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STEESMAT

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Smart **T**ransformer for **E**nhanced **E**fficiency and **S**ustainability in **MA**ritime **T**ransportation

Deliverable 3.1– LVDC Hub Design

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Abstract

Deliverable abstract	
This deliverable outlines the design and functionality of the Low Voltage DC (LVDC) distribution system and the DC Hub developed by The Switch for the STEESMAT project. The DC Hub serves as a critical interface between energy sources (battery and fuel cell) and loads, enabling efficient power conversion and protection within maritime applications. The document summarizes technical specifications, system architecture, and protection strategies, while emphasizing the importance of optimized control for operational efficiency. Key components include DC/DC converters, Active Front End (AFE), Electronic Bus Link (EBL), and integrated protection devices. The report also presents efficiency data for the DC Hub under nominal operating conditions.	

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1 Introduction

In the STEESMAT project the low voltage section has components provided by various vendors including The Switch. These low voltage components connect to the common DC bus, instead of an AC distribution system. This common DC bus forms the DC distribution system with various fast electronic and other protection devices. The DC distribution system along with the power conversion units and protection components form a product to interface sources and loads (AC or DC). This product supplied by The Switch is called as DC Hub.

At the low voltage section, the STEESMAT concept has battery and fuel cell as energy source. The connection between the medium voltage section and the low voltage section is through the Solid-State transformer (SST). All the energy sources, battery and the fuel cell, at the low voltage section feed the power into the medium voltage section via the SST. It is important that the DC Hub is connected to SST with adequate protection. The DC hub provides such protection unit which forms the basis for connecting various components in the low voltage section.

The document outlines basic concepts of the DC distribution system and provides information on the DC hub provided by The Switch. Reference to all the technical documentation is provided. At the end, the overall efficiency of the DC hub is discussed which is vital for operational optimization of the system.

2 STEESMAT Project Concept

The STEESMAT project concept focuses on the development of technologies in the MVDC distribution and a methodology for integration between components in MVDC and LVDC distribution with optimal performance in terms of operational efficiency, weight and overall footprint. The Switch (TSW) focuses on providing a robust DC hub to form a LVDC distribution system and investigate into methods to mitigate effects of Electromagnetic Interference (EMI) and electronic circuit breakers for protection. The STEESMAT project concept is shown in Figure 1 and the DC hub from TSW is the component 2.1. It is important to highlight here that the component 1.3 is part of the DC hub and it is located with the component 2.1. The component 1.3 is depicted outside the DC hub as part of the SST for clarity.

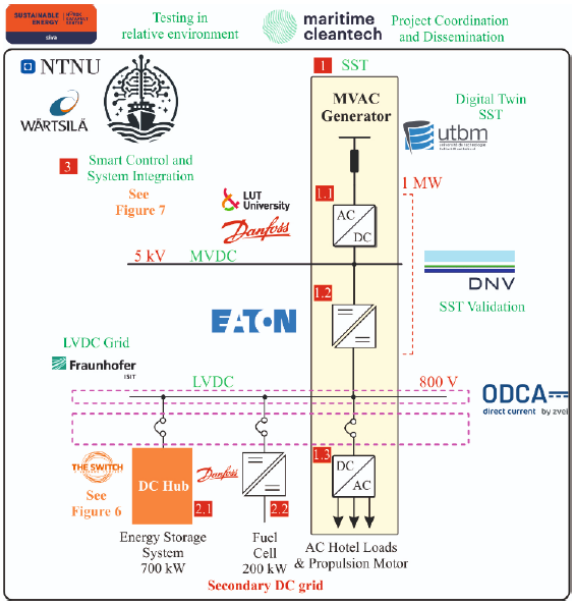


Figure 1 STEESMAT Project concept [1].

3 Low Voltage DC (LVDC) distribution system

3.1 General concepts

The LVDC distribution system allows connection of equipment to a common DC bus either directly or through the power conversion units. Typically, the power is delivered to the electrical loads in a direct controlled manner using the power conversion units with one exception i.e., when a battery system is directly connected to the DC bus. In this case the power through the battery system is indirectly controlled. The entire LVDC distribution system can be viewed as a multiport system, wherein the power flows through the LVDC switchboard. The power conversion unit in the LVDC distribution are

a. AC/DC converter
b. DC/DC converter
c. DC/AC converter

The power flow between the AC sources and the DC bus is controlled with the use of one or more AC/DC converters, often referred as active front-end (AFE) converters. The DC/DC converters are used by the DC source or loads. The power flow between the DC bus and the AC load is controlled with one or more DC/AC converters, often referred as inverters. The source and the load usually require galvanic isolation, with few exceptions.

General merits of LVDC distribution are:

1. Reduction in two-stage conversion process as compared to the AC distribution system. This reduction in the conversion stages results in centralized converters and increases the overall efficiency. In some cases, the total footprint of the system also reduces.
2. Other advantage of reduced converter stages are lower EMI and decreased harmonics.

The ideal LVDC distribution system should be able to:

1. Absorb or provide desired voltages and currents at the input and output interface.
2. Allow bi-directional power flow, wherever necessary.
3. Maintain a desired DC voltage at the DC bus.
4. No losses in the LVDC distribution.

In real system, there are deviation from the ideal scenario outlined above. The design and control of the power conversion units and the DC switchboard will be such that the system comes close to the ideal behaviour.

The power quality issues from the sources and the load variations are typically handled effectively by the control of the power conversion units, so that the DC bus voltage remains at the desired value with negligible ripple. However, in a poorly designed DC switch board, oscillations may occur during a sudden load variation which needs to be effectively suppressed. The optimal design of the busbar and the choice of connectors and subcomponents in the DC switchboard is crucial to minimize the parasitic oscillations and reduce the DC losses. Also, the power conversion units can be optimally controlled at different operating points based on the power demand and efficiency of the system to achieve an overall increase in the efficiency.
In case of AC power distribution, the choice of voltage level, regulation of voltage, protection and safety are well established. In case of the DC distribution, the best practises followed by each vendor can be different. The system typically is approved case by case basis with customers consent and classification society, especially for Maritime applications.
An infinite current cannot pass through the DC switchboard. This limitation predominantly comes from the thermal limits. The maximum operating DC current in the DC switchboard due to thermal limits dictates the power that the DC switchboard can handle. This intern limits the number of sources that can be connected to the DC switchboard. The power limitation is a challenge when all the source and loads are centralized. This challenge can be overcome by distributing the sources and loads into several sections to form multiple DC systems with local production and consumption. These DC systems are interconnected to increase reliability and availability as illustrated in Figure 2.

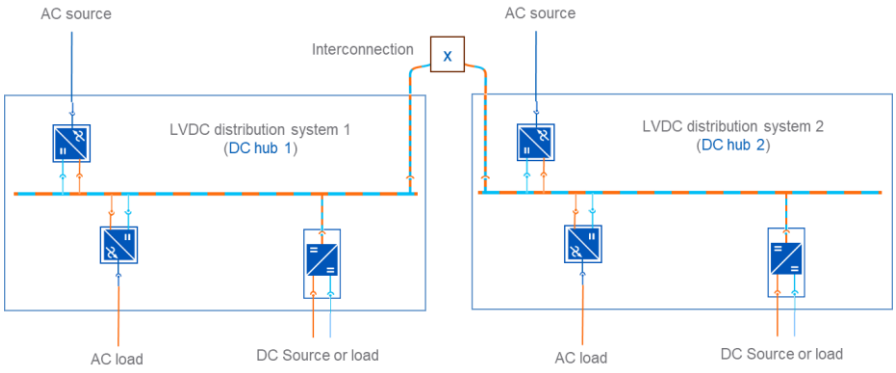


Figure 2 A simple illustration of DC distribution systems with AC source/load, DC source/load and an interconnection between the DC distribution systems.

3.2 Description of the LVDC system from The Switch

The DC hub from TSW is shown in the Figure 3. The DC hub has following components:

1. DC bus
2. Electronic Bus Link (EBL)
3. DC/DC Chopper (DC/DC Converter)
4. Active Front End (AC/DC Converter
5. EBL ready cabinet

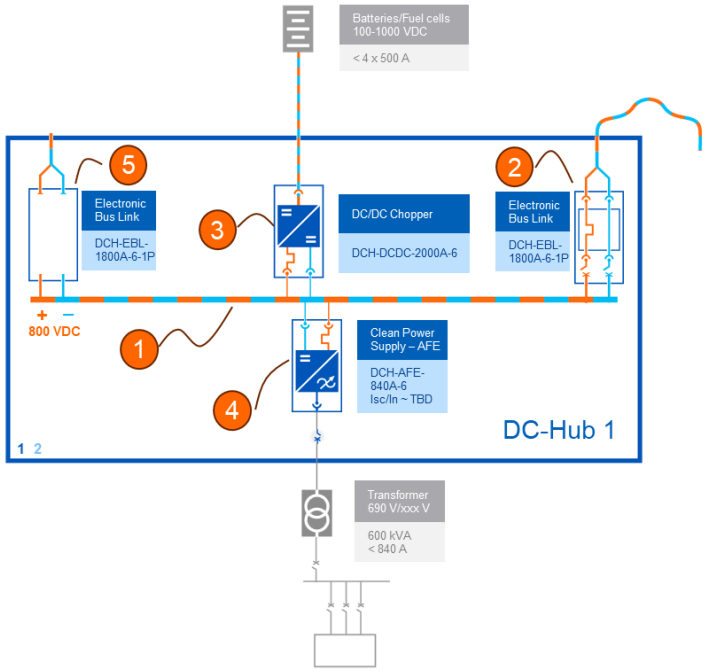


Figure 3 The DC hub from TSW

The DC bus is designed for interconnection of many power conversion units. In this system, the power source such as battery is connected to the DC hub using a DC/DC chopper, the hotel load are connected to the DC hub using a AFE and the DC bus is interconnected to other LVDC bus using an EBL fast protecting device.

3.3 DC/DC chopper

A DC-to-DC converter (DC/DC) converts one DC voltage level to another DC voltage level. The Switch DC/DC converter can connect a DC source (e.g., battery or fuel cell) to the DC link enabling bi-directional power flow. It can operate in either load mode or source mode.
In load mode, there are two control modes that can be used. Power and current control. When power control mode is selected, a power reference set-point is used to control the power flow to or from the DC link. When the current control mode is selected, a current set-point is used to control the power flow to or from the DC link. This can be constant power or dynamic power for peak-shaving applications. This power reference, together with the instantaneous battery voltage, determines the battery charging/discharging current.
In source mode, the DC/DC is responsible for controlling the DC link either solely or together with other units using droop. The battery charging/discharging current is then dependent on the various units connected to the same DC link.
Limiter and protection functions are implemented in the DC/DC control to protect the power electronic converter itself and the battery from overcurrent, overvoltage or undervoltage during operation.

Each DC/DC application in a DC-Hub comes with a breaker between the power module and the DC link. The purpose of the breaker is to isolate the module completely from any voltage by disconnecting both the – and + pole between the DC link and power module [2].

3.4 Active Front End

An active front end converter (AFE) connects the DC link to an AC grid for bi-directional power flow. It means that when the power flows from the grid to the DC link, then the AFE behaves as a controlled rectifier. And when the power flows from DC link to the Grid, then AFE behaves as synchronized inverter.
The AFE can either be connected to shore or an on-board switchboard. The voltage and frequency are configurable.
The Switch AFE can be operated in two different modes, termed as load mode and source mode.
In load mode (AC frequency droop control), the AFE controls the amplitude & phase of voltage and current of the converter for a fixed grid frequency (50/60 Hz), It can synchronize to an existing grid or perform black-start and operate in island (off grid) mode. The power flow between AC grid and DC link can be controlled using frequency increase/decrease pulses.
In source mode (DC link voltage control), the AFE is responsible for controlling the DC link either solely or together with other units using droop. Reactive power control using a set-point is also possible while in this mode.
The AFEs are controlled remotely either the upper-level system by Modbus UDP-IP or application PLC – or locally by HMI display. Various limiter and protection functions are implemented in the AFE to ensure safe operation [2].

3.5 Electronic Bus Link

The main target of the EBL is for connecting one DC-Hub together with another one and maintaining the selectivity even with a major fault in one DC-Hub – and not pulling down the other, healthy DC-Hub.
The EBL reacts as a fuse but responds electronically within microseconds. While a fast thermal fuse or an electromechanical breaker act within milliseconds.
With microseconds response the DC-link in the healthy DC-Hub typically drops less than 50 V (from around 1000 Vdc) with a full short circuit in the shorted DC-Hub, or in the cables interconnecting them. The EBL is a two-pole protective device, which means that it can interrupt the current bi-directionally [2].

- Electronic bus link (EBL) offers ultra-fast protection between DC-Hubs.

- EBL allows a ring network.
- EBL allows DP3 operation as an option.
- Improve redundancy while enabling fuel savings.
- Several units can be connected to a system.
- Connects The Switch DC-Hubs together.
- Critical faults are detected and disconnected in approximately 10 microseconds.
- DP3 tested and approved by DNV.

4 DC distribution protection

4.1 General concept

The non-availability of the LVDC distribution system can be due to internal or external faults. Unplanned downtime of the LVDC distribution system cannot be tolerated in applications such as Maritime. Therefore, a protection strategy that either mitigates or eliminates the effects of the internal and external faults is needed. Two main distinctions in this protection strategy are:

1. Isolating the equipment from the fault.
2. Clearing the fault.

There are no clear standards or guidelines for the protection strategy in LVDC distribution. The protection strategy adopted is usually vendor specific. But some best practices are often followed. Such as use of fuse, DC breaker (wherever applicable) and disconnectors.

One important aspect before the protective equipment can be selected is the type of grounding concept the system uses. Most of the analysis and discussion is limited to the IT grounding system. The other grounding concept such as TT and TN systems will not be considered.
In case of the IT grounding system, it is required to have an insulation monitoring device (IMD) followed by a fault clearing device. In a 3-phase, 3-wire scheme it is not recommended to distribute the neutral conductor. When it is necessary to provide the neutral, typically the neutral point of the star connected secondary side of the transformer is made available as neutral. It is quite common to choose the cross-section area of the neutral conductor to be either equal or smaller to the phase conductors. In such cases, the neutral conductor is protected against fault.

4.2 Protection concept

The DC-Hub is equipped with an insulation monitoring device which monitors the electrical current flowing through DC link towards ground and issues an alarm if there is a leakage current. An earth fault in the system is caused by a conductor insulation failure (breakage), allowing the live conductor to get in contact with the hull or an earthed metallic electrical cabinet.

5 The Switch DC Hub product

The detailed discussion of the DC hub for STEESMAT is presented in [2]. In this chapter the product will be briefly introduced. The DC hub houses all the components in the system and is arranged in sections. These sections are grouped into:

1. Power sections
2. Control sections
3. Split sections

Power section
The power section contains one or combination of the following units:

- Motor inverter (MI)
- Active front-end rectifier (AFE)
- DC/DC converter (DC/DC)
- Passive rectifier (PR)
- Electronic bus-link (EBL)
- Electronic current limiter (ECL)
- Battery short circuit limiter (BSCL)
- Electronic DC breaker (EDCB)
- DC connection with fuses (DCF)
- Output Disconnector Cabinet (ODC)
- Starpoint Disconnector Cabinet (SDC)

The width is dependent on the number of installed applications like MI, AFE, DC-DC converter, EBL and rectifier. The power sections are designed to house power modules and have a modular design.

Split Section
Wide DC hubs are divided into smaller multiple transportation sections. Split sections are situated between the transport sections. The transport sections are joined together in the split sections at the site.

Control section (CC)
Control sections have varying sizes, depending on their function and location. The control section controls internal functionality including power modules.

5.1 DC-hub arrangement for the STEESMAT concept

The DC-hub arrangement for the STEESMAT concept along with service area and water inlet is shown in Figure 4. The general assembly of the STEESMAT concept is presented in [3]. Each of these sections will be elaborated in detail. The sections included are:

1. AFE
2. DCDC
3. EBL
4. CC
5. Empty power section, for future expansion or interconnection to other DC hubs.

The foundation requirement for the DC hub is discussed in section 7.4 in [2]. These requirements remain same irrespective of the DC hub configurations. One important thing to note is that the sections have vibration dampers for marine applications. Typically, the sections are bolted to the floor through the vibration dampers.

