This document gives an overview of the HVDC Protection System.

The HVDC protections are grouped to:

- DC protections
- AC protections
- Apparatus Protective Relays

Common features of the protection philosophy, the protective functions and the fault clearing actions are given. Also, tools for the system programming and supervision are briefly described.
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1. INTRODUCTION

This document describes the common features for a complete HVDC Protection System.

The protection system uses powerful computers and allows both a future adoption of new protective functions and adjustments of existing protections in a very flexible manner. The protection system is built in a modular way, thus enabling a structured design of the system.

The detection principles and the protective functions are briefly described, but for a more detailed description a reference is made to the Functional Descriptions of corresponding protective function.

The backup protections are separately presented only in case the protective principles differ from each other.

2. GENERAL PROTECTION PHILOSOPHY

The purpose of the HVDC protection system is to promptly remove main circuit equipment from service at short circuits or at abnormal operation that might cause damage or interfere with the operation of the neighbouring system.

The HVDC control and protection system is divided into two Redundant systems A and B, based on an Active Standby concept. Both systems include a complete set of control and protection systems. Each protection system consists of both set1 and set2 protections.

As soon as a protection operates a fast change over is executed from the active system to the standby system, to ensure that the protection action is based on a correct external measurement. The concept is equal for both the DC and the AC protections.

The protective scheme is designed to meet the following general requirements:

a) Fault or other abnormal conditions, that might expose the equipment to hazards are detected. Also, the cause of an unacceptable disturbance should be detected and the faulty or overstressed equipment should either be taken out of service or relieved from stresses in a controlled way.

b) The aim of the protection design is to detect every condition according to above with at least two protective functions.

c) The protection setup should be arranged into overlapping protective zones. For each fault case, there should be a fast main protection with a limited protective zone. The main protective function should normally be supported with a slower or less sensitive backup protective function. The backup protective function should, if possible, be based on a different measuring principle and when applicable, with a more extended protective zone. For those cases where the main/backup philosophy can not be applied without difficulties, essential protective functions should be doubled.

d) Steps shall be taken to minimize the possibility of a fault in one converter causing protective actions in other converters.

e) The protection system shall be provided with recording facilities. All signals used by the protection system shall be recorded and time marked. The recording facility shall always save the latest event, even if there already are information stored.

f) Where applicable, the alarm and trip references shall be set so as to give level and time separated operation.

g) The protection system shall be active/standby as long as the power supply is OK and there is no fault on the system.

h) Tripping paths to the breaker should be redundant and fed by two different auxiliary voltage supplies.

i) The protections shall be arranged so that testing and maintenance can be carried out without affecting the operation of the transmission.
Bipole aspects

The aim with the overall protection philosophy, especially for bipole related protective functions shall be to avoid any undue bipole outage during any circumstances.

Examples of possible faults and disturbances which shall be covered by the protection philosophy:

- Common mode disturbances and faults e.g. in the AC system causing disturbances to both poles.
- DC side disturbances related to common bipole equipment i.e. the bipole neutral bus, station ground, metallic return, electrode line/cable and transfer breakers.
- Domino effect i.e. faults in one converter causing a protective action in the other converter.

According to the above philosophy:

a) Protective functions related to equipment within a pole shall be separated between the poles and have separate measuring devices.

b) There shall be a set of protective functions for equipment common for both poles in a bipole, called bipole protections. Each pole shall have a separate set of bipole protections, using separate measuring devices.

c) No protective function, pole related or bipole related, is allowed to trip the other pole in a bipole.

d) There shall be no single protective actions for bipole related faults or disturbances which can lead to a bipole outage.

e) A bipole related protective function should not initiate protective actions on a single criterion.
3. DC PROTECTIONS

Converter protections

Figure 1

Valve short circuit protection
The protection detects valve short circuits and other phase to phase short circuits on the DC-side of the converter transformer. The protective function uses the AC conductor currents IVY and IVD and the DC pole line and neutral bus direct currents, IDL respectively IDNE. Higher amplitudes in the AC conductor currents than in the DC current is a criterion of a valve or an other phase to phase short circuit.

Commutation failure protection
The Commutation failure protection detects failures in the twelve pulse converter due to abnormal commutation conditions by measuring the AC currents IVY and IVD in combination with DC currents IDL and IDNE. During commutation failures the DC current is higher than the AC conductor current, which is detected by the protection.

