the transformer

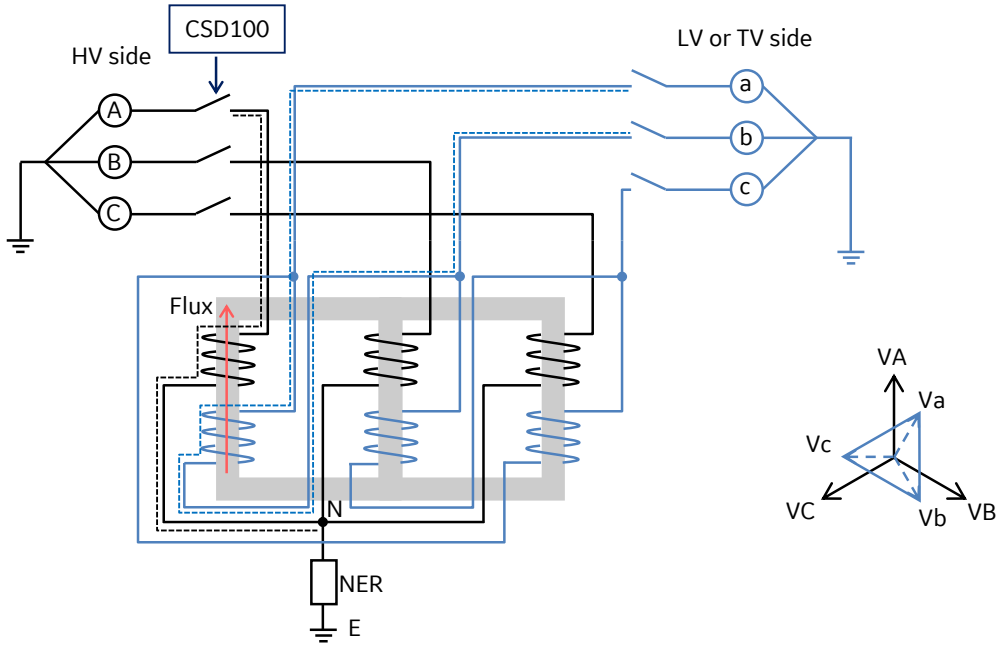


Figure 193 Example of required voltage for integration at transformer terminals

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Note 1: these voltages are automatically selected and computed by the CSD100, according to transformer type and neutral position settings.

Note 2: Figure 194 and Table 70 summarize the various transformer windings arrangements that can be managed by CSD100

Note 3: transformer earthed with NER shall be declared/set with a neutral:

- Earthed from switching perspective (switching angles computation).
- Isolated from voltage measurement perspective for residual flux estimation (activates computation of neutral voltage).

Two different settings are provided.

Note 4: neutral voltage is computed as (VA+VB+VC)/3 or (Va+Vb+Vc)/3.

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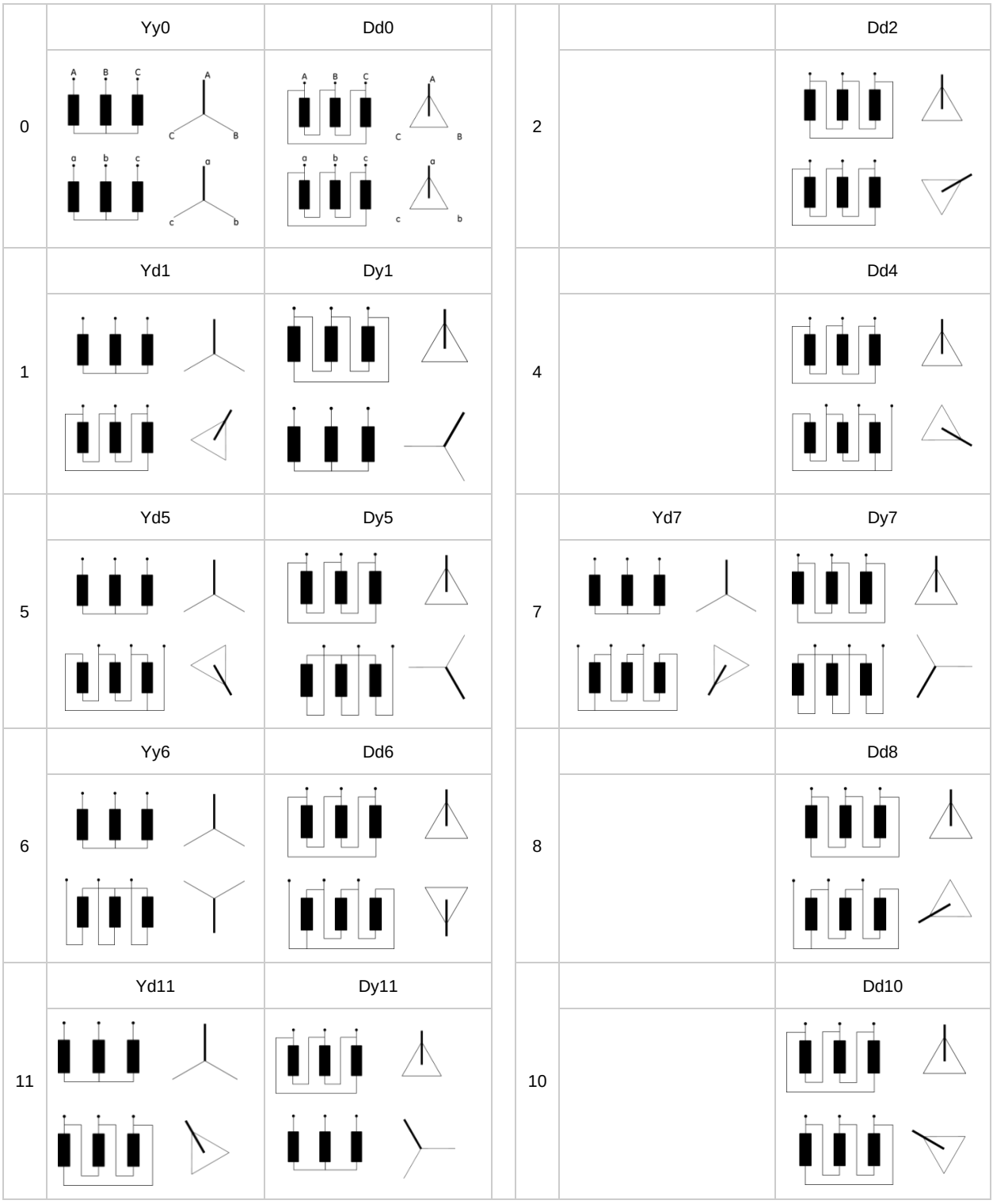


Figure 194 Main transformer types – Illustrating star and delta connections

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Table 70 Reference voltages for integration (residual flux computation)

Transformer vector group	Voltage measurement side	Voltage reference for integration					
		Neutral at measurement side grounded			Neutral at measurement side isolated		
		L1 core	L2 core	L3 core	L1 core	L2 core	L3 core
Yy0	HV	VA	VB	VC	VA-VN	VB-VN	VC-VN
Dd0		VA-VB	VB-VC	VC-VA	VA-VB	VB-VC	VC-VA
Yd1		VA	VB	VC	VA-VN	VB-VN	VC-VN
Dy1		VA-VC	VB-VA	VC-VB	VA-VC	VB-VA	VC-VB
Dd2		VA-VC	VB-VA	VC-VB	VA-VC	VB-VA	VC-VB
Dd4		VA-VB	VB-VC	VC-VA	VA-VB	VB-VC	VC-VA
Yd5		VA	VB	VC	VA-VN	VB-VN	VC-VN
Dy5		VA-VB	VB-VC	VC-VA	VA-VB	VB-VC	VC-VA
Yy6		VA	VB	VC	VA-VN	VB-VN	VC-VN
Dd6		VA-VB	VB-VC	VC-VA	VA-VB	VB-VC	VC-VA
Yd7		VA	VB	VC	VA-VN	VB-VN	VC-VN
Dy7		VA-VC	VB-VA	VC-VB	VA-VC	VB-VA	VC-VB
Dd8		VA-VC	VB-VA	VC-VB	VA-VC	VB-VA	VC-VB
Dd10		VA-VB	VB-VC	VC-VA	VA-VB	VB-VC	VC-VA
Yd11		VA	VB	VC	VA-VN	VB-VN	VC-VN
Dy11		VA-VB	VB-VC	VC-VA	VA-VB	VB-VC	VC-VA
Yy0	LV	Va	Vb	Vc	Va-Vn	Vb-Vn	Vc-Vn
Dd0		Va-Vb	Vb-Vc	Vc-Va	Va-Vb	Vb-Vc	Vc-Va
Yd1		Va-Vb	Vb-Vc	Vc-Va	Va-Vb	Vb-Vc	Vc-Va
Dy1		Va	Vb	Vc	Va-Vn	Vb-Vn	Vc-Vn
Dd2		Va-Vb	Vb-Vc	Vc-Va	Va-Vb	Vb-Vc	Vc-Va
Dd4		Vc-Va	Va-Vb	Vb-Vc	Vc-Va	Va-Vb	Vb-Vc
Yd5		Vc-Va	Va-Vb	Vb-Vc	Vc-Va	Va-Vb	Vb-Vc
Dy5		-Va	-Vb	-Vc	Vn-Va	Vn -Vb	Vn -Vc
Yy6		-Va	-Vb	-Vc	Vn -Va	Vn -Vb	Vn -Vc
Dd6		Vb-Va	Vc-Vb	Va-Vc	Vb-Va	Vc-Vb	Va-Vc
Yd7		Vb-Va	Vc-Vb	Va-Vc	Vb-Va	Vc-Vb	Va-Vc
Dy7		-Va	-Vb	-Vc	Vn -Va	Vn -Vb	Vn -Vc
Dd8		Vb-Va	Vc-Vb	Va-Vc	Vb-Va	Vc-Vb	Va-Vc
Dd10		Va-Vc	Vb-Va	Vc-Vb	Va-Vc	Vb-Va	Vc-Vb
Yd11		Va-Vc	Vb-Va	Vc-Vb	Va-Vc	Vb-Va	Vc-Vb
Dy11		Va	Vb	Vc	Va-Vn	Vb-Vn	Vc-Vn

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12.10 Transmission line switching application

12.10.1 General concern with overhead line switching

Switching overvoltage as well as current zero missing (highly compensated lines) are the main concerns.

12.10.1.1 Overvoltage concern and mitigation

Closing and autoreclose of no-load lines generate a voltage wave which, when reflected from the open end of the line, provokes over-voltages along the length of the line. Switching over-voltages determine the insulation level of the line and thus has a significant impact on the surge arresters wear (Figure 198) and the global cost of the line (maintenance and sizing).

Re-closing of lines causes larger over-voltages than simple closing because of trapped charge (uncompensated line, Figure 195) or self-oscillation (compensated line, Figure 197), due to the risk of closing at opposite polarity.

Therefore, optimum strategy consists in closing or reclosing the breaker when the voltage across its terminals is as close as possible to zero, to propagate the smallest possible voltage wave along the line. For that, CSD100 can identify in real time the situation from line voltages and currents analyzed right before reclosing order occurrence, as well as elapsed time from previous opening. Different strategies may be applied.

- Automatic distinction between compensated and non-compensated lines
- Automatic distinction between healthy and faulty phases
- Single pole reclosing or three (or multiple) pole reclosing is supported.
- VT nature (inductive or capacitive) : parameters

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With **uncompensated line**, two mitigation strategies are applicable:

- Zero of source voltage (faulty phases)
- Peak of source voltage with polarity identification (healthy phases)

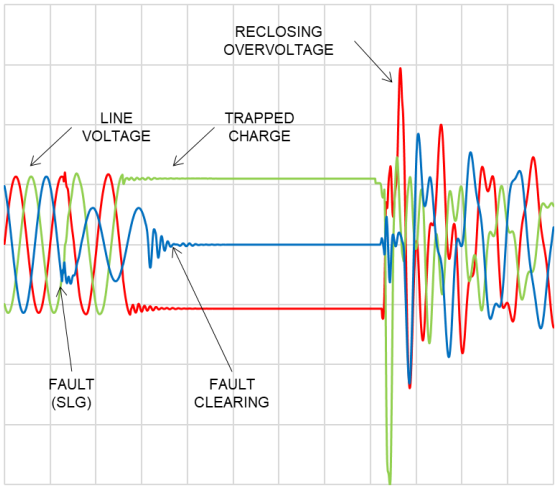


Figure 195 Uncompensated line reclosing (SLG fault, 3-phase reclose) – Random operation

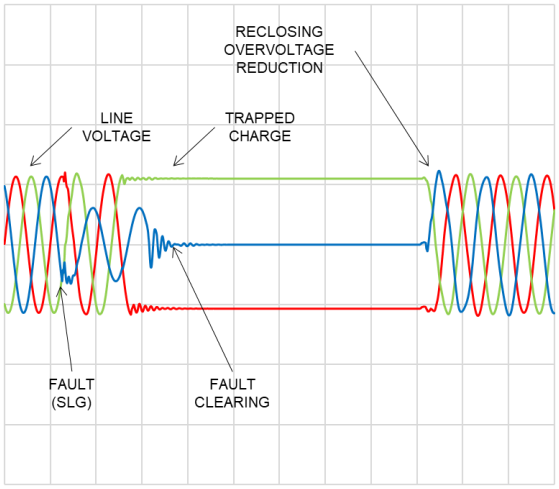


Figure 196 Uncompensated line reclosing (SLG fault, 3-phase reclose) – Controlled operation

With **compensated line**, two mitigation strategies are applicable:

- Zero of source voltage (typically for faulty phases)
- Minimum of voltage beat (healthy phases, or faulty phases with early fault extinction and strong phase to phase influence, leading to voltage recovery).

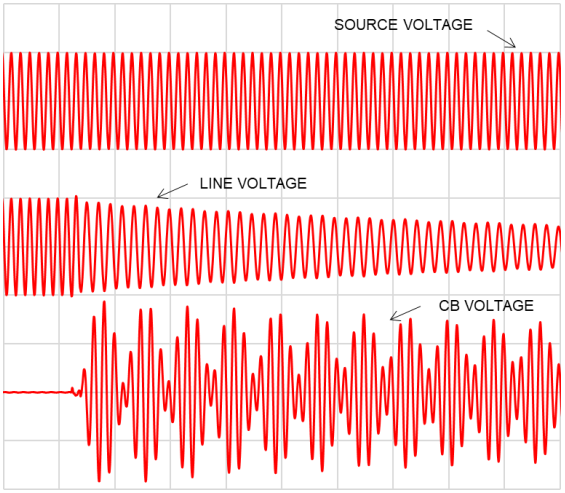


Figure 197 High-degree of compensation voltage waveforms

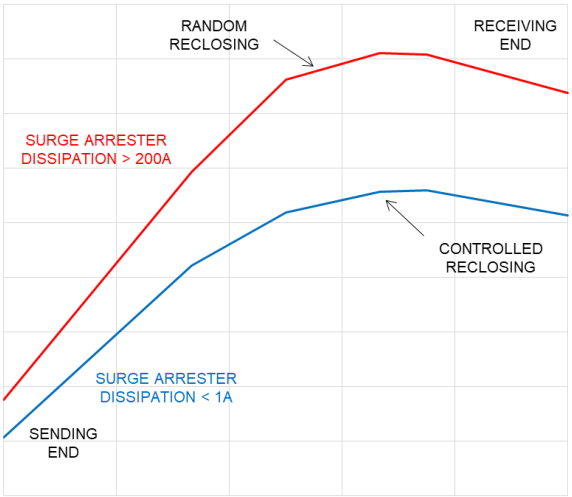


Figure 198 Compensated OHL switching performance (SPR) – Overvoltage profile and surge arrester dissipation

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12.10.1.2 Current zero missing concern and mitigation

For shunt compensated transmission line (overhead line or underground cable) with a compensation rate higher than 50 %, current zero missing phenomenon (Figure 199) can occur, due to the asymmetry of the shunt reactor current, when randomly energized or when energized with traditional capacitive load closing angles, i.e. voltage zero. If a trip arises right after closing operation (CO cycle), there's a risk of current interruption failure.

Controlled energizing at each phase respective voltage peak (Figure 200) allows reduction of current asymmetry and reduces the risk of current zero missing phenomenon.

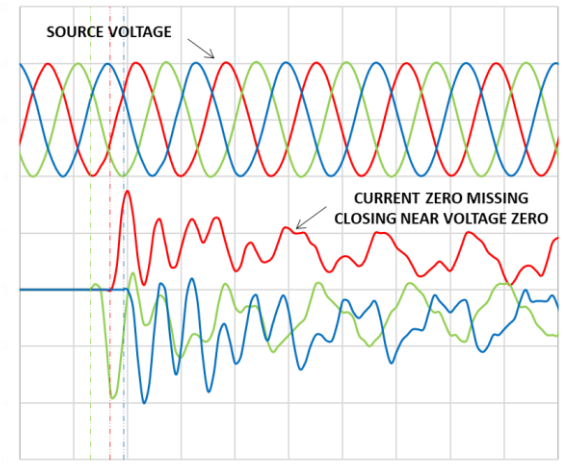


Figure 199 Current zero missing phenomenon

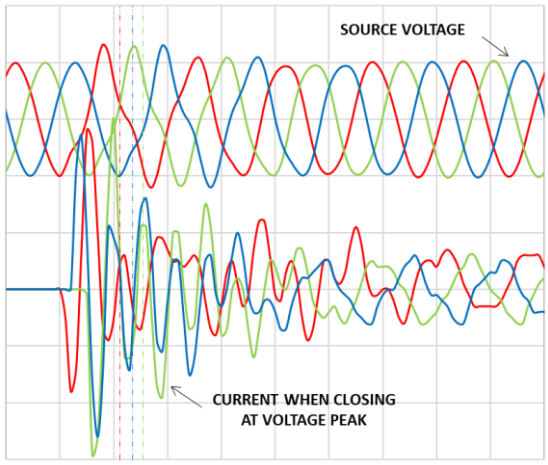


Figure 200 Current zero missing mitigation

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12.10.2 Uncompensated transmission lines application

Two different situations are to be distinguished:

- The line is fitted with Inductive Voltage Transformers (IVT) on each phase (Figure 202).
- The line is fitted with Capacitive type Voltage Transformers (CVT) (Figure 203), conventional or not, which doesn't discharge the line.

12.10.2.1 Transmission line fitted with Inductive Voltage Transformers application

In this case, following an opening of the unloaded line, the instrument transformer rapidly discharges the line generally in less time than it takes for a re-closing (refer to Figure 123 which represents 400 kV uncompensated transmission line trapped charge evacuation through 420 kV GIS IVTs for line lengths from 100 km to 400 km - Note: line capacitance value assumed 15 nF / km).

Therefore, all closings, or re-closings, are executed on a discharged line.

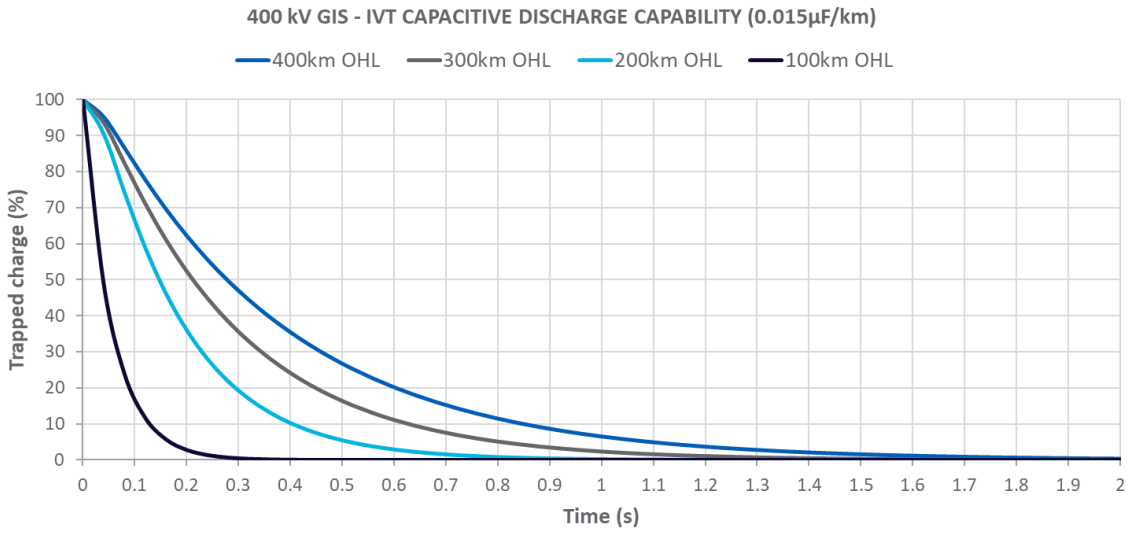


Figure 201 Line discharge through IVT

So, when using controlled switching, the closing target must be at zero of the source voltage, both for closing and re-closing operations.

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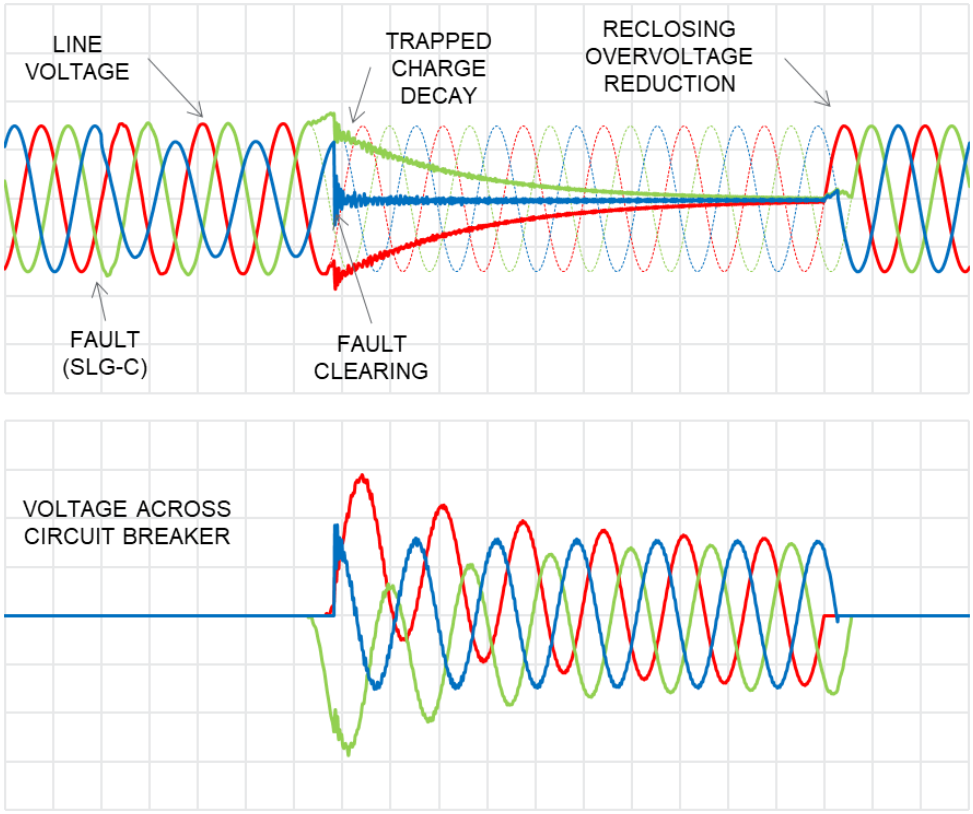


Figure 202 Uncompensated transmission lines fitted with IVT, voltages waveforms (fault on blue phase)

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12.10.2.2 Transmission line fitted with capacitive type Voltage Transformers application

In this case, line is not discharged by the voltage transformer and trapped charge concern is faced if:

- Phase is reclosed shortly after tripping (post fault management)
- AND phase is healthy

It is not possible to measure trapped charge from conventional VTs (either capacitive or inductive). Thus, choice between voltage zero source strategy and voltage source minimum or maximum strategy is deducted.

It is considered that after a short delay from previous tripping (practically, in the range of a second), operation is no longer a reclosing operation, and line is considered as discharged. Indeed, for machine or network stability, reclosing cycles cannot exceed a few seconds.

Also, it is assumed that faulty phases do not retain trapped charges.

Practically, CSD100:

- Measures elapsed time from previous opening (tripping). If long enough, trapped charges are no longer considered for applied strategy.
- Determines for each phase if it is faulty or healthy by observation of the current at the time of tripping. For faulty phases, trapped charges are no longer considered for applied strategy.
- Consider VT type (settings). If line is equipped with IVT, trapped charges are no longer considered for applied strategy.
- Analyze line voltages upon reclose order occurrence. If any significant oscillation is observed, trapped charges are no longer considered for applied strategy.
- In case all above conditions are not fulfilled, trapped charges are considered, and voltage source minimum or maximum strategy is applied.

For healthy phases within a reclose cycle, line voltage values at the opening instant are retrieved from the records, in order to check trapped charge polarity ($+V_{peak}$ or $-V_{peak}$).

CSD100 independently analyses the condition of each phase to calculate optimum switching instants. In case of trapped charge, phase is reclosed at the corresponding polarity of source peak voltage. If not, phase is reclosed at zero source voltage.

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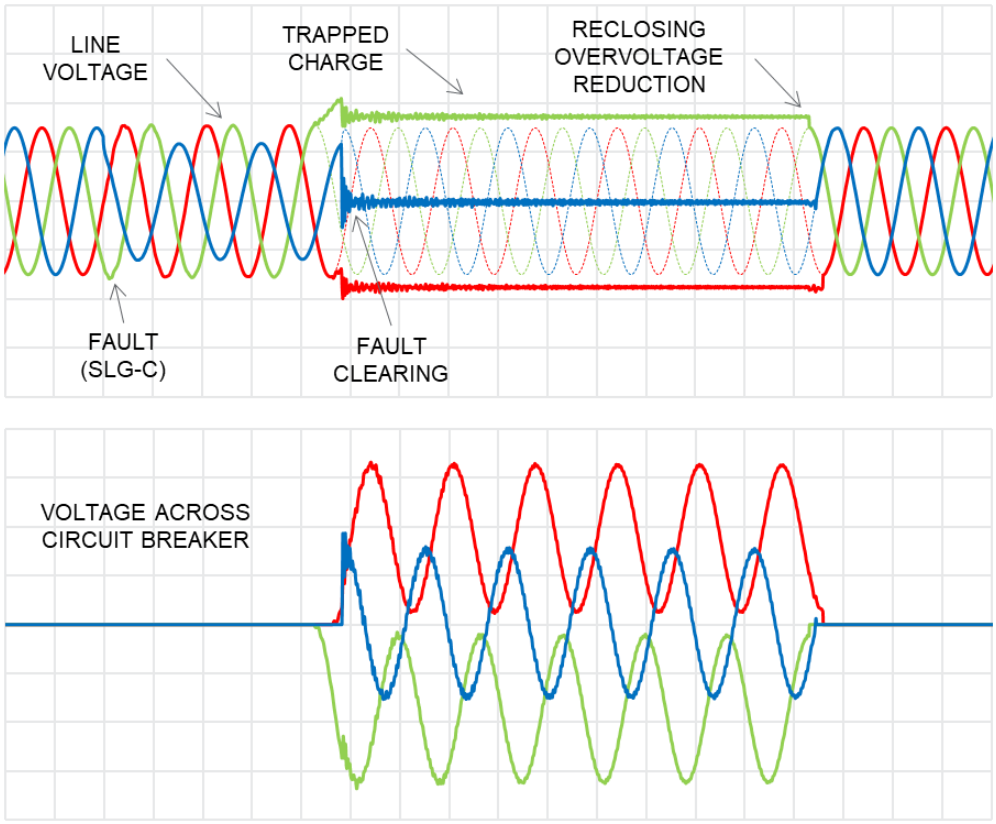


Figure 203 Uncompensated transmission lines fitted with CVT voltages waveforms (fault on blue phase)

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12.10.3 Shunt-reactor compensated transmission lines application

Controlled high speed reclosing of a shunt-reactor compensated line is complex since line side voltages can contain several natural oscillation frequency modes, due to line capacitance and shunt reactor(s) interaction as well as some transient recovery voltages from the faulted phase arc interruptions and inter-phase coupling phenomena.

Thus, with fundamental voltages on the source side, voltages appearing across each phase of the circuit breaker show various degrees of oscillations with distinct beat frequencies depending on the level of shunt reactor compensation.

The level of shunt compensation applied on a long transmission line may be a priori unpredictable and it can change during operation, depending on the power transfer requirements by the system dispatch. Typically for long reactor compensated line, a line may have one, or two shunt reactors in service, or none under contingency condition. These compensation differences translate into frequency differences on the line side that entails a beat pattern waveform of the voltage (voltage difference between source and line side) at the circuit breaker terminals that is compensation dependent (see Figure 205 and Figure 206).

Whenever minimum switching transient is desired, the optimum time to close the breaker is when the voltage across the circuit breaker is zero.

For compensated lines displaying beat frequencies, the practical closing time is to close near voltage zero within the beat minimum. Also, to minimize change of pattern due to inter-phase coupling interference, it is desirable to sequence the reclosing and keep the operating time period of all three phases to a minimum.

Note: The line voltage sinusoidal component has a fundamental frequency ranging between 40 and 90% of the network frequency. It is essential that the measurement of this line signal is as accurate as possible to guarantee accuracy of reclosing times:

- Inductive voltage transformers are generally applicable
- If the line is fitted with CVT, user must pay attention to the capability to accurately reproduce voltages in the range of 20Hz to power frequency value without significant amplitude and phase error.

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12.10.3.1 Transmission line with shunt compensation layout

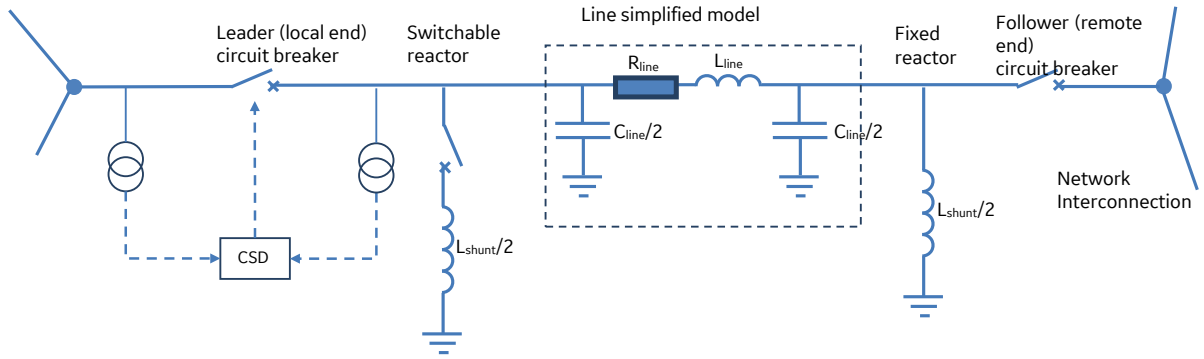


Figure 204 Shunt reactor compensated overhead transmission line simplified model

- Compensation rate $\%comp = \frac{100}{L_{shunt} \cdot C_{line} \cdot {\omega_0}^2}$
- Network rated pulsation $\omega_0 = 2\pi \cdot f_0$
- Line free oscillation mode $\omega_{line} = \frac{1}{\sqrt{(L_{shunt}+L_{line}) \cdot C_{line}}}$
- Typical values $L_{line} = 10^{-3}\, H/km\,;\; C_{line} = 10^{-2}\, \mu F/km$

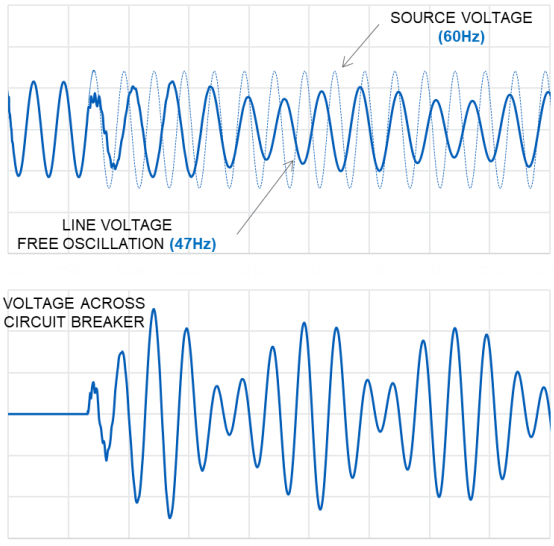


Figure 205 High degree of compensation voltages waveforms (long beat)

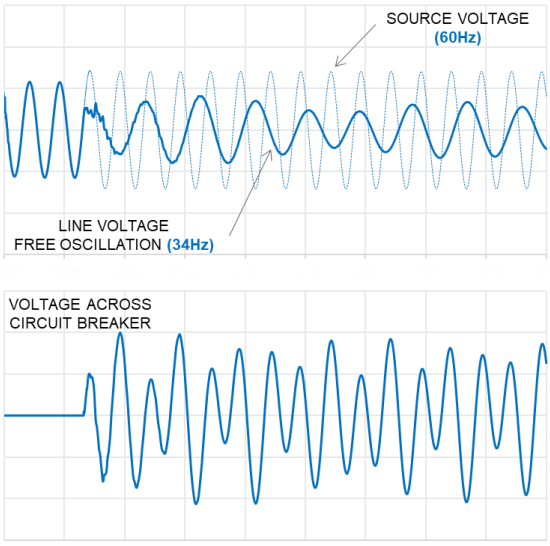


Figure 206 Low degree of compensation voltages waveforms (short beat)

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12.10.4 Application overview

12.10.4.1 Transmission line layout

Figure 207 gives an overview of the functional arrangement to perform a controlled switching operation during closing or auto-reclosing on a transmission line and signals to be connected.

The CSD receives the following data from the high voltage installation at the substation:

- Source voltage US: A single-phase voltage is enough to assess the three phases, assuming that the source is a typical three-phase balanced system.
- Three phases load voltage UL, mandatory for line reclosing applications to identify any trapped charge or oscillating mode on a line.
- Three phases load current IL, mandatory for line reclosing applications to discriminate faulty and healthy phase for post-fault clearing reclosing sequence.
- The operating order coming from either the supervisory control board, SCADA system, or the auto-reclose relay.
- The circuit-breaker auxiliary contacts. This provides the information on the main contact position and mechanical operating time of the circuit breaker as well as detection of circuit breaker trip from protection.

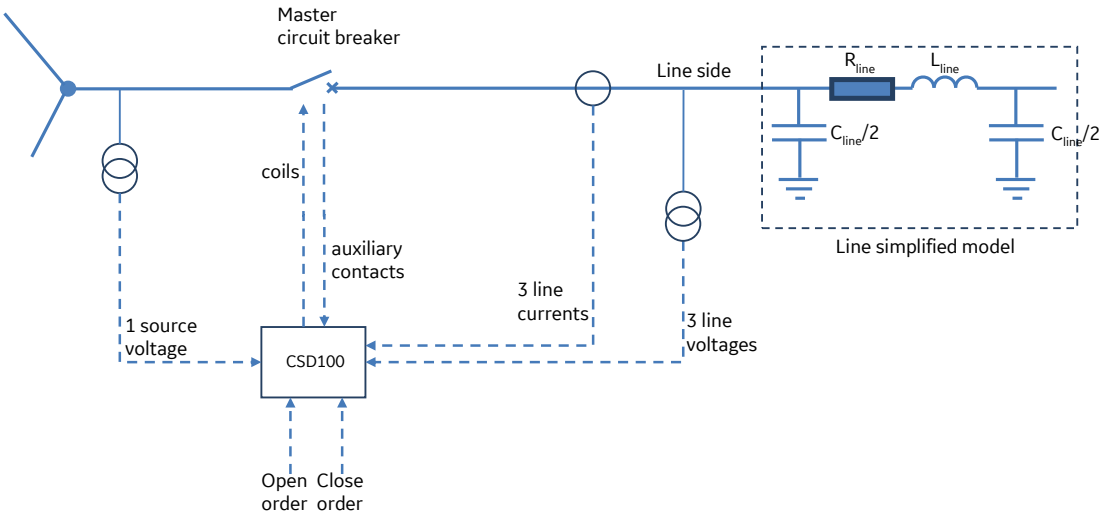


Figure 207 Overhead transmission line controlled switching layout

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12.10.4.2 CSD100 internal logic (state machine)

Controlled sequencing for line switching application is summarized in Figure 208.

The general algorithm of the CSD100 is represented by state machine formalism. In the CSD100, three identical state machines operate in parallel, one for each phase. Upon occurrence of a close order, the voltage waveform analysis is performed on the most recent data and over a time window as short as possible (100ms) to minimize the influence resulting from network and signal non stationarity (instability).

- **Discrimination between faulty and healthy phase**: this is done by circuit breaker current observation before and near the instant of opening operation (detected with 52a), by regard to previous values.
- **The algorithm separates into two branches for simple closing and reclosing cases**, by measurement of elapsed duration from last opening order and a timeout function.
- In case of **simple energization**, processing is like other programs: fixed targets (settable) are applied.
- In case of **reclose, analysis of voltage waveform**: voltage analysis is performed by fitting a model over a short signal window (100ms). This model is well adapted to multi-mode oscillation analysis and is accurate even for short term window.
- **Strategy selection and detection of trapped charges**: strategy selection is carried out from multi-mode oscillation voltage analysis, heathy/faulty status, VT type (IVT/CVT). As the voltage transformers do not provide for DC information, DC trapped charge presence is deducted (no oscillation, no IVT, healthy phase…).
- **End of the algorithm:** in real-time, algorithm provides a set of optimal closing times in the targeted reclosing window for each phase. Last step is then to choose the best overall set of instants for the three-phase reclosing, based on two criteria:
    - Minimum dispersion between phases (narrow sequence)
    - Set of targets as close as possible from the beginning of the targeted reclosing window.

Note: In case of a single phase reclose, no dispersion criterion applies, the first reachable date is chosen. CSD100 self-adapts to the number of phases to be reclosed.

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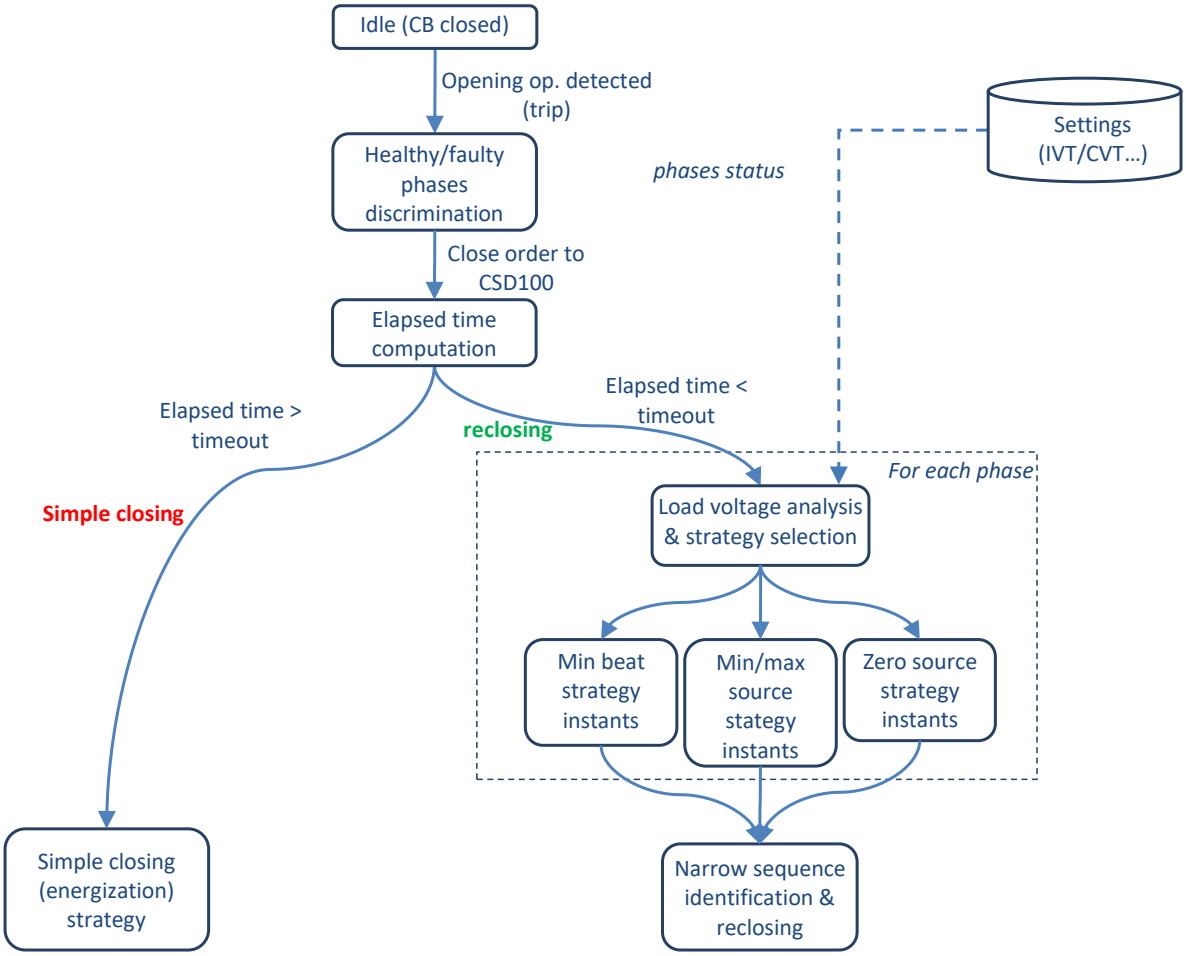


Figure 208 CSD100 logic diagram for line application

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12.10.5 Transmission line closing

In the simple case of line energization (line pick-up) it is assumed that no trapped charge nor oscillatory regime are present.

Table 71 Transmission line closing program

Use case	Switching program		L1 (ref)	L2 (ref - 120 deg)	L3 (ref + 120 deg)
Closing at voltage zero	Line (default angles)	Angle [deg]	0	120	60
		CB voltage [p.u.]	1	1	1
		R.D.D.S [p.u.]	1	1	1
		Prearcing time (eq. capacitive bank)	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \sin(\omega \times 3\sigma)$	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \sin(\omega \times 3\sigma)$	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \sin(\omega \times 3\sigma)$
Closing at voltage peak	Line (modified angles)	Angle [deg]	90	30	150
		CB voltage [p.u.]	1	1	1
		R.D.D.S [p.u.]	1	1	1
		Prearcing time (eq. shunt reactor)	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \cos(\omega \times 3\sigma)$	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \cos(\omega \times 3\sigma)$	$\sqrt{\frac{2}{3}} \times \frac{U_r}{RDDS} \times \cos(\omega \times 3\sigma)$

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12.10.6 Transmission line auto-reclosing

12.10.6.1 Transmission line fault clearance and auto-reclosing

Typical sequence of events is depicted below:

1. Normal operation, energy flowing through the line
2. Fault occurrence. Single phase to ground (80% of cases, due to lightning strikes and surge overvoltage), dual phase, dual phase to ground…
   Fault may be temporary or permanent.
3. Fault clearing: circuit breakers at both ends are tripped by protection system. Primary arc de-ionization
4. Wait for secondary arc extinction (deadtime before reclose order, timeout programmed in auto reclose relay, according to line characteristics)
5. Leader circuit breaker (equipped with CSD100) to reclose first, within set reclose window.
6. Follower circuit breaker (not equipped with CSD100) to reclose a few cycles later, before system limit of stability.

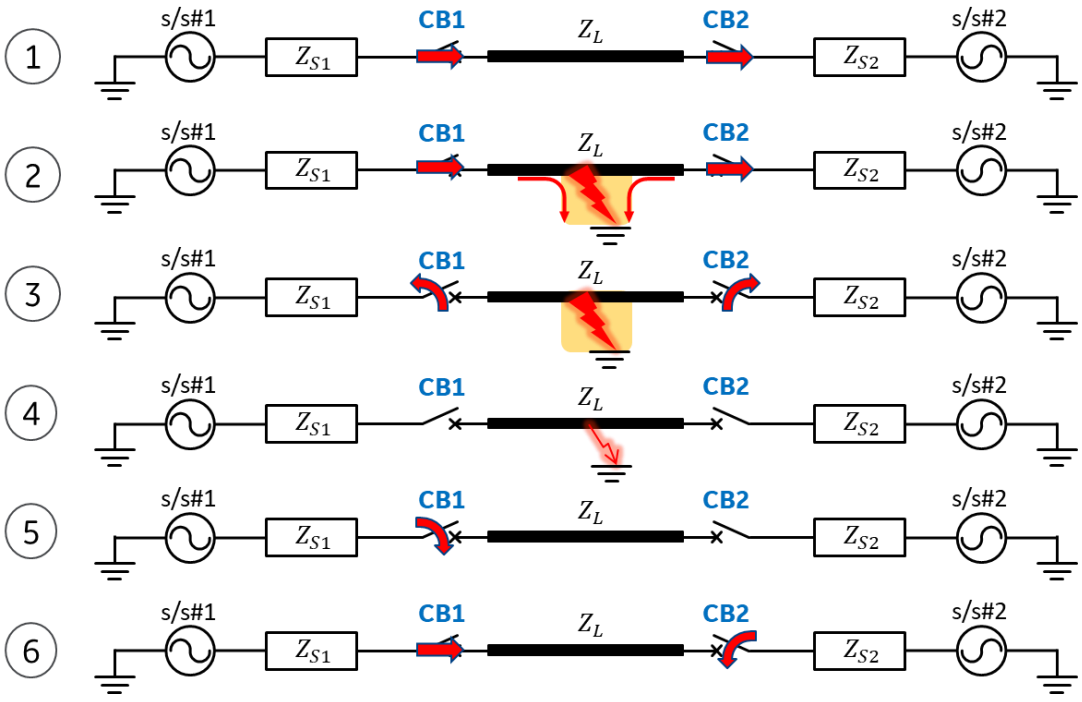


Figure 209 Transmission line fault clearing and post-fault sequence

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12.10.6.2 Specific algorithm timing

The line application self-adapts to various situations (compensated or non-compensated line, degree of compensation…). However, some critical timing information remains to be set.

- Allowed reclose time window: two parameters are provided to adjust beginning and end of reclose window, each of them being referred to the instant at which the circuit was previously open.
- Timeout to discriminate between simple energization and reclose operation. This timeout is also referred to the instant at which the circuit was previously open.
- Additional delay to start line voltage analysis (beginning of calculation): in case additional delay to reclose is necessary (for instance to wait for secondary arc extinction), this parameter may be set to a non-null value. It is usually set to zero, as the reclose delay is handled by the external recloser relay. This delay is referred to the instant of close order reception and has a null default value.

Overhead transmission line controlled switching algorithm timings defined in the logic diagram are described in this section.

Table 72 Auto-reclosing specific timing

Parameter label	Parameter description
Begin of calculation (“t1”)	Additional delay to start auto-reclosing algorithm, from close order occurrence. Usually a null value is used since the reclose delay is managed by the line recloser device.
Timeout for auto-reclosing control order (“t2”)	This is the maximum time delay from the previous opening (trip) for the CSD100 to receive an auto-reclosing order. If no closing order has been received within that delay, simple energization strategy is applied.
Begin of reclose window (“t3”)	Beginning of targeted reclose window, being referred to the instant at which the circuit was previously open.
End of reclose window (“t4”)	End of targeted reclose window, being referred to the instant at which the circuit was previously open. After this delay, if the CSD100 does not achieve a valid set of reclosing data, the switching strategy defaults to the backup strategy (usually reclose at source zero-voltage).

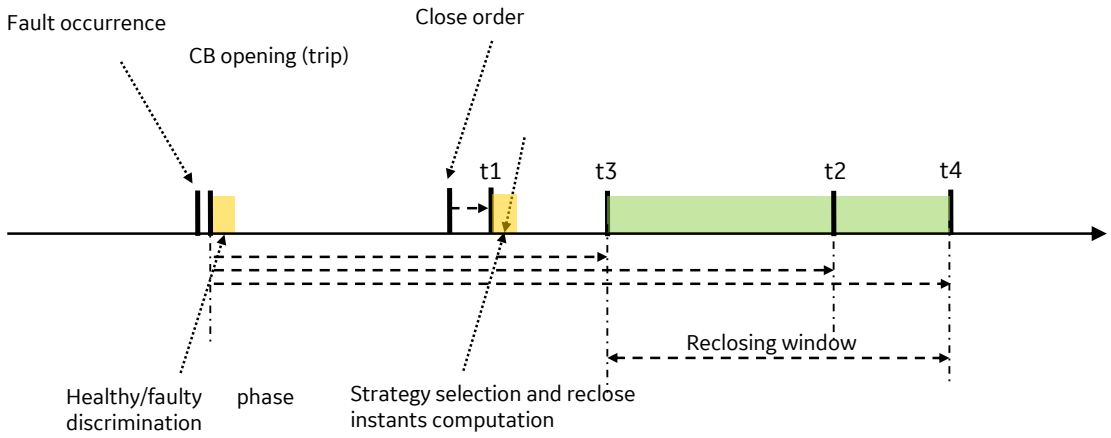


Figure 210 CSD100 typical reclosing timing chart

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12.10.6.3 Single-phase reclose (SPR)

In SPR situation only one phase is tripped in case of single-phase fault. Thus, line voltage is initially low (due to the fault) but may recover due to phase to phase influence, in case of temporary fault. The two different situations are depicted below. CSD100 self-adapts to both situations.

12.10.6.3.1 Negligible line coupled voltage

The line voltage main oscillation mode (analyzed by CSD100 upon occurrence of reclose order) is lower than set threshold.

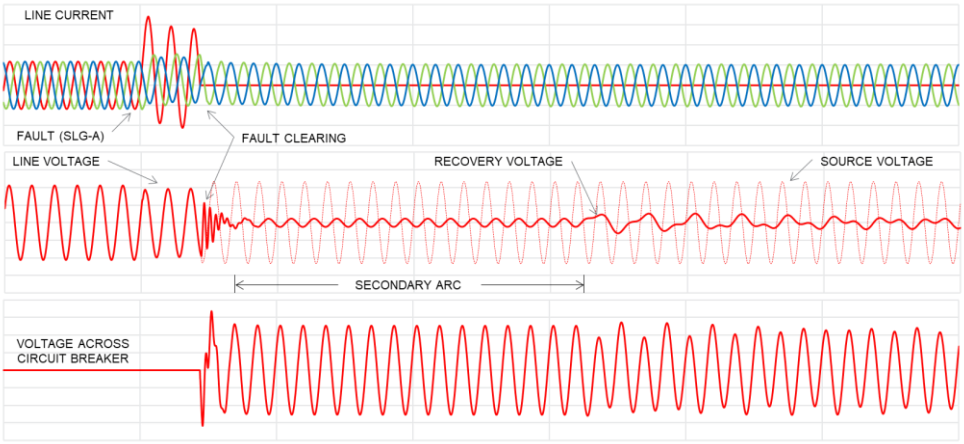


Figure 211 Transmission line fault clearing and post-fault sequence

12.10.6.3.2 Significant line coupled voltage

The line voltage main oscillation mode (analyzed by CSD100 upon occurrence of reclose order) is higher than set threshold and allows consideration of minimum beat strategy.

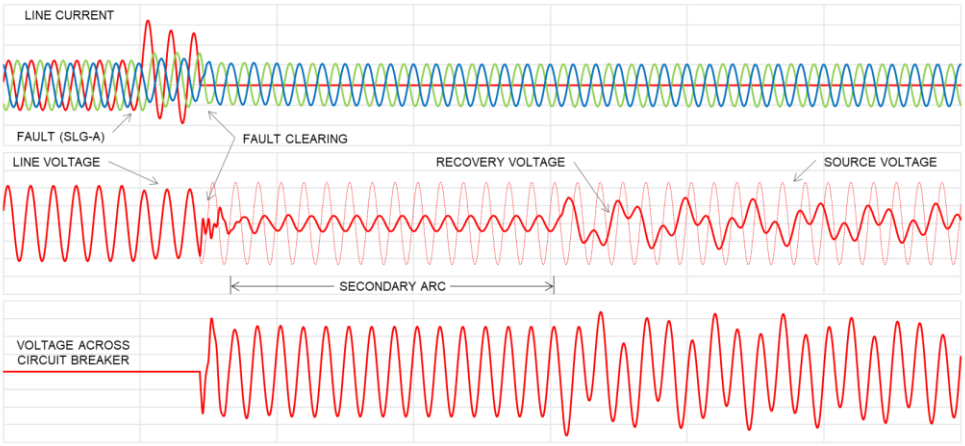


Figure 212 Transmission line fault clearing and post-fault sequence

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12.10.6.4 Three-phase reclose (3PR)

In “three phases trip and reclose” situation, whatever fault nature, the three phases are tripped. Healthy phases exhibit oscillations (compensated line) or trapped charge (uncompensated line) while faulty phases, initially discharged, but may recover voltage due to phase to phase or line to line influence.

12.10.6.4.1 Possible targets computation (phase by phase)

Initial algorithm step is to compute a set of possible targets for each phase, independently. In below figures are depicted a situation with temporary fault on L1 phase and two degrees of compensation.

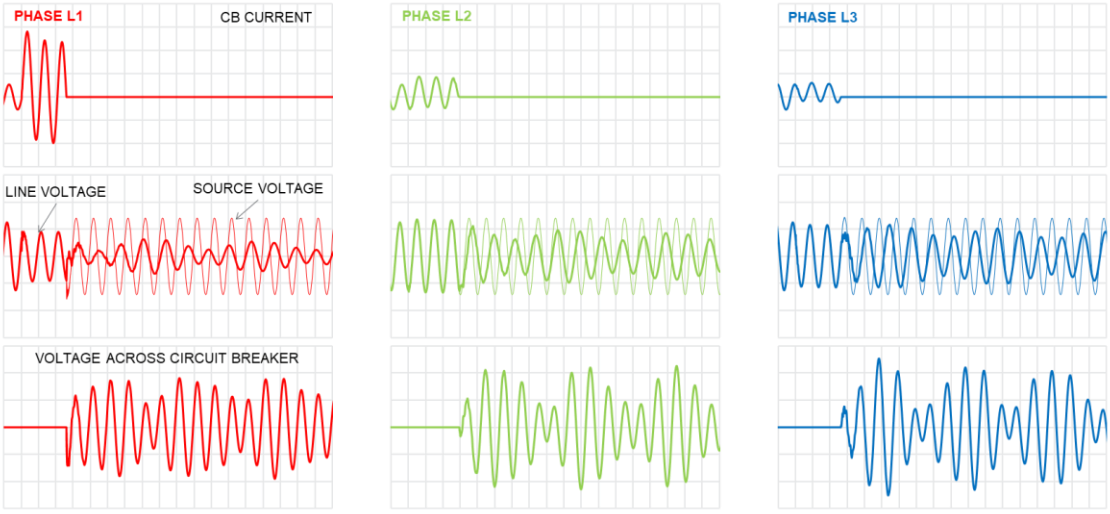


Figure 213 Transmission line fault clearing and post-fault sequence (high degree of compensation)

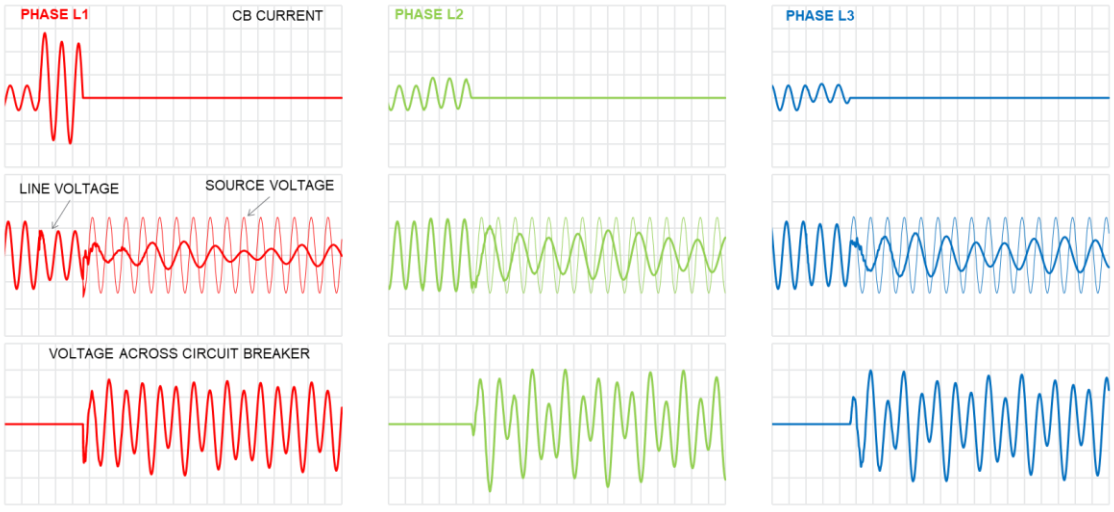


Figure 214 Transmission line fault clearing and post-fault sequence (low degree of compensation)

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12.10.6.4.2 Final set of targets

Next algorithm step is to select a set of three targets for each phase with combination of two requirements:

- Lowest difference between three phases
- Earliest global operation in reclosing window

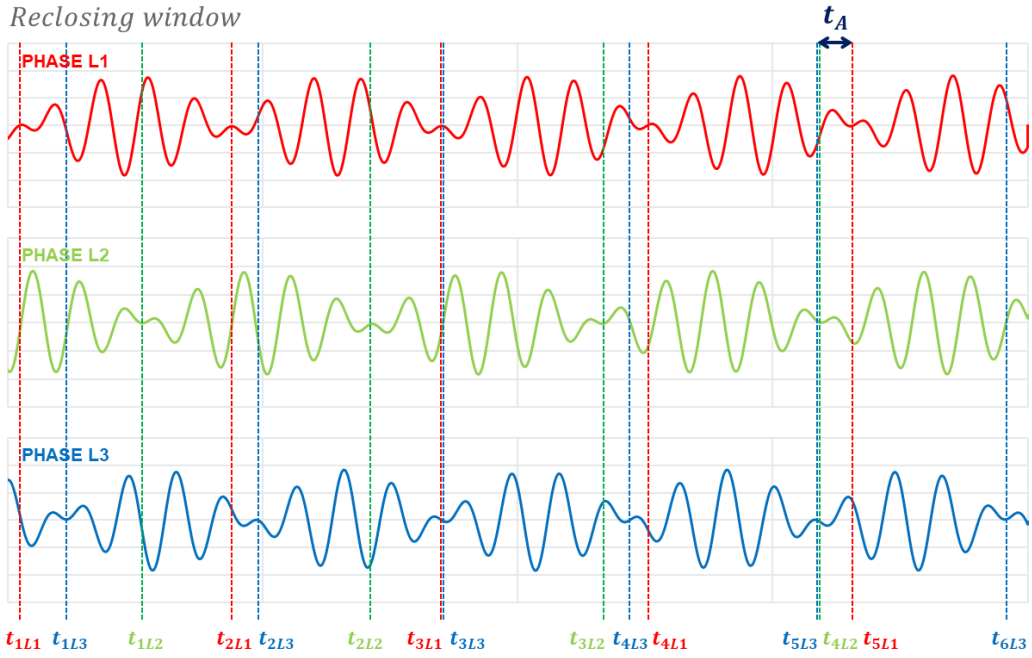


Figure 215 Transmission line fault clearing and post-fault sequence

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12.10.6.5 Transmission line reclosing strategy

Table 73 Transmission line reclosing program

Use case	Source voltage	Line voltage	Switching program		Reclosing strategy
Line energization or reclosing faulty phase (long fault duration, fast reclosing cycle)	Rated amplitude, industrial frequency	0 (faulty phase, line discharged)	Line	Angle [deg]	Zero source
				CB voltage [p.u.]	1
				R.D.D.S [p.u.]	1
				Prearcing time	See 12.5.8.4
Fast reclosing healthy phase, uncompensated line, no IVT	Rated amplitude, industrial frequency	DC, near rated amplitude	Line	Angle [deg]	Source-voltage peak with same DC trapped charge polarity
				CB voltage [p.u.]	1
				R.D.D.S [p.u.]	1
				Prearcing time	See 12.5.8.7.1
Fast reclosing healthy phase, compensated line (or faulty phase with early fault extinction)	Rated amplitude, industrial frequency	Significant fraction of rated amplitude @ likely self-oscillating frequency (20~60Hz)	Line	Angle [deg]	Minimum of beat pattern
				CB voltage [p.u.]	1
				R.D.D.S [p.u.]	1
				Prearcing time	See 12.5.8.8

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12.10.7 Transmission line controlled opening

12.10.7.1 Uncompensated line opening

Controlled opening of unloaded non compensated transmission line (absence of fault, simple de-energization) is similar to solidly grounded neutral capacitor bank and is dependent of the following characteristics:

- Synchronizing waveform
  - reference voltage;
  - reference current;

Duty is to deenergize each line phase with an arcing time long enough to reduce restrike probability. There is no provision for trapped charge management, since it is assumed that the line will not be re-energized in a short delay (before natural discharge).

Phases are independent from each other and operated at respective natural current zero crossing. As current is leading voltage by 90° (capacitive circuit), the recommended sequence is 90°/30°/150° (Ref phase / Phase -120° / Phase -240°), this sequence being referred to a positive going source voltage zero crossing.

Table 74 Uncompensated line opening program

Use case	Switching program		L1 (ref)	L2 (ref - 120 deg)	L3 (ref + 120 deg)
Synchronizing on reference voltage					
Solidly grounded capacitor bank	Line (*)	Angle [deg]	90	30	150
		Trapped charge [p.u.]	+1	−1	−1
Synchronizing on reference current					
Solidly grounded capacitor bank	Line (*)	Angle [deg]	180	120	240
		Trapped charge [p.u.]	+1	−1	−1

(*) CSD100 default settings.

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12.10.7.2 Shunt compensated line opening

No load current of shunt compensated lines may be of low amplitude, in case of high degree of compensation. Furthermore, voltage to current phase shift may be far from 90°, still depending of degree of compensation.

Therefore:

- Default target angles of line program may be adjusted in case of synchronizing according to voltage and high degree of line compensation.
- Synchronization according to current reference waveform is not recommended for high degree of line compensation.

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12.11 Multiple load switching

In some specific substation layouts such as 1 ½ circuit-breaker arrangement or ring busbar scheme, the CSD100 - operated tie circuit breaker may have to switch two different loads at each side of the circuit breaker (at different instants). In order to avoid installation of two CSD controlling the same circuit breaker (with two different strategies), CSD100 can switch from one strategy to another, in accordance with substation switchgear positions. Similarly, when both circuit breaker side voltages are connected, CSD100 can automatically reverse source and load information ("Dual Switching").

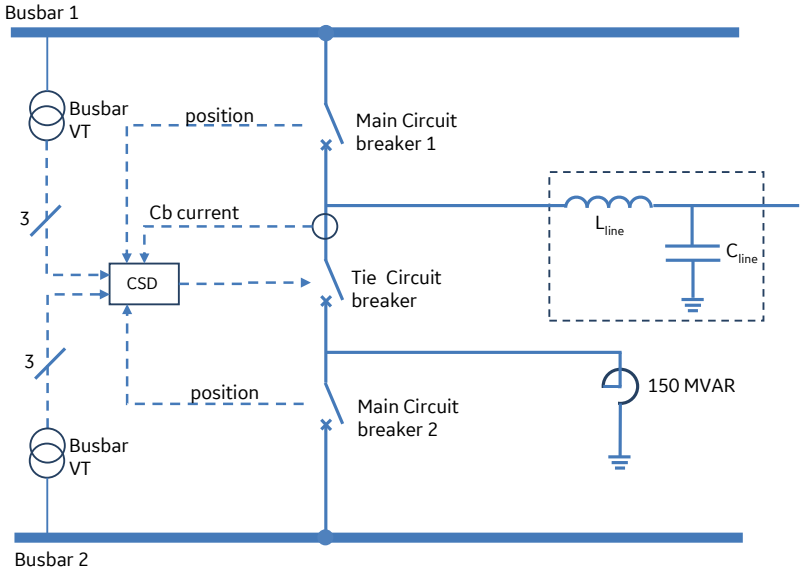


Figure 216 One breaker and half configuration

For example, in Figure 216, Tie circuit breaker may be called upon to switch the reactor from busbar 1 or to switch the outgoing line from busbar 2. Thus, source and load side voltages are automatically inverted ("Dual switching" enabled), provided that both are connected to the CS100, and strategy is automatically adjusted, according to main circuit breakers positions (dedicated digital inputs).

An example of strategy selection between transformer and line programs is given below.

Table 75 One breaker and half configuration strategy choice matrix

Main CB1	Main CB2	Strategy	Dual switching
ON	OFF	Reactor	No
OFF	ON	Line	Yes
OFF	OFF	Not applicable	Not applicable
ON	ON	Not applicable	Not applicable

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12.11.1 Variable load: simple use case

Under some installations' layouts and operation contingencies, the circuit breaker is likely to operate on a variable load.

The position of the substation apparatus (circuit breakers, disconnector switches…) defines the strategy to apply.

For example, in Figure 219, circuit breaker may be used to energize a line and manage line faults, or to power up a generating power plant (black start).

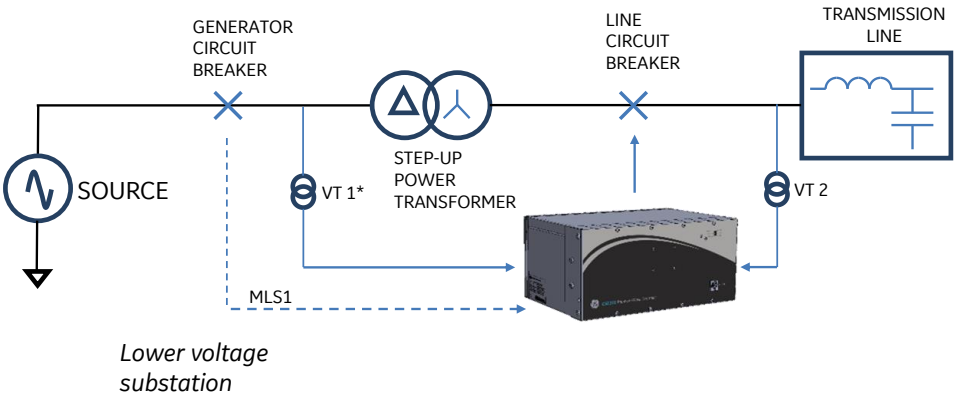


Figure 217 Multiple load switching – a simple case. Line switching or power plant black start

Table 76 Multiple load switching configuration - a simple case. Line switching or power plant blackstart

MLS1	MLS2	MLS3	MLS4	Switching program	Synchronizing voltage
1	-	-	-	LINE	VT1
0	-	-	-	TRANSFO1	VT2

*Note: in this example, VT1 may be connected from low or high voltage side of the power transformer. In case low voltage is used (as shown in above figure), CSD100 shall be set accordingly, to compensate for phase shift due to power transformer vector group.

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12.11.2 Layout with tie circuit breaker

In some complex substation with a tie circuit breaker such as 1 ½ CB, 1,3CB, ring configuration, H configuration, the tie circuit breaker is likely to operate on two different loads, one on each side of the circuit breaker.

Practically, the CSD100 considers the position of the substation apparatus (circuit breakers, disconnector switches…), through a combinatorial logic, to define the strategy to apply and manage reversal of source and load side to synchronize on the appropriate signal.

For example, in Figure 218, circuit breaker may be used to switch a line, or a reactor, or a power transformer.

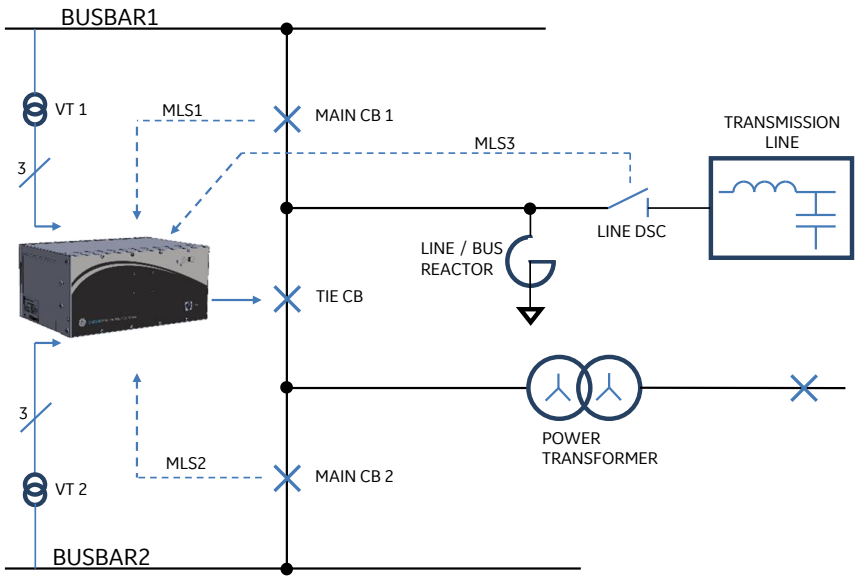


Figure 218 Multiple load switching - Tie circuit breaker and bus/line reactor layout example

Table 77 Multiple load switching configuration - Tie circuit breaker and bus/line reactor layout example

MLS1	MLS2	MLS3	MLS4	Switching program	Synchronizing voltage
0	0	0	-	NA	NA
0	0	1	-	NA	NA
0	1	0	-	REACT1	VT2
0	1	1	-	LINE	VT2
1	0	0	-	TRANSFO1	VT1
1	0	1	-	TRANSFO1	VT1
1	1	0	-	X	X
1	1	1	-	X	X

Note: In this example, if customer finally requests for a different strategy according to PTR secondary side circuit breaker (loaded/unloaded condition), it would be straightforward to connect the circuit breaker position to MLS4 input, to introduce additional strategies.

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12.11.3 Complex use case

Some complex situations involve use of the four MLS inputs. Hereunder is depicted a situation with 1 ½ CB arrangement and three different substations, in which positions of switchgears from distant substations are acquired by the CSD100 to adjust strategy, through a combinatorial logic.

In Figure 219, circuit breaker may be called upon to switch LOAD1 or LOAD2.

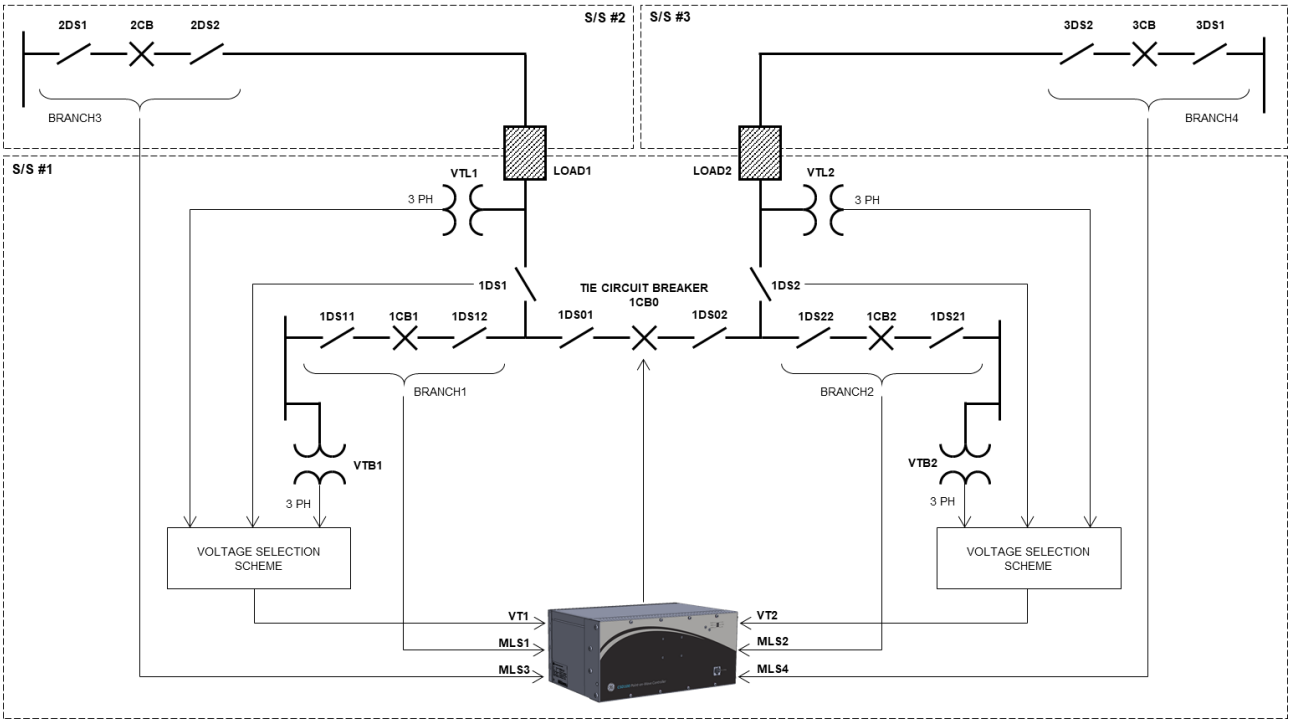


Figure 219 Multiple load switching – complex use case

Table 78 Multiple load switching configuration - Tie circuit breaker layout example

MLS1	MLS2	MLS3	MLS4	Switching program	Synchronizing voltage
0	0	0	0	NA	NA
0	0	0	1	LOAD1	VT2
0	0	1	0	LOAD2	VT1
0	0	1	1	X	X
0	1	0	0	LOAD1	VT2
0	1	0	1	LOAD1	VT2
0	1	1	0	X	X
0	1	1	1	X	X
1	0	0	0	LOAD2	VT1
1	0	0	1	X	X
1	0	1	0	LOAD2	VT1
1	0	1	1	X	X
1	1	0	0	X	X
1	1	0	1	X	X
1	1	1	0	X	X
1	1	1	1	X	X

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13 SETTING AND OPERATING THE CSD100

13.1 Setting the CSD100 with embedded Web HMI

The CSD100 provides an embedded secured web server acting as control interface and accessible with a standard WEB browser (Mozilla Firefox, Google Chrome, Edge, Brave…). This control interface allows:

- Real time data displaying (alarms, measurements)
  - Homepage
  - Measurements page
- Adjustment of settings (switching program, circuit breaker characteristics, network data, …)
  - Settings section
  - System section
  - Language page
- Users and security management
  - System section
- Switching records download
  - Download page

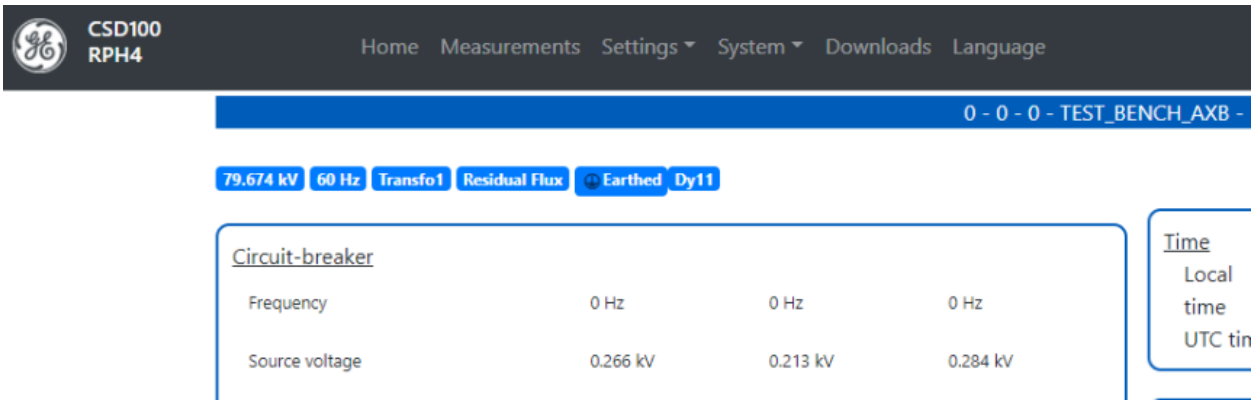


Figure 220 CSD100 HMI main menu

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For a “block” configuration, settings file of the CSD100 (XML format) can also be generated off-line and uploaded to the device through the web interface (dedicated button). Current settings file can also be downloaded from the CSD100 at any moment. It is not possible to upload a settings file from a previous 1.0 version in a version 1.1. However, during firmware upgrade (1.0 to 1.1), settings are preserved.

The IP address of the CSD100 must be known. IP address is either dynamically allocated (from DHCP server) or fixed, depending on network administration. In case of fixed IP address and point to point connection between PC and CSD100, computer ethernet interface network mask shall be configured in the same address range.

Preset IP addresses (DHCP disabled):

- Front port: **192.168.0.2**
- Rear ports: **192.168.5.2**

Refer to section 14.3 for credentials.

Note : essential settings are clamped by internal limits (not settable) to prevent big mistakes and editing errors.

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13.1.1 Login page

Login page is the section where user lands upon first connection (or after session timeout). User is prompted to enter credentials and accept the terms of the system use.

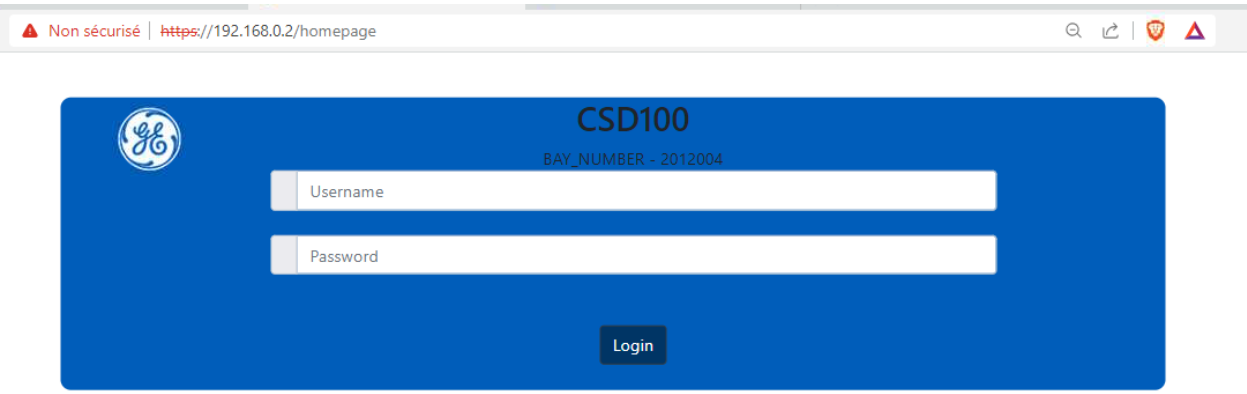


Figure 221 CSD100 HMI login window



Figure 222 CSD100 HMI system use notification message

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13.1.2 Home

This section summarizes essential information, and the details are accessible to users with VIEWER, OPERATOR or ENGINEER role.

- Main live measurements:
  - Frequencies, current, source and load voltages for each phase
  - Circuit breaker position
  - DC control voltages for opening and closing circuits (from substation batteries)
  - Circuit breaker ambient temperature from external probe (typ. 4-20mA)
  - Current Date & Time
- Reminder of main parameters (rated voltage, rated frequency, switching program)
- Alarms and status.
  - Reboot button (restart device, user action)
  - Reset alarm button (user action).
  - External bypass circuit position (measured from dedicated digital input)
  - Communication alarm status: Problem on local network communication
  - System alarm status: gather internal alarms (copy of signaling latching relay 2)
  - Application alarm status (copy of signaling latching relay 1): gather alarms related to operations (example: absence of reference voltage, operation too long, temperature out of range, reignition, excessive inrush current...)
  - Ready to close status: if reference waveform is absent or failure reported from power outputs dedicated to close circuits (internal monitoring), CSD100 is not able to operate.
  - Ready to open status: if reference waveform is absent or failure reported from power outputs dedicated to open circuits (internal monitoring), CSD100 is not able to operate.
- Essential log files events (last 10 events): change of parameters, order received, archive created…

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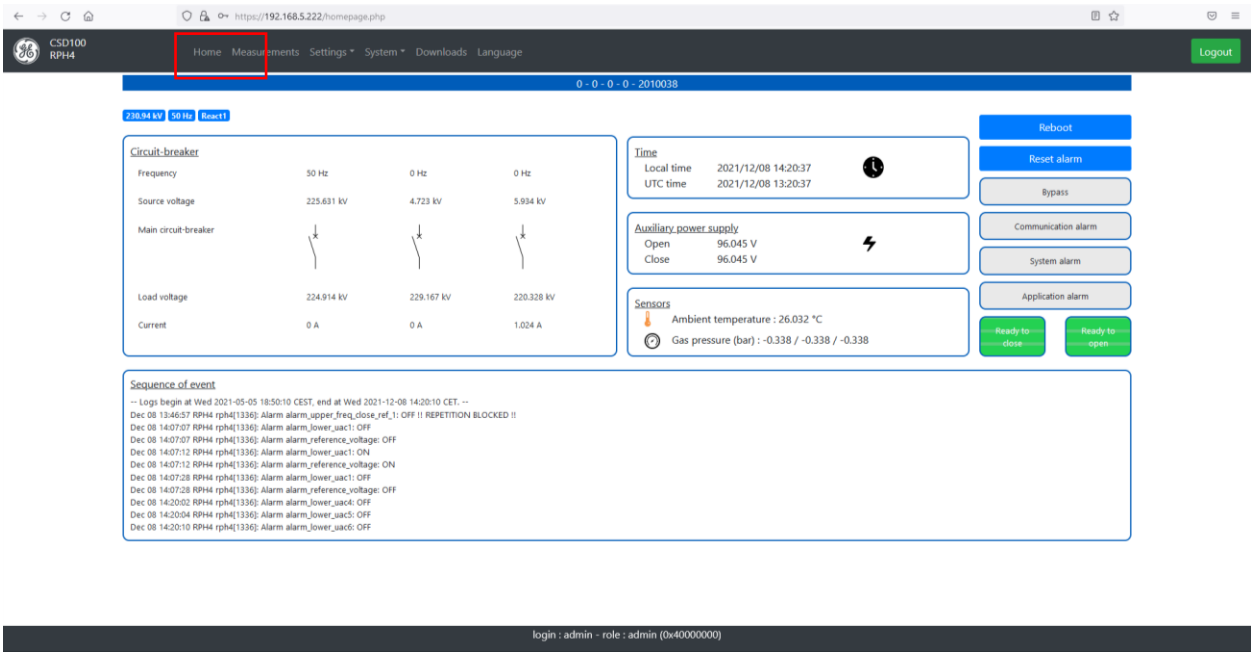


Figure 223 CSD100 HMI home area (HMI)

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13.1.3 Settings\General

This section provides access to general functional settings of the controller and is accessible:

- In read only mode to users with VIEWER role
- In write mode to users with OPERATOR or ENGINEER role

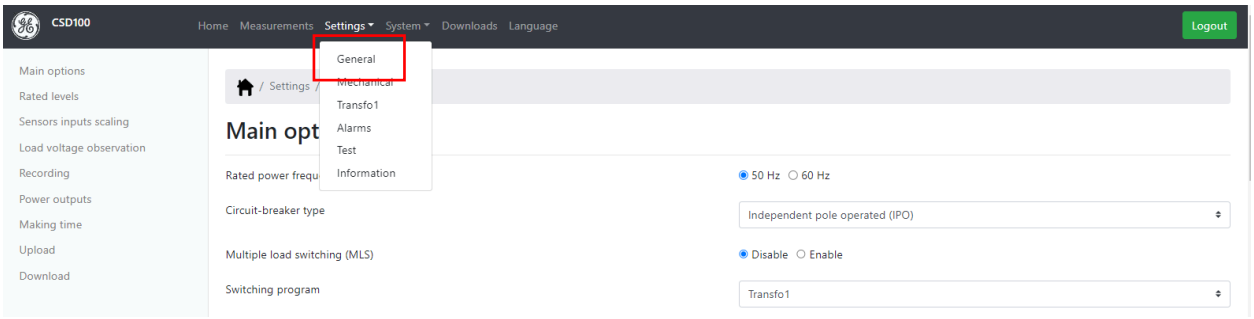


Figure 224 CSD100 HMI access to "Settings\General" page

"**Main options**" subsection allows access to system related settings:

- **Rated power frequency** (50Hz or 60Hz)
- **Circuit breaker type** (Independent pole operated (IPO), Closing resistor, Double closing mechanism, Double opening mechanism). See 10.2.2
- **Multiple load switching (MLS)** activation. See 12.11
- **Switching program** (strategy / load type): Transfo1, Transfo2, React1, React2, Capa1, Capa2, Line, User1, User2, User3, User4. Each program comes with preset dedicated settings.
- **Automatic reference phase selection** activation (in case 3x source voltage are connected). Leave as "disabled" in the general case (without specific constraint regarding input-output delay). If activated the reference phase will be chosen in real time at the time of input order occurrence, to minimize input to output delay.
- **Open sync on current**: for opening it may be necessary for very specific cases (variable load power factor) to synchronize according to circuit breaker current waveform. Leave as "disabled" in the general case (load with fixed power factor), since voltage is easier to handle (more stable in amplitude) than current.
- **Sync with differential voltage**: for closing operations, it may be necessary for very specific cases (circuit breaker fitted with grading capacitors leading to significant residual voltage at load side while CB is open) to consider difference between source and load voltage as synchronization waveform. In case of doubt leave as "disabled".
- **Reference voltage**: indicates which reference voltage is connected (L1 / L2 / L3) to the CSD100. If L1 is selected, it is expected a voltage connected to UAC1 physical input. If L2 is selected, it is expected a voltage connected to UAC2 physical input. If L3 is selected, it is expected a voltage connected to UAC3 physical input. See 12.1. If all 3 phases are connected and "optimize delay" disabled, the synchronizing reference is the one set here

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- **Reference voltage phase shift (°)**: To compensate any phase shift between measured reference voltage and actual voltage present at circuit breaker terminal (preset to zero). Typical case: reference voltage comes from secondary side of a power transformer or a phase-to-phase voltage signal. A positive phase shift value introduces a target delay.