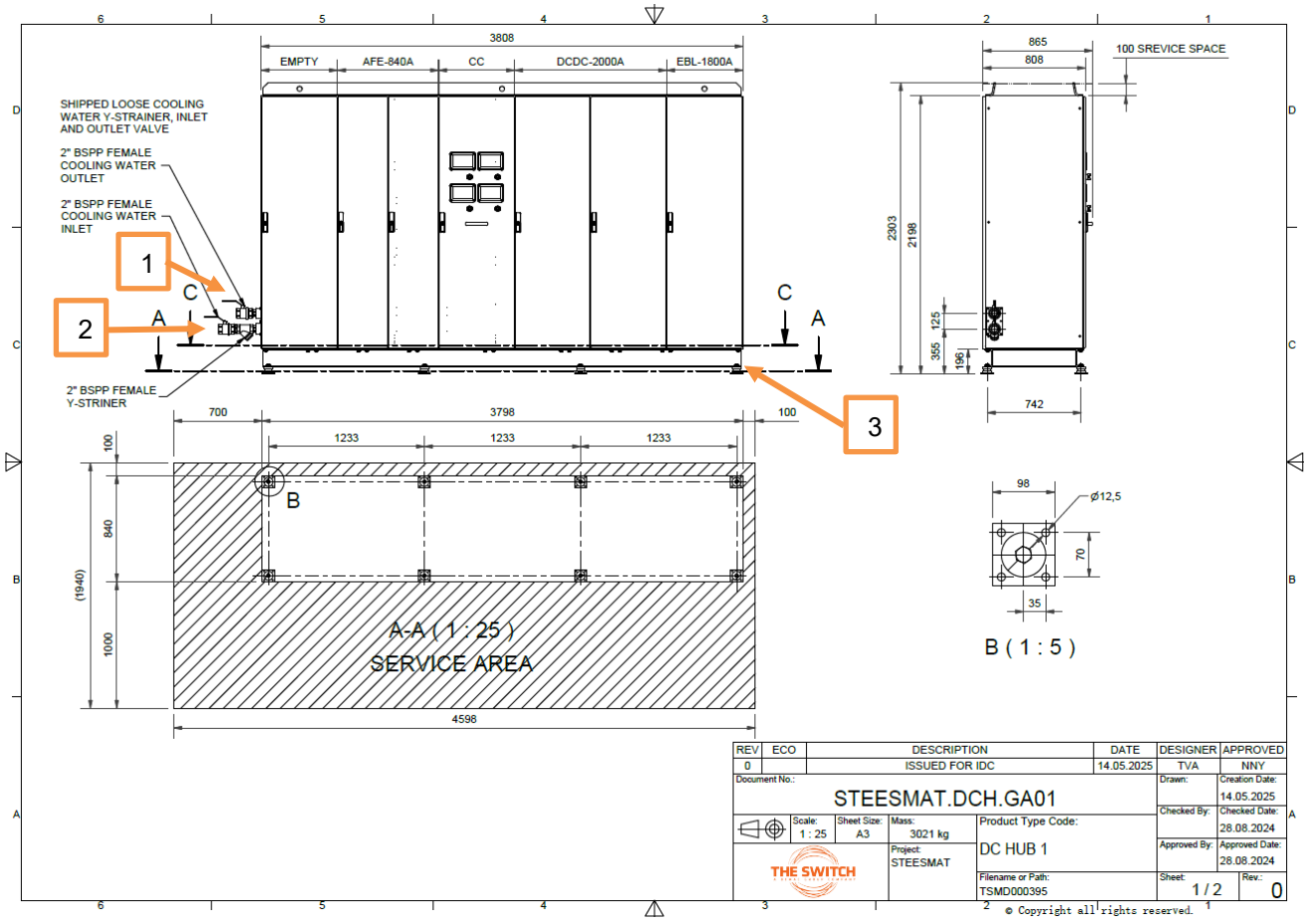


Figure 4 Front- and top view of the complete DC hub unit for STEESMAT with dimensions, the service area is also indicated.

1	Cooling water outlet connection
2	Cooling water inlet connection
3	Vibration dampers

An important feature is the cooling system for the DC hub. The structure remains same for all the units in the power sections. An example of cooling system for the DC hub is shown in Figure 5. The DC-Hub is to be connected to the freshwater cooling system of the ship. The cooling water requirements, the assembly and filtering are discussed in chapter 8 of [2].

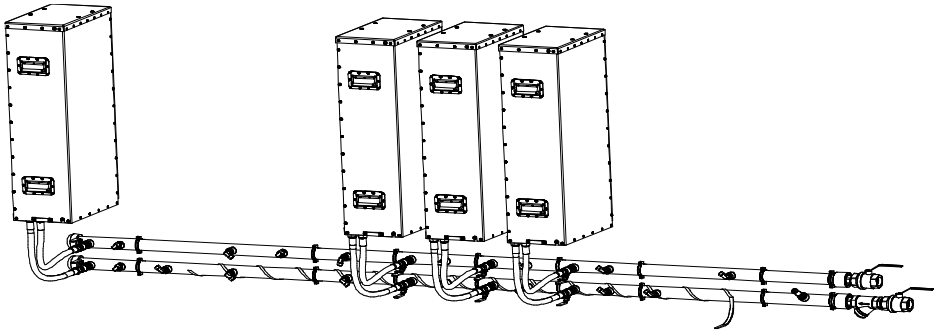


Figure 5 An example of the DC hub cooling system [2]

5.2 Cable and busbar arrangement in the power section

In the power section, the DC bus bar is on top and the connection to the external load or source is through bottom of the cabinet. The DC link of the power conversion unit connects to the DC bus of the power section through a protective device - a fast electronic breaker called, integrated EDCB. It is internal to the power conversion unit.
It is preferred that all the cables, AC and DC, are symmetrical. In an IT system, a four-wire cable with shielding is preferred. The AC phase conductors are symmetrically placed in a delta shape with the PE conductor arranged symmetrically around the periphery of the phase conductors. For the DC cables, equal number of plus and minus conductor is preferred. The details of all types of cables allowed for connection with DC hub is discussed in chapter 9 of [2]. An illustration is shown in Figure 6.

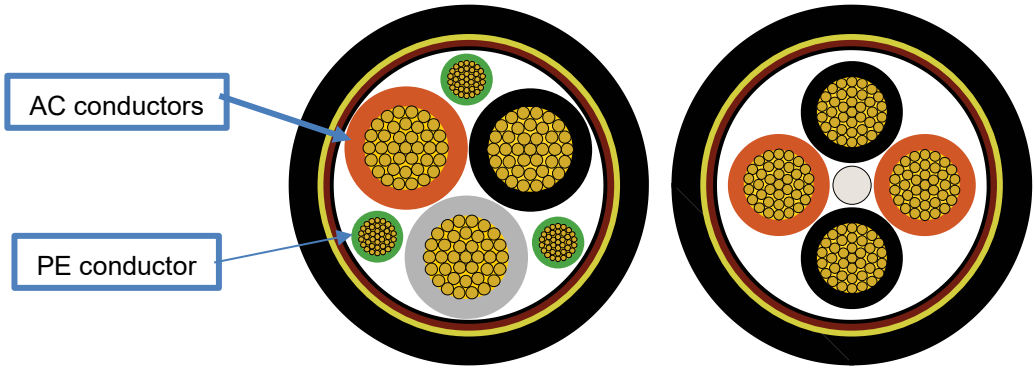


Figure 6 Symmetric cable recommendation for AC and DC side.

5.3 Power Modules

The chapters 10 to 14 in [2] discusses the power module concept and various types, installations, local processes, control, protection and additional functionality. TSW power module is designed with pluggable connections making it easy to disconnect from the system. The cooling system is also flexible to movement up to certain length within the cabinet. The internal arrangement and external interface of power module is shown in Figure 7.

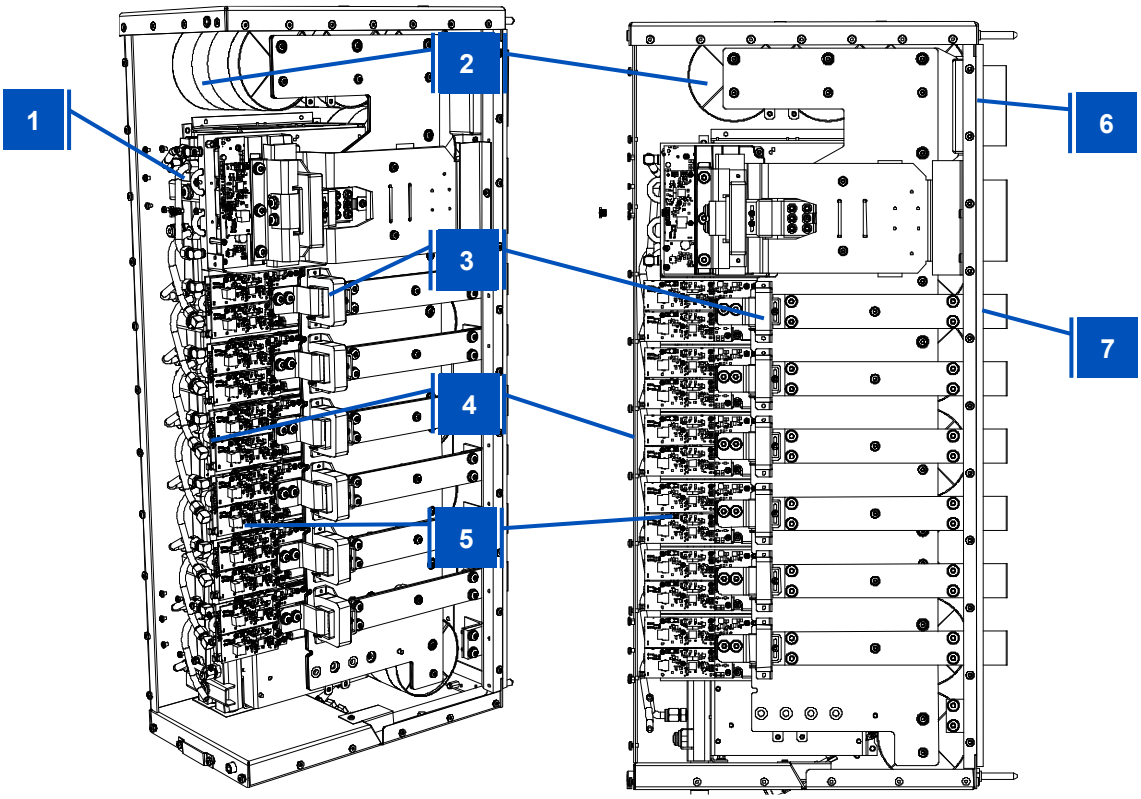


Figure 7 Internal and external connections of a power module.

1	Cooling liquid distribution block
2	Capacitors
3	Current measurement
4	IGBT´s on heatsink
5	Gate Drivers
6	DC-terminals
7	AC-terminals

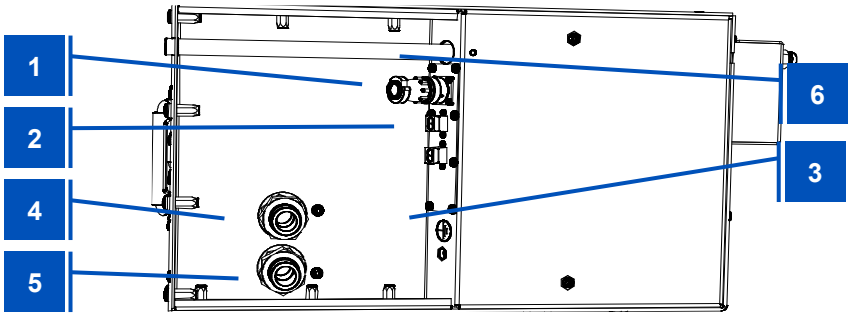


Figure 8 Bottom view of the power module.

1	Power connector 230 VAC
2	Fiber connectors
3	Earthing
4	Cooling water inlet
5	Cooling water outlet
6	Guide spindle for pull-in

The power terminals are split into two groups.

- **Common DC bus.**
  These are the two uppermost terminals with the DC- terminal on the top and the DC+ terminal below that. These terminals are used to exchange power between the power module and the main DC bus. Maximum continuous operating voltage is 1100 V DC, short-time overvoltage up to 1250 V is allowed.
- **Load terminals (AC or DC).**
  These are the output terminals of the IGBTs and are the controlled outputs from the module. Each output will be PWM modulated and may be used for both AC and DC.
- Water connections refer to chapter Internal cooling arrangement of the power module.

The interface towards the control section is at the bottom of the module (refer Figure 8) and has multiple connectors.

- Auxiliary Power Dual 230 V AC
- 1x or 2x optical fibers (POF serial link)

The Switch power modules provide an integrated EDCB (electronic DC breaker). The purpose of the EDCB is to protect the other power module on a common DC link. EDCB disconnects the power module for a duration of 10 µs in case of a critical fault. This ensures very small voltage disturbance in DC link and allows all other applications, connected to the same DC-bus, to run continuously without being affected by a fault. With EBL and EDCB ultrafast protection DC-voltage does not drop (max drop 50 VDC) and keep operations running.

6 Technical Specifications

The detailed technical specification of the DC hub for STEESMAT concept is presented in [4]. The DC hub provided by The Switch is designed to meet all the requirements for the STEESMAT concept. Operational DC bus voltage used in the STEESMAT concept is lower than what is typically used in the industry. Therefore, the standard components in the DC hub are under utilized at nominal load.

Error! Reference source not found. summarizes the building blocks that are made available in the DC hub for STEESMAT concept. Figure 3 shows the DC hub with the application, material name and power ratings.

Label	Customer Label	Application	Material Name
		Transport section 1	
EBL1	-	Electronic Bus Link to another DC-Hub EMPTY?	DCH-EBL-1800A-6-1P
AFE1	-	Active Front End to transformer	DCH-AFE-840A-6
CC1	-	Control cabinet	DCH-CC-600
DCDC1	-	DC/DC chopper to battery/fuel cell	DCH-DCDC-2000A-6
EBL2	-	Electronic Bus Link to another DC-Hub	DCH-EBL-1800A-6-1P

Table 1 Building blocks used in the DC hub for STEESMAT

7 Efficiency

The DC hub for the demonstrator has a DC-DC converter with EDCB and an EBL. The DC-DC converter provided for the STEESMAT project has four IGBT bridge legs all of them connected in parallel. The switching frequency is 3 kHz and the nominal power is 2 MW with 1050 V DC-link. In the STEESMAT project the DC link is set at 800 Vdc and the DC-DC converter output current nominal value is 500 A. Refer [4] discusses all the technical specification of the system.
The overall efficiency of the DC hub is shown in the Figure 9. The curve represents the net efficiency of the DC hub with the power losses in the power converter, auxiliary units and the passive components. The x-axis is the DC-DC converter output current (or battery system current). The efficiency for currents lower than 400 A can be obtained by extrapolation.