Voltage stress protection
The Voltage stress protection protects the converter equipment from dielectric stresses by interlocking the converter transformer tap changers. Dielectric stresses are caused by the AC side voltage. The interlocking prevents a further increase of the ideal no-load direct voltage UDI0. The UDI0 is calculated by using the AC bus voltage measurement UAC, the tap-changer position and the frequency.
**Back up UD Supervision**
The back up UD supervision calculates the DC voltage out of UDI0, α, γ and the neutral bus current IDNE. The calculated DC voltage is compared with the measured DC voltage and the difference is used to detect and prevent transmission disturbances due to abnormal control or measuring circuit conditions. The function is coordinated with the UD calculation in the control system.

**Valve misfire protection**
The control pulse generator in the converter firing control system delivers control pulses CP to each valve with a duration corresponding to the required conducting interval. To facilitate detection of faulty valves the CP is compared with information about firing. Thereby, a valve firing outside the CP interval as well as failure to fire within the CP interval is prohibited by this protection.

**Thyristor monitoring**
The thyristor valve monitoring system is a self supervising system. In every valve control unit there is a function, detecting if the voltage is picked up within a specified time by the corresponding thyristor. At the time the thyristor picks up the voltage an indication pulse IP is sent on an optical fiber to the valve control. A failed thyristor does not pick up voltage and this condition is detected.

**High Angle Supervision**
The stresses on the main circuit equipment caused by an increased angle operation, due to the extreme requirements on increased firing and extinction angles, are calculated by the High Angle Supervision HAS function.

The HAS calculates the limitations on the HVDC system. It includes a theoretical model of the valve damping circuits, the arresters across the valve and the valve reactor.

**DC overcurrent protection**
The DC overcurrent protection protects the valves and the converter equipment. The AC conductor currents IVY and IVD, the neutral bus current IDNE and the cooling water temperature are measured. The protection contains two parts, one for the overcurrent and the other for the thyristor overtemperature detection.
Pole protections

Figure 2

DC abnormal voltage protection
The protective zone includes all equipment exposed to DC voltage and the thyristor valves at bypass pair firing of the inverter. The DC abnormal voltage protective function detects both over and undervoltages on the DC line by measuring the voltage UDL, the current IDL and the converter firing angle.

DC harmonic protection
DC harmonic protection detects abnormal harmonics in the converter current, generated at control equipment malfunction or during valve and AC network disturbances. The direct current is filtered for the fundamental and second harmonic frequencies.

DC differential protection
The protective zone of the DC differential protection is from the converter transformer secondary bushings to the measurements of both the line and electrode currents, at the DC side of the converter. To detect ground faults within the protective zone the direct currents IDL and IDNE are measured in combination with the AC conductor currents IVY and IVD neutral bus currents IANC and ICN in addition with the DC filter currents IF1 and IF2.

DC line ground fault protection
Detects ground faults on the DC line. The protection initiates control actions to extinguish the fault current, and if conditions permit, restores the power transmission. The detection is made by measuring the level of the DC line voltage and the derivatives of both the direct line voltage UDL and the direct line current IDL.

DC filter overload protection
The protection detects an overload on a filter component by measuring the two filter currents IF1 and IF2. The protection calculates the heating in the resistors and the reactors caused by high currents and initiates control actions to
prevent a further exposure, when one or several components has become overheated.

**Electrode line open circuit protection**
Electrode line open circuit protection protects the neutral bus equipment from dielectric stresses due to an electrode line open circuit. This is done by monitoring the neutral bus direct voltage UDN and the neutral bus direct current IDNE.

**DC switchyard protections**

**DC BIPOLE SWITCH YARD**

**SET 1 BIPOLE PROTECTIONS, SYSTEM A, POLE 1**

- **BIPOLE NEUTRAL DIFFERENTIAL PROTECTION**
- **TRANSFER BREAKER PROTECTION, NBS, NBGS, GRTB, MRTB**
- **METALLIC RETURN GROUND FAULT PROTECTION**
- **ELECTRODE LINE LONG DISC. PROTECTION**
- **DC current measuring device**

*) To pole 2 bi-pole protection setup

**) From electrode station if applicable

**SET 2 BIPOLE PROTECTIONS, SYSTEM A, POLE 1**

- **POLE 1 DC LINE**
- **POLE 1 NEUT BUS**
- **POLE 2 NEUT BUS**
- **POLE 2 DC LINE**

**Figure 3**

**Bipole Neutral differential protection**
The electrode line conductor IDEL1&2, the metallic return path IDME, the station ground IDGND and the neutral bus IDNE1&2 currents are measured. A differential current exceeding a preset level is a criterion for a ground fault within the protective zone. The protection is disabled in the metallic return operating mode.