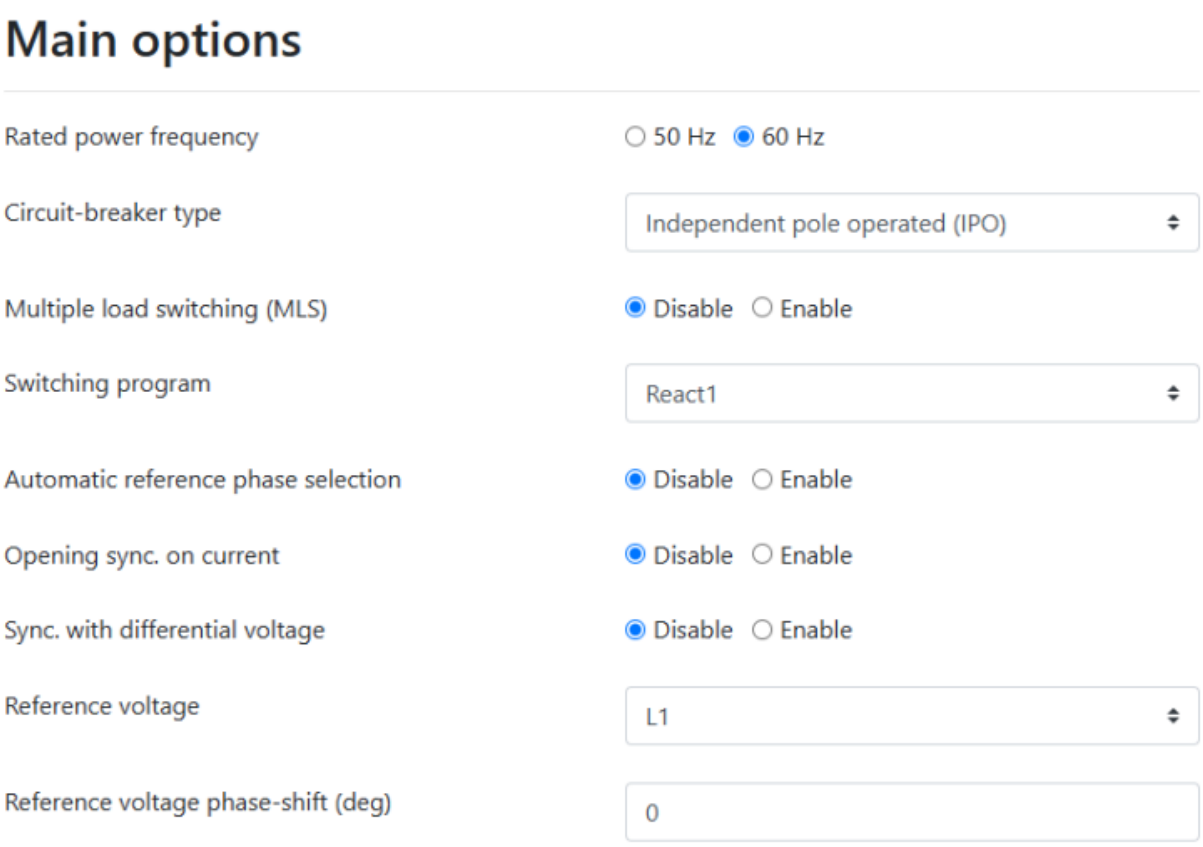


Figure 225 CSD100 HMI access to "Settings\Genera\Main optionsl" page

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If Multiple Load Switching (MLS) is activated, additional parameters become available:

- **Mode**: selected program for each of the MLS digital inputs combination (4 inputs, 16 combinations: X17-3 to X17-10).
- **Dual Switching**: activation of source–load side inversion, individually activable for each of the MLS digital inputs combination (4 inputs, 16 combinations). See 12.11

4 3 2 1	Mode	Dual Switching	4 3 2 1	Mode	Dual Switching
0 0 0 0	Line	☐	1 0 0 0	User2	☐
0 0 0 1	React1	☐	1 0 0 1	User3	☐
0 0 1 0	React2	☐	1 0 1 0	User4	☐
0 0 1 1	Capa1	☐	1 0 1 1	User1	☐
0 1 0 0	Capa2	☐	1 1 0 0	User1	☐
0 1 0 1	Transfo1	☐	1 1 0 1	User1	☐
0 1 1 0	Transfo2	☐	1 1 1 0	User1	☐
0 1 1 1	User1	☐	1 1 1 1	User1	☐

Figure 226 CSD100 HMI access to MLS selection and Dual Switching (HMI)

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"**Rated levels**" subsection allows access to voltage and current transformers related settings:

- **V1..V3 phase-earth voltage (kV):** rms value of AC voltage system physically connected to inputs V1 to V3 (in standard cases, the source side), phase to ground (system line-line voltage divided by square root of three).
- **V4..V6 phase-earth voltage (kV):** rms value of AC voltage system physically connected to inputs V4 to V6 (in standard cases, the load side). May be different from V1..V3 if voltages are measured at secondary side of a power transformer, for example.
- **V1..V3 VT ratio** (= Vprimaire / Vsecondaire)**:** applicable to the three phases.
- **V4..V6 VT ratio** (= Vprimaire / Vsecondaire)**:** applicable to the three phases.
- **Primary rated current (A):** rms nominal value of circuit breaker current, per phase.
- **CT ratio** (= Iprimaire / Isecondaire)**:** current transformer ratio, applicable to the three phases

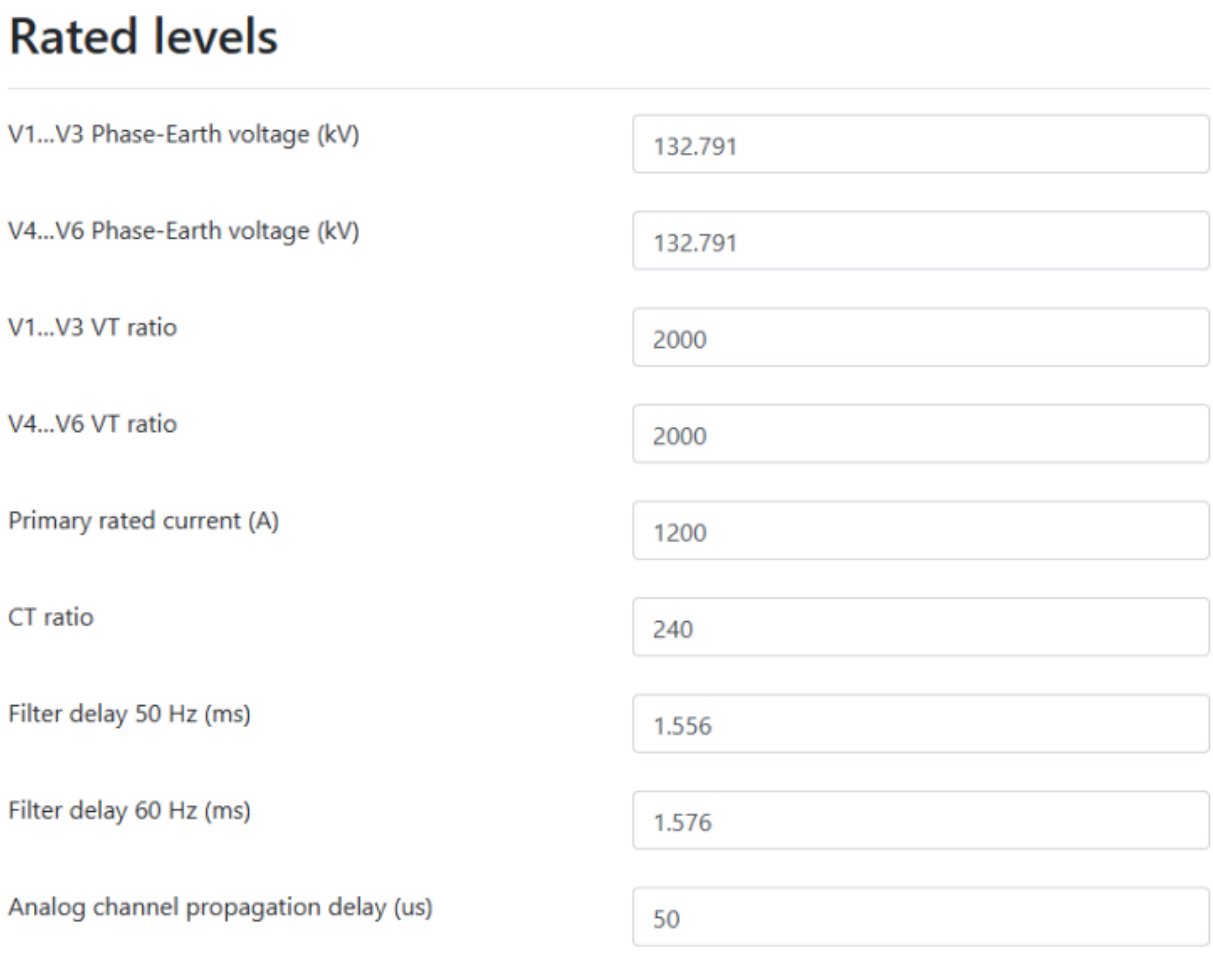


Figure 227 CSD100 HMI access to "Settings\Genera\Rtaed levelsl" page

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"**Load voltage observation"** subsection allows access to thresholds related to load status (energized / de-energized) as well as distinction between controlled / uncontrolled de-energization. These settings are related to power transformer switching. Preset values are applicable to most cases and should not be modified.

- **Load voltage rms de-energization threshold (%):** threshold on decreasing voltage to consider each phase as deenergized.
- **Load voltage rms energization threshold** (%): threshold on increasing voltage to consider each phase as energized.
- **Uncontrolled opening timeout (ms):** maximum time difference between expected 52a switching and measured 52a switching to consider an opening operation as controlled (synchronized), for power transformer switching application.

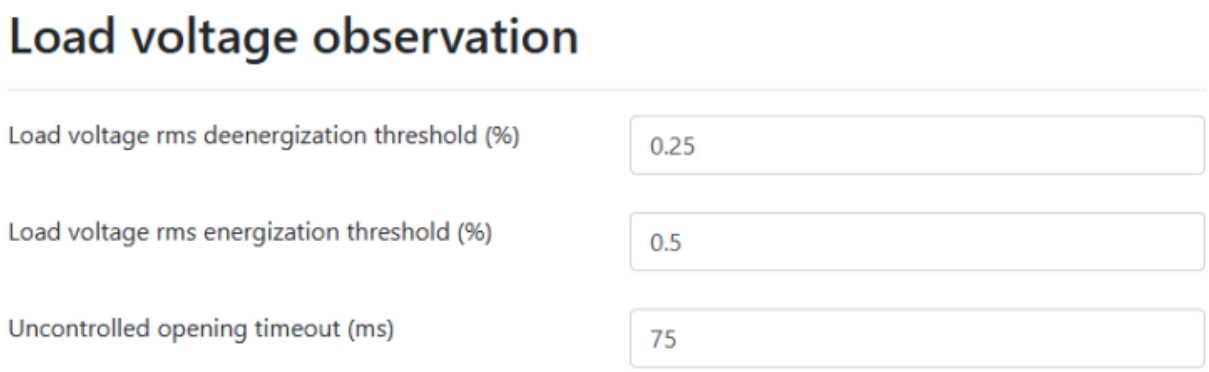


Figure 228 CSD100 HMI access to "Settings\General\Load voltage observation" page

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“**Recording**” subsection allows adjustments of records trigger source and records duration.

- **Voltage event:** creation of record upon reference voltage presence/absence (triggered by corresponding alarm)
- **MLS:** creation of record upon MLS digital inputs change (switching strategy automatic change).
- **52a:** creation of record upon 52a switching (uncontrolled operation).
- **Open**: creation of record upon opening order occurrence
- **Close**: creation of record upon closing order occurrence
- **External trigger**: creation of record upon dedicated digital input activation (trigger). This is the recorder function of the CSD100.
- **Comtrade duration (opening) (sec)**: total record duration for opening. 1s as standard, 4s for extended records.
- **Comtrade pretrigger duration (opening) (sec)**: fraction of record duration before event. Must not exceed total duration.
- **Comtrade duration (closing) (sec)**: total record duration for closing. 1s as standard, 4s for extended records.
- **Comtrade pretrigger duration (closing) (sec)**: fraction of record duration before event. Must not exceed total duration.

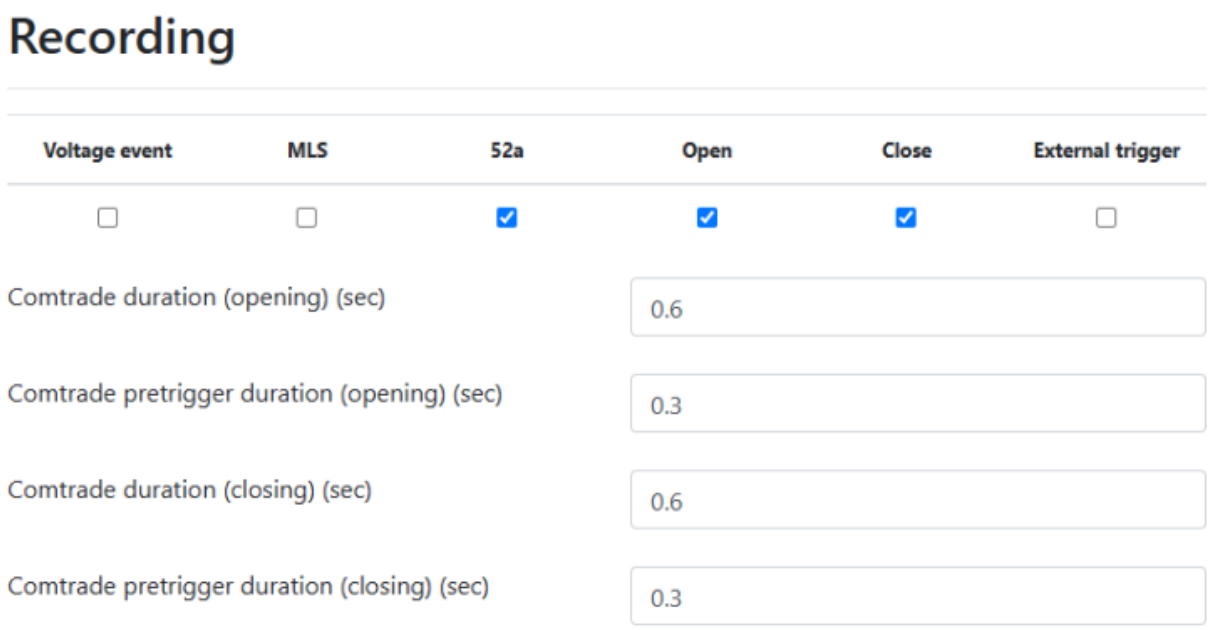


Figure 229 CSD100 HMI access to “Settings\General\Recording” page

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"**Making time**" subsection allows configuration of making times measurement method. See 12.5.9.

- **Making time measurement method**: "Voltage" (observation of load voltage rise/change, typically for power transformers), "Current threshold" (direct threshold of current, typically for capacitive loads), "Current delay" (threshold with delay compensation with sine model, typically for inductive loads).
- **Making time measurement current threshold (A):** current threshold (primary value) for "Current threshold" and "Current delay" methods.

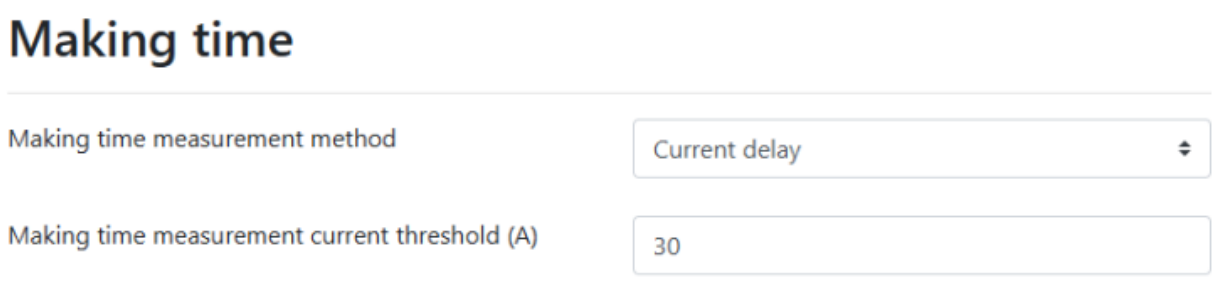


Figure 230 CSD100 HMI access to "Settings\Genera\Making timeI" page

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“**Upload param file**” subsection allows to select and upload a parameter file, for block configuration.

A popup window will ask for a file from the user: after file upload, it is necessary to validate changes through the HMI and press the “Apply” button when it appears.

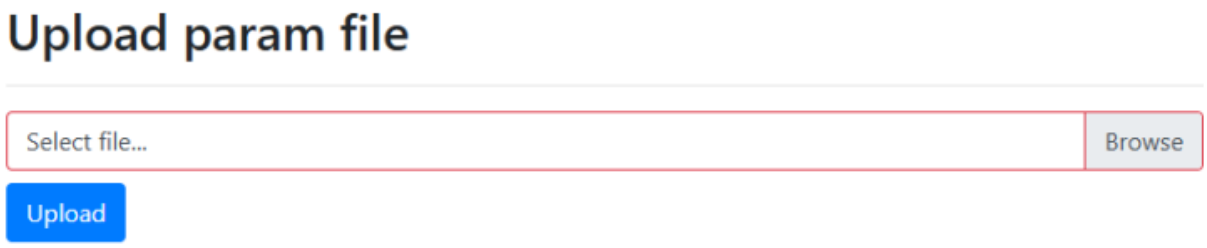


Figure 231 CSD100 HMI access to “Settings\Genera\Upload param file\” page

“**Download the parameter file**” subsection allows to download and retrieve current parameter (configuration file).

Configuration (parameter) files are xml type (text file with imposed syntax).

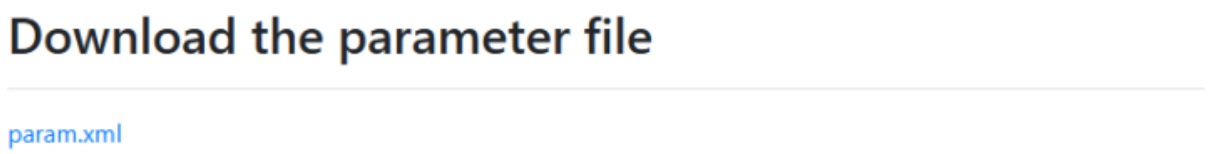


Figure 232 CSD100 HMI access to “Settings\Genera\Download param file\” page

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13.1.4 Settings\Sampled Values

CSD100 supports the following variants:

- **F4000S1I4U4**: 4000 Hz / 1 ASDU (80 SPC @ 50 Hz) – 9-2LE guideline compatible
- **F4800S1I4U4**: 4800 Hz / 1 ASDU (80 SPC @ 60 Hz) – 9-2LE guideline compatible
- **F4800S2IxUy**: 4800 Hz / 2 ASDU (up to 24 quantities per ASDU, with x + y ≤ 24)

This section provides access to Sampled Values subscription settings and is accessible:

- In read only mode to users with VIEWER role
- In write mode to users with OPERATOR or ENGINEER role

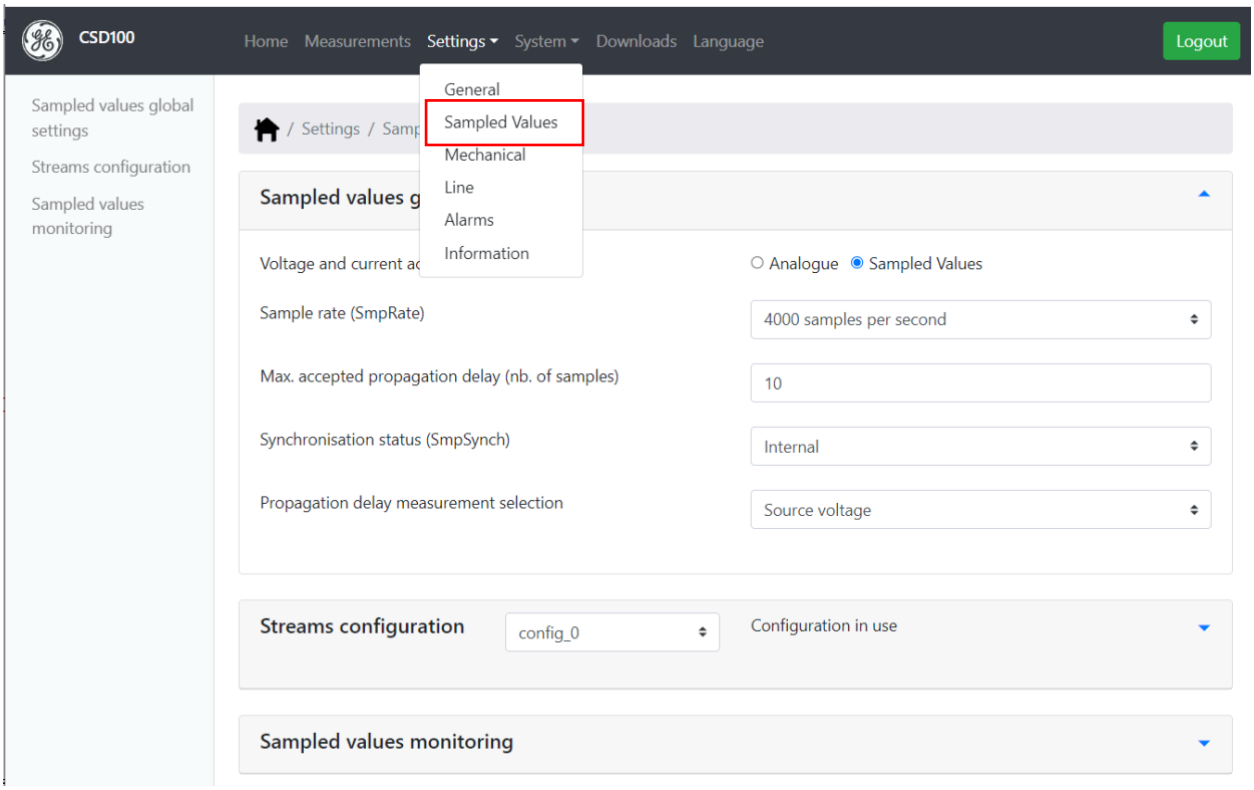


Figure 233 CSD100 HMI access to Sampled values subscription settings

Note: this section provides description of operational settings needed for SV configuration. Further details on SV terminologies and some use cases are described in section 24.

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"**Sampled values global settings**" subsection allows access to generic settings:

- **Voltage and current acquisition mode** (Analogue or Sampled Values): When set with "Sampled Values" acquisition mode, CSD100 monitors voltages and currents from digital streams instead of analog signals. All functions of the device remain similar in "Analog" or "Sampled Values" mode.
- **Sample rate (SmpRate)** (4000 sps or 4800 sps), this value shall be set to
    - 4000 for sampled values conforming to IEC 61869-9 variant F4000S1I4U4 (compatible with 9-2LE guideline) at 50 Hz
    - 4800 for sampled values conforming to IEC 61869-9 variant F4800S1I4U4 (compatible with 9-2LE guideline) at 60 Hz
    - 4800 for sampled values conforming to IEC 61869-9 variant F4800S2IxUy
- **Max. accepted propagation delay (nb. of samples)** (1 to 18), this value corresponds to the maximum SV transmission delay, from the physical event on the HV line to the subscriber (including MU filter delay and processing time), the CSD100 tolerates for correct processing. For example, with a SmpRate of 4000 sps at 50 Hz, if this value is set to 5, CSD100 rejects all samples transmitted with a delay higher than 1.250 ms. To set this value consistently, it is possible to measure the average propagation delay of each stream in monitoring section and consider a 5 times margin for example. When the sampled values come from multiple merging units, the longest delay needs to be considered.
- **Synchronization status (SmpSynch)** (Global or Local or Internal): Quality of sample timing the CSD100 tolerates for correct processing.
    - When value is set to Global, CSD100 processes SV with SmpSynch field set to Global (2) only.
    - When value is set to Local, CSD100 processes SV with SmpSynch field set to Local or Global (1 or 2).
    - When value is set to Internal, CSD100 processes SV with SmpSynch field set to Internal, Local or Global (0, 1 or 2).
- **Propagation delay measurement selection** allows selection of the stream for which the measured propagation delay needs to be displayed in monitoring section.

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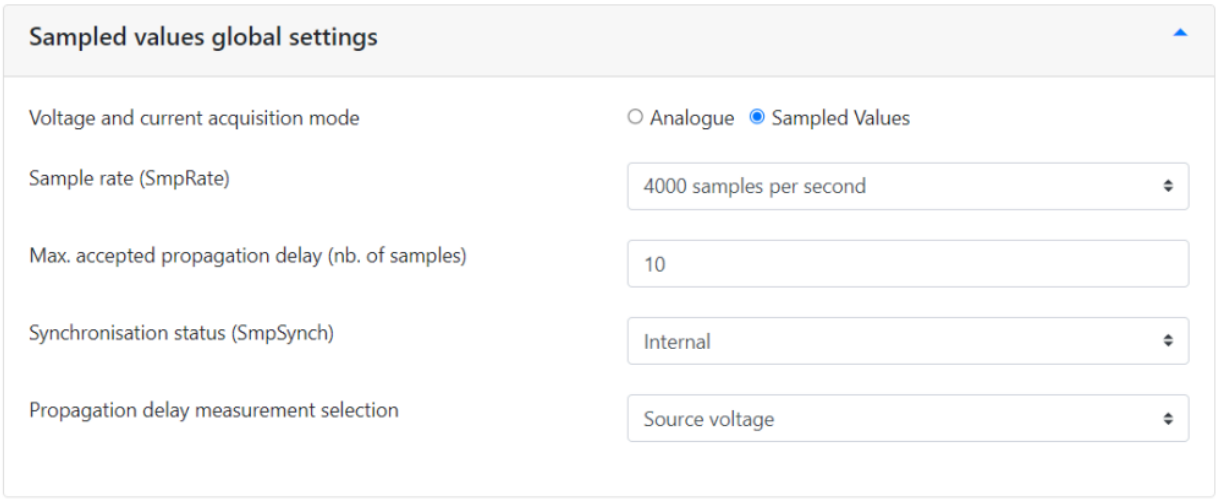


Figure 234 CSD100 HMI access to Sampled values global settings

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"**Streams configuration**" subsection allows configuration of subscribed streams.

CSD100 can subscribe to a maximum of 7 streams, simultaneously, divided in two categories:

- **"Processed" sampled values**: these streams are the one used for operation of the device. Voltage and current measurements are transmitted to the CSD100 processor through these streams. 3 configuration sets are available:
  - U1…U3
  - U4…U6
  - I1…I3

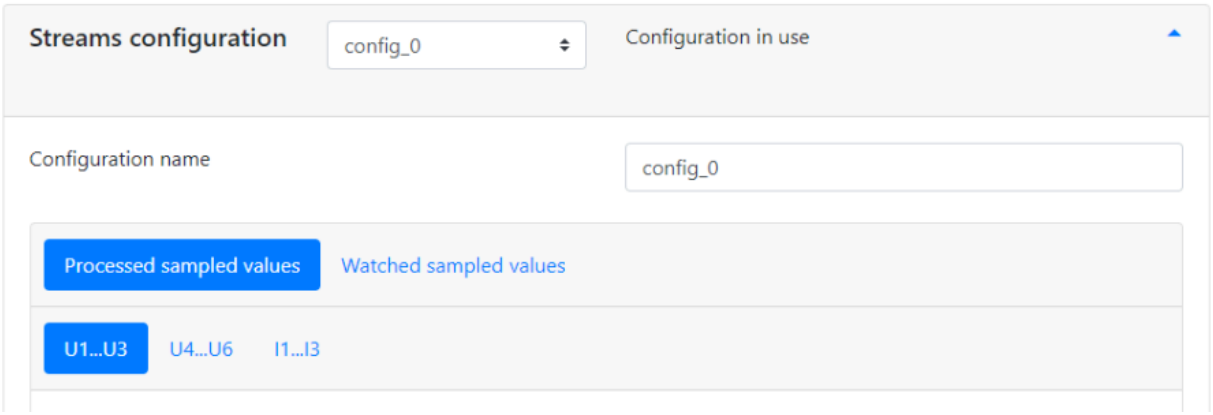


Figure 235 CSD100 HMI access to Sampled values processed streams

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- **“Watched” sampled values**: these streams are monitored by the device but not processed for operation. They allow following possible alternatives to processed streams. 4 configuration sets are available:
    - Watched stream 1
    - Watched stream 2
    - Watched stream 3
    - Watched stream 4

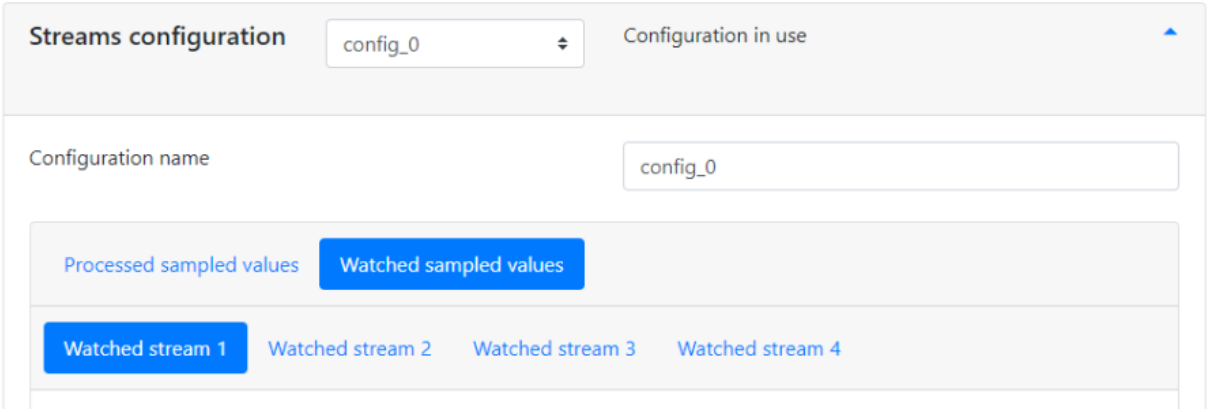


Figure 236 CSD100 HMI access to Sampled values watched streams

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These 7 streams are constituting a **“configuration”**. A set of 10 configurations is available to select the streams reflecting the substation configuration.

Table 79 CSD100 available SV configuration sets

SV Configuration	Processed stream			Watched stream			
	U1…U3	U4…U6	I1…I3	1	2	3	4
Config_0	Stream a	Stream b	Stream c	Stream d	Stream e	Stream f	Stream g
…	…	…	…	…	…	…	…
Config_9	Stream s	Stream t	Stream u	Stream w	Stream x	Stream y	Stream z

The user can select one of them either manually from the web HMI or dynamically from GOOSE subscription (13.8.6).

“**Configuration selection**” allows manual selection of a configuration.

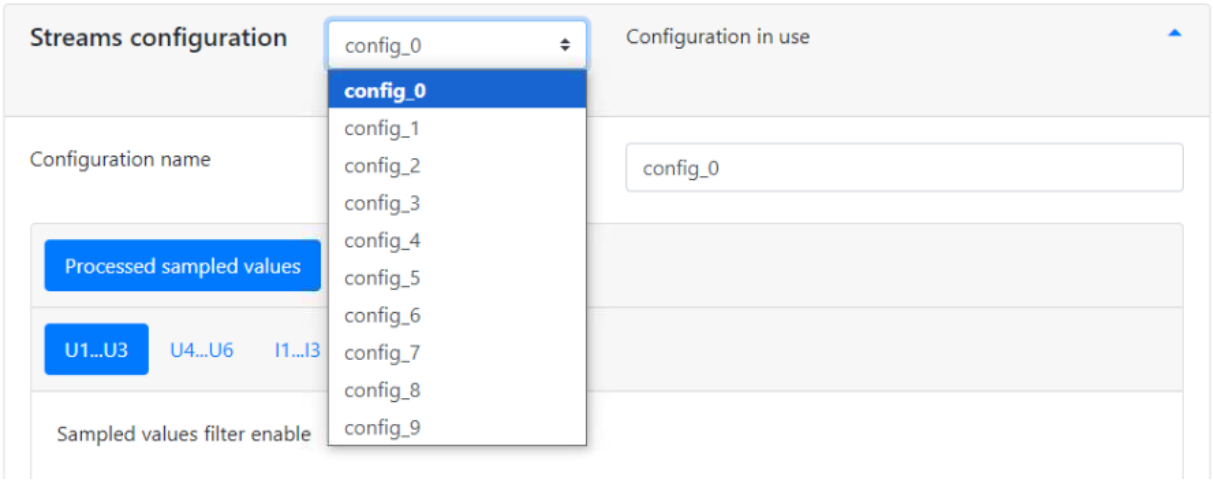
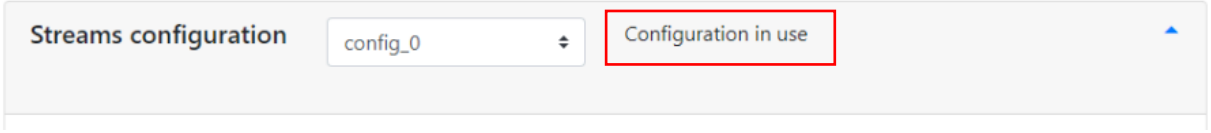


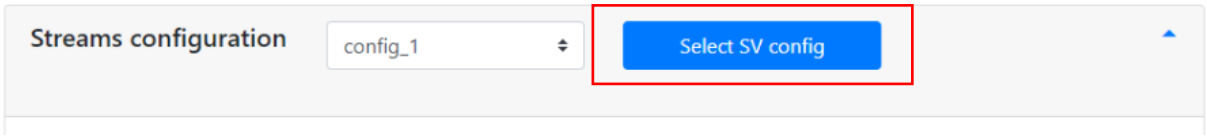
Figure 237 CSD100 HMI access to Sampled values manual configuration selection

When a configuration is selected for operation, for example “config_0”, the display shows the information “Configuration in use”.

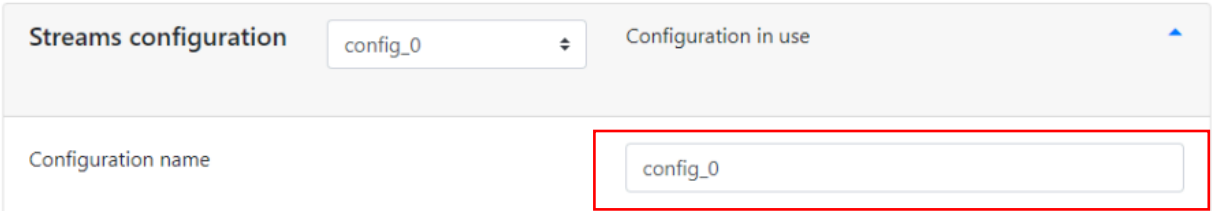


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When selecting another configuration for operation, for example “config_1”, it is necessary to click on the “Select SV config” button to validate the configuration selection.



Note: For convenience, it is possible to customize the configuration name. This change needs to be applied, clicking on the “Apply” button.



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The configuration of each individual streams includes:

- **Filtering options:** when filtering is enabled, CSD100 processes the streams with consideration of
  - **MAC@**, set in hexadecimal, from 010CCD040000 to 010CCD0401FF (recommended values from standardization bodies)
  - **APPID**, set in hexadecimal, from 0x4000 to 0x7FFF
  - **Simulated frames**, Original or Simulated
  - **SVID**, set in alphanumeric, from 1 to 12 characters.
- **Position in ASDU | Phase 1 value (0…23)**, for example, with a 9-2LE variant (F4000S1I4U4 or F4800S1I4U4), value shall be set to
  - **0** if the desired measured value is the current of phase 1
  - **4** if the desired measured value is the voltage of phase 1
- **Position in ASDU | Phase 2 value (0…23),** for example, with a 9-2LE variant (F4000S1I4U4 or F4800S1I4U4), value shall be set to
  - **1** if the desired measured value is the current of phase 2
  - **5** if the desired measured value is the voltage of phase 2
- **Position in ASDU | Phase 3 value (0…23),** for example, with a 9-2LE variant (F4000S1I4U4 or F4800S1I4U4), value shall be set to
  - **2** if the desired measured value is the current of phase 3
  - **6** if the desired measured value is the voltage of phase 3

Note: Filtering options can be enabled all simultaneously or not, using the individual checkboxes. They shall correspond to the characteristics of the streams to which subscription is desired, as published by other IEDs or Merging Units on the process bus. To enable any of the individual filter, it is necessary to enable the global "**Sampled values filter enable**" option, otherwise none of the individual filter is applied.

Note: when the SVID of the streams to which subscription is desired exceeds 12 characters, filtering can be enabled using the 12 first characters.

Note: For better understanding of ASDU notion and position of a sample in ASDU, please refer to 24.1. Some use cases are also described in 24.2.

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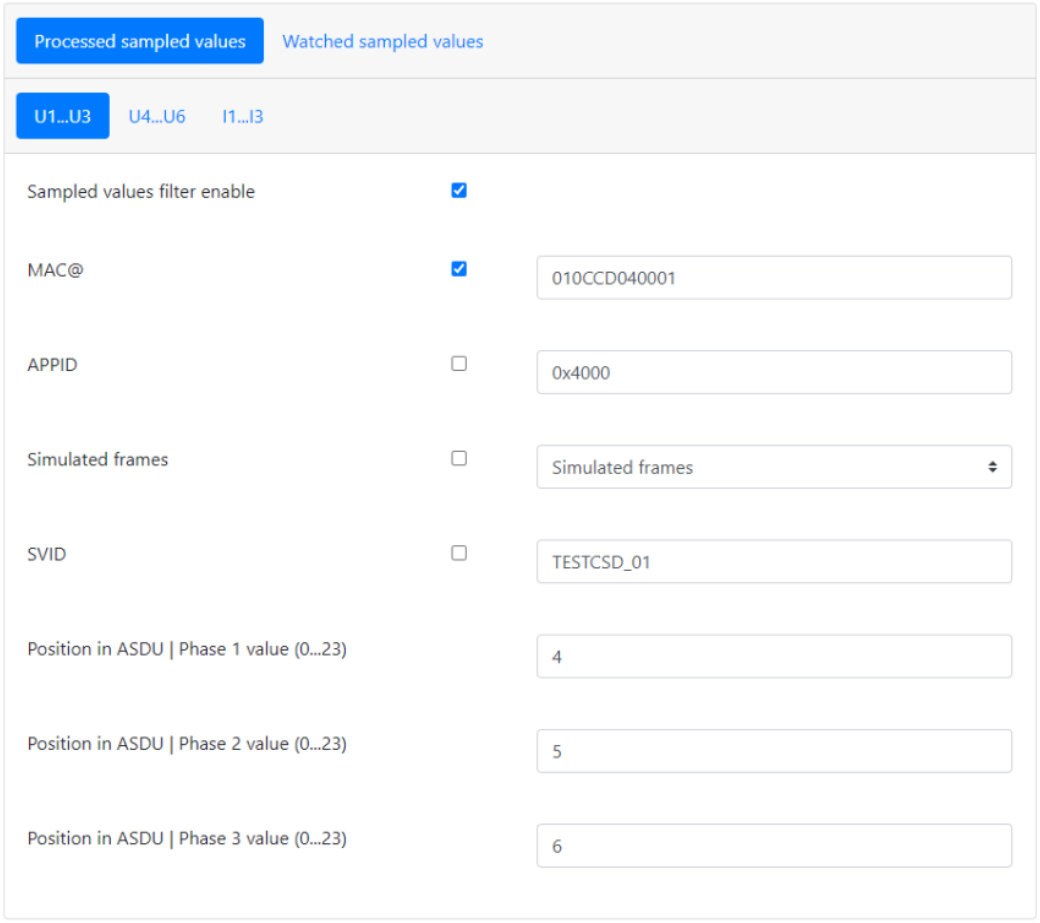


Figure 238 CSD100 HMI access to SV stream configuration

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"**Sampled values monitoring**" subsection allows monitoring of SV indicators.

General indicators:

- **PTP status** source of time synchronization (GPS, internal oscillator, …)
- **PTP Grand Master Clock** refers to the Clock ID of the Grand Master Clock used for CSD100 synchronization.
- **SV sync counter error** counts each time one stream undergoes a SmpSync value change or CSD100 loose synchronization with PTP GMC.
- **Total SV frame rate** refers to the total rate of SV frames received by CSD100 before filtering.
- **SV delay measurement** refers to, for the selected stream, the measured transmission delay value from the SV publisher to CSD100. The value is displayed in µs.

Indicators for each stream:

- **SmpSynch:** Synchronization status of the stream as delivered by the publisher, reflects the synchronization status of the publisher and the quality of sample timing.
- **Quality | Phase 1:** Quality for the measured signal on phase 1 (quality is good when all bit equal 0)
- **Quality | Phase 2:** Quality for the measured signal on phase 2 (quality is good when all bit equal 0)
- **Quality | Phase 3:** Quality for the measured signal on phase 3 (quality is good when all bit equal 0)
- **SV rate after filtering:** Total frame rate received by CSD100 for processing after filtering
- **Missing sampled values count:** Number of samples missed since last counter reset
- **Count of non-Good quality | Phase 1:** Number of samples counted with a quality different from Good since last counter reset on phase 1
- **Count of non-Good quality | Phase 2:** Number of samples counted with a quality different from Good since last counter reset on phase 2
- **Count of non-Good quality | Phase 3:** Number of samples counted with a quality different from Good since last counter reset on phase 3

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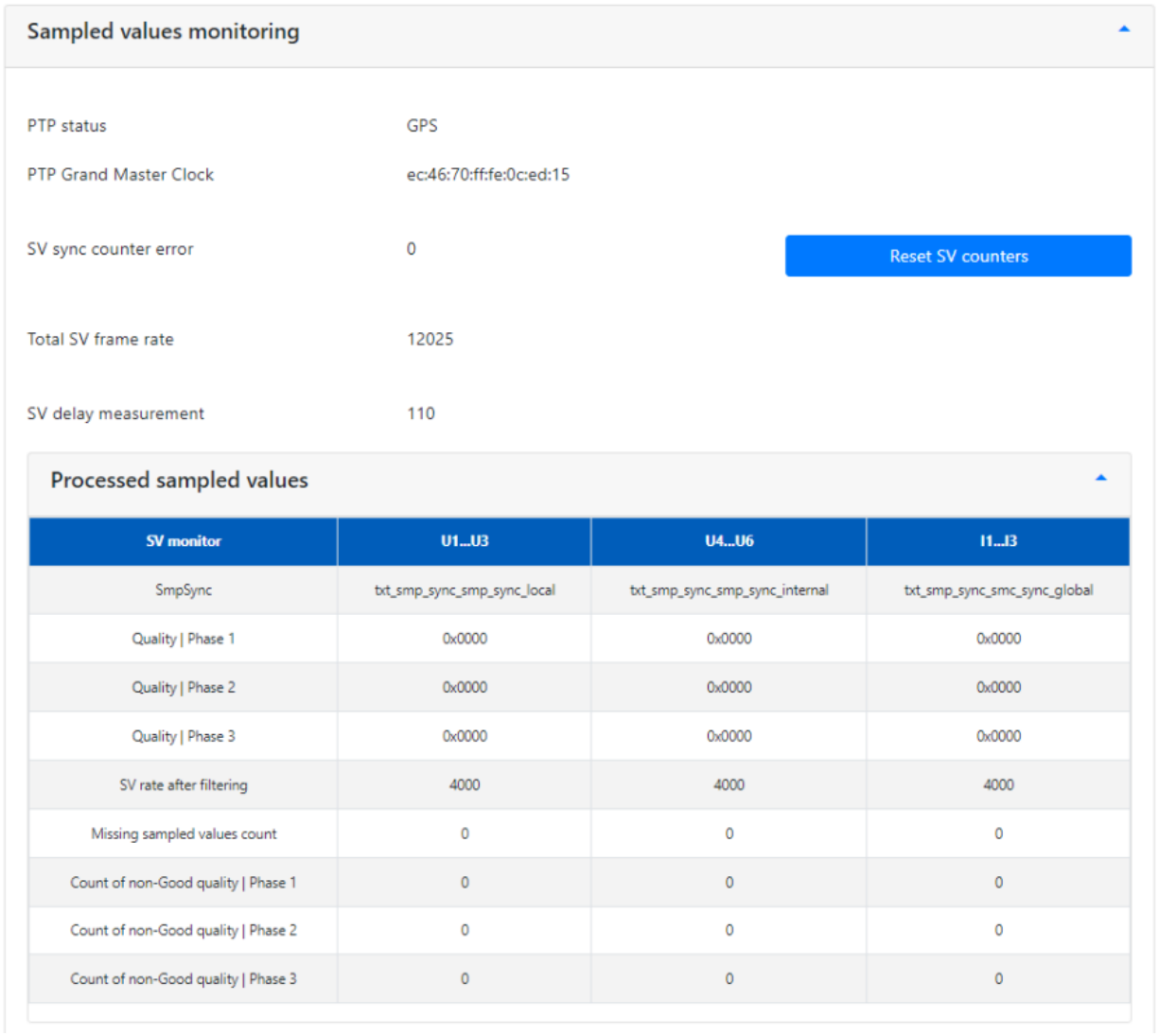


Figure 239 CSD100 HMI access to Sampled values indicators

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13.1.5 Settings\Mechanical

This section provides access to mechanical characteristics of the circuit breaker, both for opening and closing operations. This section is accessible:

- In read only mode to users with VIEWER role
- In write only mode to users with OPERATOR or ENGINEER role

"**Main options**" subsection provides access to coils voltage and drive type settings.

- **Control voltage (opening):** voltage input (DC1 or DC2) which is used to monitor opening control voltage.
- **Control voltage (closing):** voltage input (DC1 or DC2) which is used to monitor closing control voltage.
- **DC1 (V):** nominal value for DC1 input (for control voltage time compensation)
- **DC2 (V):** nominal value for DC2 input (for control voltage time compensation)
- **Hydraulic drive** (Yes/No): if hydraulic drive is present, specific time compensation option becomes available, and associated settings (rated hydraulic pressure and tables both for open and close operations).
- **Gas monitoring option** (Enable/Disable): if gas sensors are present (RS485 port, digital sensors), option can be activated.
- **"Electrical wear option"** (Enable/Disable): electrical wear can be computed. Electrical wear is the cumulated "∫i².t" from contact separation to circuit breaker current zero, for each opening operation.

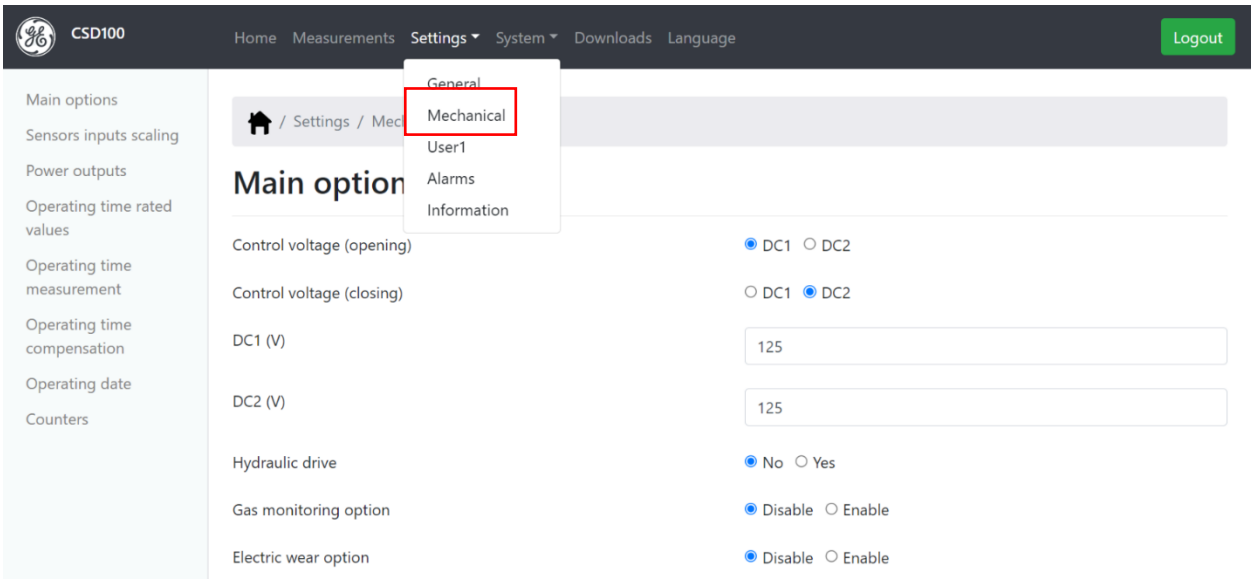


Figure 240 CSD100 HMI access to "Settings\Mechanical" section

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“Sensors input scaling” subsection allows configuration of connected sensors.

- **Gas rated pressure (bar):** nominal filling pressure of circuit breaker (equivalent absolute pressure at 20°C). Optional (gas monitoring).
- **Ambient temperature 4mA (°C):** lower scale value of the 4-20mA ambient temperature transducer.
- **Ambient temperature 20mA (°C):** upper scale value of the 4-20mA ambient temperature transducer.
- **Travel sensor 1 type:** either current (4-20mA) or voltage (0-5V). Standard (preset) value is current. Optional.
- **Travel sensor 2 type:** either current (4-20mA) or voltage (0-5V). Standard (preset) value is current. Optional.
- **Travel sensor 3 type:** either current (4-20mA) or voltage (0-5V). Standard (preset) value is current. Optional.
- **Ambient temperature sensor type:** either current (4-20mA) or voltage (0-5V). Standard (preset) value is current.
- **Digital transmitter baud rate:** communication speed for digital transmitter used for gas monitoring (pressure and temperature) and pressure monitoring (hydraulic drive).
- **Gas pressure monitoring sensor addresses**: addresses of RS485 gas and CB drive hydraulic pressure monitoring sensors on the RS485 bus. From these sensors, gas density may be monitored (optional). Addresses must be different since all sensors are multiplexed on the same unique RS485 port.
- **Insulating gas type**: dry air / g3 / SF6+CF4 / SF6+N2 / SF6
- **Gas pressure alarm hysteresis (bar)**: difference in thresholds for set and reset gas alarms (the thresholds are located in HMI section “Alarms”)
- **Initial equivalent absolute pressure at 20°C (bar):** for mixtures, this is the total initial (filling) pressure, equivalent at 20°C.
- **Gas mixture ratio:** for mixtures, this is the initial ratio (alternative gas density divided by SF6 density). [0..1].

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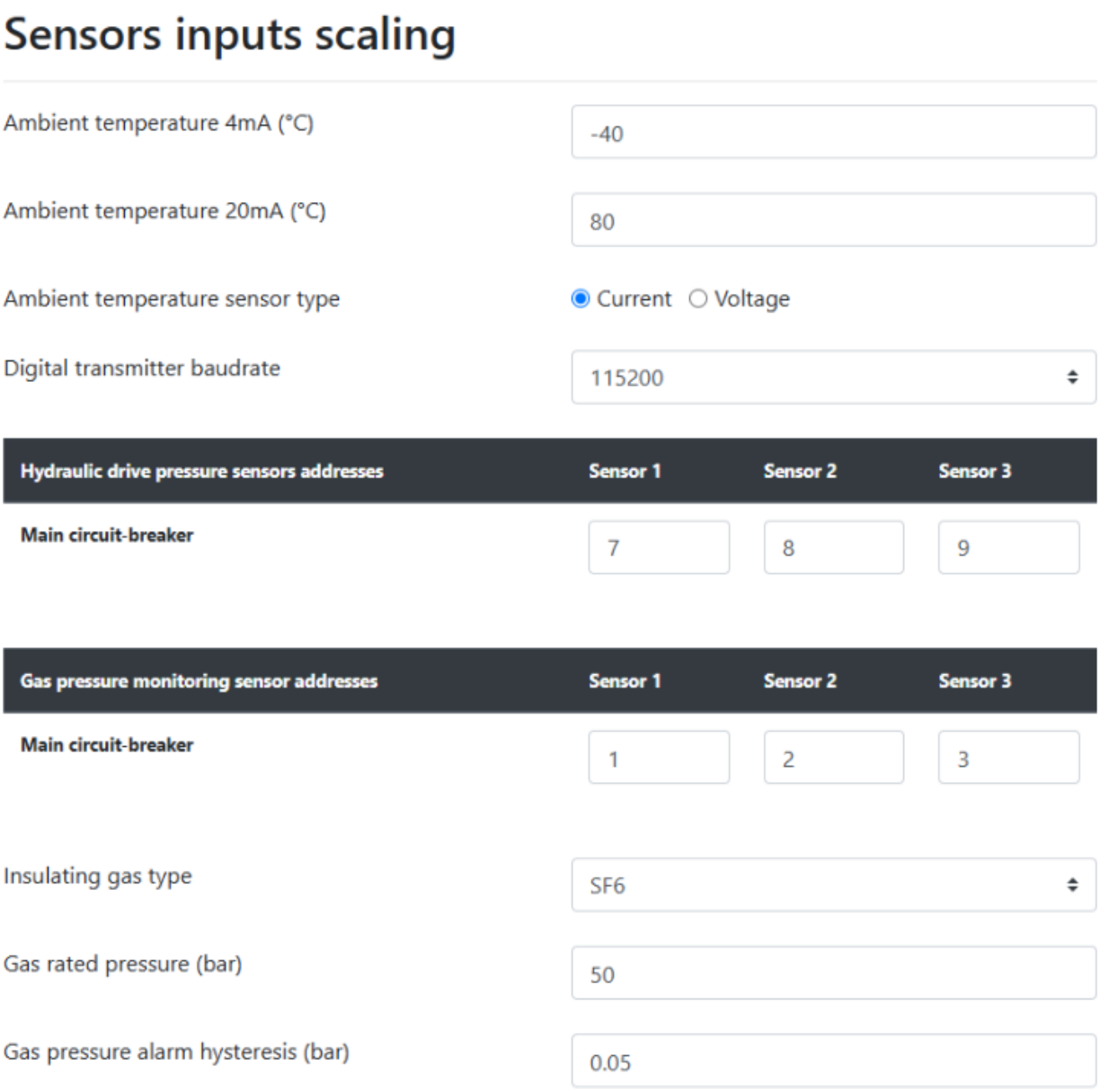


Figure 241 CSD100 HMI access to "Settings\Mechanical\Sensors inputs" section

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"**Power outputs**" subsection allows access to set coils activation durations and threshold energy.

- **Opening impulse duration (ms)**: opening coils activation duration
- **Closing impulse duration (ms)**: closing coils activation duration
- **Power output energy threshold (opening) (J):** threshold energy above which it is considered that CSD100 has activated the coils (=operation controlled by CSD100). Preset value (1) should not be changed, except for test purpose.
- **Power output energy threshold (closing) (J):** threshold energy above which it is considered that CSD100 has activated the coils (=operation controlled by CSD100). Preset value (1) should not be changed, except for test purpose.

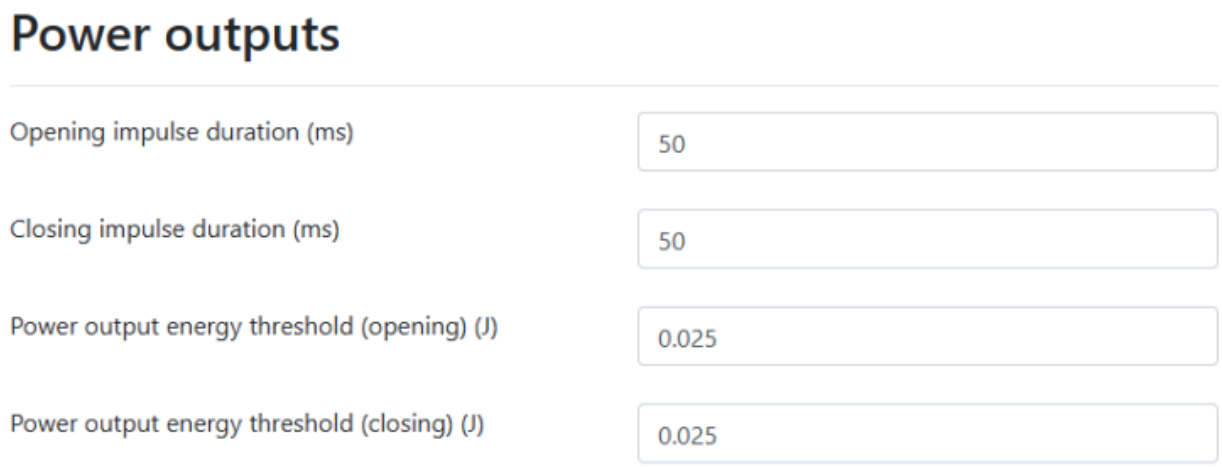


Figure 242 CSD100 HMI access to "Settings\Mechanical\Power outputs" section

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"**Operating time**" subsection provides access to nominal circuit breaker times settings (measured during commissioning). All times measured from coil activation instant, for each phase.

- **Main circuit breaker opening / Arcing contact time (ms):** nominal arcing contact separation time for L1, L2, L3 (opening).
- **Main circuit breaker opening / Auxiliary contact time (ms):** nominal auxiliary contact ("a" type) switching time for L1, L2, L3 (opening).
- **Main circuit breaker closing / Arcing contact time (ms):** nominal arcing contact touch time for L1, L2, L3 (closing).
- **Main circuit breaker closing / Auxiliary contact time (ms):** nominal auxiliary contact ("a" type) switching time for L1, L2, L3 (closing).

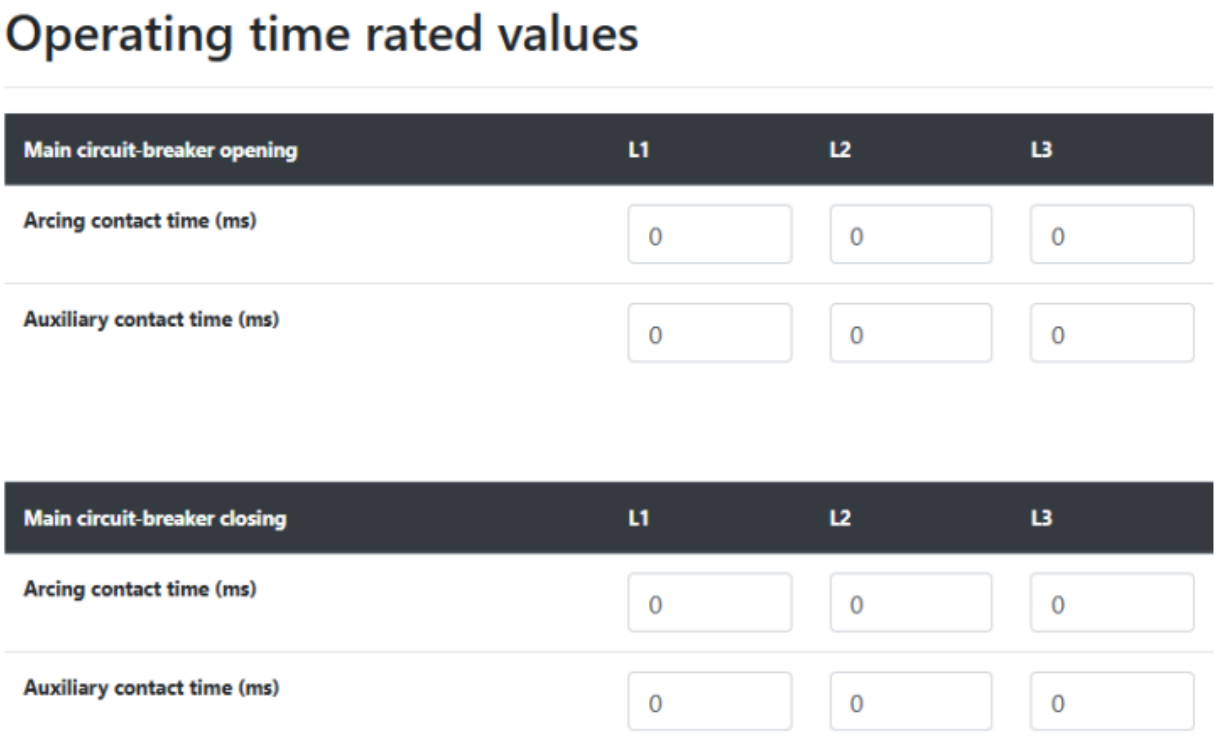


Figure 243 CSD100 HMI access to "Settings\Mechanical\Operating time rated values" section

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"**Operating time measurement**" subsection provides access to mechanical times measurement method.

- **Opening time measurement method**: auxiliary contacts (52a) or travel curve. If travel curve is selected (travel sensor fitted in circuit breaker drive) additional parameters become available. Travel curve method is for future use (the travel curve is included in records, but no measurement is automatically computed).
- **Closing time measurement method**: auxiliary contacts (52a) or travel curve. If travel curve is selected (travel sensor fitted in circuit breaker drive) additional parameters become available. Travel curve method is for future use (the travel curve is included in records, but no measurement is automatically computed).
- **Stability duration**: (1/2/3/4/5ms). filtering duration for 52a timestamping through dedicated digital inputs. Recommended value: 2ms. This is the amount of time the digital input must be stable after any change of value detection, to be considered as definitely switched. A too large value may delay the timestamping and introduce error, because the risk of capturing noise not related to auxiliary contacts switching is higher.
- **Edge detection duration:** this parameter introduces a time window limitation for search of "first edge", before beginning of stability duration. Any edge before beginning of stability minus edge detection duration is ignored. The earliest edge inside edge detection duration window before stability duration is considered. See 10.1.8.14 for illustration.

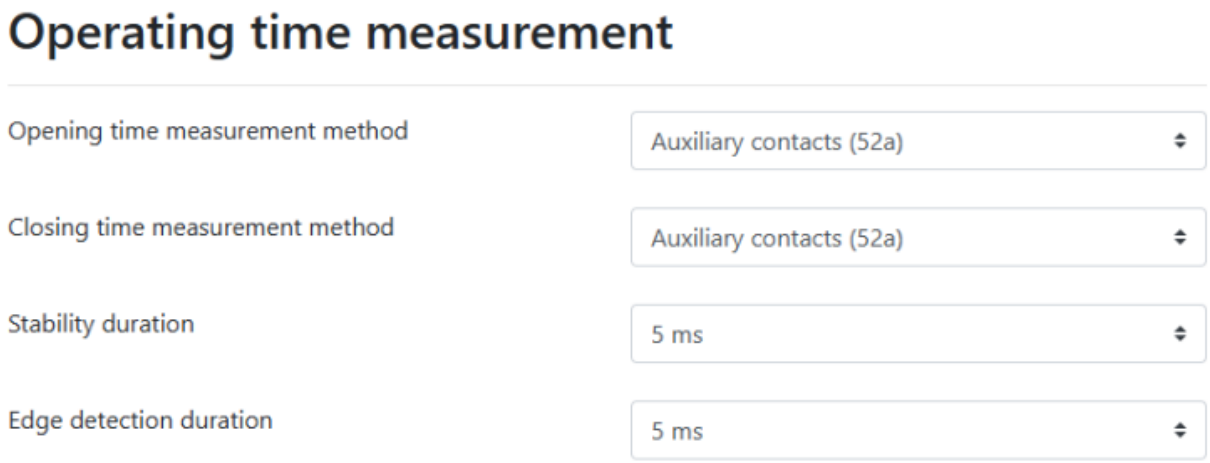


Figure 244 CSD100 HMI access to "Settings\Mechanical\Operating time measurement options" section

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- **Travel curve/Current at travel 0% (mA)**: circuit breaker being in open position, these are the values from the travel curve sensors (mA), for L1, L2, L3.
- **Travel curve/Current at travel 100% (mA)**: circuit breaker being in close position, these are the values from the travel curve sensors (mA), for L1, L2, L3.
- **Travel curve/Contact separation stroke (mm)**: distance (from open position reference) at which contacts separate during open operation, for L1, L2, L3 (usually same value for three phases).
- **Travel curve/Contact touch stroke (mm)**: distance (from open position reference) at which contacts touch during close operation, for L1, L2, L3 (usually same value for three phases).
- **Total stroke between open and closed positions (mm)**: converts percentage of displacement (linearly calculated from travel curve sensor) to circuit breaker arcing contact distance.
- **Timeshift with arcing contact separation (ms)**: difference between arcing contact opening time and travel sensor separation stroke time
    - Arcing contact opening time = Travel sensor separation time + Timeshift
- **Timeshift with arcing contact touch (ms)**: difference between arcing contact closing time and travel sensor touch stroke time
    - Arcing contact closing time = Travel sensor touch time + Timeshift

Travel curve	L1	L2	L3
Current at travel 0% (mA)	4	4	4
Current at travel 100% (mA)	20	20	20
Contact separation stroke (mm)	50	50	50
Contact touch stroke (mm)	50	50	50
Total stroke between open and closed positions (mm)	100	100	100
Timeshift with arcing contact separation (ms)	0	0	-10
Timeshift with arcing contact touch (ms)	0	0	10

Figure 245 CSD100 HMI access to "Settings\Mechanical\Travel curve settings" section

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"**Operating time compensation**" subsection provides access to mechanical times compensation settings.

- **Ambient temperature** (disable/enable): If enabled, additional parameters become available. Usually activated in cold countries or environment with large temperature variation.
- **Control voltage** (disable/enable): If enabled, additional parameters become available.
- **Idle time** (disable/enable): If enabled, additional parameters become available. Usually activated for hydraulic drives.
- **Adaptive control** (disable/enable): If enabled, additional parameters become available. Recursive compensation from mechanical times measurement feedback.
- **Mechanical time max. compensation** (ms): to clamp total compensation.

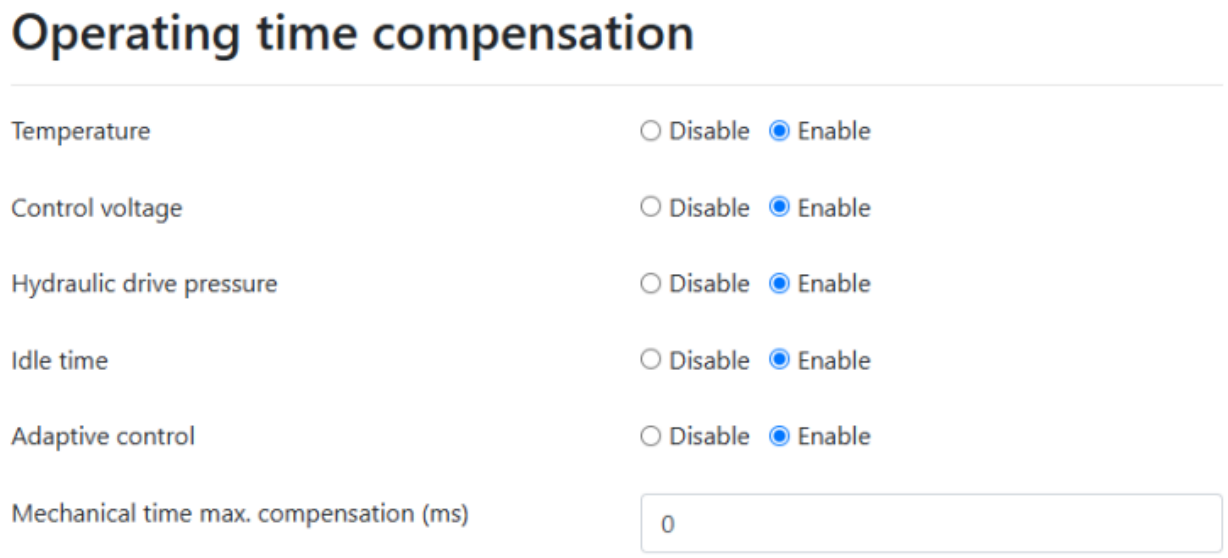


Figure 246 CSD100 HMI access to "Settings\Mechanical\Operating time compensation options" section

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- **Ambient temperature compensation (opening) (ms):** table to set circuit breaker temperature compensation law, from -50°C to +50°C. Table value is added to calculated mechanical time and linear interpolation is carried out, between each table input.
- **Ambient temperature compensation (closing) (ms):** table to set circuit breaker temperature compensation law, from -50°C to +50°C. Table value is added to calculated mechanical time and linear interpolation is carried out, between each table input.

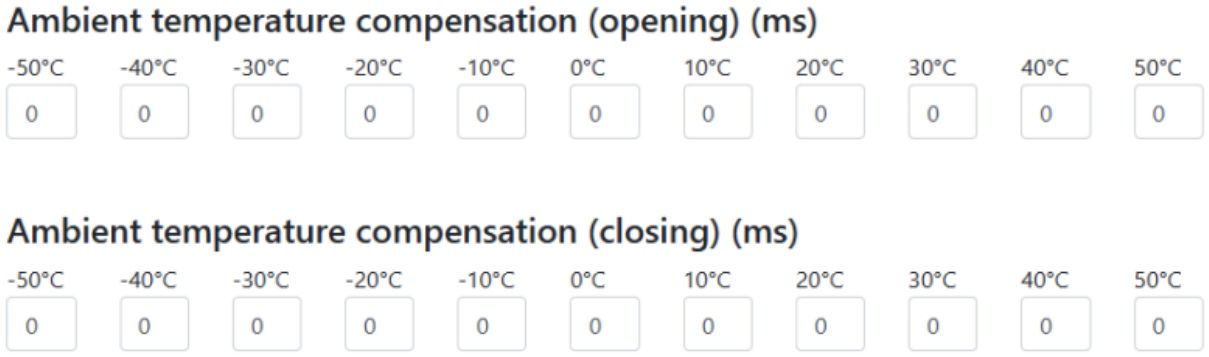


Figure 247 CSD100 HMI access to "Settings\Mechanical\Ambient temperature compensation" section

- **Control voltage compensation (opening) (ms):** table to set circuit breaker control voltage compensation law, from 70% to 110% of set control voltage. Table value is added to calculated mechanical time and linear interpolation is carried out, between each table input.
- **Control voltage compensation (closing) (ms):** table to set circuit breaker control voltage compensation law, from 85% to 110% of set control voltage. Table value is added to calculated mechanical time and linear interpolation is carried out, between each table input.

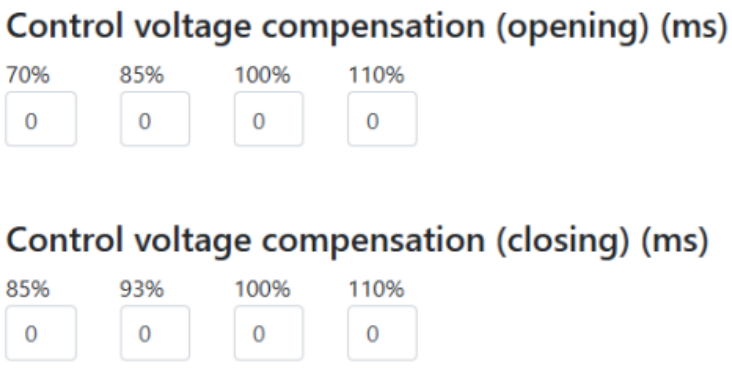


Figure 226 CSD100 HMI access to "Settings\Mechanical\Control voltage compensation" section

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- **Hydraulic pressure compensation (opening) (ms):** table to set circuit breaker hydraulic pressure compensation law, from 50% to 140% of set rated pressure. Table value is added to calculated mechanical time and linear interpolation is carried out, between each table input.
- **Hydraulic pressure compensation (closing) (ms):** table to set circuit breaker hydraulic pressure compensation law, from 50% to 140% of set rated pressure. Table value is added to calculated mechanical time and linear interpolation is carried out, between each table input.

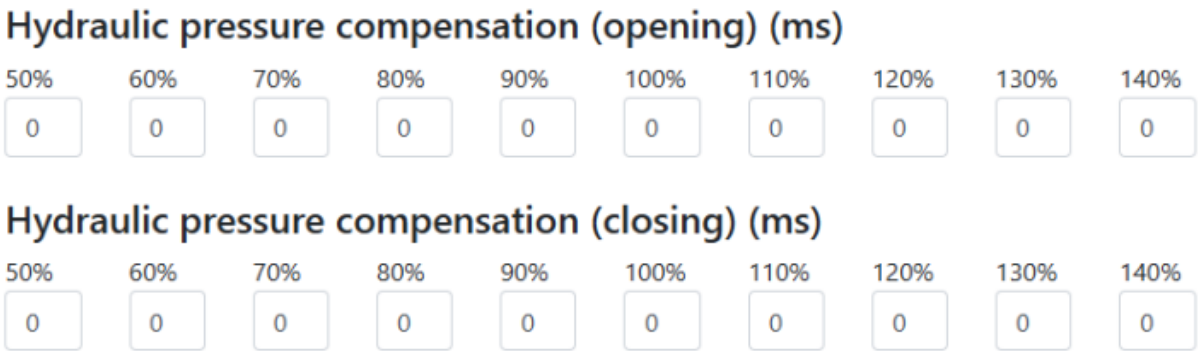


Figure 226 CSD100 HMI access to "Settings\Mechanical\Hydraulic pressure compensation" section

- **Idle time compensation (opening) (ms):** table to set circuit breaker idle time compensation law, from 1h to 168h (and asymptotic value) of elapsed time from last opening. Table value is added to calculated mechanical time and linear interpolation is carried out, between each table input.
- **Idle time compensation (closing) (ms):** table to set circuit breaker idle time compensation law, from 1h to 168h (and asymptotic value) of elapsed time from last closing. Table value is added to calculated mechanical time and linear interpolation is carried out, between each table input.

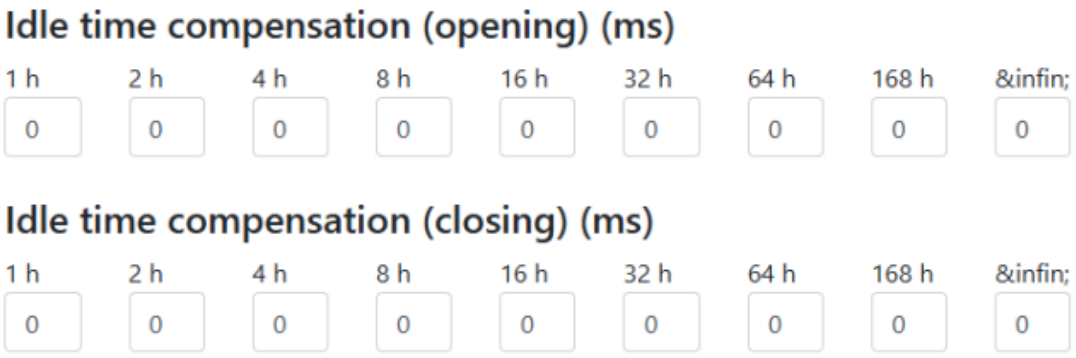


Figure 226 CSD100 HMI access to "Settings\Mechanical\Idle time compensation" section

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- **Adaptive control/open/gain:** gain of the feedback loop (fraction of the error between measured and calculated which is added to the next operation mechanical time forecast). Should not exceed 0.1.
- **Adaptive control/open/Max. (ms):** to clamp adaptive compensation value.
- **Adaptive control/close/gain:** gain of the feedback loop (fraction of the error between measured and calculated which is added to the next operation mechanical time forecast). Should not exceed 0.1.
- **Adaptive control/close/Max. (ms):** value to clamp adaptive compensation value.

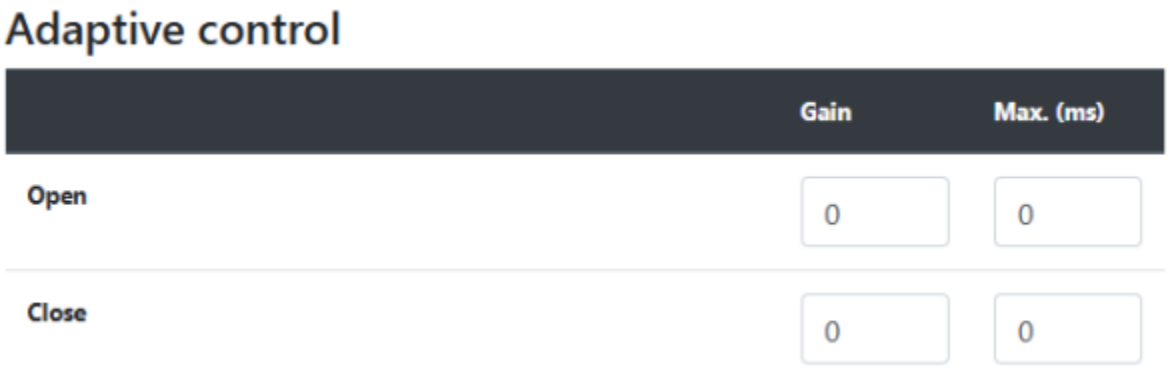


Figure 226 CSD100 HMI access to "Settings\Mechanical\Adaptive control" section

- **Last adaptive value/Main circuit breaker opening (ms):** initial adaptive compensation values, to set or reset compensation. Usually zero (reset).
- **Last adaptive value/Main circuit breaker closing (ms):** initial adaptive compensation values, to set or reset compensation. Usually zero (reset).

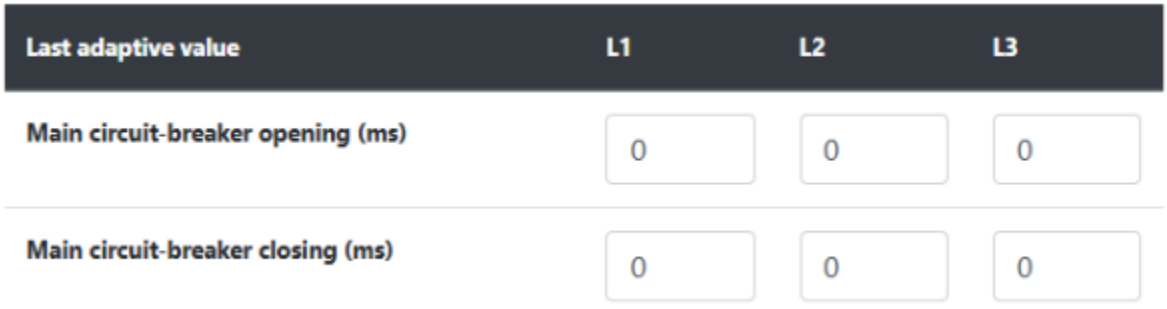


Figure 226 CSD100 HMI access to "Settings\Mechanical\Adaptive control" section

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- **Last measured value/Main circuit breaker opening (ms):** initial measured mechanical times for adaptive compensation. Usually set to nominal mechanical times.
- **Last measured value/Main circuit breaker closing (ms):** initial measured mechanical times for adaptive compensation. Usually set to nominal mechanical times.

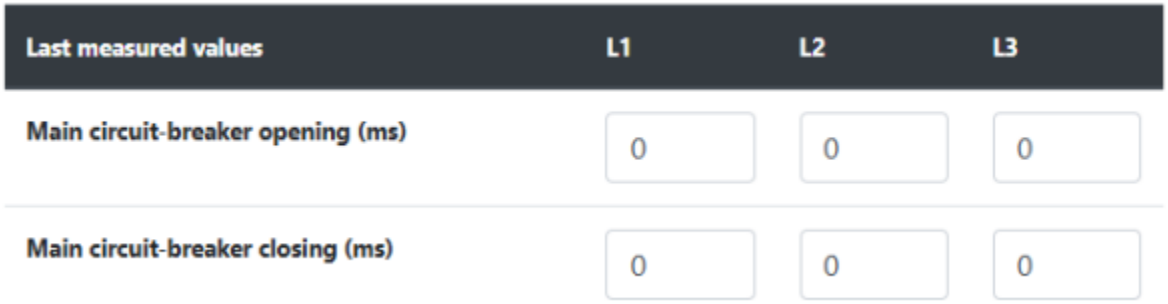


Figure 226 CSD100 HMI access to "Settings\Mechanical\Adaptive control" section

Note: in case last measured values are out of the allowed range, they are discarded for adaptive compensation calculation and replaced by **"Last valid measured values"**

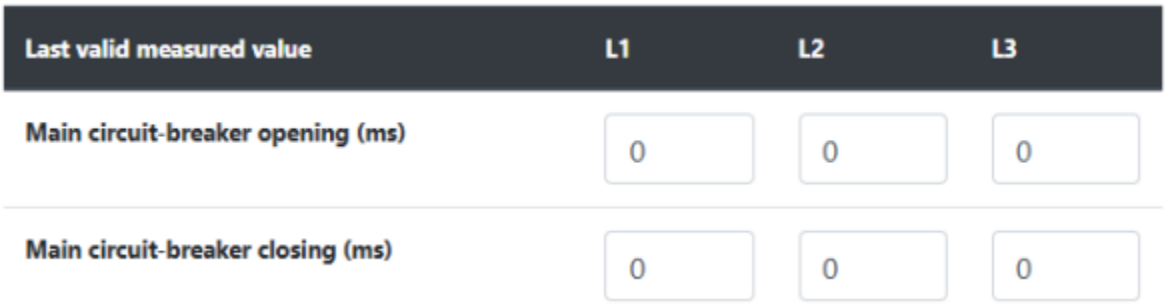


Figure 226 CSD100 HMI access to "Settings\Mechanical\Adaptive control" section

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- **Calculated operating time/Main circuit breaker opening (ms):** initial calculated mechanical times for adaptive compensation. Usually set to nominal mechanical times.
- **Calculated operating time/Main circuit breaker closing (ms):** initial calculated mechanical times for adaptive compensation. Usually set to nominal mechanical times.

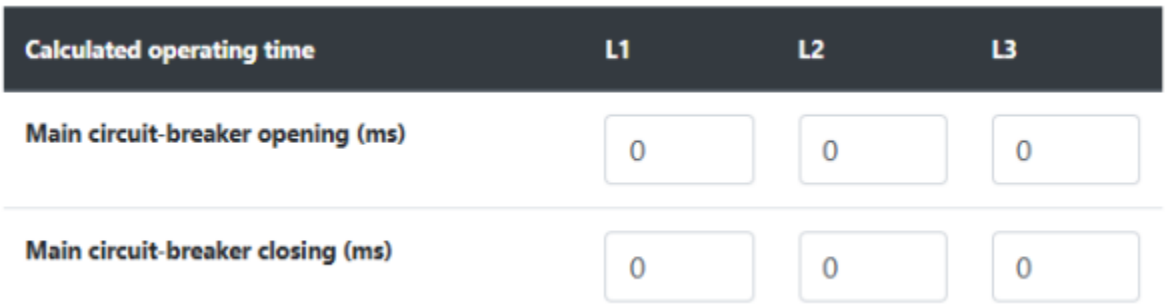


Figure 226 CSD100 HMI access to "Settings\Mechanical\Adaptive control" section

"**Operating date**" subsection provides access to initial values of last operation date (idle time compensation).

- **Main circuit breaker opening:** initial value for last date of opening. Set to current date to reset idle time compensation.
- **Main circuit breaker closing:** initial value for last date of closing. Set to current date to reset idle time compensation.

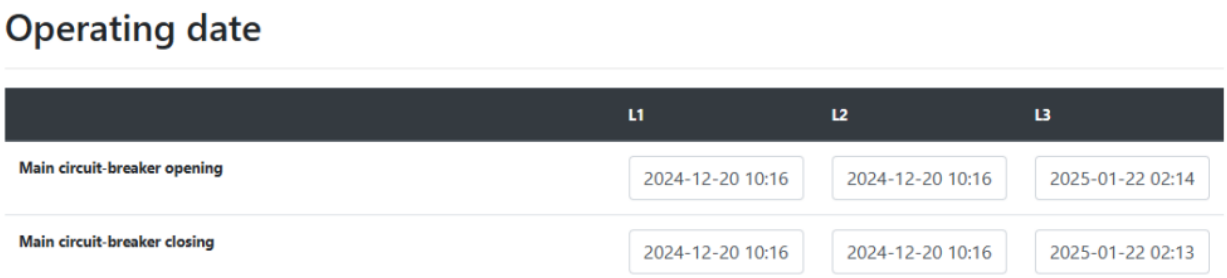


Figure 248 CSD100 HMI access to "Settings\Mechanical\Idle time" section

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"**Electrical wear**" subsection provides access to initial values of electrical abrasion during opening.