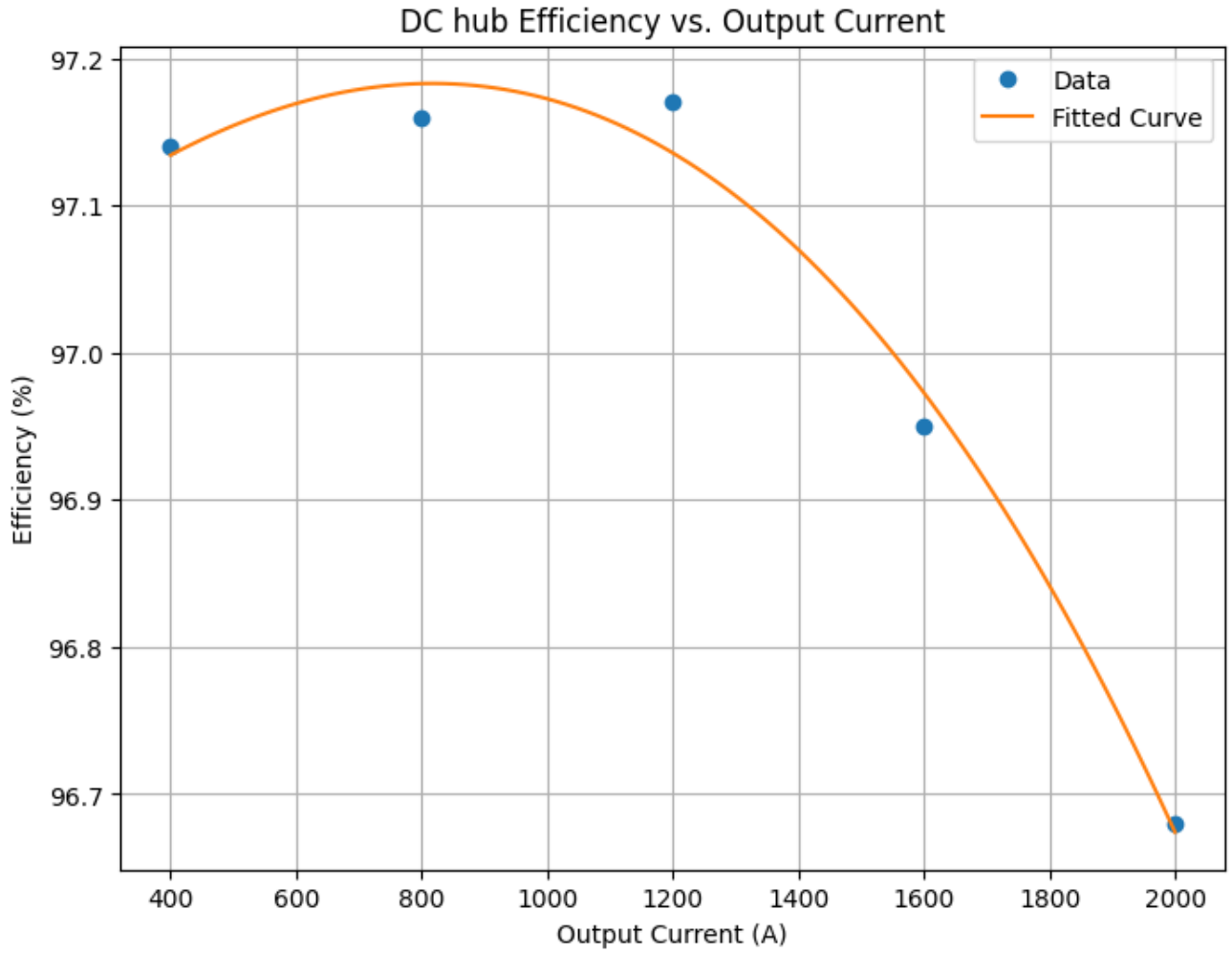


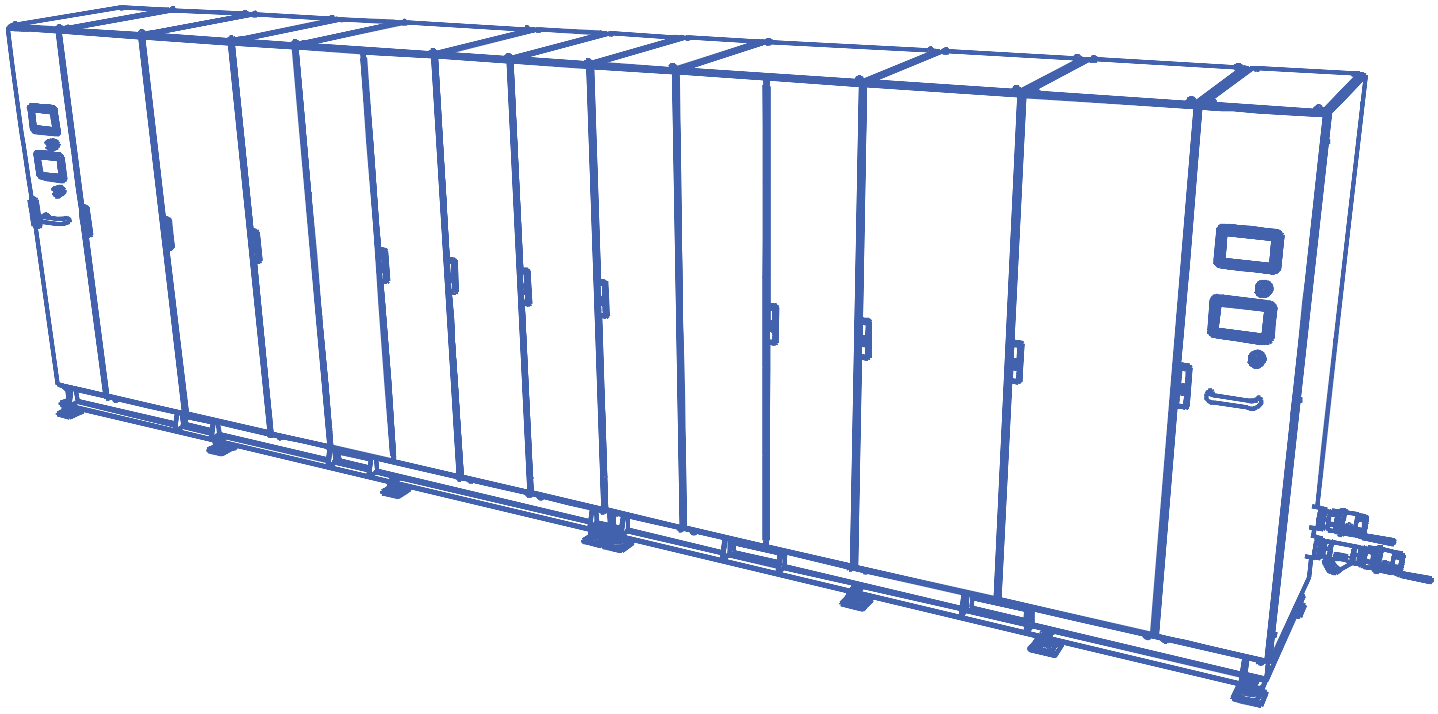
Figure 9 Efficiency curve of the DC hub

Reference

[1] Smart Transformer for Enhanced Efficiency and Sustainability in Maritime Transportation (STEESMAT), proposal number 101192740.
[2] The Switch DC-Hub Product Manual, STEESMAT, File ID: 13127, The Switch
[3] General Assembly Diagram for DC Hub STEESMAT, 905.DCH.2015-2018.GA02, The Switch.
[4] STEESMAT DC Hub Technical Specifications, 905202, The Switch.

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THE SWITCH DC-HUB
PRODUCT MANUAL



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3 Product information

3.1 The Switch DC-Hub serial number

Type plates of power modules are located on inner surface of cabinet door.
Name plate of the DC-Hub is located on the cabinet door.

3.2 Reference documents

Referenced documents for this product manual:

- Technical Specification (Datasheet), TS
- General Arrangement, GA01
- Internal Arrangement, GA02
- Circuit Diagram, XK
- Interface List, LA
- Network Topology, XI
- FAT Procedure, KA01
- Installation Check List, KA02
- Fuse list, FL01
- Handling Instructions, MG
- Material Declaration, MD
- Spare Part List, MF
- Single line diagram, XS

4 Introduction

4.1 About this manual

This product manual is intended for system integrators and the end-users of The Switch DC-Hub units and as well as for the people who integrate, install, commission, maintain and service the system.
The manual contains a functional description of the hardware and software of the DC-Hub units and their interface to external systems. Installation and maintenance procedures are also included. This manual is aimed at ensuring proper installation according to safe procedures for personnel and equipment.
The guidelines are here to ensure that the installation is done according to class specified rules and regulations. Failure to perform the installation correctly can result in loss of class acceptance, loss of safety/health and equipment warranty.
It is required to follow every step in this document to minimize the risk of unexpected challenges to a minimum level.

4.2 Acronyms and terms

Below is a list of the most common acronyms and terms used in The Switch's manuals.

Table 4-1 Common acronyms and terms used in this manual.

Abbreviation	Explanation
AFE	Active Front End
Alarm	An event that alerts the user but does not trip the converter.
BMS	Battery Management System
BSCL	Battery Short Circuit Limiter
CCO	Central Control Board
CEL	Central Electronics
DC/DC	DC/DC converter
EBL	Electronic Bus Link (ultra-fast semiconductor breaker)
ECL	Electronic Current Limiter
EDCB	Electronic DC breaker
EIB	Encoder Interface Board
EMC	Electro Magnetic Compatibility
EMF	Electric and Magnetic Fields
EPAL	Euro-pallet
EQB	Equipotential bonding
ESD	Electrostatic Discharge
FAT	Factory Acceptance Test
Fault	An event that trips the converter.
HFG	High Frequency Ground
HMI	Human Machine Interface
IGBT	Insulated Gate Bipolar Transistor
IM	Induction Machine (squirrel cage AC motor)
Limit	An event that causes power reduction (limitation) in the converter.
Local Display	Local touch display showing the alarms, limits and faults of the converter.
Main Board	The main control board for each DC-Hub unit (AFE, DC-DC, MI etc.)
MCT	Multi Cable Transit
MEL	Module Electronics
MI	Motor Inverter
MSB	Main Switch Board
ODC	Output Disconnector Cabinet
PLC	Programmable Logic Controller

PTH	Power Take Home
PTI	Power Take In
PTO	Power Take Out
PWM	Pulse Width Modulation
SDC	Starpoint Disconnector Cabinet

5 Safety and precaution information

The purpose of these safety instructions is to eliminate or minimize all eventual hazards and to avoid accidents involving personnel injury or severe damage to the equipment. The term ‘equipment’ refers to all devices delivered by The Switch.
These safety instructions do not cover every imaginable hazard situation during operation. Therefore, it is also on each employee’s responsibility to contribute towards safer working methods and environments to reduce the risks of accidents.
Inexpert use may cause serious injury or severe damage to the equipment. Therefore, it is important to follow these safety instructions and local safety regulations, and to train new personnel in safety issues.

5.1 Safety and warning symbols used in this document



Note!
Indicates information that the reader should pay attention to or gives suggestions and useful tips to the reader.



Caution!
Indicates important information or warning. Indicates the presence of a hazard which could result in equipment damage, loss of data or unwanted restarts of the drive.



Warning!
A black symbol inside a yellow triangle with a black triangular band defines a safety label that **indicates a hazard or a danger,** which could result in personal injury. E.g., electrical hazard. Before working on any equipment, be aware of the hazards involved with electrical circuitry and familiarize yourself with standard practices for preventing accidents.



Mandatory signs
A white symbol inside a blue circle defines a safety label that indicates that the action should be taken to avoid a hazard. E.g., general mandatory sign.



Prohibition signs
A black symbol inside a red circular bar with a red diagonal bar defines a safety label that an action should not be taken or should be stopped. E.g., Do not alter the state of the switch.



Warning!
Before working on any equipment, be aware of the hazards involved with electrical circuitry and familiarize yourself with standard practices for preventing accidents. This safety warning helps identify electrical issues that can be hazardous to either the equipment or a user.



This **ESD warning** indicates components which can be destroyed by electrostatic discharge (ESD).

5.2 Definitions used in warning notices

In this document, **skilled personnel** means someone who is familiar with the installation, mounting, start-up and operation and maintenance of the product. He or she must have the following qualifications:

- Trained or authorized to energize, de-energize, ground and tag circuits and equipment in accordance with established safety procedures. E.g., Safety at Electrical Work course and professional qualifications for the job in question.
- Trained or authorized in the proper care and use of protective equipment in accordance with established safety procedures. E.g., Occupational Safety Card course.
- Has completed a first aid course in case of accidents caused by electricity. E.g., Basic First Aid Course, Red Cross.

5.3 Electrical safety



Warning!
Only qualified electricians are allowed to open electrical cabinet.



Warning!
Risk of electrical shock from energy stored in capacitors do not open until 5 min after disconnecting all sources of supply.



Warning!
Ensure that device is separated from all electric power supplies before servicing.



Warning!
Risk of electrical shock – both AC sides voltage sources are terminated inside this equipment. Each circuit must be individually disconnected before servicing.



Warning!
Risk of electrical shock more than one disconnect switch may be required to de-energize equipment.



Warning!
Always measure the voltage of the internal component before touching them or dealing with them. Otherwise, it may cause harm or injury.



Warning!
The main switch does not disconnect the control voltage.



Caution!
Insulation alarm detected in converter, possible earth fault present in circuitry. The cause of the alarm must be clarified. Double earth fault can be hazardous. It is the user's responsibility to continue using the product.

5.4 General notes, cautions, warnings, mandatory and prohibitions



Warning!
Use of wrong spare parts can cause an explosion or fire.



Use personal protective equipment and protective clothing as requested. Use protective gloves, safety footwear, protective clothing, safety helmet, safety goggles and hearing protection. If the work phase requires special protective equipment, this is indicated a needed mandatory sign at this manual.



Hearing protection is mandatory during operation.
During normal operation, the sound pressure level may exceed 70 dB.
When the circuit breaker is operated, the sound level may temporarily rise above 90 dB.



Warning!
To avoid static discharge damage to the components, use ESD protection when working inside the cabinet.

5.5 Lifting safety

Make sure that the lifting equipment (gantry crane, longitudinal rail, and tackle) is in good condition and has enough capacity to lift the DC-Hub. Refer to the Handling Instruction.



Warning!
Crushing hazard. Beware of hanging loads newer go underneath it.



Use only approved chains and slings. They must be in good condition. Use marked lifting points.



Caution!
Do not operate any equipment while they are suspended.



Centre of Gravity – symbol, used in GA drawings.



Centre of gravity packing label to indicate the center of gravity of the transport package which will be handled as a single unit.

Make sure that you lift the component using the center of gravity of the component. You can use special devices to lift with correct balance and operate safely.



Sling here, used in packing label.



There is forklift pocket packing label to indicate the location or area of the pocket where a forklift can insert forks to safely lift the equipment.



Caution!
Beware of tilting when lifting the cabinet.
The center of gravity may not be in line with the lifting point. When the cabinet is raised into the air it will tilt until the center of gravity is underneath the crane hook.



Warning!
Crushing hazard. Beware of swinging cabinet when lifting it. Stay away from the lifting area.



Packing labels – this side up, handle with care, keep dry, fragile

5.6 Fire and explosion protection

All fuels, lubricants and many chemicals are flammable. Always read and refer to the instructions on the product packaging. Fuel leakage and spillage on hot surfaces or electrical components can cause fires.



Warning!
Beware of flammable chemicals.

Scheduled maintenance is important for fire protection. You must do regular inspections of fuel and lubricating oil lines and connections. Make sure that the screws and clamps are correctly tightened and replace the seals if there are leaks. After the maintenance, install all the protective covers before starting the DC-Hub.

5.7 Hot surfaces

During operation, the power module and enclosure walls can get hot. To avoid injuries from hot surfaces, all insulation shields, covers etc. should be monitored for damage or wear.



Warning!
Beware of hot surfaces.

5.8 Spare parts



Warning!
Use of wrong spare parts can cause an explosion or fire.

5.9 Electrostatic discharge (ESD) protection



The power modules are highly sensitive to electrostatic discharge (ESD) when removed from the original packaging. Always keep the power module in original packaging unless it is going to be installed in the DC-Hub. If opening is required (e.g., customs clearance), take caution when the transport box is opened. The warranty is void if the ingress protection is broken, or the electrostatic foil has been damaged.



Symbol for an ESD protection equipment – ESD Protected Area (EPA).

Always ensure that all personnel working on the power module and its components are at the same electrical potential; this can be achieved by using an ESD wrist strap grounding and appropriate work clothing and footwear.

5.10 Touch current



Caution!
Touch current in the protective earthing conductor exceeds 3,5 mA AC or 10 mA DC.



Caution!
In the event of a failure of the PE conductor, touch current on conductive accessible parts of the DC-Hub may exceed 3.5 mA AC or 10 mA DC.

5.11 Electrical safety – potential arc flash hazards



Warning!
Due to the risk of electrical arcs caused by potential short circuits in power sections, the doors of both power and control sections must remain closed during operation.



Live working is not allowed in the power or control sections. Do not open the door of the section when DC-Hub is energized.

5.12 Hazardous EMFs



Warning!
Opening the doors or back panels of power sections while energized may expose personnel to hazardous Electric and Magnetic Fields (EMFs).



Do not open any section door while the DC-Hub is energized.



No access to the immediate vicinity of the DC-Hub for individuals with medical implants if a section door is open.
There is a risk of electromagnetic interference that may affect the functionality of medical devices.

5.13 Electrical safety in installation, start-up and maintenance for ECL and BSCL

5.13.1 Electrical safety precautions

These electrical safety precautions are for all personnel who do installation, start-up and maintenance on the DC-Hub, ECL, and BSCL.
It must be noted that ECL and BSCL modules do not provide galvanic isolation.
Before any maintenance or service measures inside the DC-Hub or BSCL standalone cabinet. Stop and disconnect the main sources of the voltages of the DC-Hub and follow normal earthing procedure. Disconnect or pull out the battery system and ensure that the battery is isolated from the BSCL. Wait at least 5 minutes after stopping the DC-Hub before working on the power module to ensure it has been fully discharged.



Warning!
Risk of electric shock with exposed live terminals.



Live working is not allowed in the power sections. Do not open the door of the power section when DC-Hub is energized.



Obey these instructions. If you ignore them, you may be exposed to electric shock.



Make sure the breakers and pre-charge fuses are opened and secured with a personal padlock. Always measure voltage with a CAT III 1000V multimeter before touching electrical parts

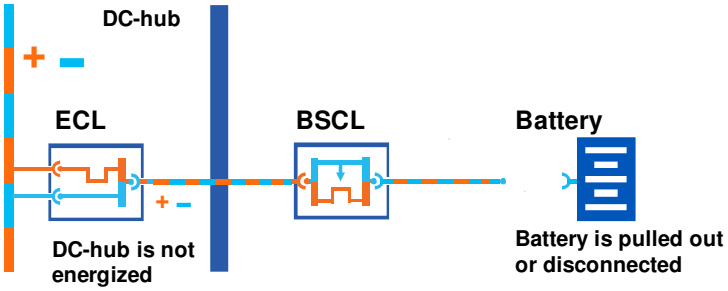


Figure 5-1 Mandatory safety measure before service measures.