**Metallic return conductor ground fault protection**
Metallic return conductor ground fault protection monitors the ground current in the grounded station. Depending on whether the station is grounded by the two electrode conductors or the grounding switch, the corresponding currents IDEL1&2 or IDGND are measured. A detected ground current is a criterion for a ground fault on the return conductor.
**Transfer breaker protection**
Protects the transfer breaker in case the commutation of the current fails during DC yard switching.

**Station ground overcurrent protection**
The Station ground overcurrent protection protects the station ground, converter transformer and the bus between the electrode line and the pole neutral bus.
Electrode cable longitudinal differential protection

The protection device measures and compares the currents in both ends of the electrode cable. The detection is coordinated for possible time difference between the sampling of the two measured currents. The protection shall only be active if the communication with the remote end is in service.

Electrode line unbalance supervision

The direct current in each electrode line conductor (IDEL1 and IDEL2) is measured. When the difference between the two measured currents exceeds a preset level the criterion for a ground fault or an open circuit on one of the conductors is fulfilled. The preset level has one fixed part and one part proportional to the neutral current IDNE.
Electrode line impedance supervision

The impedance to ground is measured by injecting a high frequency signal on the electrode line between the blocking filters, and from the response of the line the impedance is calculated.
4. AC PROTECTIONS

Converter transformer and AC bus protections

Figure 5

**AC conductor ground fault protection**
The protection detects ground faults on the AC conductors by measuring the vector sum of the phase-to-ground voltages on the valve side of the converter transformers. As long as the converter is blocked and no ground fault is present, this sum is zero. In the case of a single phase ground fault no fault current will develop as long as the converter is blocked, but a significant zero sequence component will appear in the phase-to-ground voltages. This component is detected.

The detection principles are not applicable when the converter is deblocked and thus the protection is disabled.

**Converter transformer restricted earth fault protection**
Protects the converter transformer primary and secondary windings against damage caused by internal ground faults. At the secondary side the winding current is measured by two CT’s for each phase, one on each side of the winding. The protection operates due to a definite time function and the processed differential current is compared to a preset value.
Converter transformer neutral ground overcurrent protection
The neutral currents are measured in the transformer neutrals and the instantaneous values of the three phase measurements are added. The sum is fed into the protection thus making the neutral ground overcurrent protection sensitive to the zero sequence current component. The protection operates due to a definite time function and/or a selective inverse time characteristic.

Converter AC bus & transformer differential protection
All currents flowing into the AC bus and the converter transformer are compared phase by phase. Measurements are made on both the primary and secondary sides of the converter transformer.

The transformer differential protective function is monitoring the tap changer position, detecting both the 2nd harmonics in the inrush currents and the 5th harmonics due to an overexcitation of the transformer, and restrains the operation. The protection is stabilized against a through current, which might flow during an external fault. The stabilization is especially important if the protection looses information about the tap changer position.

The AC bus differential protective function monitors both the AC bus and the AC filter currents. There is also a fast non-restrained function, operating for a high differential current and without respect to harmonics.

Converter AC bus differential and overcurrent protection
Differential part:
All currents flowing into the AC bus are compared phase by phase. The protection operates if the vectorial sum differs from zero. The protection is sensitive for fundamental current only and is stabilized for through currents.

Overcurrent part:
The protection calculates the converter bus rms current and operates by a preset inverse time characteristic and/or by a definite time function.

AC overvoltage protection
The objective is to prevent severe sustained overvoltage conditions, which could cause damage to the equipment connected to the AC bus. The voltage is measured per phase on the converter AC bus. The protection is sensitive for fundamental voltage and/or harmonic voltages. In order to detect an abnormal overvoltage condition the phase to ground rms and/or peak voltage is compared to a preset reference.

Commutation Capacitor (CC) Unbalance protection
The capacitor cans are arranged in a symmetrical bridge, shaped like an “H”. In case a certain number of capacitor elements has been short circuited, the voltage stress on healthy elements may develop unacceptably high currents causing an operation of the fuses. The current is measured per phase in the midpoint of the filter bridge and if fuses have operated, there will flow an unbalance current. The protection orders a trip when the current exceeds a preset level. The protection is continuously compensated for actual load current by monitoring the CC phase current.