- **Last opening electrical wear (kA².s):** initial value for last opening operation.
- **Cumulative electrical wear (kA².s):** initial value for accumulated wear, in case of circuit breaker retrofit or equipment exchange.
- **Maximum cumulative electrical wear (kA².s)**: maximum level before raising an alarm and to compute electrical wear in % (61850 published value).
- **Electrical wear warning (%)**: threshold to issue a first level of alarm, percentage of maximum set value.
- **Electrical wear alarm (%)**: threshold to issue a second level of alarm, percentage of maximum set value.

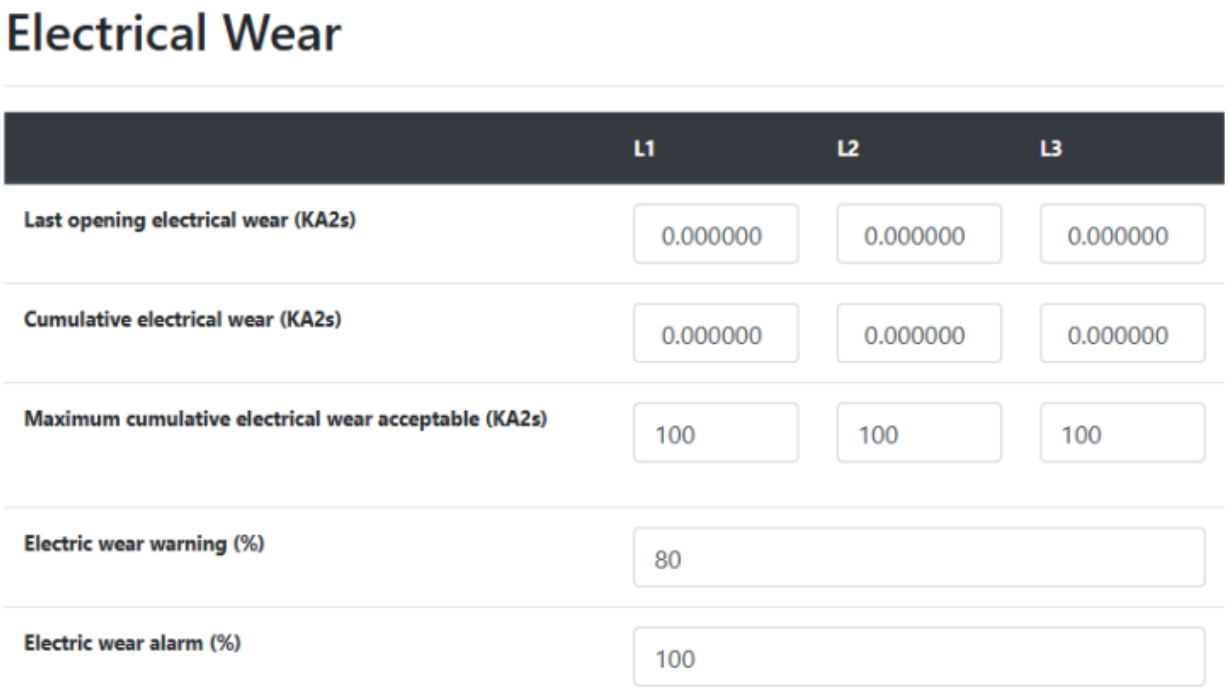


Figure 226 CSD100 HMI access to "Settings\Mechanical\Electric wear" settings section

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"**Counters**" subsection provides access to initial values of counters (set or reset). Thus, these counters may be reset to zero individually, in case of maintenance or pole replacement.

- **Counter controlled closing:** initial value for controlled closing operations counters (preset to actual counter value).
- **Counter uncontrolled closing:** initial value for uncontrolled closing operations counters (preset to actual counter value).
- **Counter controlled opening:** initial value for controlled closing operations counters (preset to actual counter value).
- **Counter uncontrolled opening:** initial value for uncontrolled closing operations counters (preset to actual counter value).
- **Counter reignition controlled operations:** initial value for reignition counters during controlled operations (preset to actual counter value).
- **Counter reignition uncontrolled operations:** initial value for reignition counters during uncontrolled operations (preset to actual counter value).

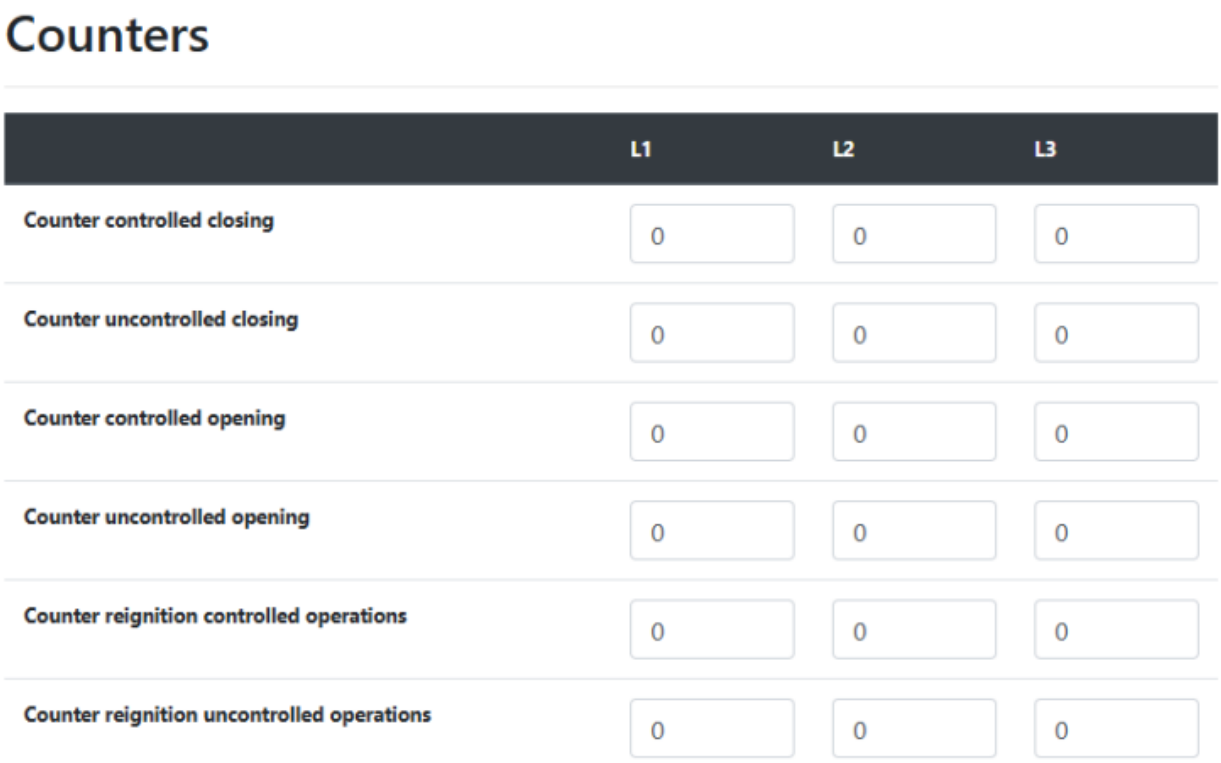


Figure 226 CSD100 HMI access to "Settings\Mechanical\Counters" section

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13.1.6 Settings\Transfo1\Transfo2\Capa1\Capa2\React1\React2\Line\User1\User2\User3\User4

In case strategy is fixed (MLS disabled), settings related to selected strategy only are displayed. If MLS is enabled (dynamic strategy choice), settings related to every selected strategy are displayed.

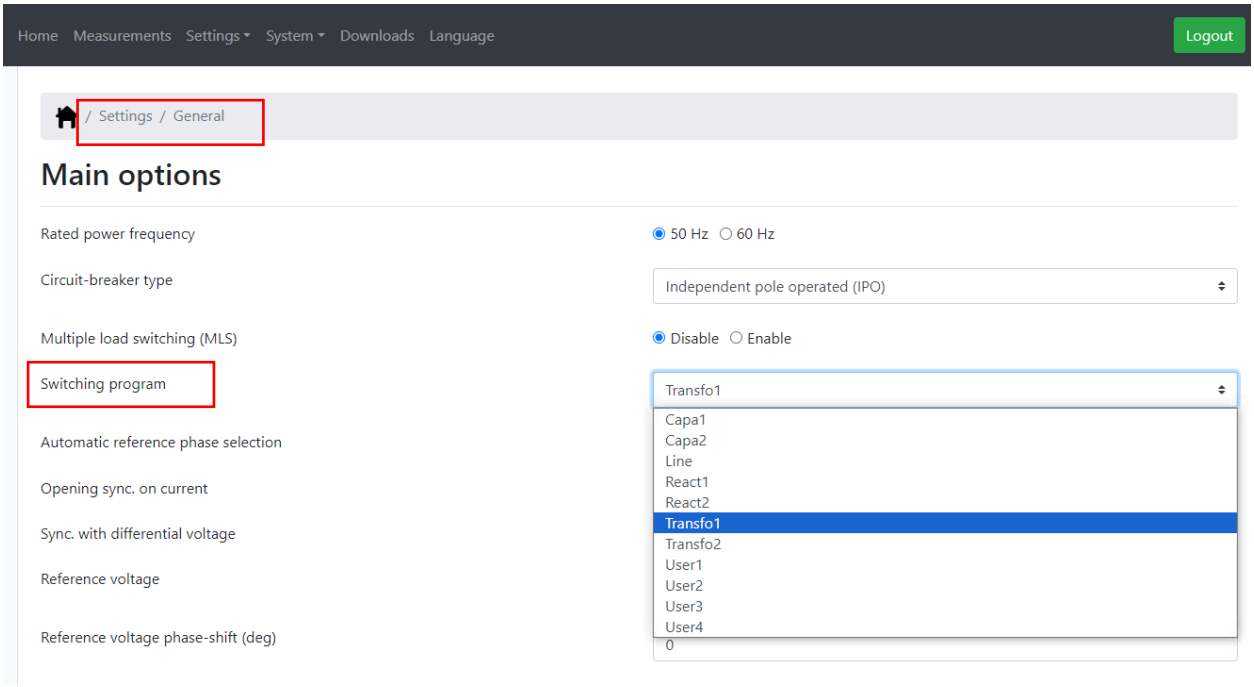


Figure 249 CSD100 HMI "Switching program" setting

These sections are accessible:

- In read only mode to users with VIEWER role
- In write only mode to users with OPERATOR or ENGINEER role

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13.1.7 Settings\React1

"**React1**" is the preset program for grounded neutral shunt reactors.

- **Open/Switching angles voltage (°)**: targets for current interruption, by reference to a positive going reference voltage zero crossing. See 12.7.5.1
- **Open/Switching angles current (°)**: targets for current interruption, by reference to a positive going reference current zero crossing. See 12.7.5.1
- **Open/Arcing times (ms)**: arcing times to use to operate circuit breaker, in case reignition counter is less or equal than 2, between 2 and 5, above 5. See 12.7.5.4
- **Close/Switching angles (°)**: targets for making times, by reference to a positive going reference voltage zero crossing. See 12.7.4.1
- **Close/prearcing times (ms)**: prearcing times for each phase. Shall be adjusted (preset to zero) with a value typically falling between 2ms and 3.5ms (peak voltages). Depends on circuit breaker RDDS, system voltage, circuit breaker mechanical scatter. See 12.7.4.1

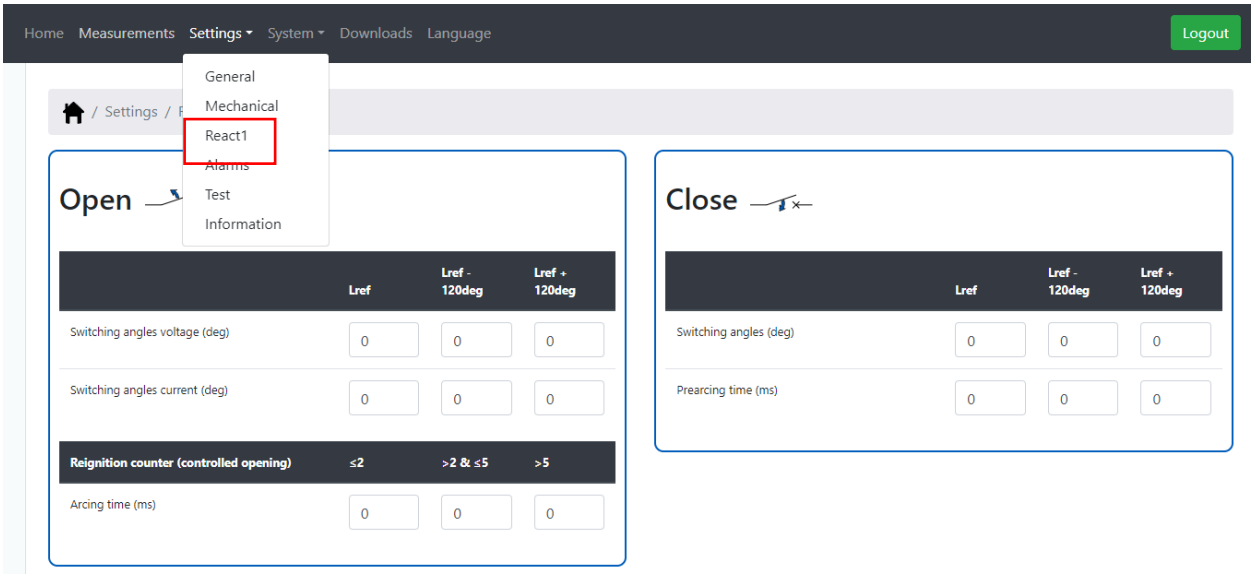


Figure 250 CSD100 HMI "React1" switching program setting

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13.1.8 Settings\React2

“**React2**” is the preset program for isolated neutral shunt reactors. Same settings are provided as “React1”, but preset values correspond to isolated neutral reactor situation.

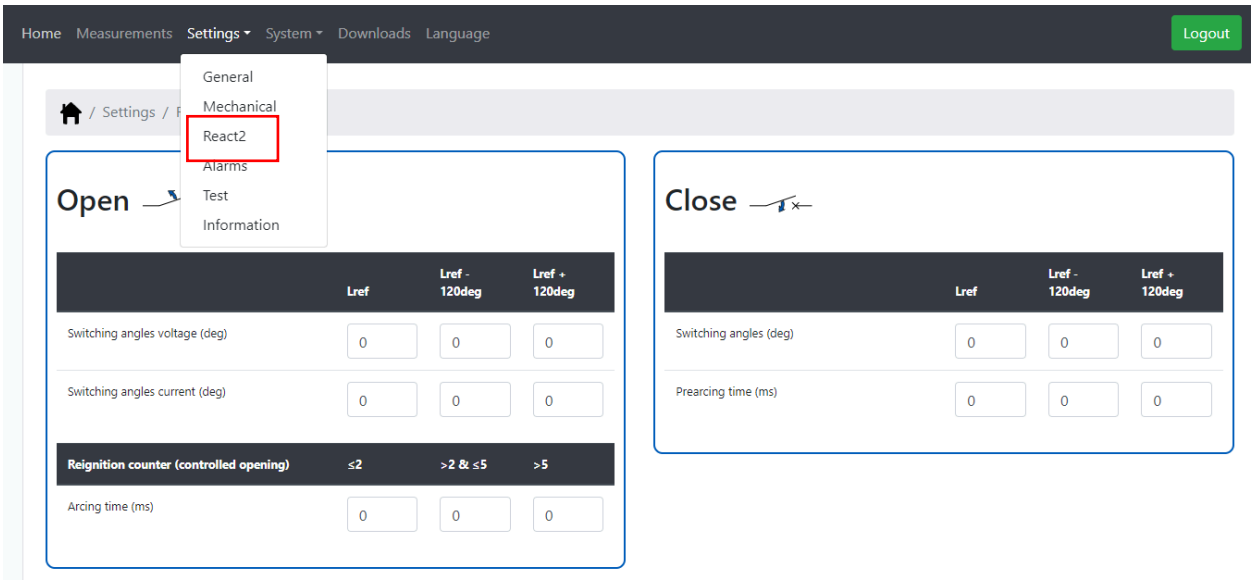


Figure 251 CSD100 HMI “React2” switching program setting

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13.1.9 Settings\Capa1

“**Capa1**” is the preset program for grounded neutral capacitor banks.

- **Open/Switching angles voltage (°)**: targets for current interruption, by reference to a positive going reference voltage zero crossing. See 12.8.5.1
- **Open/Switching angles current (°)**: targets for current interruption, by reference to a positive going reference current zero crossing. See 12.8.5.1
- **Open/Arcing time (ms)**: arcing time to use to operate circuit breaker. See 12.8.5.3
- **Close/Switching angles (t<t1) (°)**: targets for making times, by reference to a positive going reference voltage zero crossing. If elapsed time from previous opening is less than set t1 (trapped charge).
- **Close/prearcing times (t<t1) (ms)**: prearcing times for each phase. Shall be adjusted (preset to zero). Depends on circuit breaker RDDS, system voltage, circuit breaker mechanical scatter.
- **Close/Switching angles (t1<t<t2) (°)**: targets for making times, by reference to a positive going reference voltage zero crossing. If elapsed time from previous opening is between set t1 and t2 (half trapped charge).
- **Close/prearcing times (t1<t<t2) (ms)**: prearcing times for each phase. Shall be adjusted (preset to zero). Depends on circuit breaker RDDS, system voltage, circuit breaker mechanical scatter.
- **Close/Switching angles (t>t2) (°)**: targets for making times, by reference to a positive going reference voltage zero crossing. If elapsed time from previous opening is above set t2 (no trapped charge).
- **Close/prearcing times (t>t2) (ms)**: prearcing times for each phase. Shall be adjusted (preset to zero). Depends on circuit breaker RDDS, system voltage, circuit breaker mechanical scatter.
- **Time threshold t1 (min):** limit of time from previous opening to consider full trapped charge.
- **Time threshold t2 (min):** limit of time from previous opening to consider absence of trapped charge.

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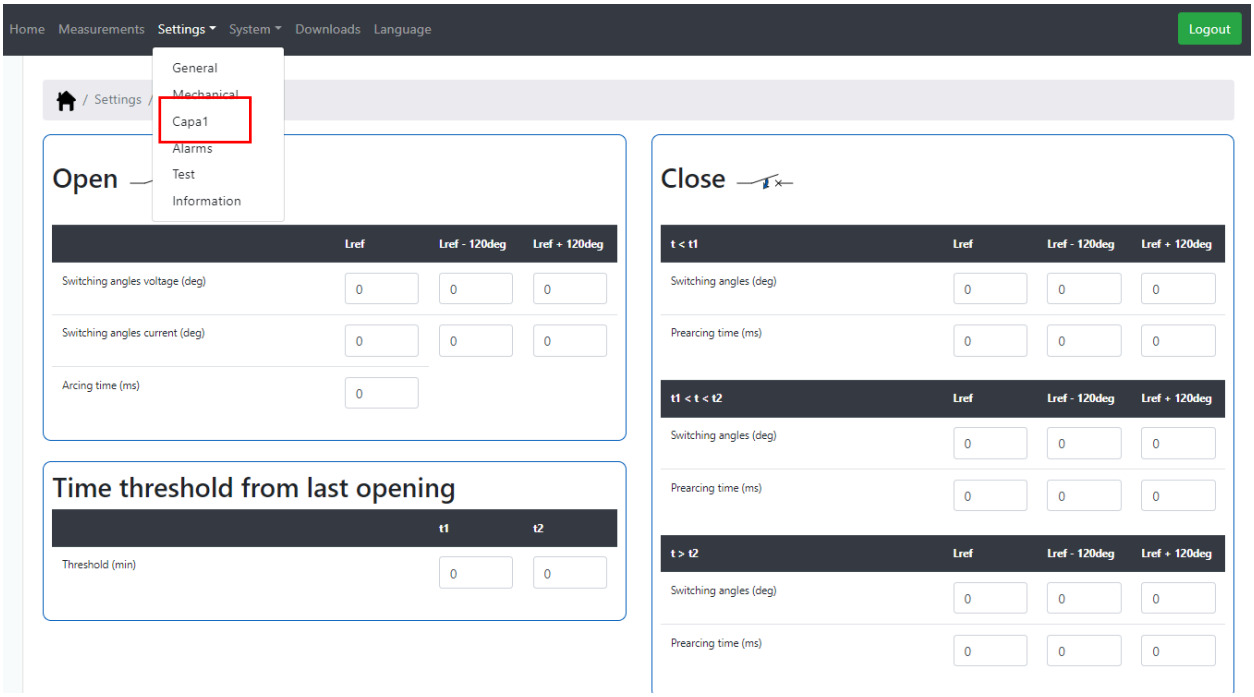


Figure 252 CSD100 HMI "Capa1" switching program setting

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13.1.10 Settings\Capa2

"**Capa2**" is the preset program for isolated neutral capacitor banks. Same settings are provided as "Capa1", but preset values correspond to isolated neutral capacitor bank situation. See 12.8.4.2

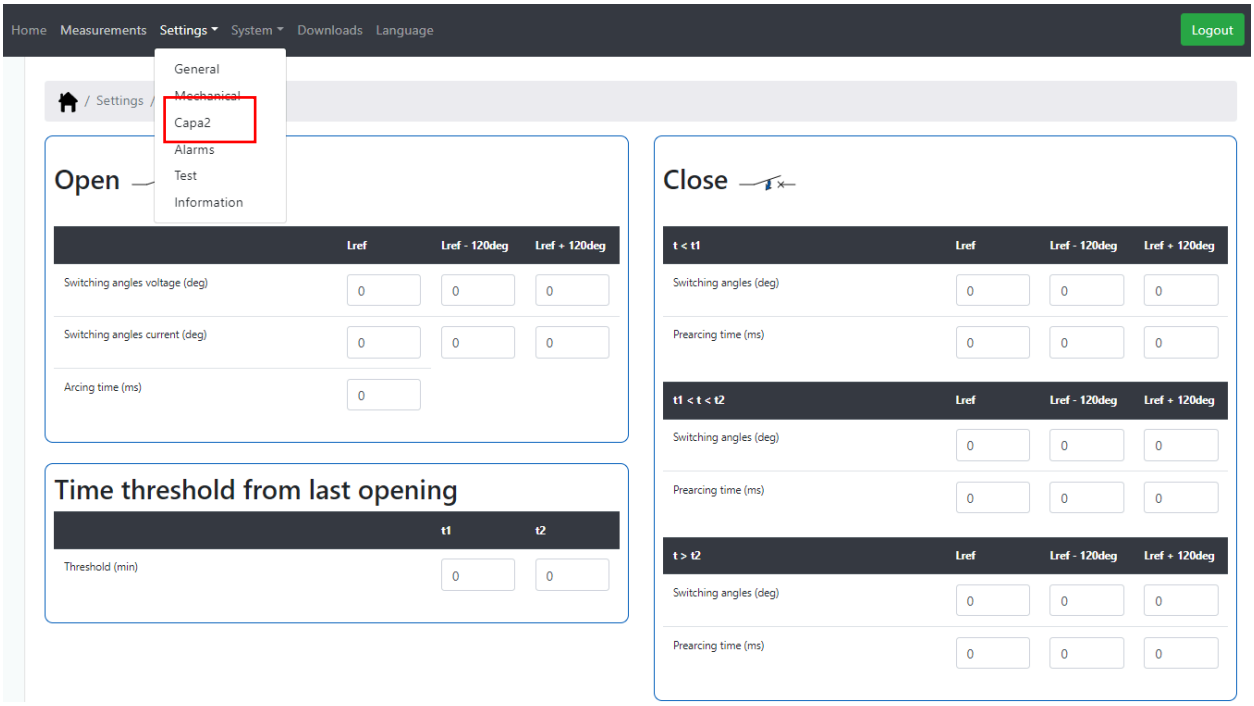


Figure 253 CSD100 HMI "Capa2" switching program setting

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13.1.11 Settings\Transfo1

"**Main options**" subsection provides access to high voltage system related settings.

- **Vector group**: type of transformer, to be chosen within a list of sixteen.
- **Mode**: mode of operation. "Fixed angles" does not consider residual flux to adjust closing targets (assumption of zero residual flux). "Residual flux" considers residual flux (measured from load voltages during previous de-energization) to adjust closing targets. In "Mixed mode" residual flux is considered only if previous de-energization was detected as uncontrolled (trip from protection…). See 12.9.4.1, 0, 12.9.4.4
- **Circuit breaker side**: indicates at which side is located the circuit breaker controlled by CSD100, by reference to selected vector group (uppercase denotes high voltage side).
- **Circuit breaker side neutral position**: either earthed or isolated. If impeding (NGR), select earthed.
- **Magnetic core**: either shared (three phases in a single tank) or individual (bank of single-phase transformers). See 12.9.3.1.
- **Voltage transformer**: IVT (inductive, wire wound), CVT (capacitive) or other. This is to apply a specific residual flux computation algorithm. See 12.9.4.3.1

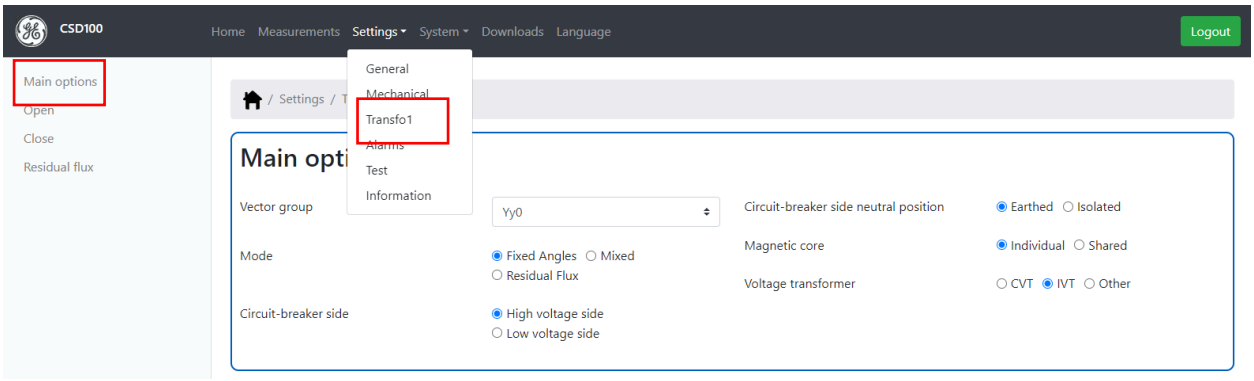


Figure 254 CSD100 HMI "Transfo1" main options setting

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"**Open**" subsection provides access to open targets and arcing times.

- **Switching angles earthed (°)**: targets in earthed neutral situation (neutral position at breaker side), with a "fixed angles" mode.
- **Switching angles isolated (°)**: targets in isolated neutral situation (neutral position at breaker side), with a "fixed angles" mode.
- **Arcing time loaded (ms):** arcing time to program if transformer is detected as loaded
- **Arcing time unloaded (ms):** arcing time to program if transformer is detected as unloaded (standard situation). Typical value below 1ms (0.1ms).
- **Threshold (A):** measured current limit value above which transformer is considered as loaded.

"**Close**" subsection provides access to close targets and prearcing times (fixed targets strategy).

- **Star Neutral connected (°)**: targets in earthed neutral situation (neutral position at breaker side), with a "fixed angles" mode. See 12.9.4.2.3
- **Star Neutral isolated or Delta (°)**: targets in isolated neutral situation (neutral position at breaker side), with a "fixed angles" mode. Either star isolated or delta. See 12.9.4.2.3
- **Yy independent core (°):** targets in phase-to-phase independence situation (bank of single-phase transformers without any delta winding). See 12.9.4.2.3
- **Prearcing times (ms):** prearcing times for each phase. Shall be adjusted (preset to zero). Depends on circuit breaker RDDS, system voltage, circuit breaker mechanical scatter. See 12.5.8.5 and 12.5.8.9

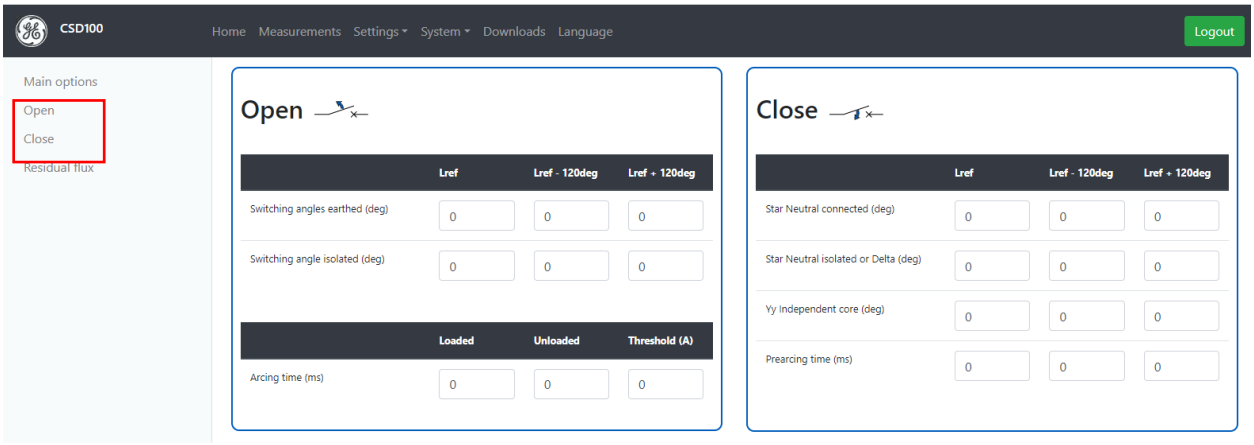


Figure 255 CSD100 HMI "Transfo1" switching program setting

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"**Residual flux**" subsection provides access to residual flux computation options.

- **Measurement side:** indicates at which side of the transformer is located the VTs dedicated to load voltage measurements, by reference to selected vector group (uppercase denotes high voltage side). See 12.9.5.1
- **Measurement side neutral position:** either earthed or isolated. If impeding (NGR, NER), select isolated (neutral point will be recalculated).
- **RDDS (kV/ms):** circuit breaker intrinsic characteristic of Rate of Decrease of Dielectric Strength. Typical value ranges from 50 to 300kV/ms (from lower to higher system voltages). A RDDS of 1 pu is the slope of the phase-to earth system voltage at zero crossing. See 12.5.8.3
- **Derating factor:** RDDS derating factor for last phase(s) to close. Preset to 1. Aim is to adjust prearcing times independently for last phases to close, during live tests.
- **Closing time scatter (ms):** mechanical scatter of the circuit breaker for closing operations (3xsigma)
- **Delay last phase:** (no/yes) To delay the last phase to close by additional 90°
- **Dead half period:** insertion of half periods between phases targets (larger sequence). See 12.9.4.2.3 and 12.9.4.3.4
- **Residual flux (pu):** value reminding last measured residual flux. Editable to set or reset initial value (for usual operations, do not change). See 12.9.4.3.1
- **Switching angles Min. (°):** These values indicate calculated limit angles for switching, near voltage zero crossing (due to RDDS and mechanical scatter) in the different transformer coupling situations. Do not edit or change. See 12.9.4.3.5
- **Switching angles Max. (°):** These values indicate calculated limit angles for switching, near voltage peak (due to RDDS and mechanical scatter) in the different transformer coupling situations. Do not edit or change. See 12.9.4.3.5

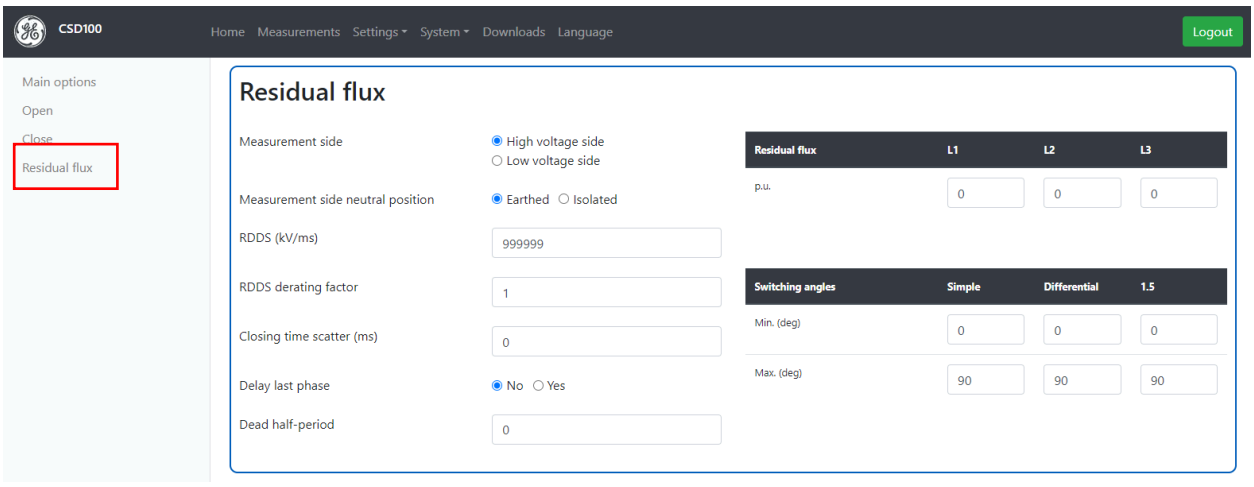


Figure 256 CSD100 HMI "Transfo1" residual flux option setting

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13.1.12 Settings\Transfo2

Same settings are provided as “Transfo1”, with same preset values. Thus, Transfo2 program interest is to be associated with Multiple Load Switching.

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13.1.13 Settings\Line

"**Open**" subsection provides access to opening targets and arcing time settings. See 12.10.7

- **Switching angles voltage (°)**: targets for current interruption, by reference to a positive going reference voltage zero crossing.
- **Switching angles current (°)**: targets for current interruption, by reference to a positive going reference current zero crossing.
- **Arcing time (ms)**: arcing time to use to operate circuit breaker.

"**Close**" subsection provides access to close targets and pre-arcing time settings. These settings are used in the case of line energization (line pick-up). See 12.10.5

- **Switching angles (°)**: targets for making times, by reference to a positive going reference voltage zero crossing. Preset values give priority to overvoltage mitigation (zero of source voltage). In case of highly compensated line, may be changed to peak voltage, if priority to be given to current zero missing concern.
- **Prearcing time (ms)**: targets for current interruption, by reference to a positive going reference current zero crossing.

"**Reclose**" subsection provides access to reclose settings. These settings are used in the case of line auto reclose. In that case, strategy and targets computed automatically in real time. See 12.10.6

- **Computation delay (t1) (ms)**: this parameter adds an additional delay from the instant of close order occurrence. Usually set to zero. See 12.10.6.2. Limited to 30ms max.
- **Reclosing order timeout (t2) (ms)**: this is the time limit (timeout) for close order occurrence (measured from last circuit breaker opening instant) after which close order will be processed as simple energization. If close order occurs before elapsed time reach t2, close order will be processed as a reclosing operation. See 12.10.6.2. Limited to positive values.
- **Start of reclosing window (t3) (ms)**: beginning of target reclose window (measured from last circuit breaker opening instant). See 12.10.6.2. Limited to positive values
- **End of reclosing window (t4) (ms)**: end of target reclose window (measured from last circuit breaker opening instant). See 12.10.6.2. Must be larger than t2+400ms AND larger than t3+400ms.
- **Prearcing time – Reclose min. beat strategy (ms)**: prearcing time for beat minimum strategy, applicable to the three phases. Depends on circuit breaker RDDS, system voltage, circuit breaker mechanical scatter. Usual value is low (<<1ms), especially for high line compensation rates.
- **Prearcing time – Reclose zero source strategy (ms)**: prearcing time for zero of source voltage strategy, applicable to the three phases. Depends on circuit breaker RDDS, system voltage, circuit breaker mechanical scatter. Usual values are same as "Capa1" program when no trapped charge is considered. See 12.5.8.4

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- **Prearcing time – Reclose Min./Max. strategy (ms)**: prearcing time for minimum or maximum of source voltage strategy, applicable to the three phases. Depends on circuit breaker RDDS, system voltage, circuit breaker mechanical scatter. Usual value is low (<1ms). See 12.5.8.7.1
- **Load voltage detection level (%):** the percentage of nominal rms load voltage above which an oscillation is considered as significant during load side analysis. Preset to 20%, applicable to most cases.
- **Minimum beat frequency (Hz):** The minimum oscillating (low compensation rate) frequency to consider during load side analysis. Preset to 20Hz, applicable to most cases. See 12.10.3.1
- **Overcurrent threshold (%):** The current increase (due to line fault) (by reference to measured pre fault value) to consider that a phase is faulty. Preset to 12%, applicable to most cases.
- **Voltage transformer type:** type of VTs installed at line side. Influences the strategy choice since inductive voltage transformers can discharge non compensated line trapped charge (thus, min/max strategy is not applicable if IVT is present).

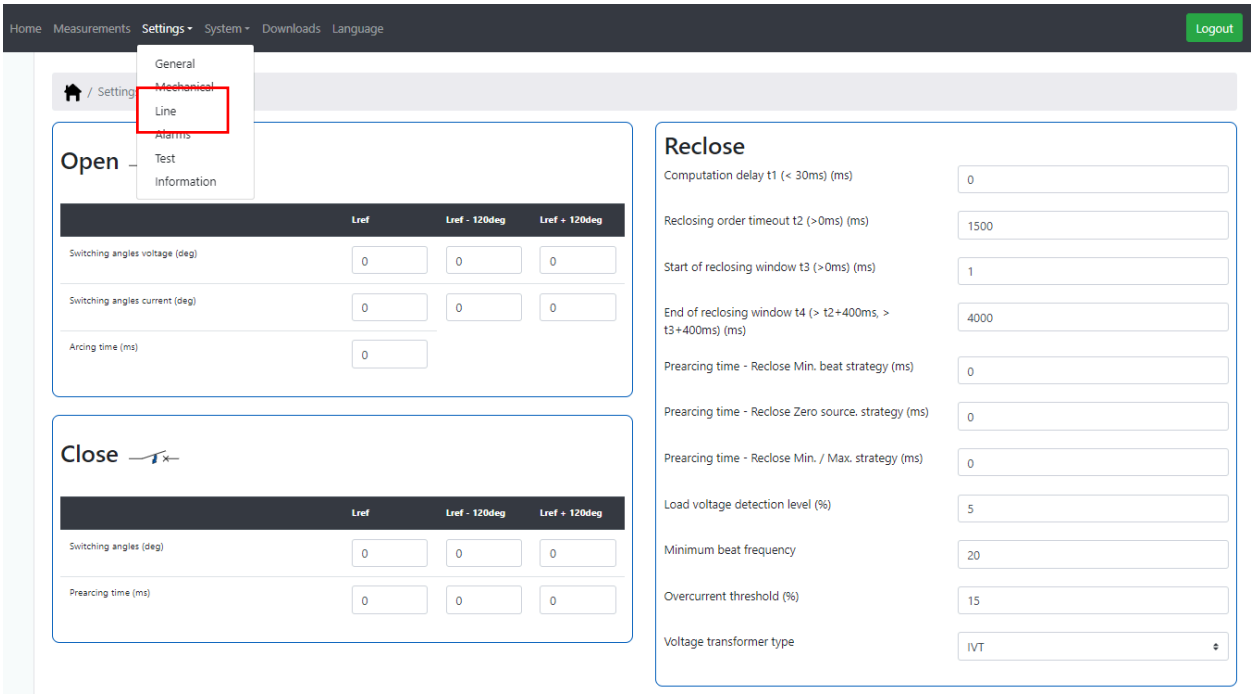


Figure 257 CSD100 HMI "Line" switching program setting

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13.1.14 Settings\User1 (User2, User3, User4)

“User1”, “User2”, “User3”, “User4” are user defined programs, with each value preset to zero.

- **Open/Switching angles voltage (°)**: targets for current interruption, by reference to a positive going reference voltage zero crossing.
- **Open/Switching angles current (°)**: targets for current interruption, by reference to a positive going reference current zero crossing.
- **Open/Arcing time (ms)**: arcing time to use to operate circuit breaker. Applicable to the three phases.
- **Close/Switching angles (°)**: targets for making times, by reference to a positive going reference voltage zero crossing.
- **Close/prearcing times (ms)**: prearcing times for each phase. Depends on circuit breaker RDDS, system voltage, circuit breaker mechanical scatter.

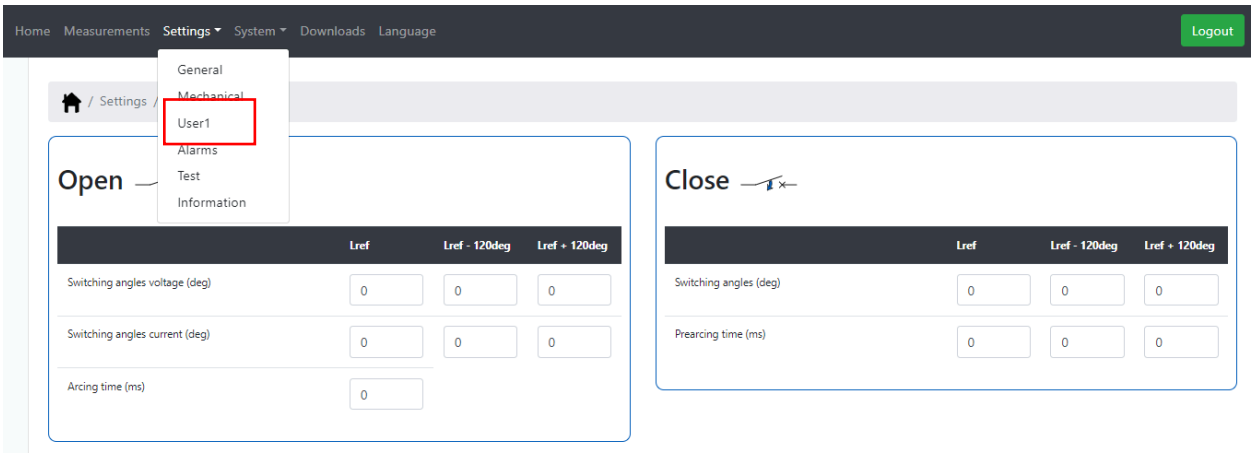


Figure 258 CSD100 HMI “User1” switching program setting

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13.1.15 Settings\Alarms

This section is accessible:

- In read only mode to users with VIEWER role
- In write only mode to users with OPERATOR or ENGINEER role

This section allows user to:

- Set alarm thresholds (min and/or max) on measured values (continuous or post operation).
- Assign alarms to physical outputs (LED, bistable relays 1 & 2, monostable relay). Bistable relays (latching relays) are typically used to report alarms while monostable relay is typically used to activate bypass external circuitry. Assigning multiple alarms to a single relay results in a logical “or” of those alarms.
- Activate archive creation upon alarm occurrence (caution: multiple records file creation and record system saturation may occur, in case of recurrent alarms).

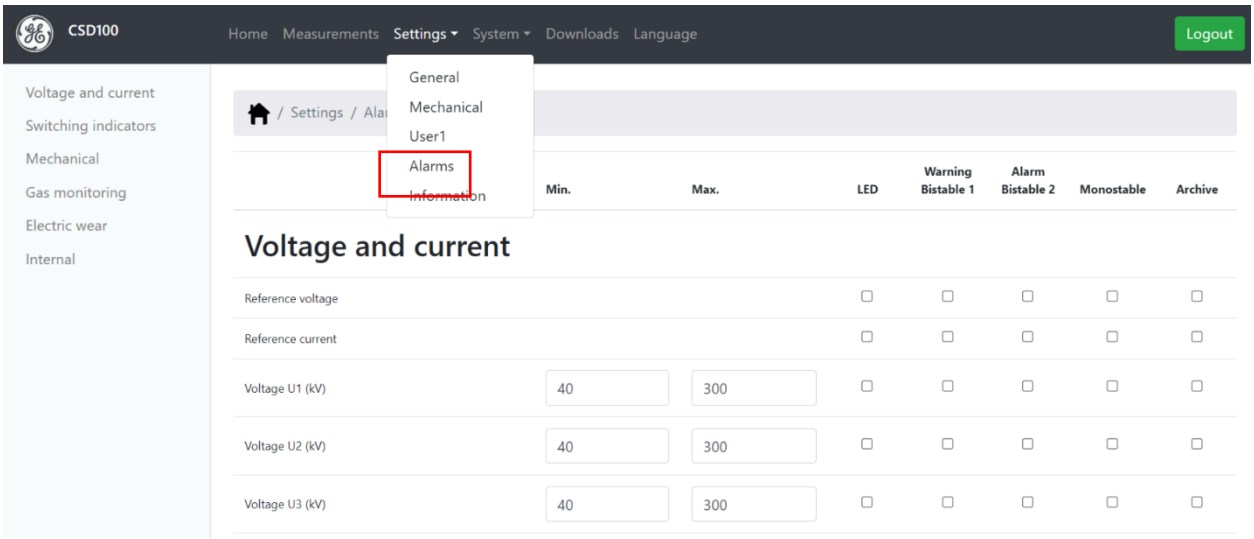


Figure 259 CSD100 HMI “alarms settings” page

Alarms update events: two types of alarms must be distinguished:

- Alarms updated permanently in steady state (absence of reference waveform for synchronization…): those alarms are not resettable and are set or reset upon alarm cause occurrence or extinction.
- Alarms updated after an operation (operation monitoring, performance indicators…): those alarms are latched after operation analysis and can be manually reset (HMI or dedicated digital input).

Some alarms are blocking, e.g. lock controlled switching application. These alarms are typically to be affected to the bypass relay.

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Table 80 Settings/alarms HMI section

Name	Description	Blocking (->byp.)	Updated	Preset min. thresh.	Preset max. thresh.
Voltage and current					
Reference voltage	Absence of reference voltage for synchronization	Yes	Cont.	-	-
Reference current	Absence of reference current for synchronization	Yes	Cont.	-	-
Voltage U1 (kV)	Source voltage L1 (dual switching dependent, physical input “UAC1” is dual switching OFF)	No	Cont.	40	300
Voltage U2 (kV)	Source voltage L2 (dual switching dependent, physical input “UAC2” is dual switching OFF)	No	Cont.	40	300
Voltage U3 (kV)	Source voltage L3 (dual switching dependent, physical input “UAC3” is dual switching OFF)	No	Cont.	40	300
Voltage U4 (kV)	Load voltage L1 (dual switching dependent, physical input “UAC4” is dual switching OFF)	No	Cont.	40	300
Voltage U5 (kV)	Load voltage L2 (dual switching dependent, physical input “UAC5” is dual switching OFF)	No	Cont.	40	300
Voltage U6 (kV)	Load voltage L3 (dual switching dependent, physical input “UAC6” is dual switching OFF)	No	Cont.	40	300
Current 1 (kV)	Circuit break. current L1 (physical input “IAC1”)	No	Cont.	100	2000
Current 2 (kV)	Circuit break. current L2 (physical input “IAC2”)	No	Cont.	100	2000
Current 3 (kV)	Circuit break. current L3 (physical input “IAC3”)	No	Cont.	100	2000
Opening ref. frequency 1 (Hz)	Reference frequency from phase L1 for opening operations	No	Cont.	47	63
Opening ref. frequency 2 (Hz)	Reference frequency from phase L2 for opening operations	No	Cont.	47	63
Opening ref. frequency 3 (Hz)	Reference frequency from phase L3 for opening operations	No	Cont.	47	63
Closing ref. frequency 1 (Hz)	Reference frequency from phase L1 for closing operations	No	Cont.	47	63
Closing ref. frequency 2 (Hz)	Reference frequency from phase L2 for closing operations	No	Cont.	47	63
Closing ref. frequency 3 (Hz)	Reference frequency from phase L3 for closing operations	No	Cont.	47	63
UDC1 (V)	Coil control polarity 1	No	Cont.	40	280
UDC2 (V)	Coil control polarity 2	No	Cont.	40	280
Switching indicators					
Making time (ms)	Error between final (electrical) target and measured making time (close)	No	Op.	-	2

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Name	Description	Blocking (->byp.)	Updated	Preset min. thresh.	Preset max. thresh.
Reignition last opening	Reignition detected during last opening	No	Op.	-	-
Reignition rate	Alarm is set if 2 reignitions are detected during last N operations (N is settable)	No	Op.	-	10
Reignition max cumulated	Limit for total number of reignitions	No	Op.	-	20
Arcing time	Alarm is set if measured arcing time is above one period.	No	Op.	-	-
Peak current (A)	Limit for peak inrush current (close)	No	Op.	-	10000
Voltage dip phase-earth (%)	Limit for source voltage dip (close)	No	Op.	%	10
Voltage dip phase-phase (%)	Limit for source voltage dip (close)	No	Op.	%	10
Mechanical					
Ambient temperature (°C)	External probe (analogue sensor)	No	Cont.	-50	55
Circuit breaker 1 stroke (mm)	Circuit breaker L1 chamber position (travel curve sensor) limits	No	Cont.	0	200
Circuit breaker 2 stroke (mm)	Circuit breaker L2 chamber position (travel curve sensor) limits	No	Cont.	0	200
Circuit breaker 3 stroke (mm)	Circuit breaker L3 chamber position (travel curve sensor) limits	No	Cont.	0	200
Opening time tolerance (ms)	Maximum difference between calculated mechanical time and measured mechanical time	No	Op.	-	2
Opening time (ms)	Boundaries for measured mechanical time	No	Op.	0	200
Opening timeout (ms)	Limit for 52a switching	No	Op.	-	2000
Closing time tolerance (ms)	Maximum difference between calculated mechanical time and measured mechanical time	No	Op.	-	2
Closing time (ms)	Boundaries for measured mechanical time	No	Op.	0	200
Closing timeout (ms)	Limit for 52a switching	No	Op.	-	2000
Hydraulic pressure					
Gas monitoring					
Pressure CB1 L1 (bar)	Gas pressure (20°C eq.) above set threshold. 1st, L1	No	Cont.		
Pressure CB1 L2 (bar)	Gas pressure (20°C eq.) above set threshold. 1st, L2	NO	Cont.		
Pressure CB1 L3 (bar)	Gas pressure (20°C eq.) above set threshold. 1st, L3	No	Cont.		
Pressure CB2 L1 (bar)	Gas pressure (20°C eq.) above set threshold. 2nd, L1	No	Cont.		

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Name	Description	Blocking (->byp.)	Updated	Preset min. thresh.	Preset max. thresh.
Pressure CB2 L2 (bar)	Gas pressure (20°C eq.) above set threshold. 2nd, L2	No	Cont.		
Pressure CB2 L3 (bar)	Gas pressure (20°C eq.) above set threshold. 2nd, L3	No	Cont.		
Electric wear					
Electrical wear warning	Cumulated electrical wear above first threshold	No	Op.		
Electrical wear alarm	Cumulated electrical wear above second threshold	No	Op.		
Internal					
Internal temperature (°C)	Internal probe	No	Cont.	-	85
Low data storage (%)	Remaining storage area for records threshold	No	Cont.	20	-
Power outputs	Internal self-monitoring of coils activation circuitry	Yes	Cont.	-	-
ADC alarms	Self-monitoring (OR) of analogue inputs.	Yes/No	Cont.	-	-
Date not reliable	Out of date	No	Cont.	-	-
Sampled values alarm	Loss of samples, excess of samples, quality different from GOOD, smpSynch lower than set value	No	Cont.	-	-
IEC 61850 MMS server failure	CSD100 server failure	No	Cont.	-	-

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13.1.16 Settings\Commissioning mode

As soon as DI15 is activated, see Figure 19 , (this is a safety precaution, commissioning mode cannot be activated remotely), this section is available to users with OPERATOR or ENGINEER role.

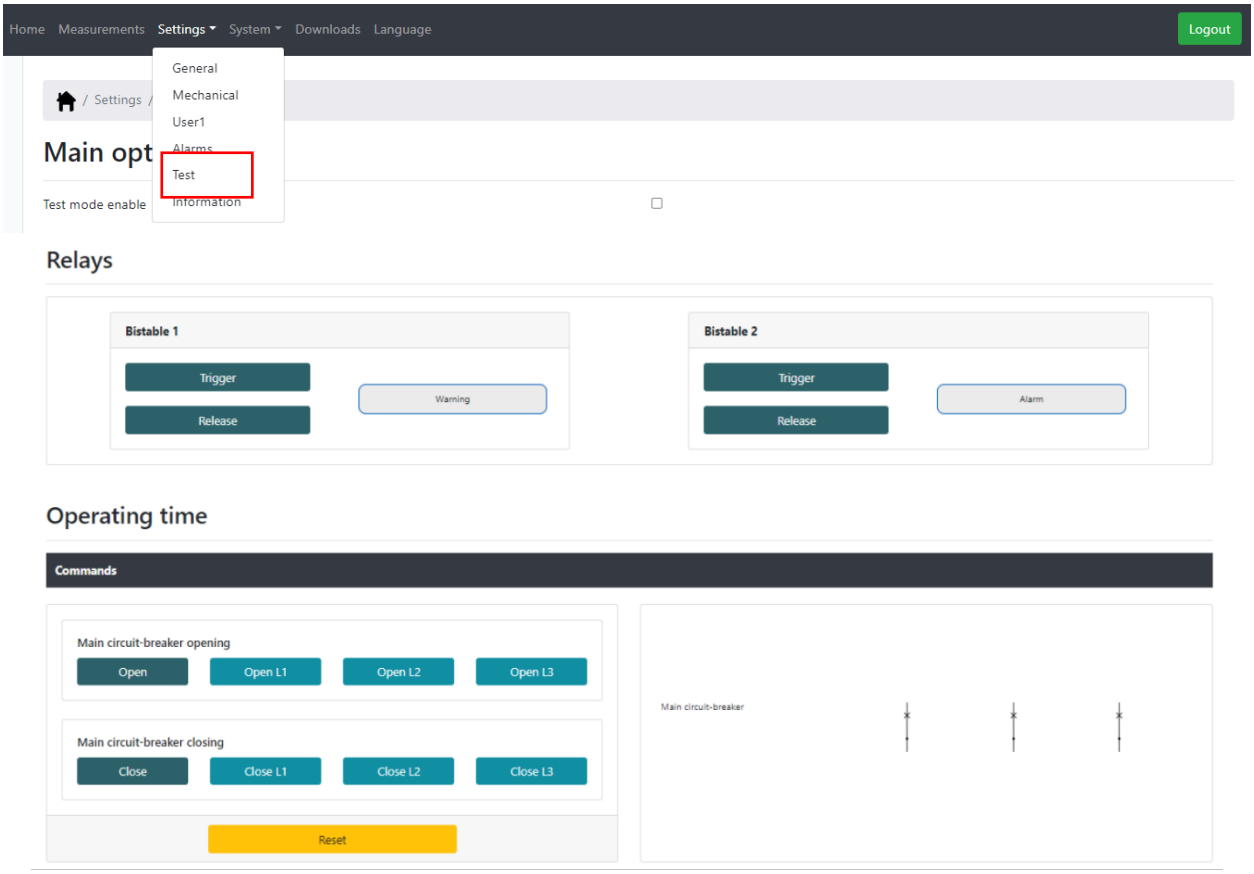


Figure 260 CSD100 HMI "Commissioning mode" page

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Commissioning mode allows to:

- Operate the breaker directly from the HMI:
  - Single phase operations allow to check that there is no mismatch in cabling of coils and auxiliary contacts, which is mandatory at the beginning of dry tests.
  - Three-phase operations allow to measure timings. The three phases are operated with the exact sequence currently selected from strategy (transfo1, capa1…).
- Measure and display timings (including average of a batch of operations), both from auxiliary contacts and main contacts (if connection of main contacts to the CSD100 digital inputs is allowed).
- Operate the alarm bistable relays (activate and release), for test purposes.
- Check for the three travel curve sensors raw information (mA), and propagate the measurements to the settings located in section “Settings\mechanical”, while CB is in stable close and open positions.

Prior to this, commissioning mode shall be enabled with a dedicated control and timing display shall be choose between ms and µs.

See section 15 for practical procedure.

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13.1.17 Settings\Information

This section allows user to:

- Remind (read only) key information about CSD100.
- Assign personalized names to the project and installation (COMTRADE archives file names)
- Assign personalized names to signals and channels (COMTRADE archives signals and traces).

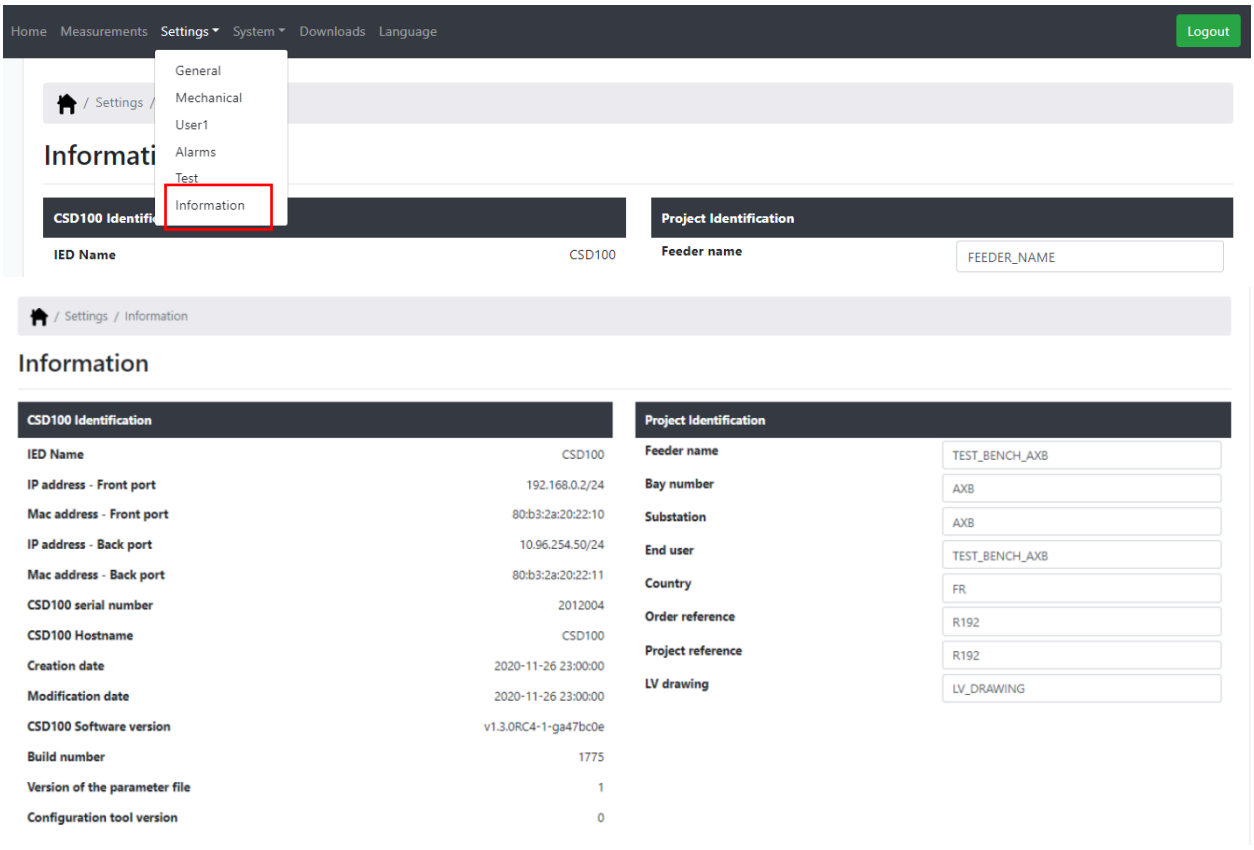


Figure 261 CSD100 HMI « Information settings » page

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Table 81 Settings/Information HMI section

Name	Preset	Usage
Project identification		
Feeder name	FEEDER_NAME	Informative
Bay number	BAY_NUMBER	Informative
Substation	SUBSTATION	Comtrade file name
End user	END_USER	Comtrade file name
Country	COUNTRY	Informative
Order reference	ORDER_REFERENCE	Informative
Project reference	PROJECT_REFERENCE	Informative
LV drawing	LV_DRAWING	Informative
Sensors identification		
Name of the Low level input 1	Ambient temperature sensor	
Name of the Low level input 2	CB travel sensor	
Name of the Low level input 3	CB travel sensor	
Name of the Low level input 4	CB travel sensor	
Name of the gas mon. sensor 1	GAS_PRESSURE_CB1 phase 1	
Name of the gas mon. sensor 2	GAS_PRESSURE_CB1 phase 2	
Name of the gas mon. sensor 3	GAS_PRESSURE_CB1 phase 3	
Name of the gas mon. sensor 4	GAS_PRESSURE_CB2 phase 1	
Name of the gas mon. sensor 5	GAS_PRESSURE_CB2 phase 2	
Name of the gas mon. sensor 6	GAS_PRESSURE_CB2 phase 3	
Name of the gas mon. sensor 7	HYDRAULIC_PRESSURE_CB1 phase 1	
Name of the gas mon. sensor 8	HYDRAULIC_PRESSURE_CB1 phase 2	
Name of the gas mon. sensor 9	HYDRAULIC_PRESSURE_CB1 phase 3	
Name of the gas mon. sensor 10	HYDRAULIC_PRESSURE_CB2 phase 1	
Name of the gas mon. sensor 11	HYDRAULIC_PRESSURE_CB2 phase 2	
Name of the gas mon. sensor 12	HYDRAULIC_PRESSURE_CB2 phase 3	
Network identification		
System frequency	0.000000	informative
Voltage level	0.000000	Informative
Name of the Phase 1	L1	Comtrade signal
Name of the Phase 2	L2	Comtrade signal
Name of the Phase 3	L3	Comtrade signal
Name of the IAC1 (CT name)	IAC1	Comtrade signal
Name of the IAC2	IAC2	Comtrade signal
Name of the IAC3	IAC3	Comtrade signal
Name of the UAC1	UAC1	Comtrade signal
Name of the UAC2	UAC2	Comtrade signal
Name of the UAC3	UAC3	Comtrade signal
Name of the UAC4	UAC4	Comtrade signal
Name of the UAC5	UAC5	Comtrade signal
Name of the UAC6	UAC6	Comtrade signal
Binary inputs		Comtrade signal
Name of the digital input 1	Open input order	Comtrade signal
Name of the digital input 2	Close input order	Comtrade signal
Name of the digital input 3	CB1_52a	Comtrade signal
Name of the digital input 4	CB1_52a	Comtrade signal
Name of the digital input 5	CB1_52a	Comtrade signal
Name of the digital input 6	CB2_52a	Comtrade signal
Name of the digital input 7	CB2_52a	Comtrade signal
Name of the digital input 8	CB2_52a	Comtrade signal
Name of the digital input 9	Record trigger	Comtrade signal
Name of the digital input 10	MLS_1	Comtrade signal
Name of the digital input 11	MLS_2	Comtrade signal
Name of the digital input 12	MLS_3	Comtrade signal
Name of the digital input 13	MLS_4	Comtrade signal
Name of the digital input 14	Bypass_Key	Comtrade signal
Name of the digital input 15	Test_Mode	Comtrade signal

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Name	Preset	Usage
Name of the digital input 16	Alarm reset	Comtrade signal
Binary outputs		
Name of the UVLO 1	UVLO_1	Comtrade signal
Name of the UVLO 1	UVLO_1	Comtrade signal
Name of the UVLO 1	UVLO_1	Comtrade signal
Name of the UVLO 1	UVLO_1	Comtrade signal
Name of the UVLO 1	UVLO_1	Comtrade signal
Name of the UVLO 1	UVLO_1	Comtrade signal
Name of the command IGBT 1	IGBT_CMD_1	Comtrade signal
Name of the command IGBT 2	IGBT_CMD_2	Comtrade signal
Name of the command IGBT 3	IGBT_CMD_3	Comtrade signal
Name of the command IGBT 4	IGBT_CMD_4	Comtrade signal
Name of the command IGBT 5	IGBT_CMD_5	Comtrade signal
Name of the command IGBT 6	IGBT_CMD_6	Comtrade signal
Name of the make target 1	Make_target	Comtrade signal
Name of the make target 2	Make_target	Comtrade signal
Name of the make target 3	Make_target	Comtrade signal
Name of the separation target 1	Break_target	Comtrade signal
Name of the separation target 2	Break_target	Comtrade signal
Name of the separation target 3	Break_target	Comtrade signal
Low level signals		
Name of the UDC1	UDC1	Comtrade signal
Name of the UDC2	UDC2	Comtrade signal
Name of the Icoil1 (pow. output 1)	ICOIL_1	Comtrade signal
Name of the Icoil2 (pow. output 2)	ICOIL_1	Comtrade signal
Name of the Icoil3 (pow. output 3)	ICOIL_1	Comtrade signal
Name of the Icoil4 (pow. output 4)	ICOIL_1	Comtrade signal
Name of the Icoil5 (pow. output 5)	ICOIL_1	Comtrade signal
Name of the Icoil6 (pow. output 6)	ICOIL_1	Comtrade signal
Circuit-breaker identification		
Circuit breaker model	CB_MODEL	informative
CB serial number – Phase 1	0	informative
CB serial number – Phase 2	0	informative
CB serial number – Phase 3	0	informative

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13.1.18 System\Date and Time

This section allows to adjust Date and Time, either manually or automatically from the ethernet network and is accessible to users with ENGINEER role.

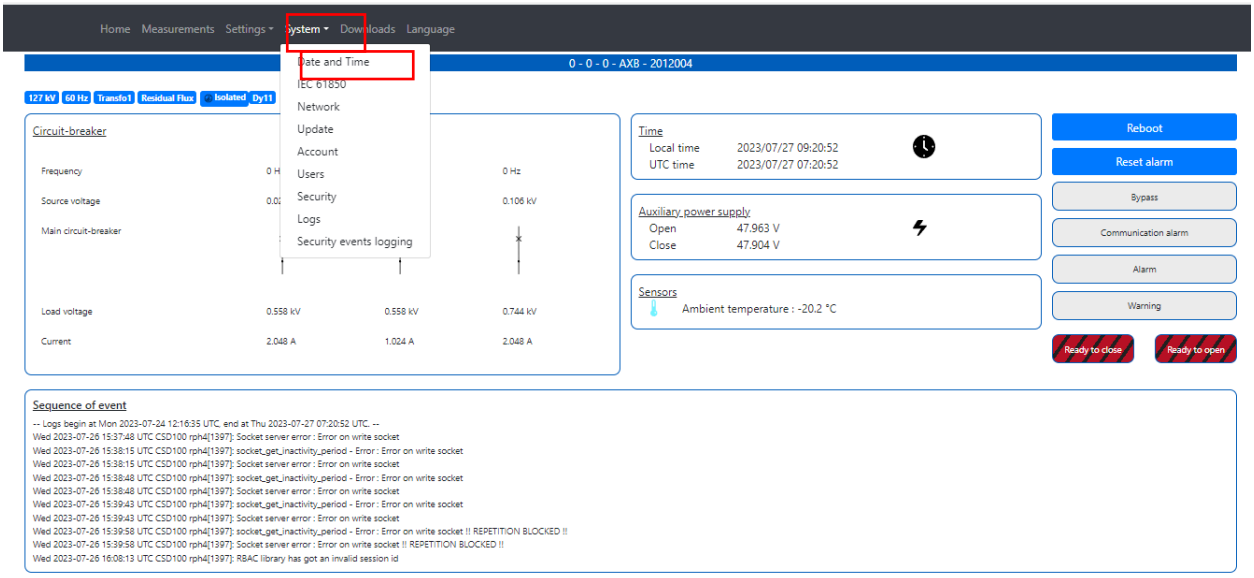


Figure 262 CSD100 HMI access to "Date and time" setting page

- **Manually** (Local time and Timezone settings). UTC time will be automatically computed. Date is memorized in internal independently clock device (with remanent energy) when power is turned off.

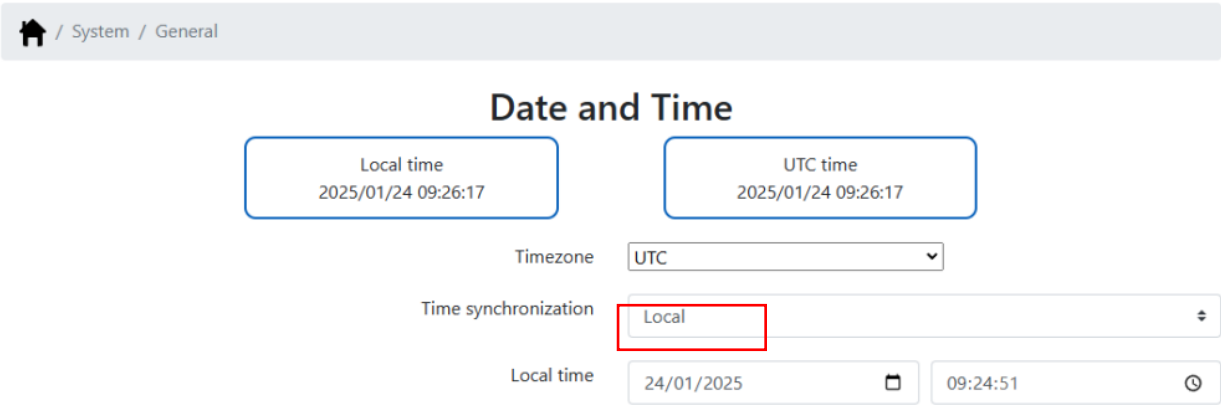


Figure 263 CSD100 HMI "Date and time" manual setting page

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- Automatically from the network:
    - From a **SNTP** server located within local network (same IP address range). SNTP server IP address shall be correctly set. CSD100 supports SNTP synchronization from a single server only.

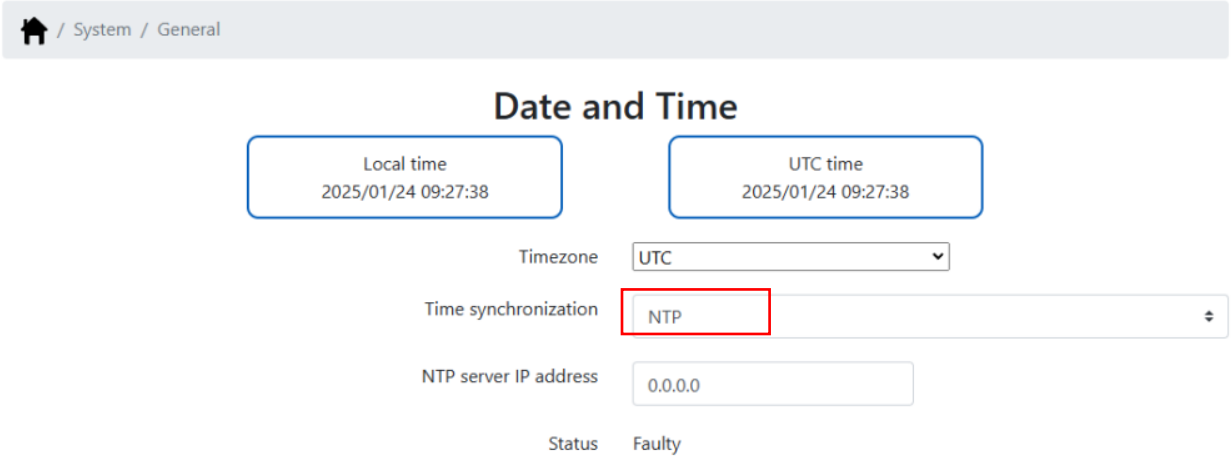


Figure 264 CSD100 HMI "Date and time" SNTP setting page

    - From **PTP** (IEEE1588), if available from local network (rear ports only). CSD100 is a PTP client, but also supports PTP clock function (because CSD100 supports ethernet switch function):
        - PTP domain: Shall reflect the master clock domain value

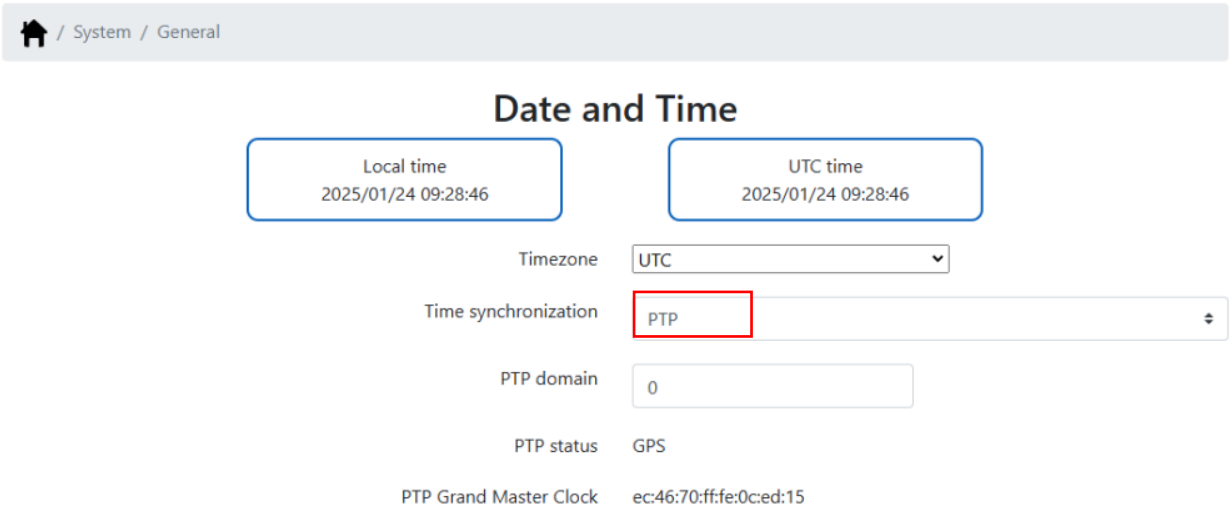


Figure 265 CSD100 HMI "Date and time" PTP setting page

Remark: PTP implemented profile is IEC/IEEE 61850-9-3 ("power profile").

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13.1.19 System\Network

In this section all Network parameters can be set by a user with ENGINEER role except physical ports enabling / disabling reserved to user with SECADM role.

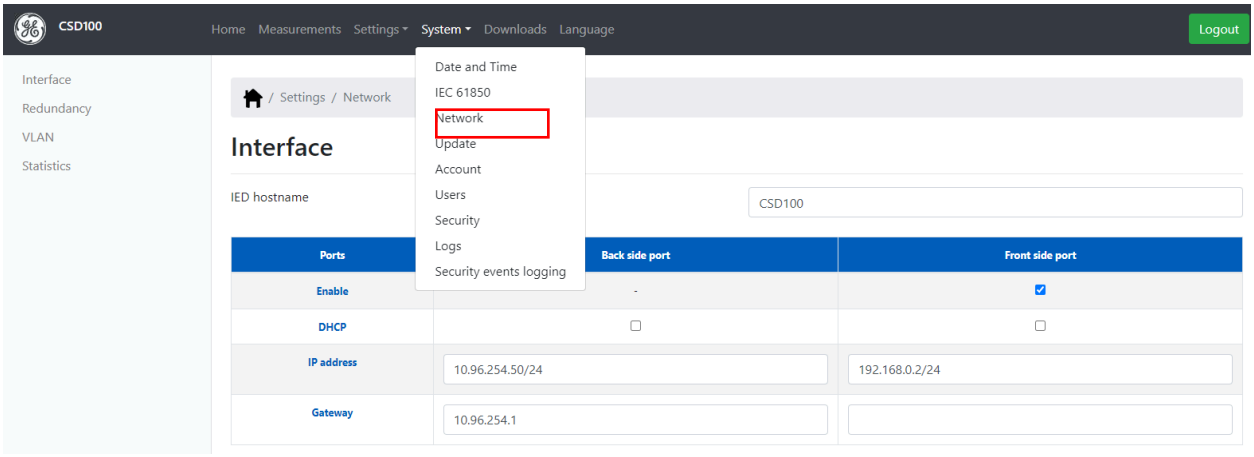


Figure 266 CSD100 HMI access to "Network" setting page

"**Interface**" subsection provides access to TCP/IP addressing parameters and rear ports detailed management.

Front port -X1, and rear ports -X2, -X4 general TCP/IP considerations:

- **Hostname**: ethernet network alias
- **Enable / Disable**, by a user with SECADM role, only for front port (rear ports to be enable/disabled with other settings, below)
- DHCP client enable / disable for each port
- **IP address and gateway** for each port (if DHCP is disabled). Delete to disable gateway.

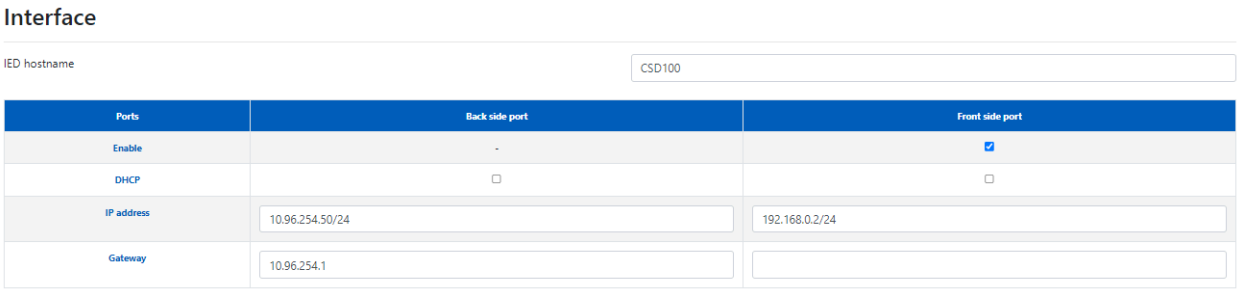


Figure 267 CSD100 HMI "Interface" setting page

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Rear ports detailed settings:

- Each port can be **disabled/enabled** individually by a user with SECADM role.
- **Link mode** (speed option : autonegociation - 1000Mbits/s - 100Mbits/s - 10Mbits/s)
- Optical SFP module are not settable. This option only applies to copper SFP modules.
- **VLAN tag:** VLAN and PCP activation/deactivation (output frames)
- **Default VLAN Id :** incoming traffic without VLAN will be VLAN tagged with this Id
- **Default PCP** (priority code point) : incoming traffic without VLAN will be assigned this priority

Remark: each port can carry multiple VLANs at same time (trunk mode)

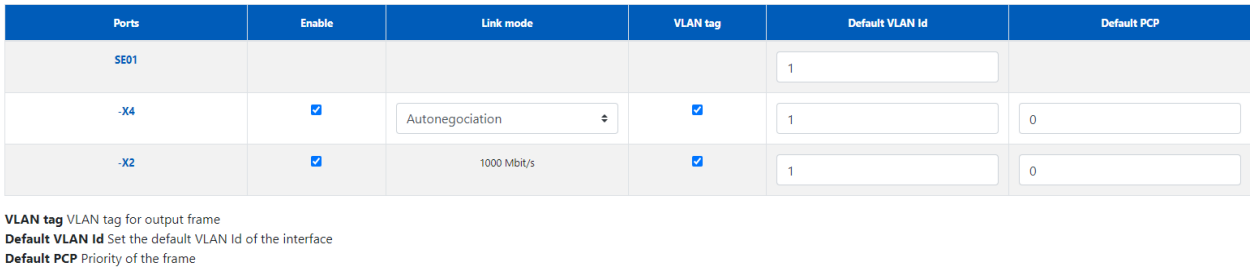


Figure 268 CSD100 HMI "Interface" setting page

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“**Redundancy**” subsection provides access to redundancy management (HSR or PRP, rear ports only).

- None / HSR / PRP
  - **HSR:** Redundancy is supported with a unique LAN in a ring topology. Being a HSR compatible device, CSD100 is a DANH (Doubly Attached Node for High Availability Seamless Redundancy) and supports two ports operated simultaneously: -X2 and -X4.
  - **PRP:** Redundancy is supported with two independent LAN segments operated in parallel. Being a PRP compatible device, CSD100 is a DANP (Doubly Attached Node for Parallel Redundancy Protocol) and supports two ports operated in parallel : -X2 (LAN A) and -X4 (LAN B).
- **Redundancy MAC address :** the last byte of the supervision MAC address is settable.

Note: a reboot of the device is required after Redundancy is set to apply the network configuration.

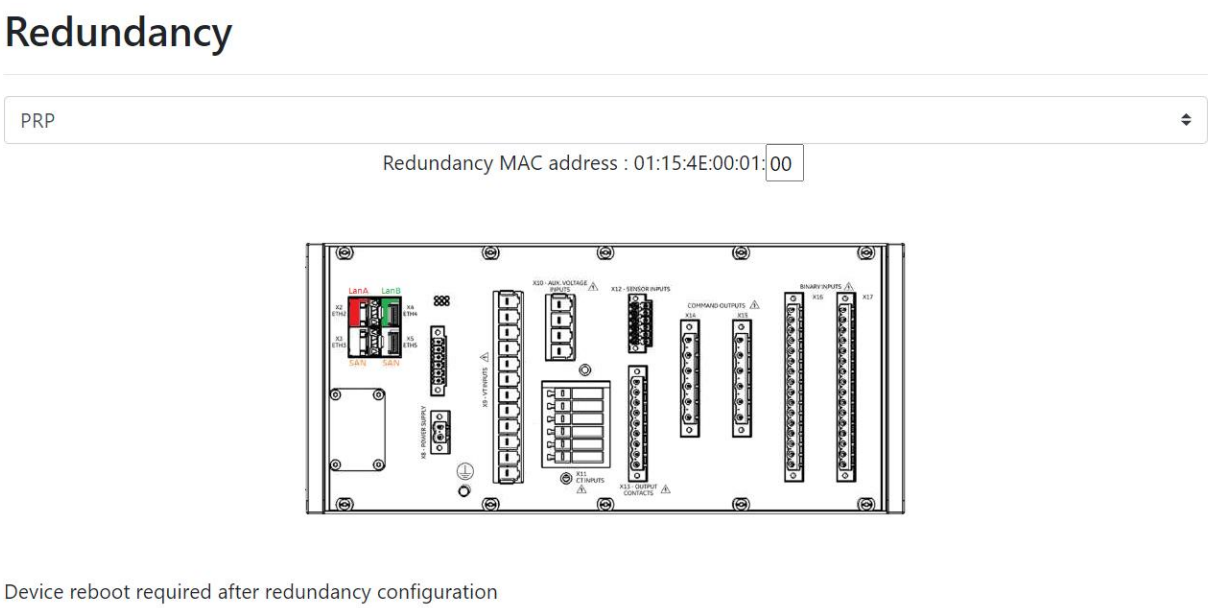


Figure 269 Rear panel, rear ports configured as redundant (x2)

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"**VLAN**" subsection allows for configuration of VLAN networks, individually for each of the rear ports. VLAN are identified with:

- VLAN Id (2 to 4094)
- VLAN name (1 to 11 characters)
- Ports: -X4, -X2, stand for the rear ports. SE01 is the internal connection port between external ports and CSD100 internal system. If it is not activated, VLAN management is strictly limited to external port to port traffic, like an ethernet switch.

Remark : 2 VLAN rules (VLAN id 0 and 1) are already configured for the system to work properly by default.

Note: Port -X1 does not support VLAN

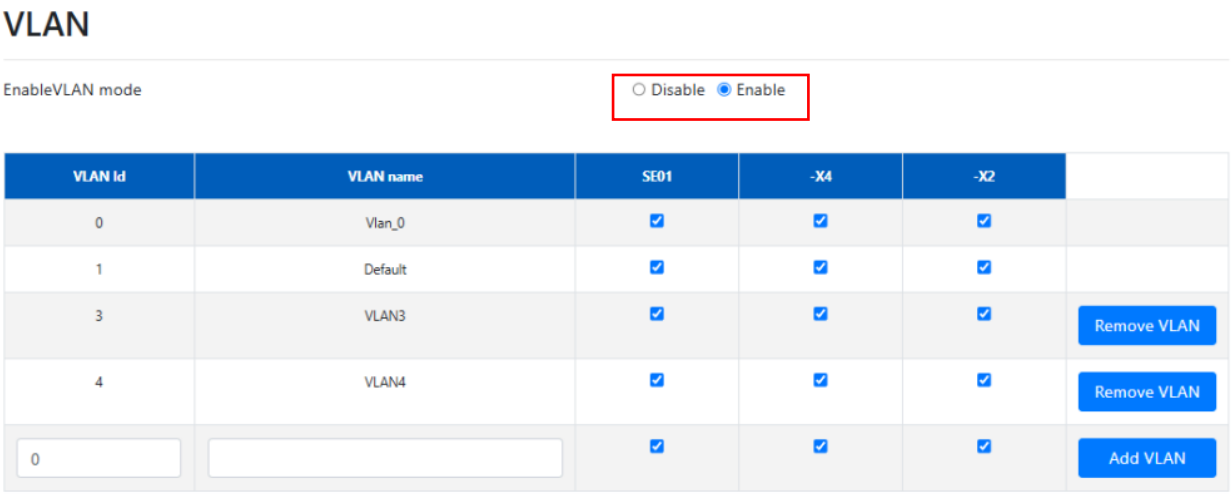


Figure 270 HMI, VLAN configuration

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"**Statistics**" subsection provides read only information about traffic flowing through each port.