5.13.2 Risk scenarios

The personnel must be aware of live parts in the electrical installation even if the two modules are open (in OFF state). The leakage current in these modules is in the range of 5 mA. A few cases are described below. **All these risk scenarios can be avoided by obeying instructions 5.13.1 Electrical safety precautions!**

5.13.2.1 ECL connected to an energized DC-Hub with BSCL-battery disconnected

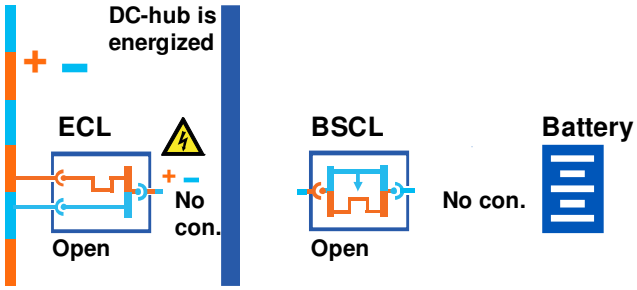


Figure 5-2

When the ECL module is connected to an energized DC-Hub, then the terminals of the ECL towards the BSCL (i.e. cable connection) will see approximately half of the DC voltage even if the ECL is open (in OFF state). Although the current is limited by the leakage current of the transistors, the personnel should still be careful. This current level can be harmful if a person comes in contact with the energized cables.

5.13.2.2 BSCL and ECL connected to an energized DC-Hub with battery disconnected

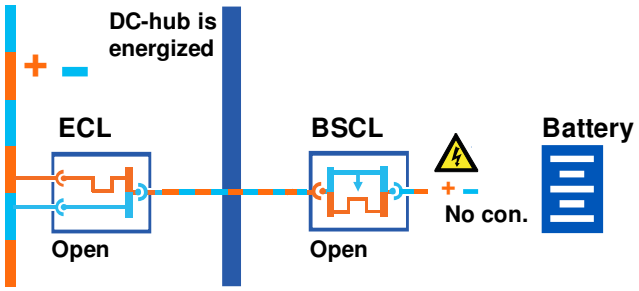


Figure 5-3

In case that the BSCL is also connected to the energized DC-Hub via the ECL module, and assuming that the batteries are disconnected, then there will also be a voltage seen by the BSCL terminals towards the battery even if both the BSCL and the ECL are open (in OFF state). The voltage level is expected to be in the range of 5 – 25 % of the DC link voltage, and the current is limited by the leakage current of the transistors (≈ 5 mA). The cable connection of the ECL with the BSCL will also see a voltage in the same range, limited by the same leakage current. This implies that the personnel must be aware and careful of live parts in the electrical installation.

5.13.2.3 BSCL and ECL connected to battery but disconnected from DC-Hub

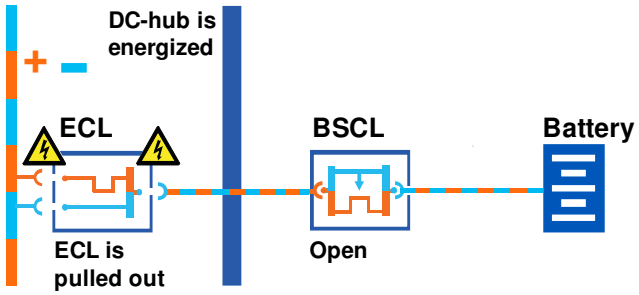


Figure 5-4 ECL is pulled out to the disconnected position.

Special attention should be paid by the personnel when the ECL module is connected to the BSCL and at the same time its terminals of the DC-Hub are open. The reason is that the ECL module is not isolated even when the ECL is OFF. In that case, approximately half of the battery voltage (assuming that the BSCL is connected to the battery) can be seen at the DC-Hub terminals of the ECL, limited by the leakage current of the transistors (≈ 5 mA).

5.13.2.4 BSCL and ECL connected to an energized DC-Hub with battery connected

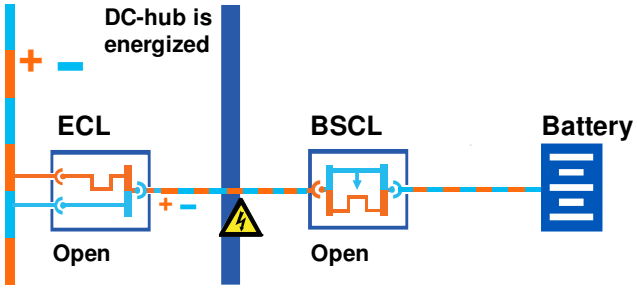


Figure 5-5

In case the DC-Hub is energized and the ECL-BSCL pair is also connected to battery, then the cable connection in the ECL-BSCL will also be energized, even if the two modules are in OFF state. The voltage seen in this connection is in the same range as the DC-Hub and battery voltages, and the current is limited by the leakage current of the transistors (≈ 5 mA).

5.14 Cabinet protection during commissioning and maintenance

The product shall always be protected against any environmental hazards and contamination from ongoing activities at location. Use a fireproof cover to protect the equipment if welding or other hot work is carried out nearby. When sandblasting, spray painting, grinding, or performing other work that can lead to dust, particle, or chemical contamination, completely cover all surfaces and openings (remember cable inlets!) of the equipment before starting. Do not perform any work inside the cabinets while there is a risk of exposure to such hazards. The doors and covers must be kept closed and always locked when work is not performed inside the cabinets.

Caution!
Dust particles reduce the creepage distance, resulting in a lower high voltage withstand level.
Dust particles can lead to short circuits and other electrical issues.

Make sure that debris from drilling, cutting and grinding does not enter the cabinet.

Note!
Failure to comply with the above demands will void all warranties.

6 The Switch DC-Hub overview

The Switch DC-Hub cabinet is arranged in a system consisting of sections. The sections are grouped as:

- Power sections
- Control sections
- Split sections (optional)

6.1 DC-Hub general technical specification

Refer to the technical specification and GA drawings of the DC-Hub for more detailed information.

6.2 Reference standards

Table 6-1

IEC 61800-3	Adjustable speed electrical power drive systems – Part 3: EMC product standard including specific test methods
IEC 61800-5-1	Adjustable speed electrical power drive systems - Part 5-1: Safety requirements - Electrical, thermal and energy
IEC 60146-1-1	Semiconductor Converters – General requirement and line commutated converter – Part 1-1: Specification of basic requirements
IEC 61439-1, -2	Low-voltage switchgear and control gear assemblies – Part 1: General rules, Part 2: Power switchgear and control gear assemblies
IEC 62040-1	Uninterruptible power systems – Part 1: safety requirements
IEC60721-3-6:1987	Classification of environmental conditions. Part 3: Classification of groups of environmental parameters and their severities. Ship environment
IEC 60721-3-1:1997	Classification of environmental conditions - Part 3 Classification of groups of environmental parameters and their severities - Section 1: Storage
IEC 60721-3-2:1997	Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities - Section 2: Transportation
IEC 60529	Degrees of protection provided by enclosures (IP Code)
IEC 60950	Safety standard for information technology equipment (ITE)

6.3 Power Section

The power sections contain one or a combination of the applications as described:

- **Motor inverter (MI**)
  A Motor Inverter connected to the DC link, can be used as both motor and generator application PTI/PTO. It can control/drive a permanent magnet motor, an induction motor, or a synchronous motor. This can be used for ship's propulsion, pumps, compressors, winches etc.
  Power take in (PTI) mode provides propulsion power that either functions in boost mode to provide the main engine with temporary extra power or alone in power take home mode if the main engine is out of operation. The main idea is to provide an alternative or additional source of mechanical power for the propulsion, thereby increasing redundancy.
  Power take home (PTH) is an operational mode that the main engine is switched off and the PM shaft generator works as a motor, and it is fed by an energy storage or source.
  Power take out (PTO) is an operational mode that the main engine is switched on and the PM shaft generator works as a generator.
- **Active front-end rectifier (AFE)**
  A power electronic unit converting AC to DC and vice versa. **AFE** is typically connected to a 690 V AC main switchboard (MSB) via a switchboard breaker. It synchronizes to the MSB when started towards a live switchboard. The AFE provides blackout start capabilities. The AFE is like a virtual generator with voltage and frequency droop for operation of connected with grid (other generators) or can work as standalone/island power source, and the classical generator inertia and damping effect are implemented in the control system.
- **DC/DC converter (DC/DC)**
  A power electronic unit converting one DC voltage level to another level.
- **Passive rectifier (PR)** or diode Rectifier (DR)
  A diode rectifier connected to the grid, converting AC power to DC. It cannot be used to control the DC link voltage, and it cannot transfer energy from the DC link to the grid.
- **Electronic bus-link (EBL)**
  The main target of the EBL is for connecting one DC-Hub together with another one. EBL is an independent unit in protection. Externally can only give on/off command. It reacts like a fuse but responds electronically within microseconds.
- **Electronic current limiter (ECL)**
  Ultra-fast semi-conductor switch only in the positive pole.
- **Battery short circuit limiter (BSCL)**
  - Enables large batteries to be connected to existing electrical system.
  - Limits battery short-circuits current.
  - Same technology as EDCB and EBL.
  - Standalone cabinet.
- **Electronic DC breaker (EDCB)**
  Each PD3.1 drive module in DCH includes integrated EDCB. The EDCB serves 3 main functions:

  - Ultra-rapid fuse-function, connecting and disconnecting the power modules from/to the DC link. If a full short-circuit in the load is detected, the EDCB interrupts the current within ~10 microseconds after detection.
  - Pre-charging power modules, no additional and external pre-charging circuit needed, ensures that the inrush current to the power modules is controlled.
  - Dampening oscillations on the DC-bus between modules with a dedicated and accurate inductance.
- **DC connection with fuses (DCF)**
  Direct connection to DC link.
- **Output Disconnector Cabinet (ODC)**
- **Starpoint Disconnector Cabinet (SDC)**

The width is dependent on the number of installed applications like MI, AFE, DC-DC converter, EBL and rectifier.
The power sections are designed to house power modules and have a modular design. In this product manual, there is a detailed chapter for each power section.
The DC-Hub cabinet consists of standard sections rated IP44 and is manufactured in steel. Vibration dampers are used between cabinet and foundation. All power cable entries are located at the rear bottom, and the cabinets must have access from front.
All cabinets have effective EMC shielding by EMC tight enclosure with conductive gaskets and EMC shielded multi cable transits.
A cabinet cooling unit which includes water to air heat exchanger and fans is installed at the top back of each power section.

6.3.1 General arrangement

The figure below is an example of the front general arrangement of The Switch DC-Hub. The DC-Hub is divided into transportation sections if needed.

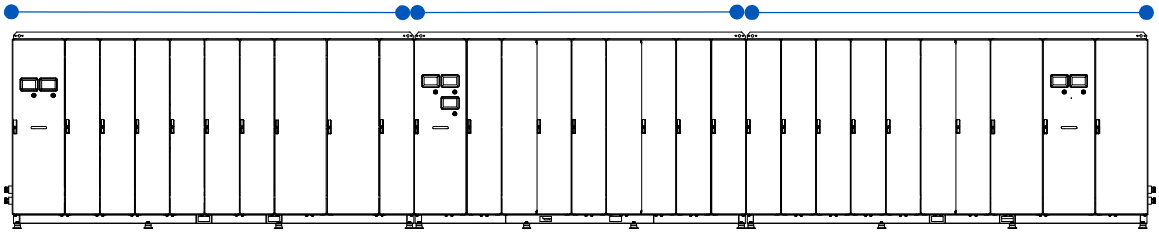


Figure 6-1 Large DC-Hub is divided into transport sections (example).

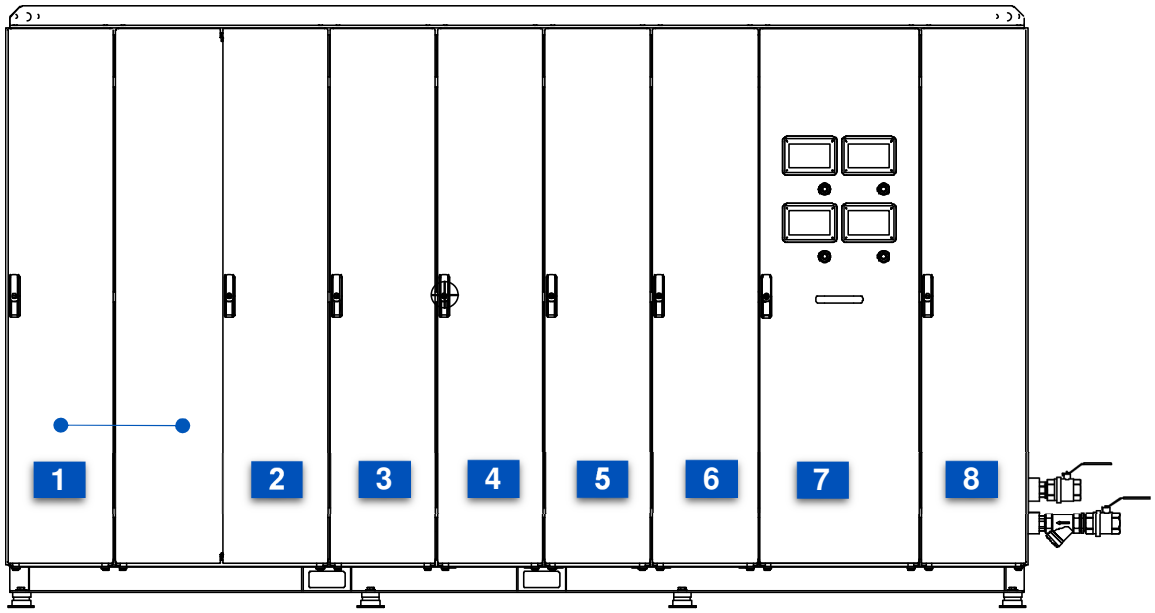


Figure 6-2 DC-Hub front arrangements (example).

1	AFE
2	Grid interface
3	Battery connection
4	Motor inverter MI1 - shaft generator
5	Motor inverter MI2 – bow thruster
6	Motor inverter MI3 – stern thruster
7	Control section CC
8	Application PLC control section AC

The DC-Hub shown (Figure 6-2) is comprised of 1 x AFE and 3 x MI, all these units are connected to a common, low-impedance DC link.

6.4 Split sections

Wide DC-Hubs are delivered in multiple transport sections. Split sections are situated between the transport sections. The transport sections are joined together in the split sections.

6.5 Control section

Control sections are attached beside the cabinet. Signal transfer or communication between the control section and power sections happen through fiber connection.

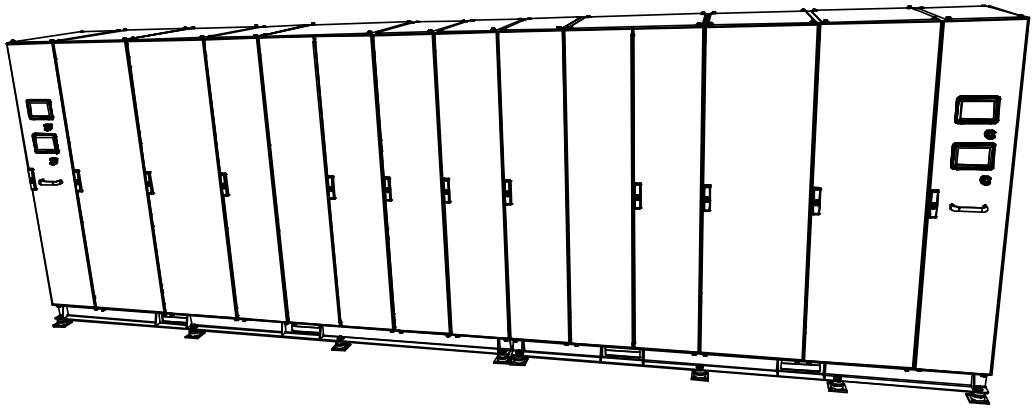


Figure 6-3 Control sections on left and right with local touch displays, process stop buttons (example).

Control sections have varying sizes, depending on their function and location. The control section controls internal functionality including power modules. The control section is equipped with an application PLC for MI applications. The interface can be either hardwire, Modbus TCP/IP, Modbus UDP/IP, or a combination of them.
HMI (Human machine Interface) local touch display for communicating with the main board of that specific application:

- The HMI is mounted in front of the local control section.
- Each application in the DC-Hub has its own HMI. The protection device applications have optional local controls.
- HMI local touch display for communication and control towards system controllers.
- Power modules can be operated and monitored both from the local touch display or remotely.
- The control section is equipped with the process stop buttons, which shut down the specific application.
- Process stop push buttons for each redundancy group are possible to connect external push button.