In general, the component tolerances always cause a small initial unbalance current. Therefore, to improve the sensitivity of the protection, the initial unbalance current is compensated by adding a fraction of the phase current in the CC branch. This adjustment is done only once, when energizing the CC bank for the very first time.

Commutation Capacitor (CC) Varistor protection
The protection detects CC varistor short circuits. In normal operation the varistor currents are zero except when the varistor is expected to conduct, i.e. during temporary peaks in the capacitor voltages. A thermal model of the varistor is used
to calculate for how long it can conduct a certain amount of current.

**Commutation Capacitor (CC)**

**Varistor protection, Backup**

Instead of the varistor currents the protective function uses the AC conductor currents IVY and IVD and the corresponding voltages UVY and UVD, the DC line voltage and the voltage in the neutral midpoint of the two six pulse bridges.

The detection is based on a capacitor voltage derivative measurement which is available since the voltage differs between the AC and DC side during certain time intervals of the commutation. The AC conductor currents are used to trigger the measuring.

At normal operation the derivative is expected to be at a certain level. If the varistor and thereby also the capacitor is short circuited the derivative will be zero. If the derivative is below a preset level during a certain amount of time the converter is tripped.

**AC filter and Shunt bank protections**

![Diagram showing AC filter and Shunt bank protections.](image)

**Figure 6**

**AC filter / Shunt capacitor unbalance protection (Classic H bridge)**

The capacitor cans are arranged in a symmetrical bridge, shaped like an “H”. In case a certain number of capacitor elements has been short circuited, the voltage stress on healthy elements may develop unacceptably high causing an operation of the fuses. The current is measured per phase in the midpoint of the filter bridge and if fuses have operated, there will flow an unbalance current. The protection orders a trip when the current exceeds a preset level.

**AC filter / Shunt capacitor unbalance protection, backup**

The protection calculates the capacitance of the high voltage capacitor bank by measuring the filter current and the AC bus voltage. The signals are filtered and tuned for the fundamental frequency.
**Shunt reactor / capacitor overcurrent protection**

Protects the Shunt reactor/capacitor against overcurrents caused by internal faults. The reactor current measurement is made on the high and the capacitor current on the low potential. The protection is sensitive only for the fundamental frequency and it operates due to a definite time function.

**Shunt reactor differential protection**

Protects the reactor against damages caused by ground faults. The reactor current is measured by two CT’s for each phase, one at high potential and one at low potential.

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**Figure 7**

**AC filter capacitor unbalance protection (Contune)**

Each capacitor can in the capacitor bank is built up of a number of capacitor elements. The elements are connected in series and parallel. If one or a certain number of capacitor elements has been short circuited, the voltage stress on healthy elements may develop unacceptably high. The same phase currents between two filters are compared in the bottom of the filters. In order to reduce the influence of differences in harmonics between filters the protection is sensitive only for the fundamental frequency.

**AC filter resistor and reactor thermal overload protection**

Protects the filter reactors and resistors against thermal damages. When applicable, the current is measured either through the component, or at the bottom of the filter. In the latter case the current through the reactor and the resistor is calculated by modeling the current sharing.

The protection calculates an equivalent temperature by first calculating the dissipated
power for each component and then integrating
the power with respect to the thermal time
constant of the component. Thus the thermal
stress on each component is determined.

**AC filter reactor overtemperature
protection, backup**

Protects the reactor against overheating as a
consequence of regulator faults (Contune) or an
internal fault. Each reactor is equipped with
temperature measurement for both the winding
and the core. There are two trip levels for each
measurement.

**AC filter detuning supervision**

Detects short circuits in the parallel circuit
components of the AC filter. The zero sequence
current is detected in the bottom of the filter. It is
sensitive for harmonic zero sequence current and
detects single phase changes of the filter
impedance.

**AC filter / Shunt capacitor / Shunt
reactor ground fault protection**

The AC filter/Shunt bank is protected against
damages caused by internal short circuits. The
protection will also detect open phases e.g. as a
consequence of non successful phase opening or
closing of the breakers.

The zero sequence current is detected in the low
potential of the filter/shunt bank. In order to
reduce the influence of sustained AC net
disturbances, the protection is sensitive only for
the fundamental frequency.