Statistics

Ports	SE01	-X4	-X2
RX good octets	1735	296931785	285716504
RX bad octets	0	5083866	5118191
RX unicast frames	0	18	18
RX broadcast frames	5	8	6
RX multicast frames	1	1678140	1614462
Undersize frames	0	0	0
Fragment frames	0	112850	113523
RX oversize frames	0	0	0
RX error frames	0	0	0
RX crc error frames	0	0	0
RX memory drop frames	0	0	0
RX HSR/PRP good frames	0	11696	12015
RX PRP wrong lan frames	0	0	0
RX HSR/PRP duplicate drop	0	122	9417
TX octets	121491	283382589	291922799
TX unicast frames	0	18	18
TX broadcast frames	19	11	11
TX multicast frames	1027	1601204	1649757
TX HSR/PRP frames	0	573	573
TX priority queue full drop	0	0	0
TX early drop	0	0	0

Figure 271 HMI, ethernet ports network statistics

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13.1.20 System\IEC61850

This section allows to configure IEC 61850 communication capabilities.

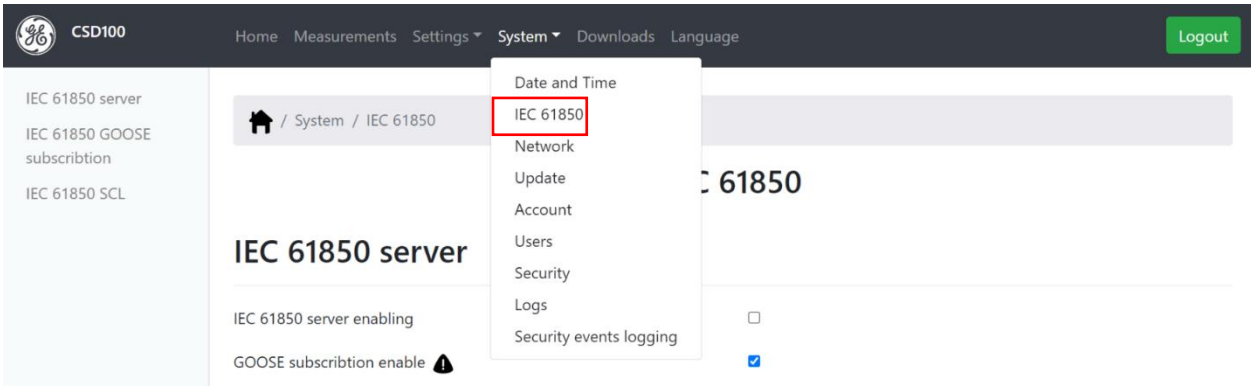


Figure 272 CSD100 HMI access to "61850" setting page (HMI)

"IEC 61850 server"

- Activate or de-activate the IEC 61850 communication feature **"IEC 61850 server enabling"**
- Adjust the name of the IED in the IEC 61850 network **"IED name"**
- Activate or de-activate the subscription to GOOSE messages "**GOOSE subscription enable**"
- Choose between back side port and front side port for IEC 61850 communication for MMS and GOOSE messages (back side recommended)
- Adjust the access point name **"AP name"**

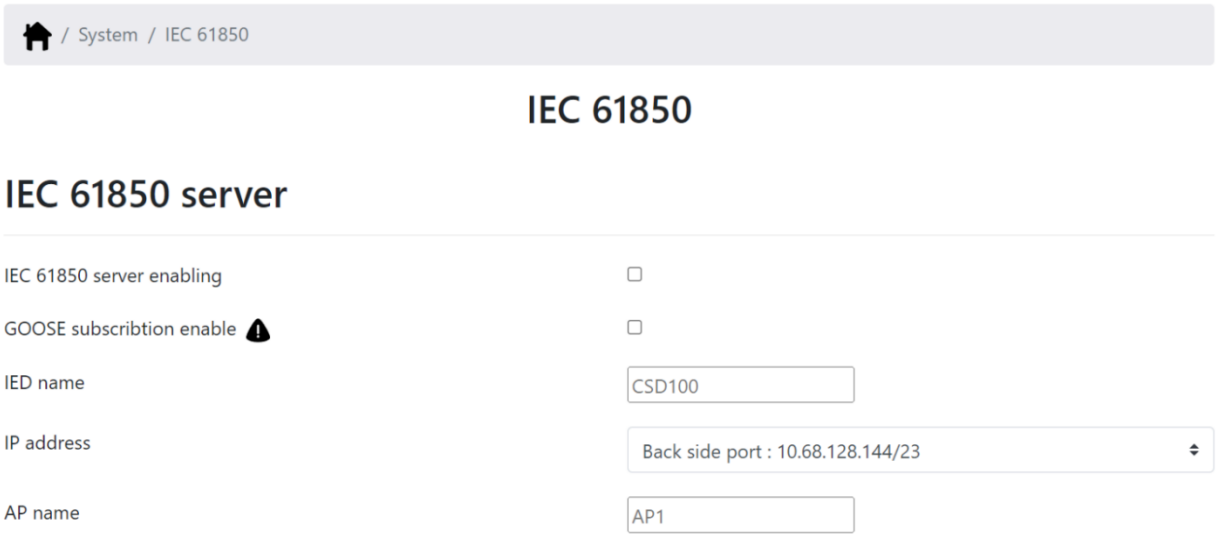


Figure 273 Server enabling options (HMI)

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“IEC 61850 GOOSE subscribtion”

Subscription to a GOOSE published by another IED allows dynamic selection of the SV streams, needed for the CSD100 operation. A GOOSE control block (GoCB) must be configured with data consistent with GOOSE publisher IED. Configuration shall be transmitted using “Generic integer status input” (IntIn), an integer from 0 to 9, from a GGIO logical node for example.

Settings include:

- Set the IED name of the GOOSE publisher **“GOOSE publisher IED name**”
- Set the AP name of the GOOSE publisher **“GOOSE publisher AP name”**

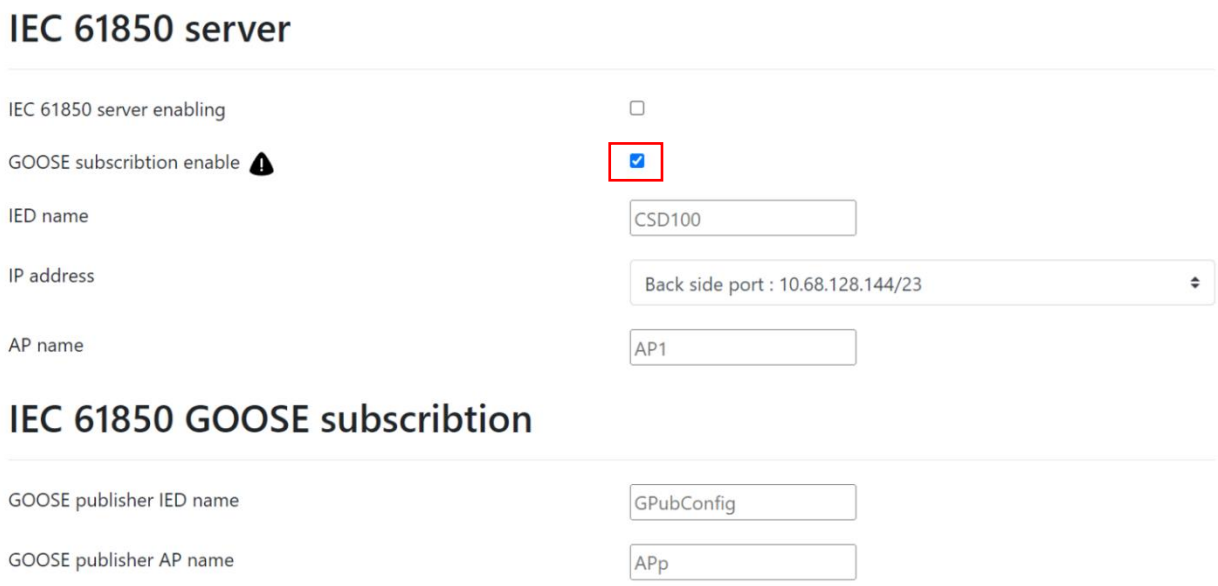


Figure 274 GOOSE subscription setting page (HMI)

Notes:

- CSD100 supports Layer 2 multicast GOOSE.
- GOOSE subscription status can be monitored through a LGOS logical node
- Active SV subscription scheme is available in CPOW logical node “ActSvSet”

⚠ GOOSE subscription requires use of a custom CID file.
Use of default CID file is not compatible with GOOSE subscription.

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“IEC 61850 SCL”

- Choose between default configuration file (CID file) and customized configuration file. Default file activates the whole dataset and communication capabilities.
- Download ICD file (IED capability description).
- Download default CID file (configured IED description), to serve as starting point for editing.
- Download customized CID file.
- Upload customized CID file (after edition and modification with appropriate configuration tool)
- Download IEC 61850 log file (61850 related diary of events)

Remark: above parameters settable only when IEC 61850 server is disabled.

Only user with ENGINEER access is allowed to configure the IEC 61850 server. Settings are accessible in edition mode when the server is disabled.

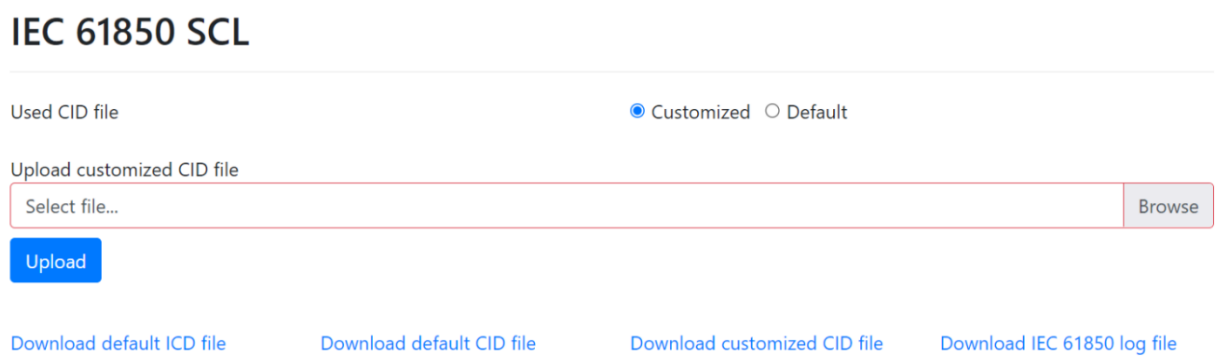


Figure 275 61850 SCL section (HMI)

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13.1.21 System\Update

Within the HMI, users with the INSTALLER role have the capability to upgrade CSD100 firmware using a new package accessible under the **“System\update”** section. When accessing this section, a popup window will prompt the user to provide the required file. It's important to note that only users with the INSTALLER role are permitted to proceed with the firmware update.

- Firmware package files are **.tar** type (compressed archive).
- Current version is displayed.
- Firmware upgrade does not impact user data (settings and records).

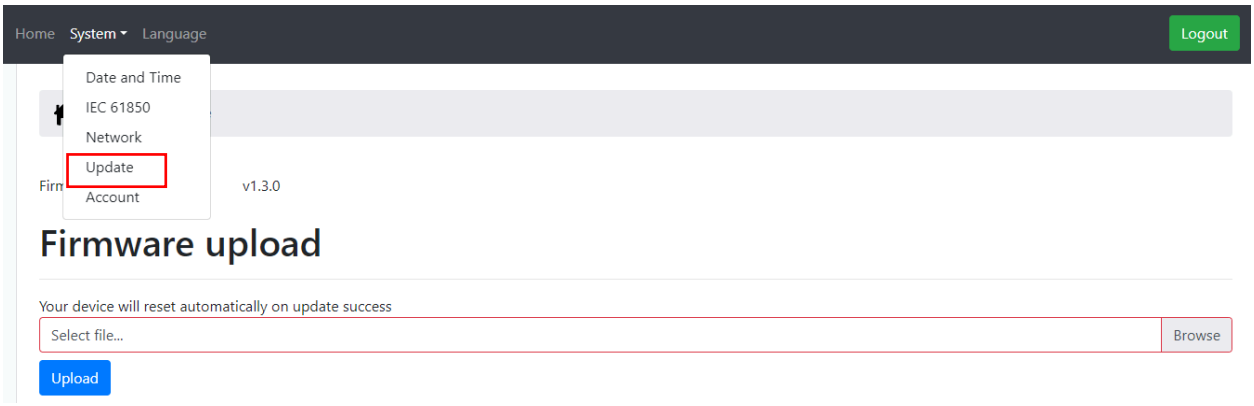


Figure 276 CSD100 HMI access to “Update” page

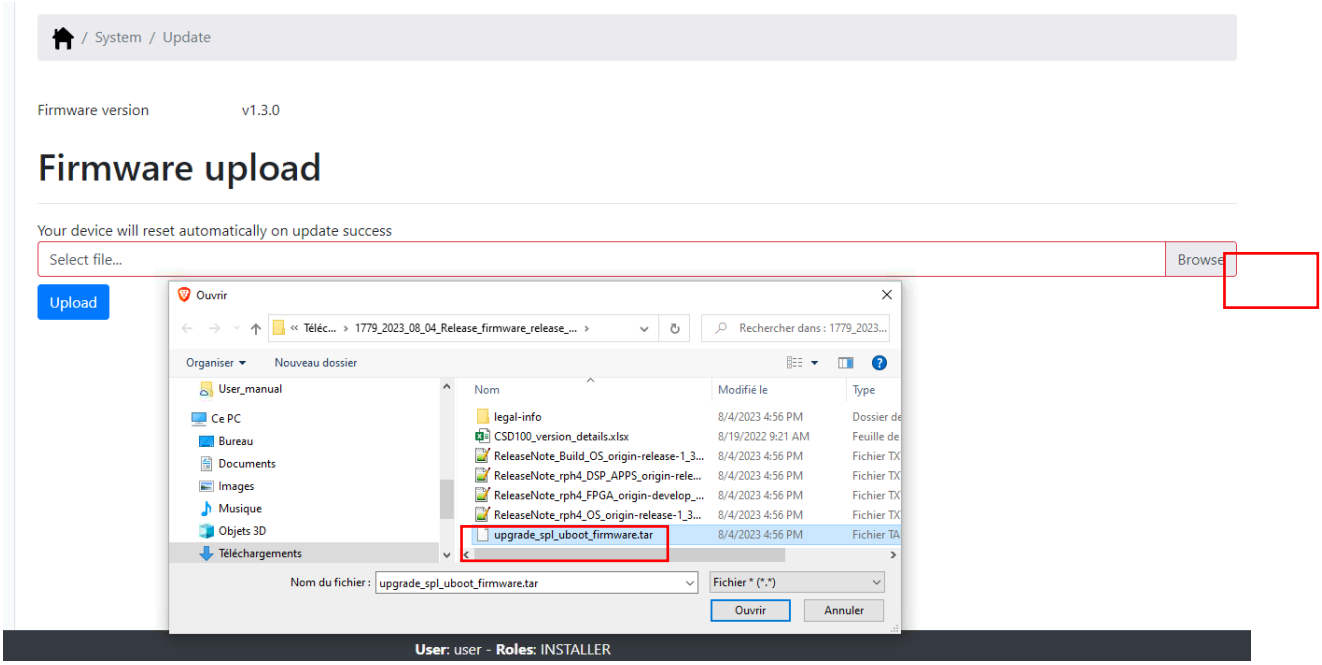
This is a secured process since HMI access is granted with login and password. Furthermore, each firmware package is proofed and signed.

After an upgrade from a version earlier than version 1.3, it is necessary to create user accounts. Refer to 13.1.23.

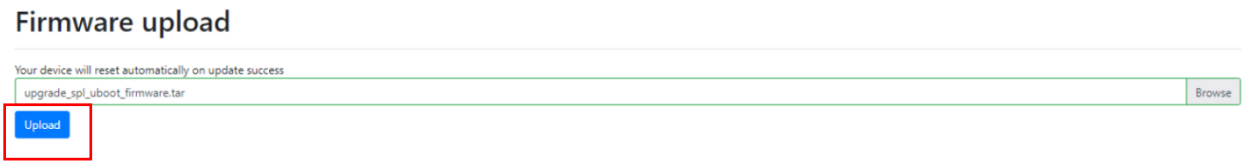
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The following captures describe how to proceed to a Firmware installation:

- Selection of the .tar image



- Upload of the .tar image

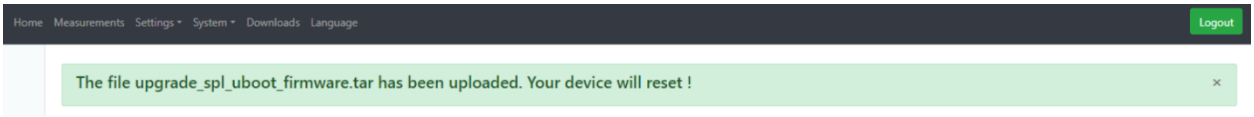


- During the upload, the firmware integrity is verified



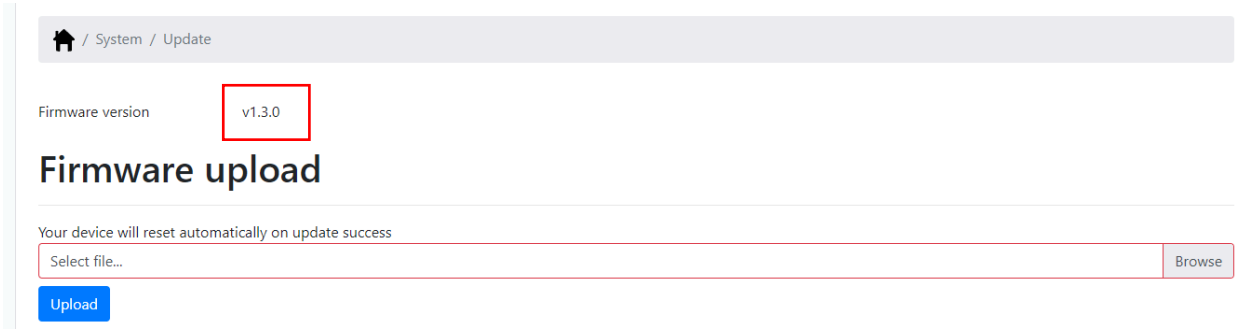
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- When the firmware integrity is confirmed, the following confirmation is displayed



At the end of the update, the device restarts. It is important not to interrupt the power supply during the process.

The verification of the installed version can be done relogging to the device and checking “Firmware version” value.



In case a user tries to update the device with a wrong firmware or signature, a mechanism blocks the update and the following warning is displayed.



Remarks :

- In case of power failure during update, previous firmware version is recovered.
- Do not try to downgrade the firmware. If downgrade is necessary, contact assistance for a special procedure.

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13.1.22 System\Account (passwords management)

HMI provides possibility to change currently logged user password, in section "**System\Account**". Current password, new password and confirmation of new password will be requested from the user.

The new password must respect following rules:

- A minimum of 15 characters
- At least 3 conditions among:
  - At least one upper case letter
  - At least one lower case letter
  - At least one number
  - At least one special character among @$!%*#&_-+

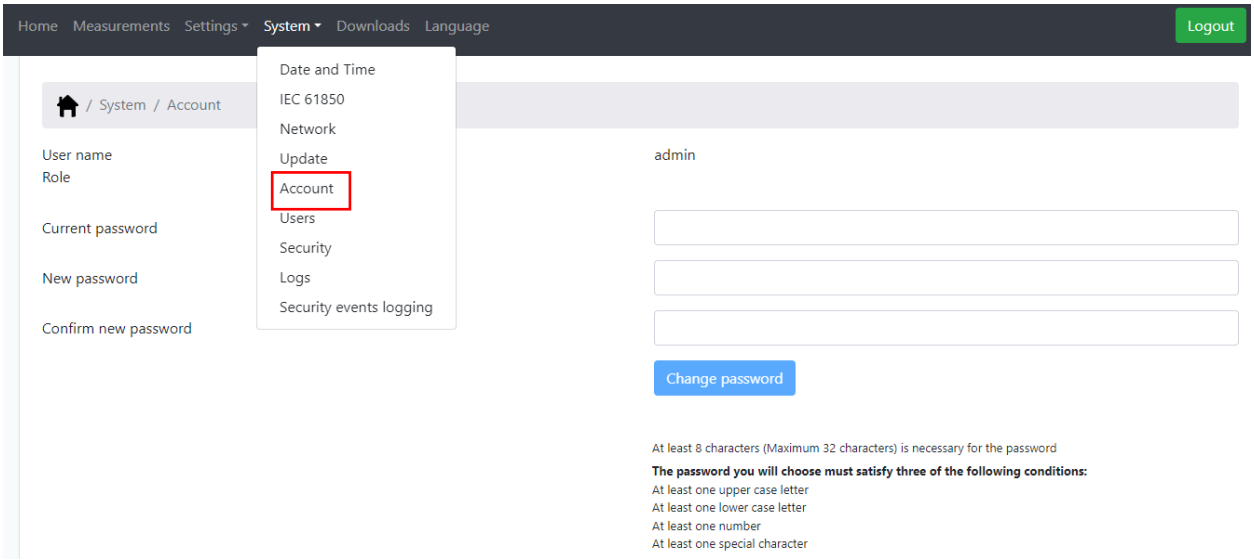


Figure 277 CSD100 HMI "Password management" page

Note: Each user can change its own password, and in the event a user has lost his password, another user with SECADM role can reinitialize it through the System\Users page as described in 13.1.23. Once the password is reinitialized, the user has to change it during first connection.

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13.1.23 System\Users (Users creation and management according to RBAC)

Through section **“System\Users”** HMI provides possibility for a user with SECADM role to

- Create/delete users;
- Initialize the password of each user newly created;
- Assign a role to each user, a minimum of one role is required for each user, and a user can cumulate multiple roles;
- Reinitialize the password for each user in case of lost password.

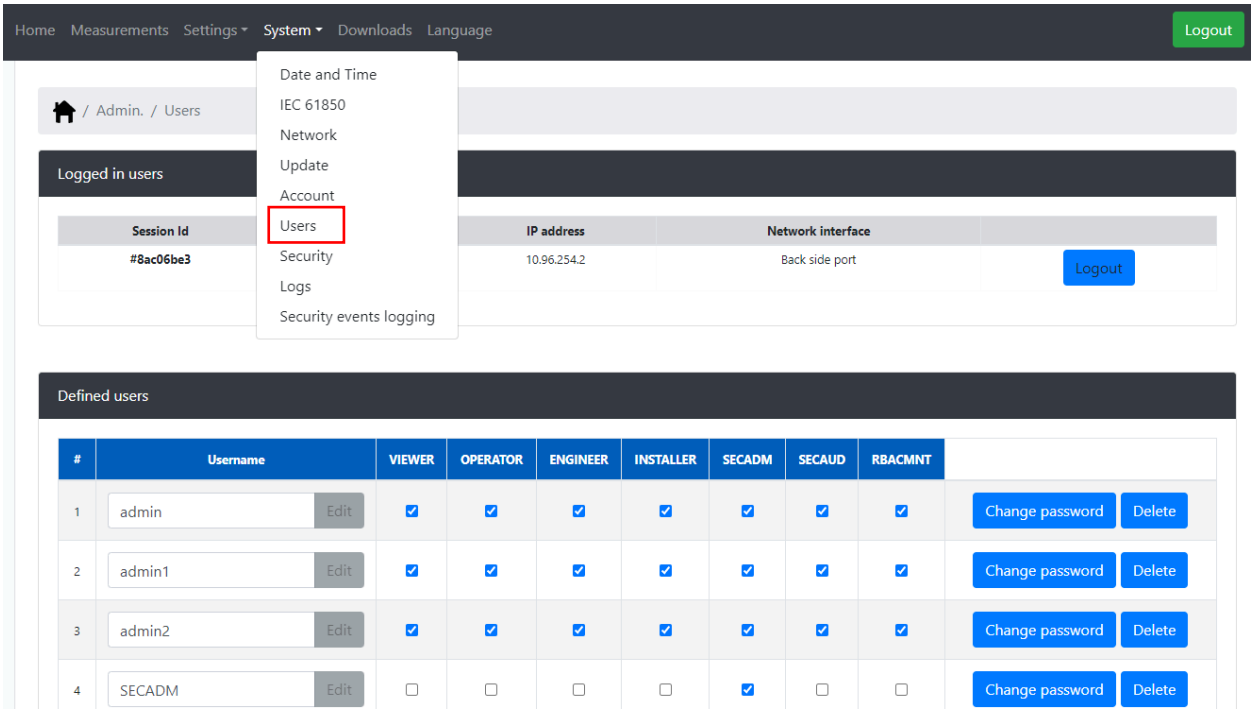


Figure 278 CSD100 HMI access to “Users’ accounts” page

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A user with SECADM role is systematically maintained in the system to allow security administration of the device, and it is not possible to delete the last SECADM present.

HMI provides possibility to create/delete users with settable role (each role having different permissions), in section “**System\Users**”. Upon creation of a new user, a popup window is displayed, asking for a new password. Role may be chosen among “VIEWER”, ”OPERATOR”, “ENGINEER”, “INSTALLER”, “SECADM”, “SECAUD”, “RBACMNT” allowing for different levels of access in the HMI.

Three action buttons are provided on this page allowing the following functions:

- **Add**: creates a new local account
- **Delete**: removes the selected account
- **Change password**: password reinitialization for other users

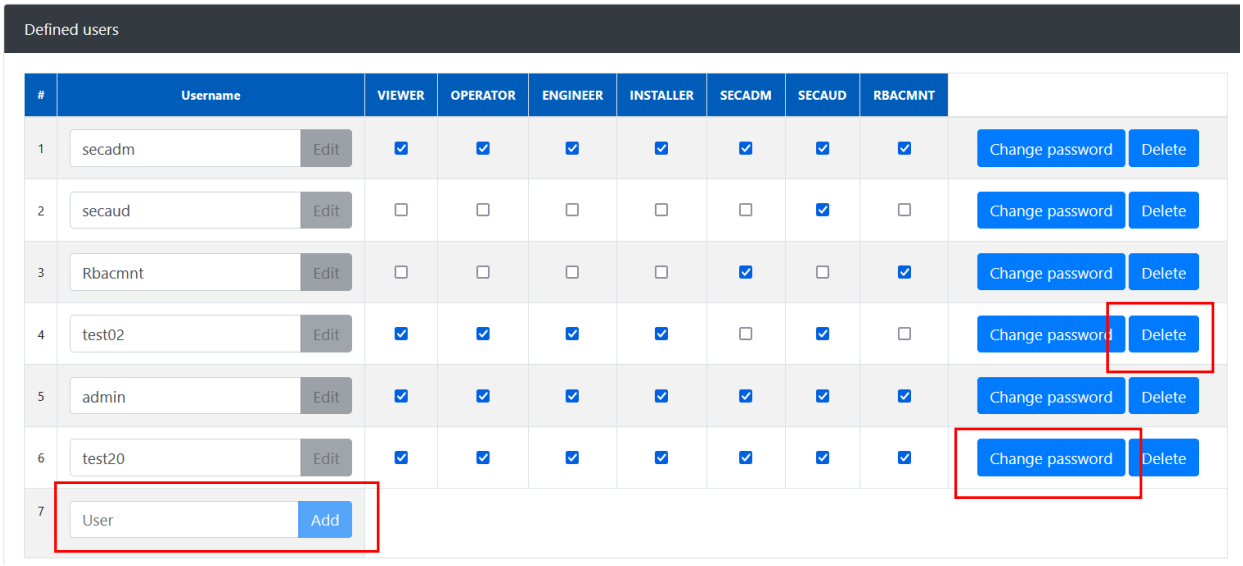


Figure 279 CSD100 HMI “Users’ accounts” management

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To add a role to a user, simply check the box corresponding to the role. By default, a user created has only the Viewer role.

Note: If the roles assigned to a user change, the user must log out and log back in to exercise his/her privileges.

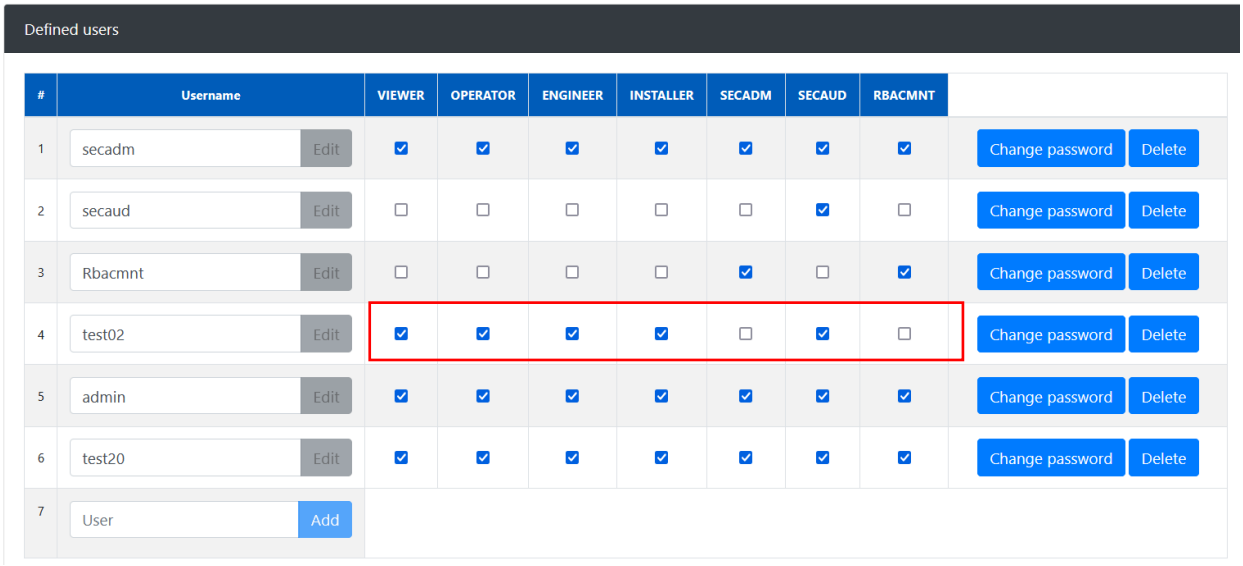


Figure 280 CSD100 HMI main menu

The different roles supported by the device are listed in Table 82.

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Table 82 CSD100 list of roles access rights

HMI section	Function	URL	VIEWER	OPERATOR	ENGINEER	INSTALLER	SECADM	SECAUD	RBACMNT
HOMEPAGE	Live data and log of event sequence	https://192.168.0.2/homepage	R	R	R	R	R	R	R
	Reset alarm button	https://192.168.0.2/homepage	-	X	X	-	-	-	-
	Reboot CSD100 button	https://192.168.0.2/homepage	-	X	X	-	-	-	-
MEASUREMENTS PAGE	Measurements page	https://192.168.0.2/measurements	R	R	R	-	-	-	-
	Next operation	https://192.168.0.2/measurements#next	R	R	R	-	-	-	-
	Last operation	https://192.168.0.2/measurements#last	R	R	R	-	-	-	-
	Transfo1 specific	https://192.168.0.2/measurements#transfo1	R	R	R	-	-	-	-
	Transfo2 specific	https://192.168.0.2/measurements#transfo2	R	R	R	-	-	-	-
	Line specific	https://192.168.0.2/measurements#line	R	R	R	-	-	-	-
	Electric wear	https://192.168.0.2/measurements#electric_wear	R	R	R	-	-	-	-
	Binary input signaling	https://192.168.0.2/measurements#signaling	R	R	R	-	-	-	-
	Sensors	https://192.168.0.2/measurements#sensors	R	R	R	-	-	-	-
	Current alarms	https://192.168.0.2/measurements#alarms	R	R	R	-	-	-	-
Settings\ General	General parameters	https://192.168.0.2/general	R	W	W	-	-	-	-
	Main options	https://192.168.0.2/general#main_options	R	W	W	-	-	-	-
	Rated levels	https://192.168.0.2/general#rated_levels	R	W	W	-	-	-	-
	Sensors input scaling	https://192.168.0.2/general#sensors_inputs_scaling	R	W	W	-	-	-	-

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HMI section	Function	URL	VIEWER	OPERATOR	ENGINEER	INSTALLER	SECADM	SECAUD	RBACMNT
	Load voltage observation	https://192.168.0.2/general#miscellaneous	R	W	W	-	-	-	-
	Recording	https://192.168.0.2/general#recording	R	W	W	-	-	-	-
	Power output	https://192.168.0.2/general#poweroutput	R	W	W	-	-	-	-
	Making time detection	https://192.168.0.2/general#makingtime	R	W	W	-	-	-	-
	Upload parameters	https://192.168.0.2/general#upload	R	W	W	-	-	-	-
	Download parameters	https://192.168.0.2/general#download	-	-	X	-	-	-	-
Settings\ Sampled Values	Sampled values subscription	https://192.168.0.2/sampled_values	R	W	W	-	-	-	-
	Global settings	https://192.168.0.2/sampled_values#global_settings	R	W	W	-	-	-	-
	Configuration	https://192.168.0.2/sampled_values#configuration	R	W	W	-	-	-	-
	Monitoring	https://192.168.0.2/sampled_values#monitoring	R	W	W	-	-	-	-
Settings\ Mechanical	Mechanical parameters	https://192.168.0.2/mechanical	R	W	W	-	-	-	-
	Main options	https://192.168.0.2/mechanical#main_options	R	W	W	-	-	-	-
	Operating time	https://192.168.0.2/mechanical#operating_time	R	W	W	-	-	-	-
	Operating time measurement	https://192.168.0.2/mechanical#time_measurement	R	W	W	-	-	-	-
	Operating time compensation	https://192.168.0.2/mechanical#operating_time_compensation	R	W	W	-	-	-	-
	Operating date	https://192.168.0.2/mechanical#operating_date	R	W	W	-	-	-	-
	Electric wear	https://192.168.0.2/mechanical#electric_wear	R	W	W	-	-	-	-
	Counters	https://192.168.0.2/mechanical#counters	R	W	W	-	-	-	-

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HMI section	Function	URL	VIEWER	OPERATOR	ENGINEER	INSTALLER	SECADM	SECAUD	RBACMNT
Settings\ React1	Load parameters React1	https://192.168.0.2/react1	R	W	W	-	-	-	-
	Load parameters React1	https://192.168.0.2/react1#open_close	R	W	W	-	-	-	-
Settings\ React2	Load parameters React2	https://192.168.0.2/react2	R	W	W	-	-	-	-
	Load parameters React2	https://192.168.0.2/react2#open_close	R	W	W	-	-	-	-
Settings\ Capa1	Load parameters Capa1	https://192.168.0.2/capa1	R	W	W	-	-	-	-
	Load parameters Capa1	https://192.168.0.2/capa1#open_close	R	W	W	-	-	-	-
Settings\ Capa1	Load parameters Capa2	https://192.168.0.2/capa2	R	W	W	-	-	-	-
	Load parameters Capa2	https://192.168.0.2/capa2#open_close	R	W	W	-	-	-	-
Settings\ Transfo1	Load parameters Transfo1	https://192.168.0.2/transfo1	R	W	W	-	-	-	-
	Load parameters Transfo1	https://192.168.0.2/transfo1#main_options	R	W	W	-	-	-	-
	Load parameters Transfo1	https://192.168.0.2/transfo1#open_close	R	W	W	-	-	-	-
	Load parameters Transfo1	https://192.168.0.2/transfo1#flux	R	W	W	-	-	-	-
Settings\ Transfo2	Load parameters Transfo2	https://192.168.0.2/transfo2	R	W	W	-	-	-	-
	Load parameters Transfo2	https://192.168.0.2/transfo2#main_options	R	W	W	-	-	-	-
	Load parameters Transfo2	https://192.168.0.2/transfo2#open_close	R	W	W	-	-	-	-

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HMI section	Function	URL	VIEWER	OPERATOR	ENGINEER	INSTALLER	SECADM	SECAUD	RBACMNT
	Load parameters Transfo2	https://192.168.0.2/transfo2	R	W	W	-	-	-	-
Settings\ Line	Load parameters Line	https://192.168.0.2/line	R	W	W	-	-	-	-
	Load parameters Line	https://192.168.0.2/line#open_close	R	W	W	-	-	-	-
Settings\ User1	Load parameters User1	https://192.168.0.2/user1	R	W	W	-	-	-	-
	Load parameters User1	https://192.168.0.2/user1#open_close	R	W	W	-	-	-	-
Settings\ User2	Load parameters User2	https://192.168.0.2/user2	R	W	W	-	-	-	-
	Load parameters User2	https://192.168.0.2/user2#open_close	R	W	W	-	-	-	-
Settings\ User3	Load parameters User3	https://192.168.0.2/user3	R	W	W	-	-	-	-
	Load parameters User3	https://192.168.0.2/user3#open_close	R	W	W	-	-	-	-
Settings\ User4	Load parameters User4	https://192.168.0.2/user4	R	W	W	-	-	-	-
	Load parameters User4	https://192.168.0.2/user4#open_close	R	W	W	-	-	-	-
Settings\ Alarms	Alarms thresholds and assignment	https://192.168.0.2/alarm	R	W	W	-	-	-	-
Settings\ Information	Information	https://192.168.0.2/information	R	W	W	-	-	-	-
	CSD information	https://192.168.0.2 /information#info_csd	R	W	W	-	-	-	-
	Project information	https://192.168.0.2 /information#info_project	R	W	W	-	-	-	-
	Sensors information	https://192.168.0.2 /information#info_sensors	R	W	W	-	-	-	-

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HMI section	Function	URL	VIEWER	OPERATOR	ENGINEER	INSTALLER	SECADM	SECAUD	RBACMNT
	Network information	https://192.168.0.2 /information#info_network	R	W	W	-	-	-	-
	Binary input information	https://192.168.0.2 /information#info_di	R	W	W	-	-	-	-
	Power output information	https://192.168.0.2 /information#info_do	R	W	W	-	-	-	-
	Low voltage information	https://192.168.0.2 /information#info_lv	R	W	W	-	-	-	-
	Circuit breaker information	https://192.168.0.2 /information#info_cb	R	W	W	-	-	-	-
	Available memory information	https://192.168.0.2 /information#info_memory	R	W	W	-	-	-	-
Settings\ Test Mode	Test mode	https://192.168.0.2/test_mode	-	X	X	-	-	-	-
System\ Date and Time	System date and time	https://192.168.0.2/system_general	R	R	W	R	R	R	R
System\ Network	Network parameters (base)	https://192.168.0.2/network	R	R	W	R	R	R	R
	Network parameters (security): enable ports	https://192.168.0.2/network#interface	R	R	R	R	W	R	R
	Fonction redondance	https://192.168.0.2/network#redundancy	R	R	W	R	R	R	R
	VLAN	https://192.168.0.2/network#vlan	R	R	W	R	R	R	R
	Network statistics	https://192.168.0.2/network#statistics	R	R	W	R	R	R	R
System\ 61850	Server enabling	https://192.168.0.2/iec61850	R	R	W	R	R	R	R
	IED name	https://192.168.0.2/iec61850	R	R	W	R	R	R	R
	Used CID	https://192.168.0.2/iec61850	R	R	W	R	R	R	R
	IP address	https://192.168.0.2/iec61850	R	R	W	R	R	R	R
	Upload customized CID 61850	https://192.168.0.2/iec61850	-	-	W	-	-	-	-

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HMI section	Function	URL	VIEWER	OPERATOR	ENGINEER	INSTALLER	SECADM	SECAUD	RBACMNT
	Download default CID 61850	https://192.168.0.2/iec61850	-	-	R	-	-	-	-
	Download customized CID 61850	https://192.168.0.2/iec61850	-	-	R	-	-	-	-
	Download default ICD 61850	https://192.168.0.2/iec61850	-	-	R	-	-	-	-
	Download 61850 logs	https://192.168.0.2/iec61850	-	-	R	-	-	-	-
System\ Update	Upgrade firmware	https://192.168.0.2/update	-	-	-	X	-	-	-
System\ Account	Current account password management	https://192.168.0.2/account	R	R	R	R	R	R	R
System\ Security	Security policy Settings	https://192.168.0.2/security	-	-	-	-	W	-	-
	Login banner	https://192.168.0.2/security#login_banner	-	-	-	-	W	-	-
	Upload certificates	https://192.168.0.2/security#certificates	-	-	-	-	W	-	-
System\ Users	Users management (create & delete user accounts)	https://192.168.0.2/admin_users	-	-	-	-	W	-	-
	Roles management (assign role to user)	https://192.168.0.2/admin_users	-	-	-	-	W	-	-
System\ Logs	Read / Download applicative logs	https://192.168.0.2/log	R	R	R	-	-	-	-
System\ Syslog	Security log (syslog) config (X4)	https://192.168.0.2/securitylog#main_options	-	-	-	-	W	-	-
	Security log (syslog) lecture (X3)	https://192.168.0.2/securitylog#security_log_field	-	-	-	-	-	R	-

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HMI section	Function	URL	VIEWER	OPERATOR	ENGINEER	INSTALLER	SECADM	SECAUD	RBACMNT
Download	Download records individually	https://192.168.0.2/downloads	X	X	X	-	-	-	-
	Download all switching records	https://192.168.0.2/downloads	X	X	X	-	-	-	-
	Delete switching records	https://192.168.0.2/downloads	-	-	X	-	-	-	-
	Trigger a manual record	https://192.168.0.2/downloads	-	X	X	-	-	-	-
Language	Select interface language	https://192.168.0.2/language	R	R	R	R	R	R	R
	Upload a new language	https://192.168.0.2/language	-	-	-	X	-	-	-

Note: W = read and write access; R = read access; X = execute access; - = no access (forbidden)

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13.1.24 System\Security

A user with SECADM role can set the security policies from **“System\Security”** page.

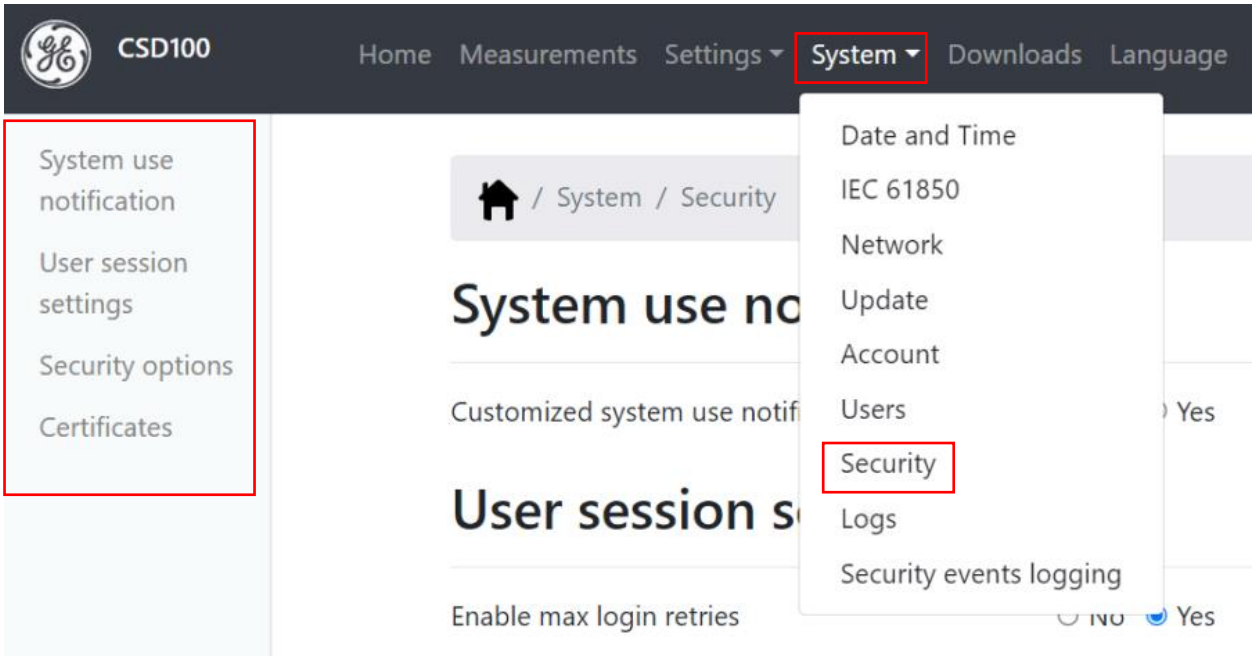


Figure 281 CSD100 HMI access to “Security policies” management page

Login disclaimer banner:

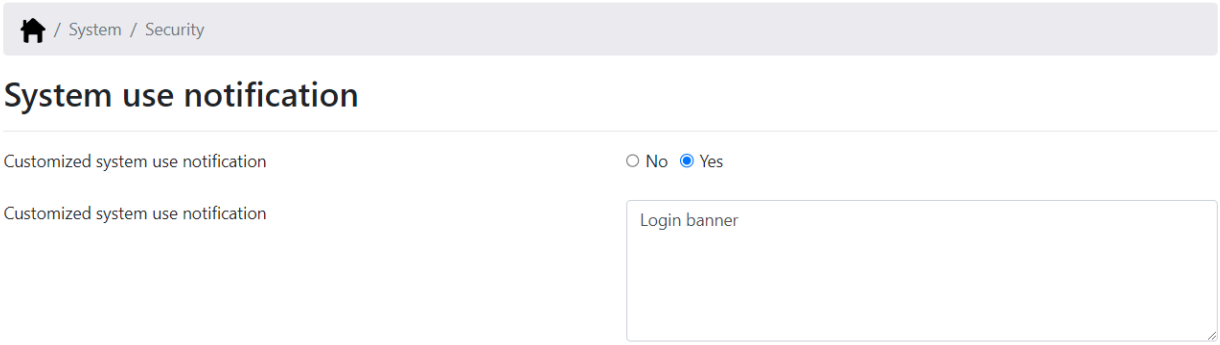


Figure 282 CSD100 HMI “System use notification” setting

- Enable or disable a customized **system use notification** message to be accepted by user immediately after log in. This popup message is user settable (plain text with a maximum of 3072 characters).

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User session settings:

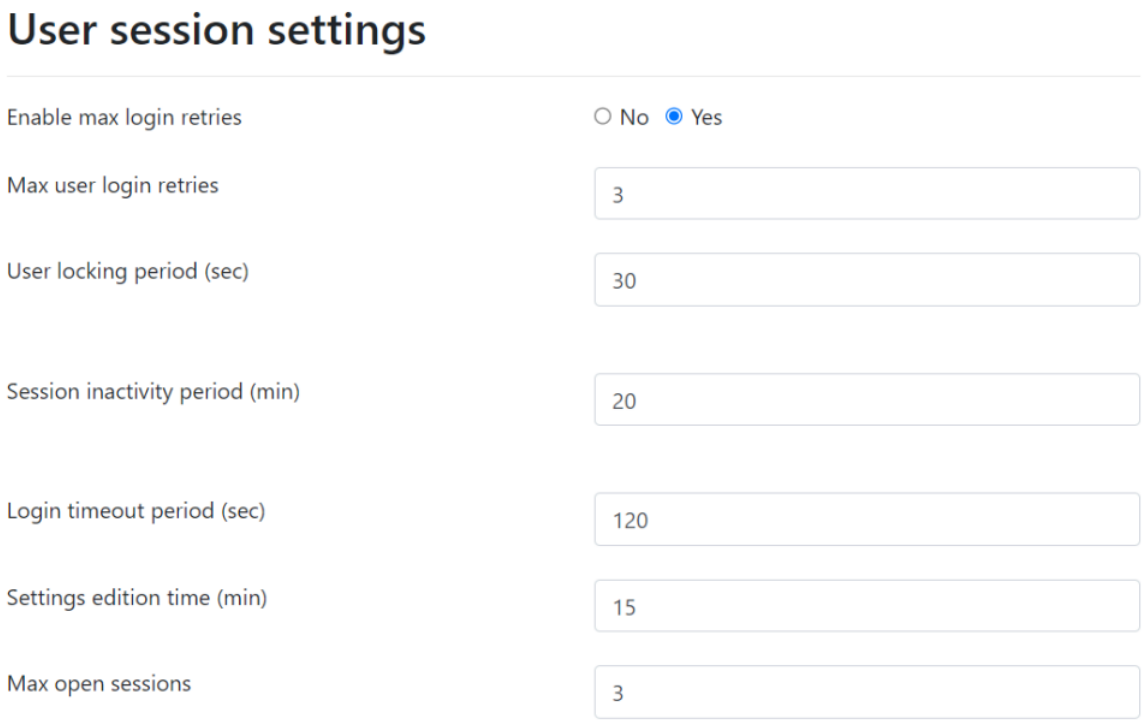


Figure 283 CSD100 HMI "User session policy" settings

- "**Enable max login retires**" : a mechanism to filter out excessive login attempts in a given amount of time. If number of login attempts exceeds "**Max user login retries**" during a fixed predefined period, the CSD100 is locked for "**User locking period**" (sec).
- "**Session inactivity period (min)**" : the amount of time (inactivity time) after which a user session is automatically closed (user has to log in again).
- "**Login timeout period** (sec)" : if the user does not validate credentials before **login timeout period,** credentials are automatically deleted.
- "**Settings edition time** (min)" : mechanism to manage multiple accesses to same setting (concurrent edition of settings) by simultaneously logged users. The first user to edit a given setting has priority, and this priority has a timeout of "**Settings edition time".**



Figure 284 CSD100 HMI "Concurrent sessions" display

- "**Max open sessions**" : maximum total number of simultaneous sessions, all users combined.

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Table 83 CSD100 list of security policy settings

Security policy setting	Variable type	Default value	Min. value	Max. value
Customized system use notification	Boolean	No	-	-
Customized system use notification message	String	« Login banner »	6 characters	3072 charcaters
Enable max login retries	Boolean	Yes	-	-
Max user login retries	Int	3	0	99
User locking period	Int (sec)	30	0	86400
Session inactivity period	Int (min)	20	1	60
Login timeout period	Int (sec)	120	20	86400
Settings edition time	Int (min)	15	1	240
Max open sessions	Int	3	0	99

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Security options:

- **“Enable ping”** : under some operational circumstances, the device ping is needed to allow operation of some client. ICMP protocol can be enabled using this security option. Protocol is disabled by default.

⚠ Exercise utmost caution and refrain from enabling unnecessary options, as doing so may expose the device to potential security risks and vulnerabilities.

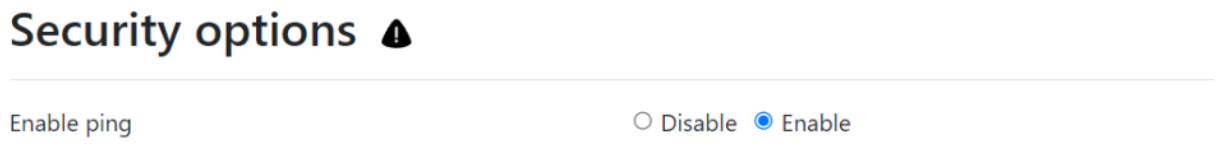


Figure 285 CSD100 HMI “Ping” management page

“**HTTPS certificate**” subsection allows to upload certificate and key (if available), to avoid the warning message (linked to an auto-certification) at the first connection to the web HMI.

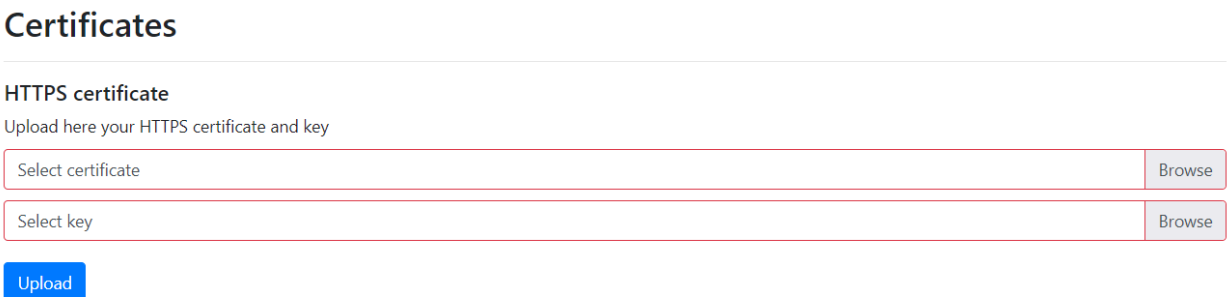


Figure 286 CSD100 HMI “Certificates” management page

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13.1.25 System\Logs

This section displays detailed events log, as well as possibility to download the log in a file (“rph4.log”) as a text document.

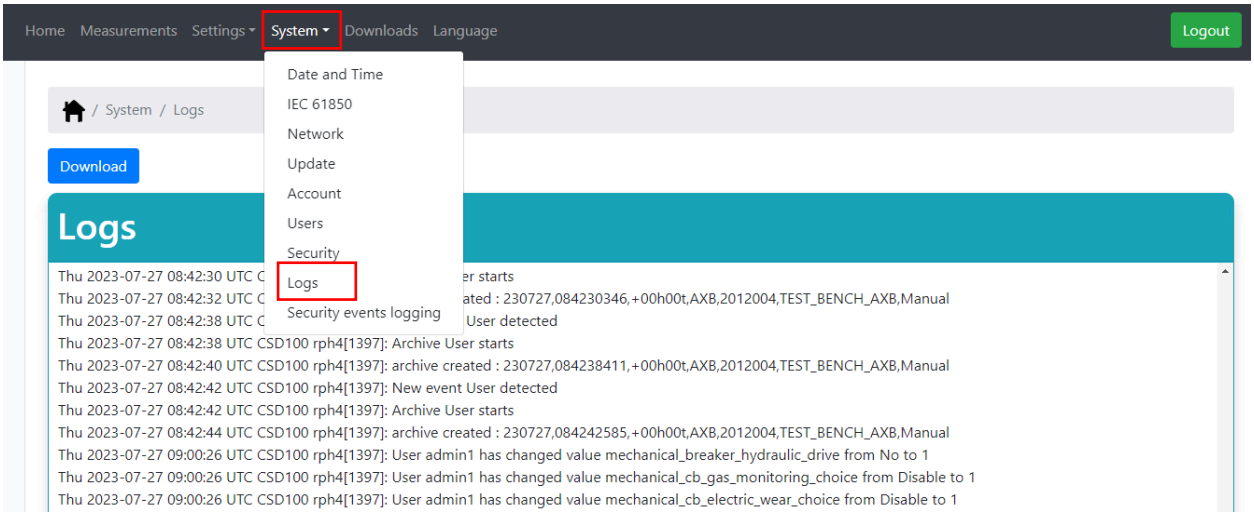


Figure 287 CSD100 “Functional log” access

Each log entry is time stamped, and most recent ones located at bottom of the log (scroll down for latest entries).

Log file inputs includes:

- Settings change with indication of logged used responsible for the change
- Operations orders occurrence and digital input change
- Detailed indications during synchronized operations processing

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13.1.26 System\Security events logging

This section is accessible to SECAUD and SECADM.

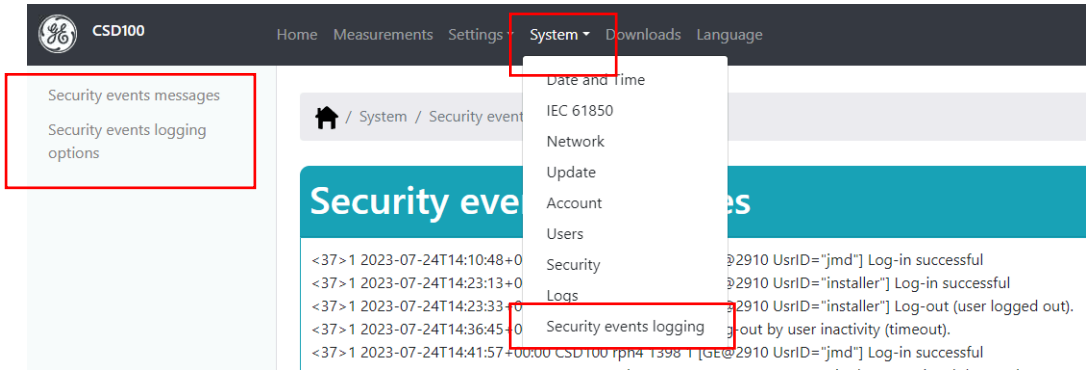


Figure 288 CSD100 HMI "Security events logging" page

This section allows:

- A **SECAUD** user (security auditor) to review the security log messages.

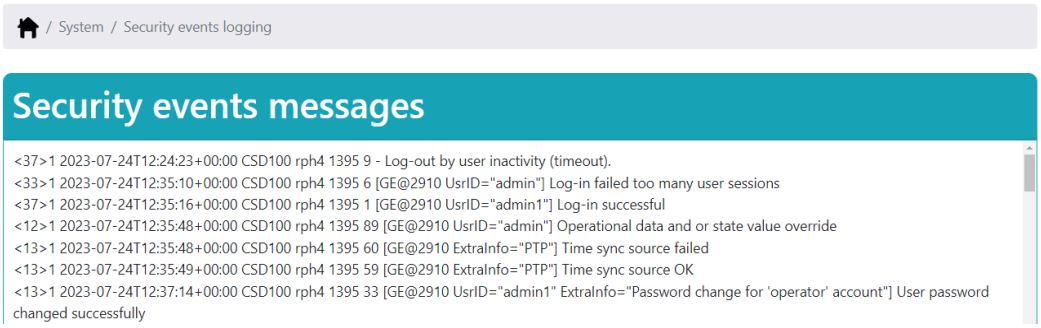


Figure 289 CSD100 HMI main menu

- A **SECADM** user (security administrator) to adjust remote syslog settings (primary server and secondary server, which is used for backup, if requested).
    - "**Redirect security audit log to a server**": enables / disables remote syslog functionality.
    - Server protocol: UDP
    - Server IP address: the IP address of the remote server.
    - Server port (refer to Table 94)

Remark: syslog server can be connected either at front port or rear port.

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13.1.26.1 Configuration with UDP protocol

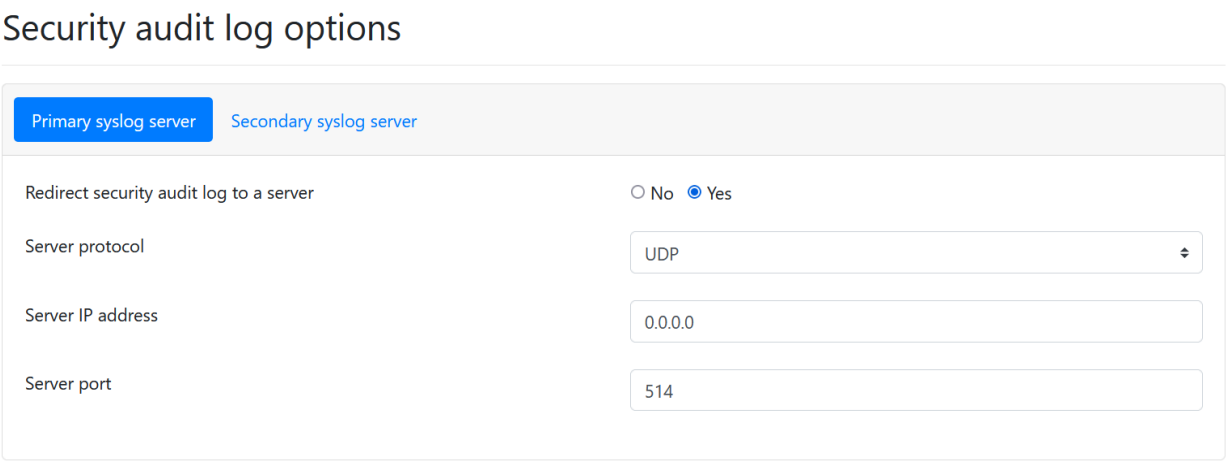


Figure 290 CSD100 HMI syslog main server UDP settings

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13.1.26.2 Configuration of secondary server

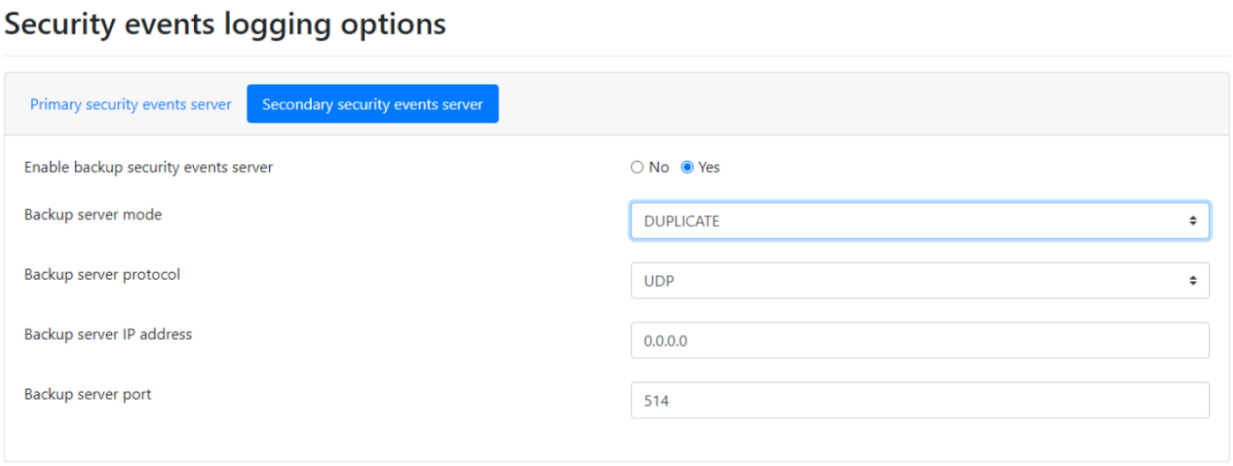


Figure 291 CSD100 HMI syslog secondary server settings

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13.1.27 Downloads

This section provides access to:

- Download archive files (see 13.7) individually.
- Download all archives at once (a .zip file will be created, “AllArchives.zip”)
- Manually trigger the creation of a new archive
- Delete all archives (a popup will ask for confirmation)

Note: A filter can be applied by type of archives and/or date, to ease the selection or deletion of a batch of records.

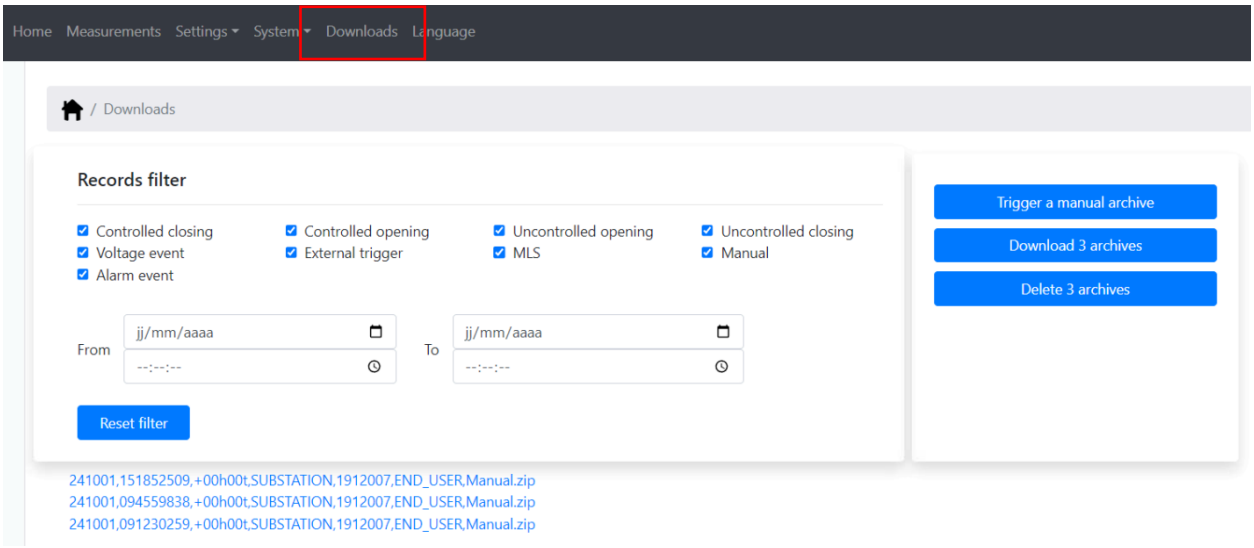


Figure 292 CSD100 HMI “download” section

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13.1.28 Language

This section allows user to dynamically switch between already installed language files. No need to restart the CSD100.

Any new language can also be uploaded using the web interface. Language files can be made available on request to your GE representative.

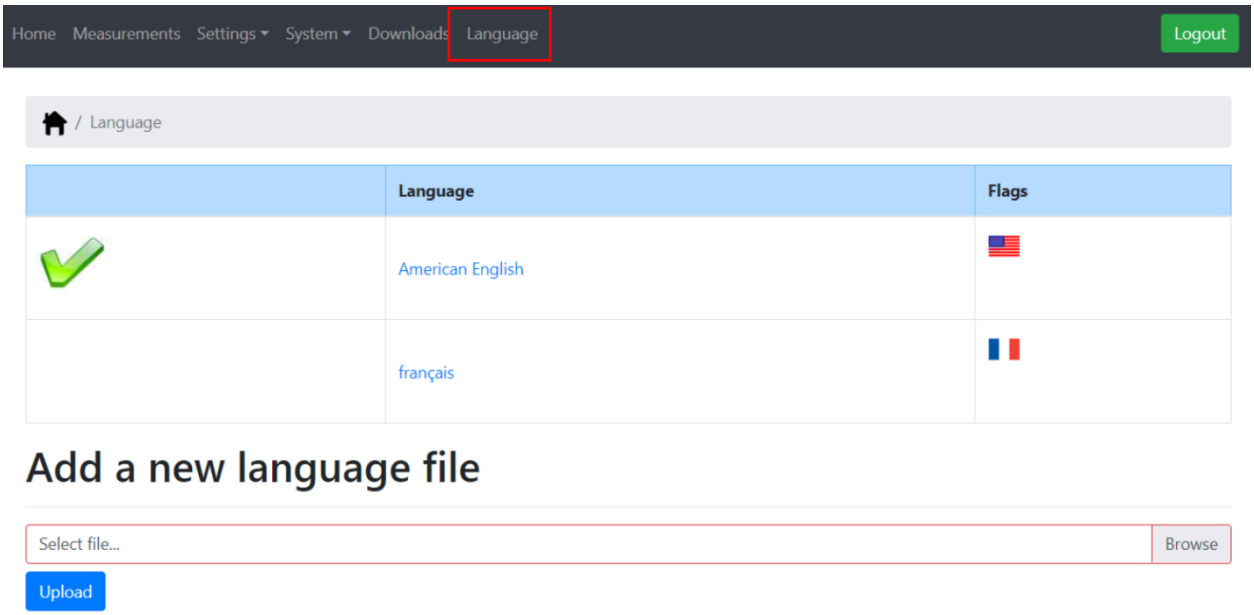


Figure 293 CSD100 HMI "language" section

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13.1.29 HMI known/common issues

Table 84 CSD100 HMI known issues

Issue	Workaround
Button “Apply” (HMI top right) is not displayed after setting change	Purge web browser cache (CTRL+F5 with Mozilla Firefox)
Firmware upload does not resume	Press “ESC”, purge web browser cache and cookies, and retry
Impossible to connect to HMI (“login fail due to number of sessions limit”)	Reboot the CSD and retry (many user sessions not correctly closed)
Nothing happens when user click on “Change password” after entering new passwords (password change is normally instantaneous)	Purge web browser cache (CTRL+F5 with Mozilla Firefox)
Use of USB-A to RJ45 converters (laptop / PC side)	Spurious disconnection from the device requiring the restart of the USB-A to RJ45 converter

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13.2 Getting Measurements

Measurement section provides for read only data.

"**Next operation**" subsection summarizes, in a single view, main values for upcoming close and open operations.

- **Close/Switching angles (°)**: targets for making times, L1, L2, L3, by reference to a positive going reference wave zero crossing.
- **Open/Switching angles (°)**: targets for current interruption, L1, L2, L3, by reference to a positive going reference wave zero crossing.
- **Close/Prearcing time**: prearcing times for each phase.
- **Open/arcing time**: arcing times for each phase.
- **Close/Calculated operating time**: mechanical times for each phase.
- **Open/Calculated operating time**: mechanical times for each phase.
- **Program selected:** program for next operation, directly from settings or multiple switching automatic selection.



	L1	L2	L3	L1	L2	L3
Switching angles	0 °	0 °	0 °	0 °	0 °	0 °
Prearcing / arcing time	0 ms	0 ms	0 ms	0 ms	0 ms	0 ms
Rated operating time	0 ms	0 ms	0 ms	0 ms	0 ms	0 ms
Calculated operating time	0 ms	0 ms	0 ms	0 ms	0 ms	0 ms
Program selected	React1					

Figure 294 CSD100 HMI "Measurement\Next Operation" section

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"**Last operation**" subsection gathers calculated values before operation and measured values after operation, to facilitate performance assessment, and display performance indicators.

- **Close/Calculated angle**: targets (°) for making times, L1, L2, L3, by reference to a positive going reference wave zero crossing.
- **Close/Measured angle**: achieved angles (°), computed from measured making times, for comparison with targets, for each phase.
- **Close/Making time error**: deviation (in ms) from ideal target.
- **Open/Calculated angle**: targets (°) for current interruption, L1, L2, L3, by reference to a positive going reference wave zero crossing.
- **Open/Measured angle**: achieved angles (°), computed from measured current interruption times, for comparison with targets, for each phase.
- **Close/Calculated prearcing time**: prearcing times for each phase.
- **Close/Measured prearcing time**: measured prearcing times for each phase (difference between measured making time and calculated mechanical time), for comparison with calculated values.
- **Open/Calculated arcing time**: arcing times for each phase.
- **Open/Measured arcing time**: measured arcing times for each phase (difference between measured current interruption time and calculated mechanical time), for comparison with calculated values.
- **Close/Calculated operating time**: mechanical times for each phase (forecast).
- **Close/Measured operating time**: measured mechanical times for each phase, for comparison with calculated values.
- **Open/Calculated operating time**: mechanical times for each phase (forecast).
- **Open/Measured operating time**: measured mechanical times for each phase, for comparison with calculated values.
- **Close/Open/Program Selected:** reminder for program during last operations.
- **Close/Open/Operating date:** timestamp (with seconds) of last operations, for each phase.
- **Close/Inrush current:** peak inrush current during last close operation (primary), for each phase.
- **Close/Voltage dip:** maximum source voltage dip during last close operation, for each phase.
- **Close/Open/Counter controlled operations:** cumulated number of operations managed by CSD100 (synchronized), for each phase. These counters are resilient to CSD100 turn off (non-volatile memory).
- **Close/Open/Counter uncontrolled operations:** cumulated number of operations not managed by CSD100 (unsynchronized), detected from 52a switching, for each phase. These counters are resilient to CSD100 turn off (non-volatile memory).
- **Open/Counter reignition controlled operations:** cumulated number of reignitions, for each phase, during controlled operations (synchronized). These counters are resilient to CSD100 turn off (non-volatile memory).

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- **Open/Counter reignition uncontrolled operations:** cumulated number of reignitions, for each phase, during uncontrolled operations (unsynchronized, detected from 52a switching). These counters are resilient to CSD100 turn off (non-volatile memory).

Last operation

	L1	L2	L3	L1	L2	L3
Calculated angle	0 °	0 °	0 °	0 °	0 °	0 °
Measured angle	0 °	0 °	0 °	0 °	0 °	0 °
Making time error	0 ms	0 ms	0 ms		-	
Calculated prearcing / arcing time	0 ms	0 ms	0 ms	0 ms	0 ms	0 ms
Measured prearcing / arcing time	0 ms	0 ms	0 ms	0 ms	0 ms	0 ms
Calculated operating time	0 ms	0 ms	0 ms	0 ms	0 ms	0 ms
Measured operating time	0 ms	0 ms	0 ms	0 ms	0 ms	0 ms
Program selected		NA			NA	
Operating date	NaN	NaN	NaN	NaN	NaN	NaN
Inrush current	0 A	0 A	0 A		-	
Voltage dip	0 %	0 %	0 %		-	
Counter controlled operations	0	0	0	0	0	0
Counter uncontrolled operation	0	0	0	0	0	0
Counter reignition controlled operations		-		0	0	0
Counter reignition uncontrolled operations		-		0	0	0

Figure 295 CSD100 HMI "Measurement\Last Operation" section

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"**Line**" subsection is specific to line reclose case. Strategy (zero of source voltage, min. of beat voltage, max/min of source voltage) as well as phase status (healthy / faulty) are indicated, since they are automatically computed.

- **Line reclose strategy**: zero source / min. beat / min/max source
- **Faulty phase**: Faulty/healthy

Line

	L1	L2	L3
Line reclose strategy	NA	NA	NA
Faulty phase	Faulty	Faulty	Faulty

Figure 296 CSD100 HMI "Measurement\Line" section

"**Transfo1**" subsection indicates current residual flux values (computed upon each de-energization) and calculated limit angles for switching (due to RDDS and mechanical scatter) in the different transformer coupling situations and sequence: single voltage to earth(voltage x1), differential voltage (voltage x√3), differential voltage in isolated neutral and last phase to close situation (voltage x1.5). Residual flux values are resilient to CSD100 turn off (non-volatile memory).

- **Residual flux**: expressed in pu ([-1.0…1.0]), for each phase or winding.
- **Residual flux voltage:** indicates which voltage is used for residual flux computation, for each phase or winding. According to other settings, it may be a combination of measured voltages, at primary or secondary side of the transformer. See Table 70
- **Switching angles Min.:** Indicates the first reachable angle value right after voltage zero crossing, usually a few angular degrees, due to circuit breaker RDDS and scatter, in different voltage conditions.
- **Switching angles Max.:** Indicates the last reachable angle value right before voltage peak crossing, usually a few angular degrees below 90°, due to circuit breaker RDDS and scatter, in different voltage conditions.

Transfo1

	L1	L2	L3
Residual flux	0	0	0
Residual flux voltage	A	B	C

Switching angles	Simple	Differential	1.5
Min.	0.002	0.002	0.003
Max.	90	90	90

Figure 297 CSD100 HMI "Measurement\Transfo1" section

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"**Transfo2**" subsection provides same type of information as Transfo1.

Transfo2

	L1	L2	L3
Residual flux	0	0	0
Residual flux voltage	A-B	B-C	C-A

Switching angles	Simple	Differential	1.5
Min.	0.002	0.002	0.003
Max.	90	90	90

Figure 298 CSD100 HMI "Measurement\Transfo2" section

"**Signaling**" subsection indicates circuit breaker current position (from 52a and travel sensors, if fitted) as well as other digital inputs.

- **Main circuit breaker position**: Current position from 52a, for each phase (Open/close)
- **Main circuit breaker stroke**: Current position from travel curve sensor, for each phase (mm).
- **Multiple load switching (MLS)**: Current status of the 4 digital inputs dedicated to strategy selection.
- **Binary inputs**: Current status of remaining digital inputs (bypass position acquisition, commissioning mode, opening order, closing order, reset alarm).

Signaling

	L1	L2	L3
Main circuit-breaker position	Open	Open	Open
Main circuit-breaker stroke	0 (mm)	0 (mm)	0 (mm)

	4	3	2	1
Multiple load switching (MLS)	Disable	Disable	Disable	Disable

	Bypass	Test mode	Opening order	Closing order	Reset alarm
Binary inputs	Disable	Disable	No	No	No

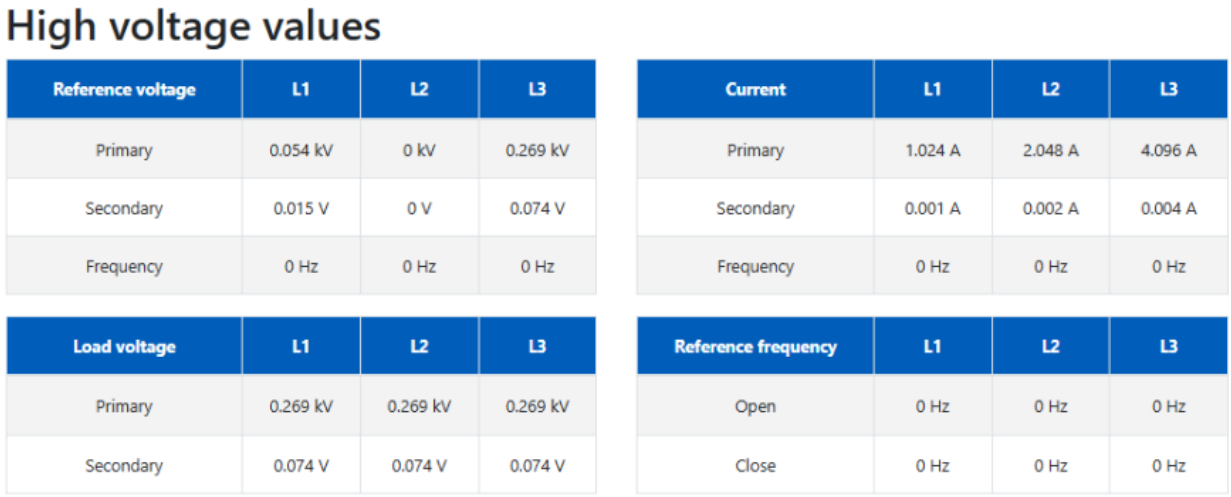
Figure 299 CSD100 HMI "Measurement\Signalling" section

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"**Sensors**" subsection gathers live analogue and digital sensors values: primary and secondary values (voltages, currents, frequencies), substation control voltages (DC1 & DC2), ambient temperature and data from circuit breaker gas monitoring (pressure and temperature).

High voltage values:

- **Reference voltage/ Primary**: live voltage primary values at reference side (source side), for each phase.
- **Reference voltage/ Secondary**: live voltage secondary values (CSD100 input port, X9) at reference side (source side), for each phase.
- **Reference voltage/ Frequency**: live voltage frequencies at reference side (source side), for each phase.
- **Load voltage/ Primary**: live voltage primary values at load side, for each phase.
- **Load voltage/ Secondary**: live voltage secondary values (CSD100 input port, X9) at load side, for each phase.
- **Current/ Primary**: live circuit breaker current primary values, for each phase.
- **Current/ Secondary**: live circuit breaker current values (CSD100 input port, X11), for each phase.
- **Current/ Frequency**: live circuit breaker current frequencies, for each phase.
- **Reference frequency/Open**: live frequencies for synchronization (currents or reference voltages).
- **Reference frequency/Close**: live frequencies for synchronization (same as reference voltages).



High voltage values

Reference voltage	L1	L2	L3
Primary	0.054 kV	0 kV	0.269 kV
Secondary	0.015 V	0 V	0.074 V
Frequency	0 Hz	0 Hz	0 Hz

Current	L1	L2	L3
Primary	1.024 A	2.048 A	4.096 A
Secondary	0.001 A	0.002 A	0.004 A
Frequency	0 Hz	0 Hz	0 Hz

Load voltage	L1	L2	L3
Primary	0.269 kV	0.269 kV	0.269 kV
Secondary	0.074 V	0.074 V	0.074 V

Reference frequency	L1	L2	L3
Open	0 Hz	0 Hz	0 Hz
Close	0 Hz	0 Hz	0 Hz

Figure 300 CSD100 HMI "Measurement\High voltage values" section

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Local values

- **Control voltage/DC1**: live coil control voltage 1 (CSD100 input port X10).
- **Control voltage/DC2**: live coil control voltage 2 (CSD100 input port X10).
- **Ambient temperature**: live ambient temperature from analogue sensor (CSD100 input port X12).
- **Ambient temperature/Main circuit breaker**: live temperature from circuit breaker pressure and temperature digital sensors (CSD100 input port X7), for each phase.



Local values

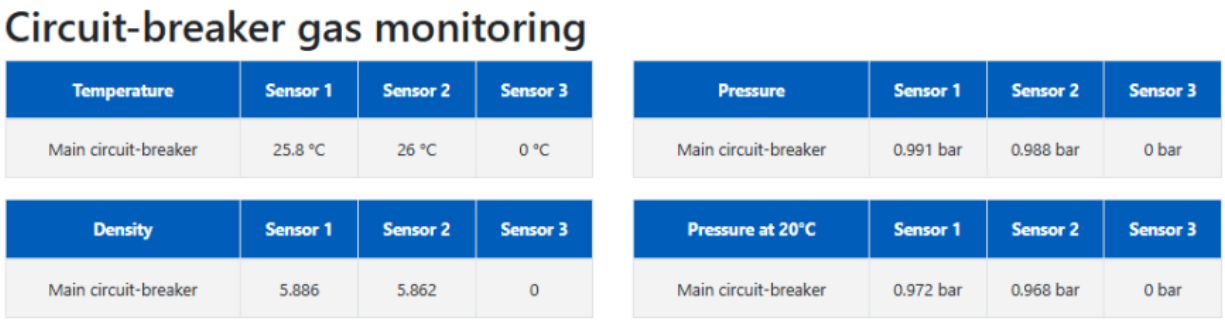
Control voltage	
DC1	0.012 V
DC2	0.012 V

Temperature	
Ambient temperature	-75.3 °C
Internal	40.8 °C

Figure 301 CSD100 HMI "Measurement\Local values" section

Gas monitoring

- **Temperature/Main circuit breaker**: live temperature from circuit breaker gas temperature and pressure digital sensors (CSD100 input port X7), for each phase.
- **Pressure/Main circuit breaker**: live pressure from circuit breaker gas temperature and pressure digital sensors (CSD100 input port X7), for each phase.
- **Equivalent pressure at 20°C/Main circuit breaker**: equivalent pressure calculated from temperature, pressure and dielectric characteristics of the insulating gas.
- **Density/Main circuit breaker**: gas density calculated from temperature, pressure and dielectric characteristics of the insulating gas.



Circuit-breaker gas monitoring

Temperature	Sensor 1	Sensor 2	Sensor 3
Main circuit-breaker	25.8 °C	26 °C	0 °C

Pressure	Sensor 1	Sensor 2	Sensor 3
Main circuit-breaker	0.991 bar	0.988 bar	0 bar

Density	Sensor 1	Sensor 2	Sensor 3
Main circuit-breaker	5.886	5.862	0

Pressure at 20°C	Sensor 1	Sensor 2	Sensor 3
Main circuit-breaker	0.972 bar	0.968 bar	0 bar

Figure 302 CSD100 HMI "Measurement\Local values" section

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Hydraulic drive monitoring

- **Hydraulic pressure/Main circuit breaker**: live pressure from circuit breaker hydraulic drive pressure digital sensors (CSD100 input port X7), for each phase.

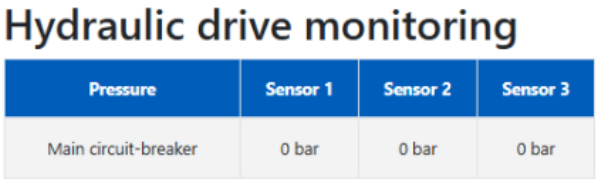


Figure 303 CSD100 HMI "Measurement\Hydraulic drive monitoring" section

"**Electrical wear**" subsection gathers electrical wear information for each phase of each circuit breaker, along with opening operations.

- **Last opening electrical wear**: expressed in kA².s for each phase of each circuit breaker (up to 6 values)
- **Cumulative electrical wear**: expressed in kA².s for each phase of each circuit breaker (up to 6 values)
- **Cumulative electrical wear as a percentage of the max acceptable wear (%)**: expressed in % of a settable maximum, for each phase of each circuit breaker (up to 6 values)

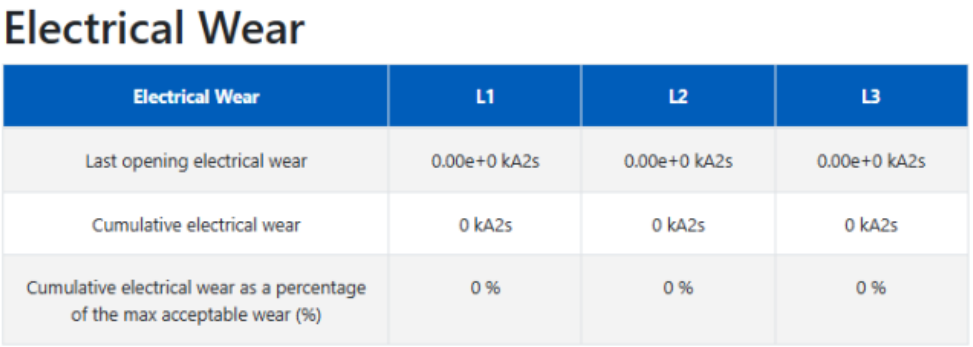


Figure 304 CSD100 HMI "Measurement\Electrical wear" section

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13.3 Getting Alarms - Alarms acknowledgement

"**Measurements\Alarms**" subsection reports detailed alarms status.