Design features for redundancy and failure mode behavior:

- Applications are segmented if one application is out of order and other ones are still functional.
- Auxiliary voltage (230 V) is redundant.
- Network topology is designed so that input connection from the upper-level system to the DC-Hub is made with two ethernet cables.
- Network topology is designed in a way that the internal and external networks are separated by creating individual Virtual LANs. On the external network there are two incoming Ethernet cables from the external system. A firewall protects the internal network and port forwarding is used for limiting data traffic from VLAN to VLAN.
- While our system maintains a high level of reliability, it’s essential to recognize that its operation is dependent on the cabinet automation PLC and the Ethernet switch to which it’s connected.

- The DC-Hub is equipped with an insulation monitoring device (option) which monitors the electrical current flowing through DC link towards ground and issues an alarm if there is a leakage current. An earth fault in the system is caused by a conductor insulation failure (breakage), allowing the live conductor to get in contact with the hull or an earthed metallic electrical cabinet.
- The DC-Hub is equipped with a water leakage sensor (option).
- The DC-Hub is equipped with fan control and monitoring.

6.5.1 Power module HMI

The background template will be visible on every screen (Figure 6-4) In the bottom of the screen is the menu bar. Here are five buttons which will give access to different screens. On the right side there are four buttons which will open an event list of that specific event type. Buttons will light up in color if an event is active. Fault will light up in red, the alarm in yellow and the limit button in blue. On top of the event buttons there are two indication boxes. The one on the top is indicating if local control is active or not. The second one will show if the drive is running. When the drive module is running the box will light up in green and the text will change to “Running”.

Up in the right corner clock time is shown. In the upper left corner, the latest event is shown.

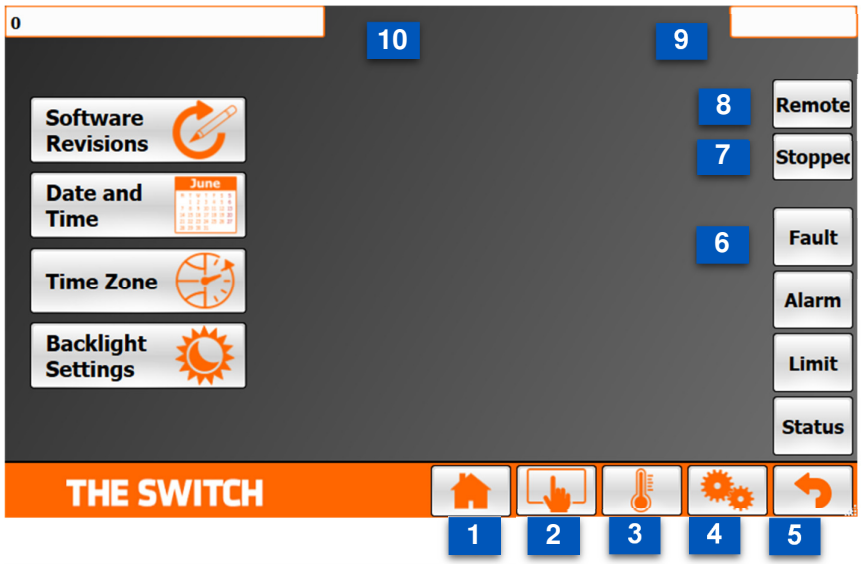


Figure 6-4 Background template.

1	Open the home screen
2	Open the local control screen
3	Open the temperatures screen
4	Open the settings screen
5	Go back to the previous screen
6	Event buttons: fault, alarm, limit, status
7	Power module running or stopped
8	Remote or local control
9	Time
10	Latest event

6.5.2 Events screen

There are event screens for each type of event shown on the right side of every screen. These are listing events that have occurred and color those which are active. Each event is listed from newest to the oldest with a given number, date, time, and description. Event details can also be opened, by pushing on the wanted event, for more detailed description. Arrow buttons are available for scrolling pages up and down in the event list.

6.5.3 Fault screen

As shown in Fault screen (Figure 6-5) the registered faults are listed. Active faults are colored red, and the reset button can be pressed to reset active faults.

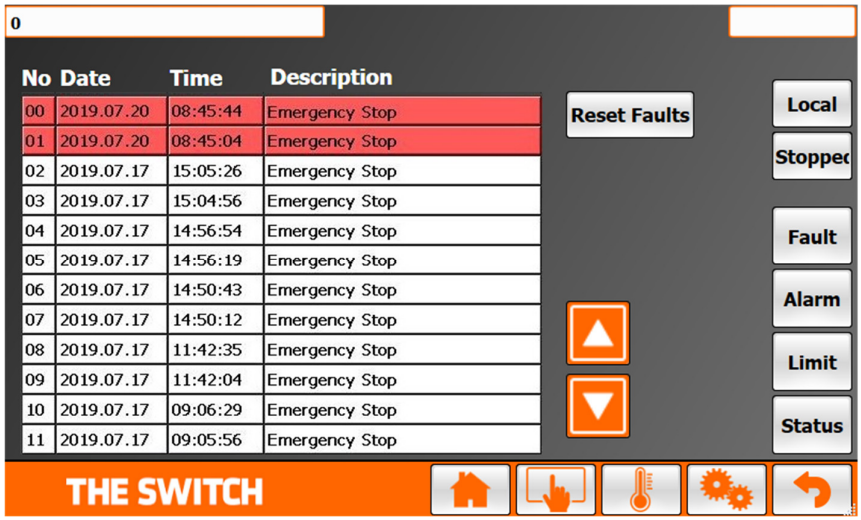


Figure 6-5 Fault screen.

6.5.4 Alarm screen

(Figure 6-6) shows the alarm screen, listing the registered alarms. Currently active alarms are colored yellow and can be reset by clicking the Reset Alarms button.

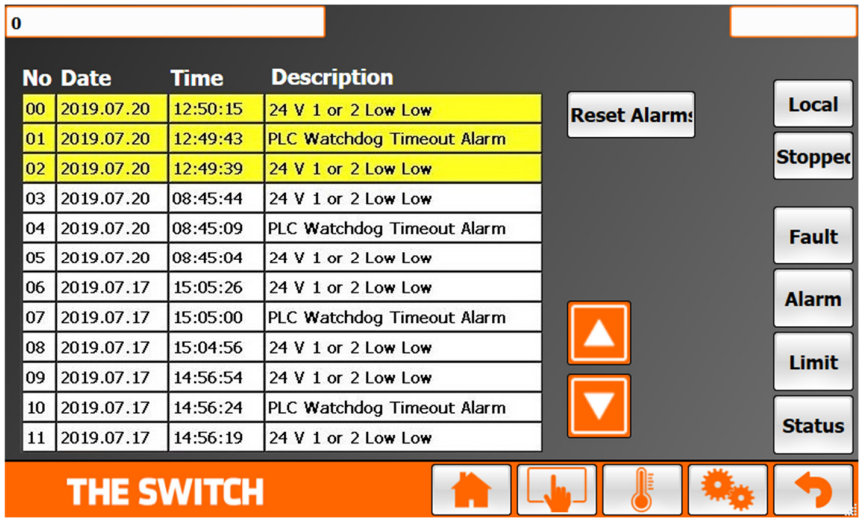


Figure 6-6 Alarm screen.

6.5.5 Limit screen

By pushing the Limit button on the right, a list of latest registered limits is shown. The limit button will light up in blue if there is an active limit. Note that limits cannot be reset and are just state monitoring of measurements.

6.5.6 Status screen

By pressing the Status button on the right, a list of registered statuses from the control is shown.

6.5.7 Detailed event info screen (Popup)

In (Figure 6-7) the detailed event info model popup screen is shown. This screen is accessed by pushing on the wanted event row in one of the event screens described above. The popup contains the description from the event list, date and time of when the event occurred, an event code and data for the specific event, and the source of the event. The source explains where the given event occurred. At the bottom of the screen there is a detailed description of the specific event – for more detailed event information.

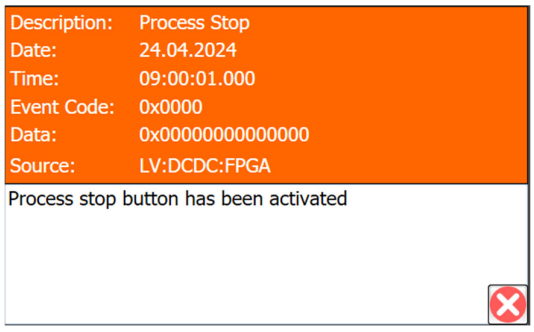


Figure 6-7 Detailed event info screen (Popup).

6.5.8 Settings screen

In the settings screen different configurations and settings can be changed for the HMI. Date and time can be changed by pressing the Date and Time button. To change the time zone, press the Time Zone button. HMI backlight settings can be set by pressing the back-light settings button. Here you can set the backlight to automatically turn off after set amount of time. Software revisions can be viewed by clicking on the Software Revisions button. The Settings screen can be accessed by pressing the settings icon in the menu bar fourth from the left (Figure 6-8).



Figure 6-8 Setting screen.

For more HMI operation instructions refer to application chapters.

6.5.9 Software revision screen

In the software revision screen, all software used for the application will be listed (Figure 6-9). The following information will be displayed:

- Control software release
- Change file used for the control software
- Cabinet automation PLC software revision
- Application PLC software revision
- HMI display software revision



Figure 6-9 Software revision screen.

6.6 PLC

There will always be at least one PLC in the control section of a DC-Hub and Single Drive. This is the cabinet automation PLC which handles all automation related control and monitoring inside the DC-Hub or Single Drive. The cabinet automation PLC has no interface towards the external control systems. If the DC-Hub is split into two or more transport sections, there will be a remote IO in the second control section. This will have communication with the cabinet automation PLC but no communication to any external control system. The brand of the PLC is WAGO which is marine certified.

6.6.1 Cabinet automation PLC

The cabinet automation PLC is placed inside the control section. It's connected to either AFE1 application's internal network or if an AFE is not used it will be connected to MI1. Communication towards all CCOs will be established with Modbus UDP/IP protocol and the PLC will function as master. External control systems will have no communication with the cabinet automation PLC as they will communicate with the CCOs instead.

6.6.2 Application PLC

As an option, the customer can select to have an application PLC for one or more applications. Application PLCs purpose is to be the interface towards external control systems. The application PLC can be used as an alternative interface towards external control systems. The interface between the external control system and the application PLC is mainly hard-wired but Modbus TCP/IP can also be used if required. The main signals of the application PLC are control, reference and status signals. Application PLC will have Modbus TCP/IP or UDP/IP communication with the specific applications CCO instead of the external control system. There is no communication between the cabinet automation PLC and an application PLC. Automation PLC will take care of all automation (breakers, fan control, fan monitoring, temperature monitoring). If an application PLC is used for the application, critical automation related control and protection are moved to the application PLC such as disconnector control, temperature monitoring and precharge. This means that even if the cabinet automation PLC fails, the application can still be controlled locally since the application PLC will take care of necessary functionalities.

In EBL application failure in automation PLC will not open breakers automatically. The breakers open if an actual fault is detected in circuit or the process stop button is pushed.

7 DC-Hub mechanical installation

The standard mechanical installation method is valid for inclination static ±15°, dynamic 0 ± 22.5° in four directions.

7.1 Storage

If the equipment is stored it shall be in an area where the temperature variations do not cause any condensation. Storage temperature is +5–+55°C.
The cabinet contains Vapor phase Corrosion Inhibitor (VpCI® – 111 emitter or equivalent product) plastic cups must be replaced each 12 months of storage.
The product shall always be protected against any environmental hazards and contamination from ongoing activities at location. Use a fireproof cover to protect the equipment if welding or other hot work is carried out nearby. When sandblasting, spray painting, grinding, or performing other work that can lead to dust, particle, or chemical contamination, completely cover all surfaces and openings (remember cable inlets!) of the equipment before starting. Do not perform any work inside the cabinets while there is a risk of exposure to such hazards. The doors and covers must be kept closed and always locked when work is not done inside the cabinets.



Note!
Failure to comply with the above demands will void all warranties.

7.2 Lifting and moving

All liftings must be carried out with great precaution. The sections are lifted from the lifting bars on top. The slings shall have an angle of at least 45 degrees against the roof. If this is not possible because of the height a lifting spreader must be used. Take care with alignment to the foundation. Lifting bars on top of the cabinet are removed after installation. The center of gravity can be found in the GA drawing. The size of the lifting holes in the lifting bars is Ø 29 mm. The pin size of the lifting shackle must be at least Ø 24 mm.



Warning!
Crushing hazard. Beware of hanging loads newer go underneath it.



Use only approved chains and slings. They must be in good condition. Use marked lifting points.



Caution!
Do not operate any equipment while they are suspended.



Note!
The center of gravity and the crane must be in a vertical line. Use special devices to lift with correct balance. E.g., asymmetric chains length may be required.



Note!
When the DC-Hub is lifted, please check that all remains of the transportation crate are removed. Be especially aware to remove all wood screws that are used to fasten wood crate to cabinet beam.



Lifting the cabinet with power modules installed is not allowed.



Do not lift combined cabinets.



Centre of Gravity – symbol, used in GA drawings.



Centre of gravity packing label to indicate the center of gravity of the transport package which will be handled as a single unit.
Make sure that you lift the component using the center of gravity of the component. You can use special devices to lift with correct balance and operate safely.



Sling here, packing label.



Caution!
Beware of tilting when lifting the cabinet.
The center of gravity may not be in line with the lifting point. When the cabinet is raised into the air it will tilt until the center of gravity is underneath the crane hook.



Warning!
Crushing hazard. Beware of swinging cabinet when lifting it. Stay away from the lifting area.

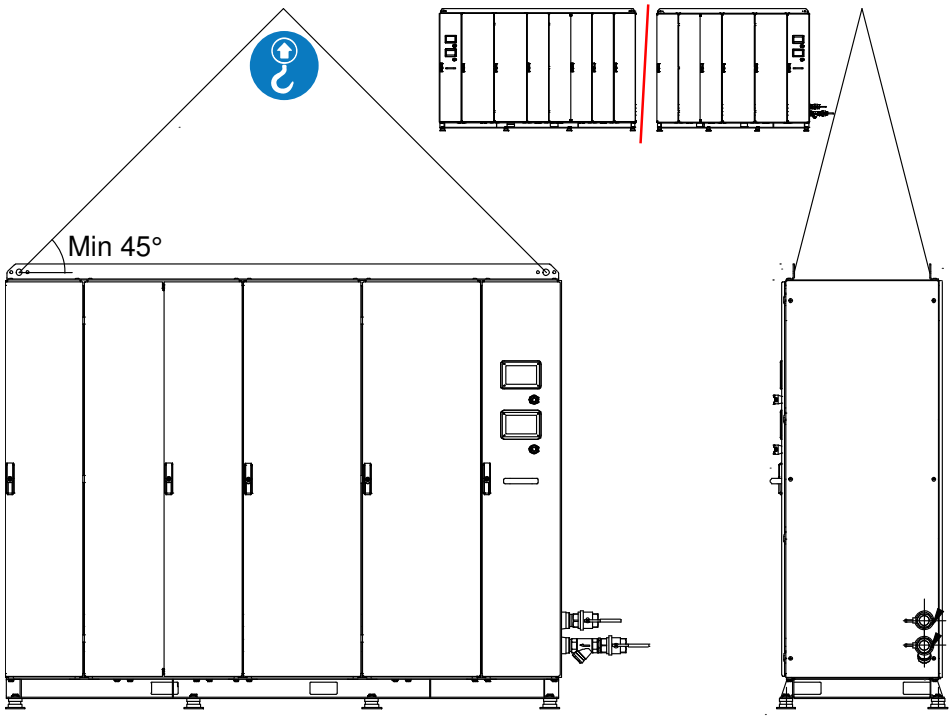


Figure 7-2 Four lifting points of the transportation section (example).

Special precautions to be taken when lifting by a forklift. The cabinet was delivered with a wooden pallet. The transportation crate can be removed, and the bottom pallet can be left under the cabinet for lifting the forklift. The forks shall be placed under the pallet in relation to the center of gravity in the right place. The lifting bars on the roof could be used to place the cabinet in its final position.

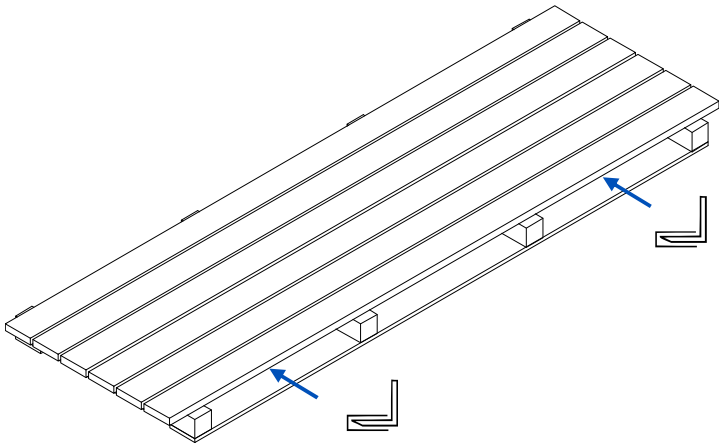


Figure 7-3 Forklift pockets are on the bottom pallet.