**Breaker failure protection**

The protection action will isolate the faulty circuit
breaker from the AC system and trip the next
breaker in line.

The three phase currents and the residual current
are fed to the protection via different input
amplifiers. The measured phase currents and the
residual current are compared with a preset
level. The protection detects a fault based on a
two out of four decoding logic. Start of the
5. APPARATUS PROTECTIVE RELAYS

The following guards are used to protect the Converter transformer, Shunt reactor and an oil cooled Smoothing reactor, when applicable.

**Oil temperature indicator**

The oil temperature at the top of the converter transformer is measured and an overheating, as a consequence of a sustained operation during overload conditions or malfunction in the cooling equipment, is detected.

**Reactor pressure and oil flow relays**

The tap changer tank is protected against overpressure by two relays. A rapid oil flow in the pipe between the tap changer compartment and the conservator tank is detected by a **Flow relay**. In case of an overpressure in the conservator tank the **Pressure relay**, located on the tap changer compartment housing, will be activated.

**Low oil level detector**

A low oil level in the converter transformer and tap changer conservator tank is detected by a float.

**Oil leakage detector**

Capacitance changes of a dielectric sensor, in the rubber bag of the conservator tank, is a criterion of an oil leakage inside the bag.

**Gas detector**

The relay detects the gas produced by winding short circuits and operates if a certain volume has been collected. The relay also operates when it detects a shock wave in the oil due to an internal flashover.

**Winding temperature indicator**

Temperature and current indications are obtained from the hot spot temperature meters of the transformer windings and from a current transformer, located around the connection lead or the bushing of the winding.

**Cooling system failure protection**

The cooling fan motors are provided with a thermal motor protection. If the motor is overloaded the protection will trip the voltage supply to the motor. The cooling system failure protection detects an overheating of the transformer caused by a tripped motor.
6. FAULT CLEARING ACTIONS

Transfer to redundant control & protection system

The pole control and protection system is divided to two Redundant systems; Active and Standby, each accommodated in a cubicle of its own.

Before every execution of a trip order, an attempt to keep the system in service is made by transferring the control from the active system to the redundant standby control and protection system, as shown in Figure 8 below. If a control or protection failure was the reason for the protection action, the trip condition will disappear since the whole control is changed to a healthy system. Thus the probability for unwarranted protective actions due to for example measurement failures is essentially reduced.

In case the trip condition remains after the system change the trip order is executed by the activated system. Thus a two out of four selection logic is obtained. To separate between change over and a block/trip orders both a time and a level separation is used.

A minor fault in the Active system will result in a soft switch over, if the Standby system is OK and without minor faults. The previously Active system will be left in Standby mode.

A severe fault will reset also the Standby system. In the Active system it will also result in a system switch over if the other system is Standby.

Emergency faults will first order a reset of the Standby system or a system switch over. If the other system is unable to take over the control or has the same kind of failure, the following measures shall be taken:

- Block of the converter or if the fault is in the firing circuitry, initiate emergency BPP in two pretermined valves in the inverter.
- Trip of the AC breaker.

After a protective switch over and a trip an Automatic System Activation (ASA) system will set the inactivated system in Standby.

![Figure 8](image-url)

Control actions

Retarding of the converter

This is normally performed in the rectifier, which normally operates with firing angles around 15 electrical degrees. Retarding means that the successive control pulse is delayed in respect to the previous one. This increases the firing angle until a full inverter operation is obtained and thus a limitation of the firing angles has been achieved. The retarding will reverse the polarity of the rectifier converter voltage and thereby extinguish the direct current. To make the extinguishing of the current more efficient, the inverter will decrease the firing angle gamma.

Blocking of the converters

Blocking means removing the control pulses from the thyristors. When this is done, the valves will stop conducting when the current reaches zero. Blocking at high DC currents still running in the main circuit requires a safe bypassing current path across the converter. The bypass is provided by simultaneously fired bypass pairs, meaning two opposite valves, within the same six
pulse group and connected to the same AC phase. This procedure is normally employed when a permanent ground fault is detected.

![Diagram of Pulse Group Connection](image)

**Figure 9**

The protective blocking actions can be categorized as X, Y, Z or S type blocking. An X-blocking always implies a blocking without simultaneous firing of bypass pairs. A Z-blocking always implies a blocking with simultaneous firing of bypass pairs. A Y-blocking is conditional and implies blocking without bypass pairs in the rectifier and with bypass pairs in the inverter. Unlike X, Y and Z blocking the S blocking only implies a power decrease (ramp) followed by an initiation of the stop sequence. All converter blocking orders are redundant and have redundant signal paths to the converter blocking sequences.