Alarms related to continuous monitoring process are not resettable. Alarms computed after operation are resettable (dedicated hardware digital input or "Reset Alarm" button in HMI home section).

Alarms related to absence of reference voltage or absence of reference current, and internal monitoring of coil activation circuitry are blocking (e.g. open and/or close orders are rejected).

Label	Description	Category
Reference voltage (L1, L2 or L3)	User settable min/max thresholds on source side voltages.	Permanent monitoring
Load voltage (L1, L2, L3)	User settable min/max thresholds on source side voltages.	Permanent monitoring
Current (L1, L2, L3)	User settable min/max thresholds on primary currents.	Permanent monitoring
Closing reference frequency (L1, L2, L3)	User settable min/max thresholds on measured frequency for synchronization	Permanent monitoring
Opening reference frequency (L1, L2, L3)	User settable min/max thresholds on measured frequency for synchronization	Permanent monitoring
UDC1	User settable min/max thresholds on coil control voltage 1.	Permanent monitoring
UDC2	User settable min/max thresholds on coil control voltage 2.	Permanent monitoring
Reference voltage	Absence of reference voltage for synchronization.	Permanent monitoring
Reference current	Absence of reference current for synchronization.	Permanent monitoring
Low data storage	Remaining data storage area for records is low.	Permanent monitoring
Date not reliable	Out of date	Permanent monitoring
Ambient temperature	User settable min/max thresholds on ambient temperature.	Permanent monitoring
Gas density (main circuit breaker) (L1, L2, L3)	User settable min/max thresholds on gas density.	Permanent monitoring
Gas density (second circuit breaker) (L1, L2, L3)	User settable min/max thresholds on gas density.	Permanent monitoring
Circuit breaker stroke (L1, L2, L3)	User settable min/max thresholds on circuit breaker position (mm).	Permanent monitoring
Internal temperature	User settable max threshold on internal temperature.	Internal monitoring
Power outputs (closing) (L1, L2, L3)	Monitoring of coil activation circuitry.	Internal monitoring
Power outputs (opening) (L1, L2, L3)	Monitoring of coil activation circuitry.	Internal monitoring
Making time (L1, L2, L3)	User settable max thresholds on making time error.	Post operation indicator
Peak current (L1, L2, L3)	User settable max thresholds on peak (inrush) current.	Post operation indicator
Reignition last opening (L1, L2, L3)	Reignition detected during last opening.	Post operation indicator
Reignition rate (L1, L2, L3)	Reignition rate is too high (user settable number of operations).	Post operation indicator

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Label	Description	Category
Reignition total (L1, L2, L3)	Total number of reignitions is above user settable threshold.	Post operation indicator
Arcing time (L1, L2, L3)	Arcing time is above one period.	Post operation indicator
Closing time tolerance (L1, L2, L3)	User settable max thresholds on difference between measured mechanical time and forecast.	Post operation indicator
Opening time tolerance (L1, L2, L3)	User settable max thresholds on difference between measured mechanical time and forecast.	Post operation indicator
Closing timeout (L1, L2, L3)	52a switching timeout	Post operation indicator
Opening timeout (L1, L2, L3)	52a switching timeout	Post operation indicator
Closing time (L1, L2, L3)	User settable min/max thresholds on measured mechanical times	Post operation indicator
Opening time (L1, L2, L3)	User settable min/max thresholds on measured mechanical times	Post operation indicator
Voltage dip phase-earth	User settable max threshold on source voltage dip phase-earth.	Post operation indicator
Voltage dip phase-phase	User settable max threshold on source voltage dip phase-phase.	Post operation indicator
ADC IAC (L1, L2, L3)	Int. monitoring of analogue channels	Perm.monitoring
ADC UAC (L1, L2, L3)	Int. monitoring of analogue channels	Perm.monitoring
ADC IDC (L1, L2, L3)	Int. monitoring of analogue channels	Perm.monitoring
ADC UDC 1	Int. monitoring of analogue channels	Perm.monitoring
ADC UDC 2	Int. monitoring of analogue channels	Perm.monitoring
ADC sensor 1	Int. monitoring of analogue channels	Perm.monitoring
ADC sensor 2	Int. monitoring of analogue channels	Perm.monitoring
ADC sensor 3	Int. monitoring of analogue channels	Perm.monitoring
ADC sensor 4	Int. monitoring of analogue channels	Perm.monitoring
Main circuit breaker electrical wear (L1, L2, L3)	Cumulated electrical wear above setable threshold	Post operation indicator
IEC 61850 MMS server failure	CSD100 server failure	Perm.monitoring
Sampled values alarm	Loss of samples, excess of samples, quality different from GOOD, smpSync lower than set value	Perm.monitoring

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Alarms



Alarm	L1	L2	L3
Reference voltage	−	−	−
Load voltage	−	−	−
Current	−	−	−
Closing reference frequency			
Opening reference frequency			
Power outputs (closing)			
Power outputs (opening)			
Gas density (main circuit-breaker)			
Gas density (second circuit-breaker)			
Circuit-breaker stroke			
Making time			
Peak current			
Reignition last opening			
Reignition rate			
Reignition total			
Arcing time			
Closing time tolerance			
Opening time tolerance			
Closing timeout			
Opening timeout			
Closing time			
Opening time			

Alarm	
UDC1	
UDC2	
Reference voltage	−
Reference current	−
Voltage dip phase-earth	
Voltage dip phase-phase	
Low data storage	
Date not reliable	
Internal temperature	
Ambient temperature	

Figure 305 Detailed alarms report subsection (HMI)

Note: alarms computed with min and max thresholds are displayed with a “minus” in case min threshold was exceeded and with a “plus” in case max threshold was exceeded.

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13.4 Alarms acknowledgement

To reset alarms, a dedicated HMI button (**Settings\Alarms** or **Home**) or a dedicated digital input shall be used.

Two types of alarms are to be distinguished:

- Alarms updated permanently in steady state (absence of reference waveform for synchronization…): those alarms are not acknowledgeable and are automatically set or reset upon alarm cause occurrence or extinction.
- Alarms updated after an operation (operation monitoring, performance indicators…): those alarms are latched after operation analysis and can be manually reset only if alarm cause has disappeared during last operation. If an alarm is still raised from last operation, it cannot be reset.

13.5 Local display

Local panel may be used to show measurements and essential information, without need for a laptop. It should not be used to set parameters. It is delivered as an option.

Physical connection is copper Ethernet (RJ45, recommended) or optical fiber.

The display embeds a web browser and shows same information as embedded HMI. Thus, a dedicated user/profile shall be created in the system specifically for the display.

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13.6 Equipment status (LEDs)

CSD100 status is summarized with 6 bicolor indicators (LED1 to LED6).

13.6.1 Signaling LED1 « Power »

Table 85 General power on/off indicator.

Status CSD100	LED1
Power ON	Fixed green
Power OFF	CSD100 is off

13.6.2 Signaling LED2 « Ready »

Synthesis of mandatory conditions to operate:

- Monitoring of power output circuitry (coils command power outputs self-monitoring)
- Presence/absence of reference synchronization waveform

Table 86 Ready to operate indicator

Status CSD100	LED2
Normal conditions (CB closed, ready to open and close)	Fixed green
Not able to operate (at least one mandatory condition is absent)	Fixed orange

13.6.3 Signaling LED3 « Alarm »

Any applicative or system alarm(s) may be assigned to this LED through user configuration.

Table 87 Alarm indicator

Status CSD100	LED3
No alarm	OFF
Alarms is set and assigned	Fixed orange

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13.6.4 Signaling LED4 « Eth »

Synthesis of active Ethernet communications on rear ports

Table 88 Ethernet activity indicator

Status CSD100	LED4
No physical link (link is broken)	OFF
Physical link is established, no traffic	Fixed green
Ethernet traffic	Blinking green

13.6.5 Signaling LED5 « Sync »

Table 89 Time synchronizing indicator

Status CSD100	LED5
Option to synchronize time on a server (NTP or PTP) is disabled	OFF
Time is synchronized by a server (PTP or NTP)	Fixed green
Connection to a time server is interrupted	Fixed orange

13.6.6 Signaling LED6 « SD »

This LED6 is a step-by-step indicator during use of the special SD card which resets CSD100 memory with factory default content (default settings, no records, deletes memorized values…). See section 14.4.5.

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13.7 Record files (archives)

CSD100 supports switching records, with local storage and provision for download through HMI.

A record consists in a zip file (archive file) which contains:

- **Comtrade files** (.dat and .cfg) which contains analogue and digital waveforms. This format is a standard format to exchange data.
- **Measurements file** in text / xml format, which indicates measurements during record creation.
- **Parameter file** in text / xml format, which reminds the settings (the context) during record creation.

The name of each record file (.zip) is made of:

- Year (2 digits)
- Month (2 digits)
- Day (2 digits)
- comma
- Hour (2 digits)
- Minutes (2 digits)
- Seconds (2 digits)
- Milliseconds (3 digits)
- Comma
- Time shift from UTC time (timezone),
- Comma
- Substation information (variable length)
- Comma
- CSD100 serial number (not settable)
- Comma
- End user information (company name)
- Comma
- Source of event creation (“Close”, “Open”, “unsync_open”, “unsync_close”, “voltage_event”, “trigger_event”, “config_event”)

Example of record file name:

“201214,122330877,+00h00t,SUBSTATION,7363427697,END_USER,trigger_event.zip”

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According to settings, archive generation can be triggered by:

- Incoming orders (open and close), as a default situation.
- Change of the circuit breaker position, to record transients during uncontrolled operations
- Occurrence / extinction of reference waveform
- Dedicated binary input for external triggering
- Change of MLS configuration (dedicated digital inputs)
- Alarms (individually settable)

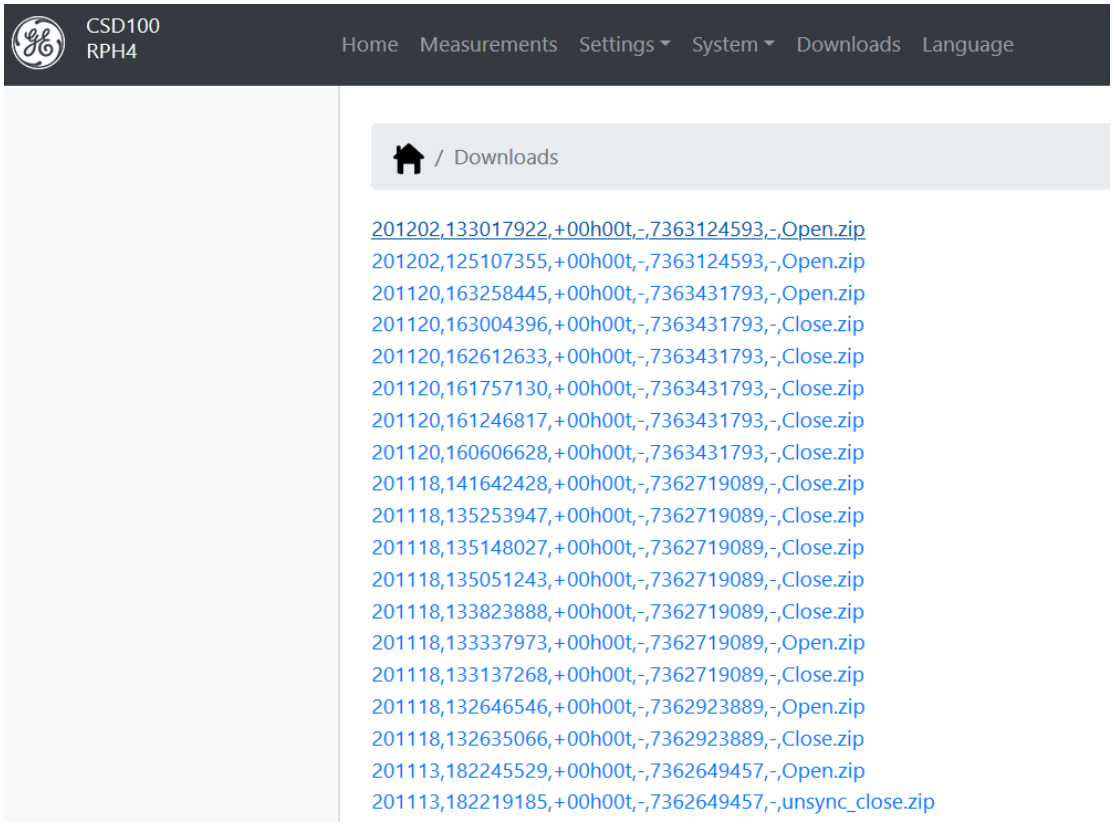


Figure 306 HMI records download section

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13.7.1 Param file

Param file “**param.xml**” is text file with xml formatting. See **Erreur ! Source du renvoi introuvable.**

13.7.2 Measurement file

Param file “**measures.xml**” is text file with xml formatting. See 21

13.7.3 Comtrade

Comtrade files main features:

- Sampling rate: 40 kHz.
- Record length: settable (pre trigger and post trigger).
- Maximum number of records: >10000 (with 1 second duration each), >2000 (5 seconds duration).

Available data:

- Analogue channels (x33) : voltage traces, circuit breaker current traces, auxiliary voltages, circuit breaker coils currents, analogue sensors traces.
- Digital channels (x34): digital inputs, power outputs, computed targets

See section 19

13.7.3.1 Naming of channels

Each comtrade channel name is settable and is made of:

- Prefix, settable individually for each channel (preset values in 0)
- Suffix, settable (automatically added to analogue channels) to identify each phase according to customer designation (“L1”, “L2”, “L3” : preset values).

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13.7.3.2 Analogue channels

Table 90 Comtrade analogue channels

Channel #	Channel name preset value (settable)	Description	Unit
1	UAC1 L1	L1 source side voltage measurement (X9-1-2)	V
2	UAC2 L2	L2 source side voltage measurement (X9-3-4)	V
3	UAC3 L3	L3 source side voltage measurement (X9-5-6)	V
4	UAC4 L1	L1 load side voltage measurement (X9-7-8)	V
5	UAC5 L2	L2 load side voltage measurement (X9-9-10)	V
6	UAC6 L3	L3 load side voltage measurement (X9-11-&2)	V
7	IAC1 L1	L1 Current measurement (X11-1-2)	A
8	IAC2 L2	L2 Current measurement (X11-3-4)	A
9	IAC3 L3	L3 Current measurement (X11-5-6)	A
10	UDC1	Coil control voltage 1 (preset to open) (X10-1-2)	V
11	UDC2	Coil control voltage 2 (preset to close) (X10-3-4)	V
12	ICOIL_1 L1	L1 coil current (open). Internal measurement.	A
13	ICOIL_2 L2	L2 coil current (open). Internal measurement.	A
14	ICOIL_3 L3	L3 coil current (open). Internal measurement.	A
15	ICOIL_4 L1	L1 coil current (close). Internal measurement.	A
16	ICOIL_5 L2	L2 coil current (close). Internal measurement.	A
17	ICOIL_6 L3	L3 coil current (close). Internal measurement.	A
18	Ambient temperature sensor	Ambient temperature from external analogue sensor (X12-10-11-12)	°C
19	CB travel sensor L1	L1 circuit breaker travel from analogue sensor (X12-1-2-3)	mm
20	CB travel sensor L2	L2 circuit breaker travel from analogue sensor (X12-4-5-6)	mm
21	CB travel sensor L3	L3 circuit breaker travel from analogue sensor (X12-7-8-9)	mm
22	pression sf6 CB1 phase 1	L1 SF6 pressure (20°C) from digital sensor (X7)	MPa
23	pression sf6 CB1 phase 2	L2 SF6 pressure (20°C) from digital sensor (X7)	MPa
24	pression sf6 CB1 phase 3	L3 SF6 pressure (20°C) from digital sensor (X7)	MPa
25	pression sf6 CB2 phase 1	L1 SF6 pressure (20°C) from digital sensor (X7), second circuit breaker	MPa
26	pression sf6 CB2 phase 2	L2 SF6 pressure (20°C) from digital sensor (X7), second circuit breaker	MPa
27	pression sf6 CB2 phase 3	L3 SF6 pressure (20°C) from digital sensor (X7), second circuit breaker	MPa
28	pression hydraulique CB1 phase 1	L1 hydraulic drive pressure from digital sensor (X7)	MPa
29	pression hydraulique CB1 phase 2	L2 hydraulic drive pressure from digital sensor (X7)	MPa
30	pression hydraulique CB1 phase 3	L3 hydraulic drive pressure from digital sensor (X7)	MPa
31	pression hydraulique CB2 phase 1	L1 hydraulic drive pressure from digital sensor (X7), second circuit breaker	MPa
32	pression hydraulique CB2 phase 2	L2 hydraulic drive pressure from digital sensor (X7), second circuit breaker	MPa
33	pression hydraulique CB2 phase 3	L3 hydraulic drive pressure from digital sensor (X7), second circuit breaker	MPa

Note: number of recorded analogue channels may vary according to actual settings and installed sensors.

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13.7.3.3 Digital channels

Table 91 Comtrade digital channels

Channel #	Channel name preset value (settable)	Measurement description	Type
1	Open input order	Order to start open operation	DI external input
2	Close input order	Order to start close operation	DI external input
3	CB1 _52a L1	L1 signaling from 52a	DI external input
4	CB1 _52a L2	L2 signaling from 52a	DI external input
5	CB1 _52a L3	L3 signaling from 52a	DI external input
6	CB2 _52a L1	L1 signaling from 52a, 2nd circuit breaker	DI external input
7	CB2 _52a L2	L2 signaling from 52a, 2nd circuit breaker	DI external input
8	CB2 _52a L3	L3 signaling from 52a, 2nd circuit breaker	DI external input
9	Record trigger	External trigger signal for record creation	DI external input
10	MLS_01	Multiple load switching 1	DI external input
11	MLS_02	Multiple load switching 2	DI external input
12	MLS_03	Multiple load switching 3	DI external input
13	MLS_04	Multiple load switching 4	DI external input
14	Bypass_Key	External bypass position measurement	DI external input
15	Test_Mode	Activation of commissioning mode	DI external input
16	Alarm_reset	Reset signal for alarms	DI external input
17	UVLO_01 L1	Power output internal monitoring L1 (open)	DI internal
18	UVLO_02 L2	Power output internal monitoring L2 (open)	DI internal
19	UVLO_03 L3	Power output internal monitoring L3 (open)	DI internal
20	UVLO_04 L1	Power output internal monitoring L1 (close)	DI internal
21	UVLO_05 L2	Power output internal monitoring L2 (close)	DI internal
22	UVLO_06 L3	Power output internal monitoring L3 (close)	DI internal
23	IGBT_CMD_1 L1	L1 power transistor activation (open)	DO internal
24	IGBT_CMD_2 L2	L2 power transistor activation (open)	DO internal
25	IGBT_CMD_3 L3	L3 power transistor activation (open)	DO internal
26	IGBT_CMD_4 L1	L1 power transistor activation (close)	DO internal
27	IGBT_CMD_5 L2	L2 power transistor activation (close)	DO internal
28	IGBT_CMD_6 L3	L3 power transistor activation (close)	DO internal
29	Make_target L1	L1 making time target (close)	Computed status
30	Make_target L2	L2 making time target (close)	Computed status
31	Make_target L3	L3 making time target (close)	Computed status
32	Sep_target L1	L1 current extinction target (open)	Computed status
33	Sep_target L2	L2 current extinction target (open)	Computed status
34	Sep_target L3	L3 current extinction target (open)	Computed status

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13.8 Communication over Ethernet (100/1000Mbps)

CSD100 supports and embeds:

- Web based interface based on HTTPS protocol, the mandatory entry point to set the device. This interface is available on both front port and rear ports (with different IP addresses)
- Fixed/static IP addresses or DHCP (client) for dynamic IP settings (front port and rear ports).
- Gateway, to direct communications to an external network (WAN). Gateways at front port and rear ports are forbidden.
- 61850 Ed.2 protocol to publish internal data (front port and rear ports)
- Rear ports ethernet switch management functions:
- “IEEE 802.1Q” including VLAN.
- Redundancy, for two of the four rear ports, with two modes available:
    - PRP
    - HSR

13.8.1 Communication protocols over Ethernet TCP/IP

CSD100 requires IP addresses, either fixed (from set of parameters) or dynamic (from DHCP server located in the network).

The rear face (connectors face) 2 Ethernet ports (SFP modules) are connected to an internal ethernet switch. Thus, a single IP address is necessary for this set of ports.

The front face (RJ45) Ethernet port is managed separately and requires its own address.

Table 92 CSD100 available communication protocols

Protocol / Standard	Description	Comment
HTTPS (Hypertext transfer protocol secure)	Embedded web server access for web pages. Access is secured by login/password.	Display of embedded web pages with standard web browser (Mozilla Firefox or Google Chrome recommended): settings and measurements.
IEC 61850-8-1 Ed.2	IEC61850 server to publish a relevant subset (“data model”) of internal numerical quantities and associated status (quality…). See 13.8.2 (dataset)	Conforms to Edition 2. Publication of measurements and alarms Polling and reports (unbuffered) Disturbance recorder function and file transfer service. Flexible logical node naming

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13.8.2 Embedded ethernet switch configuration: VLAN

This section provides information about the four rear ethernet ports only.

In the context of CSD100, VLAN can reinforce data security, by placing data exchanges in a VLAN with restricted accesses.

Each of the four rear ports is manageable independently: VLAN can be activated/deactivated, and VLAN id & names can be set for each port.

Each port transmits (in both directions) only:

- Frames with VLAN tag and VLAN id for which this port is configured.
- Frames without VLAN tag (these frames are internally VLAN tagged with default VLAN id, and are untagged while retransmitted outside)

13.8.3 Redundancy

Redundancy is implemented to guarantee seamless availability of information, as well as short recovery time. When activated, this option is mandatorily supported by ethernet physical ports X2 (LAN A) and X4 (LAN B). See 10.1.5

Two types of redundancy are supported:

- PRP: two separated networks, operated in parallel (same MAC address).
- HSR: a network ring or meshed topology.

Remarks:

- It is necessary to reboot the equipment after changing redundancy mode (None / HSR / PRP)
- Redundancy MAC address is the address to send the supervision frame of a redundancy network (each subscriber of the network sends periodic signaling at this address, for monitoring purpose)

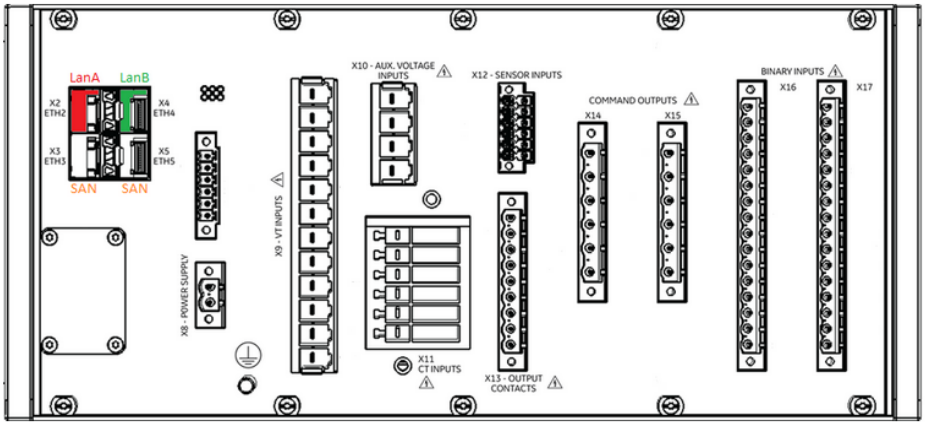


Figure 307 Rear ports configuration in PRP mode

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13.8.4 IEC 61850-8.1 Ed.2

Model Implementation Conformance Statement (MICS), Protocol Implementation Conformance Statement (PICS) and Protocol Implementation Conformance Extra Information for Testing (PIXIT) documents are available on request.

13.8.4.1 Data model

The CSD100 IEC 61850 data model is summarized below. Several recurrent data attributes (“Beh”, “Mod”) have been intentionally removed, for brevity.

Table 93 CSD100 summarized IEC 61850 mapping

Logical Node	Data object name	Comment
LPHD1	PhyHealth	“OK” or “Alarm”. Internal hardware monitoring, including internal temperature.
	Proxy	“false” (constant)
STMP1	Tmp	Circuit breaker ambient temperature
LTMS1	TmSrc	Current time source identity
	TmSrcTyp	Origin of the clock source (SNTP, PTP)
	TmChSt1	Time channel status (true = live)
LCCH1	Mod	Communication redundancy enabled (« true » or « false »)
	ChLiv	Communication port A status
	RedChLiv	Communication port B status
LGOS1**	St	Goose subscription active (« true » or « false »)
	LastStNum	Last state number of the received GOOSE message.
	GoCBRef	Object reference of subscribed GOOSE control block
GGIO1**	IntIn1	Integer for SV selection among predefined configurations
LOAD_MMXU1	A.phsA	Circuit breaker current (phase A)
	A.phsB	Circuit breaker current (phase B)
	A.phsC	Circuit breaker current (phase C)
	PhV.phsA	Load voltage (phase A)
	PhV.phsB	Load voltage (phase B)
	PhV.phsC	Load voltage (phase C)
SRC_MMXU1	PhV.phsA	Source voltage (phase A)
	PhV.phsB	Source voltage (phase B)
	PhV.phsC	Source voltage (phase C)
	Hz	Measured network frequency
ASOPM1	HyPres	Hydraulic drive pressure (% of rated value, 0% = lockout). Phase A, 1st CB.
	EnAlm	Hydraulic drive pressure out of boundaries. Phase A, 1st CB.
BSOPM1	HyPres	Hydraulic drive pressure (% of rated value, 0% = lockout). Phase B, 1st CB.
	EnAlm	Hydraulic drive pressure out of boundaries. Phase B, 1st CB.
CSOPM1	HyPres	Hydraulic drive pressure (% of rated value, 0% = lockout). Phase C, 1st CB.
	EnAlm	Hydraulic drive pressure out of boundaries. Phase C, 1st CB.
ASOPM2	HyPres	Hydraulic drive pressure (% of rated value, 0% = lockout). Phase A, 2nd CB.
	EnAlm	Hydraulic drive pressure out of boundaries. Phase A, 2nd CB.
BSOPM2	HyPres	Hydraulic drive pressure (% of rated value, 0% = lockout). Phase B, 2nd CB.

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Logical Node	Data object name	Comment
	EnAlm	Hydraulic drive pressure out of boundaries. Phase B, 2nd CB.
CSOPM2	HyPres	Hydraulic drive pressure (% of rated value, 0% = lockout). Phase C, 2nd CB.
	EnAlm	Hydraulic drive pressure out of boundaries. Phase C, 2nd CB.
ASIMG1	P20	Computed gas equivalent pressure at 20°C (tot. pressure). Ph A, 1st CB.
	Den	Computed density. Ph A, 1st CB.
	DenAlm	Computed density alarm. Ph A, 1st CB.
	InsAlm	Computed density alarm. Ph A, 1st CB.
BSIMG1	P20	Computed gas equivalent pressure at 20°C (tot. pressure). Ph B, 1st CB.
	Den	Computed density. Ph B, 1st CB.
	DenAlm	Computed density alarm. Ph B, 1st CB.
	InsAlm	Computed density alarm. Ph B, 1st CB.
CSIMG1	P20	Computed gas equivalent pressure at 20°C (tot. pressure). Ph C, 1st CB.
	Den	Computed density. Ph C, 1st CB.
	DenAlm	Computed density alarm. Ph C, 1st CB.
	InsAlm	Computed density alarm. Ph C, 1st CB.
ASIMG2	P20	Computed gas equivalent pressure at 20°C (tot. pressure). Ph A, 2nd CB.
	Den	Computed density. Ph A, 2nd CB.
	DenAlm	Computed density alarm. Ph A, 2nd CB.
	InsAlm	Computed density alarm. Ph A, 2nd CB.
BSIMG2	P20	Computed gas equivalent pressure at 20°C (tot. pressure). Ph B, 2nd CB.
	Den	Computed density. Ph B, 2nd CB.
	DenAlm	Computed density alarm. Ph B, 2nd CB.
	InsAlm	Computed density alarm. Ph B, 2nd CB.
CSIMG2	P20	Computed gas equivalent pressure at 20°C (tot. pressure). Ph C, 2nd CB.
	Den	Computed density. Ph C, 2nd CB.
	DenAlm	Computed density alarm. Ph C, 2nd CB.
	InsAlm	Computed density alarm. Ph C, 2nd CB.
ASCBR1	OpCntRs	Open operation counter (controlled and uncontrolled, 52a transition). Phase A.
	AuxSwTmOpn	Timing of the open operation measured by auxiliary switches. Phase A.
	AuxSwTmCls	Timing of the close operation measured by auxiliary switches. Phase A.
	TgtDscCls	Measured making time error. Phase A.
	OpTmOpn	Operation timing of main contact during open operation. Phase A.
	OpTmCls	Operation timing of main contact during close operation. Phase A.
	ColEnOpn	actuation charge open coil. Phase A.
	ColEnCls	actuation charge close coil. Phase A.
	ArcTm	Measured arcing time. Phase A.
	OpTmClsAlm	close time out of boundaries. Phase A.
	OpTmOpnAlm	open time out of boundaries. Phase A.
	ArcTmAlm	arcing time exceeded. Phase A.
	ArcTmDscCnt	Cumulated number of reignitions (controlled operations). Phase A.
	ColOpn	If true, coil was energized by CSD100
	AbrAlm	Accumulated electrical wear above second threshold. Ph. A, 1st CB

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Logical Node	Data object name	Comment
	AbrWrn	Accumulated electrical wear above first threshold. Ph. A, 1st CB
	ActAbr	Last opening electrical wear. Phase A.
	AccmAbr	Accumulated electrical wear. Phase A.
BSCBR1	OpCntRs	Open operation counter (controlled and uncontrolled, 52a transition). Phase B.
	AuxSwTmOpn	Timing of the open operation measured by auxiliary switches. Phase B.
	AuxSwTmCls	Timing of the close operation measured by auxiliary switches. Phase B.
	TgtDscCls	Measured making time error. Phase B.
	OpTmOpn	Operation timing of main contact during open operation. Phase B.
	OpTmCls	Operation timing of main contact during close operation. Phase B.
	ColEnOpn	actuation charge open coil. Phase B.
	ColEnCls	actuation charge close coil. Phase B.
	ArcTm	Measured arcing time. Phase B.
	OpTmClsAlm	close time out of boundaries. Phase B.
	OpTmOpnAlm	open time out of boundaries. Phase B.
	ArcTmAlm	arcing time exceeded. Phase B.
	ArcTmDscCnt	Cumulated number of reignitions (controlled operations). Phase B.
	ColOpn	If true, coil was energized by CSD100
	AbrAlm	Accumulated electrical wear above second threshold. Ph. B, 1st CB
	AbrWrn	Accumulated electrical wear above first threshold. Ph. B, 1st CB
	ActAbr	Last opening electrical wear. Phase B.
	AccmAbr	Accumulated electrical wear. Phase B.
CSCBR1	OpCntRs	Open operation counter (controlled and uncontrolled, 52a transition). Phase C.
	AuxSwTmOpn	Timing of the open operation measured by auxiliary switches. Phase C.
	AuxSwTmCls	Timing of the close operation measured by auxiliary switches. Phase C.
	TgtDscCls	Measured making time error. Phase C.
	OpTmOpn	Operation timing of main contact during open operation. Phase C.
	OpTmCls	Operation timing of main contact during close operation. Phase C.
	ColEnOpn	actuation charge open coil. Phase C.
	ColEnCls	actuation charge close coil. Phase C.
	ArcTm	Measured arcing time. Phase C.
	OpTmClsAlm	close time out of boundaries. Phase C.
	OpTmOpnAlm	open time out of boundaries. Phase C.
	ArcTmAlm	arcing time exceeded. Phase C.
	ArcTmDscCnt	Cumulated number of reignitions (controlled operations). Phase C.
	ColOpn	If true, coil was energized by CSD100
	AbrAlm	Accumulated electrical wear above second threshold. Ph. C, 1st CB
	AbrWrn	Accumulated electrical wear above first threshold. Ph. C, 1st CB
	ActAbr	Last opening electrical wear. Phase C.
	AccmAbr	Accumulated electrical wear. Phase C.
ASCBR2 (*)	OpCntRs	Open operation counter (controlled and uncontrolled, 52a transition). Phase A.
	AuxSwTmOpn	Timing of the open operation measured by auxiliary switches. Phase A.
	AuxSwTmCls	Timing of the close operation measured by auxiliary switches. Phase A.

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Logical Node	Data object name	Comment
	TgtDscCls	Measured making time error. Phase A.
	OpTmOpn	Operation timing of main contact during open operation. Phase A.
	OpTmCls	Operation timing of main contact during close operation. Phase A.
	ColEnOpn	actuation charge open coil. Phase A.
	ColEnCls	actuation charge close coil. Phase A.
	ArcTm	Measured arcing time. Phase A.
	OpTmClsAlm	close time out of boundaries. Phase A.
	OpTmOpnAlm	open time out of boundaries. Phase A.
	ArcTmAlm	arcing time exceeded. Phase A.
	ArcTmDscCnt	Cumulated number of reignitions (controlled operations). Phase A.
	ColOpn	If true, coil was energized by CSD100
	AbrAlm	Accumulated electrical wear above second threshold. Ph. A, 2nd CB
	AbrWrn	Accumulated electrical wear above first threshold. Ph. A, 2nd CB
	ActAbr	Last opening electrical wear. Phase A. CB2
	AccmAbr	Accumulated electrical wear. Phase A. CB2
BSCBR2 (*)	OpCntRs	Open operation counter (controlled and uncontrolled, 52a transition). Phase B.
	AuxSwTmOpn	Timing of the open operation measured by auxiliary switches. Phase B.
	AuxSwTmCls	Timing of the close operation measured by auxiliary switches. Phase B.
	TgtDscCls	Measured making time error. Phase B.
	OpTmOpn	Operation timing of main contact during open operation. Phase B.
	OpTmCls	Operation timing of main contact during close operation. Phase B.
	ColEnOpn	actuation charge open coil. Phase B.
	ColEnCls	actuation charge close coil. Phase B.
	ArcTm	Measured arcing time. Phase B.
	OpTmClsAlm	close time out of boundaries. Phase B.
	OpTmOpnAlm	open time out of boundaries. Phase B.
	ArcTmAlm	arcing time exceeded. Phase B.
	ArcTmDscCnt	Cumulated number of reignitions (controlled operations). Phase B.
	ColOpn	If true, coil was energized by CSD100
	AbrAlm	Accumulated electrical wear above second threshold. Ph. B, 2nd CB
	AbrWrn	Accumulated electrical wear above first threshold. Ph. B, 2nd CB
	ActAbr	Last opening electrical wear. Phase B. CB2.
	AccmAbr	Accumulated electrical wear. Phase B. CB2.
CSCBR2 (*)	OpCntRs	Open operation counter (controlled and uncontrolled, 52a transition). Phase C.
	AuxSwTmOpn	Timing of the open operation measured by auxiliary switches. Phase C.
	AuxSwTmCls	Timing of the close operation measured by auxiliary switches. Phase C.
	TgtDscCls	Measured making time error. Phase C.
	OpTmOpn	Operation timing of main contact during open operation. Phase C.
	OpTmCls	Operation timing of main contact during close operation. Phase C.
	ColEnOpn	actuation charge open coil. Phase C.
	ColEnCls	actuation charge close coil. Phase C.
	ArcTm	Measured arcing time. Phase C.

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Logical Node	Data object name	Comment
	OpTmClsAlm	close time out of boundaries. Phase C.
	OpTmOpnAlm	open time out of boundaries. Phase C.
	ArcTmAlm	arcing time exceeded. Phase C.
	ArcTmDscCnt	Cumulated number of reignitions (controlled operations). Phase C.
	ColOpn	If true, coil was energized by CSD100
	AbrAlm	Accumulated electrical wear above second threshold. Ph. C, 2nd CB
	AbrWrn	Accumulated electrical wear above first threshold. Ph. C, 2nd CB
	ActAbr	Last opening electrical wear. Phase C. CB2.
	AccmAbr	Accumulated electrical wear. Phase C. CB2.
CPOW1	TmExc	Constant (false)
	Health	Capacity to ensure proper synchronization (internal monitoring and presence of synchronization waveform)
	MaxTrsA.phsA	last closing - Current peak value phase A
	MaxTrsA.phsB	last closing - Current peak value phase B
	MaxTrsA.phsC	last closing - Current peak value phase C
	MinTrsPhVPct.phsA	last closing - Voltage drop phase A
	MinTrsPhVPct.phsB	last closing - Voltage drop phase B
	MinTrsPhVPct.phsC	last closing - Voltage drop phase C
	MinTrsPPVPct.phsAB	last closing - Voltage drop phase A-B
	MinTrsPPVPct.phsBC	last closing - Voltage drop phase B-C
	MinTrsPPVPct.phsCA	last closing - Voltage drop phase C-A
	Dc1	Control voltage DC1
	Dc2	Control voltage DC2
	OpCntOpnA1	Opening operation counter, phase A, circuit breaker 1
	OpCntOpnB1	Opening operation counter, phase B, circuit breaker 1
	OpCntOpnC1	Opening operation counter, phase C, circuit breaker 1
	OpCntOpnA2	Opening operation counter, phase A, circuit breaker 2
	OpCntOpnB2	Opening operation counter, phase B, circuit breaker 2
	OpCntOpnC2	Opening operation counter, phase C, circuit breaker 2
	OpCntClsA1	Closing operation counter, phase A, circuit breaker 1
	OpCntClsB1	Closing operation counter, phase B, circuit breaker 1
	OpCntClsC1	Closing operation counter, phase C, circuit breaker 1
	OpCntClsA2	Closing operation counter, phase A, circuit breaker 2
	OpCntClsB2	Closing operation counter, phase B, circuit breaker 2
	OpCntClsC2	Closing operation counter, phase C, circuit breaker 2
	TestKey	Commissioning mode enable input position
	PosA	Circuit breaker position (Phase A)
	PosB	Circuit breaker position (Phase B)
	PosC	Circuit breaker position (Phase C)
	CritAlm	Position of bistable 2 output signaling relay (according to alarm assignment)
	Wrn	Position of bistable 1 output signaling relay (according to alarm assignment)
	BypPos	Bypass input position

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Logical Node	Data object name	Comment
	TmpAlm	Ambient temperature alarm
	RefPhVAlm	Reference voltage alarm
	RefAALm	Reference current alarm
	DC1LoAlm	Voltage DC1 low
	DC1HiAlm	Voltage DC1 high
	DC2LoAlm	Voltage DC2 low
	DC2HiAlm	Voltage DC2 high
	ATgtClsAlm	Making time error, phase A
	BTgtClsAlm	Making time error, phase B
	CTgtClsAlm	Making time error, phase C
	AArcTmCntAlm	Reignition alarm during last opening, phase A
	BArcTmCntAlm	Reignition alarm during last opening, phase B
	CArcTmCntAlm	Reignition alarm during last opening, phase C
	AMaxTrsAAlm	Peak current alarm, phase A
	BMaxTrsAAlm	Peak current alarm, phase B
	CMaxTrsAAlm	Peak current alarm, phase C
	MinTrsPhVAlm	Voltage dip alarm, phase to earth
	MinTrsPPVAlm	Voltage dip alarm, phase to phase
	ActSvSet	Active sampled values subscription scheme
RDRE1	RcdMade	New record available
	FltNum	Record number

(*) in case of double circuit breaker (open or close)

(**) custom CID in case SV subscription is enabled

13.8.4.2 Configuration

The IED Capability Description file (.icd) is available for download in the dedicated section of the HMI.

The default Configured IED Description file (.cid) is available for download in the dedicated section of the HMI. This file activates the whole dataset of the CSD100. From this default CID file, user can adjust communication capabilities (text editing or external configurator, not supplied) and upload personalized CID file.

At any moment, it is possible to switch between default CID file and customized CID file, with HMI.

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13.8.5 Sampled Values subscription

When set with “sampled values” acquisition mode, CSD100 monitors voltages and currents from digital streams instead of analog signals. All functions of the device remain similar in “Analogue” or “Sampled values” mode.

A set of 10 configurations is available to select the final data needed by the CSD100 (U1..U3, U4..U6, I1..I3) from all incoming streams (reflecting the substation configuration).

The user can select one of them either manually from the web HMI or dynamically from GOOSE subscription.

The user can select one of them (one among ten) either manually from the web HMI or dynamically from GOOSE subscription.

CSD100 supports following variants:

- **F4000S1I4U4**: 4000 Hz / 1 ASDU (80 SPC @ 50 Hz) – 9.2LE guideline compatible
- **F4800S1I4U4**: 4800 Hz / 1 ASDU (80 SPC @ 60 Hz) – 9.2LE guideline compatible
- **F4800S2IxUy**: 4800 Hz / 2 ASDU ($x + y \leq 24$)

Refer to 13.1.4 for configuration details and 24 for some use cases description.

Note: Sampled Values messages are only processed from back side ports.

13.8.6 GOOSE subscription

CSD100 supports Layer 2 multicast GOOSE.

Subscription to a GOOSE published by another IED allows dynamic selection of the SV streams, needed for the CSD100 operation. A GOOSE control block (GoCB) must be configured with data consistent with GOOSE publisher IED.

Configuration shall be transmitted using “Generic integer status input” (IntIn), an integer from 0 to 9, from a GGIO logical node for example.

Section 13.1.20 describes how to enable GOOSE subscription and set publisher identifiers.

Notes:

- GOOSE subscription status can be monitored through a LGOS logical node
- Active SV subscription scheme is available in CPOW logical node “ActSvSet”



GOOSE subscription requires use of a custom CID file.
Use of default CID file is not compatible with GOOSE subscription.
Configuration of a GOOSE subscription (with a GoCB) in the CID file is an activity for a 61850 specialist or requires a dedicated configurator tool.

An example extract from a CSD100 custom CID file and content of ad ’hoc publisher are given in 24.3

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14 SECURE DEPLOYMENT GUIDE: SECURITY MANAGEMENT AND RECOMMENDATIONS

This section outlines measures for secure operation of CSD100. It applies to firmware version 1.3.x.

It describes security hardening setup and best practices to configure CSD100. It provides an overview of supported cybersecurity capabilities and recommended settings.

This section is the response to IEC62443-4-1 “Practice 8 – Security Guidelines” requirements.

14.1 Product Defense-in-Depth strategy

The product implements the following security features:

- Secure design process to ensure that cyber security is part of the design process and not an afterthought.
- Security testing to detect as much as possible vulnerabilities at the design stage.
- Digital signature of firmware/software package to allow integrity and authenticity verification before installation.
- Monitoring of software components vulnerabilities.
- User authentication.
- Role based access control and least privileges to enforce area of responsibilities.
- Password and user account policies to prevent use of weak passwords and password brute force attack.
- Security event logging for post-incident analysis.
- Centralized security event logging using SYSLOG protocol to send event to a SOC and allow close to real time security monitoring.
- Secure configuration protocols using TLS to protect credentials and sensitive information while in transit.
- Hardening to reduce the attack surface.

To complement the defense in depth strategy, the product shall be installed in a secure environment. See paragraph 14.2

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14.2 Environment

CSD100 is designed to be installed and operated in a utility and industrial environment, connected to a private network inside the electronic security perimeter (ESP). It is not recommended to connect a device, directly or indirectly, to the Internet.

While this guide covers product-level security, it's crucial to remember that complete security involves broader considerations beyond the product alone.

GE recommends applying security measures to the entire system in which CSD100 is installed, following a defense-in-depth approach. Security includes (but is not restricted to)

- Physical security, such as building access control, locked cabinets.
- Security policies.
- Network security measures, such as segmentation, use of firewalls, use of secure protocols.
- Security monitoring, such as network intrusion detection systems, as well as security event logging using a centralized server.
- System hardening by disabling unused processes and ports.
- If remote access into the substation network is required, employ secure methods, such as a Virtual Private Network (VPN), using dual authentication, recognizing that the VPN is only as secure as the connected devices.
- Exercise utmost caution and refrain from connecting the CSD100 to the internet and business networks, as doing so may expose it to potential security risks and vulnerabilities.
- User security awareness training.

In addition, remote configuration/monitoring of the device (i.e. not from the front panel) shall be done from a secure engineering workstation through a trusted network link.

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14.3 Secure installation - Hardening

Upon receipt of a CSD100 device, the following actions are recommended.

- Verifying software integrity
- Upgrade to the latest firmware available.
- Configure accounts and passwords.
- Disable unused ports and protocols.

Authentication is mandatory for CSD100 access. Each of CSD100 features can be managed with embedded HMI and standard web browser. Mozilla Firefox is recommended.

14.3.1 Verifying software integrity

Before installing any firmware, installation package integrity shall be verified. Refer to section 23.

GE software are digitally signed.

Digital signature verification of a piece of software is done by right-clicking on the filename and selecting the Digital Signature tab in the Properties menu. The signature Details shall read “This digital signature is OK”.

The software shall not be installed when the signature verification fails. In such a case, please contact your support organization.

For artefacts integrity verification, please refer to section 23, GE provides a manual process to verify integrity of configuration file, and certificates.

14.3.2 Upgrading firmware to the latest version

CSD100 firmware must be upgraded to the latest version available for the major version used, to take advantage of all fixed known vulnerabilities. Make sure you are using the firmware package downloaded from GE official site. Firmware upgrade procedure can be found in section 13.1.21.

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To be kept updated on the available package and receive notification, you can subscribe to the web portal and manage your subscription.

Note: an account is required to access the available resources of the portal.

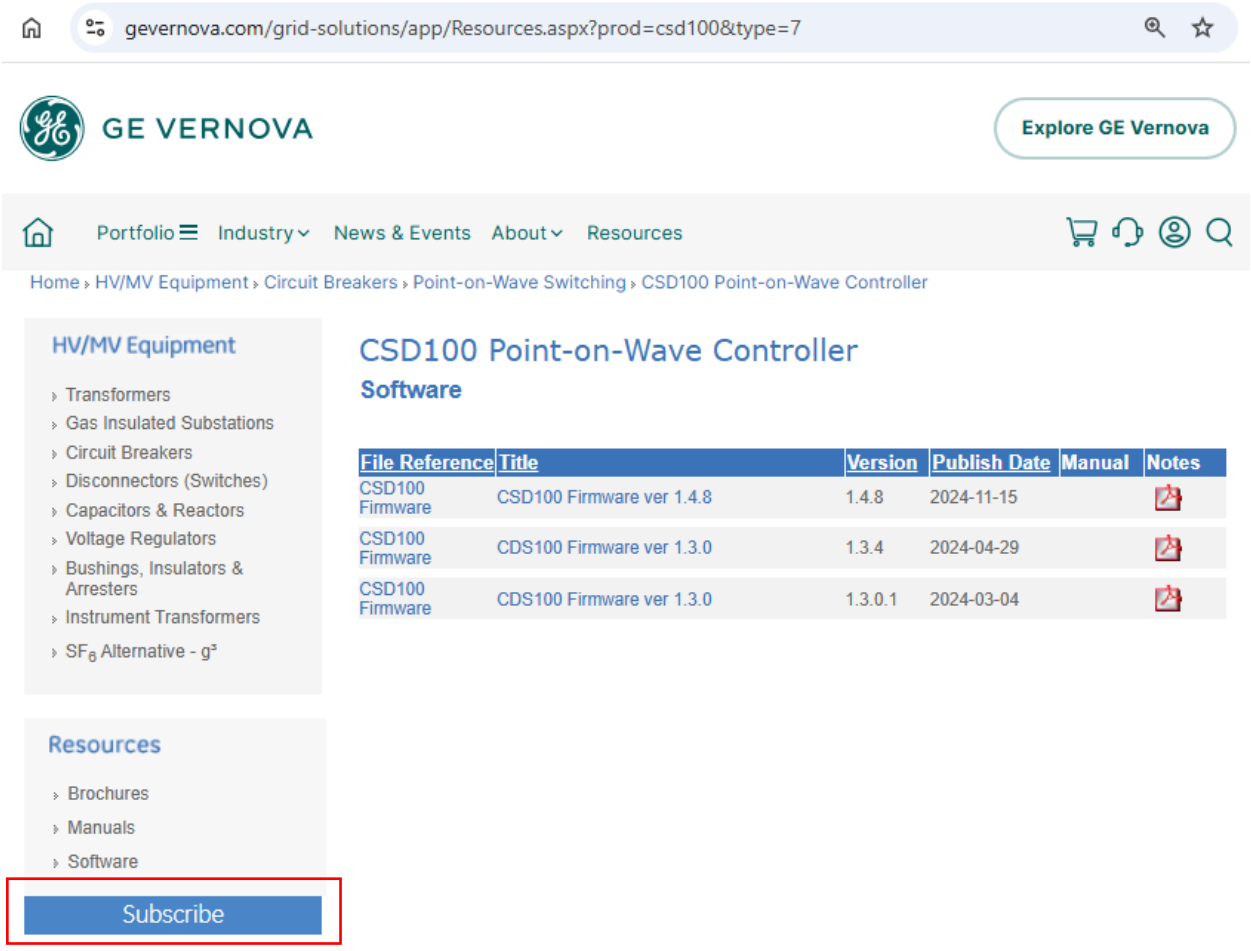


Figure 308 Web portal resources

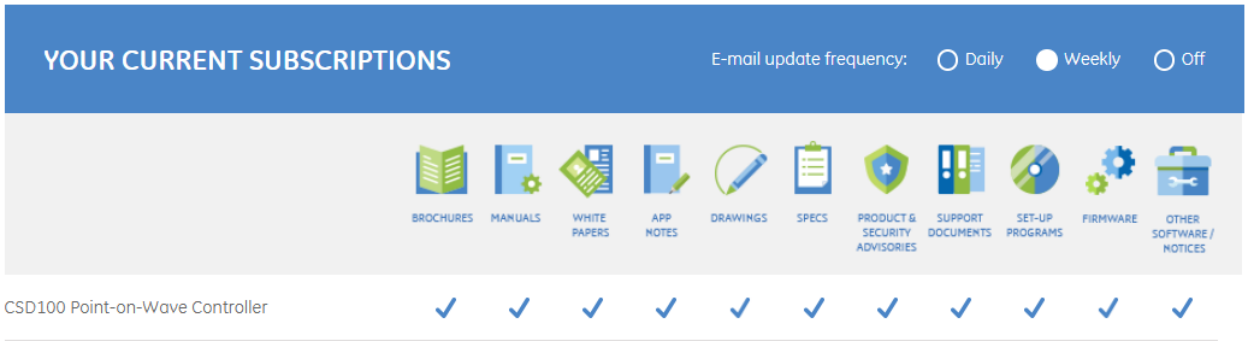


Figure 309 Web portal resources subscription management

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14.3.3 Disable unused logical ports and protocols.

CSD100 supports the following protocols. All ports that are enabled by default cannot be disabled by design because they are core service required for the reliable function of the device.

Purpose of this table is also to facilitate firewall port control (rules definition), if any.

Table 94 CSD100 list of supported protocols

Service	Protocol	Port	Purpose	Default status	Authentication	HMI section
HTTPS	TCP	443	Web HMI: settings, measurements, records	Active (not settable)	yes	13.1
DHCP	TCP	68	IP address automatic attribution	Not active	no	13.1.19
Ping	ICMP	NA	Device ping	Not active	no	13.1.24
Idserver	UDP	7777	IP address retrieve service	Active (not settable)	no	
IEC 61850 - MMS	TCP	102	Data publication (measurements and alarms) GOOSE subscription for selection of sampled value incoming streams	Not active	no	13.1.20
Sampled values	9.2LE, IEC 61869-9	NA (Layer 2)	Subscription to multicast sampled values control block	Not active	no	13.1.4
NTP	TCP	123	Time synchronization	Not active	no	13.1.18
PTP v2	UDP	319-320	Time synchronization	Not active	no	13.1.18
Syslog	UDP	514* (settable)	Security events logging	Not active	no	13.1.26.1

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14.3.4 Configuring secure protocols

CSD100 uses the secure protocol in the following cases:

- Web interface access

TLS needs a private key and public key certificate (PKC) to be deployed on the CSD100, and a PKC to be deployed on the engineering workstation. Refer to section 22 appendix.

Limitations:

- As CSD100 does not support Certification Revocation Lists not certificate auto provisioning, GE recommends self-signed certificates with long expiring date. In this case, GE Vernova recommends verifying the self-certificate before any web server connection".
- CSD100 does not support IEC 61850 protocols encryption, giving possibility to a breach of integrity or authenticity. Recommendations in sections 14.1 and 14.2 shall be implemented to mitigate this limitation.

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14.3.5 User access control and authorization enforcement - Account management guideline

14.3.5.1 Default user account

After firmware upgrade to V1.3 or upon delivery, CSD100 will initiate with a single user possessing the SECADM role (login: ”admin”, password: ”admin”). Additionally, CSD100 embeds a mechanism to prevent deletion of the last SECADM user, to prevent for loss of accessibility.

First connection to the device requires a password change.

It is mandatory to create new users with appropriate roles for the operation of the equipment immediately after first connection, **including a user with SECADM privileges**. A user with SECADM privileges shall remain active in the system at any time.

14.3.5.2 Local user account

CSD100 supports the creation of up to 20 personal user accounts. CSD100 firmware v1.3 does not support central account administration (RADIUS, LDAP). Therefore, credentials (including usernames and passwords) are stored locally (Salt and strong hashing algorithms are used) and shall be managed individually for each CSD100.

Access to the CSD100 device is granted to uniquely identified users using individual passwords. To maintain the security of the system, these passwords must adhere to the device password policy (see **Erreur ! Source du renvoi introuvable.**)

Notes:

- Username is NOT case sensitive.
- GE recommends manually refreshing passwords with a pre-defined frequency.

When configuring a CSD100, personal local user accounts shall be created and granted the minimum number of roles needed to accomplish their work.

Recommendations:

- At least two users with SECADM role (can create new users and modify privileges, if needed)
- At least one user with VIEWER role (archive download)
- At least one user with OPERATOR role (alarm reset, device restart)
- Deletion of ENGINEER and INSTALLER users after commissioning, the SECADM is capable to create these profiles whenever they are further needed.

See 13.1.22

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14.3.5.3 Role base access control

CSD100 v1.3.x supports seven roles, each with specific permissions:

Table 95 CSD100 list of supported roles

Role	Description	Use case or recommended assignation
VIEWER	Measurements review, switching records download	Basic daily management of the device
OPERATOR	Measurements review, switching records download, some controls (alarms reset, restart, archive creation)	Advanced daily management of the device
ENGINEER	OPERATOR plus core function related settings (CB synchronization)	Commissioning
INSTALLER	Software and language files installation	Commissioning
SECADM	User account management, security policy management, certificates management	Commissioning (user creation) Daily management of security
SECAUD	Review of security logs	Security daily monitoring of the device
RBACMNT	Set permissions of roles	Reserved for future use

When creating the users, a SECADM can allocate the necessary roles to the users. A single user can assume multiple roles.

Table 96 outlines the permissions for each predefined user role. Access rights to the control interface are detailed in Table 82.

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Table 96 CSD100 list of permissions per supported roles

Permission description	ROLE						
	VIEWER	OPERATOR	ENGINEER	INSTALLER	SECADM	SECAUD	RBACMNT
All users access Can change a user own password Can change device language	x	x	x	x	x	x	x
Can read main information on the IED status (homepage)	x	x	x	x	x	x	x
Can upload customized CID file			x				
Can read detailed applicative data (measurements, alarms, applicative logs)	x	x	x				
Can read process related parameter (functional settings) Can download switching records	x	x	x				
Can download param file Can download 61850 files (ICD, CID, Logs) Can download switching records			x				
Can read security log						x	
Can trigger manual record			x				
Can upload language file. Can upload firmware file and update the device				x			
Can delete switching records			x				
Can upload certificates. Can configure session security settings (session timeout, login retries,...)					x		
Can perform controls (alarm reset, IED reboot, tests mode tasks) Can trigger manual record		x	x				
Can configure communication features			x				
Can set process related parameters (functional settings) Can upload param file.		x	x				
Can create / delete user accounts. Can configure user / role assignation. Can reset user password. Can configure syslog options (clients, certificates, ...) Can enable / disable physical ports					x		

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14.3.5.4 Local security policies

Recommendations for local security settings:

- Session's inactivity timeout (in minutes): **20**.
- Password minimum length: **8** (not settable).
- Enabling max. login retries before an account is locked: **Yes.**
- Maximum number of failed logins attempts before account locking: **3**.
- Duration of locking period (in seconds): **30**.
- Proper usage HMI banner customization: **No.**
- Duration of login timeout period (in seconds): **120** (time to accept the terms of use of the device).
- Settings edition time (in minutes): **15** (management of concurrent edition of settings, token duration limit).
- Max number of sessions open simultaneously: **3** (a single user can open a single session only)

14.3.5.5 Password management

Password for new created user is initialized by a SECADM and the new created user must change its password upon the first connection. See 13.1.22.

In case of forget password by a user, the SECADM can reinitialize it.

However, if the last SECADM user loose its credential, as there is no password recovery procedure or firecall procedure, a complete system recovery is necessary (See 14.4.5 and 14.4.2). This procedure deletes all existing users and restore the system to its original delivery status. This recovery will entail recreating all users from scratch and reset all functional parameters, ensuring a fresh start, and maintaining system integrity.

14.3.5.6 Maximum user connections and concurrent sessions

At any given time, a single user with appropriate role can change the settings of the CSD100. Other session might be open with read-only permission while the previous user has not applied its modification.

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14.3.6 Configuring security events logging

14.3.6.1 Local security event logs

When a syslog server is not configured, CSD100 software version 1.3.x logs security events in a text file. The log file cannot be modified. The file stores up to 2048 events and is circular: when full, the oldest event is deleted and the newest added. These entries can be audited locally by a user with appropriate permission, i.e. SECAUD, through the web interface. These messages cannot be downloaded, modified, or deleted. Local security logging cannot be disabled and there is no need to configure it.

14.3.6.2 Central logging

CSD100 software version 1.3.x and upper supports the use of system log (syslog) servers to feed log files. GE recommends use of a syslog server for event logging, as it provides a centralized view of all system events, and it enforces long-term storage of logs and integrity.

CSD100 captures security-related events that are sent to a syslog server if a syslog server is configured and reachable. Depending on the level of criticality/severity, a syslog server or a reporting tool gathering information from a syslog server can produce reports, charts, and so on. All severity levels are defined in RFC 5424.

Logging to a syslog server is configured using the CSD100 Web interface.

Note: CSD100 doesn’t support TLS and TCP use

Table 97 outlines that CSD100 publishes to a syslog server.

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Table 97 CSD100 list of logged security events

MNEMONIC	Severity	Priority	Text
LOGIN_OK	notice	37	Log-in successful
LOGIN_FAIL_WRONG_CR	notice	37	Log-in failed - Wrong credentials
LOGIN_FAIL_SESSIONS_LIMIT	alert	33	Log-in failed too many user sessions
LOCK_USER_WRONG_CR	alert	33	User locked – Wrong credentials
LOGOUT_USER	notice	37	Log-out (user logged out).
LOGOUT_TIMEOUT	notice	37	Log-out by user inactivity (timeout).
VIEW_SEC_EV_LIST_OK	notice	13	Viewed Security Event logs successfully
FILE_HASH_CHECK_FAIL	alert	9	File hash check failed
FILE_DS_CHECK_FAIL	alert	9	File digital signature check failed
WRITE_CERTS_FAIL	warning	12	Storing and writing certificates in the entity failed
SW_UPDATE_OK	notice	13	Software update was successful
SW_UPDATE_FAIL	alert	9	Software update failed
VIEW_SEC_EV_LIST_FAIL	alert	9	View of Security Event list failed
USER_ACCNT_CREATE_OK	notice	13	User account created successfully
USER_ACCNT_DEL_OK	notice	13	User account deleted successfully
USER_ACCNT_CREATE_FAIL	notice	13	User account creation failed
USER_ACCNT_DEL_FAIL	notice	13	User account deletion failed
USER_NEW_ROLE_OK	notice	13	New role assigned to user successfully
USER_ROLE_REMOVED_OK	notice	13	User role assignment removed successfully
USER_PW_CHANGE_OK	notice	13	User password changed successfully
USER_PW_CHANGE_FAIL	notice	13	Change of user password failed
USER_NEW_ROLE_FAIL	notice	13	New user role assignment failed
USER_ROLE_REMOVED_FAIL	notice	13	Role assignment removal failed
TCP_COMM_LOG_SUBS_FAIL	alert		
LOG_DATA_HASH_FAIL	alert		Log data hash check failed (Log data altered)
TCP_COMM_LOG_PUBL_FAIL	alert		TCP communication with security log publisher failed.
TCP_COMM_LOG_SRV_FAIL	alert		TCP communication with security log server failed - Event not sent
TLS_CONN_OK	notice		
TLS_CERT_ACCEPTED_OK	notice		
TLS_CERT_CHECK_DIS_OK	notice		
TLS_CONN_FAIL_CERT	alert		
TLS_CONN_FAIL_IKE	alert		
TIME_SYNC_SRC_OK	notice	13	Time sync source OK
TIME_SYNC_SRC_FAIL	notice	13	Time sync source failed
NEW_CERT_GEN_OK	notice	13	New certificate generated successfully
VALUE_FORCING	warning	12	Operational data and or state value override
REBOOT	alert	9	Device reboot
UNAUTHORIZED CONFIGURATION	alert	9	Illegitimate configuration software
SYSLOG_CERTIFICATES_CHANGE_OK	warning	12	Syslog server certificate changed successfully
SYSLOG_CERTIFICATES_CHANGE_FAIL	alert	9	Syslog server certificate changed failed
SYSLOG_CERTIFICATES_DELETE_OK	warning	9	Syslog server certificate removed successfully
SYSLOG_CERTIFICATES_DELETE_FAIL	alert	12	Syslog server certificate removed failed
SV_NON_EXISTENT	notice	13	No SV subscription
SV_ACTIVATE	notice	13	SV subscription(s) configured
SV_SUBSCRIBE	notice	13	SV message received
GOOSE_NON_EXISTANT	notice	13	No GOOSE subscription
GOOSE_ACTIVATE	notice	13	GOSSE subscription(s) configured
GOOSE_SUBSCRIBE	notice	13	GOOSE message received

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14.3.7 Configuring network interfaces

14.3.7.1 Dedicated port for configuration

Front panel RJ45 being dedicated to device administration, configuration, and maintenance, it is recommended to keep it enabled (default status, as per least privilege principle).

While it is possible to do configuration and maintenance using any ethernet port, GE recommendation is to separate configuration and maintenance (front port) with operations as IEC 61850 and time synchronization (rear ports).

In any case, at least one port shall remain active, to support further maintenance.

14.3.7.2 Ethernet interfaces

HMI provides possibility to disable/enable front panel RJ45 ethernet port, or rear SFP ethernet ports. Refer to System\Network.

With basic installations, for which CSD100 is not connected to SCADA or station bus, it is expected that all four rear ethernet ports are disabled.

In some cases where the device is installed on DIN rail, a back port shall remain enabled for operation.

14.3.7.3 VLAN

To enforce network segregation and reduce the network attack surface, GE recommends to configure VLAN on all Ethernet ports, in accordance with customer network configuration, as described in 13.1.19.

Remarks:

- Default VLAN number of the CSD100 must be equal to the default VLAN number of the customer network.

VLAN can be activated on rear ports only.

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14.4 Maintaining security

Once security has been properly configured, it is important to create procedures to maintain security over time.

14.4.1 Periodic security audits

The configuration applied in Secure installation section shall be recorded (backup).

Periodically, particularly after maintenance activity, the security configuration shall be audited, and deviations tracked and fixed.

14.4.2 Backup and restore procedures.

There is no mechanism to automatize backup or restoration of the CSD100 configuration. This must be done manually: settings (parameter) file, IEC61850 customized CID file, system log and security log (cannot be restored), archives (cannot be restored).

Configuration files shall be backed up following any configuration/maintenance activity:

- Main settings file. See 13.1.3
- IEC 61850 configuration file (customized .cid file). See 13.1.20

Remarks:

- It is not possible to backup certificates.
- Firmware packages and language files do not need to be saved (factory version).

The restore procedure consists in (quick service restoration following an incident):

- Firmware update from factory
- Upload of language files from factory
- Upload of main settings file from backup
- Upload of IEC 61850 configuration file from backup
- Upload of certificates from customer

14.4.3 Vulnerability monitoring and firmware updates.

Known products vulnerabilities are published by GE: users shall periodically check for newly published vulnerabilities and available firmware updates, and define a security update policy.

https://www.gegridsolutions.com/hvmv_equipment/catalog/csd100.htm

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14.4.4 Reporting a vulnerability

Providing a legitimate pathway for vulnerability disclosure provides an essential link between GE Vernova and the cybersecurity community.

To submit a vulnerability in a Grid Solutions product to the GE PSIRT team, please fill up the form at https://www.gevernova.com/security. We actively encourage reports to be sent to us for remediation prior to a public disclosure, so that we can properly address any vulnerabilities.

We request the following when reporting a vulnerability:

- Please provide your report in English
- Include specific information about affected products, including model or serial numbers, geographic location, software version, and the means of obtaining the product.
- If you have developed a proof-of-concept for exploiting the vulnerability, please include the code and explanation for the exploit.
- If you are aware of any incidents of this vulnerability being exploited on equipment in the field (e.g. a Grid Solutions customer was directly impacted by this vulnerability)
- Information on how you discovered the vulnerability, your thoughts on impact or CVSS (common vulnerability scoring system) scoring, and potential remediations will help us to triage the vulnerability more quickly.
- Please include relevant information about yourself or the company/organization you're representing, or if you'd prefer to remain anonymous.
- Please let us know if you have a preferred method of contact during our internal triage process.
- Please include your intentions for disclosing the vulnerability to us, or if you intend to disclose the vulnerability to the public.

In response, you can expect the following from us:

- Acknowledgement of receipt of your report within 48 hours
- During our initial triage of the vulnerability, the GE PSIRT team may reach out to you to do one of the following:
    - Request additional information to your initial report.
    - Communicate our expected triage process and timeline.
    - Notify you that the report is either out of scope or will not be triaged for other reasons.
- Once we have conducted our own assessment of the vulnerability, we will communicate our process and findings as a result of the investigation.
- If requested, we will include the reporter’s name in our final report if it results in a public disclosure.

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14.4.5 Reset to factory status / defaults

A special procedure, involving a dedicated SD memory card exists. It can recover a CSD100 in case of:

- Password loss (last user with SECADM role)
- Altered CSD100

A blank SD card is delivered with the device. Contact your GE support representative to request the appropriate SD content.

Step by step procedure:

- Power down the CSD100
- Remove the small rear cover (4 screws, Torx n°9)
- Insert special SD card (≥16GB) programmed with dedicated image (contact factory).
- Insert jumper (2.54mm pitch)
- Power up CSD100
- Wait for power LED to stay ORANGE.
- Wait for SD LED to stay GREEN (a few seconds delay)
- Remove jumper (CSD100 being powered). LED SD immediately goes OFF, which indicates start of cleaning process. LED power stays ORANGE.
- Wait for LED power goes OFF, which indicates CSD100 restart after cleaning.
- Wait for LED power to stay GREEN. CSD100 is reset to factory default status.
- Wait a few seconds more, then power down CSD100
- Remove SD card and put small rear cover back in place.

Remark: archives, settings (including IP addresses) will be deleted in this process.



Figure 310 Example of a 2.54mm pitch jumper



Figure 311 Example of a µSD card

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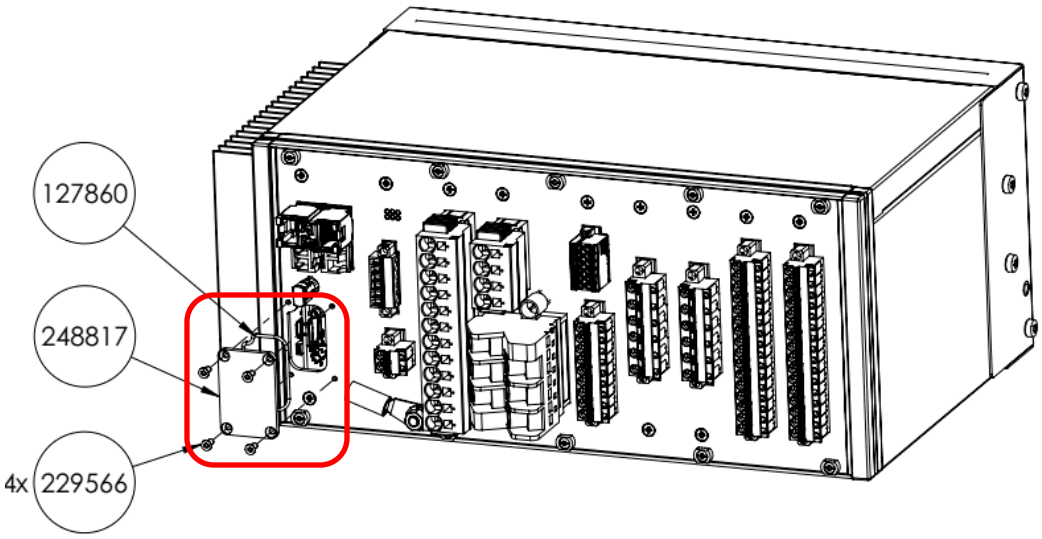


Figure 312 CSD100 access to µSD card slot and boot jumper

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14.5 Decommissioning – removing configuration and sensitive data

Prior to CSD100 unit decommissioning (refer to 7.6), settings can be backed up, as outlined in section 14.4.1. Additionally, it is recommended to back up the records (see HMI section 13.1.27, button “Download all”).

To clear files and settings in the decommissioned unit, the procedure described in section 14.4.5 is applicable.

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14.6 Secure operations guideline

For a secure operation of the product, GE recommends that:

- Users be assigned a specific role and not rely on the almighty Administrator account for tasks that do no necessitate full administrative power.
- Users don’t share their passwords.
- Users change their passwords when they believe there might be a possibility of unwanted disclosure.
- Users log out of their session when finished (although an inactivity timeout can be set to automatically terminate user sessions).
- GE delivered certificates shall be replaced with certificate provided by the end user.
- The product shall not be connected to a public network, nor the internet.
- Any transient asset that must be connected to the product shall be carefully controlled and checked for malware.
- Periodical review of all user accounts be carried out, and inactive accounts be disabled / removed.

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15 COMMISSIONING

15.1 Warning



The equipment ratings, operating instructions and installation instructions shall be checked before commissioning or maintenance. Only qualified and trained staff shall undertake commissioning.

15.2 Commissioning tools

15.2.1 Hardware

The following equipment is required:

- Multifunctional voltage and current secondary injection test set
- Portable multimeter with suitable AC and DC voltage ranges of [0; 250] VAC and [0; 250] VDC respectively
- Portable insulation tester
- Multichannel recorder or oscilloscope
- AC/DC current clamps, isolated voltage probes
- Circuit-breaker analyzer device (depends on the method applied for mechanical times measurement)
- Specific loads for mechanical times measurement (oscilloscope/recorder method)

15.2.2 Software

- Comtrade viewer (standard file format for transient data exchange), or
- Dedicated CSD100 record viewer (recommended):
    - https://spo-teamsite.ge.com/sites/GrIEDresAISapps_Community/CSD%20Software%20tools/CSD100%20(RPH4)/CSD100%20Records%20Viewer/Install%20CSD100%20Records%20Viewer.msi
      (This link requires a GE SSO and is thus only accessible for GE employees). This viewer requires an activation key at first startup.

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15.3 Preliminary checks

15.3.1 Product checks with the IED de-energized

15.3.1.1 Visual inspection



Before energizing the CSD100, following should be checked:

Check that no physical damage has occurred since installation (visual inspection).

Check that the IED is properly installed according to the recommendations given in chapter 11.

Check IED label and S/N identification.

Check that all removable connectors are unplugged at rear side of the device.

Check the connections:

- Earthing connection
  - Ensure that the case earthing terminal is connected to a local earth bar using an adequate protective conductor gauge
  - Ensure that power supply earthing terminal is connected to the same local earth bar using an adequate protective conductor
  - Ensure that no other terminal, except the case earthing terminal, is connected to the local earth bar
- Power supply connection
  - Check the proper polarity and supply range of the power supply
- Auxiliary supply connection
  - Care should be taken to check proper polarity and supply range of the auxiliary supply (coil control voltage)
- Current transformer connection
  - Check that that CT secondary circuits are wired to IED safety plug using wires terminated with ring terminals
- All other connections
  - Check that all conductors are terminated with ferrules in case of screw type connectors (not necessary for push-in type connectors)
  - Check that only a single conductor is wired to each connector pin
- All connections: apply a light manual effort to each wire (or group of wires) to check each wire is securely fastened in connector.

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15.3.1.2 Insulation

Insulation between input, output ports and earth may be checked. If insulation tester (>100Mohm @ 500 VDC) is not available, degraded method consists in checking resistance with standard portable multimeter.

15.3.1.3 Circuit breaker coils resistance

This is to check that the circuit breaker coils are directly connected to the CSD100, without any intermediate circuit in between.

From the power output connector, the coil low resistance must be measurable with a portable multimeter (ohm position):

- Close coils when circuit breaker is in open position
- Open coils when circuit breaker is in close position

Remark: this measurement might not be possible if diodes are inserted downstream in the low voltage schematic. In this case, this measurement may be taken upstream of diodes.

Typical coil resistance values for GE brand circuit breakers:

- 48VDC circuits: 5.6Ω
- 110/125VDC circuits: 35Ω
- 220/250VDC circuits: 140Ω

15.3.1.4 External wiring

Check that the external wiring is correct according to the LV scheme diagram (continuity test).

CSD100 connectors can be plugged and locked once this preliminary checklist is completed.

15.3.1.5 Power supply

CSD100 is delivered with appropriate external power supply which accepts voltage in the range of [90VDC – 250VDC]. 48VDC support is also available on request (alternative power supply reference).

Ensure that the power supply is within this operating range before switching on the CSD100 power supply MCB.

15.3.1.6 Auxiliary supply (control voltage)

CSD100 accepts auxiliary supply voltages in the range of [48VDC – 250VDC].

Ensure that the auxiliary supply is within the adequate operating range before switching on the CSD100 auxiliary supply MCB.

15.3.1.7 Energizing the device

CSD100 device can be energized once this preliminary checklist is completed.

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15.3.2 Product checks with the IED energized

15.3.2.1 Test LEDS

Upon CSD100 power up:

Check that the LED “power” is OFF, then turns orange for a few seconds and then green.

Check that the LED “ready” turns orange or green, a few seconds after LED “power” turned to green.

15.3.2.2 Watchdog contacts

Check that the watchdog relay briefly picks-up (~1s) during CSD100 power up.

15.3.2.3 Output relays

Check that all connected output relays (max 2) pick-up after the CSD100 energization.

15.3.2.4 Connection to the embedded HMI (Ethernet IP address)

For subsequent procedure (dry tests…), CSD100 HMI must be accessible from web browser.

If CSD100 is not connected to an ethernet network, Laptop and CSD100 will be connected in a point-to-point scheme which will require static IP addresses for both devices.

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15.4 Dry tests

These tests are carried out without primary system voltage. Circuit breakers terminals are accessible. Main goal is to check for low voltage wiring and measure circuit breaker mechanical times.

A step-by-step procedure is provided for which a specific form is to be completed at site. The procedure is the same for AIS or GIS switchgear, but some minor differences may exist (method of measuring circuit breaker timings).

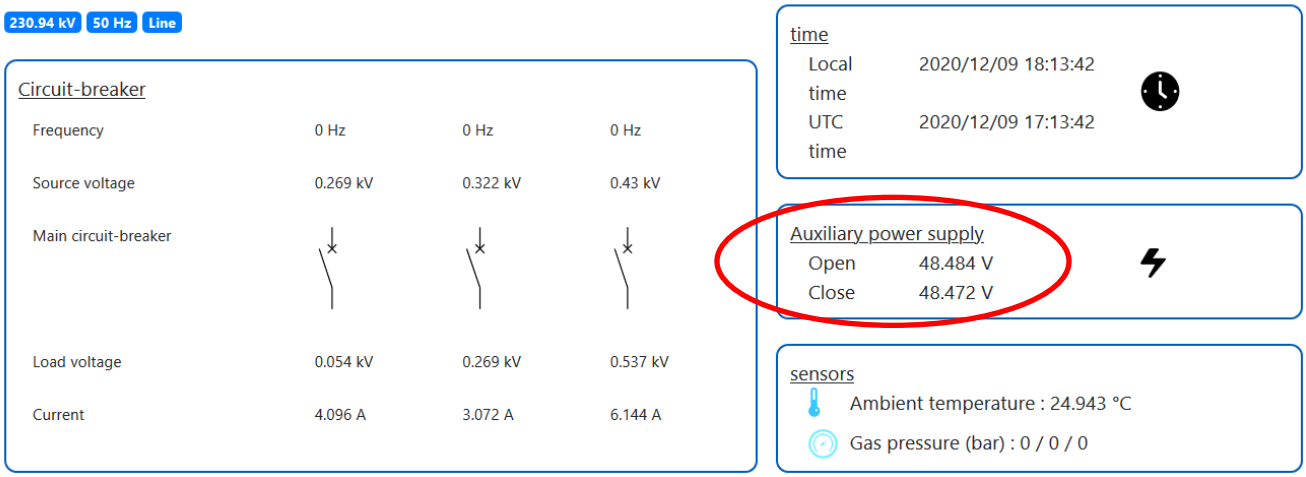
15.4.1 Initial step

- Date / Time adjustment. HMI section System\Date and Time.
  If SNTP or PTP are available in the network, first, it shall be disabled and a wrong date/time programmed. Then, SNTP and IP address of SNTP server, or PTP, shall be enabled. After a few seconds, date should be automatically corrected if SNTP or PTP server is linked.
- Upgrade of the CSD100 firmware to the latest available version
- Upload of the settings file (“param.xml”), if available
- IP addresses settings and gateway. It is recommended to keep the fixed front port default IP address (192.168.0.2): maintenance port for momentary usage.

15.4.2 Power supply and control voltages inspection

Table 98 Dry tests – power supply and control voltages testing

Action	Verification
Multimeter connected to power supply input	Check DC voltage
Multimeter connected to control voltage 1 (“DC1”)	Check DC voltage with multimeter and HMI
Multimeter connected to control voltage 2 (“DC2”)	Check DC voltage with multimeter and HMI



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15.4.3 Circuit breaker aux. contact signaling and phase mismatch – Use of CSD100 commissioning mode

After pole discrepancy relay turn off, it is to check that no phase inversion is at play in low voltage schematic for two sets of signals:

- coil command circuit (CSD100 power outputs)
- auxiliary contacts feedback (CSD100 digital inputs).

For that purpose, each phase is successively operated, and visual check is carried out (circuit breaker position from the drives) as well as 52a position reported in CSD100 embedded control interface (HMI).

Commissioning mode is highly recommended:

Table 99 Dry tests – connections to circuit breaker phase mismatch testing

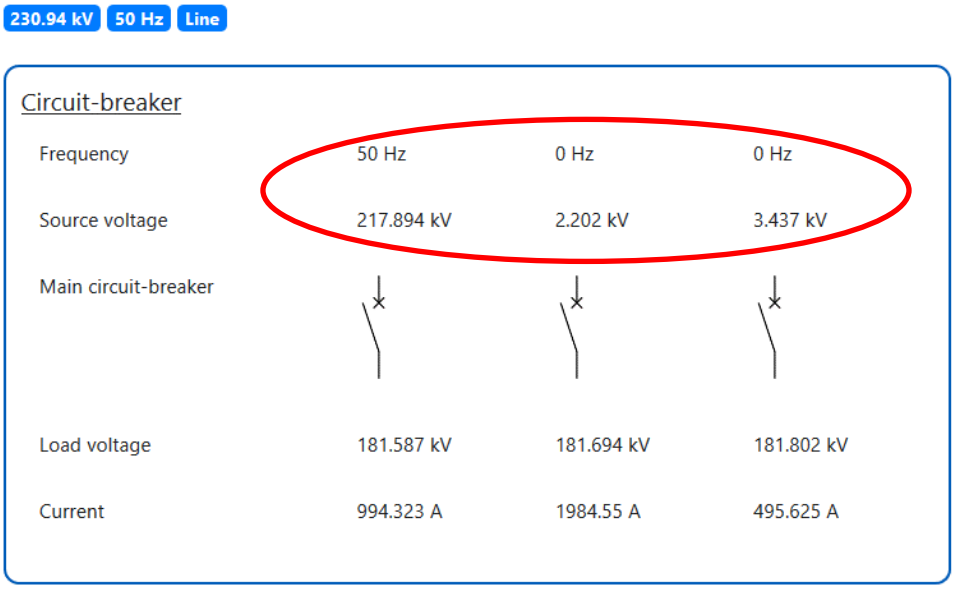
Action	Verification
“Pole discrepancy” function to be disabled	
Connect DI15 to a suitable DC voltage (above 30V)	HMI “Settings\commissioning mode” section becomes available
Activate commissioning mode through HMI	New parameters/measurements are displayed, including wiring indication
Select between display ms or µs	ms
Click “Close”: start position → CLOSE	L1, L2, L3 reported as closed in HMI CB visually in close position L1 L2 L3 (drive)
Click “Open L1”	L1 reported as open in HMI L2, L3 reported as close in HMI CB visually in open position L1 (drive) CB visually in close position L2 L3 (drive)
Click “Close L1”	L1, L2, L3 reported as close in HMI CB visually in close position L1, L2, L3 (drive)
Click “Open L2”	L1, L3 reported as close in HMI L2 reported as open in HMI CB visually in close position L1, L3 CB visually in open position L2
Click “Close L2”	L1, L2, L3 reported as close in HMI CB visually in close position L1, L2, L3 (drive)
Click “Open L3”	L1, L2 reported as close in HMI L3 reported as open in HMI CB visually in close position L1, L2 CB visually in open position L3
Click “Close L3”	L1, L2, L3 reported as close in HMI CB visually in close position L1, L2, L3 (drive)
De-activate commissioning mode through HMI	
Disconnect DI15 (floated)	

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15.4.4 Source reference voltages & phase mismatch checking

Table 100 Dry tests – source voltages phase mismatch testing

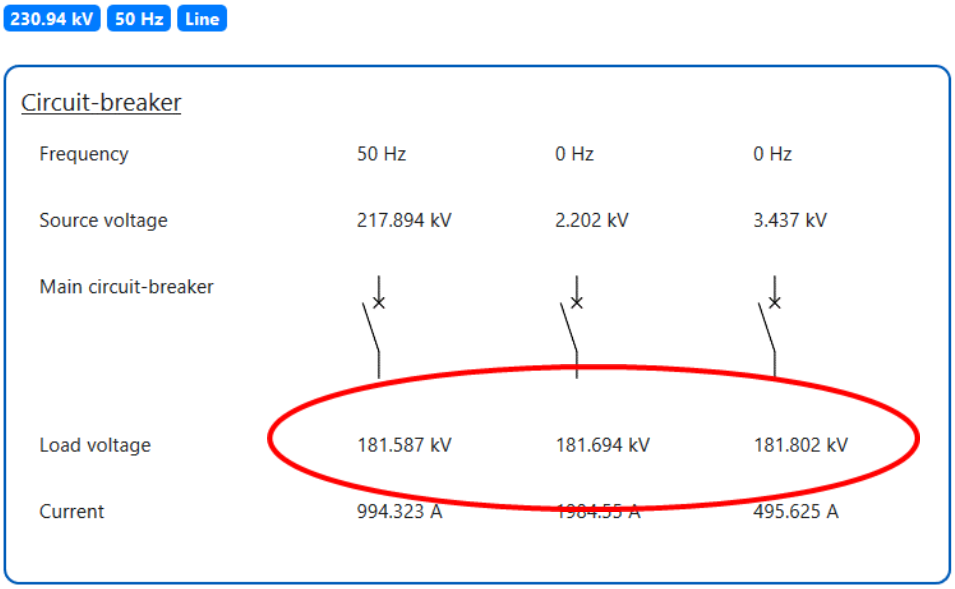
Action	Verification
inject 3x AC 50Hz/60Hz voltages of different amplitudes at source side (secondary voltages)	check consistency of voltage information in HMI (primary voltages), taking account of set VT ratio



15.4.5 Load voltages & phase mismatch checking

Table 101 Dry tests – load voltages phase mismatch testing

Action	Verification
inject 3x different AC 50Hz/60Hz voltages at load side (secondary voltages)	check consistency of voltage information in HMI (primary voltages), taking account of set VT ratio

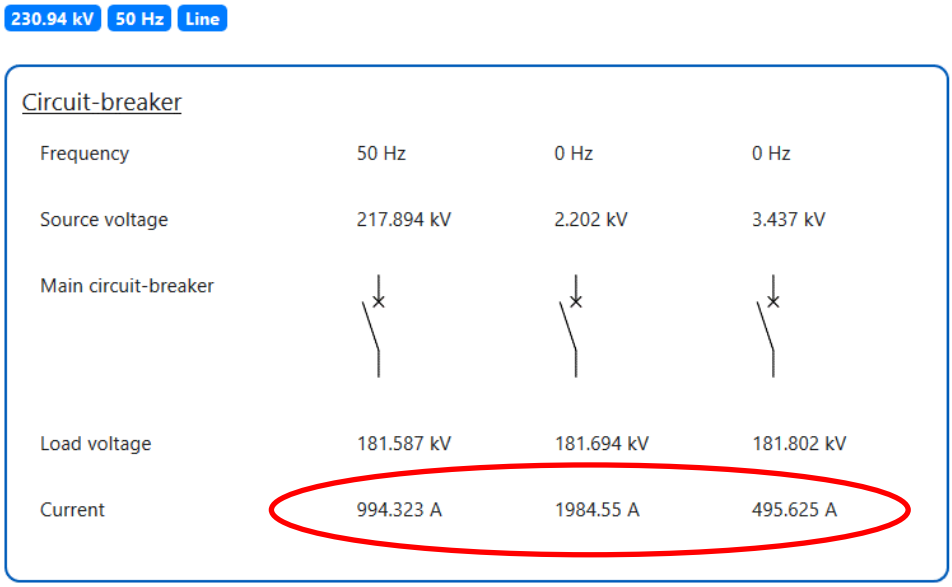


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15.4.6 Load currents & phase mismatch checking

Table 102 Dry tests – load currents phase mismatch testing

Action	Verification
inject 3x different AC 50Hz/60Hz currents (secondary currents)	check consistency of current information in HMI (primary currents), taking account of set CT ratio



15.4.7 Phase shift voltage & current verification (180° error detection: +/- inversion)

Action	Verification
inject 1x AC 50Hz/60Hz reference voltage (secondary voltage) inject 3x AC 50Hz/60Hz load voltages (secondary voltage), with 120° phase shift inject 3x AC 50Hz/60Hz currents (secondary currents), with 120° phase shift	check that respective amplitudes are correctly reported in HMI (primary voltages/currents)
Trigger an archive with CSD100 HMI (“download” section)	With appropriate archive viewer or comtrade viewer, check respective phase shifts

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15.4.8 Bypass circuitry

Table 103 Dry tests – bypass circuitry testing

Action	Verification
CSD100 is turned OFF	
Issue a close command from remote location	check that circuit breaker operates (3 phases).
Issue an open command from remote location	check that circuit breaker operates (3 phases).
Issue a close command from local location	check that circuit breaker operates (3 phases).
Issue an open command from local location	check that circuit breaker operates (3 phases).
CSD100 is turned ON	
inject 1x valid AC 50Hz/60Hz reference voltage (secondary voltage)	check that CSD100 is “ready to open” and “ready to close” in HMI
turn bypass selector to active (bypass forced by user)	
Issue a close command from remote location	Issue a close command from remote location
Issue an open command from remote location	Issue an open command from remote location
Issue a close command from local location	Issue a close command from local location
Issue an open command from local location	Issue an open command from local location
Stop injecting 1x valid AC 50Hz/60Hz reference voltage (secondary voltage)	check that CSD100 is not “ready to open” and not “ready to close” in HMI
turn bypass selector to inactive (normal position)	
Issue a close command from remote location	check that circuit breaker operates (3 phases).
Issue an open command from remote location	check that circuit breaker operates (3 phases).
Issue a close command from local location	check that circuit breaker operates (3 phases).
Issue an open command from local location	check that circuit breaker operates (3 phases).