7.3 Installation and service space requirement

Service space is the free space required around the DC-Hub cabinet to ensure that installation and service can be performed easily without any incident.

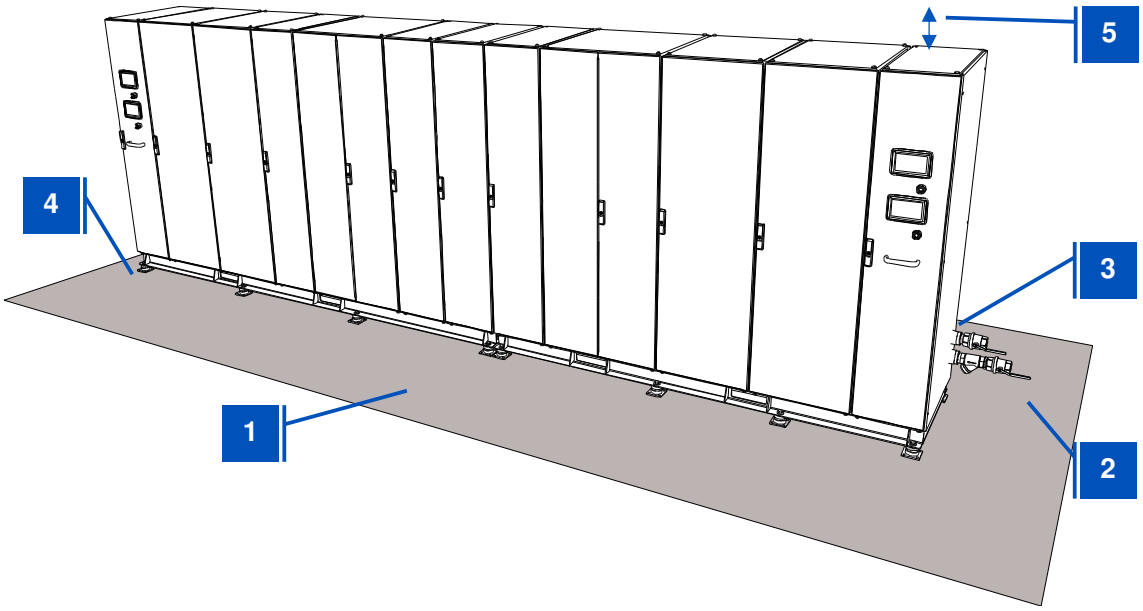


Figure 7-4 Service space (example).

1	Front service space: 1000 mm along the whole front of the DC-Hub
2	Right side service space: 700 mm on. Leaves room for liquid connections and a door to open (Optional bottom water connections 100 mm).
3	100 mm along the whole rear
4	Left side service space: 100 mm on
5	Space above: minimum 100 mm

Service space for the DC-Hub can overlap with service space for other equipment. Please see the project general arrangement (GA) drawing.

In case of arc flash and pressure relief function, the cabinet must have free space above.

The DC-Hub must be installed with enough room to access the front service panels. The door can open 90°, 110° or 140° (default), depending on how the door stopper is mounted.

Refer to the technical specification and the GA drawings of the DC-Hub.

7.4 Foundation requirements for the DC-Hub

The following must be prepared during construction of foundations:

- The foundation must be dimensioned properly for suitable strength and outline dimensions.

- Applicable weight and dimensions can be checked against general arrangement drawings supplied by The Switch.
- Foundation must be levelled in horizontal direction (max vertical deviation: 1 mm per meter of equipment).
- Cut-outs for cable entry must suit the multi cable transit MCT of the DC-Hub cabinet.
- Ensure adequate space for bending radius of the power cable.
- Cooling water connections must be installed. Fixed pipe installation is not allowed due to vibration of the DC-Hub. Refer to the chapter 8 DC-Hub cooling system.
- Flexible hoses can be prepared for connection to cabinet water inlet and cooling water pipes. Make sure dimensions of connections match the input and output on the DC-Hub, pipe thread external R 2”.
- Drill holes for vibration dampers are suitable for M12 bolts.
- Bolt the cabinet to the floor through the dampers at base of the cabinet using e.g., M12 lubricated bolts with spring washer, 4 pcs per damper. Recommended tightening torque 40 Nm.
- Use appropriate method to secure bolts in the floor.

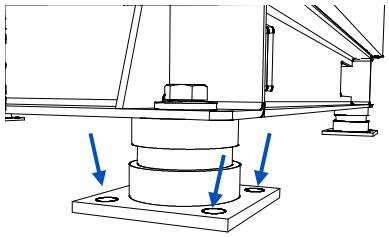


Figure 7-5 Vibration damper

- During cabinet installation, attaching the vibration dampers may require more working space than the minimum service space (100 mm).

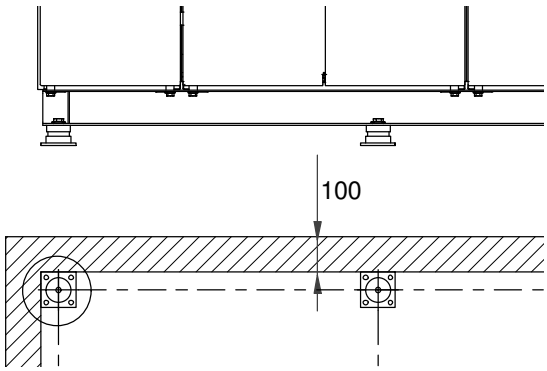


Figure 7-6 Minimum clearance 100 mm behind the cabinet.

7.5 Removing lifting bars

The bolts on the roof plate must be replaced by nylon pressure stoppers with pressure relief function (Rittal SV 9674.790, IP54) at the rear and roof mounting screws (Rittal PS 4198.000) at the front to ensure potential equalization and IP rating.

Remove lifting bars and install mounting screws and pressure stoppers Ensure that there is enough room for pressure relief function.

The roof of the DC-Hub must be kept clear for all kinds of objects. Do not store anything on the roof while the DC-Hub is in operation.

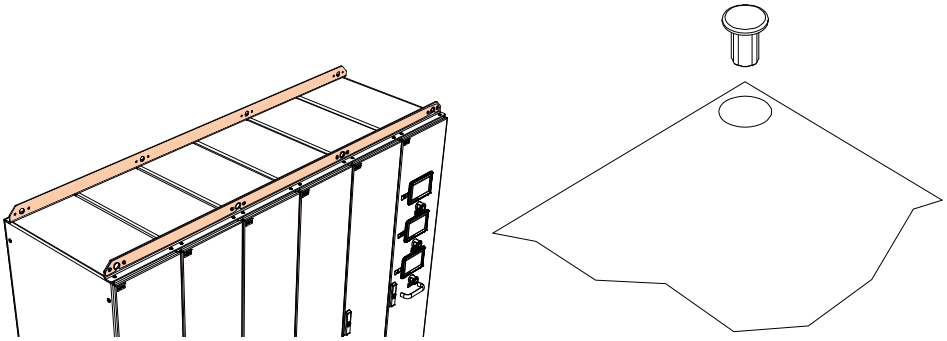


Figure 7-7 Remove both lifting bars and install nylon pressure stoppers on the rear and roof mounting screws on the front.

7.6 Bottom entry space requirements

Enough space below the DC-Hub foundation must be available for cables to be installed in the DC-Hub. The space for cables must line up with MCTs.

Note!
It is important that cables and hoses have the possibility to absorb vibrations before entering the DC-Hub cabinet. A 45 to 90-degree bend will often be enough.

Note!
If cables are passing through another MCT directly beneath the DC-Hub (e.g., to a deck below), the straight-line cable will not be able to absorb vibrations, and the vibrations will be transferred to the DC-Hub cabinet. This situation must be avoided.

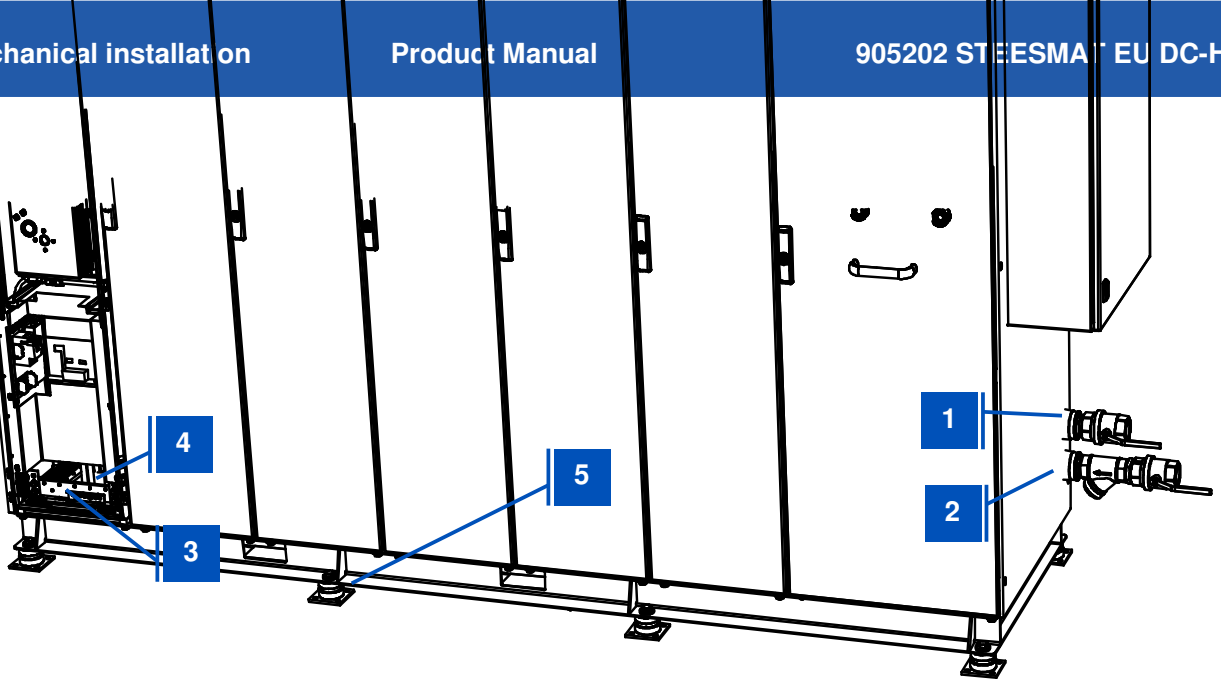


Figure 7-8 Cable and cooling water connections (example).

1	Cooling water outlet connection
2	Cooling water inlet connection
3	Earthing bar
4	Multicable transit
5	Vibration dampers

7.7 Joining transport sections

Wide cabinet line-ups are delivered in multiple transport sections. The sections are to be joined on-site.

7.7.1 DC-link and PE-busbar

DC-link between transport sections shall be connected with flexible busbars. Flexible busbar connections are tightened 1.5 times the recommended tightening values. Connection bars shall be mounted, with 4 x 6 pcs Zinc plated 8.8 M10x (70 – 110, bolt length may vary depending on number of busbars) hex cap bolts which should be tightened with a torque of 40 Nm (dry) with spring and pressure washers. Note there is a spacer copper bar (**2**) between the two mid busbars.
The bolts should be installed in such a way that they are inserted from the side towards the center of the bus bar system.

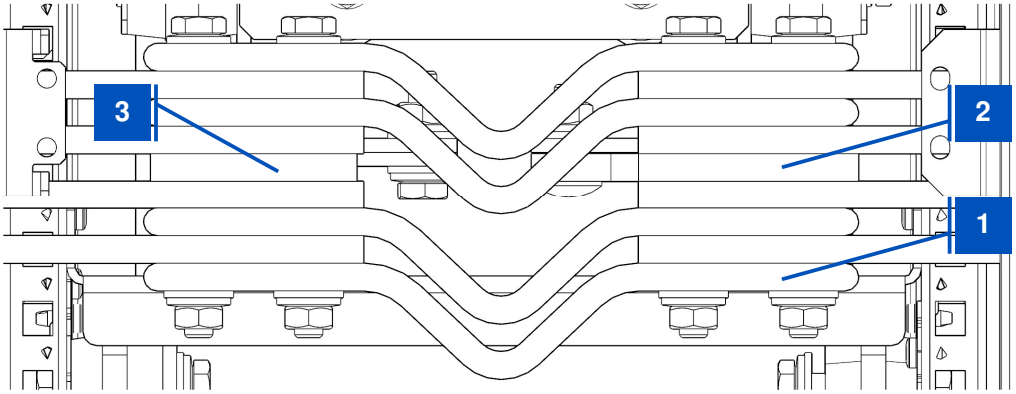


Figure 7-9 Flexible busbar connection at the DC link (example).

1	Flexible busbars (4 pcs)
2	Busbar connection piece (or e.g. DC- capacitor busbar)
3	Busbar connection piece

PE-busbar between transport sections shall be connected with a busbar. The busbar shall be mounted with 4 x Zinc plated 8.8 M10x45 hex head cap bolts (4 pcs) which should be tightened with a torque of 40 Nm (dry) with spring and pressure washers.

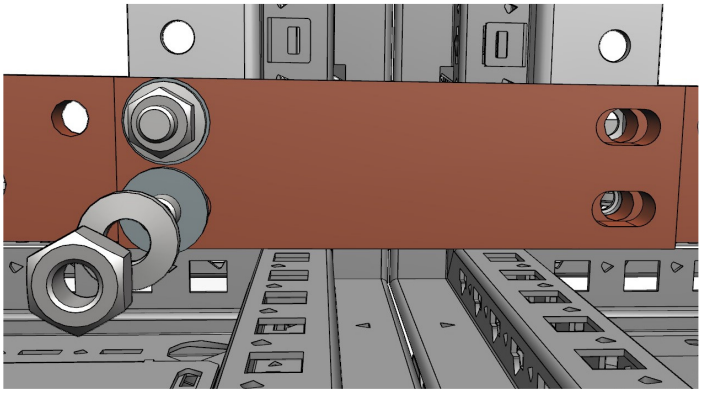


Figure 7-10 PE-busbar connection between transport sections.

7.7.2 Attachment of transport sections

After installation of the transport sections on the foundations, and connection of the DC-link is completed, the cabinets shall be connected together refer to separate Rittal Assembly Instruction Baying bracket, internal 8617500, Baying connector external 8617502 and Baying block, internal 86175501.

Checking list for baying:

- Baying seals must be installed between the sections.

Do not lift combined cabinets.

7.7.3 Cables connections in the split section

Cable connections shall be made after mechanical installation is complete.
Cables between transport sections are disconnected and rolled up. The cables are marked with the equipment name and connection point.
Refer to the circuit diagram.
Connect the following cables between transport sections:

- Ethernet N x plugs on the top of the split section (Figure 7-11).
- Heating WAGO connector at the bottom of the split section.

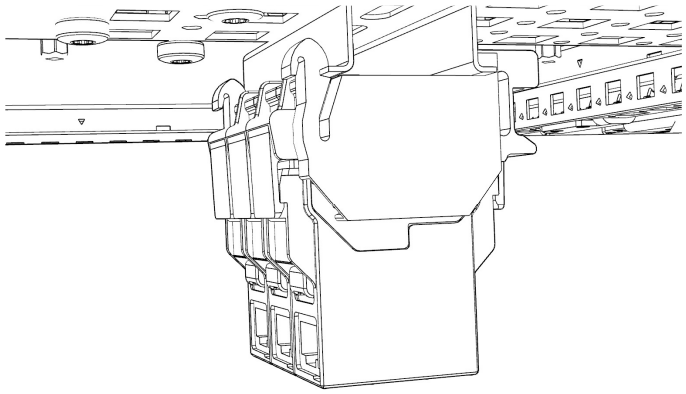


Figure 7-11 Ethernet cable plugs

- For the breakers/switch disconnectors/applications control and status to the automation or application PLC:
  - N pcs female connectors 2..n pole Wago 2020-10X
  - N pcs carrier terminal block 2020-1201

8 DC-Hub cooling system

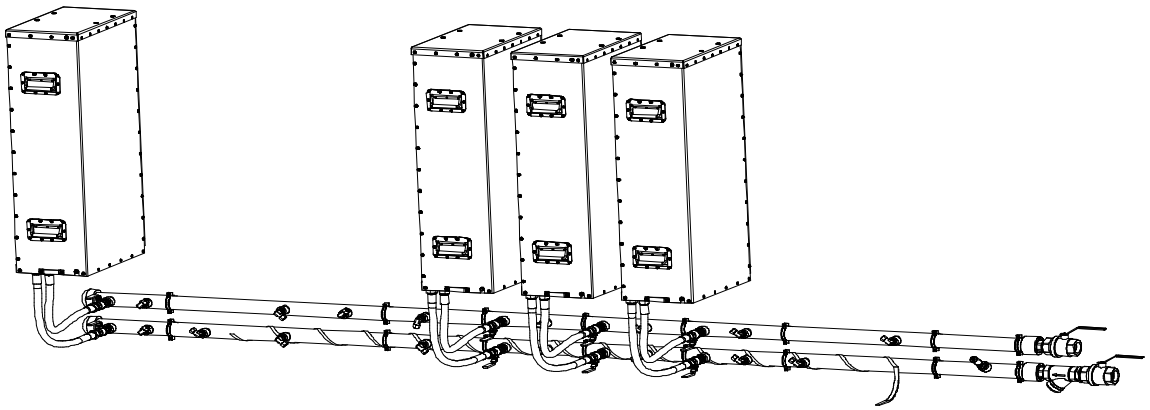


Figure 8-1 DC-Hub cooling system (example).