**Converter actions**

- **Pole Isolate**: The isolate pole sequence implies disconnecting the DC bus from the DC line and disconnecting the converter neutral from the electrode line. This is made either manually during normal shut downs or by protective actions.

- **Runback**: To keep the transmission in operation a runback is ordered, thus reducing the transmitted power to a preset level. The runback level is defined from the lowest current order.

- **Pole balancing**: The pole currents are balanced at normal operation. However, if the transmission is running in an other operation mode, a high electrode current may occur.

The pole balancing is ordered either manually or by a protection.

- **Close the neutral bus ground switch**: In order to reduce high neutral bus voltages, the neutral bus ground switch close sequence is initiated by the electrode line open circuit protection.

- **Reclose the DC yard transfer breaker**: In case the current commutation fails during a mode shift, a reclose order is initiated by the corresponding transfer breaker protection.

**Disconnection from the AC system**

The AC circuit breakers disconnect the AC side of the converter transformers from the AC power source. By this action the AC system, primarily being a constant voltage source, is prevented from feeding a fault to the valve side of the converter transformer. Also, a removal of the AC voltages from the valves will prevent unnecessary voltage stresses, especially after the valves have been exposed to severe current stresses.

All protective trip orders to the AC circuit breakers will energize both trip coils in the breakers via two separate trip devices. The redundant trip orders will also be fed by two redundant auxiliary power supplies.

**Figure 10**

Simultaneously with a trip order to the AC-breaker an order to **start the breaker failure protection** is executed. If the breaker does not
succeed to open, the breaker failure protection is ordering a trip of the next breaker in line.

A protective trip order to the AC breaker will also set a **lockout relay**. The relay will prevent the breaker being closed until the operator has checked for the cause of the trip. The lockout relay is reset by the operator.

**7. SYSTEM SUPERVISION**

The HVDC control and protection system is primarily designed to minimize the need for a periodic maintenance.

For the protection system this means, that all parts of the protection system are continuously supervised and the need for the manual checks is completely eliminated.

All computing elements incorporate well proven supervisory techniques, such as:

- **Program execution control** (stall alarm or watch dog alarms), which will check that calculations are executed normally. In combination with the predictable cyclic execution and the HiDraw function block program development tool, it will give an excellent supervision of the individual microprocessors that makes up the HVDC Control and Protection system.

- **Memory checks**
  
  Flash PROM memories are checked by a checksum calculation. This makes it possible to check that both the program code and all protection settings remain unchanged.

  Static RAMs are checked at regular intervals by writing and reading special test patterns to each memory cell.

  Dynamic RAM memories are checked by either continuous parity check or by ECC (Error Correction Code) techniques.

These techniques ensure that all computers used for protections will behave correctly and that the settings are intact.

To ensure that the measuring elements are not faulty, all measurements are made with two electronic measuring circuits (aux. CTs or OCTs, input amplifiers, S&H circuits A/D converters etc.). Although, only one of these measurements is used for a particular protection, both measurements should always show reasonably similar values, if no part of the system is faulty. When applicable, an additional comparison is made with the results from other locations measuring the same parameter. The control and protection system is automatically monitoring all measurements and an alarm is generated if an error is detected and an alarm is generated if an error is detected.

Indications from breakers and disconnectors are supervised with the normal double point technique (one closing and one opening contact) but they are also read by two independent switch control units.

All indications and trip signals are transferred by redundant field busses, where both all units on the bus and all segments are continuously monitored with “alive messages”.

To verify that a tripping signal is able to trip the breaker, the corresponding switch control unit will perform an automatic check of the output circuitry and the breaker tripping coil by energizing one side of the trip coil at a time.

When a manual opening of the breaker is performed the protection system alternates between the two trip coils every other time. This means, that as long as a breaker is opened a separate trip test from the protections is not needed and in the rare case where a breaker is never operated, a “trip test” is easily performed by twice opening and closing the breaker from the SCM system.

In conclusion, the supervision of the control and protection system is thus regarded as completely automatic. This means not only a remarkable improvement of the overall reliability of the system but also a total elimination of both the test switches and handles.