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15.4.9 Operations in nominal conditions – check for coil circuitry

Test performed with both local and remote close and open orders.

Table 104 Dry tests – coil circuitry testing

Action	Verification
inject 1x valid AC 50Hz/60Hz reference voltage (secondary voltage)	check that CSD100 is “ready to open” and “ready to close” in HMI
Turn bypass selector to inactive	
Issue a close command from remote location	check that circuit breaker operates (3 phases).
Download and open CSD100 archive with appropriate viewer or comtrade viewer	1/ Duration of close command is larger than 100ms (typically). 2/ The auxiliary contacts are closed according to expected sequence 3/ The coil currents (analogue channels) are initiated exactly at the instant of activation of respective outputs (digital channels). 4/ The coils current shape is normal and comparable from one phase to another. 5/ The measured energy transmitted to each coil is approximately the same 6/ the counters for controlled operations and uncontrolled operations are consistent
Repeat same procedure for open channel	
Repeat same procedure with close and open orders from local location.	

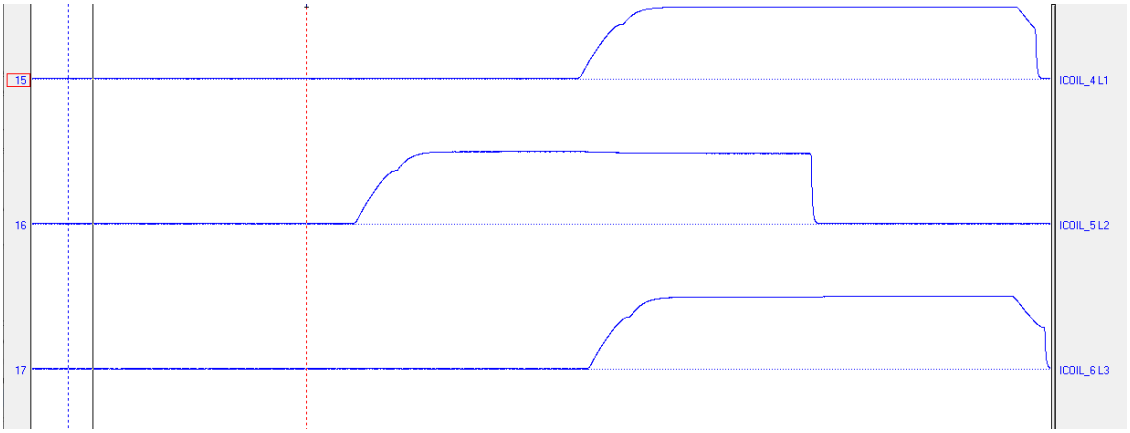


Figure 313 Coils current sequence, shape and amplitude, in comtrade file

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15.4.10 Circuit-breaker operating time measurement

Different methods are available, each of them with pros and cons.

Table 105 Methods for circuit breaker timings measurements

Method	Comment	Advantage	Drawback
Circuit breaker timing analyzer (without CSD100)	Circuit breaker is operated from CB analyzer. Aux contacts measured by CB analyzer. Main contacts measured by CB analyzer.	Does not require CSD100: timings can be measured in advance	Risk of error (bias): different cable length, different DC power supply, different measurements filters
Circuit breaker timing analyzer + CSD100	Circuit breaker is operated from CSD100. Aux. contacts measured by CSD100. Main contacts measured by circuit breaker analyzer.	Good accuracy	More complex setup: requires 2 pairs of wires between CB analyzer and CSD100 (tripolar open and close orders).
CSD100 only	Commissioning mode. Circuit breaker is operated from CSD100. Aux contacts measured by CSD100. Main contacts measured by CSD100 (some digital inputs are functionally diverted to measure main contacts).	Very accurate Very simple	CSD100 needs to be located near the circuit breaker. Voltage induction may impair measurement of main contacts timings.

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General recommendations:

- For accurate results (<0.1ms error) it is recommended to measure mechanical times when circuit breaker is operated by the CSD100 itself. Thus, methods 2 and 3 are recommended.
- Filter settings of CB analyzer must be reduced as much as possible (filtering typically induces additional delay)
- If CB analyzer drives the circuit breaker coils (first method), it is mandatory to use the coils which will be connected to the CSD100.
- If CB analyzer measures the circuit breaker aux. contacts (first method), it is mandatory to use the aux. contacts which will be connected to the CSD100.
- At least 5 close operations and 5 open operations are necessary to get a consistent average result.
- Ambient conditions are to be noted during the procedure (inspection form).

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15.4.10.1 Circuit breaker analyzer method

Circuit breaker analyzer is connected to main contacts (main contacts timing measurements), auxiliary contacts (auxiliary contacts timing measurements) and also energizes circuit breaker coils.

Thus, timings are measured independently from the CSD100.

It is advised to pay attention to the circuit breaker analyzer filtering circuit to measure contacts, because it can introduce a bias in case of high level of filtering and rejection of rebounds.

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15.4.10.2 CSD100 + circuit breaker analyzer combined method

Circuit breaker analyzer is connected to main contacts and measures main contacts timing.

Circuit breaker analyzer outputs usually directly connected to coils (coils energization) are disconnected from circuit breaker coils and one of them is connected to CSD100 tripolar orders inputs (open & close). It is assumed that all circuit breaker analyzer outputs are activated at the same instant.

CSD100 measures auxiliary contacts timings and energizes circuit breaker coils, as for final installation (advantage of this method: cabling is not different from final cabling except for incoming tripolar orders).

Results:

- Auxiliary contacts timings will be directly obtained from CSD100 (HMI or measurement file)
- Main contacts timing will be obtained from the circuit breaker analyzer, but these timings must be lowered by the CSD100 input to output delay (timestamp_igbt_drive – timestamp_close_order or timestamp_igbt_drive – timestamp_open_order, for each phase). All these timestamps are to be found in the records which are created upon each operation.

Remark : it is necessary to feed the CSD100 with a dummy reference waveform (usually an AC voltage).

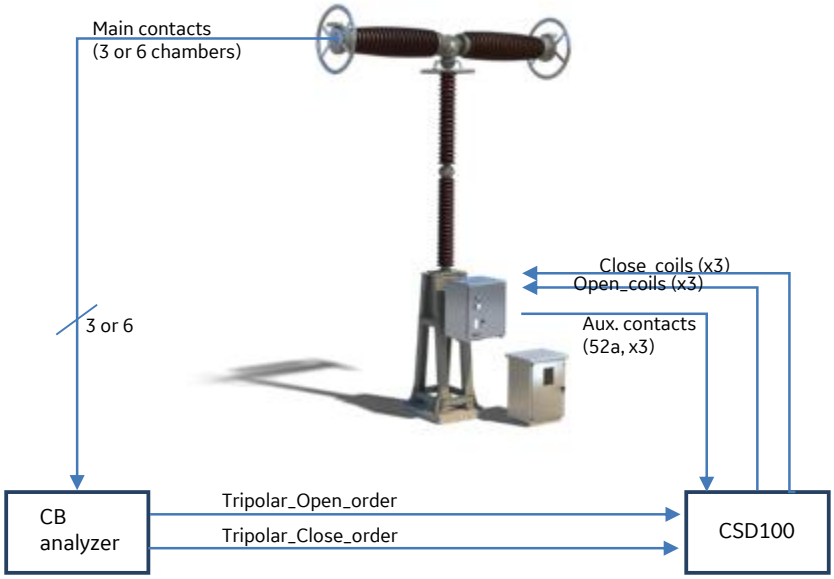


Figure 314 CSD100 and circuit breaker analyzer timing measurements combined method

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15.4.10.3 CSD100 method – commissioning mode

While in commissioning mode, circuit breaker main contacts are to be connected to three digital inputs (DI9, DI10, DI11, initially dedicated to trigger record and MLS) in an exact same wiring scheme as auxiliary contacts measurements (use of a substation control voltage). Thus, CSD100 will measure main contacts and auxiliary contacts in the same operations.

Note: this method requires the CSD100 not to be located far away from the circuit breaker, to connect temporary wires from main contacts to the CSD100. As an alternative (CSD100 too far), it is possible to measure main contacts by temporarily re-using auxiliary contacts circuitry/wires. In that case, auxiliary contacts cannot be measured within same operations (additional circuit breaker operations are necessary to measure auxiliary contacts, in a second step).

Procedure is straightforward:

- Circuit breaker is successively open and closed (three phases) by the operator, with dedicated controls (it is recommended to wait tens of seconds between two operations, to prevent from circuit breaker coils heating, which may slightly influence results).
- Timing measurements are automatically added to the average. Detailed results are also displayed at the bottom of the view, for information. Web page needs to be manually refreshed to display new measurements.
- Timing measurements may be manually copy/pasted to settings. However, clicking on each measurement automatically copy the value to relevant setting.
- Procedure can be started again and measurements can be reset with dedicated control.

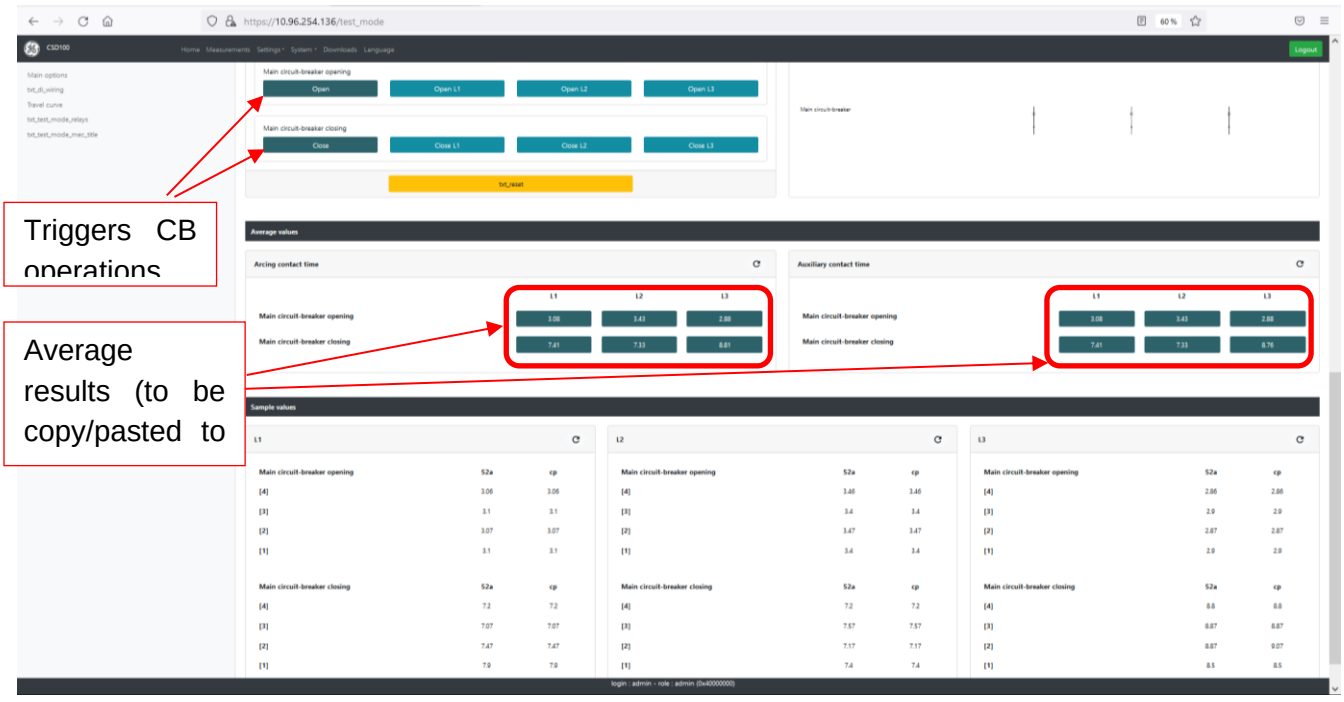


Figure 315 CSD100 HMI, commissioning mode controls and measurements

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15.4.10.4 Voltage induction concern from adjacent lines or circuits

Connection of wires from circuit breaker main contacts to ground potential (CB analyzer, loads, CSD100…) raise a safety concern (voltage induction from adjacent lines).

It is highly recommended to reduce as much as possible the loop surface between these wires, as illustrated below with worst case double break AIS circuit breaker. Additionally, these wires may be twisted together.

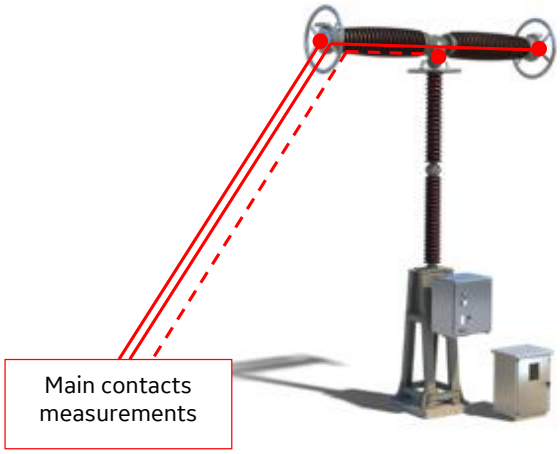


Figure 316 Preferred wire paths for main contact timings measurement

15.4.11 Alarms signaling - contact relays outputs

Table 106 Dry tests – relays testing

Action	Verification
Reference voltage alarm is assigned to bistable 1 and bistable 2 relays	check consistency of current information in HMI (primary voltages), taking account of set CT ratio
inject 1x valid AC 50Hz/60Hz reference voltage (secondary voltage)	No alarm displayed at SCADA/control system
Stop injecting 1x valid AC 50Hz/60Hz reference voltage (secondary voltage)	System alarm and application alarm are correctly set at SCADA/control system

Remark: commissioning mode also allows to manually activate both bistable 1 and bistable 2 relays.

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15.4.12 Final settings and backup

Table 107 Dry tests – final steps

Action	Verification
Adjust IP addresses (front and back) according to customer specification and reconnect to HMI. It is recommended not to change the front port IP address (192.168.0.2)	check that reconnection is working properly
Backup of settings file (“param.xml”)	
Backup of counters: controlled opening/closing operations, uncontrolled opening/closing operations, reignitions (controlled), reignitions (uncontrolled)	
Backup of commissioning archives	
Backup of logs: system and security	
Backup of users : logins and passwords	

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15.5 Live tests

During live tests (operations with circuit breaker connected to load and system voltage), switching performances are verified.

At least two operations should be carried out to get confidence on results.

15.5.1 Signals recording

CSD100 records (comtrade files) usually serve as live test assessment (40kHz sampling frequency).

However, if it is required to record signals by external means (for independency purpose), it is necessary to record:

- Source voltage, 3 phases
- Load voltage, 3 phases
- Load current, 3 phases
- CSD100 output closing orders, 3 phases
- CSD100 output opening orders, 3 phases

Voltage signals are measured on the dedicated terminal block equipped with test plugs, with isolated differential voltage probes.

Current signals are measured using isolated current clamps.

Multichannel recorder acquisition frequency is set to 10 kHz min., 40kHz recommended.

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15.5.2 Performance evaluation

15.5.2.1 Energizing operations

During energizing, it is to be checked that:

- Load side voltages and/or currents rise at expected target angles, with typical tolerance of +/-1 ms (best case) to +/-2ms (average).
- Performance indicators (inrush currents, voltage dip…) are under control.

Table 108 Essential checks after close operations

	After CLOSE operations	Origin of information
Capacitor bank	Making times errors	HMI or archive (“measures.xml”: “making_time_error_”)
	Making times near source zero voltages (consideration of absence of trapped charge)	Oscillography (comtrades)
	Limited inrush current, typically below 2pu	HMI or archive (“measures.xml” : “peak_current_”)
Shunt reactor	Making times errors	HMI or archive (“measures.xml”: “making_time_error_”)
	Making times at peak voltages (or different target)	Oscillography (Comtrade)
	Absence of current asymmetry (if target peak voltages)	Oscillography (Comtrade)
Power transformer	Making times errors	HMI or archive (“measures.xml”: “making_time_error_”)
	Inrush current peak (less than power transformer nominal load value, 1pu)	HMI or archive (“measures.xml” : “peak_current_”)
	Which phase(s) is (are) responsible for inrush current(s)	Oscillography (Comtrade)
	Source Voltage dip (some networks being more sensitive than others, due to high source impedance).	HMI or archive (“measures.xml”: “alarm_voltage_dip_ph_e”, “alarm_voltage_dip_ph_ph”, “voltage_dip_”)
Line	Making times errors	HMI or archive (“measures.xml”: “making_time_error_”)
	Making times at minimum of differential voltage (“min beat”), source voltage zero, or source voltage peak (acc. to trapped charge polarity)	Oscillography (Comtrade)
	Limited load side overvoltage, typically below 2pu	Oscillography (Comtrade)

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15.5.2.2 De-energizing operations

During de-energizing, check that load currents extinguish at expected targeted angles.

Table 109 Essential checks after open operations

	After OPEN operations	Origin of information
Capacitor bank	Absence of re-ignitions or re-strikes	Arcing time measurement: HMI or archive (“measures.xml”: “measured_arc_time_”)
Shunt reactor	Absence of re-ignitions	Alarms (x4) : HMI or archive (“measures.xml” : “alarm_reignition_last_open_”, “alarm_reignition_rate_”, “alarm_reignition_total_”, ” alarm_arcing_time_”
	Arcing time measurement	HMI or archive (“measures.xml”: “measured_arc_time_”)
Power transformer	Absence of overvoltages during opening sequence	Oscillography (Comtrade)
	Residual fluxes values (sum approx. null)	HMI or archive (“measures.xml”: “_flux_value_”)
Line	Trapped charge polarity	HMI or archive (“measures.xml”: “trapped_charge_polarity_”)
	Absence of overvoltages during opening sequence	Oscillography (Comtrade)

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16 MAINTENANCE AND TROUBLESHOOTING

The Maintenance and Troubleshooting chapter provide details of how to maintain and troubleshoot CSD100 controller. It is important to heed the warning signs in this chapter, as not do so may result injury or defective equipment.

Caution Before carrying out any work on the equipment you should be familiar with the contents of the Safety Section and the ratings on the equipment's rating label.

16.1 Maintenance

Equipment failure



Repair of CSD100 device consists in its replacement only. There are no serviceable subparts within the product enclosure. All servicing must be made with the prior agreement of GE by qualified staff.

Note: to make the maintenance operations easier (that is limited to device replacement), the connectors are all removable. Replacement of the device doesn't require any re-wiring work. Please note that the two connectors supporting power outputs are of same reference and shall not be mixed upon reconnection. Same concern exists for the two digital inputs connectors.

Note: software maintenance: an emergency procedure exists to recover the full software image. This procedure shall be undertaken by qualified GE staff only.

Refer to troubleshooting section for detailed diagnosis and corrective actions.

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16.2 Troubleshooting

16.2.1 General concerns and potential causes

Hereunder are listed some practical concerns from return of experience and field observations, potential causes and possible workarounds.

Table 110 Synchronous switching possible concerns

Issue	Potential causes	Investigation and workaround
Misoperation: spurious operation	Coil(s) activation(s) do not come from the CSD100 (circuit breaker coils shared between different IEDs) Spurious order at opening or closing input port (digital input) Hardware failure in power outputs circuitry (one phase spurious operation)	Check for presence/absence of CSD100 records. Check for log notification (“open order detected”, “close order detected”) Check for coil current in records (if exists)
Misoperation: open operations are denied	Absence of reference waveform Internal UVLO alarm is raised (self-monitoring) for one of the three open circuits Bypass circuitry is not activated due to incorrect alarm assignment to monostable relay	Check for alarm in HMI Check for alarm assignment to bypass in HMI
Misoperation : close operations are denied	Absence of reference waveform Internal UVLO alarm is raised (self-monitoring) for one of the three close circuits Bypass circuitry is not activated due to incorrect alarm assignment to monostable relay	Check for alarm in HMI Check for alarm assignment to monostable relay in HMI
Misoperation: inadequate targets/making times during close operation	Wrong settings (program…) Wrong mechanical time measurements during dry tests Wrong mechanical time compensations tables Wrong or shifted adaptive compensation (possibly due to wrong mechanical time measurement) Mismatch between coils outputs (L1, L2, L3) Wrong residual flux computation (power transformer, first phase/ winding to close) Circuit breaker out of wear (making time earlier than expected by half a period or more, due to dielectric withstand weakening) Power transformer: missed target for last phase(s) to close.	Check program and targets (if MLS is activated, check record for MLS digital inputs positions) Check (comtrade file) that voltage across breaker right before closing, for each phase, is in line with expectation (excessive voltage yields earlier making times, lower voltage yields later making times)
Misoperation: excessive inrush current during close operation	See above Residual flux control is not efficient from controlled opening (power transformer)	

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Issue	Potential causes	Investigation and workaround
Misoperation: reignition observed during open operation	Transient recovery voltage exceeds circuit breaker capability, whatever arcing time setting Arcing time setting too low Circuit breaker is out of wear (repetitive reignitions)	Check circuit breaker applicability Increase circuit breaker gas pressure Increase arcing time setting Observe closing archives in search for excessive prearcing times (evidence of dielectric weakness)
Loss of signalization	Wiring issue to 52a, wire is broken, 52a contact is shared with another circuit	Check that low voltage diagram is in accordance with actual wiring.
Mechanical time(s) measurement error	Mismatch between coils outputs (L1, L2, L3) Coils are wired together (L1, L2, L3) A parallel impedance exists between coils (L1, L2, L3), from protection system or other relay Mismatch between 52a circuits (L1, L2, L3) Dependence between 52a contacts (in series or in parallel) Wrong settings: mechanical time tolerance is set to zero or at very low value Wrong settings: nominal 52a times or main contacts times incorrectly set	Check wiring Insert serial diodes to other IEDs outputs suspected to drive the same circuit breaker coils (shared coils) Check settings (it is reminded that nominal main contact and auxiliary contact times are expected. Time difference between main and auxiliary contacts shall not be set)
No communication	Wrong IP address (either static or dynamic) Defective ethernet cable (copper or optical)	Check ethernet activity LEDs at both ends Check that laptop IP address is in the same address range (subnet). Ping CSD100 address

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16.2.2 Power transformer energization specific concerns and potential causes

After general causes have been reviewed (see 16.2.1), some specific causes may be envisaged.

It is important to distinguish between excessive inrush due to first phase(s) to close and last phase(s) to close. For that, introducing dead half periods in the closing sequence (with dedicated parameter) may help.

- First phase(s) to close excessive inrush: a common cause is that the residual flux is not correctly computed. It is reminded that residual fluxes are updated (for each phase independently) upon load voltages extinction. Thus, parameters “general_load_voltage_rms_threshold_deenergization” and “general_load_voltage_rms_threshold_energization” are to be checked. It is also reminded that capacitive voltage transformers usually yield to underestimated residual flux values. If inductive voltage transformers are used, it generally gives a consistent flux information. Thus, power transformer type choice (“transfo1_type”, “transfo2_type”) is to be re-checked since working voltages to compute residual fluxes are directly dependent on this parameter.
- Last phase(s) to close inrush: a common cause is that the actual voltage across circuit breaker right before closing is higher (for example due to presence of additional oscillations) or lower than expected, leading to respectively earlier or later making times. In flux mode, this can be fixed by decreasing or increasing the “RDDS derating factor” parameter, which applies to last phase(s) to close only, and is an indirect way to control prearcing times: Prearcing times to be increased (RDDS to be decreased with a derating factor lower than 1) in case of higher CB voltage, and Prearcing times to be decreased (RDDS to be increased with a derating factor higher than 1) in case of lower CB voltage.

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16.2.3 Diagnosis methodology

Information is available within HMI to serve as a first level of investigation (alarms and measurements).

16.2.3.1 Home page HMI indications

First step is to refer to “home” page status (top right).

- **Bypass** position is indicated (position of the external bypass circuit, measured from a dedicated digital input). External bypass circuit may be activated by the CSD100 monostable relay (typically in case of reference waveform absence) or by any external cause (unknown from the CSD100). Final bypass position is to be wired to dedicated digital input, to be reported in the HMI. If bypass is activated:
  - Check alarms assignment to monostable relay.
  - Check status of assigned alarms and thresholds (some thresholds may not be appropriate).
- **Communication alarm** is reserved for future use.
- **System alarm** are summarized in a single status (internal alarms).
  - if “alarm date not reliable” is set, manually adjust date or try to ping SNTP server from a laptop in the same network.
- **Application alarm** are summarized in a single status (Application alarms).
- **Ready to close** status is related to absence of reference voltage for closing or internal fault of close power outputs. These are alarms reported in HMI “Measurements” section.
- **Ready to open** status is related to absence of reference waveform for opening (either voltage or current) or internal fault of open power outputs. These alarms are reported in HMI “Measurements” section.

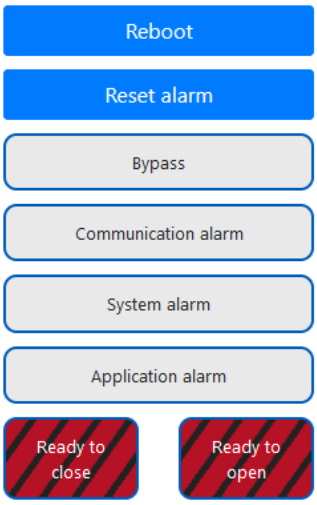


Figure 317 HMI home section (alarms summary)

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16.2.3.2 Detailed alarms reporting

On a second step, detailed alarm reporting shall be checked.

16.2.3.3 Log file

Log files (system and applicative events) shall be inspected.

- HMI **home** section shows a simplified version of the log file
- HMI **System\Logs** section shows a full view of the log file (can be downloaded)

Each input is timestamped.

16.2.3.4 Comtrade files analysis

If switching performances are not satisfying, it is useful to look at waveforms. CSD100 high resolution recording capability helps to diagnose making time issues during closing (too early or too late) and to fine tune settings.

Some examples:

- if making time is too early a usual workaround is to increase prearcing times (or decrease RDDS, power transformer with consideration of residual flux).
- if making time is too late a usual workaround is to decrease prearcing times (or increase RDDS, power transformer with consideration of residual flux).
- Power transformer switching: due to inter phase coupling, closing a first phase or winding causes voltage apparition on remaining phases. In some cases (long distance between circuit breaker and power transformer), superimposed high frequency parasitic oscillation may be observed. This oscillation changes voltage condition at the time of subsequent phases closing and thus changes prearcing times and ultimately can lead to target missing. Usual workaround is to introduce dead half periods between first phase or winding to close and subsequent ones, to let time for this oscillation to damp.
- For reactor energization, measured current may appear distorted (harmonic). This is due to current transformer saturation: actual current exhibits asymmetry (energization not exactly at peak voltage) and current is measured through metering core current transformer with nominal range near actual current. As CT saturation is observed, actual current flowing into the reactor is wrongly measured.

16.2.3.5 Measurement and alarms file analysis

Measurement and alarms file include the same information available in HMI (at the exception of some minor measurements, for example coils actuation energy).

The main advantage of the measurement file is to keep trace of information at the time of the operation. Refer to 21: for each information it is indicated if the value is latched at the beginning or end of the recording process (before or after operation).

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17 TECHNICAL INFORMATION

17.1 Technical data

Description		Value
Dimensions W x H x D	With DIN rail mounting brackets	323.78 x 147.25 x 256.54 mm (12.72 x 5.79 x 10.08 inches)
	With 19'' rack mounting brackets	482.40 x 132.50 x 246.04 mm (18.98 x 5.20 x 9.69 inches)
Weight		5.2 kg (11.4 lbs)
		5.6 kg (12.4 lbs) with DIN rail mounting brackets
		5.8 kg (12.8 lbs) with rack mounting brackets
		7.1 kg (15.5 lbs) with the packaging and accessories
Operation temperature range		-40…+55°C (continuous) / -40…+70°C (16h)
Storage temperature range		-40…+85°C (-40ºF to +158ºF).
Relative humidity		< 93%, non-condensing
MTBF		188000 hours
Altitude		< 2000 m
Minimum permissible atmospheric pressure		784 hPa
Maximum permissible atmospheric pressure		1050 hPa
Enclosure class		IP5x
Connection terminals		IP20
Ingress protection rating at the front		IP5x
Pollution degree		2
Insulation class		Class 1
Overvoltage category		III
Power supply range		18 - 30 V DC 90-250VDC (Phoenix Contact power supply unit included in delivery)
Power consumption		< 30 W
Switching time resolution		< 0.01 ms
Input transducer interfaces		4 x 4-20 mA, 24 V, 2 or 3 wires
Terminal blocks		PHOENIX CONTACT push-in spring type (removable) Screw type connectors upon request
		PHOENIX CONTACT short-circuit connector for CT secondary connection (make before brake)
Max. wiring section	Current and voltage inputs	6 mm² (AWG10)
	Other IOs	2.5 mm² (AWG14)
	Transducers inputs	1.5 mm² (AWG16)
Digital communication interface SFP transceivers		10/100/1000BASE-T (RJ45, copper, x2), or 100BASE-FX (LC optic fiber x 2, on-demand), or 1000BASE-SX (LC optic fiber x 2, on-demand)

17.2 Compliance

Description	Directive	Standard
Product safety	LV directive 2014/35/EU	EN 60950-1 EN 61010-1 IEC 60255-27
EMC compliance	EMC directive 2014/30/UE	IEC 60255-26 IEC 61000-6-5 EN 61000-4-x EN 55032
Eco-design	RoHS directive 2011/65/EU REACH regulation (EC) No 1907/2006	-

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17.3 Ratings

Item	Description	Value
Voltage inputs	Rated voltage, V_n	250 VAC phase to neutral
	Voltage withstand	250 VAC, continuous phase to neutral 300 VAC, 10 s
	Operating range	1– 250 VAC
	Rated frequency	50 – 60 Hz (settable)
	Power consumption at rated voltage	< 0.2 VA at rated voltage
	Accuracy at rated voltage	2%
Current inputs	Rated current, I_n	1 A and 5 A (one single option)
	Thermal short-time withstand	20 A, continuous 500 A - 1 s
	Rated frequency	50/60 Hz ±1 %
	Power consumption of measuring inputs	< 0.1 VA at 5 A
	Accuracy at rated current	2%
Opto-isolated digital inputs	Rated voltage	48 to 250 VDC
	Operating range	30 to 280 VDC
	Time resolution	Turn-on <100 µs Turn-off <100 µs*
	Burden	3.2 mA at 250 VDC
Power outputs	Rated voltage	250 VDC
	Maximum continuous current	5 A
	Short duration withstand carry	20 A – 1 s 35 A – 200 ms
Relays output contacts (monostable)	Breaking capacity, dc resistive	0.2A @ 250 VDC
	Breaking capacity, dc inductive	0.1A @ 250 VDC (L/R = 50 ms)
	Short term withstand	30A – 1s
Relays output contacts (bistable)	Breaking capacity, dc resistive	0.4 A @ 250 VDC
	Breaking capacity, dc inductive	0.2 A @ 250 VDC (L/R = 300 ms)
	Short term withstand	30A – 1s
Sensors input accuracy	Control voltage	±2 %
	Ambient temperature	±3 %
	Hydraulic pressure	±3 %
Nominal burden	Power supply	<30 W
	Addition for energized binary input	800 mW at 250 VDC
	Addition for energized monostable relay	254 mW
	Addition for digital sensor (Keller)	192 mW
	Addition for travel sensor (Positek)	288 mW

* for external capacitor < 1nF (due to cable length)

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17.4 Environmental withstand

Description	Standard	Test level
Cold	IEC 60068-2-1	Start / Operation: -40°C (start after 96h) Storage: -40°C, 96h
Dry Heat	IEC 60068-2-2	Operation: +55°C / 70°C, 16 hrs. Storage: +85°C
Change of temperature	IEC 60068-2-14	Operation: -25 °C / +55 °C, 5 cycles
Damp Heat (steady state)	IEC 60068-2-78	+40°C / 93%RH; 240 hrs.
Cyclic temperature with humidity test	IEC 60068-2-30	+25°C; +55°C / 95% RH, 6 cycles

17.5 Mechanical withstand

Description	Standard	Test level
Sinusoidal Vibration	EN 60068-2-6 IEC 60255-21-1	Response: Class 2 Endurance: Class 1
Shock & Bump	EN 60068-2-27 IEC 60255-21-2	Response: Class 2 Withstand: Class 1 Bump: Class 1
Seismic	EN 60068-2-6 IEC 60255-21-3	Class 2
Ingress protection	IEC 60529	Enclosure IP5x

17.6 Dielectric withstand

Description	Standard	Test level
Power frequency withstand	IEC 60255-27	CM 2 kV – 50/60 Hz / 1 minute DM 1 kV – 50/60 Hz / 1 minute
Insulation resistance test	IEC 60255-27	>100 MΩ at 500 V
Impulse voltage withstand	IEC 60255-27	CM ±5 kV 0.5J DM ±1 kV 0.5J
Voltage tolerance	IEC 60255-27	DC -20% / + 10% AC -20% / +10%

17.7 Emission

Description	Standard	Level
Conducted and radiated emissions	EN 55032 / CISPR 32	Class A

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17.8 Electromagnetic immunity

Test levels compliant with IEC/EN 61000-6-5 (substation environment) and IEC/EN 60255-26 (severe environment).

Description	Standard	Test level	Observed criterion
Electrostatic discharge	EN 61000-4-2	Contact: ±6 kV Air: ±8 kV	A A
Radiated, radio-frequency, electromagnetic field	EN 61000-4-3	80 MHz to 1000 MHz: 10 V/m 1400 MHz to 2700 MHz: 3 V/m 2700 MHz to 6000 MHz: 1 V/m (80% AM @ 1kHz)	A A A
Electrical fast transient / burst	EN 61000-4-4	Power port: ±4 kV – 5/50 ns – 5kHz and 100kHz I/Os port: ±4 kV – 5/50 ns – 5kHz and 100kHz Power output port: ±6 kV – 5/50 ns – 5kHz and 100kHz Communication port: ±2 kV – 5/50 ns – 5kHz and 100kHz	A
Surge (1,2/50 µs)	EN 61000-4-5	±4 kV line to earth ±2 kV line to line	A A
Conducted disturbances, induced by radio-frequency fields	EN 61000-4-6	Sweep 150 kHz to 80 MHz, 10 V, 80% AM (1kHz sine) Spot @ 27 MHz, 10 V, 80% AM (1 kHz sine) Spot @ 68 MHz, 10 V, 80% AM (1 kHz sine)	A A A
Power frequency magnetic field	EN 61000-4-8	Continuous: 100 A/m Impulse (1s): 1000 A/m	A A
Voltage dips, short interruptions and voltage variations on A.C. input power	EN 61000-4-11	Interruption: 20 ms; 50 ms; 100 ms; 200 ms; 500 ms 5000 ms	 A C
		Dip (% of nom. Voltage): 40 % - 200 ms; 70 % - 500 ms; 80 % - 5000 ms	 A
Voltage dips, short interruptions and voltage variations on D.C. input power	EN 61000-4-29	Interruption: 50 ms; 100 ms; 200 ms 500 ms; 5000 ms	 A C
		Dip: (% of nom. voltage) 40% - 200ms; 70% - 500ms	 A
Immunity to conducted, common mode disturbances	EN 61000-4-16	Sweep test: 15 Hz – 150 kHz Continuous test: 30 V at 50 Hz, 60 Hz, DC Impulse test (1 sec): 300 V at 50 Hz, 60 Hz, DC	A A A
Ripple on D.C. input power port	EN 61000-4-17	15% of the nominal value Ripple frequency: 100 Hz and 120 Hz	A
Damped oscillatory wave	EN 61000-4-18	Communication access: Slow wave 1 MHz ±2.5 kV line to earth ±1 kV line to line	A
		Power, I/O port: Slow wave 1 MHz ±2.5 kV line to earth ±1 kV line to line Fast wave 10 MHz ±2.5 kV line to earth ±1 kV line to line	A

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18 APPENDIX A – COMMISSIONING RECORD SHEET

CSD100 commissioning record						
Commissioning date						
Inspection performed by						
Inspection witnessed by						
Commissioning report reference						
Project identification						
Project reference						
Country						
End user						
Substation						
Voltage level						
Bay number						
Circuit breaker identification	1L1	1L2	1L3	2L1	2L2	2L3
Circuit-breaker type						
Circuit-breaker serial number						
CSD100 controller identification						
CSD100 serial number						
CSD100 MAC address						
CSD100 IP address						
CSD100 software version						
Application type						
LV drawing number						
Commissioning tools	Model			S/N		Validity
Relay test set						
Multimeter						
Current clamp						
Digital multichannel recorder						
Insulation tester						
Circuit breaker performances	1L1	1L2	1L3	2L1	2L2	2L3
Arcing contact closing time (ms)						
Auxiliary contact closing time (ms)						
Arcing contact opening time (ms)						
Auxiliary contact opening time (ms)						
Ambient temperature (degC)						
Closing control voltage (VDC)						
Opening control voltage (VDC)						
Preliminary checking						
Earthing inspection						
Wiring conformity						
Power supply value						
Source voltage measurement						
Load voltage measurement						
Load current measurement						
Functional check						
Bypass inspection						
Alarms inspection						
Logics						
Dry tests						
Live test						

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19 APPENDIX B – COMTRADE FILE

19.1 CFG file

station_name,device_name,1999
57,21A,36D
1,UAC1,L1,,V,0.0147697,0,0,-32767,32767,230.94,0.0635086,S
2,UAC2,L2,,V,0.0147697,0,0,-32767,32767,230.94,0.0635086,S
3,UAC3,L3,,V,0.0147697,0,0,-32767,32767,230.94,0.0635086,S
4,UAC4,L1,,V,0.0147697,0,0,-32767,32767,230.94,0.0635086,S
5,UAC5,L2,,V,0.0147697,0,0,-32767,32767,230.94,0.0635086,S
6,UAC6,L3,,V,0.0147697,0,0,-32767,32767,230.94,0.0635086,S
7,IAC1,L1,,A,0.00102402,0,0,-32767,32767,174,0.174,S
8,IAC2,L2,,A,0.00102402,0,0,-32767,32767,174,0.174,S
9,IAC3,L3,,A,0.00102402,0,0,-32767,32767,174,0.174,S
10,UDC1,,,V,0.0118427,0,0,-32767,32767,1,1,P
11,UDC2,,,V,0.0118427,0,0,-32767,32767,1,1,P
12,ICOIL_1,L1,,A,0.00068268,0,0,-32767,32767,1,1,P
13,ICOIL_2,L2,,A,0.00068268,0,0,-32767,32767,1,1,P
14,ICOIL_3,L3,,A,0.00068268,0,0,-32767,32767,1,1,P
15,ICOIL_4,L1,,A,0.00068268,0,0,-32767,32767,1,1,P
16,ICOIL_5,L2,,A,0.00068268,0,0,-32767,32767,1,1,P
17,ICOIL_6,L3,,A,0.00068268,0,0,-32767,32767,1,1,P
18,Ambient temperature sensor,,,°C,1,0,0,-32767,32767,1,1,P
19,CB travel sensor,L1,,mm,1,0,0,-32767,32767,1,1,P
20,CB travel sensor,L2,,mm,1,0,0,-32767,32767,1,1,P
21,CB travel sensor,L3,,mm,1,0,0,-32767,32767,1,1,P
1,Open input order,,,0
2,Close input order,,,0
3,IGBT_CMD_1,L1,,0
4,IGBT_CMD_2,L2,,0
5,IGBT_CMD_3,L3,,0
6,IGBT_CMD_4,L1,,0
7,IGBT_CMD_5,L2,,0
8,IGBT_CMD_6,L3,,0
9,CB1_52a,L1,,0
10,CB1_52a,L2,,0
11,CB1_52a,L3,,0
12,CB2_52a,L1,,0
13,CB2_52a,L2,,0
14,CB2_52a,L3,,0
15,Record trigger,,,0
16,MLS_1,,,0

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17,MLS_2,,,0
18,MLS_3,,,0
19,MLS_4,,,0
20,Bypass_Key,,,0
21,Test_Mode,,,0
22,Alarm_reset,,,0
23,UVLO_1,L1,,1
24,UVLO_2,L2,,1
25,UVLO_3,L3,,1
26,UVLO_4,L1,,1
27,UVLO_5,L2,,1
28,UVLO_6,L3,,1
29,Make_target,L1,,0
30,Make_target,L2,,0
31,Make_target,L3,,0
32,Break_target,L1,,0
33,Break_target,L2,,0
34,Break_target,L3,,0
35,closing,,,0
36,opening,,,0
50
1
40000,80000
14/12/2020,16:17:59.524829
14/12/2020,16:18:0.024829
BINARY
1

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19.2 Example of record

This record is an example of power transformer energization:

- Thanks to high resolution of analogue channels:
  - Load voltages ease making time assessment
  - Inrush currents for each phase (zoomed) are recorded even in case of low amplitude
  - Coils currents are recorded in order to detect any abnormality in low voltage wiring (for example, order coming from another device)
- Digital channels ease operation analysis:
  - input close order
  - power outputs activation (internal power transistors “IGBT”)
  - circuit breaker signalization (52a)
  - make targets (theoretical target for making times, computed before operation)

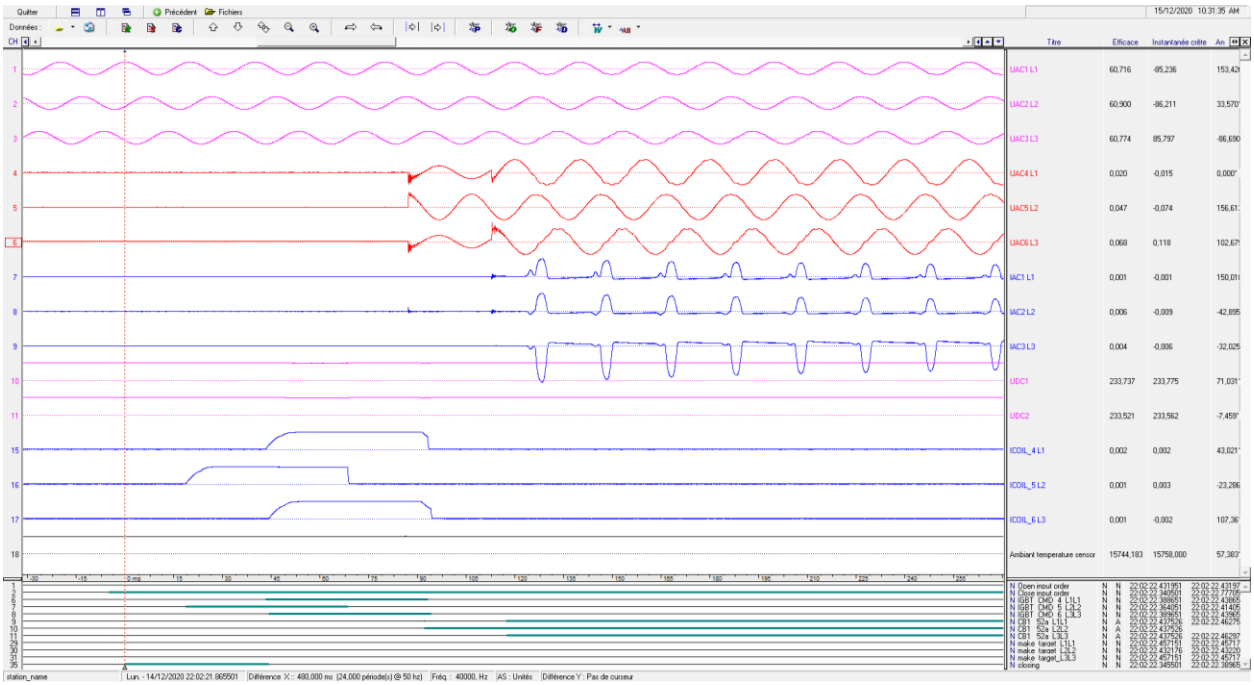


Figure 318 Comtrade file content (comtrade viewer)

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20 APPENDIX C – LIST OF PARAMETERS – PARAMETERS FILE

Essential parameters are accessible from the web HMI interface (see 13.1).

However, a reduced subset of non-essential parameters is only accessible through parameter file editing.

This appendix is a comprehensive list of settings as found in parameter file.

Note : essential settings are clamped by internal limits (not settable) to prevent for big mistakes and editing errors.

20.1 Information

20.1.1 System information

Table 111 Project and system identification settings

Parameter label	Parameter description	Unit	Preset value
information_bay_number	bay number	String	0
information_feeder_name	feeder name	String	Feeder_name
information_cb_model	cb model	String	Cb_model
information_cb1_sn_1	CB #1 serial number L1	String	0
information_cb1_sn_2	CB #1 serial number L2	String	0
information_cb1_sn_3	CB #1 serial number L3	String	0
information_cb2_sn_1	CB #2 serial number L1	String	0
information_cb2_sn_2	CB #2 serial number L2	String	0
information_cb2_sn_3	CB #2 serial number L3	String	0
information_end_user	end user name	String	0
information_lv_drawing	Low Voltage drawing reference	String	Lv_drawing
information_country	country of installation	String	Country
information_project_reference	project reference	String	Project_reference
information_substation	substation name	string	Substation
information_system_frequency	system frequency	Hz	0
information_system_voltage_level	system voltage level	kV	0
information_creation_date	creation date of the param file linked to the CSD100 serial number	YYYY-MM-DD hh:mm:ss.µs	2020-11-26 14:00:00.000000

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20.1.2 CSD100 controller information

Table 112 CSD100 identification settings

Parameter label	Parameter description	Unit	Preset value
information_csd100_config_tool_version	csd100 configuration tool version	String of characters	0
information_csd100_ip_address	csd100 ip address rear ports	String of characters	192.168.5.2/24
information_csd100_ip_address_front	csd100 ip address front port	String of characters	192.168.0.2/24
information_csd100_mac_address	csd100 mac address rear ports	String of characters	80:b3:2a:20:1f:37
information_csd100_mac_address_front	csd100 mac address front port	String of characters	80:b3:2a:20:1f:36
information_csd100_serial_number	csd100 serial number	String of characters	Csd100_serial_number
information_csd100_software_version	csd100 software version	String of characters	1.0
information_modification_date	modification date	YYYY-MM-DD hh:mm:ss.µs	2020-11-26 14:00:00.000000
information_order_reference	order reference	String of characters	Order_reference
information_param_master_version	param master version	String of characters	1
information_param_version	param file version	String of characters	1
information_csd100_ied_name	61850 ied name	String of characters	CSD100
sntp_server_ipaddr	IP address of the network SNTP server	String of characters	
use_sntp_server	Enable/disable of SNTP client function	boolean	0

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20.1.3 Labels definition for records

This section of parameter file allows customization of labels/names used in comtrade files.

Table 113 Records labels settings

Parameter label	Parameter description	Unit	Preset value
information_name_phase_0	Suffix added to all phase related channels names (L1)	string	L1
information_name_phase_1	Suffix added to all phase related channels names (L2)	string	L2
information_name_phase_2	Suffix added to all phase related channels names (L3)	string	L3
information_name_uac_1	UAC1 physical input name	string	UAC1
information_name_uac_2	UAC2 physical input name	string	UAC2
information_name_uac_3	UAC3 physical input name	string	UAC3
information_name_uac_4	UAC4 physical input name	string	UAC4
information_name_uac_5	UAC5 physical input name	string	UAC5
information_name_uac_6	UAC6 physical input name	string	UAC6
information_name_iac_1	IAC1 physical input name	string	IAC1
information_name_iac_2	IAC2 physical input name	string	IAC2
information_name_iac_3	IAC3 physical input name	string	IAC3
information_name_udc_1	UDC1 physical input name	string	UDC1
information_name_udc_2	UDC2 physical input name	string	UDC2
information_name_icoil_1	Coil current name (L1, open)	string	ICOIL_1
information_name_icoil_2	Coil current name (L2, open)	string	ICOIL_2
information_name_icoil_3	Coil current name (L3 open)	string	ICOIL_3
information_name_icoil_4	Coil current name (L1, close)	string	ICOIL_4
information_name_icoil_5	Coil current name (L2, close)	string	ICOIL_5
information_name_icoil_6	Coil current name (L3 close)	string	ICOIL_6
information_name_low_level_input_0	Name of the analogue sensor input 1	string	Ambient temperature sensor
information_name_low_level_input_1	Name of the analogue sensor input 2	string	CB travel sensor
information_name_low_level_input_2	Name of the analogue sensor input 3	string	CB travel sensor
information_name_low_level_input_3	Name of the analogue sensor input 4	string	CB travel sensor
Information_name_keller_sensor_0	Name of the digital sensor input 1 L1 (cb1)	string	Gas_pressure_cb1
Information_name_keller_sensor_1	Name of the digital sensor input 2 L2 (cb1)	string	Gas_pressure_cb1
Information_name_keller_sensor_2	Name of the digital sensor input 2 L3 (cb1)	string	Gas_pressure_cb1
Information_name_keller_sensor_3	Name of the digital sensor input 4 L1 (cb2)	string	Gas_pressure_cb2
Information_name_keller_sensor_4	Name of the digital sensor input 5 L2 (cb2)	string	Gas_pressure_cb2
Information_name_keller_sensor_5	Name of the digital sensor input 6 L3 (cb2)	string	Gas_pressure_cb2
Information_name_keller_sensor_6	Name of the digital sensor input 7 L1 (cb1)	string	Hydraulic_pressure_cb1
Information_name_keller_sensor_7	Name of the digital sensor input 8 L2 (cb1)	string	Hydraulic_pressure_cb1
Information_name_keller_sensor_8	Name of the digital sensor input 9 L3 (cb1)	string	Hydraulic_pressure_cb1
Information_name_keller_sensor_9	Name of the digital sensor input 10 L1 (cb2)	string	Hydraulic_pressure_cb2
Information_name_keller_sensor_10	Name of the digital sensor input 11 L2 (cb2)	string	Hydraulic_pressure_cb2
Information_name_keller_sensor_11	Name of the digital sensor input 12 L3 (cb2)	string	Hydraulic_pressure_cb2
information_name_di_01	Name of DI #1 physical input	string	Open input order
information_name_di_02	Name of DI #2 physical input	string	Close input order
information_name_di_03	Name of DI #3 physical input	string	CB1_52a
information_name_di_04	Name of DI #4 physical input	string	CB1_52a
information_name_di_05	Name of DI #5 physical input	string	CB1_52a
information_name_di_06	Name of DI #6 physical input	string	CB2_52a
information_name_di_07	Name of DI #7 physical input	string	CB2_52a
information_name_di_08	Name of DI #8 physical input	string	CB2_52a
information_name_di_09	Name of DI #9 physical input	string	Record trigger
information_name_di_10	Name of DI #10 physical input	string	MLS_1
information_name_di_11	Name of DI #11 physical input	string	MLS_2
information_name_di_12	Name of DI #12 physical input	string	MLS_3
information_name_di_13	Name of DI #13 physical input	string	MLS_4
information_name_di_14	Name of DI #14 physical input	string	Bypass_Key
information_name_di_15	Name of DI #15 physical input	string	Test_Mode
information_name_di_16	Name of DI #16 physical input	string	Alarm_reset
information_name_uvlo_01	Name of internal DI UVLO #1	string	UVLO_1
information_name_uvlo_02	Name of internal DI UVLO #2	string	UVLO_2
information_name_uvlo_03	Name of internal DI UVLO #3	string	UVLO_3
information_name_uvlo_04	Name of internal DI UVLO #4	string	UVLO_4

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Parameter label	Parameter description	Unit	Preset value
information_name_uvlo_05	Name of internal DI UVLO #5	string	UVLO_5
information_name_uvlo_06	Name of internal DI UVLO #6	string	UVLO_6
information_name_cmd_igbt_01	Name of internal DO IGBT #1	string	IGBT_CMD_1
information_name_cmd_igbt_02	Name of internal DO IGBT #2	string	IGBT_CMD_2
information_name_cmd_igbt_03	Name of internal DO IGBT #3	string	IGBT_CMD_3
information_name_cmd_igbt_04	Name of internal DO IGBT #4	string	IGBT_CMD_4
information_name_cmd_igbt_05	Name of internal DO IGBT #5	string	IGBT_CMD_5
information_name_cmd_igbt_06	Name of internal DO IGBT #6	string	IGBT_CMD_6
information_name_make_target_01	Name of computed DI make target #1	string	Make_target
information_name_make_target_02	Name of computed DI make target #2	string	Make_target
information_name_make_target_03	Name of computed DI make target #3	string	Make_target
information_name_sep_target_01	Name of computed DI break target #1	string	Break_target
information_name_sep_target_02	Name of computed DI break target #2	string	Break_target
information_name_sep_target_03	Name of computed DI break target #3	string	Break_target

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20.2 General

20.2.1 Main options

Table 114 Main settings

Parameter label	Parameter description	Unit or possible value	Preset value
general_cb_type	Circuit breaker type (standard: 1 drive per phase, Inserter: 2 cb in parallel with delay in between, 2 drives per phase (open only), 2 drives per phase (close only)	Standard Inserter 2 CB Open 2 CB Close	Standard
general_cb_type_insertion_time	Resistor pre-insertion mechanical time (inserter made of a second circuit breaker in parallel). Applicable when cb_type is selected as “Inserter”	ms	0
general_switching_program	Switching program selection for static (fixed) strategy (MLS inactive).	Transfo1 Transfo2 React1 React2 Capa1 Capa2 Line User1 User2 User3 User4	User1
general_enable_multiple_load_switching	“Multiple load switching” mode activation (dynamic strategy selection)	Boolean (Enable/Disable)	Disable
general_rated_power_frequency	Rated network power frequency. Used to raise alarm if measured frequency is out of range (reference sync waveform)	Hz	50
general_ref_phase	Indicates which phase is to be taken as the reference for synchronization. For example, if L2 is selected, ref phase shall be wired to L2 physical input).	L1/L2/L3	L1
general_optimize_delay	Dynamic selection of synchronizing phase, to reduce global input to outputs latency. This mandatorily requires physical connection of the three source reference waveforms (for voltage reference, only one is usually connected)	Boolean (Enable/Disable)	Disable
general_reference_voltage_phase_shift	Phase shift to apply to reference waveform, in case reference waveform is not the actual one present at circuit breaker terminal (VT located far away, at another side of power transformer, line to line instead of expected lien to earth…)	deg	0
general_synchronize_with_differential_voltage	In case residual voltage is expected at load side (cb with grading capacitors), it may be necessary to synchronize on circuit breaking voltage (differential voltage)	Boolean (Enable/Disable)	Disable
general_open_sync_on_current	Reference waveform is the circuit breaker current from AC current inputs (opening operations). Typically, applicable for variable load power factor.	Boolean (Enable/Disable)	Disable
general_control_voltage_open	Defines which DC voltage input is used to measure open coils control voltage.	DC1 DC2	DC1
general_control_voltage_close	Defines which DC voltage input is used to measure close coils control voltage.	DC1 DC2	DC2
general_igbt_duration_open	Duration of power outputs activation (open coils control).	ms	50
general_igbt_duration_close	Duration of power outputs activation (open coils control).	ms	100
general_igbt_energy_threshold_open	Minimum energy value to consider that CSD100 has initiated open operation (from coil current measurement)	J	1
general_igbt_energy_threshold_close	Minimum energy value to consider that CSD100 has initiated close operation (from coil current measurement)	J	2

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20.2.2 Multiple load switching

Table 115 Multiple load switching related settings

Parameter label	Parameter description	Unit or possible value	Preset value
general_multiple_load_switching_0	Selected strategy when MLS digital inputs (x4) equal to 0.	Transfo1 / Transfo2 / React1 / React2 / Capa1 / Capa2 / Line / User1 / User2 / User3 / User4	Line
…	…		
general_multiple_load_switching_15	Selected strategy when MLS digital inputs (x4) equal to 15.	Transfo1 / Transfo2 / React1 / React2 / Capa1 / Capa2 / Line / User1 / User2 / User3 / User4	User4
general_dual_switching_0	Dual Switching activated when MLS digital inputs (x4) equal to 0.	Boolean (Yes/No)	No
…	…		
general_dual_switching_15	Dual Switching activated when MLS digital inputs (x4) equal to 15.	Boolean (Yes/No)	No

20.2.3 Rated levels

Table 116 Primary rated level settings

Parameter label	Parameter description	Unit or possible value	Preset value
general_rated_primary_voltage_source	System voltage rated value at source side (phase-ground)	kV	230.94
general_rated_primary_voltage_load	System voltage rated value at load side (phase-ground)	kV	230.94
general_primary_current_rated	Rated primary current	A	174
general_vt_ratio_source	Source voltage transformers ratio	sd	3636.36
general_vt_ratio_load	Load voltage transformer ratio	sd	3636.36
general_ct_ratio	Current transformer ratio	sd	1000
general_load_voltage_rms_threshold_deenergization	Threshold to detect load de-energization (rms)	%	25
general_load_voltage_rms_threshold_energization	Threshold to detect load energization (rms)	%	50
general_uncontrolled_open_timeout	Time difference between expected controlled switching time and measured switching time above which operation is considered as uncontrolled (not handled by CSD100)	ms	75
ouv_rph	Last opening operation status: controlled by CSD100 or uncontrolled	String of characters Controlled/Uncontrolled	Uncontrolled

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20.2.4 Analogue sensors inputs scaling

Table 117 Analogue sensors settings

Parameter label	Parameter description	Unit or possible value	Preset value
general_low_level_input_type_0	1st sensor input type	Boolean Current / Voltage 4-20mA or 0-5VDC	Current
general_low_level_input_type_1	2nd sensor input type	Boolean Current / Voltage 4-20mA or 0-5VDC	Current
general_low_level_input_type_2	3rd sensor input type	Boolean Current / Voltage 4-20mA or 0-5VDC	Current
general_low_level_input_type_3	4th sensor input type	Boolean Current / Voltage 4-20mA or 0-5VDC	Current
general_ambient_temperature_4ma	Sensor linear scaling: ambient temperature @4mA	degC	-50
general_ambient_temperature_20ma	Sensor linear scaling: ambient temperature @20mA	degC	50
general_sf6_pressure_rated	Rated SF6 pressure	MPa	0.85

20.2.5 Digital transmitter

Table 118 Digital sensors (RS485) settings

Parameter label	Parameter description	Unit or possible value	Preset value
mechanical_pressure_sensor_baudrate	Digital transmitter communication speed	List: 115200 / 19200 / 38400 / 57600 / 9600	115200
general_keller_sensor_address_0	CB1 phase L1 gas sensor RS485 address	string	1
general_keller_sensor_address_1	CB1 phase L2 gas sensor RS485 address	string	2
general_keller_sensor_address_2	CB1 phase L3 gas sensor RS485 address	string	3
general_keller_sensor_address_3	CB2 phase L1 gas sensor RS485 address	string	4
general_keller_sensor_address_4	CB2 phase L2 gas sensor RS485 address	string	5
general_keller_sensor_address_5	CB2 phase L3 gas sensor RS485 address	string	6
general_keller_sensor_address_6	CB1 phase L1 hydraulic drive pressure sensor RS485 address	string	7
general_keller_sensor_address_7	CB1 phase L2 hydraulic drive pressure sensor RS485 address	string	8
general_keller_sensor_address_8	CB1 phase L3 hydraulic drive pressure sensor RS485 address	string	9
general_keller_sensor_address_9	CB2 phase L1 hydraulic drive pressure sensor RS485 address	string	10
general_keller_sensor_address_10	CB2 phase L2 hydraulic drive pressure sensor RS485 address	string	11
general_keller_sensor_address_11	CB2 phase L3 hydraulic drive pressure sensor RS485 address	string	12

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20.2.6 Recording

Table 119 Comtrade records settings

Parameter label	Parameter description	Unit or possible value	Min value	Max value	Preset value
general_buffer_depth_open	Record total duration, opening operations.	Seconds	0	5	2.0
general_buffer_pretrigger_time_open	Record pre-event duration, opening operations.	Seconds	0	5	1.0
general_buffer_depth_close	Record total duration, closing operations.	Seconds	0	5	2.0
general_buffer_pretrigger_time_close	Record pre-event duration, closing operations.	Seconds	0	5	1.0
general_recording_alarms_discrepency_time	Rearming time for record creation, between two alarms occurrence (to avoid excessive file creation and memory saturation, if record creation upon alarm is activated)	ms			400.0
general_recording_52a_discrepency_time	Rearming time for record creation, between two 52a switching occurrence (to avoid excessive file creation and memory saturation, if record creation upon 52a switching is activated)	ms			400.0
general_recording_52a_activation_time	Minimum 52a duration time for record creation (if record creation upon 52a switching is activated)	ms			4000.0
archive_filter	Encoding number for record creation causes. Do not edit (changes only with HMI).				
last_archive_number					

20.2.7 Internal

Settings description are provided for information purpose only and **must never been changed**.

Table 120 Internal parameters

Parameter label	Parameter description	Unit or possible value	Preset value
general_biquad_filter_coef_a_0	Butterworth filter: denominator 1	String	1
general_biquad_filter_coef_a_1	Butterworth filter: denominator 2	String	-1.96668
general_biquad_filter_coef_a_2	Butterworth filter: denominator 3	String	0.967227
general_biquad_filter_coef_b_0	Butterworth filter: numerator 1	String	0.000136511
general_biquad_filter_coef_b_1	Butterworth filter: numerator 2	String	0.000273021
general_biquad_filter_coef_b_2	Butterworth filter: numerator 3	string	0.000136511
general_biquad_filter_delay_50hz	Butterworth filter: filter delay 50 Hz	ms	1.54
general_biquad_filter_delay_60hz	Butterworth filter: filter delay 60 Hz	ms	1.59

Table 121 Internal delays and ratios (factory use)

Parameter label	Parameter description	Unit or possible value	Preset value
Internal_delay_di_turn_off	Compensation for internal digital input, during turn off.	µs	
Internal_delay_di_turn_on	Compensation for internal digital input, during turn on.	µs	
Internal_adc_ratio_uac	Internal scaling ratio for analogue AC voltage inputs.		
Internal_adc_ratio_udc	Internal scaling ratio for analogue DC voltage inputs.		
Internal_adc_ratio_iac	Internal scaling ratio for analogue AC current inputs.		
Internal_adc_ratio_4-20ma	Internal scaling ratio for analogue 4-20mA inputs.		
Internal_adc_ratio_0-5v	Internal scaling ratio for analogue 0-5V inputs.		
Internal_adc_ratio_idc	Internal scaling ratio for analogue power outputs current measurements.		

These delays and ratios are for factory use only and shall never been modified (unless warranty is void).

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20.3 Sampled values

Table 122 Sampled values settings

Parameter label	Parameter description	Unit or possible value	Preset value
sv_applied_config	SV subscription configuration selected for operation	List 0 … 9	0
sv_config_0 … sv_config_9	Values set for each SV configuration	Refer to following note	Refer to following note
sv_enable_sampled_values_acquisition	Voltage and current measurement acquisition mode	Boolean (Analogue/Sampled values)	Analogue
sv_sample_rate	SV sample rate (SmpRate), number of samples per second transmitted by a SV publisher.	List 4000sps / 4800sps	4000sps
sv_max_accepted_propagation_delay	This value corresponds to the maximum SV transmission delay, from the publisher to the subscriber, the CSD100 tolerates for correct processing. For example, with a SmpRate of 4000 sps, if this value is set to 5, CSD100 rejects all samples transmitted with a delay higher than 1.250 ms. To set this value consistently, it is possible to measure the average propagation delay of each stream in monitoring section and consider a 5 times margin for example.	Number of samples 1 … 18	10
sv_smp_sync	SV SmpSync, reflects the minimum level of SV synchronization the CSD100 tolerates for operation. For instance, if this parameter is set to Global and the SmpSync status of the SV received is Internal, the CSD100 will not consider the SV as valid for operation.	List Internal / Local / Global	Global
sv_delay_meter_sel_chan	This value allows selection of the stream for which the measured propagation delay needs to be displayed in monitoring section	List Source voltage / Load voltage / Current	Source voltage

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Note: The frame for a SV configuration follows this rule:

Config index	Processed stream 1 (U1…U3)	Processed stream 2 (U4…U6)	Processed stream 3 (I1…I3)	Watched stream 1	Watched stream 2	Watched stream 3	Watched stream 4

The content for each stream is:

SV filtering enabling 0 → Disabled 1 → Enabled	MAC@ filtering enabling 0 → Disabled 1 → Enabled	Destination MAC@ adress of the publisher (6 bytes in HEXA)	APPID filtering enabling 0 → Disabled 1 → Enabled	APPID of the publisher (in HEXA)	Simulated frames filtering enabling 0 → Disabled 1 → Enabled	Type of frame 0 → regular frame 1 → simulated frame	SVID filtering enabling 0 → Disabled 1 → Enabled	SVID of the publisher (1 to 12 characters)	Position of Phase L1 measurement in the ASDU (0 to 23)	Position of Phase L2 measurement in the ASDU (0 to 23)	Position of Phase L3 measurement in the ASDU (0 to 23)
1	1:010CCD040001		0:0x4001		0:1		0:TESTCSD_01		4	5	6

As an exemple,

<value lbl="**sv_config_0**">

<![CDATA[config_0,1,1:010CCD040001,0:0x4001,0:1,0:TESTCSD_01,4,5,6,1,1:010CCD040002,0:0x4002,0:1,0:TESTCSD_02,4,5,6,1,1:010CCD040002,0:0x4003,0:1,0:TESTCSD_03,0,1,2,1,1:010CCD040002,1:0x4002,1:0,1:TESTCSD_04,23,23,23,1,1:010CCD040004,1:0x4000,1:0,1:TESTCSD_05,23,23,23,1,1:010CCD040006,1:0x4009,1:0,1:TESTCSD_06,23,23,23,1,1:010CCD040001,1:0x4007,1:1,1:TESTCSD_07,23,23,23]]>

</value>

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20.4 Mechanical

20.4.1 Operating mechanism

Parameter label	Parameter description	Unit	Preset value
mechanical_breaker_hydraulic_drive	Indicates if circuit breaker is fitted with a hydraulic drive.	Boolean (Yes/No)	no

20.4.2 Operating time setting

Table 123 Mechanical times settings

Parameter label	Parameter description	Unit	Preset value
mechanical_arcing_contact_time_rated_0 mechanical_arcing_contact_time_rated_1 mechanical_arcing_contact_time_rated_2	L1 / L2 / L3 nominal arcing contacts opening times (mechanical contact separation).	ms	0.0/0.0/0.0
mechanical_arcing_contact_time_rated_3 mechanical_arcing_contact_time_rated_4 mechanical_arcing_contact_time_rated_5	L1 / L2 / L3 nominal arcing contacts closing time (mechanical contact touch).	ms	0.0/0.0/0.0
mechanical_aux_contact_time_rated_0 mechanical_aux_contact_time_rated_1 mechanical_aux_contact_time_rated_2	L1 / L2 / L3 nominal auxiliary contacts (52a) opening time.	ms	0.0/0.0/0.0
mechanical_aux_contact_time_rated_3 mechanical_aux_contact_time_rated_4 mechanical_aux_contact_time_rated_5	L1 / L2 / L3 nominal auxiliary contacts (52a) closing time.	ms	0.0/0.0/0.0
mechanical_arcing_contact_time_max_0 mechanical_arcing_contact_time_max_1 mechanical_arcing_contact_time_max_2	L1 / L2 / L3 maximum arcing contacts opening times (mechanical contact separation). Exceeding values will raise an alarm.	ms	200
mechanical_arcing_contact_time_max_3 mechanical_arcing_contact_time_max_4 mechanical_arcing_contact_time_max_0	L1 / L2 / L3 maximum arcing contacts closing times (mechanical contact touch). Exceeding values will raise an alarm.	ms	200

Notes:

- if CB is chosen as “Closing resistor”, timings 0 to 2 are reused as 1st circuit breaker closing times
- if CB is chosen as “Double closing mechanism”, timings 0 to 2 are reused as 1st circuit breaker closing times
- if CB is chosen as “Double opening mechanism”, timings 3 to 5 are reused as 2nd circuit breaker opening times

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20.4.3 Operating time measurement (mechanical and electrical)

Table 124 Operating time measurement settings

Parameter label	Parameter description	Unit	Preset value
mechanical_measurement_option_52a	This parameter indicates presence or absence of 52a sensors (mechanical time measurement).	Boolean (Yes/No)	yes
mechanical_measurement_option_travel_curve	This parameter indicates presence or absence of travel curve sensors (mechanical time measurement).	Boolean (Yes/No)	yes
mechanical_time_measurement_mode_open	This parameter indicates which sensor to consider for mechanical times measurement, for opening and closing operations.	String: “Auxiliary contact” / “Travel curve”	Auxiliary contact
mechanical_time_measurement_mode_close	This parameter indicates which sensor to consider for mechanical times measurement, for close operations.	String: “Auxiliary contact” / “Travel curve”	Auxiliary contact
making_time_measurement_method	This parameter indicates which method to consider for making times measurement, during closing operations. Methods are based on load currents or load voltages observation.	String: current threshold / current reconstruction / voltage rise	Current threshold
making_time_measurement_current_threshold	This parameter defines the threshold to detect current rise (“current threshold” or “current reconstruction” method selected).	A	50
mechanical_time_measurement_opening_sep_distance_0 mechanical_time_measurement_opening_sep_distance_1 mechanical_time_measurement_opening_sep_distance_2	Contact separation distance (measured from static fully open position) during opening motion. L1 / L2 / L3.	mm	0/0/0
mechanical_time_measurement_closing_touch_distance_0 mechanical_time_measurement_closing_touch_distance_1 mechanical_time_measurement_closing_touch_distance_2	Contact touch distance (measured from static fully open position) during closing motion. L1 / L2 / L3.	mm	0/0/0
stability_duration	Minimum signal stability duration from first edge/transition detected (digital input 52a). Datation is taken at the end of stability duration. Applicable both for turn on (close) and turn off (open).	ms	2ms
edge_detection_duration	Time window before beginning of stability to search for first transition	ms	0ms

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20.4.4 Circuit breaker travel curve

Table 125 Travel curve settings

Parameter label	Parameter description	Unit	Preset value
mechanical_time_measurement_travel_sensor_signal_open_position_0 mechanical_time_measurement_travel_sensor_signal_open_position_1 mechanical_time_measurement_travel_sensor_signal_open_position_2	Travel curve sensor raw value when circuit breaker is in static fully open position (open extreme position). L1 / L2 / L3	mA	0.0/0.0/0.0
mechanical_time_measurement_travel_sensor_signal_close_position_0 mechanical_time_measurement_travel_sensor_signal_close_position_1 mechanical_time_measurement_travel_sensor_signal_close_position_2	Travel curve sensor raw value when circuit breaker is in static fully close position (close extreme position). L1 / L2 / L3	mA	0.0/0.0/0.0
mechanical_max_travel_stroke_0 mechanical_max_travel_stroke_1 mechanical_max_travel_stroke_2	Convert travel information from raw sensor measurement (mA) to distance at circuit breaker arcing contact level.	mm	0.0/0.0/0.0
mechanical_time_measurement_travel_sensor_signal_open_timeshift_0 mechanical_time_measurement_travel_sensor_signal_open_timeshift_1 mechanical_time_measurement_travel_sensor_signal_open_timeshift_2	Difference between arcing contact opening time and Travel sensor stroke separation time	ms	0.0/0.0/0.0
mechanical_time_measurement_travel_sensor_signal_close_timeshift_0 mechanical_time_measurement_travel_sensor_signal_close_timeshift_1 mechanical_time_measurement_travel_sensor_signal_close_timeshift_2	Difference between arcing contact closing time and Travel sensor stroke touch time	ms	0.0/0.0/0.0

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20.4.5 Operating time compensation functions

Table 126 Mechanical times compensation settings

Parameter label	Parameter description	Unit	Preset value
mechanical_time_gas_density_comp_enable	Reserved for future use.	Boolean (Enable/Disable)	Disable
mechanical_time_temperature_comp_enable	This parameter enables or disables mechanical times compensation according to circuit breaker ambient temperature.	Boolean (Enable/Disable)	Disable
mechanical_time_voltage_comp_enable	This parameter enables or disables mechanical times compensation according to circuit breaker coil control voltages (DC1 and DC2).	Boolean (Enable/Disable)	Disable
mechanical_time_hydraulic_comp_enable	This parameter enables or disables mechanical times compensation according to circuit breaker drive hydraulic pressure (if applicable).	Boolean (Enable/Disable)	Disable
mechanical_time_idle_time_comp_enable	This parameter enables or disables mechanical times compensation according to idle time (amount of time elapsed from previous operation).	Boolean (Enable/Disable)	Disable
mechanical_time_adaptive_comp_enable	This parameter enables or disables mechanical times adaptive compensation (based on previous mechanical time measurements, loopback process). If disabled, this compensation remains computed but not applied. It may be reset at any time with dedicated parameters.	Boolean (Enable/Disable)	Disable
mechanical_time_compensation_max_abs	This value sets a limit to the total computed mechanical time compensation, in absolute value. Exceeding compensations will be clamped.	ms	5.0
mechanical_time_gas_open_comp_0 .. mechanical_time_gas_open_comp_3	Reserved for future use.	ms	
mechanical_time_gas_close_comp_0 .. mechanical_time_gas_open_comp_3	Reserved for future use.	ms	
mechanical_time_temperature_open_comp_0 … mechanical_time_temperature_open_comp_10	These 11 values form a look-up table to convert ambient temperature (-50°C to +50°C) measurement to mechanical time compensation (added to nominal time), for opening operations. If measurement exceed table range, extreme value is retained. If temperature measurement is in alarm compensation is automatically disabled.	ms	0.0 … 0.0
mechanical_time_temperature_close_comp_0 … mechanical_time_temperature_close_comp_10	These 11 values form a look-up table to convert ambient temperature (-50°C to +50°C) measurement to mechanical time compensation (added to nominal time), for closing operations. If measurement exceed table range, extreme value is retained. If temperature measurement is in alarm compensation is automatically disabled.	ms	0.0 … 0.0
mechanical_time_voltage_comp_open_rated_value	Rated value of DC control voltage used to drive circuit-breaker opening coils (substation batteries).	V	125
mechanical_time_voltage_comp_open_0 … mechanical_time_voltage_comp_open_3	These 4 values form a look-up table to convert measured control voltage (in percentage of rated) to mechanical time compensation (added to nominal time), for opening operations. Values for [70% 85% 100% 110%] of rated. If measurement exceeds table range, extreme value is retained. If control voltage measurement is in alarm compensation is automatically disabled.	ms	0.0 … 0.0
mechanical_time_voltage_comp_close_rated_value	Rated value of DC control voltage used to drive circuit-breaker closing coils (substation batteries).	V	125

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Parameter label	Parameter description	Unit	Preset value
mechanical_time_voltage_comp_close_0 … mechanical_time_voltage_comp_close_3	These 4 values form a look-up table to convert measured control voltage (in percentage of rated) to mechanical time compensation (added to nominal time), for closing operations. Values for [85% 93% 100% 110%] of rated. If measurement exceeds table range, extreme value is retained. If control voltage measurement is in alarm compensation is automatically disabled.	ms	0.0 … 0.0
mechanical_time_hydraulic_comp_rated_value	Rated value of drive hydraulic pressure.	MPa	34.0
mechanical_time_hydraulic_comp_open_0 … mechanical_time_hydraulic_comp_open_9	These 10 values form a look-up table to convert measured drive hydraulic pressure (in percentage of rated) to mechanical time compensation (added to nominal time), for opening operations. Values from 50% to 140% of rated (10% increment). If measurement exceeds table range, extreme value is retained. If hydraulic pressure measurement is in alarm compensation is automatically disabled.	ms	0.0
mechanical_time_hydraulic_comp_close_0 … mechanical_time_hydraulic_comp_close_9	These 10 values form a look-up table to convert measured drive hydraulic pressure (in percentage of rated) to mechanical time compensation (added to nominal time), for closing operations. Values from 50% to 140% of rated (10% increment). If measurement exceeds table range, extreme value is retained. If hydraulic pressure measurement is in alarm compensation is automatically disabled.	ms	0.0 … 0.0
mechanical_time_idle_time_comp_open_0 … mechanical_time_idle_time_comp_open_8	These 9 values form a look-up table to convert elapsed time from last operation to mechanical time compensation (added to nominal time), for opening operations. Input values: [1h 2h 4h 8h 16h 32h 64h 168h +inf].	ms	0.0 … 0.0
mechanical_time_idle_time_comp_close_0 … mechanical_time_idle_time_comp_close_8	These 9 values form a look-up table to convert elapsed time from last operation to mechanical time compensation (added to nominal time), for closing operations. Input values: [1h 2h 4h 8h 16h 32h 64h 168h +inf].	ms	0.0 … 0.0
mechanical_time_adaptive_comp_closing_gain	This parameter sets the fraction of the mechanical time error measured from previous operation, which is added to the next operation mechanical time forecast (adaptive compensation) for closing operations.	sd	0.01
mechanical_time_adaptive_comp_closing_max_abs	This value sets a limit to the computed adaptive compensation, in absolute value, for closing operations. Exceeding compensations will be clamped.	ms	5
mechanical_time_adaptive_comp_opening_gain	This parameter sets the fraction of the mechanical time error measured from previous operation, which is added to the next operation mechanical time forecast (adaptive compensation) for opening operations.	sd	0.01
mechanical_time_adaptive_comp_opening_max_abs	This value sets a limit to the computed adaptive compensation, in absolute value, for opening operations. Exceeding compensations will be clamped.	ms	5

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20.4.6 Initial values for compensation

The compensations for which memorization of values is necessary (to ensure for consistent operations if CSD100 is turned off and on) require initial values to be set.

This is only for first operation (or to reset adaptive compensation). For subsequent operations, process is fully automatic.

- Adaptive compensation: previous compensation value and previous mechanical time forecast.
- Idle time compensation: date of previous operation.

Table 127 Initial values for compensations settings

Parameter label	Parameter description	Unit	Preset value
measured_meca_time_0 measured_meca_time_1 measured_meca_time_2	Previous opening date/time for phases L1 / L2 / L3	ms	0.0 / 0.0 / 0.0
measured_meca_time_3 measured_meca_time_4 measured_meca_time_5	Previous closing date/time for phases L1 / L2 / L3	ms	0.0 / 0.0 / 0.0
last_valid_measured_meca_time_0 last_valid_measured_meca_time_1 last_valid_measured_meca_time_2	Initial value for previous opening date/time for phases L1 / L2 / L3 that was inside set boundaries. This value feed adaptive control.	ms	
last_valid_measured_meca_time_3 last_valid_measured_meca_time_4 last_valid_measured_meca_time_5	Initial value for previous closing date/time for phases L1 / L2 / L3 that was inside set boundaries. This value feed adaptive control.	ms	
calculated_meca_time_adaptive_compensation_0 calculated_meca_time_adaptive_compensation_1 calculated_meca_time_adaptive_compensation_2	Previous adaptive compensation value for opening operations and for phases L1 / L2 / L3	ms	0.0 / 0.0 / 0.0
calculated_meca_time_adaptive_compensation_3 calculated_meca_time_adaptive_compensation_4 calculated_meca_time_adaptive_compensation_5	Previous adaptive compensation value for closing operations and for phases L1 / L2 / L3	ms	0.0 / 0.0 / 0.0
calculated_meca_time_0 calculated_meca_time_1 calculated_meca_time_2	Previous computed mechanical time (forecast) value for opening operations and for phases L1 / L2 / L3	ms	0.0 / 0.0 / 0.0
calculated_meca_time_3 calculated_meca_time_4 calculated_meca_time_5	Previous computed mechanical time (forecast) value for closing operations and for phases L1 / L2 / L3	ms	0.0 / 0.0 / 0.0
timestamp_open_0 timestamp_open _1 timestamp_open _2	Last open operation date L1 L2 L3 (CB #1)	YYYY-MM-DD hh:mm:ss.µs	2020-11-26 22:00:00.000000
timestamp_open_3 timestamp_open _4 timestamp_open _5	Last open operation date L1 L2 L3 (CB #2)	YYYY-MM-DD hh:mm:ss.µs	2020-11-26 22:00:00.000000
timestamp_close_0 timestamp_close_1 timestamp_close_2	Last close operation date L1 L2 L3 (CB #1)	YYYY-MM-DD hh:mm:ss.µs	2020-11-26 22:00:00.000000
timestamp_close_3 timestamp_close_4 timestamp_close_5	Last close operation date L1 L2 L3 (CB #2)	YYYY-MM-DD hh:mm:ss.µs	2020-11-26 22:00:00.000000

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20.4.7 Electrical wear

Circuit breaker electrical wear assessment requires some initial values to be set.

This is only for first operation (or to reset adaptive compensation). For subsequent operations, process is fully automatic.

Also, for IEC61850, as electrical wear is expressed in term of %, the maximum electrical wear shall be setable.