The DC-Hub is to be connected to the freshwater cooling system of the ship. Cooling water systems may contain corrosion inhibitors. Follow the instructions of the entire cooling system and the requirements of other devices connected to the cooling system. Inhibitors are chemicals added to the cooling water to prevent corrosion and the build-up of scale.
The DC-Hub liquid cooling circuit contains red metals and other materials compatible to red metals. The DC-Hub cannot be connected to the cooling system including aluminum. The cooling system must be flushed before installing the power modules.
An optional strainer with a filter must be installed before the DC-Hub inlet if the Y-filter is not in use. Select filter size to secure all particles Ø ≥1mm are filtered out. Make sure filter opening is not selected too small (high mesh number). Note that the required flow shall be maintained when filter is in use (including a normal number of particles caught by the filter).
If the cooling water inlet is shared by multiple applications, only one filter for the common inlet needs to be installed. The cooling system shall have inlet/outlet valve, pressure sensors / flow sensors, and temperature sensors to monitor the cooling system.

Table 8-1 Cooling water requirements (example)

Cooling medium	Fresh water with corrosion inhibitors content
Maximum inlet pressure	6.0 bar
Approx. pressure difference at correct flow (inlet minus outlet)	2.0 bar
Maximum inlet temperature	38 °C
Minimum inlet temperature	22 °C, or above condensation level
Flow	Refer to the technical specification
Heat dissipation	Refer to the technical specification
pH	6 - 9
Chlorides	< 50 mg/l
Iron (Fe)	< 1 ppm (parts per million)
Ammonia	= not detectable ~ < 10mg/l

Note!
The cooling water system is designed for freshwater mixed with corrosion inhibitors without aluminum particles. The precise mixture is determined by the datasheet of the chemical.

Note!
Make sure the mesh size of the filter selected is appropriate to secure flow according to the technical specification.

Note!
Failure to not add glycol/corrosion inhibitor can cause rust and clogged cooling system which can lead to cooling failure. Monitor water quality and corrosion inhibitor percentage regularly.

The water must be free from impurities particles such as.

- oil or grease
- mud
- foam forming particles
- rust flakes
- metallic parts
- sand or other waste particles

The impurities particles can prevent effective heat transfer from the equipment to the cooling-water. It is the yard's responsibility to keep clean the cooling system from such impurities and particles.
If additives are used in the cooling water, they must be non-reactive with the following materials.

- PEX (cross-linked polyethylene) tubes
- EPDM (ethylene propylene diene monomer) hoses
- Stainless steel, brass, nickel, copper

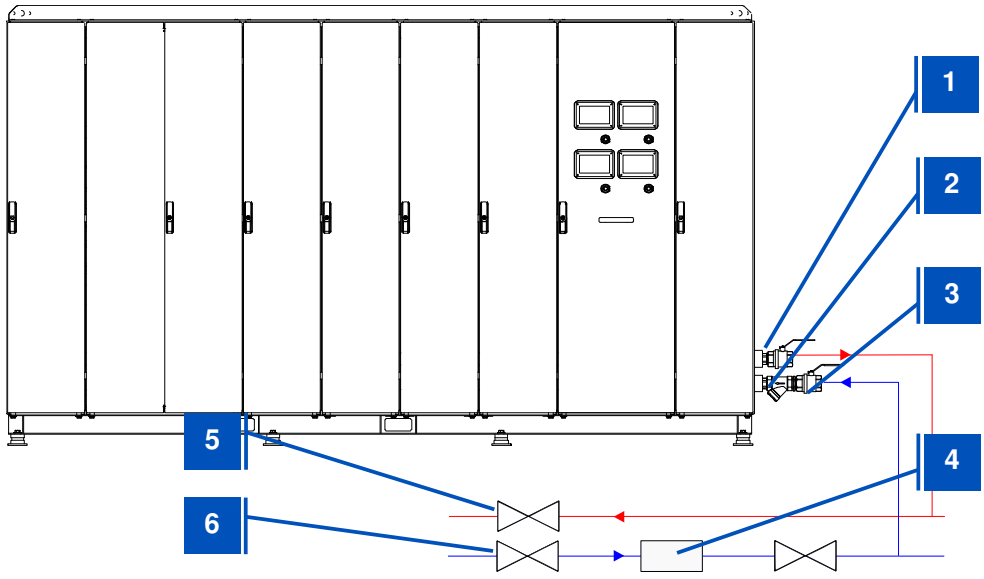


Figure 8-2 Water cooling inlet and outlet manifold with its respective valves and a strainer (example).

1	Cooling water outlet connection, ball valve, pipe thread external R 2”
2	Optional Y-filter
3	Cooling water inlet connection, Y-filter, ball valve, pipe thread external R 2”
4	Optional external filter, all particles Ø ≥ 1 mm are filtered out.[1]
5	Ball valve outlet.[2]
6	Ball valve inlet (on both side of the external filter).[3]

Do not remove the Y-filter and connect the DC-Hub to cooling water system without straining.

The customer must ensure correct cooling water pressure and flow. Manometers are recommended for measurement of inlet/outlet pressure.
If other or longer manifolds are used, the pressure must be measured at the “furthest” inlet on the inlet manifold, and the “first” outlet on the outlet manifold. A fixed installation with flow sensors is recommended but not required.

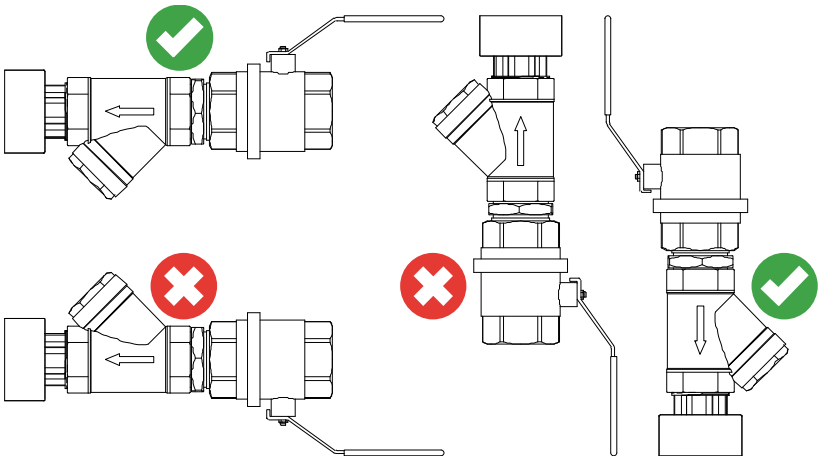


Figure 8-3 Accepted Y-filter installation positions. Note the flow direction arrow at filter bodies.

The Y-filter leg must be pointing downwards to ensure that any filtered material does not interfere with the main flow. Which must be considered if a bottom cooling water connections are used.

Note!
A pressure difference of minimum 2 bar guarantees correct water flow in all cabinets connected to the manifolds.

[1] Not included in the scope. An external strainer is an alternative to the Y-filter.
[2] Not included in the scope. An external ball valve is an alternative to the ball valve at inlet.
[3] Not included in the scope. External ball valves are an alternative to the ball valve at outlet.

Caution!
Do not start the DC-Hub without enough cooling-water flow. Repeated start-ups without cooling water flow will reduce the lifetime of the power module or can damage the power module.

Caution!
Correct flow must be measured and verified before powering up the DC-Hub.

8.1 Cooling water system flushing

Ensure the DC-Hub is bypassed before flushing the ship's cooling water system. If the DC-Hub is not bypassed during flushing, impurities and particles from the cooling system may enter and clog the internal cooling channels of the power modules. If necessary, the DC-Hub can be flushed separately. When flushing the DC-Hub separately, ensure that the power module valves are opened or closed according to the intended flushing procedure.

The flushing must be completed by the shipyard. The quality of the water must be inspected before installing power modules.

Refer to chapter 15.8 Flushing.

8.2 Internal cooling arrangement of the power module

The water connections are located beneath the module and are located so that it is possible to disconnect the power terminals by pulling the module out approximately 50 mm without disconnecting the water pipes. Flexible water pipes are to be used. The inlet water terminal is the rightmost terminal when looking at the module from the front whereas the outlet water terminal is to the left of the outlet terminal.

The internal ball valves for the connected modules must be opened before operation. In cabinets where there is only one module, the second cooling water branch is blinded off. The water circulation to each module can be handled individually.

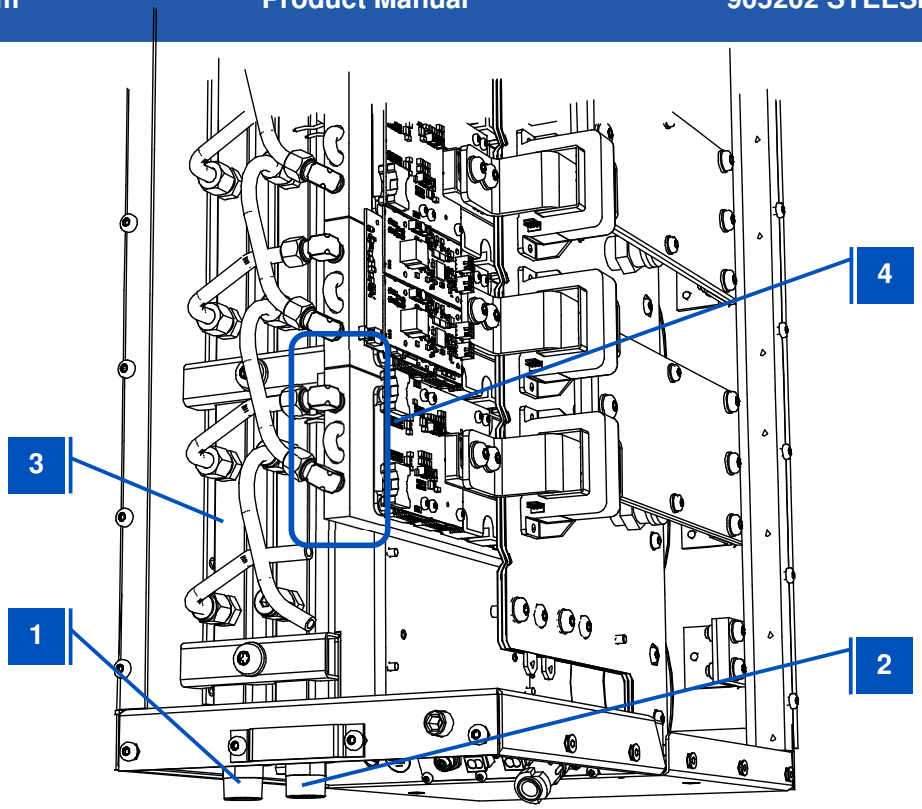


Figure 8-4 Water manifolds and heat sinks (example).

1	Water outlet
2	Water inlet
3	Distribution block
4	Heat sinks

There are two water manifolds for distribution of cooling water inside the power module, one for inlet and one for outlet water. Each heat sink has a single connection to both where the inlet water is connected to the bottom water connection on the heat sink and the outlet to the topmost to make it easier to get air out of the system.
Each power module operates independently. If the temperature goes above the limit set-point for a high trip, only this power module (application) will turn off.

8.3 Ambient requirements

The DC-Hub is designed to operate at a normal room temperature, switchboard-rooms, machinery spaces or an ambient temperature up to 45 ºC. Special attention must be given so that the cooling water is not too cold if the humidity is high. Minimum cooling medium temperature is 22 ºC or above condensation temperature according to the dew point table. The maximum cooling medium temperature is 38 ºC. If the water temp exceeds 38 ºC the drive shall limit the power.
To avoid condensation forming on cooling pipes, it is important that the cooling medium is at a higher temperature than the dew point for the actual room temperature and relative air humidity. See Table 8-2.

Table 8-2 Dew point temperature [ºC] as function of relative air humidity [%] at sea level and 1 ATM pressure

Ambient room temp. [ºC]	Relative air humidity [%]										
	20%	30%	40%	50%	60%	70%	80%	85%	90%	95%	100%
10 ºC	<0	<0	<0	0	3	5	7	8	8	9	10
20 ºC	<0	2	6	9	12	14	16	17	18	19	20
25 ºC	1	6	10	14	17	19	21	22	23	24	25
30 ºC	5	10	15	18	21	24	26	27	28	29	30
35 ºC	9	15	19	23	26	29	31	32	33	34	35
38 ºC	11	17	22	26	29	31	34	35	36	37	38
40 ºC	13	19	24	27	31	33	36	37	38	39	40
45 ºC	17	23	28	32	35	38	41	42	43	44	45
50 ºC	21	27	33	37	40	43	45	47	48	49	50

Temperatures are rounded to the nearest ºC. Condensation will take place if the inlet temperature of the cooling medium is much lower than the ambient room temperature. The actual difference in room temperature and cooling medium will depend on the relative air humidity.

Caution!
The cooling medium temperature must always be warmer than the dew point temperature in the table. Operation outside the specification causes risk of equipment damage.

8.4 Water leakage monitoring

The water leakage sensor is mounted inside on the floor of the control section. The sensor wire is running all the way through the sections and will give an alarm if the sensor wire is exposed for water.
Refer to chapter 15.19 Testing water leakage .

8.5 Heating cable

A self-regulating heating cable is applied on the inlet manifold for purpose to maintain temperature in the cabinet to minimize risk of condensation and keep equipment in conditions ready to be powered up while the system is not active mode and operating.
The heating cable shall be powered up from external 230 V_{AC} service with protective and control equipment. Refer to the circuit diagram for details.

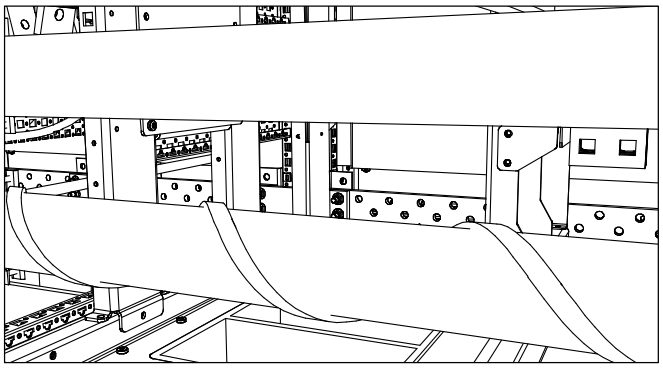


Figure 8-5 The self-regulating heating cable is wrapped around the water inlet pipe.

8.6 Dew point monitoring

The DC-Hubs and Single Drives can be connected to an external relative humidity sensor located in the room where the cabinets are situated. It is crucial to prevent the formation of dew points inside the cabinets. The external sensor monitors air temperature and relative humidity, and these are used to define the dew point in the PLC. The calculated dew point is compared to cooling water temperature. An alarm is triggered if the relative humidity is out of range, and a separate alarm is activated if there is a risk of dew point formation.

9 General guidelines for cables

9.1 Cable trays

Cable trays must be electrically conductive and connected to ground and connected with each other to ensure that they always have the same earth potential.

9.2 Cable routing outside cabinets

Cable routing outside cabinets is the customer's responsibility. Correct cable routing is important to prevent unforeseen problems. These points will not be checked but are general rules and recommended based on class rules and experience.

Single core cables placed in cable trays must be placed in “threefold” and must be rotated periodically to minimize differences in capacitance to ground. One benefit of 3 core cables is that this is handled automatically inside the cable distances between cables.

Power cables and signal cables running in parallel must have a minimum of 300 mm between them. If power cables and signal cables must cross, then they must be crossed at a 90°angle.

Fiber cables to be protected against wear, mechanical impact, and bending to avoid signal attenuation and ensure reliability. Do not cut or splice the fiber cables. The minimum bending radius is 40 mm when there is no tension to the fiber cable. If tension is applied to the fiber, the possibility of bend radius violation increases. Any unprotected bend is a potential point of failure; the fiber cable management should provide bend radius protection at all points where the fiber makes a bend.