Table 128 Electrical wear settings

Parameter label	Parameter description	Unit	Preset value
cumulative_electric_wear_0 cumulative_electric_wear_1 cumulative_electric_wear_2	Initial value for accumulated electrical wear, L1, L2, L3	kA².s	0.0
cumulative_electric_wear_3 cumulative_electric_wear_4 cumulative_electric_wear_5	Initial value for accumulated electrical wear, L1, L2, L3 (CB2 open, unless unused)	kA².s	0.0
last_opening_electric_wear_0 last_opening_electric_wear_1 last_opening_electric_wear_2	Initial value for last opening electrical wear, L1, L2, L3	kA².s	0.0
last_opening_electric_wear_3 last_opening_electric_wear_4 last_opening_electric_wear_5	Initial value for last opening electrical wear, L1, L2, L3 (CB2 open, unless unused)	kA².s	0.0
max_cumulative_electric_wear_0 max_cumulative_electric_wear_1 max_cumulative_electric_wear_2	Maximum value for accumulated electrical wear, L1, L2, L3	kA².s	1.0
max_cumulative_electric_wear_3 max_cumulative_electric_wear_4 max_cumulative_electric_wear_5	Maximum value for accumulated electrical wear, L1, L2, L3 (CB2 open, unless unused)	kA².s	1.0
mechanical_cb_electric_wear_choice	Enable / disable electrical wear monitoring		Disable

20.5 Gas monitoring

Table 129 Gas monitoring settings

Parameter label	Parameter description	Unit	Preset value
mechanical_cb_gas_monitoring_choice	Enable / disable gas monitoring		Disable
gas_type	List of gases		SF6
alpha_gas_ratio	Ratio of gas mixture (SF6 mixtures)		0.0
pressure_20_filling_init	Initial filling pressure (20°C eq.)	bar	
percent_mol_novec	G3 mixture percent of Novec gas		0.0
percent_mol_o2	G3 mixture percent of dioxygen gas		0.0

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20.6 Application alarms and allocation to physical outputs

Table 130 Application alarms settings

Parameter label	Parameter description	Unit	Preset value
alarm_upper_uac1_value	Upper rms limit for L1 source side voltage.	kV	300.0
alarm_lower_uac1_value	Lower rms limit for L1 source side voltage.	kV	40.0
alarm_mask_uac1	Alarm affectation to outputs	Bit field	0000
alarm_upper_uac2_value	Upper rms limit for L2 source side voltage.	kV	300.0
alarm_lower_uac2_value	Lower rms limit for L2 source side voltage.	kV	40.0
alarm_mask_uac2	Alarm affectation to outputs	Bit field	0000
alarm_upper_uac3_value	Upper rms limit for L3 source side voltage.	kV	300.0
alarm_lower_uac3_value	Lower rms limit for L3 source side voltage.	kV	40.0
alarm_mask_uac3	Alarm affectation to outputs	Bit field	0000
alarm_upper_uac4_value	Upper rms limit for L1 load side voltage.	kV	300.0
alarm_lower_uac4_value	Lower rms limit for L1 load side voltage.	kV	40.0
alarm_mask_uac4	Alarm affectation to outputs	Bit field	0000
alarm_upper_uac5_value	Upper rms limit for L2 load side voltage.	kV	300.0
alarm_lower_uac5_value	Lower rms limit for L2 load side voltage.	kV	40.0
alarm_mask_uac5	Alarm affectation to outputs	Bit field	0000
alarm_upper_uac6_value	Upper rms limit for L3 load side voltage.	kV	300.0
alarm_lower_uac6_value	Lower rms limit for L3 load side voltage.	kV	40.0
alarm_mask_uac6	Alarm affectation to outputs	Bit field	0000
alarm_upper_iac1_value	Upper rms limit for L1 current.	A	2000
alarm_lower_iac1_value	Lower rms limit for L1 current.	A	100
alarm_mask_iac1	Alarm affectation to outputs	Bit field	0000
alarm_upper_iac2_value	Upper rms limit for L2 current.	A	2000
alarm_lower_iac2_value	Lower rms limit for L2 current.	A	100
alarm_mask_iac2	Alarm affectation to outputs	Bit field	0000
alarm_upper_iac3_value	Upper rms limit for L3 current.	A	2000
alarm_lower_iac3_value	Lower rms limit for L3 current.	A	100
alarm_mask_iac3	Alarm affectation to outputs	Bin	0000
alarm_upper_udc1_value	Upper limit for DC1 voltage.	V	280
alarm_lower_udc1_value	Lower limit for DC1 voltage.	V	40
alarm_mask_udc1	Alarm affectation to outputs	Bin	0000
alarm_upper_udc2_value	Upper limit for DC2 voltage.	V	280
alarm_lower_udc2_value	Lower limit for DC2 voltage.	V	40
alarm_mask_udc2	Alarm affectation to outputs	Bin	0000
alarm_upper_temperature_value	Upper limit for ambient temperature.	degC	55
alarm_lower_temperature_value	Lower limit for ambient temperature.	degC	-50
alarm_mask_temperature	Alarm affectation to outputs	Bit field	0000
alarm_upper_hydraulic_pressure_value	Upper limit for hydraulic drive pressure.	MPa	40
alarm_lower_hydraulic_pressure_value	Lower limit for hydraulic drive pressure.	MPa	30
alarm_mask_hydraulic_pressure	Alarm affectation to outputs	Bit field	0000
alarm_mask_gas_density	Alarm affectation to outputs	Bit field	0000
alarm_upper_pos_cb1_value	Upper limit for circuit breaker position, L1.	mm	200
alarm_lower_pos_cb1_value	Lower limit for circuit breaker position, L1.	mm	0
alarm_mask_pos_cb1	Alarm affectation to outputs	Bit field	0000
alarm_upper_pos_cb2_value	Upper limit for circuit breaker position, L2.	mm	200
alarm_lower_pos_cb2_value	Lower limit for circuit breaker position, L2.	mm	0
alarm_mask_pos_cb2	Alarm affectation to outputs	Bit field	0000
alarm_upper_pos_cb3_value	Upper limit for circuit breaker position, L3.	mm	200
alarm_lower_pos_cb3_value	Lower limit for circuit breaker position, L3.	mm	0
alarm_mask_pos_cb3	Alarm affectation to outputs	Bit field	0000
alarm_upper_freq_open_ref_1_value	Upper limit for synchronizing waveform frequency, for L1 opening.	Hz	63
alarm_lower_freq_open_ref_1_value	Lower limit for synchronizing waveform frequency, for L1 opening.	Hz	47
alarm_mask_freq_open_ref_1	Alarm affectation to outputs	Bit field	0000
alarm_upper_freq_open_ref_2_value	Upper limit for synchronizing waveform frequency, for L2 opening.	Hz	63
alarm_lower_freq_open_ref_2_value	Lower limit for synchronizing waveform frequency, for L2 opening.	Hz	47
alarm_mask_freq_open_ref_2	Alarm affectation to outputs	Bit field	0000
alarm_upper_freq_open_ref_3_value	Upper limit for synchronizing waveform frequency, for L3 opening.	Hz	63

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Parameter label	Parameter description	Unit	Preset value
alarm_lower_freq_open_ref_3_value	Lower limit for synchronizing waveform frequency, for L3 opening.	Hz	47
alarm_mask_freq_open_ref_3	Alarm affectation to outputs	Bit field	0000
alarm_upper_freq_close_ref_1_value	Upper limit for synchronizing waveform frequency, for L1 closing.	Hz	63
alarm_lower_freq_close_ref_1_value	Lower limit for synchronizing waveform frequency, for L1 closing.	Hz	47
alarm_mask_freq_close_ref_1	Alarm affectation to outputs	Bit field	0000
alarm_upper_freq_close_ref_2_value	Upper limit for synchronizing waveform frequency, for L2 closing.	Hz	63
alarm_lower_freq_close_ref_2_value	Lower limit for synchronizing waveform frequency, for L2 closing.	Hz	47
alarm_mask_freq_close_ref_2	Alarm affectation to outputs	Bit field	0000
alarm_upper_freq_close_ref_3_value	Upper limit for synchronizing waveform frequency, for L3 closing.	Hz	63
alarm_lower_freq_close_ref_3_value	Lower limit for synchronizing waveform frequency, for L3 closing.	Hz	47
alarm_mask_freq_close_ref_3	Alarm affectation to outputs	Bit field	0000
alarm_mechanical_timeout_open	Timeout to detect mechanical switching for opening.	ms	2000
Alarm_upper_mechanical_open_time	Upper limit for measured opening mechanical time.	ms	200
Alarm_lower_mechanical_open_time	Lower limit for measured opening mechanical time.	ms	0
alarm_mechanical_open_time_tolerance	Limit for difference between measured opening mechanical time and forecast.	ms	2
alarm_mask_open_time	Alarm affectation to outputs	Bit field	0000
alarm_mechanical_timeout_close	Timeout to detect mechanical switching for closing.	ms	2000
Alarm_upper_mechanical_close_time	Upper limit for measured closing mechanical time.	ms	200
Alarm_lower_mechanical_close_time	Lower limit for measured closing mechanical time.	ms	0
alarm_mechanical_close_time_tolerance	Limit for difference between measured closing mechanical time and forecast.	ms	2.0
alarm_mask_close_time	Alarm affectation to outputs	Bit field	0000
alarm_making_time_error_abs	Limit (absolute value) for the difference between measured making time and target.	ms	2.0
alarm_mask_making_time	Alarm affectation to outputs	Bit field	0000
alarm_max_peak_primary_current	Limit for peak inrush current.	A	10000
alarm_mask_peak_primary_current	Alarm affectation to outputs	Bit field	0000
alarm_max_voltage_dip_ph_e	Limit for source voltage dip, phase to earth.	%	10.0
alarm_max_voltage_dip_ph_ph	Limit for source voltage dip, phase to phase.	%	10.0
alarm_mask_voltage_dip	Alarm affectation to outputs	Bit field	0000
alarm_mask_reignition_last_open	Alarm affectation to outputs	Bit field	0000
alarm_mask_reference_voltage	Alarm affectation to outputs	Bit field	0000
alarm_mask_reference_current	Alarm affectation to outputs	Bit field	0000
alarm_mask_upper_arcing_time	Alarm affectation to outputs	Bit field	0000
alarm_reignition_rate	Number of previous opening operations considered to compute reignition rate and alarm (2 reignitions within X previous operations).	integer	10
alarm_mask_reignition_rate	Alarm affectation to outputs	Bit field	0000
alarm_reignition_max_cumulated	Limit for cumulated number of reignitions.	integer	20
alarm_mask_reignition_max_cumulated	Alarm affectation to outputs	Bit field	0000
alarm_mask_iec61850_server_status	Alarm affectation to outputs	Bit field	0
alarm_mask_pressure_keller0	Alarm affectation to outputs	Bit field	0
alarm_mask_pressure_keller1	Alarm affectation to outputs	Bit field	0
alarm_mask_pressure_keller2	Alarm affectation to outputs	Bit field	0
alarm_mask_pressure_keller3	Alarm affectation to outputs	Bit field	0
alarm_mask_pressure_keller4	Alarm affectation to outputs	Bit field	0
alarm_mask_pressure_keller5	Alarm affectation to outputs	Bit field	0
alarm_lower_gas_pressure_0_value	Alarm threshold		
alarm_lower_gas_pressure_1_value	Alarm threshold		
alarm_lower_gas_pressure_2_value	Alarm threshold		
alarm_lower_gas_pressure_3_value	Alarm threshold		
alarm_lower_gas_pressure_4_value	Alarm threshold		
alarm_lower_gas_pressure_5_value	Alarm threshold		
alarm_gas_pressure_hysteresis	difference in thresholds for set and reset gas		
alarm_mask_max_electric_wear	Alarm affectation to outputs	Bit field	0
alarm_mask_wrn_electric_wear	Alarm affectation to outputs	Bit field	0
alarm_max_electric_wear	Alarm threshold (2nd threshold)		

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Parameter label	Parameter description	Unit	Preset value
alarm_wrn_electric_wear	Alarm threshold (1st threshold)		

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20.7 System alarms and allocation to outputs

Table 131 System alarms settings

Parameter label	Parameter description	Unit	Default value
alarm_mask_uvlo	Alarm affectation to outputs (internal monitoring of power outputs)	Bit field	0000
alarm_mask_date_not_reliable	Alarm affectation to outputs	Bit field	0000
alarm_mask_adc	Alarm affectation to outputs (internal monitoring of analogue channels hardware)	Bit field	0000
alarm_upper_internal_temperature_value	Limit for CSD100 internal temperature.	degC	85
alarm_mask_internal_temperature	Alarm affectation to outputs	Bit field	0000
alarm_lower_data_storage_remaining	Lower limit for remaining data storage space.	%	20.0
alarm_mask_data_storage_remaining	Alarm affectation to outputs	Bit field	0000
alarm_mask_sv	Alarm affectation to outputs (monitoring of processed sampled values)	Bit field	0000
alarm_mask_iec61850_server_status	Alarm affectation to outputs (monitoring of MMS server)	Bit field	0000

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20.8 Counters

Initial values of event counters may be set or reset.

Table 132 Counters settings

Parameter label	Parameter description	Unit	Preset value
counter_closing_controlled_0 counter_closing_controlled_1 counter_closing_controlled_2	Initial value for controlled closing counters, L1 L2 L3. CB #1	Integer	0/0/0
counter_closing_controlled_3 counter_closing_controlled_4 counter_closing_controlled_5	Initial value for controlled closing counters, L1 L2 L3. CB #2	Integer	0/0/0
counter_closing_uncontrolled_0 counter_closing_uncontrolled_1 counter_closing_uncontrolled_2	Initial value for uncontrolled closing counters, L1 L2 L3. CB #1	Integer	0/0/0
counter_closing_uncontrolled_3 counter_closing_uncontrolled_4 counter_closing_uncontrolled_5	Initial value for uncontrolled closing counters, L1 L2 L3. CB #2	Integer	0/0/0
counter_opening_controlled_0 counter_opening_controlled_1 counter_opening_controlled_2	Initial value for controlled opening counters, L1 L2 L3. CB #1	Integer	0/0/0
counter_opening_controlled_3 counter_opening_controlled_4 counter_opening_controlled_5	Initial value for controlled opening counters, L1 L2 L3. CB #2	Integer	0/0/0
counter_opening_uncontrolled_0 counter_opening_uncontrolled_1 counter_opening_uncontrolled_2	Initial value for uncontrolled opening counters, L1 L2 L3. CB #1	Integer	0/0/0
counter_opening_uncontrolled_3 counter_opening_uncontrolled_4 counter_opening_uncontrolled_5	Initial value for uncontrolled opening counters, L1 L2 L3. CB #2	Integer	0/0/0
counter_reignition_0 counter_reignition_1 counter_reignition_2	Initial value for total reignition counters, L1 L2 L3	Integer	0/0/0
counter_reignition_wo_csd_0 counter_reignition_wo_csd_1 counter_reignition_wo_csd_2	Initial value for reignition counters during uncontrolled operations, L1 L2 L3	Integer	0/0/0

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20.9 Previous operations timestamps

Initial values of previous operation timestamp may be set.

Table 133 Timestamps settings

Parameter label	Parameter description	Unit	Preset value
timestamp_52a_sep_0 timestamp_52a_sep_1 timestamp_52a_sep_2	Previous opening operation timestamp, from 52a, L1 L2 L3. CB #1	YYYY-MM-DD hh:mm:ss.µs	2020-11-26 23:00:00.000000
timestamp_52a_sep_3 timestamp_52a_sep_4 timestamp_52a_sep_5	Previous opening operation timestamp, from 52a, L1 L2 L3. CB #2	YYYY-MM-DD hh:mm:ss.µs	2020-11-26 23:00:00.000000
timestamp_52a_touch_0 timestamp_52a_touch_1 timestamp_52a_touch_2	Previous closing operation timestamp, from 52a L1 L2 L3. CB #1	YYYY-MM-DD hh:mm:ss.µs	2020-11-26 23:00:00.000000
timestamp_52a_touch_3 timestamp_52a_touch_4 timestamp_52a_touch_5	Previous closing operation timestamp, from 52a L1 L2 L3. CB #1	YYYY-MM-DD hh:mm:ss.µs	2020-11-26 23:00:00.000000
timestamp_open_0 timestamp_open_1 timestamp_open_2		YYYY-MM-DD hh:mm:ss.µs	2020-11-26 23:00:00.000000
timestamp_open_3 timestamp_open_4 timestamp_open_5		YYYY-MM-DD hh:mm:ss.µs	2020-11-26 23:00:00.000000
timestamp_close_0 timestamp_close_1 timestamp_close_2		YYYY-MM-DD hh:mm:ss.µs	2020-11-26 23:00:00.000000
timestamp_close_3 timestamp_close_4 timestamp_close_5		YYYY-MM-DD hh:mm:ss.µs	2020-11-26 23:00:00.000000
archive_creation_date_utc	Date of previous archive (UTC time).	YYYY-MM-DD hh:mm:ss.µs	2020-11-26 23:00:00.000000
archive_creation_date_local	Date of previous archive (Local time).	YYYY-MM-DD hh:mm:ss.µs	2020-11-26 23:00:00.000000

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20.10 Capa1 switching program

20.10.1 Main options

Table 134 Capa1 program main settings

Parameter label	Parameter description	Unit	Preset value
capa1_timeout_t1	First elapsed time threshold from previous de-energization to automatically switch to another set of targets	min	1.0
capa1_timeout_t2	Second elapsed time threshold from previous de-energization to automatically switch to another set of targets.	min	2.0

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20.10.2 Closing operation

Table 135 Capa1 program closing settings

Parameter label	Parameter description	Unit	Preset value
capa1_angle_close_0 capa1_angle_close_1 capa1_angle_close_2	First set of targets (100% trapped charge, t<t1) applicable for reference phase, -120° phase and -240°. Default values are preset to earthed neutral situation but remain settable (caution). These targets are referred to voltage waveform (positive going zero crossing)	deg	90 / 30 /150
capa1_angle_close_3 capa1_angle_close_4 capa1_angle_close_5	Second set of targets (50% trapped charge, t in [t1..t2]) applicable for reference phase, -120° phase and -240°. Default values are preset to earthed neutral situation but remain settable (caution). These targets are referred to voltage waveform (positive going zero crossing).	deg	150 / 90 / 210
capa1_angle_close_6 capa1_angle_close_7 capa1_angle_close_8	Third set of targets (No trapped charge, t>t2) applicable for reference phase, -120° phase and -240°. Default values are preset to relevant values corresponding to earthed neutral but remain settable (with caution). These targets are referred to voltage waveform (positive going zero crossing)	deg	0 / 120/ 60
capa1_prearc_time_close_0 capa1_prearc_time_close_1 capa1_prearc_time_close_2	Targeted pre-arcing times for reference phase, -120° phase and -240°. 100% trapped charge (t<t1).	ms	0 / 0 / 0
capa1_prearc_time_close_3 capa1_prearc_time_close_4 capa1_prearc_time_close_5	Targeted pre-arcing times for reference phase, -120° phase and -240°. 50% trapped charge (t in [t1 t2]).	ms	0 / 0 / 0
capa1_prearc_time_close_6 capa1_prearc_time_close_7 capa1_prearc_time_close_8	Targeted pre-arcing times for reference phase, -120° phase and -240°. No trapped charge (t>t2).	ms	0 / 0 / 0

20.10.3 Opening operation

Table 136 Capa1 program opening settings

Parameter label	Parameter description	Unit	Preset value
Capa1_angle_open_voltage_0 Capa1_angle_open_voltage_1 Capa1_angle_open_voltage_2	Targets applicable for reference phase, -120° phase and -240°. Default values are preset to earthed neutral situation but remain settable (caution). These targets are referred to voltage waveform (positive going zero crossing).	deg	90 / 30 / 150
Capa1_angle_open_current_0 Capa1_angle_open_current_1 Capa1_angle_open_current_2	Targets applicable for reference phase, -120° phase and -240°. Default values are preset to relevant values corresponding to earthed neutral but remain settable (with caution). These targets are referred to current waveform (positive going zero crossing), if synchronization according to current has been selected.	deg	180 / 120 / 240
Capa1_arc_time_open	Arcing time to apply with capacitive circuits.	ms	6.0
timestamp_capa1_open	Initial value for last open date/time in capa1 program	YYYY-MM-DD hh:mm:ss.µs	2020-11-26 23:00:00.000000

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20.11 Capa2 switching program

Exactly same settings are provided, but with default values corresponding to isolated neutral situation.

20.11.1 Main options

Table 137 Capa2 program main settings

Parameter label	Parameter description	Unit	Preset value
Capa2_timeout_t1	First elapsed time threshold from previous de-energization to automatically switch to another set of targets	min	1.0
Capa2_timeout_t2	Second elapsed time threshold from previous de-energization to automatically switch to another set of targets.	min	2.0

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20.11.2 Closing operation

Table 138 Capa2 program closing settings

Parameter label	Parameter description	Unit	Preset value
Capa2_angle_close_0 Capa2_angle_close_1 Capa2_angle_close_2	First set of targets (100% trapped charge, t<t1) applicable for reference phase, -120° phase and -240°. Default values are preset to isolated neutral situation but remain settable (caution). These targets are referred to voltage waveform (positive going zero crossing).	deg	450 / 180 / 180
Capa2_angle_close_3 Capa2_angle_close_4 Capa2_angle_close_5	Second set of targets (50% trapped charge, t in [t1..t2]) applicable for reference phase, -120° phase and -240°. Default values are preset to isolated neutral situation but remain settable (caution). These targets are referred to voltage waveform (positive going zero crossing).	deg	510 / 120 / 120
Capa2_angle_close_6 Capa2_angle_close_7 Capa2_angle_close_8	Third set of targets (No trapped charge, t>t2) applicable for reference phase, -120° phase and -240°. Default values are preset to relevant values corresponding to isolated neutral but remain settable (with caution). These targets are referred to voltage waveform (positive going zero crossing)	deg	180 / 90 / 90
Capa2_prearc_time_close_0 Capa2_prearc_time_close_1 Capa2_prearc_time_close_2	Targeted pre-arcing times for reference phase, -120° phase and -240°. 100% trapped charge (t<t1).	ms	0 / 0 / 0
Capa2_prearc_time_close_3 Capa2_prearc_time_close_4 Capa2_prearc_time_close_5	Targeted pre-arcing times for reference phase, -120° phase and -240°. 50% trapped charge (t in [t1 t2]).	ms	0 / 0 / 0
Capa2_prearc_time_close_6 Capa2_prearc_time_close_7 Capa2_prearc_time_close_8	Targeted pre-arcing times for reference phase, -120° phase and -240°. No trapped charge (t>t2).	ms	0 / 0 / 0

20.11.3 Opening operation

Table 139 Capa2 program opening settings

Parameter label	Parameter description	Unit	Default value
Capa2_angle_open_voltage_0 Capa2_angle_open_voltage_1 Capa2_angle_open_voltage_2	Targets applicable for reference phase, -120° phase and -240°. Default values are preset to isolated neutral situation but remain settable (caution). These targets are referred to voltage waveform (positive going zero crossing). L1 / L2 / L3.	deg	90 / 180 / 180
Capa2_angle_open_current_0 Capa2_angle_open_current_1 Capa2_angle_open_current_2	Targets applicable for reference phase, -120° phase and -240°. Default values are preset to relevant values corresponding to isolated neutral but remain settable (with caution). These targets are referred to current waveform (positive going zero crossing), if synchronization according to current has been selected.	deg	0 / 90 / 90
Capa2_arc_time_open	Arcing time to apply with capacitive circuits.	ms	7.0
timestamp_capa2_open	Initial value for last open date/time in capa2 program.	YYYY-MM-DD hh:mm:ss.µs	2020-11-26 23:00:00.000000

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20.12 React1 switching program

20.12.1 Closing operation

Table 140 React1 closing settings

Parameter label	Parameter description	Unit	Default value
react1_angle_close_0 react1_angle_close_1 react1_angle_close_2	Targets applicable for reference phase, -120° phase and -240°. Default values are preset to relevant values corresponding to earthed neutral but remain settable (with caution). These targets are referred to voltage waveform (positive going zero crossing)	deg	90 / 210 / 330
react1_prearc_time_close_0 react1_prearc_time_close_1 react1_prearc_time_close_2	Targeted pre-arcing times for reference phase, -120° phase and -240°.	ms	0 / 0 / 0

20.12.2 Opening operation

Table 141 React1 opening settings

Parameter label	Parameter description	Unit	Default value
react1_angle_open_voltage_0 react1_angle_open_voltage_1 react1_angle_open_voltage_2	Targets applicable for reference phase, -120° phase and -240°. Default values are preset to relevant values corresponding to earthed neutral but remain settable (with caution). These targets are referred to voltage waveform (positive going zero crossing)	deg	90 / 210 / 330
react1_angle_open_current_0 react1_angle_open_current_1 react1_angle_open_current_2	Targets applicable for reference phase, -120° phase and -240°. Default values are preset to relevant values corresponding to earthed neutral but remain settable (with caution). These targets are referred to current waveform (positive going zero crossing), if synchronization according to current has been selected.	deg	0 / 120 / 240
react1_arc_time_open_0	Arcing time to apply if number of reignitions ≤ 2	ms	8
react1_arc_time_open_1	Arcing time to apply if number of reignitions >2 & ≤5	ms	8.3
react1_arc_time_open_2	Arcing time to apply if number of reignitions >5	ms	8.6

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20.13 React2 switching program

Exactly same settings are provided, but with default values corresponding to isolated neutral situation.

20.13.1 Closing operation

Table 142 React2 closing settings

Parameter label	Parameter description	Unit	Preset value
React2_angle_close_0 React2_angle_close_1 React2_angle_close_2	Targets applicable for reference phase, -120° phase and -240°. Default values are preset to relevant values corresponding to isolated neutral but remain settable (with caution). These targets are referred to voltage waveform (positive going zero crossing)	deg	90 / 0 / 0
React2_prearc_time_close_0 React2_prearc_time_close_1 React2_prearc_time_close_2	Targeted pre-arcing times for reference phase, -120° phase and -240°.	ms	0 / 0 / 0

20.13.2 Opening operation

Table 143 React2 opening settings

Parameter label	Parameter description	Unit	Preset value
React2_angle_open_voltage_0 React2_angle_open_voltage_1 React2_angle_open_voltage_2	Targets applicable for reference phase, -120° phase and -240°. Default values are preset to relevant values corresponding to isolated neutral but remain settable (with caution). These targets are referred to voltage waveform (positive going zero crossing)	deg	90 / 360 / 360
React2_angle_open_current_0 React2_angle_open_current_1 React2_angle_open_current_2	Targets applicable for reference phase, -120° phase and -240°. Default values are preset to relevant values corresponding to isolated neutral but remain settable (with caution). These targets are referred to current waveform (positive going zero crossing), if synchronization according to current has been selected.	deg	0 / 270 / 270
React2_arc_time_open_0	Arcing time to apply if cumulated number of reignitions ≤ 2	ms	8
React2_arc_time_open_1	Arcing time to apply if cumulated number of reignitions >2 & ≤5	ms	8.3
React2_arc_time_open_2	Arcing time to apply if cumulated number of reignitions >5	ms	8.6

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20.14 Transfo1 switching program

20.14.1 Main options

Table 144 Transfo1 main options

Parameter label	Parameter description	Unit	Preset value
transfo1_type	This parameter defines the transformer vector group, used for residual flux estimation based on voltage integration. Based on transformer vector group, core and neutral position, relevant voltage is selected for integration.	Yy0/Dd0/Yd1/ Dy1/Dd2/Dd4/ Yd5/Dy5/Yy6/ Dd6/Yd7/Dy7/ Dd8/Dd10/Yd11/Dy11	Yd1
transfo1_mode	Three switching modes are possible • “Fixed angles” mode: opening and closing operations are systematically performed at fixed angles. Residual flux is not measured but controlled from previous opening operation. • “Residual flux” mode: closing angles are variables and calculated based on the estimated residual flux in the transformer core, whatever the previous opening operation condition. • “Mixed” mode: combines “fixed angles” mode and “residual flux mode”. When previous opening operation is detected as controlled, either from HV or LV side, predefined fixed angles are applied. When previous opening operation is detected as uncontrolled (case of protection tripping), variable angles are applied, based on residual flux measurement.	Fixed angle/Flux/Mixed	Fixed angle

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20.14.2 Closing operation at fixed angles

Table 145 Transfo1 closing settings (fixed angle strategy)

Parameter label	Parameter description	Unit	Preset value
transfo1_fixed_angle_close_0 transfo1_fixed_angle_close_1 transfo1_fixed_angle_close_2	Close targets applicable for reference phase, -120° phase and -240° in shared core and earthed neutral situation (preset default values being settable, with caution). These targets are referred to voltage waveform (positive going zero crossing)	deg	90/540/540
transfo1_fixed_angle_close_3 transfo1_fixed_angle_close_4 transfo1_fixed_angle_close_5	Close targets applicable for reference phase, -120° phase and -240° in shared core and isolated neutral situation (preset default values being settable, with caution). These targets are referred to voltage waveform (positive going zero crossing)	deg	270/0/0
transfo1_fixed_angle_close_6 transfo1_fixed_angle_close_7 transfo1_fixed_angle_close_8	Close targets applicable for reference phase, -120° phase and -240° in independent core and earthed neutral situation (preset default values being settable, with caution). These targets are referred to voltage waveform (positive going zero crossing)	deg	90/30/150
transfo1_fixed_prearc_time_close_0 transfo1_fixed_prearc_time_close_1 transfo1_fixed_prearc_time_close_2	Targeted pre-arcing times for reference phase, -120° phase and -240°.	ms	0/0/0
transfo1_dead_half_periods	Number of additional dead half period to insert in the closing sequence between first phase(s) to close and subsequent phase(s) to close.	integer	2

20.14.3 Opening operation

Table 146 Transfo1 opening settings

Parameter label	Parameter description	Unit	Preset value
transfo1_angle_open_0 transfo1_angle_open_1 transfo1_angle_open_2	Open targets applicable for reference phase, -120° phase and -240° in earthed neutral situation (preset default values being settable, with caution). These targets are referred to voltage waveform (positive going zero crossing)	deg	450/30/150
transfo1_angle_open_3 transfo1_angle_open_4 transfo1_angle_open_5	Open targets applicable for reference phase, -120° phase and -240° in isolated neutral situation (preset default values being settable, with caution). These targets are referred to voltage waveform (positive going zero crossing)	deg	90/180/180
transfo1_arc_time_open_unloaded	Arcing time to apply if transformer load current is not significant (measurement)	ms	0.1
transfo1_arc_time_open_loaded	Arcing time to apply if transformer load current is significant (measurement)	ms	5.0
transfo1_open_load_threshold	Load current threshold to consider transformer as loaded or unloaded, from measurement (rms).	A	100

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20.14.4 Residual flux

Table 147 Transfo1 residual flux settings

Parameter label	Parameter description	Unit	Preset value
transfo1_cb_side	This parameter defines the side where controlled circuit-breaker is installed (CB location), either HV side or LV side of the transformer, by reference to vector group parameter.	Low side/High Side	high side
transfo1_cb_side_neutral_position	This parameter defines the neutral position at circuit breaker and thus influences the switching sequence.	Earthed/ Isolated	Earthed
transfo1_flux_measurement_side	This parameter defines the side where transformer voltage is measured for integration purpose (VT location), either HV side or LV side of the transformer.	Low side/High Side	high side
transfo1_flux_measurement_side_neutral_position	If neutral is not directly connected to earth (either fully isolated or impeding), it is advised to select isolated. In this case, neutral voltage is also computed for residual flux assessment.	Earthed/ Isolated	Earthed
transfo1_flux_core_shared	This parameter defines the transformer core type. • “Shared” for 3-phase transformer or bank of single-phase transformer with a delta winding • “Individual” for bank of single-phase transformer without any delta winding	Individual/ Shared	Shared
transfo1_flux_voltage_transformer	Type (nature) of voltage divider (at load side) used for residual flux computation.	IVT/CVT/ Other	IVT
transfo1_flux_cb_rdds	Circuit breaker characteristic of Rate of Decrease of Dielectric Strength in kV/ms. This value is used to automatically compute pre-arcing times in transformer mode when switching angles are variable (residual flux consideration).	kV/ms	999999
transfo1_flux_cb_rdds_derating_factor	Derating coefficient which is applied to RDDS of last phase(s) to close.	sd	1.0
transfo1_flux_cb_meca_scatter	Circuit breaker closing times scatter. This value is used to compute limit angles in transformer mode when switching angles are variable (residual flux consideration).	ms	1.0
transfo1_flux_delay_last_phase	This parameter automatically changes the sequence (variable switching angles) to introduce a 90° additional delay for the last phase to close. When activated, global performance relies on two first phases to close instead of the three phases, which may help in some situations (one particular phase not precise enough) and facilitates troubleshooting.	Boolean (Yes/No)	No
transfo1_flux_value_0 transfo1_flux_value_1 transfo1_flux_value_2	Initial values of residual fluxes values for each phase, used to initialize the closing targets. After first de-energization observed by CSD100, this value is continuously and automatically set with the computed values Can be set to zero before first operation or after maintenance of the transformer or to non-zero value in case of CSD100 exchange	pu	0/0/0

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20.15 Transfo2 switching program

Exactly same settings are provided.

20.15.1 Main options

Table 148 Transfo2 main options

Parameter label	Parameter description	Unit	Preset value
Transfo2_type	This parameter defines the transformer vector group, used for residual flux estimation based on voltage integration. Based on transformer vector group, core and neutral position, relevant voltage is selected for integration.	Yy0/Dd0/Yd1/Dy1/Dd2/Dd4/Yd5/Dy5/Yy6/Dd6/Yd7/Dy7/Dd8/Dd10/Yd11/Dy11	Dy11
Transfo2_mode	Three switching modes are possible • “Fixed angles” mode: opening and closing operations are systematically performed at fixed angles. Residual flux is not measured but controlled from previous opening operation. • “Residual flux” mode: closing angles are variables and calculated based on the estimated residual flux in the transformer core, whatever the previous opening operation condition. • “Mixed” mode: combines “fixed angles” mode and “residual flux mode”. When previous opening operation is detected as controlled, either from HV or LV side, predefined fixed angles are applied. When previous opening operation is detected as uncontrolled (case of protection tripping), variable angles are applied, based on residual flux measurement.	Fixed angle/Flux/Mixed	Fixed angle

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20.15.2 Closing operation at fixed angles

Table 149 Transfo2 closing settings (fixed angle strategy)

Parameter label	Parameter description	Unit	Preset value
Transfo2_fixed_angle_close_0 Transfo2_fixed_angle_close_1 Transfo2_fixed_angle_close_2	Close targets applicable for reference phase, -120° phase and -240° in shared core and earthed neutral situation (preset default values being settable, with caution). These targets are referred to voltage waveform (positive going zero crossing)	deg	90/540/540
Transfo2_fixed_angle_close_3 Transfo2_fixed_angle_close_4 Transfo2_fixed_angle_close_5	Close targets applicable for reference phase, -120° phase and -240° in shared core and isolated neutral situation (preset default values being settable, with caution). These targets are referred to voltage waveform (positive going zero crossing)	deg	270/0/0
Transfo2_fixed_angle_close_6 Transfo2_fixed_angle_close_7 Transfo2_fixed_angle_close_8	Close targets applicable for reference phase, -120° phase and -240° in independent core and earthed neutral situation (preset default values being settable, with caution). These targets are referred to voltage waveform (positive going zero crossing)	deg	90/30/150
Transfo2_fixed_prearc_time_close_0 Transfo2_fixed_prearc_time_close_1 Transfo2_fixed_prearc_time_close_2	Targeted pre-arcing times for reference phase, -120° phase and -240°.	ms	0
Transfo2_dead_half_periods	Number of additional dead half period to insert in the closing sequence between first phase(s) to close and subsequent phase(s) to close.	integer	2

20.15.3 Opening operation

Table 150 Transfo2 opening settings

Parameter label	Parameter description	Unit	Preset value
Transfo2_angle_open_0 Transfo2_angle_open_1 Transfo2_angle_open_2	Open targets applicable for reference phase, -120° phase and -240° in earthed neutral situation (preset default values being settable, with caution). These targets are referred to voltage waveform (positive going zero crossing)	deg	450/30/150
Transfo2_angle_open_3 Transfo2_angle_open_4 Transfo2_angle_open_5	Open targets applicable for reference phase, -120° phase and -240° in isolated neutral situation (preset default values being settable, with caution). These targets are referred to voltage waveform (positive going zero crossing)	deg	90/180/180
Transfo2_arc_time_open_unloaded	Arcing time to apply if transformer load current is not significant (measurement)	ms	0.1
Transfo2_arc_time_open_loaded	Arcing time to apply if transformer load current is significant (measurement)	ms	5.0
Transfo2_open_load_threshold	Load current threshold to consider transformer as loaded or unloaded, from measurement (rms).	A	100

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20.15.4 Residual flux

Table 151 Transfo1 residual flux settings

Parameter label	Parameter description	Unit	Preset value
Transfo2_cb_side	This parameter defines the side where controlled circuit-breaker is installed (CB location), either HV side or LV side of the transformer, by reference to vector group parameter.	Low side/High Side	high side
Transfo2_cb_side_neutral_position	This parameter defines the neutral position at circuit breaker and thus influences the switching sequence.	Earthed/ Isolated	Earthed
Transfo2_flux_measurement_side	This parameter defines the side where transformer voltage is measured for integration purpose (VT location), either HV side or LV side of the transformer.	Low side/High Side	high side
Transfo2_flux_measurement_side_neutral_position	If neutral is not directly connected to earth (either fully isolated or impeding), it is advised to select isolated. In this case, neutral voltage is also computed for residual flux assessment.	Earthed/ Isolated	Earthed
Transfo2_flux_core_shared	This parameter defines the transformer core type. • “Shared” for 3-phase transformer or bank of single-phase transformer with a delta winding • “Individual” for bank of single-phase transformer without any delta winding	Individual/ Shared	Shared
Transfo2_flux_voltage_transformer	Type (nature) of voltage divider (at load side) used for residual flux computation.	IVT/CVT/Other	IVT
Transfo2_flux_cb_rdds	Circuit breaker characteristic of Rate of Decrease of Dielectric Strength in kV/ms. This value is used to automatically compute pre-arcing times in transformer mode when switching angles are variable (residual flux consideration).	kV/ms	999999
Transfo2_flux_cb_rdds_derating_factor	Derating coefficient which is applied to RDDS of last phase(s) to close.	sd	1.0
Transfo2_flux_cb_meca_scatter	Circuit breaker closing times scatter. This value is used to compute limit angles in transformer mode when switching angles are variable (residual flux consideration).	ms	1.0
Transfo2_flux_delay_last_phase	This parameter automatically changes the sequence (variable switching angles) to introduce a 90° additional delay for the last phase to close. When activated, global performance relies on two first phases to close instead of the three phases, which may help in some situations (one particular phase not precise enough) and facilitates troubleshooting.	Boolean (Yes/No)	No
Transfo2_flux_value_0 Transfo2_flux_value_1 Transfo2_flux_value_2	Initial values of residual fluxes values for each phase, used to initialize the closing targets. After first de-energization observed by CSD100, this value is continuously and automatically set with the computed values. Can be set to zero before first operation or after maintenance of the transformer or to non-zero value in case of CSD100 exchange	pu	0/0/0

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20.16 Line switching program

20.16.1 Closing operation

Table 152 Line closing settings

Parameter label	Parameter description	Unit	Preset value
line_angle_close_0 line_angle_close_1 line_angle_close_2	Targets for reference phase, -120° phase and -240°. Default values are preset to relevant values (overvoltage mitigation) but remain settable, to address the highly shunt compensated line case for which reactor switching strategy may be privileged. These targets are referred to voltage waveform (positive going zero crossing)	deg	0/120/60
line_prearc_time_close_0 line_prearc_time_close_1 line_prearc_time_close_2	Targeted pre-arcing times for reference phase, -120° phase and -240°	ms	0/0/0

20.16.2 Reclosing operation

Table 153 Line reclosing settings

Parameter label	Parameter description	Unit	Preset value
line_computation_delay	Referred from the instant of closing order occurrence, it defines an additional delay to insert before processing can start. In most cases this value shall remain at zero, since it is required to reclose rapidly after reclosing order occurrence (the instant at which reclosing order occurs being defined by the line recloser device).	ms	10.0
line_reclose_timeout	Referred from the last opening operation instant, this threshold timeout defines the limit for automatic selection between reclosing strategies and simple energization strategies (line pick-up).	ms	1500.0
line_reclose_window_start	Referred from the last opening operation instant, it defines the beginning of the targeted reclose window. It is possible to set a minimal value if no constraint must be set.	ms	500.0
line_reclose_window_end	Referred from the last opening operation instant, it defines the end of the targeted reclose window. Practically, reclose window shall be large enough (>1s) to authorize and ease automatic search of best reclosing targets	ms	2000.0
line_reclose_prearc_mini_beat_strategy	Targeted prearcing time for phases reclosed with minimum of beat strategy.	ms	0
line_reclose_prearc_zero_source_strategy	Targeted prearcing time for phases reclosed with zero of source voltage strategy.	ms	0
line_reclose_prearc_min_max_strategy	Targeted prearcing time for phases reclosed with minimum or maximum of source voltage strategy.	ms	0
line_load_voltage_detection_level	% of nominal peak phase to ground voltage above which line voltage is considered as significant, during line voltage analysis. If considered significant, minimum of beat strategy will be applied, upon reclosing	%	20.0
line_minimum_beat_frequency	During line voltage analysis, this is the minimum frequency for a voltage to be considered as significant. If considered significant, minimum of beat strategy will be applied, upon reclosing	Hz	20.0
line_overcurrent_threshold	Upon circuit breaker opening, this is the minimum overcurrent % to consider a line phase as faulty	%	12.0
line_voltage_measurement_divider_type	Voltage divider type connected at line side. IVT prevents min max strategy to be applied (line discharge).	Bool (IVT / CVT)	CVT

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20.16.3 Opening operation

Table 154 Line opening settings

Parameter label	Parameter description	Unit	Preset value
line_angle_open_voltage_0 line_angle_open_voltage_1 line_angle_open_voltage_2	Targets applicable for reference phase, -120° phase and -240°. Default values are preset but remain settable (with caution). These targets are referred to voltage waveform (positive going zero crossing)	deg	90/30/150
line_angle_open_current_0 line_angle_open_current_1 line_angle_open_current_2	Targets applicable for reference phase, -120° phase and -240°. Default values are preset but remain settable (with caution). These targets are referred to current waveform (positive going zero crossing), if synchronization according to current has been selected	deg	180/120/240
line_arc_time_open	Arcing time to apply with unloaded transmission line.	ms	0

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20.17 User1 switching program

This program is provided to be fully customizable.

20.17.1 Closing operation

Table 155 User1 closing settings

Parameter label	Parameter description	Unit	Preset value
user1_angle_close_0 user1_angle_close_1 user1_angle_close_2	Targets applicable for reference phase, -120° phase and -240°. No relevant default values are provided since it is fully user customizable. These targets are referred to voltage waveform (positive going zero crossing)	deg	0/0/0
user1_prearc_time_close_0 user1_prearc_time_close_1 user1_prearc_time_close_2	Targeted pre-arcing times for reference phase, -120° phase and -240°, in coherence with user customizable targets	ms	0/0/0

20.17.2 Opening operation

Table 156 User1 opening settings

Parameter label	Parameter description	Unit	Preset value
user1_angle_open_voltage_0 user1_angle_open_voltage_1 user1_angle_open_voltage_2	Targets applicable for reference phase, -120° phase and -240°. No relevant default values are provided since it is fully user customizable. These targets are referred to voltage waveform (positive going zero crossing)	deg	0/0/0
user1_angle_open_current_0 user1_angle_open_current_1 user1_angle_open_current_2	Targets applicable for reference phase, -120° phase and -240°. No relevant default values are provided since it is fully user customizable. These targets are referred to current waveform (positive going zero crossing)	deg	0/0/0
user1_arc_time_open	Arcing time to apply.	ms	0

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20.18 User2 switching program

This program is provided to be fully customizable.

20.18.1 Closing operation

Table 157 User2 closing settings

Parameter label	Parameter description	Unit	Preset value
User2_angle_close_0 User2_angle_close_1 User2_angle_close_2	Targets applicable for reference phase, -120° phase and -240°. No relevant default values are provided since it is fully user customizable. These targets are referred to voltage waveform (positive going zero crossing)	deg	0/0/0
User2_prearc_time_close_0 User2_prearc_time_close_1 User2_prearc_time_close_2	Targeted pre-arcing times for reference phase, -120° phase and -240°, in coherence with user customizable targets	ms	0/0/0

20.18.2 Opening operation

Table 158 User2 opening settings

Parameter label	Parameter description	Unit	Preset value
User2_angle_open_voltage_0 User2_angle_open_voltage_1 User2_angle_open_voltage_2	Targets applicable for reference phase, -120° phase and -240°. No relevant default values are provided since it is fully user customizable. These targets are referred to voltage waveform (positive going zero crossing)	deg	0/0/0
User2_angle_open_current_0 User2_angle_open_current_1 User2_angle_open_current_2	Targets applicable for reference phase, -120° phase and -240°. No relevant default values are provided since it is fully user customizable. These targets are referred to current waveform (positive going zero crossing)	deg	0/0/0
User2_arc_time_open	Arcing time to apply.	ms	0

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20.19 User3 switching program

This program is provided to be fully customizable.

20.19.1 Closing operation

Table 159 User3 closing settings

Parameter label	Parameter description	Unit	Preset value
User3_angle_close_0 User3_angle_close_1 User3_angle_close_2	Targets applicable for reference phase, -120° phase and -240°. No relevant default values are provided since it is fully user customizable. These targets are referred to voltage waveform (positive going zero crossing)	deg	0/0/0
User3_prearc_time_close_0 User3_prearc_time_close_1 User3_prearc_time_close_2	Targeted pre-arcing times for reference phase, -120° phase and -240°, in coherence with user customizable targets	ms	0/0/0

20.19.2 Opening operation

Table 160 User3 opening settings

Parameter label	Parameter description	Unit	Preset value
User3_angle_open_voltage_0 User3_angle_open_voltage_1 User3_angle_open_voltage_2	Targets applicable for reference phase, -120° phase and -240°. No relevant default values are provided since it is fully user customizable. These targets are referred to voltage waveform (positive going zero crossing)	deg	0/0/0
User3_angle_open_current_0 User3_angle_open_current_1 User3_angle_open_current_2	Targets applicable for reference phase, -120° phase and -240°. No relevant default values are provided since it is fully user customizable. These targets are referred to current waveform (positive going zero crossing)	deg	0/0/0
User3_arc_time_open	Arcing time to apply.	ms	0

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20.20 User4 switching program

This program is provided to be fully customizable.

20.20.1 Closing operation

Table 161 User4 closing settings

Parameter label	Parameter description	Unit	Preset value
User4_angle_close_0 User4_angle_close_1 User4_angle_close_2	Targets applicable for reference phase, -120° phase and -240°. No relevant default values are provided since it is fully user customizable. These targets are referred to voltage waveform (positive going zero crossing)	deg	0/0/0
User4_prearc_time_close_0 User4_prearc_time_close_1 User4_prearc_time_close_2	Targeted pre-arcing times for reference phase, -120° phase and -240°, in coherence with user customizable targets	ms	0/0/0

20.20.2 Opening operation

Table 162 User4 opening settings

Parameter label	Parameter description	Unit	Preset value
User4_angle_open_voltage_0 User4_angle_open_voltage_1 User4_angle_open_voltage_2	Targets applicable for reference phase, -120° phase and -240°. No relevant default values are provided since it is fully user customizable. These targets are referred to voltage waveform (positive going zero crossing)	deg	0/0/0
User4_angle_open_current_0 User4_angle_open_current_1 User4_angle_open_current_2	Targets applicable for reference phase, -120° phase and -240°. No relevant default values are provided since it is fully user customizable. These targets are referred to current waveform (positive going zero crossing)	deg	0/0/0
User4_arc_time_open	Arcing time to apply.	ms	0

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21 APPENDIX D – LIST OF MEASUREMENTS AND ALARMS – MEASUREMENT FILE

This section describes the data included in the measurement file (“measures.xml”).

Measurement file is created during record creation and is therefore a snapshot of measurements at a given instant.

21.1 Information

These parameters (installation identification) are basically parameters which are also available as measurements (no processing).

21.1.1 System information

These measurements for system information purpose only.

Table 163 System information measurements

Parameter label	Parameter description	Unit	Preset value
information_bay_number	bay number	String	0
information_cb_model	cb model	String	Cb_model
information_cb1_sn_1	CB #1 serial number L1	String	0
information_cb1_sn_2	CB #1 serial number L2	String	0
information_cb1_sn_3	CB #1 serial number L3	String	0
information_cb2_sn_1	CB #2 serial number L1	String	0
information_cb2_sn_2	CB #2 serial number L2	String	0
information_cb2_sn_3	CB #2 serial number L3	String	0
information_end_user	end user name	String	0
information_feeder_name	feeder name	String	Feeder_name
information_lv_drawing	Low Voltage drawing reference	String	Lv_drawing
information_country	country of installation	String	Country
information_project_reference	project reference	String	Project_reference
information_substation	substation name	string	Substation
information_system_frequency	system frequency	Hz	0
information_system_voltage_level	system voltage level	kV	0
information_creation_date	creation date of the param file linked to the CSD100 serial number	YYYY-MM-DD hh:mm:ss.µs	2020-11-26 14:00:00.000000

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21.1.2 CSD100 controller information

Table 164 Controller information

Parameter label	Parameter description	Unit	Preset value
information_csd100_config_tool_version	csd100 configuration tool version	String	0
information_csd100_ip_address	csd100 ip address rear ports	String	192.168.5.2/24
information_csd100_ip_address_front	csd100 ip address front port	String	192.168.0.2/24
information_csd100_mac_address	csd100 mac address rear ports	String	80:b3:2a:20:1f:37
information_csd100_mac_address_front	csd100 mac address front port	String	80:b3:2a:20:1f:36
information_csd100_serial_number	csd100 serial number	String	Csd100_serial_number
information_csd100_ied_name	61850 ied name	String	CSD100
information_csd100_software_version	csd100 software version	String	1.0
information_csd100_build_number	Factory information	String	
information_modification_date	modification date	YYYY-MM-DD hh:mm:ss.µs	2020-11-26 14:00:00.000000
information_order_reference	order reference	String	Order_reference
information_param_master_version	param master version	String	1
information_param_version	param file version	String	1

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21.2 System alarms (internal)

21.2.1 Acquisition channels

Table 165 Analogue channels alarms

Alarm label	Alarm description	Latched
alarm_adc_uac1	Internal failure UAC1 channel. Future use.	Beginning of record
alarm_adc_uac2	Internal failure UAC2 channel. Future use.	Beginning of record
alarm_adc_uac3	Internal failure UAC3 channel. Future use.	Beginning of record
alarm_adc_uac4	Internal failure UAC4 channel. Future use.	Beginning of record
alarm_adc_uac5	Internal failure UAC5 channel. Future use.	Beginning of record
alarm_adc_uac6	Internal failure UAC6 channel. Future use.	Beginning of record
alarm_adc_udc1	Internal failure UDC1 channel. Future use.	Beginning of record
alarm_adc_udc2	Internal failure UDC2 channel. Future use.	Beginning of record
alarm_adc_iac1	Internal failure IAC1 channel. Future use.	Beginning of record
alarm_adc_iac2	Internal failure IAC1 channel. Future use.	Beginning of record
alarm_adc_iac3	Internal failure IAC1 channel. Future use.	Beginning of record
alarm_adc_sens1	Internal failure low level analogue ch. 1. Future use.	Beginning of record
alarm_adc_sens2	Internal failure low level analogue ch. 2. Future use.	Beginning of record
alarm_adc_sens3	Internal failure low level analogue ch. 3. Future use.	Beginning of record
alarm_adc_sens4	Internal failure low level analogue ch. 4. Future use.	Beginning of record
alarm_adc_idc1	Internal failure coil current ch. 1 (open) . Future use.	Beginning of record
alarm_adc_idc2	Internal failure coil current ch. 2 (open) . Future use.	Beginning of record
alarm_adc_idc3	Internal failure coil current ch. 3 (open) . Future use.	Beginning of record
alarm_adc_idc4	Internal failure coil current ch. 4 (close) . Future use.	Beginning of record
alarm_adc_idc5	Internal failure coil current ch. 5 (close) . Future use.	Beginning of record
alarm_adc_idc6	Internal failure coil current ch. 6 (close) . Future use.	Beginning of record
alarm_sv	Loss of samples, excess of samples, quality different from GOOD, smpSync lower than set value	Beginning of record

Remark : timestamps for each of above alarms are also included in the measurement file : timestamp for alarm last occurrence (“on”) and timestamp for alarm extinction (“off”). Example : “timestamp_alarm_adc_uac1_on”. The list is not included here, for brevity concern.

21.2.2 Power output channels

Table 166 Power outputs internal monitoring alarms

Alarm label	Alarm description	Latched
Alarm_uvlo_0	Internal failure power out ph. 1 (open)	Beginning of record
Alarm_uvlo_1	Internal failure power out ph. 2 (open)	Beginning of record
Alarm_uvlo_2	Internal failure power out ph. 3 (open)	Beginning of record
Alarm_uvlo_3	Internal failure power out ph. 1 (close)	Beginning of record
Alarm_uvlo_4	Internal failure power out ph. 2 (close)	Beginning of record
Alarm_uvlo_5	Internal failure power out ph. 3 (close)	Beginning of record

Remark : timestamps for each of above alarms are also included in the measurement file : timestamp for alarm last occurrence (“on”) and timestamp for alarm extinction (“off”). Example : “timestamp_alarm_uvlo_0_on”. The list is not included here, for brevity concern.

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21.2.3 Other system alarms

Table 167 Miscellaneous system alarms

Alarm label	Alarm description	Latched
alarm_clock_sync	CSD is out of date	Beginning of record
alarm_loss_of_sync_61850	Loss of 61850 connection. Future use	Beginning of record
alarm_low_data_storage_area	Records left storage area is running low	Beginning of record
alarm_internal_temperature	Internal temperature is high	Beginning of record

Remark : timestamps for each of above alarms are also included in the measurement file : timestamp for alarm last occurrence (“on”) and timestamp for alarm extinction (“off”). Example : “timestamp_alarm_clock_sync_on”. The list is not included here, for brevity concern.

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21.3 Applicative alarm

21.3.1 Reference signal frequency alarm

Table 168 Reference waveform frequency alarms

Alarm label	Alarm description	Latched
alarm_lower_freq_close_ref_1 alarm_lower_freq_close_ref_2 alarm_lower_freq_close_ref_3	Low frequency for close sync. waveform L1 L2 L3	Beg. of record
alarm_lower_freq_open_ref_1 alarm_lower_freq_open_ref_2 alarm_lower_freq_open_ref_3	Low frequency for open sync. waveform L1 L2 L3	Beg. of record
alarm_upper_freq_close_ref_1 alarm_upper_freq_close_ref_2 alarm_upper_freq_close_ref_3	High frequency for close sync. waveform L1 L2 L3	Beg. of record
alarm_upper_freq_open_ref_1 alarm_upper_freq_open_ref_2 alarm_upper_freq_open_ref_3	High frequency for open sync. waveform L1 L2 L3	Beg. of record

Remark : timestamps for each of above alarms are also included in the measurement file : timestamp for alarm last occurrence (“on”) and timestamp for alarm extinction (“off”). Example : “timestamp_ alarm_lower_freq_close_ref_1_on”. The list is not included here, for brevity concern.

21.3.2 Circuit breaker currents alarms

Table 169 Circuit breaker currents alarms

Alarm label	Alarm description	Latched
alarm_lower_iac1 alarm_lower_iac2 alarm_lower_iac3	Low current (rms) L1 L2 L3	Beg. of record
alarm_upper_iac1 alarm_upper_iac2 alarm_upper_iac3	High current (rms) L1 L2 L3	Beg. of record
alarm_reference_current	Reference current is out of boundaries	Beg. of record

Remark : timestamps for each of above alarms are also included in the measurement file : timestamp for alarm last occurrence (“on”) and timestamp for alarm extinction (“off”). Example : “timestamp_ alarm_lower_iac1_on”. The list is not included here, for brevity concern.

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21.3.3 System voltages alarms

Table 170 System voltages alarms

Alarm label	Alarm description	Latched
alarm_lower_uac1 alarm_lower_uac2 alarm_lower_uac3	Low source voltage (rms) L1 L2 L3	Beg. of record
alarm_lower_uac4 alarm_lower_uac5 alarm_lower_uac6	Low load voltage (rms) L1 L2 L3	Beg. of record
alarm_upper_uac1 alarm_upper_uac2 alarm_upper_uac3	High source voltage (rms) L1 L2 L3	Beg. of record
alarm_upper_uac4 alarm_upper_uac5 alarm_upper_uac6	High load voltage (rms) L1 L2 L3	Beg. of record
alarm_reference_voltage	Reference voltage is out of boundaries	Beg. of record

Remark : timestamps for each of above alarms are also included in the measurement file : timestamp for alarm last occurrence (“on”) and timestamp for alarm extinction (“off”). Example : “timestamp_ alarm_lower_uac_1_on”. The list is not included here, for brevity concern

21.3.4 Auxiliary voltages alarms

Table 171 Auxiliary voltages alarms

Alarm label	Alarm description	Latched
alarm_lower_udc1	Low auxiliary voltage (DC1)	Beg. of record
alarm_upper_udc1	High auxiliary voltage (DC1)	Beg. of record
alarm_lower_udc2	Low auxiliary voltage (DC2)	Beg. of record
alarm_upper_udc2	High auxiliary voltage (DC2)	Beg. of record

Remark : timestamps for each of above alarms are also included in the measurement file : timestamp for alarm last occurrence (“on”) and timestamp for alarm extinction (“off”). Example : “timestamp_ alarm_lower_udc_1_on”. The list is not included here, for brevity concern

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21.3.5 Digital sensors pressures alarms

Table 172 Digital sensors pressure alarms

Alarm label	Alarm description	Latched
alarm_lower_gas_pressure_0_den	Low gas density L1. CB #1.	End of record
alarm_lower_gas_pressure_1_den	Low gas density L2. CB #1.	End of record
alarm_lower_gas_pressure_2_den	Low gas density L3. CB #1.	End of record
alarm_lower_gas_pressure_3_den	Low gas density L1. CB #2.	End of record
alarm_lower_gas_pressure_4_den	Low gas density L2. CB #2.	End of record
alarm_lower_gas_pressure_5_den	Low gas density L3. CB #2.	End of record
alarm_low_hyd_pres_0	Low hydraulic pressure L1. CB #1.	Beg. of record
alarm_low_hyd_pres_1	Low hydraulic pressure L2. CB #1.	Beg. of record
alarm_low_hyd_pres_2	Low hydraulic pressure L3. CB #1.	Beg. of record
alarm_low_hyd_pres_3	Low hydraulic pressure L1. CB #2.	Beg. of record
alarm_low_hyd_pres_4	Low hydraulic pressure L2. CB #2.	Beg. of record
alarm_low_hyd_pres_5	Low hydraulic pressure L3. CB #2.	Beg. of record

Remark : timestamps for each of above alarms are also included in the measurement file : timestamp for alarm last occurrence (“on”) and timestamp for alarm extinction (“off”). Example : “timestamp_ alarm_lower_gas_pressure_0_den_on”. The list is not included here, for brevity concern

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21.3.6 Mechanical behavior alarms

Table 173 Circuit breaker mechanical behavior alarms

Alarm label	Alarm description	Latched
alarm_upper_mechanical_op_time_0 alarm_upper_mechanical_op_time_1 alarm_upper_mechanical_op_time_2	High mech. operating time L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	End of record
alarm_upper_mechanical_op_time_3 alarm_upper_mechanical_op_time_4 alarm_upper_mechanical_op_time_5	High mech. operating time L1 (2nd CB) (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	End of record
alarm_lower_mechanical_op_time_0 alarm_lower_mechanical_op_time_1 alarm_lower_mechanical_op_time_2	Low mech. operating time L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	End of record
alarm_lower_mechanical_op_time_3 alarm_lower_mechanical_op_time_4 alarm_lower_mechanical_op_time_5	Low mech. operating time L1 (2nd CB) (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	End of record
alarm_mechanical_time_tolerance_0 alarm_mechanical_time_tolerance_1 alarm_mechanical_time_tolerance_2	Excessive difference between measured mech. time and forecast L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	End of record
alarm_mechanical_time_tolerance_3 alarm_mechanical_time_tolerance_4 alarm_mechanical_time_tolerance_5	Excessive difference between measured mech. time and forecast L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	End of record
alarm_mechanical_timeout_0 alarm_mechanical_timeout_1 alarm_mechanical_timeout_2	Operation timeout (52a not switched) L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	End of record
alarm_mechanical_timeout_3 alarm_mechanical_timeout_4 alarm_mechanical_timeout_5	Operation timeout (52a not switched) L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	End of record
alarm_ambient_temperature	CB ambient temperature alarm (external probe)	End of record
alarm_upper_pos_cb1	CB position (mm) is higher than set threshold, L1	End of record
alarm_lower_pos_cb1	CB position (mm) is lower than set threshold, L1	End of record
alarm_upper_pos_cb2	CB position (mm) is higher than set threshold, L2	End of record
alarm_lower_pos_cb2	CB position (mm) is lower than set threshold, L2	End of record
alarm_upper_pos_cb3	CB position (mm) is higher than set threshold, L3	End of record
alarm_lower_pos_cb3	CB position (mm) is lower than set threshold, L3	End of record
alarm_high_hyd_pres_0	High hydraulic pressure L1. CB #1.	
alarm_high_hyd_pres_1	High hydraulic pressure L2. CB #1.	
alarm_high_hyd_pres_2	High hydraulic pressure L3. CB #1.	
alarm_high_hyd_pres_3	High hydraulic pressure L1. CB #2.	
alarm_high_hyd_pres_4	High hydraulic pressure L2. CB #2.	
alarm_high_hyd_pres_5	High hydraulic pressure L3. CB #2.	

Remark : timestamps for each of above alarms are also included in the measurement file : timestamp for alarm last occurrence (“on”) and timestamp for alarm extinction (“off”). Example : “timestamp_ alarm_upper_mechanical_op_time_0_on”. The list is not included here, for brevity concern

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21.3.7 Electrical behavior alarms

Table 174 Electrical behavior alarms

Alarm label	Alarm description	Latched
alarm_making_time_error_0	Excessive making time error L1	End of record
alarm_making_time_error_1	Excessive making time error L2	End of record
alarm_making_time_error_2	Excessive making time error L3	End of record
alarm_peak_current_0	Excessive peak inrush current L1	End of record
alarm_peak_current_1	Excessive peak inrush current L2	End of record
alarm_peak_current_2	Excessive peak inrush current L3	End of record
alarm_voltage_dip_ph_e	Excessive voltage dip phase to earth	End of record
alarm_voltage_dip_ph_ph	Excessive voltage dip phase to phase	End of record
alarm_reignition_last_open_0	Reignition upon last opening L1	End of record
alarm_reignition_last_open_1	Reignition upon last opening L2	End of record
alarm_reignition_last_open_2	Reignition upon last opening L3	End of record
alarm_reignition_rate_0	Excessive reignition Rate L1	End of record
alarm_reignition_rate_1	Excessive reignition Rate L2	End of record
alarm_reignition_rate_2	Excessive reignition Rate L3	End of record
alarm_reignition_total_0	Excessive total number of reignitions L1	End of record
alarm_reignition_total_1	Excessive total number of reignitions L2	End of record
alarm_reignition_total_2	Excessive total number of reignitions L3	End of record
alarm_arcing_time_0	Excessive arcing time L1 (>1 period)	End of record
alarm_arcing_time_1	Excessive arcing time L2 (>1 period)	End of record
alarm_arcing_time_2	Excessive arcing time L3 (>1 period)	End of record
alarm_max_electric_wear_0	Electrical wear above threshold 2. 1st CB, L1	End of record
alarm_max_electric_wear_1	Electrical wear above threshold 2. 1st CB, L2	End of record
alarm_max_electric_wear_2	Electrical wear above threshold 2. 1st CB, L3	End of record
alarm_max_electric_wear_3	Electrical wear above threshold 2. 2nd CB, L1	End of record
alarm_max_electric_wear_4	Electrical wear above threshold 2. 2nd CB, L2	End of record
alarm_max_electric_wear_5	Electrical wear above threshold 2. 2nd CB, L3	End of record
alarm_wrn_electric_wear_0	Electrical wear above threshold 1. 1st CB, L1	End of record
alarm_wrn_electric_wear_1	Electrical wear above threshold 1. 1st CB, L2	End of record
alarm_wrn_electric_wear_2	Electrical wear above threshold 1. 1st CB, L3	End of record
alarm_wrn_electric_wear_3	Electrical wear above threshold 1. 2nd CB, L1	End of record
alarm_wrn_electric_wear_4	Electrical wear above threshold 1. 2nd CB, L2	End of record
alarm_wrn_electric_wear_5	Electrical wear above threshold 1. 2nd CB, L3	End of record

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21.4 Status

21.4.1 General status

Table 175 General status

Measurement label	Measurement description	Unit	Latched
archive_creation_date_utc	Last record creation date (utc time)	YYYY-MM-DD hh:mm:ss.µs	End of record
archive_creation_date_local	Last record creation date (local time)	YYYY-MM-DD hh:mm:ss.µs	End of record
archive_type	String indicating type of record (open, close, manual, MLS, voltage event, 52a, External trigger	String of characters	End of record
data_storage_remaining	Remaining data storage space (records).	%	End of record
rdy_for_close	Global status gathering necessary conditions for closing. Depends on activated alarms.	Boolean (Yes/No)	Beg. of record
rdy_for_open	Global status gathering necessary conditions for opening. Depends on activated alarms.	Boolean (Yes/No)	Beg. of record
phase_ref_close	Reference phase used for last closing	L1/L2/L3	Beg. of record
phase_ref_open	Reference phase used for last opening	L1/L2/L3	Beg. of record
cb_type	Circuit breaker type: Standard (opening and closing, 3 phases), inserter, 2_CB_Open, 2_CB_Close.	Standard/inserter/2_CB_Open/2_CB_Close	Beg. of record
calculated_switching_program_open	Applied switching program, last open operation	Transfo1/Transfo2/React1/React2/Capa1/Capa2/Line/User1/User2/User3/User4	Beg. of record
calculated_switching_program_close	Applied switching program, last close operation	Transfo1/Transfo2/React1/React2/Capa1/Capa2/Line/User1/User2/User3/User4	Beg. of record
computed_dual_switching	if MLS active, indicates if dual switching was applied.	Boolean (Yes/No)	Beg. of record
test_mode_enable	Commissioning mode enable status	Boolean (1/0)	Beg. of record
test_mode_order	Origin of last order (=1 if commissioning mode).	Boolean (1/0)	Beg. of record
alarm_iec61850_server_status	61850 internal server monitoring	Boolean (1/0)	Beg. of record
alarm_sv	Monitoring of processed sampled values	Boolean (1/0)	Beg. of record
ptp_gmclock	CSD100 directly connected to grandmaster clock	Boolean (1/0)	Beg. of record

21.4.2 Power outputs status (circuit breaker coils command)

Table 176 Power output status (circuit breaker coils command)

Measurement label	Measurement description	Unit	Latched
general_igbt_duration_open	Coil activation duration L1 L2 L3 open	ms	End of record
general_igbt_duration_close	Coil activation duration L1 L2 L3 close	ms	End of record
igbt_energy_0 igbt_energy_1 igbt_energy_2	Coil activation energy L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	J	End of record
igbt_energy_3 igbt_energy_4 igbt_energy_5	Coil activation energy L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	J	End of record

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21.4.3 Transmission line strategy specific measurements

Table 177 Transmission line strategy specific measurements

Measurement label	Measurement description	Unit	Latched
faulty_phase_0 faulty_phase_1 faulty_phase_2	Indicates if phase was measured as faulty or healthy before closing operation (line current criterion). L1 L2 L3.	Healthy/Faulty	Beg. of record
line_close_reclose	Indicates line simple close (energization) or reclose (fast re-energization after trip).	Close/reclose	End of record
line_reclose_strategy_0 line_reclose_strategy_1 line_reclose_strategy_2	Strategy used in line reclose mode L1 L2 L3	Min-max_source/0_source/min beat/NA	
line_voltage_amp_0 line_voltage_amp_1 line_voltage_amp_2	Main measured amplitude during reclose cycle line side voltage analysis. L1 L2 L3	kV	End of record
line_voltage_freq_0 line_voltage_freq_1 line_voltage_freq_2	Main measured frequency during reclose cycle line side voltage analysis. L1 L2 L3	Hz	End of record
line_voltage_phi_0 line_voltage_phi_1 line_voltage_phi_2	Main measured phase during reclose cycle line side voltage analysis. L1 L2 L3	rad	End of record
line_voltage_alpha_0 line_voltage_alpha_1 line_voltage_alpha_2	Main measured damping factor during reclose cycle line side voltage analysis. L1 L2 L3		End of record
trapped_charge_polarity_0 trapped_charge_polarity_1 trapped_charge_polarity_2	Measured trapped charge polarity during reclose cycle line side voltage analysis. L1 L2 L3	1/0/-1	End of record

21.4.4 Transformer with residual flux consideration specific measurements

Table 178 Transformer with residual flux consideration specific measurements

Measurement label	Measurement description	Unit	Latched
ouv_rph	Last opening operation status: controlled by CSD100 or uncontrolled	String of characters. Controlled/Uncontrolled	End of record
branche_0 branche_1 branche_2	Phase load status: energized (close) or de-energized (open), measured from load voltages. L1 L2 L3	open/close/NA	End of record
residual_flux_voltage_0 residual_flux_voltage_1 residual_flux_voltage_2	Indicates which voltage was used for residual flux computation.		Beg. of record
transfo1_flux_value_0 transfo1_flux_value_1 transfo1_flux_value_2 timestamp_transfo1_flux_value_0 timestamp_transfo1_flux_value_1 timestamp_transfo1_flux_value_2	Memorized residual flux value in transfo1 switching program along with timestamps. L1 L2 L3	pu	End of record
transfo2_flux_value_0 transfo2_flux_value_1 transfo2_flux_value_2 timestamp_transfo2_flux_value_0 timestamp_transfo2_flux_value_1 timestamp_transfo2_flux_value_2	Memorized residual flux value in transfo2 switching program along with timestamps. L1 L2 L3	pu	End of record
cb1_l1_open_controlled cb1_l2_open_controlled cb1_l3_open_controlled	Indicates (Yes/No) if cb1 opening operation was synchronized by CSD. L1, L2, L3	String of characters	
cb2_l1_open_controlled cb2_l2_open_controlled cb2_l3_open_controlled	Indicates (Yes/No) if cb2 opening operation was synchronized by CSD. L1, L2, L3	String of characters	

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21.4.5 Binary inputs status (digital inputs)

Table 179 Digital inputs values

Measurement label	Measurement description	Unit	Latched
open_order	Open order input	Boolean (Yes/No)	Beg. of record
close_order	Close order input	Boolean (Yes/No)	Beg. of record
cb1_52a_l1	52a CB1 L1 position	Boolean Close/Open	End of record
cb1_52a_l2	52a CB1 L2 position	Boolean Close/Open	End of record
cb1_52a_l3	52a CB1 L3 position	Boolean Close/Open	End of record
cb2_52a_l1	52a CB2 L1 position	Boolean Close/Open	End of record
cb2_52a_l2	52a CB2 L2 position	Boolean Close/Open	End of record
cb2_52a_l3	52a CB2 L3 position	Boolean Close/Open	End of record
record_trigger_ext	Record external trigger	Boolean	Beg. of record
mls_1	MLS logic input 1	Boolean (enabled/disabled)	Beg. of record
mls_2	MLS logic input 2	Boolean (enabled/disabled)	Beg. of record
mls_3	MLS logic input 3	Boolean (enabled/disabled)	Beg. of record
mls_4	MLS logic input 4	Boolean (enabled/disabled)	Beg. of record
bypass	External bypass position	Boolean (enabled/disabled)	Beg. of record
reset_alarm	Alarm reset input	Boolean (Yes/No)	Beg. of record
test_mode	Commissioning mode enable status	Boolean (enabled/disabled)	Beg. of record

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21.5 Timestamps last operation

Table 180 Timestamps values

Measurement label	Measurement description	Unit	Latched
timestamp_zero_voltage_ref	date of positive zeroing of the last operation (excluding line reclose)	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_close_order	Last closing order timestamp.	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_open_order	Last opening order timestamp.	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_expected_sep_0	Calculated contact separation time, L1	YYYY-MM-DD hh:mm:ss.µs	Beg. of record
timestamp_expected_sep_1	Calculated contact separation time, L2	YYYY-MM-DD hh:mm:ss.µs	Beg. of record
timestamp_expected_sep_2	Calculated contact separation time, L3	YYYY-MM-DD hh:mm:ss.µs	Beg. of record
timestamp_close_0 timestamp_close_1 timestamp_close_2	Last main contacts close timestamp L1 L2 L3. CB #1.	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_close_3 timestamp_close_4 timestamp_close_5	Last main contact close timestamp L1 L2 L3. CB #2.	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_open_0 timestamp_open_1 timestamp_open_2	Last main contacts open timestamp L1 L2 L3. CB #1.	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_open_3 timestamp_open_4 timestamp_open_5	Last main contacts open timestamp L1 L2 L3. CB #2.	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_52a_sep_0 timestamp_52a_sep_1 timestamp_52a_sep_2	Last auxiliary contacts (52a) open timestamp L1 L2 L3. CB #1.	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_52a_sep_3 timestamp_52a_sep_4 timestamp_52a_sep_5	Last auxiliary contacts (52a) open timestamp L1 L2 L3. CB #2.	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_52a_touch_0 timestamp_52a_touch_1 timestamp_52a_touch_2	Last auxiliary contacts (52a) close timestamp L1 L2 L3. CB #1.	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_52a_touch_3 timestamp_52a_touch_4 timestamp_52a_touch_5	Last auxiliary contacts (52a) close timestamp L1 L2 L3. CB #2.	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_igbt_drive_0 timestamp_igbt_drive_1 timestamp_igbt_drive_2	Last power output activation timestamp L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_igbt_drive_3 timestamp_igbt_drive_4 timestamp_igbt_drive_5	Last power output activation timestamp L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_break_target_0 timestamp_break_target_1 timestamp_break_target_2	Last open target L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_make_target_0 timestamp_make_target_1 timestamp_make_target_2	Last close target L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_current_rise_0 timestamp_current_rise_1 timestamp_current_rise_2	Last current rise timestamp (making time dating) L1 L2 L3	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_voltage_rise_0 timestamp_voltage_rise_1 timestamp_voltage_rise_2	Last voltage rise timestamp (making time dating) L1 L2 L3	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_breaking_current_0 timestamp_breaking_current_1 timestamp_breaking_current_2	Last current extinction timestamp L1 L2 L3	YYYY-MM-DD hh:mm:ss.µs	End of record

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Measurement label	Measurement description	Unit	Latched
timestamp_capa1_open	Last opening timestamp in capa1 switching mode	YYYY-MM-DD hh:mm:ss.µs	Beg. of record
timestamp_capa2_open	Last opening timestamp in capa2 switching mode	YYYY-MM-DD hh:mm:ss.µs	Beg. of record
timestamp_travel_sep_0 timestamp_travel_sep_1 timestamp_travel_sep_2	Last opening main contacts separation timestamps from travel curve. L1, L2, L3	YYYY-MM-DD hh:mm:ss.µs	
timestamp_travel_touch_0 timestamp_travel_touch_1 timestamp_travel_touch_2	Last closing main contacts touch timestamps from travel curve. L1, L2, L3	YYYY-MM-DD hh:mm:ss.µs	
timestamp_transfo1_flux_value_0 timestamp_transfo1_flux_value_1 timestamp_transfo1_flux_value_2	Last Transfo1 residual flux calculation timestamp	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_transfo2_flux_value_0 timestamp_transfo2_flux_value_1 timestamp_transfo2_flux_value_2	Last Transfo2 residual flux calculation timestamp	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_alarm_xxxxxx_on	For each alarm listed in 21.2 and 21.3, timestamp when this alarm raised last time	YYYY-MM-DD hh:mm:ss.µs	End of record
timestamp_alarm_xxxxxx_off	For each alarm listed in 21.2 and 21.3, timestamp when this alarm was cleared last time	YYYY-MM-DD hh:mm:ss.µs	End of record

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21.6 Sensors measurements

Table 181 Sensors measurements

Measurement label	Measurement description	Unit	Latched
dc1_values	Auxiliary voltage DC1 value	V	Beg. of record
dc2_values	Auxiliary voltage DC2 value	V	Beg. of record
travel_value_tbegin_0 travel_value_tbegin_1 travel_value_tbegin_2	Travel sensor value before operation. L1, L2, L3	Mm	Beg. of record
travel_value_tend_0 travel_value_tend_1 travel_value_tend_2	Travel sensor value after operation. L1, L2, L3	Mm	End of record
ambient_temperature	CB ambient temperature value (4-20mA input)	degC	Beg. of record
internal_temperature	CSD100 internal temperature	degC	Beg. of record
hydraulic_pressure_0 hydraulic_pressure_1 hydraulic_pressure_2	CB1 drive hydraulic pressure value (RS485) L1 L2 L3. CB #1	bar	Beg. of record
hydraulic_pressure_3 hydraulic_pressure_4 hydraulic_pressure_5	CB2 drive hydraulic pressure value (RS485) L1 L2 L3. CB #2	bar	Beg. of record
cb_gas_density_0 cb_gas_density_1 cb_gas_density_2	CB1 gas density value (RS485) L1 L2 L3. CB #1	kg/m3	Beg. of record
cb_gas_density_3 cb_gas_density_4 cb_gas_density_5	CB2 gas density value (RS485) L1 L2 L3. CB #2	kg/m3	Beg. of record
cb_p20_0 cb_p20_1 cb_p20_2	CB1 gas equivalent pressure @20°C value (RS485) L1 L2 L3. CB #1	Mpa	Beg. of record
cb_p20_3 cb_p20_4 cb_p20_5	CB2 gas equivalent pressure @20°C value (RS485) L1 L2 L3. CB #2	Mpa	Beg. of record
cb_gas_pressure_0 cb_gas_pressure_1 cb_gas_pressure_2	CB1 gas pressure value (RS485) L1 L2 L3. CB #1	MPa	Beg. of record
cb_gas_pressure_3 cb_gas_pressure_4 cb_gas_pressure_5	CB2 gas pressure value (RS485) L1 L2 L3. CB #2	MPa	Beg. of record
cb_gas_temperature_0 cb_gas_temperature_1 cb_gas_temperature_2	CB1 gas temperature value (RS485) L1 L2 L3. CB #1	degC	Beg. of record
cb_gas_temperature_3 cb_gas_temperature_4 cb_gas_temperature_5	CB2 gas temperature value (RS485) L1 L2 L3. CB #2	degC	Beg. of record
idle_time_from_last_open_0 idle_time_from_last_open_1 idle_time_from_last_open_2	Elapsed time from last open operation L1 L2 L3	h	Beg. of record
cb_pos_0 cb_pos_1 cb_pos_2	Circuit breaker chamber position L1 L2 L3	mm	End of record
measured_period_close	Measured system period for last close	ms	Beg. of record
measured_period_open	Measured system period for last open	ms	Beg. of record
source_voltage_frequency_l1 source_voltage_frequency_l2 source_voltage_frequency_l3	Reference voltage frequency L1 L2 L3	Hz	Beg. of record
current_frequency_l1 current_frequency_l2 current_frequency_l3	Circuit breaker current frequency L1 L2 L3	Hz	Beg. of record
differential_voltage_frequency_l1 differential_voltage_frequency_l2 differential_voltage_frequency_l3	Differential voltage frequency (source-load) L1 L2 L3	Hz	Beg. of record
rms_source_voltage_l1_primary rms_source_voltage_l2_primary rms_source_voltage_l3_primary	Reference voltage amplitude (rms, primary) L1 L2 L3	kV	Beg. of record
rms_ source _voltage_l1_secondary rms_ source _voltage_l2_secondary rms_ source _voltage_l3_secondary	Reference voltage amplitude (rms, secondary) L1 L2 L3	V	Beg. of record

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Measurement label	Measurement description	Unit	Latched
rms_load_voltage_l1_primary rms_load_voltage_l2_primary rms_load_voltage_l3_primary	Load voltage amplitude (rms, primary) L1 L2 L3	kV	Beg. of record
rms_load_voltage_l1_secondary rms_load_voltage_l2_secondary rms_load_voltage_l3_secondary	Load voltage amplitude (rms, secondary) L1 L2 L3	V	Beg. of record
rms_current_l1_primary rms_current_l2_primary rms_current_l3_primary	Circuit breaker current amplitude (rms, primary) L1 L2 L3	A	Beg. of record
rms_current_l1_secondary rms_current_l2_secondary rms_current_l3_secondary	Circuit breaker current amplitude (rms, secondary) L1 L2 L3	A	Beg. of record
cumulative_electric_wear_0 cumulative_electric_wear_1 cumulative_electric_wear_2	Accumulated abrasion (I^2t) for CB1 opening operations. L1, L2, L3	$kA^2.s$	End of record
cumulative_electric_wear_3 cumulative_electric_wear_4 cumulative_electric_wear_5	Accumulated abrasion (I^2t) for CB2 opening operations. L1, L2, L3	$kA^2.s$	End of record
last_opening_electric_wear_0 last_opening_electric_wear_1 last_opening_electric_wear_2	Abrasion (I^2t) for CB1 last opening operation. L1, L2, L3	$kA^2.s$	End of record
last_opening_electric_wear_3 last_opening_electric_wear_4 last_opening_electric_wear_5	Abrasion (I^2t) for CB2 last opening operation. L1, L2, L3	$kA^2.s$	End of record
cumulative_electric_wear_0_61850 cumulative_electric_wear_1_61850 cumulative_electric_wear_2_61850	Accumulated abrasion (% of set max value) for CB1 opening operations. L1, L2, L3..	%	End of record
cumulative_electric_wear_3_61850 cumulative_electric_wear_4_61850 cumulative_electric_wear_5_61850	Accumulated abrasion (% of set max value) for CB2 opening operations. L1, L2, L3	%	End of record

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21.7 Electrical times

Table 182 Electrical times measurements

Measurement label	Measurement description	Unit	Latched
calculated_angle_0 calculated_angle_1 calculated_angle_2	Target angle used for last operation L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	deg	Beg. of record
calculated_angle_3 calculated_angle_4 calculated_angle_5	Target angle used for last operation L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	deg	Beg. of record
measured_angle_0 measured_angle_1 measured_angle_2	Measured achieved angle for last operation L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	deg	End of record
measured_angle_3 measured_angle_4 measured_angle_5	Measured achieved angle for last operation L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	deg	End of record
calculated_arc_time_0 calculated_arc_time_1 calculated_arc_time_2	Calculated arcing time for last open operation L1 L2 L3	ms	Beg. of record
measured_arc_time_0 measured_arc_time_1 measured_arc_time_2	Measured arcing time for last open operation L1 L2 L3	ms	End of record
calculated_arc_time_compensation_gas_0 calculated_arc_time_compensation_gas_1 calculated_arc_time_compensation_gas_2 calculated_arc_time_compensation_gas_3 calculated_arc_time_compensation_gas_4 calculated_arc_time_compensation_gas_5	For future use	ms	
calculated_prearc_time_0 calculated_prearc_time_1 calculated_prearc_time_2	Calculated prestrike time for last close operation L1 L2 L3	ms	Beg. of record
measured_prearc_time_0 measured_prearc_time_1 measured_prearc_time_2	Measured prestrike time for last close operation L1 L2 L3	ms	Beg. of record
calculated_prearc_time_compensation_gas_0 calculated_prearc_time_compensation_gas_1 calculated_prearc_time_compensation_gas_2 calculated_prearc_time_compensation_gas_3 calculated_prearc_time_compensation_gas_4 calculated_prearc_time_compensation_gas_5	For future use	ms	Debut
making_time_error_0 making_time_error_1 making_time_error_2	Making time difference between calculated and measured making time values for last close operation L1 L2 L3	µs	End of record
next_calculated_angle_0 next_calculated_angle_1 next_calculated_angle_2	Calculated target angle for next operation L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	deg	End of record
next_calculated_angle_3 next_calculated_angle_4 next_calculated_angle_5	Calculated target angle for next operation L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	deg	End of record
next_calculated_arc_time_0 next_calculated_arc_time_1 next_calculated_arc_time_2	Calculated arcing time for next open operation L1 L2 L3	ms	End of record
next_calculated_prearc_time_0 next_calculated_prearc_time_1 next_calculated_prearc_time_2	Calculated prestrike time for next close operation L1 L2 L3	ms	End of record
transfo1_max_closing_angle	Max closing target angle for transfo1 switching mode (x1 voltage condition)	deg	End of record
transfo1_max_closing_angle_1_5	Max closing target angle for transfo1 switching mode	deg	End of record

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Measurement label	Measurement description	Unit	Latched
	(x1.5 voltage condition)		
transfo1_max_closing_angle_diff	Max closing target angle for transfo1 switching mode (x√3 voltage condition)	deg	End of record
transfo1_min_closing_angle	Min closing target angle for transfo1 switching mode (x1 voltage condition)	deg	End of record
transfo1_min_closing_angle_1_5	Min closing target angle for transfo1 switching mode (x1.5 voltage condition)	deg	End of record
transfo1_min_closing_angle_diff	Min closing target angle for transfo1 switching mode (x√3 voltage condition)	deg	End of record
transfo2_max_closing_angle	Max closing target angle for transfo2 switching mode (x1 voltage condition)	deg	End of record
transfo2_max_closing_angle_1_5	Max closing target angle for transfo2 switching mode (x1.5 voltage condition)	deg	End of record
transfo2_max_closing_angle_diff	Max closing target angle for transfo2 switching mode (x√3 voltage condition)	deg	End of record
transfo2_min_closing_angle	Min closing target angle for transfo2 switching mode (x1 voltage condition)	deg	End of record
transfo2_min_closing_angle_1_5	Min closing target angle for transfo2 switching mode (x1.5 voltage condition)	deg	End of record
transfo2_min_closing_angle_diff	Min closing target angle for transfo2 switching mode (x√3 voltage condition)	Deg	End of record

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21.8 Mechanical times

Table 183 Mechanical times measurements

Measurement label	Measurement description	Unit	Latched
calculated_meca_time_0 calculated_meca_time_1 calculated_meca_time_2	Calculated mechanical time for last operation (incl. compensations) L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	ms	Beg. of record
calculated_meca_time_3 calculated_meca_time_4 calculated_meca_time_5	Calculated mechanical time for last operation (incl. compensations) L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	ms	Beg. of record
calculated_meca_time_compensation_udc_0 calculated_meca_time_compensation_udc_1 calculated_meca_time_compensation_udc_2	Calculated mechanical time voltage compensation for last operation L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	ms	Beg. of record
calculated_meca_time_compensation_udc_3 calculated_meca_time_compensation_udc_4 calculated_meca_time_compensation_udc_5	Calculated mechanical time voltage compensation for last operation L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	ms	Beg. of record
calculated_meca_time_compensation_temp_0 calculated_meca_time_compensation_temp_1 calculated_meca_time_compensation_temp_2	Calculated mechanical time temperature compensation for last operation L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	ms	Beg. of record
calculated_meca_time_compensation_temp_3 calculated_meca_time_compensation_temp_4 calculated_meca_time_compensation_temp_5	Calculated mechanical time temperature compensation for last operation L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	ms	Beg. of record
calculated_meca_time_compensation_phyd_0 calculated_meca_time_compensation_phyd_1 calculated_meca_time_compensation_phyd_2	Calculated mechanical time hydraulic drive pressure compensation for last operation L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	ms	Beg. of record
calculated_meca_time_compensation_phyd_3 calculated_meca_time_compensation_phyd_4 calculated_meca_time_compensation_phyd_5	Calculated mechanical time hydraulic drive pressure compensation for last operation L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	ms	Beg. of record
calculated_meca_time_compensation_idle_0 calculated_meca_time_compensation_idle_1 calculated_meca_time_compensation_idle_2	Calculated mechanical time idle time compensation for last operation L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	ms	Beg. of record
calculated_meca_time_compensation_idle_3 calculated_meca_time_compensation_idle_4 calculated_meca_time_compensation_idle_5	Calculated mechanical time idle time compensation for last operation L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	ms	Beg. of record
calculated_meca_time_adaptive_compensation_0 calculated_meca_time_adaptive_compensation_1 calculated_meca_time_adaptive_compensation_2	Calculated mechanical time adaptive compensation for last operation L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	ms	Beg. of record
calculated_meca_time_adaptive_compensation_3 calculated_meca_time_adaptive_compensation_4 calculated_meca_time_adaptive_compensation_5	Calculated mechanical time adaptive compensation for last operation L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	ms	Beg. of record
calculated_break_time_0 calculated_break_time_1 calculated_break_time_2	Calculated electrical opening duration L1 L2 L3 (coil activation to current extinction)	ms	End of record

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Measurement label	Measurement description	Unit	Latched
calculated_make_time_0 calculated_make_time_1 calculated_make_time_2	Calculated electrical closing duration L1 L2 L3 (coil activation to making time)	ms	End of record
measured_meca_time_0 measured_meca_time_1 measured_meca_time_2	Measured mechanical time from last operation L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	ms	End of record
measured_meca_time_3 measured_meca_time_4 measured_meca_time_5	Measured mechanical time from last operation L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	ms	End of record
measured_meca_time_error_0 measured_meca_time_error_1 measured_meca_time_error_2	Mechanical time difference between calculated and measured values for last operation L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	ms	End of record
measured_meca_time_error_3 measured_meca_time_error_4 measured_meca_time_error_5	Mechanical time difference between calculated and measured values for last operation L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	ms	End of record
next_calculated_meca_time_0 next_calculated_meca_time_1 next_calculated_meca_time_2	Calculated mechanical time for next operation (forecast) L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	ms	End of record
next_calculated_meca_time_3 next_calculated_meca_time_4 next_calculated_meca_time_5	Calculated mechanical time for next operation (forecast) L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	ms	End of record
next_calculated_meca_time_compensation_0 next_calculated_meca_time_compensation_1 next_calculated_meca_time_compensation_2	Calculated mechanical time total compensation for next operation L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	Ms	End of record
next_calculated_meca_time_compensation_3 next_calculated_meca_time_compensation_4 next_calculated_meca_time_compensation_5	Calculated mechanical time total compensation for next operation L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	ms	End of record
Next_calculated_meca_time_compensation_udc_0 Next_calculated_meca_time_compensation_udc_1 Next_calculated_meca_time_compensation_udc_2	Calculated mechanical time voltage compensation for next operation L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	ms	End of record
Next_calculated_meca_time_compensation_udc_3 Next_calculated_meca_time_compensation_udc_4 Next_calculated_meca_time_compensation_udc_5	Calculated mechanical time voltage compensation for next operation L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	ms	End of record
Next_calculated_meca_time_compensation_temp_0 Next_calculated_meca_time_compensation_temp_1 Next_calculated_meca_time_compensation_temp_2	Calculated mechanical time temperature compensation for next operation L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	ms	End of record
Next_calculated_meca_time_compensation_temp_3 Next_calculated_meca_time_compensation_temp_4 Next_calculated_meca_time_compensation_temp_5	Calculated mechanical time temperature compensation for next operation L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	ms	End of record
Next_calculated_meca_time_compensation_phyd_0 Next_calculated_meca_time_compensation_phyd_1 Next_calculated_meca_time_compensation_phyd_2	Calculated mechanical time hydraulic drive pressure compensation for next operation L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	ms	End of record

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Measurement label	Measurement description	Unit	Latched
next_calculated_meca_time_compensation_phyd_3 next_calculated_meca_time_compensation_phyd_4 next_calculated_meca_time_compensation_phyd_5	Calculated mechanical time hydraulic drive pressure compensation for next operation L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	ms	End of record
next_calculated_meca_time_compensation_idle_0 next_calculated_meca_time_compensation_idle_1 next_calculated_meca_time_compensation_idle_2	Calculated mechanical time idle time compensation for next operation L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	ms	End of record
next_calculated_meca_time_compensation_idle_3 next_calculated_meca_time_compensation_idle_4 next_calculated_meca_time_compensation_idle_5	Calculated mechanical time idle time compensation for next operation L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	ms	End of record
next_calculated_meca_time_adaptive_compensation_0 next_calculated_meca_time_adaptive_compensation_1 next_calculated_meca_time_adaptive_compensation_2	Calculated mechanical time adaptive compensation for next operation L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	ms	End of record
next_calculated_meca_time_adaptive_compensation_3 next_calculated_meca_time_adaptive_compensation_4 next_calculated_meca_time_adaptive_compensation_5	Calculated mechanical time adaptive compensation for next operation L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	ms	End of record
previous_measured_meca_time_0 previous_measured_meca_time_1 previous_measured_meca_time_2	Measured mechanical time from previous operation L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	ms	End of record
previous_measured_meca_time_3 previous_measured_meca_time_4 previous_measured_meca_time_5	Measured mechanical time from previous operation L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	ms	End of record
previous_calculated_meca_time_adaptive_compensation_0 previous_calculated_meca_time_adaptive_compensation_1 previous_calculated_meca_time_adaptive_compensation_2	Calculated mechanical time adaptative compensation from previous operation L1 L2 L3 (standard CB: open) (2CB close, ins. : close CB2) (2CB open: open CB1)	ms	End of record
previous_calculated_meca_time_adaptive_compensation_3 previous_calculated_meca_time_adaptive_compensation_4 previous_calculated_meca_time_adaptive_compensation_5	Calculated mechanical time adaptative compensation from previous operation L1 L2 L3 (standard CB: close) (2CB close, ins. : close CB1) (2CB open: open CB2)	ms	End of record

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21.9 Counters

Table 184 Counters

Measurement label	Measurement description	Unit	Latched
counter_closing_controlled_0 counter_closing_controlled_1 counter_closing_controlled_2	Counter of controlled closing operations L1 L2 L3 (standard CB or 1st CB)	integer	End of record
counter_closing_controlled_3 counter_closing_controlled_4 counter_closing_controlled_5	Counter of controlled closing operations L1 L2 L3 (2nd CB)	integer	End of record
counter_closing_uncontrolled_0 counter_closing_uncontrolled_1 counter_closing_uncontrolled_2	Counter of uncontrolled closing operations L1 L2 L3 (standard CB or 1st CB)	integer	End of record
counter_closing_uncontrolled_3 counter_closing_uncontrolled_4 counter_closing_uncontrolled_5	Counter of uncontrolled closing operations L1 L2 L3 (2nd CB)	integer	End of record
counter_opening_controlled_0 counter_opening_controlled_1 counter_opening_controlled_2	Counter of controlled opening operations L1 L2 L3 (standard CB or 1st CB)	integer	End of record
counter_opening_controlled_3 counter_opening_controlled_4 counter_opening_controlled_5	Counter of controlled opening operations L1 L2 L3 (2nd CB)	integer	End of record
counter_opening_uncontrolled_0 counter_opening_uncontrolled_1 counter_opening_uncontrolled_2	Counter of uncontrolled opening operations L1 L2 L3 (standard CB or 1st CB)	integer	End of record
counter_opening_uncontrolled_3 counter_opening_uncontrolled_4 counter_opening_uncontrolled_5	Counter of uncontrolled opening operations L1 L2 L3 (2nd CB)	integer	End of record
counter_reignition_0 counter_reignition_1 counter_reignition_2	Reignitions counter L1 L2 L3	integer	End of record
counter_reignition_wo_csd_0 counter_reignition_wo_csd_1 counter_reignition_wo_csd_2	Reignitions counter (uncontrolled opening operations) L1 L2 L3	integer	End of record

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21.10 Switching performance indicators

Table 185 Switching performance indicators

Measurement label	Measurement description	Unit	Latched
current_asymmetry_0 current_asymmetry_1 current_asymmetry_2	Calculated circuit breaker current asymmetry during last closing operation L1 L2 L3 Future use	%	End of record
peak_current_0 peak_current_1 peak_current_2	Calculated circuit breaker peak inrush current during last closing operation L1 L2 L3	A	End of record
peak_current	Maximum peak current of three phases	A	End of record
voltage_dip_0 voltage_dip_1 voltage_dip_2	Calculated source voltage dip (phase to earth) during last closing operation L1 L2 L3	%	End of record
voltage_dip_3 voltage_dip_4 voltage_dip_5	Calculated source voltage dip (phase to phase) during last closing operation L1 L2 L3	%	End of record

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21.11 Sampled values indicators

Table 186 Sampled values indicators

Measurement label	Measurement description	Unit	Latched
sv_applied_config	Applied sampled values configuration	integer	Beg. of record
sv_propagated_delay_us	Maximum SV transmission delay, from the publisher to the subscriber, the CSD100 tolerates for correct processing	µs	Beg. of record
sv_delay_meter_cnt	For the selected stream, measured transmission delay from the SV publisher	µs	Beg. of record
sv_sync_unlock_cnt	SV synchronization counter error	integer	Beg. of record
sv_mii_frame_rcv_rate	Total SV frame rate received by CSD100 before filtering	sps	Beg. of record
sv0_proc_phase_a_worst_quality	Quality value for U1	integer	Beg. of record
sv0_proc_phase_b_worst_quality	Quality value for U2	integer	Beg. of record
sv0_proc_phase_c_worst_quality	Quality value for U3	integer	Beg. of record
sv0_proc_worst_spl_sync	SmpSync value for U1…U3 processed stream	integer	Beg. of record
sv0_proc_valid_asdu_rate_after_filtering	Total frame rate received by CSD100 for U1…U3 processing after filtering	sps	Beg. of record
sv0_proc_missing_sv_count	Number of U1…U3 samples missed since last counter reset	integer	Beg. of record
sv0_proc_phase_a_non_good_quality_count	Number of U1 samples counted with a quality different from Good since last counter reset	integer	Beg. of record
sv0_proc_phase_b_non_good_quality_count	Number of U2 samples counted with a quality different from Good since last counter reset	integer	Beg. of record
sv0_proc_phase_c_non_good_quality_count	Number of U3 samples counted with a quality different from Good since last counter reset	integer	Beg. of record
sv1_proc_phase_a_worst_quality	Quality value for U4	integer	Beg. of record
sv1_proc_phase_b_worst_quality	Quality value for U5	integer	Beg. of record
sv1_proc_phase_c_worst_quality	Quality value for U6	integer	Beg. of record
sv1_proc_worst_spl_sync	SmpSync value for U4…U6 processed stream	integer	Beg. of record
sv1_proc_valid_asdu_rate_after_filtering	Total frame rate received by CSD100 for U4…U6 processing after filtering	sps	Beg. of record
sv1_proc_missing_sv_count	Number of U4…U6 samples missed since last counter reset	integer	Beg. of record
sv1_proc_phase_a_non_good_quality_count	Number of U4 samples counted with a quality different from Good since last counter reset	integer	Beg. of record
sv1_proc_phase_b_non_good_quality_count	Number of U5 samples counted with a quality different from Good since last counter reset	integer	Beg. of record
sv1_proc_phase_c_non_good_quality_count	Number of U6 samples counted with a quality different from Good since last counter reset	integer	Beg. of record
sv2_proc_phase_a_worst_quality	Quality value for I1	integer	Beg. of record
sv2_proc_phase_b_worst_quality	Quality value for I2	integer	Beg. of record
sv2_proc_phase_c_worst_quality	Quality value for I3	integer	Beg. of record
sv2_proc_worst_spl_sync	SmpSync value for I1…I3 processed stream	integer	Beg. of record
sv2_proc_valid_asdu_rate_after_filtering	Total frame rate received by CSD100 for I1…I3 processing after filtering	sps	Beg. of record
sv2_proc_missing_sv_count	Number of I1…I3 samples missed since last counter reset	integer	Beg. of record
sv2_proc_phase_a_non_good_quality_count	Number of I1 samples counted with a quality different from Good since last counter reset	integer	Beg. of record
sv2_proc_phase_b_non_good_quality_count	Number of I2 samples counted with a quality different from Good since last counter reset	integer	Beg. of record
sv2_proc_phase_c_non_good_quality_count	Number of I3 samples counted with a quality different from Good since last counter reset	integer	Beg. of record
sv0_wtch_worst_spl_sync	SmpSync value for watched stream 1	integer	Beg. of record
sv0_wtch_phase_a_worst_quality	Quality value for watched stream 1 phase 1	integer	Beg. of record
sv0_wtch_phase_b_worst_quality	Quality value for watched stream 1 phase 2	integer	Beg. of record
sv0_wtch_phase_c_worst_quality	Quality value for watched stream 1 phase 3	integer	Beg. of record
sv0_wtch_valid_asdu_rate_after_filtering	Total frame rate received by CSD100 for watched stream 1 after filtering	sps	Beg. of record
sv1_wtch_worst_spl_sync	SmpSync value for watched stream 2	integer	Beg. of record
sv1_wtch_phase_a_worst_quality	Quality value for watched stream 2 phase 1	integer	Beg. of record
sv1_wtch_phase_b_worst_quality	Quality value for watched stream 2 phase 2	integer	Beg. of record
sv1_wtch_phase_c_worst_quality	Quality value for watched stream 2 phase 3	integer	Beg. of record

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Measurement label	Measurement description	Unit	Latched
sv1_wtch_valid_asdu_rate_after_filtering	Total frame rate received by CSD100 for watched stream 2 after filtering	sps	Beg. of record
sv2_wtch_worst_spl_sync	SmpSync value for watched stream 3	integer	Beg. of record
sv2_wtch_phase_a_worst_quality	Quality value for watched stream 3 phase 1	integer	Beg. of record
sv2_wtch_phase_b_worst_quality	Quality value for watched stream 3 phase 2	integer	Beg. of record
sv2_wtch_phase_c_worst_quality	Quality value for watched stream 3 phase 3	integer	Beg. of record
sv2_wtch_valid_asdu_rate_after_filtering	Total frame rate received by CSD100 for watched stream 3 after filtering	sps	Beg. of record
sv3_wtch_worst_spl_sync	SmpSync value for watched stream 4	integer	Beg. of record
sv3_wtch_phase_a_worst_quality	Quality value for watched stream 4 phase 1	integer	Beg. of record
sv3_wtch_phase_b_worst_quality	Quality value for watched stream 4 phase 2	integer	Beg. of record
sv3_wtch_phase_c_worst_quality	Quality value for watched stream 4 phase 3	integer	Beg. of record
sv3_wtch_valid_asdu_rate_after_filtering	Total frame rate received by CSD100 for watched stream 4 after filtering	sps	Beg. of record
sv_gain_source_voltage	U1…U3 rescaling factors computed from VT ratio. Based on the voltage sensor used (LPIT or Conventional wired to AMU) a virtual ratio is necessary for scaling and testing purpose	integer	Beg. of record
sv_shift_source_voltage		integer	Beg. of record
sv_gain_load_voltage	U4…U6 rescaling factors computed from VT ratio. Based on the voltage sensor used (LPIT or Conventional wired to AMU) a virtual ratio is necessary for scaling and testing purpose	integer	Beg. of record
sv_shift_load_voltage		integer	Beg. of record
sv_gain_current	I1…I3 rescaling factors computed from CT ratio. Based on the current sensor used (LPIT or Conventional wired to AMU) a virtual ratio is necessary for scaling and testing purpose	integer	Beg. of record
sv_shift_current		integer	Beg. of record

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22 APPENDIX E – SECURED CERTIFICATES AND KEYS INSTALLATION

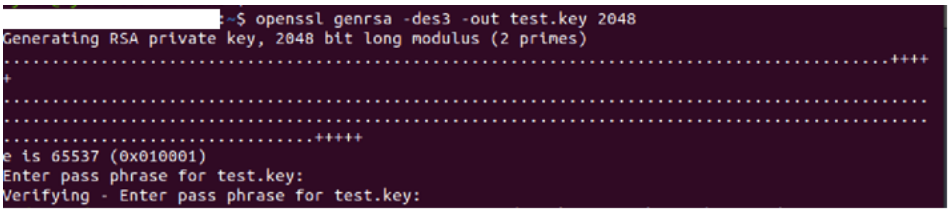
Preliminary task : install OPENSSL tool on your laptop/PC.

To download OpenSSL, please refer to following website : https://www.openssl.org/source/

To install the tool, please refer to the installation section of the OpenSSL Github page : https://github.com/openssl/openssl

Disclaimer: GE is not responsible for the choice of a vulnerable version. GE recommends to select the latest version available and verifying absence of vulnerabilities or considering the recommendations from OpenSSL contributor.

Step 01: With already installed OPENSSL tool (installed on your laptop/PC), generate a RSA key and insert the password. Output is a <file>.key



Step 02: Get the certificate sign request using the previous key. Output is a <file>.pem



Step 03: Get the certificate X509 for the CSD100:



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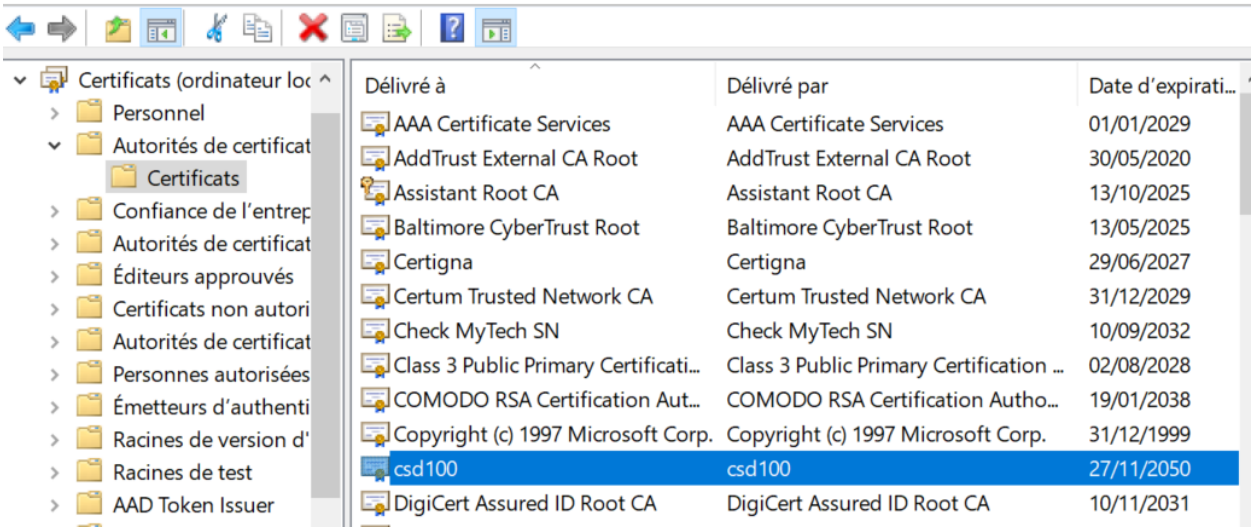
Step 04: Check that the final output corresponds to the following files:

- <file>.pem
- <file>.crt
- <file>.key



Step 05: Install the certificates under MMS.

Double click on the certificate file and choose the Authorities certification store to install.



Step 06: Sign the CSD100 using the CA created above. Output is a <file>.crt

```
[redacted]:~$ openssl x509 -req -in testkey.csr -CA test.pem -CAkey
test.key -CAcreateserial -out testcsd.crt -days 10000 -sha256 -extfile testcsd.e
xt
Signature ok
subject=C = fr, ST = ara, L = aix les bains, O = GE, OU = GE, CN = csd100, email
Address = ly[redacted].com
Getting CA Private Key
Enter pass phrase for test.key:
```


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Step 07: Set the DNS as per below screen.

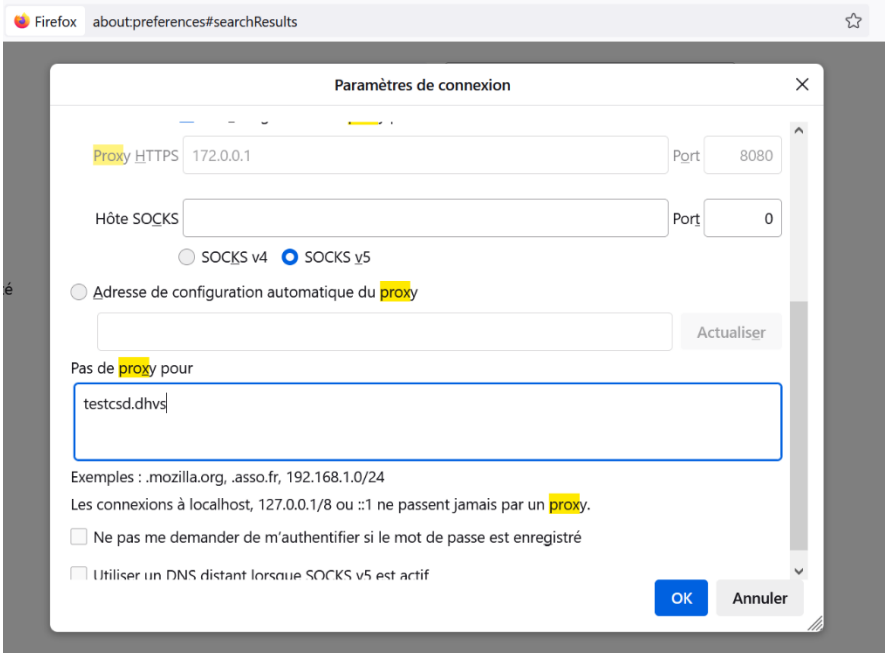
```
 GNU nano 4.8                          testcsd.ext
authorityKeyIdentifier=keyid,issuer
basicConstraints=CA:FALSE
keyUsage=digitalSignature, nonRepudiation, keyEncipherment, dataEncipherment
subjectAltName = @alt_names
[alt_names]
DNS.1 = testcsd.dhvs
```

Step 08: Edit the “localhost” file and insert the appropriate DNS

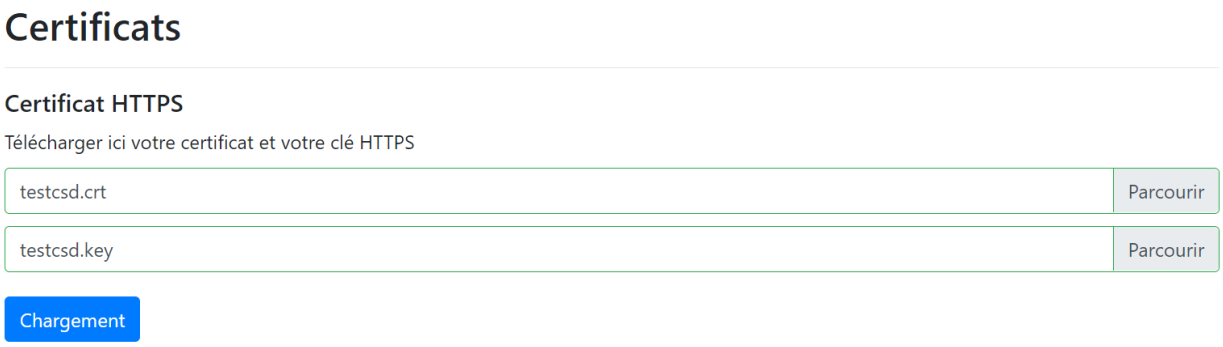
```
1   # Copyright (c) 1993-2009 Microsoft Corp.
2   #
3   # This is a sample HOSTS file used by Microsoft TCP/IP for Windows.
4   #
5   # This file contains the mappings of IP addresses to host names. Each
6   # entry should be kept on an individual line. The IP address should
7   # be placed in the first column followed by the corresponding host name.
8   # The IP address and the host name should be separated by at least one
9   # space.
10  #
11  # Additionally, comments (such as these) may be inserted on individual
12  # lines or following the machine name denoted by a '#' symbol.
13  #
14  # For example:
15  #
16  #      102.54.94.97     rhino.acme.com          # source server
17  #       38.25.63.10     x.acme.com              # x client host
18
19  # localhost name resolution is handled within DNS itself.
20  #   127.0.0.1       localhost
21  #   ::1             localhost
22  # Added by Docker Desktop
23  # To allow the same kube context to work on the host and the container:
24  127.0.0.1 kubernetes.docker.internal
25  192.168.4.2 testcsd.dhvs
26  # End of section
```


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Step 09: Configure firefox settings and insert the required domain name as per below screen:



Step 10: Upload the key and certificate on the CSD100 as per the following screen:



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23 APPENDIX F – DIGITAL SOFTWARE VERIFICATION

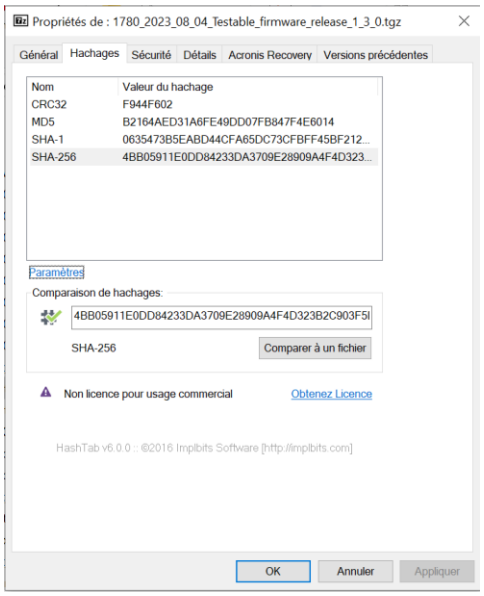
To verify the integrity of the packages provided by GE, refer to the GE website to check the signature of the specific package. A specific laptop/PC software tool must be used to confirm that the hash calculated on the GE website matches the hash calculated by the tool.

Several tools are available on the market, such as:

- HashMyFiles
- OpenHashTab
- QuickHash
- MultiHasher
- 7-Zip

In the screenshot below, GE provides an example of how to use the HashTab v6.0.0 tool:

Right-click on the file, navigate to the hash icon, and enter the hash value provided on the GE website or communicated by GE in the "Hash Comparison" icon.



Note: GE is not responsible for the choice of hash calculation tool; the customer must select the tool that is most suitable.

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24 APPENDIX G – EXAMPLES OF PROCESS BUS IMPLEMENTATION

24.1 Sampled Values terminologies

24.1.1 Introduction to variants

As per IEC 61869-9, to facilitate interoperability, only a limited variability is permitted for naming, message structure, sample rate, analogue signal content and scaling. The permitted variants are described in the device nameplate using the following notation, introduced here as an easy way to describe merging unit capabilities in a human readable text format:

F f S s I i U u

Where:

- *f* is the digital output sample rate expressed in samples per second
- *s* is the number of ASDUs (samples) contained in a sampled value message
- *i* is the number of current quantities contained in each ASDU
- *u* is the number of voltage quantities contained in each ASDU

Variant notation examples:

- **F4000S1I4U4** describes the 9-2LE MSVCB01 sampled values with 50 Hz nominal system frequency.
- **F4800S1I4U4** describes the 9-2LE MSVCB01 sampled values with 60 Hz nominal system frequency.
- **F4800S2I8U0** describes sampled values with 4800 samples per second, two ASDU (samples) per message, 8 currents, and no voltages.
- **F4800S2I12U12** describes sampled values with 4800 samples per second, two ASDU (samples) per message, 12 currents, and 12 voltages (maximum number of quantities supported by CSD100)

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24.1.2 Digital output sample rates

The standard sample rates (*f* in the variant notation) are indicated in Table 187.

Table 187 Standard sample rates

Variant	Digital output sample rates (sample/s)	Number of ASDUs per frame	Number of current quantities contained in each ASDU	Number of voltage quantities contained in each ASDU	Digital output publishing rate (frame/s)
F4000S1I4U4	4000	1	4	4	4000
F4800S1I4U4	4800	1	4	4	4800
F4800S2I12U12	4800	2	12	12	2400

24.1.3 Introduction to ASDU

Understanding the content of SV frame is essential to set properly the CSD100.

Sampled values are published in APDU (application protocol data unit) concatenating several ASDU's (application service data unit). The number of ASDU in a frame (noASDU) can be understood as the number of samples of a single quantity published in the same frame.

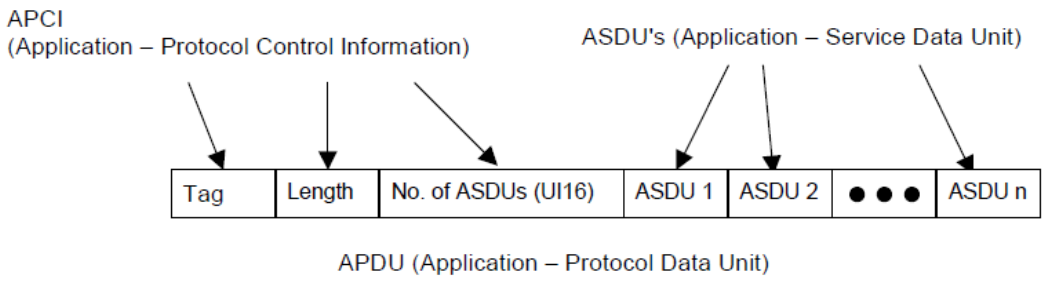


Figure 319 Concatenation of several ASDU's into one frame

As described in "variant section" an ASDU contains *i* current quantities and *u* voltage quantities in the sequence of data.

Table 188 and Table 189 provide examples of APDU content with a single and multiple ASDU's.

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Table 188 Example of APDU with a single ASDU

APDU	noASDU		L	1	
	ASDU 1	svID	L	Values	
		smpCnt	L (2)	Values	
		confRev	L (4)	Values	
		smpSynch	L (1)	Values	
		Sequence of Data	L	Data Set	Values
					Values
					Values
					Values
					Values
					Values
					Values
					Values
		gmIdentity	L (8)	Values	

L = length in byte

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Table 189 Example of APDU with 2 ASDU's

APDU	noASDU		L	2	
	ASDU 1	svID	L	Values	
		smpCnt	L (2)	Values	
		confRev	L (4)	Values	
		smpSynch	L (1)	Values	
		Sequence of Data	L	Data Set	Values
					Values
					Values
					Values
					Values
					Values
					Values
					Values
					Values
					Values
					Values
					Values
		gmIdentity	L (8)	Values	
	ASDU 2	svID	L	Values	
		smpCnt	L (2)	Values	
		confRev	L (4)	Values	
		smpSynch	L (1)	Values	
		Sequence of Data	L	Data Set	Values
					Values
					Values
					Values
					Values
					Values
					Values
					Values
					Values
					Values
					Values
					Values
		gmIdentity	L (8)	Values	

L = length in byte

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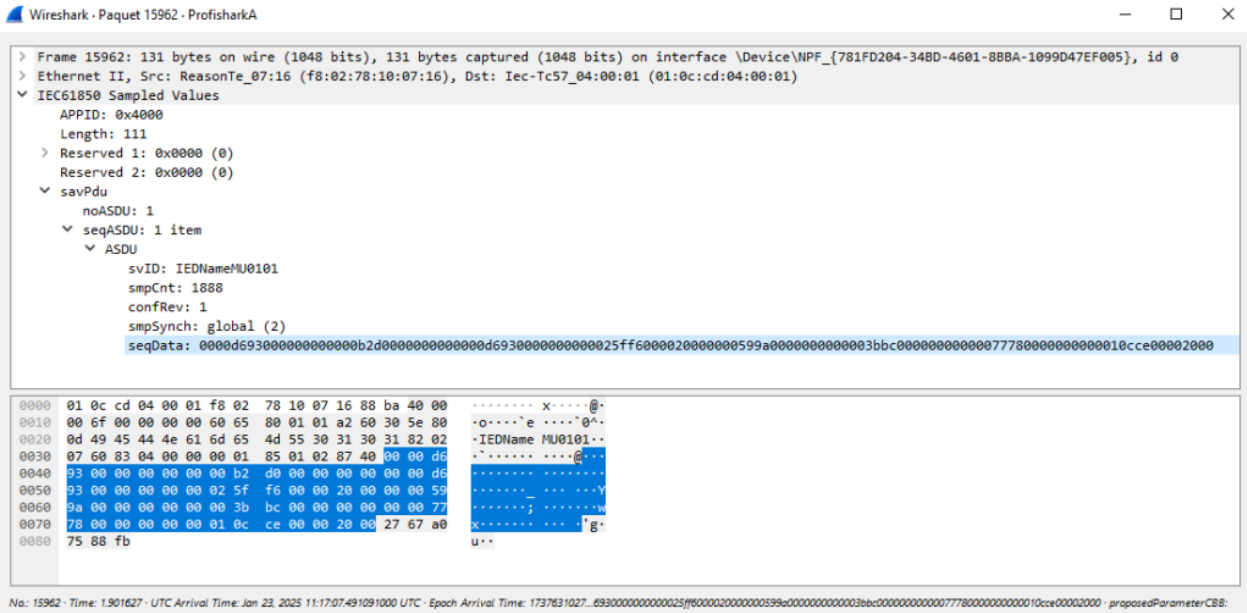
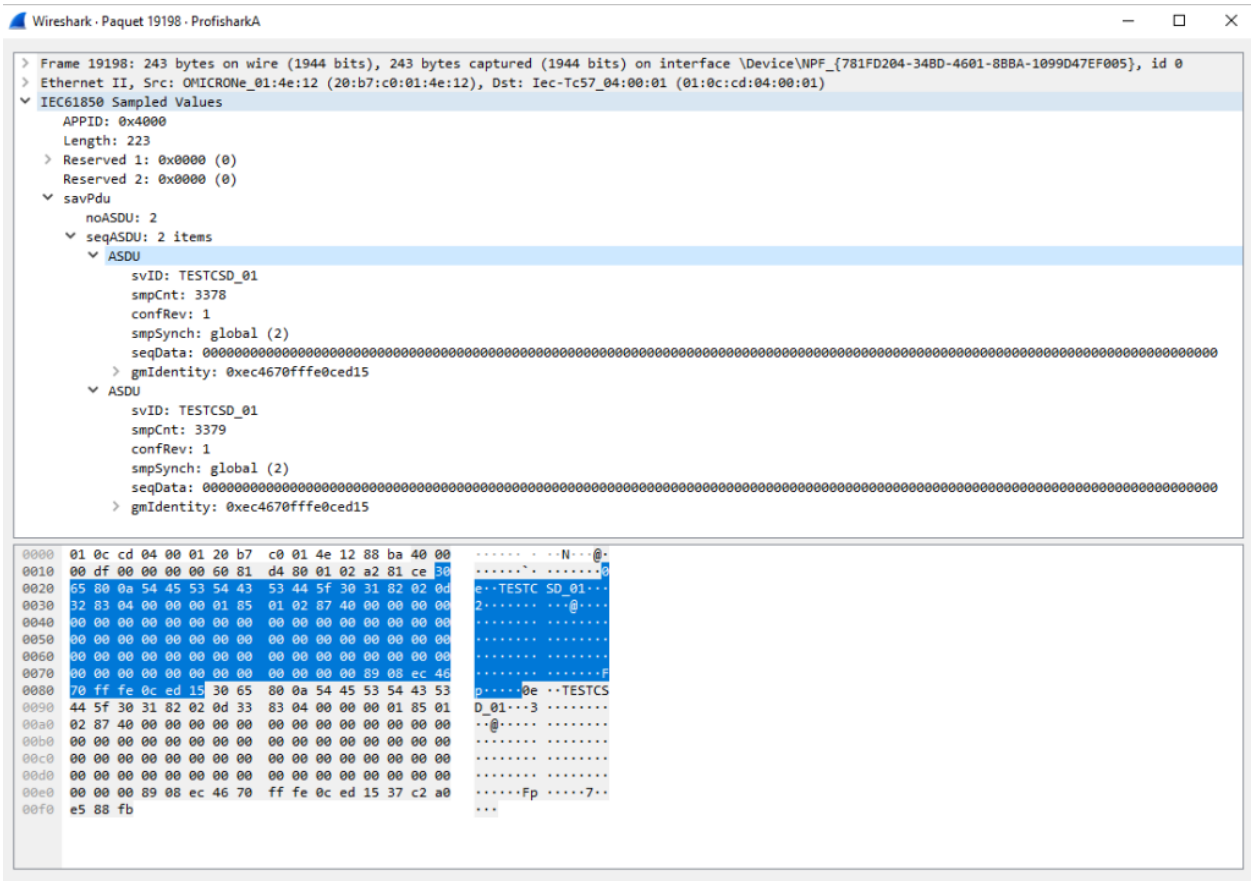


Figure 320 9.2LE frame capture


Wireshark · Paquet 19198 · ProfisharkA
Frame 19198: 243 bytes on wire (1944 bits), 243 bytes captured (1944 bits) on interface \Device\NPF_{781FD204-34BD-4601-8BBA-1099D47EF005}, id 0
Ethernet II, Src: OMICRONe_01:4e:12 (20:b7:c0:01:4e:12), Dst: Iec-Tc57_04:00:01 (01:0c:cd:04:00:01)
IEC61850 Sampled Values
APPID: 0x4000
Length: 223
Reserved 1: 0x0000 (0)
Reserved 2: 0x0000 (0)
savPdu
noASDU: 2
seqASDU: 2 items
ASDU
svID: TESTCSD_01
smpCnt: 3378
confRev: 1
smpSynch: global (2)
seqData: 0000000000000

24.1.4 Dataset(s) (IEC 61869-9)

Dataset members consist of **AmpSv.instMag.i** (current sampled value) or **VolSv.instMag.i** (voltage sampled value) attributes, each followed immediately by the corresponding AmpSv.q or VolSv.q (quality) attribute.

The number of current sampled values and the number of voltage sampled values matches the number of each specified by the variant code for the dataset.

All AmpSv members (current sampled values) precede any VolSv members (voltage sampled values), for example:

Table 190 Examples of sampled values datasets

9-2LE stream (F4000S1I4U4 or F4800S1I4U4)	IEC 61869-9 stream (F4800S2I6U6)
InnATCTR1.AmpSv.instMag.i	InnTCTR1.AmpSv.instMag.i
InnATCTR1.AmpSv.q	InnTCTR1.AmpSv.q
InnBTCTR2.AmpSv.instMag.i	InnTCTR2.AmpSv.instMag.i
InnBTCTR2.AmpSv.q	InnTCTR2.AmpSv.q
InnCTCTR3.AmpSv.instMag.i	InnTCTR3.AmpSv.instMag.i
InnCTCTR3.AmpSv.q	InnTCTR3.AmpSv.q
InnNTCTR4.AmpSv.instMag.i	InnTCTR4.AmpSv.instMag.i
InnNTCTR4.AmpSv.q	InnTCTR4.AmpSv.q
UnnATVTR1.VolSv.instMag.i	InnTCTR5.AmpSv.instMag.i
UnnATVTR1.VolSv.q	InnTCTR5.AmpSv.q
UnnBTVTR2.VolSv.instMag.i	InnTCTR6.AmpSv.instMag.i
UnnBTVTR2.VolSv.q	InnTCTR6.AmpSv.q
UnnCTVTR3.VolSv.instMag.i	UnnTVTR1.VolSv.instMag.i
UnnCTVTR3.VolSv.q	UnnTVTR1.VolSv.q
UnnNTVTR4.VolSv.instMag.i	UnnTVTR2.VolSv.instMag.i
UnnNTVTR4.VolSv.q	UnnTVTR2.VolSv.q
	UnnTVTR3.VolSv.instMag.i
	UnnTVTR3.VolSv.q
	UnnTVTR4.VolSv.instMag.i
	UnnTVTR4.VolSv.q
	UnnTVTR5.VolSv.instMag.i
	UnnTVTR5.VolSv.q
	UnnTVTR6.VolSv.instMag.i
	UnnTVTR6.VolSv.q

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24.2 Examples of implementation

24.2.1 Single busbar with 2 MUs compatible with 9.2LE

Example of implementation, in a single-busbar substation arrangement, using two merging units MU01 and MU02 with the capability, for each one, to collect 4 currents, 4 voltages, and to publish a single 9.2LE SV stream on the process bus.

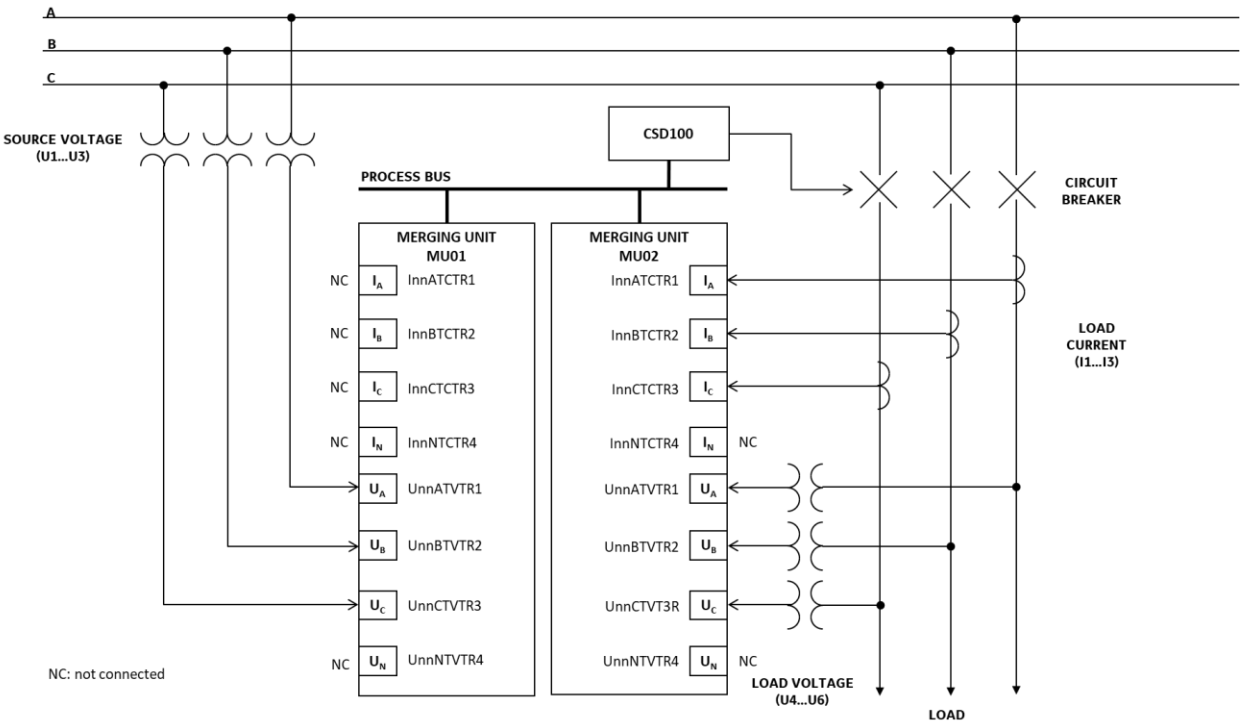


Figure 322 Process bus implementation - Single busbar arrangement with 2 MUs

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In this example,

- Merging unit MU01
  - Collects the source voltages from busbar on inputs UA, UB, UC
  - Collects the load voltages on inputs U4, U5, U6
  - Collects the load currents on inputs I4, I5, I6
  - Publishes sampled values in a single stream F4000S1I4U4 (9.2LE @50 Hz) described hereafter.
- Merging unit MU02
  - Collects the source voltages from busbar on inputs UA, UB, UC
  - Collects the load voltages on inputs UA, UB, UC
  - Collects the load currents on inputs IA, IB, IC
  - Publishes sampled values in a single stream F4000S1I4U4 (9.2LE @50 Hz)) described hereafter.

Note: inputs IA, IB, IC of the merging unit MU01 are not connected.

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Streams description

- Merging unit MU01
  - Publisher name: MU01
  - Power frequency: 50 Hz
  - Variant: F4000S1I4U4 (9.2LE @50 Hz)
  - Destination MAC address: 01:0C:CD:04:00:01
  - APPID: 0x4001
  - svID: MU01
  - VLAN Id: 111 (0x06F)
  - Dataset: refer to Table 191
- Merging unit MU02
  - Publisher name: MU02
  - Power frequency: 50 Hz
  - Variant: F4000S1I4U4 (9.2LE @50 Hz)
  - Destination MAC address: 01:0C:CD:04:00:02
  - APPID: 0x4002
  - svID: MU02
  - VLAN Id: 112 (0x070)
  - Dataset: refer to Table 191

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Table 191 Process bus implementation - Single busbar arrangement with 2 MUs – Dataset

Input	LD Instance	LN class	LN Instance	DO	DA	Dataset	Measurement
I_A	MU01	TCTR	1	AmpSv	instMag.i	TCTR1.AmpSv.instMag.i	NC (not connected)
					q	TCTR1.AmpSv.q	
I_B			2	AmpSv	instMag.i	TCTR2.AmpSv.instMag.i	NC (not connected)
					q	TCTR2.AmpSv.q	
I_C			3	AmpSv	instMag.i	TCTR3.AmpSv.instMag.i	NC (not connected)
					q	TCTR3.AmpSv.q	
I_N			4	AmpSv	instMag.i	TCTR4.AmpSv.instMag.i	NC (not connected)
					q	TCTR4.AmpSv.q	
U_A		TVTR	1	VolSv	instMag.i	TVTR1.VolSv.instMag.i	Source voltage L1
					q	TVTR1.VoSvl.q	
U_B			2	VolSv	instMag.i	TVTR2.VolSv.instMag.i	Source voltage L2
					q	TVTR2.VoSvl.q	
U_C			3	VolSv	instMag.i	TVTR3.VolSv.instMag.i	Source voltage L3
					q	TVTR3.VolSv.q	
U_N			4	VolSv	instMag.i	TVTR4.VolSv.instMag.i	NC (not connected)
					q	TVTR4.VoSvl.q	
I_A	MU02	TCTR	1	AmpSv	instMag.i	TCTR1.AmpSv.instMag.i	Load current L1
					q	TCTR1.AmpSv.q	
I_B			2	AmpSv	instMag.i	TCTR2.AmpSv.instMag.i	Load current L2
					q	TCTR2.AmpSv.q	
I_C			3	AmpSv	instMag.i	TCTR3.AmpSv.instMag.i	Load current L3
					q	TCTR3.AmpSv.q	
I_N			4	AmpSv	instMag.i	TCTR4.AmpSv.instMag.i	NC (not connected)
					q	TCTR4.AmpSv.q	
U_A		TVTR	1	VolSv	instMag.i	TVTR1.VolSv.instMag.i	Load voltage L1
					q	TVTR1.VoSvl.q	
U_B			2	VolSv	instMag.i	TVTR2.VolSv.instMag.i	Load voltage L2
					q	TVTR2.VoSvl.q	
U_C			3	VolSv	instMag.i	TVTR3.VolSv.instMag.i	Load voltage L3
					q	TVTR3.VolSv.q	
U_N			4	VolSv	instMag.i	TVTR4.VolSv.instMag.i	NC (not connected)
					q	TVTR4.VoSvl.q	

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Corresponding CSD100 processed streams configuration is:

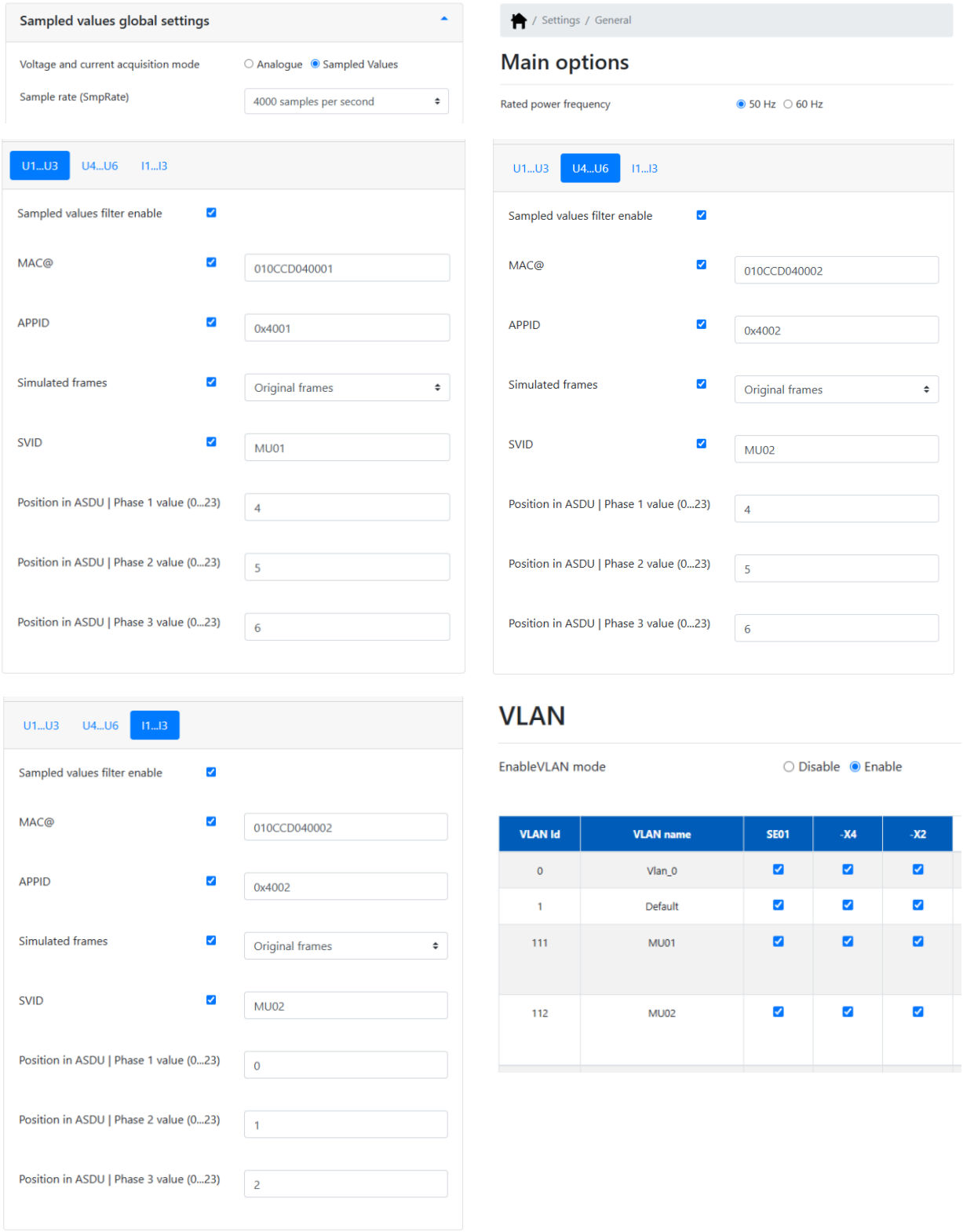


Figure 323 Process bus implementation – CSD100 settings with single busbar arrangement and 2 merging units

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24.2.2 Single busbar with 1 MU compatible with IEC 61869-9 variant

Example of implementation, in a single-busbar substation arrangement, using a single merging unit with the capability to collect 6 currents, 6 voltages, and to publish a single SV stream F4800S2I6U6 on the process bus.

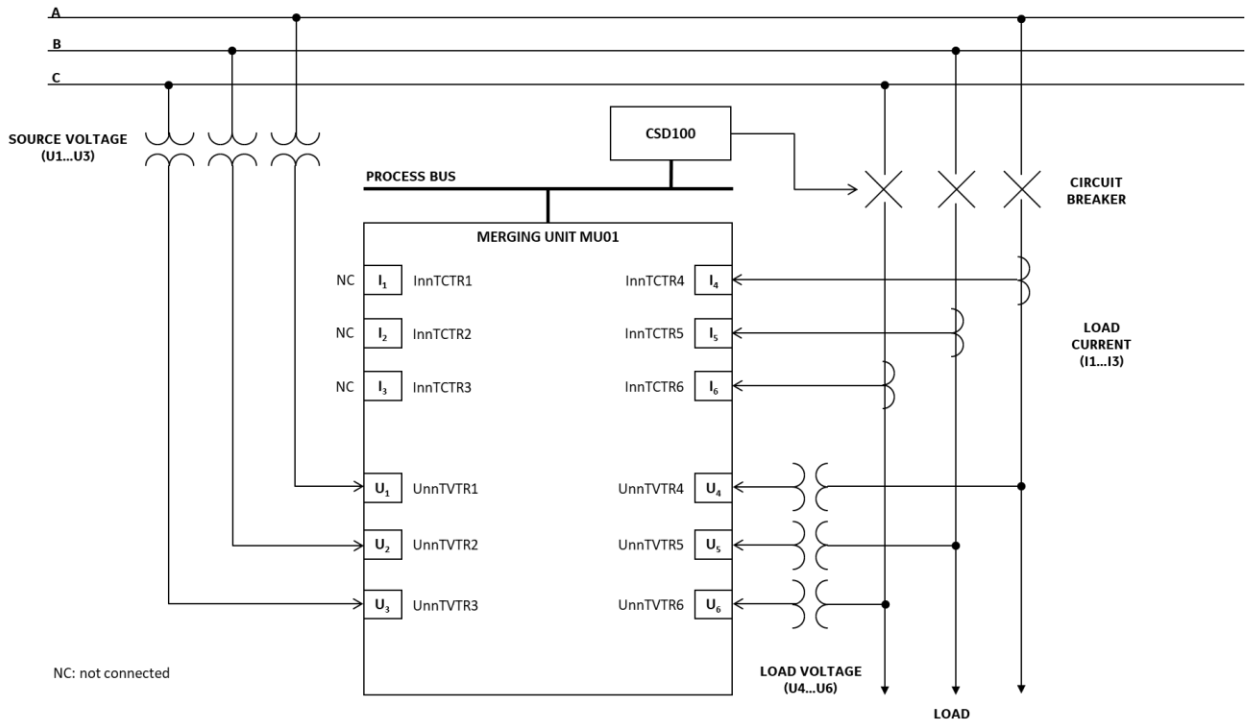


Figure 324 Process bus implementation - Single busbar arrangement with single merging unit

In this example,

- Merging unit MU01
  - Collects the source voltages from busbar on inputs U1, U2, U3
  - Collects the load voltages on inputs U4, U5, U6
  - Collects the load currents on inputs I4, I5, I6
  - Publishes sampled values in a single stream F4800S2I6U6 described hereafter.

Note: inputs I1, I2, I3 of the merging unit MU01 are not connected.

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Stream description

- Merging unit MU01
  - Publisher name: MU01
  - Power frequency: 50 Hz
  - Variant: F4800S2I6U6
  - Destination MAC address: 01:0C:CD:04:00:01
  - APPID: 0x4001
  - svID: MU01
  - VLAN Id: 110 (0x06E)
  - Dataset: refer to Table 192

Table 192 Process bus implementation - Single busbar arrangement with 1 merging unit – Datasets

Input	LD instance	LN class	LN Instance	DO	DA	Dataset	Measurement
I_1	MU01	TCTR	1	AmpSv	instMag.i	TCTR1.AmpSv.instMag.i	NC (not connected)
					q	TCTR1.AmpSv.q	
I_2			2	AmpSv	instMag.i	TCTR2.AmpSv.instMag.i	NC (not connected)
					q	TCTR2.AmpSv.q	
I_3			3	AmpSv	instMag.i	TCTR3.AmpSv.instMag.i	NC (not connected)
					q	TCTR3.AmpSv.q	
I_4			4	AmpSv	instMag.i	TCTR4.AmpSv.instMag.i	Load current L1
					q	TCTR4.AmpSv.q	
I_5			5	AmpSv	instMag.i	TCTR5.AmpSv.instMag.i	Load current L2
					q	TCTR5.AmpSv.q	
I_6			6	AmpSv	instMag.i	TCTR6.AmpSv.instMag.i	Load current L3
					q	TCTR6.AmpSv.q	
U_1		TVTR	1	VolSv	instMag.i	TVTR1.VolSv.instMag.i	Source voltage L1
					q	TVTR1.VoSvl.q	
U_2			2	VolSv	instMag.i	TVTR2.VolSv.instMag.i	Source voltage L2
					q	TVTR2.VoSvl.q	
U_3			3	VolSv	instMag.i	TVTR3.VolSv.instMag.i	Source voltage L3
					q	TVTR3.VolSv.q	
U_4			4	VolSv	instMag.i	TVTR4.VolSv.instMag.i	Load voltage L1
					q	TVTR4.VoSvl.q	
U_5			5	VolSv	instMag.i	TVTR5.VolSv.instMag.i	Load voltage L2
					q	TVTR5.VoSvl.q	
U_6			6	VolSv	instMag.i	TVTR6.VolSv.instMag.i	Load voltage L3
					q	TVTR6.VolSv.q	

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Corresponding CSD100 processed streams configuration is:

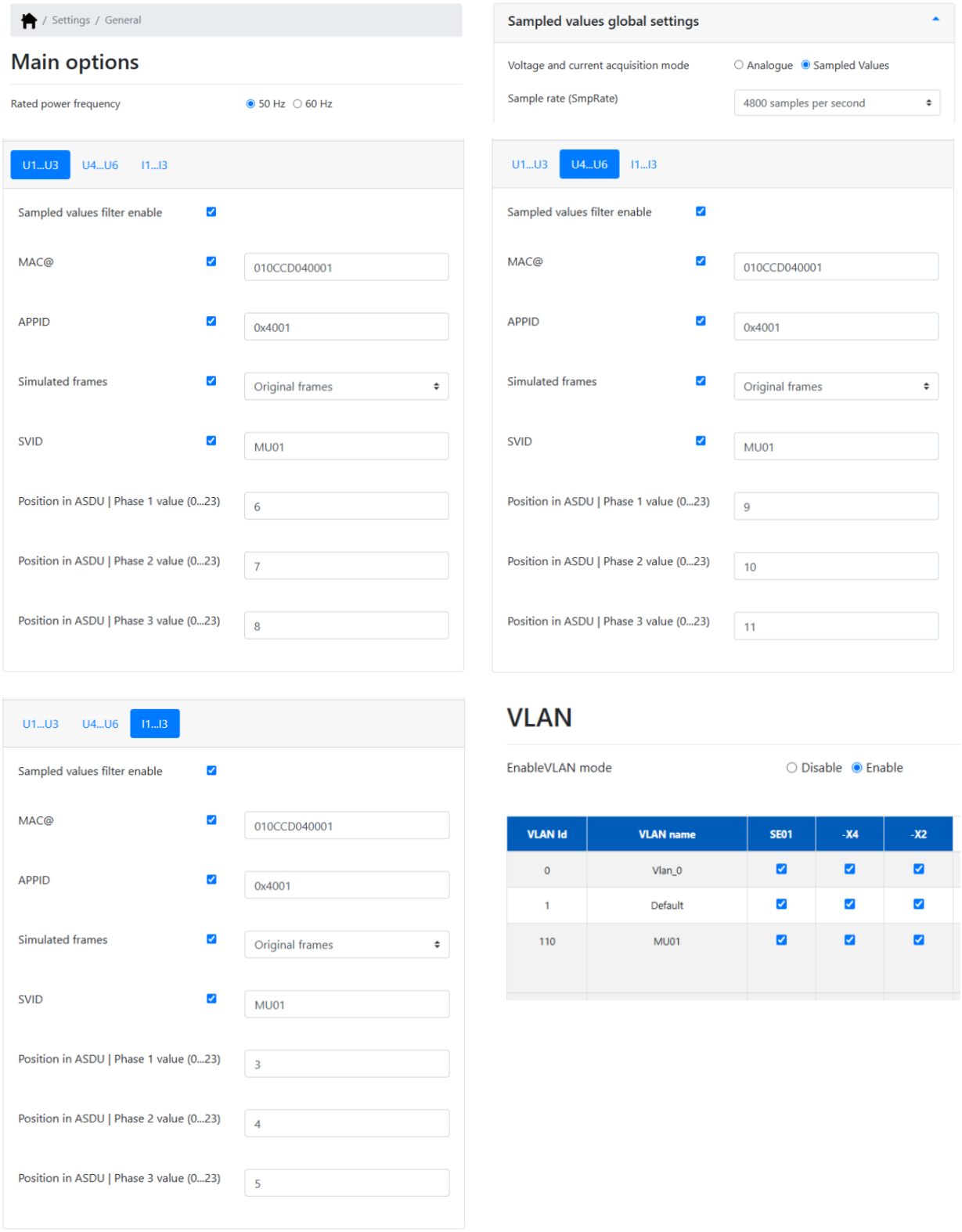


Figure 325 Process bus implementation – CSD100 settings with single busbar arrangement and single MU

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24.2.3 Double busbar with 3 MUs compatible with 9.2LE

Example of implementation, in a double-busbar substation arrangement, using 3 merging units MU01, MU02, MU03 with the capability, for each one, to collect 8 currents, 8 voltages, and to publish two 9.2LE SV stream on the process bus.

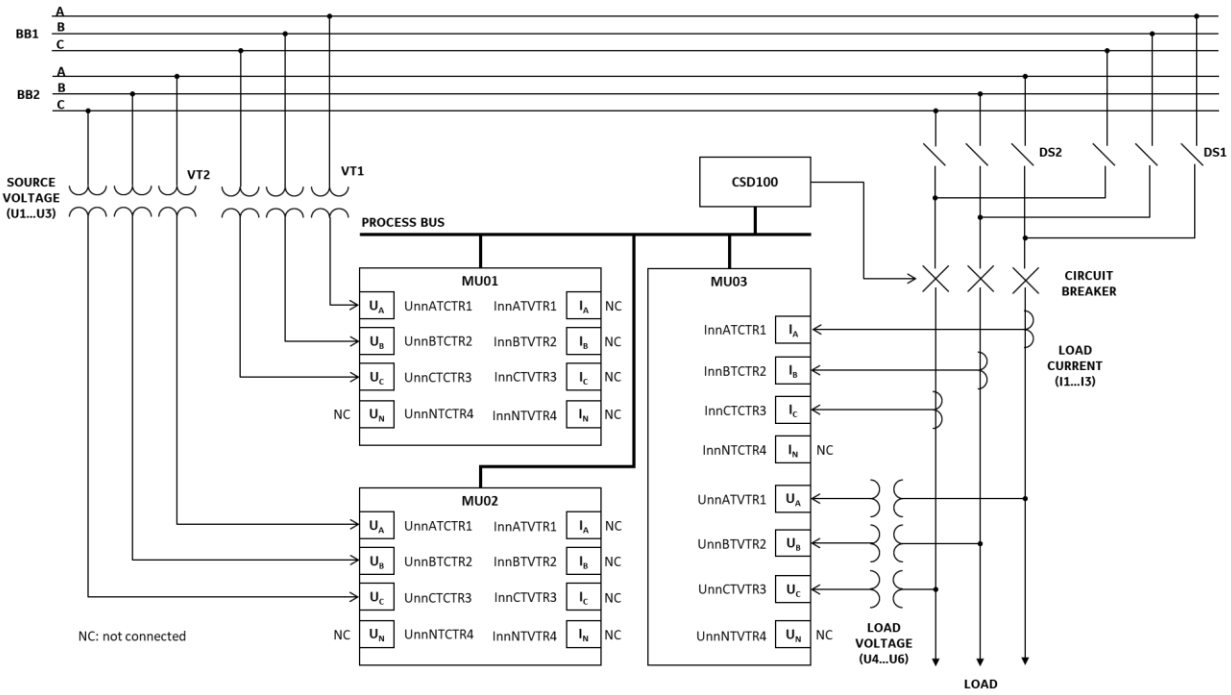


Figure 326 Process bus implementation - Double busbar arrangement with 3 merging units

In this situation, CSD100 requires use of 2 configuration sets corresponding to the following situations:

- Config_0, DS1 is in closed position, DS2 is in open position, and the source voltage is coming from BB1
- Config_1, DS2 is in open position, DS2 is in closed position, and the source voltage is coming from BB2

Automatic selection of the SV subscription scheme is enforced by GOOSE subscription. Refer to sections 13.1.4 and 13.1.20 for further details.

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In this example,

- Merging unit MU01
  - Collects the source voltages from busbar 1 on inputs UA, UB, UC
  - Publishes sampled values in a single stream F4800S1I4U4 (9.2LE) described hereafter
- Merging unit MU02
  - Collects the source voltages from busbar 1 on inputs UA, UB, UC
  - Publishes sampled values in a single stream F4800S1I4U4 (9.2LE) described hereafter
- Merging unit MU03
  - Collects load voltages on inputs UA, UB, UC
  - Collects load currents on inputs IA, IB, IC
  - Publishes sampled values in a single stream F4800S1I4U4 (9.2LE) described hereafter

Note: inputs IA, IB, IC of the merging unit MU01 , inputs IA, IB, IC of the merging unit MU02 are not connected.

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Streams description

- Merging unit MU01
  - Publisher name: MU01
  - Power frequency: 50 Hz
  - Variant: F4000S1I4U4 (9.2LE @50 Hz)
  - Destination MAC address: 01:0C:CD:04:00:01
  - APPID: 0x4001
  - svID: MU01
  - VLAN Id: 111 (0x06F)
  - Dataset: refer to Table 193
- Merging unit MU02
  - Publisher name: MU02
  - Power frequency: 50 Hz
  - Variant: F4000S1I4U4 (9.2LE @50 Hz)
  - Destination MAC address: 01:0C:CD:04:00:02
  - APPID: 0x4002
  - svID: MU02
  - VLAN Id: 112 (0x070)
  - Dataset: refer to Table 193
- Merging unit MU03
  - Publisher name: MU03
  - Power frequency: 50 Hz
  - Variant: F4000S1I4U4 (9.2LE @50 Hz)
  - Destination MAC address: 01:0C:CD:04:00:03
  - APPID: 0x4003
  - svID: MU03
  - VLAN Id: 113 (0x071)
  - Dataset: refer to Table 193

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Table 193 Process bus implementation - Double busbar arrangement with 3 merging units – Datasets

Input	LD Instance	LN class	LN Instance	DO	DA	Dataset	Measurement
IA	MU01	TCTR	1	AmpSv	instMag.i	TCTR1.AmpSv.instMag.i	NC (not connected)
					q	TCTR1.AmpSv.q	
IB			2	AmpSv	instMag.i	TCTR2.AmpSv.instMag.i	NC (not connected)
					q	TCTR2.AmpSv.q	
IC			3	AmpSv	instMag.i	TCTR3.AmpSv.instMag.i	NC (not connected)
					q	TCTR3.AmpSv.q	
IN			4	AmpSv	instMag.i	TCTR4.AmpSv.instMag.i	NC (not connected)
					q	TCTR4.AmpSv.q	
UA		TVTR	1	VolSv	instMag.i	TVTR1.VolSv.instMag.i	Source voltage L1 BB1
					q	TVTR1.VoSvl.q	
UB			2	VolSv	instMag.i	TVTR2.VolSv.instMag.i	Source voltage L2 BB1
					q	TVTR2.VoSvl.q	
UC			3	VolSv	instMag.i	TVTR3.VolSv.instMag.i	Source voltage L3 BB1
					q	TVTR3.VolSv.q	
UN			4	VolSv	instMag.i	TVTR4.VolSv.instMag.i	NC (not connected)
					q	TVTR4.VoSvl.q	
IA	MU02	TCTR	1	AmpSv	instMag.i	TCTR1.AmpSv.instMag.i	NC (not connected)
					q	TCTR1.AmpSv.q	
IB			2	AmpSv	instMag.i	TCTR2.AmpSv.instMag.i	NC (not connected)
					q	TCTR2.AmpSv.q	
IC			3	AmpSv	instMag.i	TCTR3.AmpSv.instMag.i	NC (not connected)
					q	TCTR3.AmpSv.q	
IN			4	AmpSv	instMag.i	TCTR4.AmpSv.instMag.i	NC (not connected)
					q	TCTR4.AmpSv.q	
UA		TVTR	1	VolSv	instMag.i	TVTR1.VolSv.instMag.i	Source voltage L1 BB2
					q	TVTR1.VoSvl.q	
UB			2	VolSv	instMag.i	TVTR2.VolSv.instMag.i	Source voltage L2 BB2
					q	TVTR2.VoSvl.q	
UC			3	VolSv	instMag.i	TVTR3.VolSv.instMag.i	Source voltage L3 BB2
					q	TVTR3.VolSv.q	
UN			4	VolSv	instMag.i	TVTR4.VolSv.instMag.i	NC (not connected)
					q	TVTR4.VoSvl.q	
IA	MU03	TCTR	1	AmpSv	instMag.i	TCTR1.AmpSv.instMag.i	Load current L1
					q	TCTR1.AmpSv.q	
IB			2	AmpSv	instMag.i	TCTR2.AmpSv.instMag.i	Load current L2
					q	TCTR2.AmpSv.q	
IC			3	AmpSv	instMag.i	TCTR3.AmpSv.instMag.i	Load current L3
					q	TCTR3.AmpSv.q	
IN			4	AmpSv	instMag.i	TCTR4.AmpSv.instMag.i	NC (not connected)
					q	TCTR4.AmpSv.q	
UA		TVTR	1	VolSv	instMag.i	TVTR1.VolSv.instMag.i	Load voltage L1
					q	TVTR1.VoSvl.q	
UB			2	VolSv	instMag.i	TVTR2.VolSv.instMag.i	Load voltage L2
					q	TVTR2.VoSvl.q	
UC			3	VolSv	instMag.i	TVTR3.VolSv.instMag.i	Load voltage L3
					q	TVTR3.VolSv.q	
UN			4	VolSv	instMag.i	TVTR4.VolSv.instMag.i	NC (not connected)
					q	TVTR4.VoSvl.q	

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Corresponding CSD100 processed streams configuration for config_0 is:

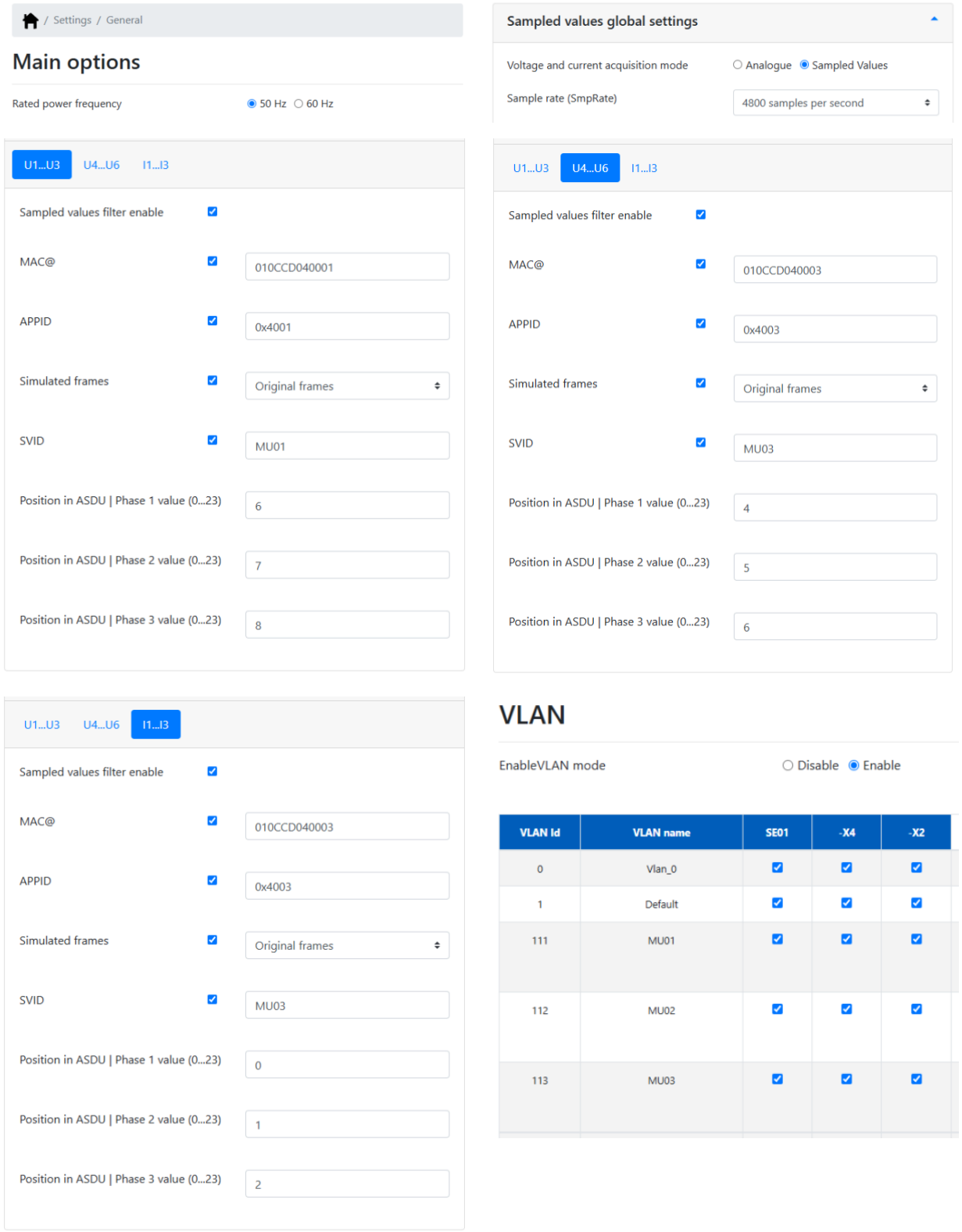


Figure 327 Process bus implementation – CSD100 settings with single busbar arrangement and single MU

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Corresponding CSD100 processed streams configuration for config_1 is:

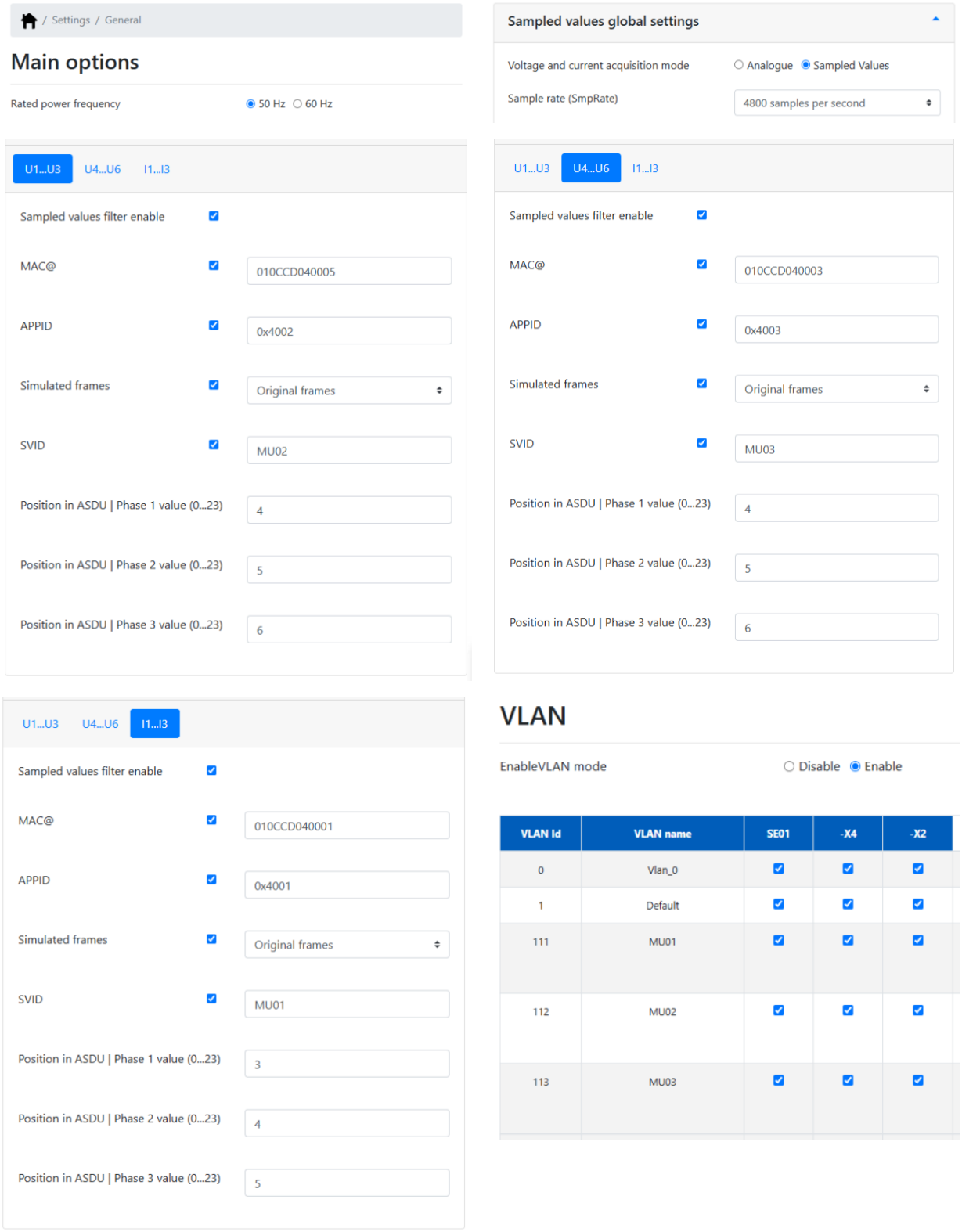


Figure 328 Process bus implementation – CSD100 settings with double busbar arrangement and 3 MU

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24.3 Example of a CID customization for SV automatic subscription using GOOSE

24.3.1 Content of GOOSE publisher “GPubConfig”

```
<ConnectedAP apName="APp" iedName="GPubConfig">
    <Address>
        <P type="OSI-AP-Title">1,1,9999,1</P>
        <P type="OSI-AE-Qualifier">12</P>
        <P type="OSI-PSEL">00000001</P>
        <P type="OSI-SSEL">0001</P>
        <P type="OSI-TSEL">0001</P>
    </Address>
    <GSE ldInst="CTRL" cbName="NewGseCtl">
        <Address>
            <P type="VLAN-ID">000</P>
            <P type="VLAN-PRIORITY">4</P>
            <P type="MAC-Address">01-0C-CD-01-00-00</P>
            <P type="APPID">1000</P>
            </Address>
            <MinTime>5000</MinTime>
            <MaxTime>60000</MaxTime>
    </GSE>
</ConnectedAP>

<AccessPoint name="APp">
    <Server>
        <Authentication />
        <LDevice inst="CTRL">
            <LN0 lnType="LLN0_2007B" lnClass="LLN0" inst="">
                <DataSet name="ConfSelect">
                    <FCDA fc="ST" ldInst="CTRL" lnClass="GGIO" lnInst="1" prefix="" doName="IntIn1" daName="stVal" />
                    <FCDA fc="ST" ldInst="CTRL" lnClass="GGIO" lnInst="1" prefix="" doName="IntIn1" daName="q" />
                </DataSet>
                <GSEControl name="NewGseCtl" appID="GPubConfig/LLN0$GO$NewGseCtl" confRev="1" datSet="ConfSelect"
type="GOOSE" />
            </LN0>
            <LN lnType="LPHD_TYPE" lnClass="LPHD" inst="1" prefix="" />
            <LN lnType="GGIO_TYPE" lnClass="GGIO" inst="1" prefix="" />
        </LDevice>
    </Server>
    <Services />
</AccessPoint>
```


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24.3.2 Customization of CSD100 SCL file

24.3.2.1 CSD100 GOOSE subscription to “GPubConfig” publisher

Customization of the CSD100 SCL file to subscribe GPubConfig is described here:

```
<ConnectedAP apName="APp" iedName="GPubConfig">
    <Address>
        <P type="IP">192.168.87.220</P>
        <P type="IP-SUBNET">0.0.0.0</P>
        <P type="IP-GATEWAY">0.0.0.0</P>
        <P type="OSI-PSEL">00000001</P>
        <P type="OSI-SSEL">0001</P>
        <P type="OSI-TSEL">0001</P>
    </Address>
    <GSE ldInst="CTRL" cbName="NewGseCtl">
        <Address>
            <P type="VLAN-ID">000</P>
            <P type="VLAN-PRIORITY">4</P>
            <P type="MAC-Address">01-0C-CD-01-00-00</P>
            <P type="APPID">1000</P>
        </Address>
        <MinTime>5000</MinTime>
        <MaxTime>60000</MaxTime>
    </GSE>
</ConnectedAP>

<AccessPoint name="APp">
    <Server>
        <Authentication />
        <LDevice inst="CTRL">
            <LN0 lnType="LLN0_2007B" lnClass="LLN0" inst="">
                <DataSet name="ConfSelect">
                    <FCDA fc="ST" ldInst="CTRL" lnClass="GGIO" lnInst="1" prefix="" doName="IntIn1" daName="stVal" />
                    <FCDA fc="ST" ldInst="CTRL" lnClass="GGIO" lnInst="1" prefix="" doName="IntIn1" daName="q" />
                </DataSet>
                <GSEControl name="NewGseCtl" appID="GPubConfig/LLN0$GO$NewGseCtl" confRev="1" datSet="ConfSelect"
type="GOOSE" />
                </LN0>
                <LN lnType="LPHD_TYPE" lnClass="LPHD" inst="1" prefix="" />
                <LN lnType="GGIO_TYPE" lnClass="GGIO" inst="1" prefix="" />
        </LDevice>
    </Server>
    <Services />
</AccessPoint>

<Inputs>
    <ExtRef daName="stVal" intAddr="19" desc="Integer for SV conf selection" serviceType="GOOSE" srcLNClass="LLN0"
    srcLDInst="CTRL" srcCBName="NewGseCtl" iedName="GPubConfig" doName="IntIn1" lnInst="1" lnClass="GGIO"
    ldInst="CTRL"/>
</Inputs>
```


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24.3.2.2 LGOS logical node

This logical node provides interface to diagnosis and monitoring of the subscription to GOOSE messages. There shall be one instance of LGOS per GOOSE subscription.

```
<LNodeType id="LGOS_TYPE" lnClass="LGOS">
    <DO name="Beh" type="TMW_Generated_ENS_BehaviourModeKind" />
    <DO name="St" type="TMW_Generated_SPS" />
    <DO name="ConfRevNum" type="TMW_Generated_INS" />
    <DO name="RxConfRevNum" type="TMW_Generated_INS" />
    <DO name="LastStNum" type="TMW_Generated_INS" />
    <DO name="GoCBRef" type="ORG" />
</LNodeType>

<LN lnType="LGOS_TYPE" lnClass="LGOS" inst="1" prefix="">
    <DOI name="GoCBRef">
        <DAI name="setSrcRef" valKind="RO">
            <Val>GPubConfigCTRL/LLN0.NewGseCtl</Val>
        </DAI>
    </DOI>
</LN>
```

END OF THE DOCUMENT

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