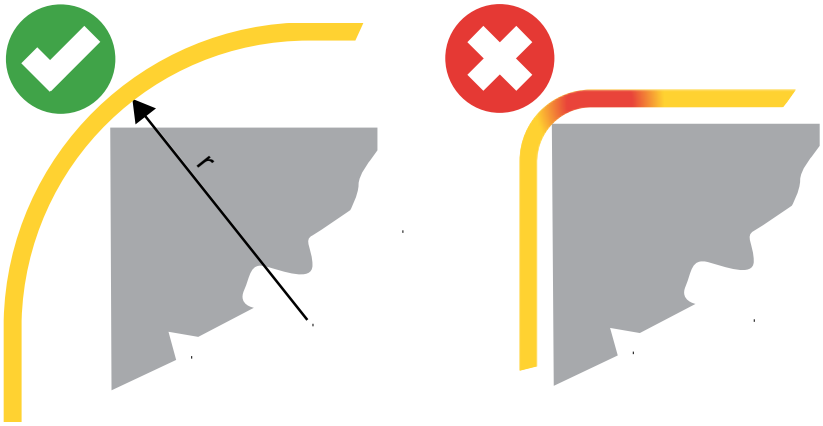


Figure 9-1 Maintain proper radius of a fiber cord. Do not violate minimum bend radius r.

9.3 Cable termination

Cables installed on bus bars shall be mounted with pressure-based cable lugs. Bolts with quality Zinc plated 8.8 shall be used as a minimum. To ensure good contact over time, conic spring washers shall be used. This will allow the spring washer to expand and contract with the cable lug when it heats up and cools down. Two pressure washers and one conic spring washer shall be used.
If bus bars are equipped with square holes so lock bolt could be used then only single cable lug assembly is possible.
If bus bars are equipped with square holes so lock bolts could be used then only single

cable lug assembly is possible.
If a bolt is lubricated - less torque is required to achieve bolt axial tension. Obey cable and cable lug manufacturers' instructions when terminations are made.
Use only tin-plated copper cable lugs.

! ***Note!***
A minimum of two thread pitches should extend beyond the top surface of the nut. *

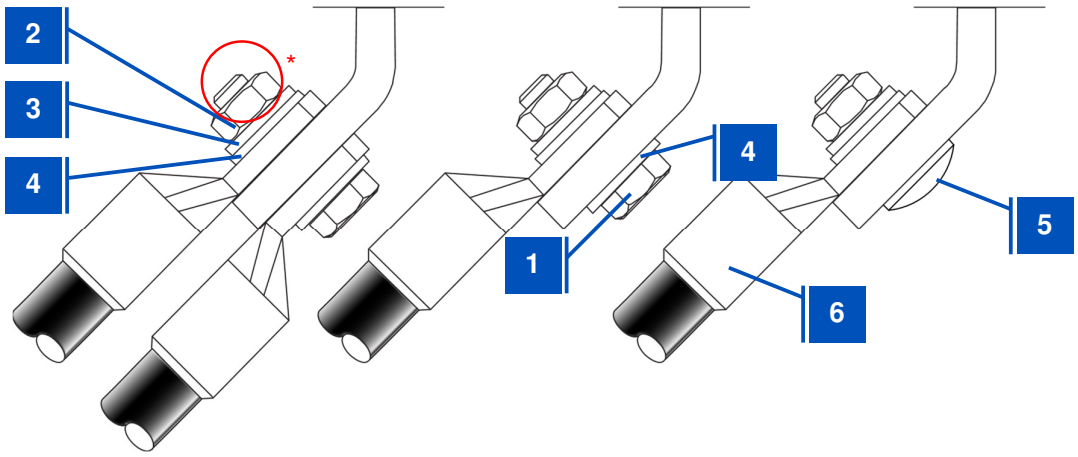


Figure 9-2 Double/single cable lug assembly and square hole - lock bolt assembly (example).

1	Hex cap bolt M12, 8.8
2	Nut M12
3	Conical spring washer M12
4	Pressure washer
5	Lock bolt M12 (low mushroom head screw with square neck) for square holes (12.5 x 12.5 mm)
6	Tin plated copper cable lug

Note: This is an example.
The size of the bolt and washers may vary depending on the cable lug used.

9.4 Power cable recommendation for different interfaces

9.4.1 General cable recommendation

Table 9-1 Cable recommendation

Interface	Cable type		Acceptable cable structure		Shielded for EMC	Max cable + source inductance
	Multicore	AC (3 phase) / DC	Single core	Symmetrical		
Grid - AFE	✓	AC	✗	✓	✓	⊖
MI - motor/generator	✓	AC	✗	✓	✓	⊖
DC link – battery	✓	DC	⊖	✓	✓	10 µH
DC/DC converter – DC source	✓	DC	✗	✓	✓	10 µH
DC/DC converter - BSCL	✓	DC	⊖[1]	✓	✓	25 µH[4]
ECL – BSCL	✓	DC	⊖	✓	✓	25 µH[4]
BSCL – battery	✓	DC	⊖[1]	✓	✓	25 µH[4]
EBL – EBL	✓	DC	⊖[1]	✓	✓[2]	25 µH[3]
ECL - shore	✓	DC	⊖	✓	✓	25 µH[3]

✓ = accepted, *recommendation* - The Switch's product will work but the system integrator shall ensure compatibility.

✗ = not accepted, *requirement* - The Switch's product may not work properly according spec unless the requirement is followed.

⊖ = Selection needs to be considered by the system integrator as part of overall system arrangement.

EMC = electromagnetic compatibility

[1] = Possible with precautions, single core.

[2] = Possible with precautions, shield connected to ground only at one common end.

[3] = considering instantaneous trip value for the EBL/ECL of 3200 A for 1800 A rated current unit.

[4] = considering instantaneous trip value for the BSCL of 2200 A for 1800 A rated current unit.

- If a cable with an outer diameter of 55 mm is used, only two cables will fit in the frame and there will not be enough transits available for input and output cables.
- Outer dimensions of the cable MUST not exceed 54 mm when using size 6 MCTs blocks (module) on a single MCT frame of size 218 mm x 120 mm x 60 mm. Refer to chapter 9.6 Multi cable transit (MCT).
- DC cables shall be symmetrical, equal amount of plus and minus conductors.
- AC cables shall be symmetrical, 3 phases delta shaped cross section with PE conductor, examples (Figure 9-4).
- For voltage ratings for AC cables, due to high du/dt, voltage reflection phenomena and common mode voltage stress. We recommend one voltage class higher than the rated voltage should be selected. Examples: For 0,6/1 kV nominal voltage, a 1,8/3 kV cable should be used.
  Please ensure cable lifetime with cable manufacturer if lower class is used.

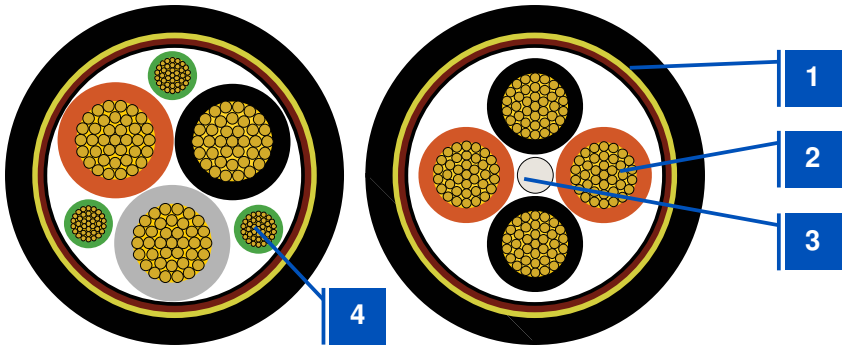


Figure 9-3 Examples of symmetrical AC and DC cable.

1	Sheath (polyolefin plastic), armor (Cu wire braid), screen (Cu tape)
2	Insulation and conductor
3	Dummy core (optional)
4	PE conductor

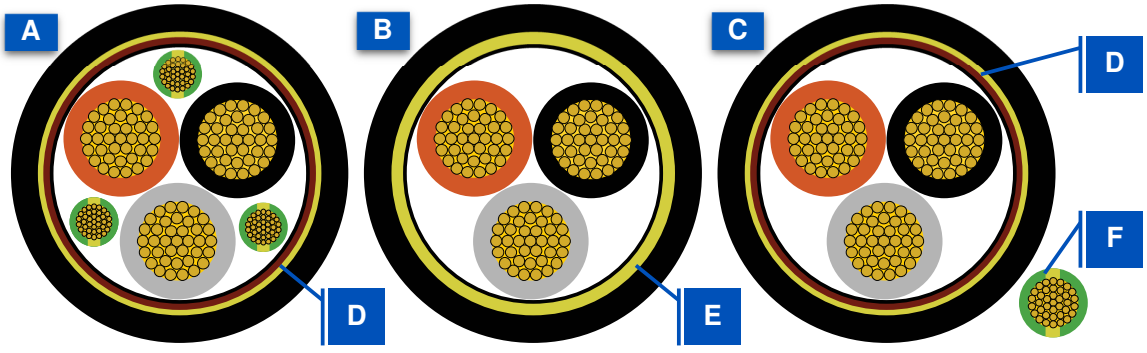


Figure 9-4 PE conductor examples for AC cables.

A	Cable with three phase conductors and symmetrically constructed PE conductors
B	Cable with three phase conductors and combined PE and shield
C	Cable with three phase conductors and separate PE cable(s)
D	Shield (EMC)
E	Combined PE and shield (EMC)
F	Separate PE cable

The size of the PE conductor and its conductivity in general shall fulfil IEC requirements.

9.4.2 Grid - AFE interface

General cabling recommendation

- Performance for EMC compliance is result of implementation of an entire. system, not verified by The Switch in prior and shall be considered by system integrator and/or owner.
- Select correct insulation class for the rated voltage.

9.4.3 MI interface

General cabling recommendation.



- Cables with sector-shaped conductors are **not** accepted.
- Follow the requirements of the classification society for cable dimensioning.
- The cables total outer diameter should not exceed 54 mm due to space limitation in the MCT frames. Vibration of the cable should be taken into consideration.
- Avoid critical lengths of cables as it increases the du/dt on an electric machine.
- Select correct insulation class for the rated voltage.

9.4.4 DC link– battery interface

General cabling recommendation.

- Follow the requirements of the classification society for cable dimensioning.
- Connection between the DC link and an external battery shall be implemented with screened 2, 3, 4 conductors symmetrical structured cables, as shown in (Figure 9-5).
- Single core cables are accepted for direct DC link connections (Figure 9-6).
- The screen or extra conductor in the cable shall be used for the purpose of PE conductor in size of 50% of live conductor cross section.

- A cross section of current carrying copper conductors in 90°C class at applied ambient temperature shall match with rated nominal continuous current.
- For the best EMC mitigation, the cable screen shall be grounded in 360° at cable entries on both ends.

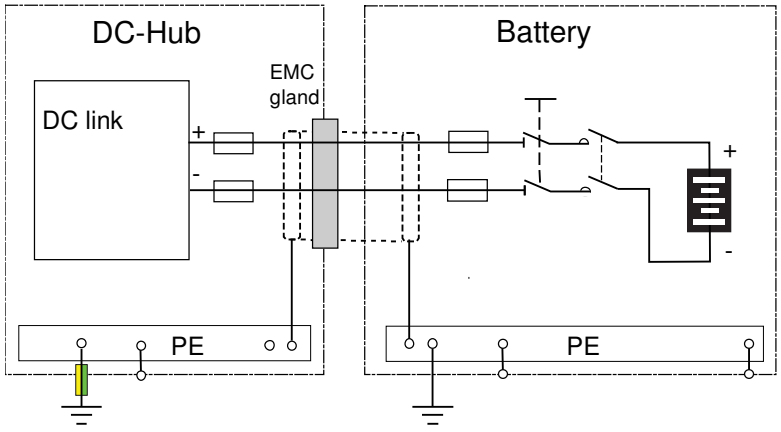


Figure 9-5 DC-link 2 conductors DC cabling to battery, EMC mitigation, PE and HF –earthing (example).

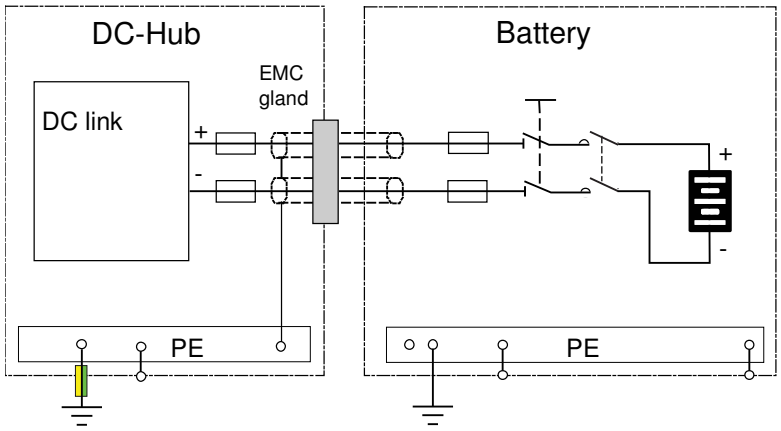


Figure 9-6 DC link single core DC cabling to battery, EMC mitigation, PE and HF –earthing (example).

- Performance for EMC compliance is result of implementation of an entire system, not verified by The Switch in prior and shall be considered by system integrator and/or owner.
- The maximum cable inductance is 10 µH. Deviation to the given limit may influence project specific functionality. Please confirm from The Switch.

9.4.5 DC/DC converter - DC source interface

General cabling recommendation:

- Follow the requirements of the classification society for cable dimensioning.
- Connection between the DC/DC converter and an external DC source shall be implemented with screened 2, 3, 4 conductors symmetrical structured cables (Figure 9-7).

- The screen or extra conductor in the cable shall be used for the purpose of PE conductor in size of 50% of live conductor cross section.
- Single core cables are **not** accepted for direct DC/DC converter connections.
- A cross section of current carrying copper conductors in 90°C class at applied ambient temperature shall match with rated nominal continuous current.
- For the best EMC mitigation, the cable screen shall be grounded in 360° at cable entries on both ends.

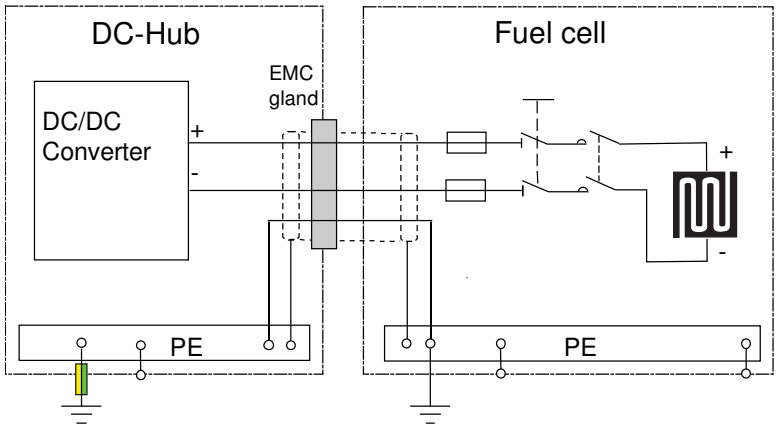


Figure 9-7 Fuel cell DC cabling, EMC mitigation, PE and HF –earthing (example).

- Performance for EMC compliance is result of implementation of an entire system, not verified by The Switch in prior and shall be considered by system integrator and/or owner.
- The maximum cable inductance is 10 µH. Deviation to the given limit may influence project specific functionality. Please confirm from The Switch.

9.4.6 DC/DC converter - BSCL interface

BSCL is used when connecting the DC-Hub to batteries. The DC/DC power module protects the DC-Hub from short-circuit in the cable and battery when BSCL is connected to the DC/DC converter.

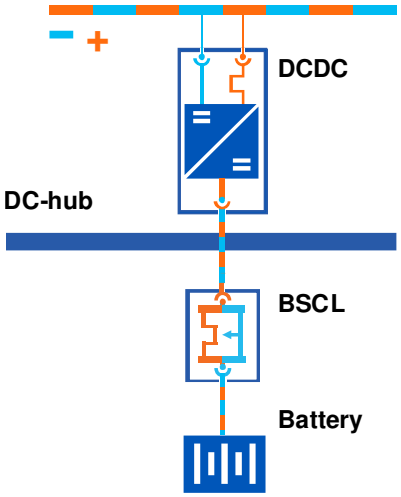


Figure 9-8 DC/DC – BSCL – battery single line diagram.

General cabling recommendation:

- The cable shall be a two or four-core symmetrical cable or other even number of conductors where plus and minus should be connected to equal number conductors each.
- It is important to allocate plus and minus to “diagonal conductors” to minimize stray inductance in four-core cables.
- With EMC screening.
- To check allowed total cable inductance.
- Total inductance depends on used cable type, length, and number of parallel cables.
- When renewing cables, the inductance must not increase, new cables shall be the same length as previous ones.
- The cable should comply with Classification Society rules or with IEC standards (IEC60092).

9.4.7 ECL - BSCL interface

The BSCL is used when connecting the DC-Hub to batteries. The ECL module protects the DC-Hub from short circuits in the cable and battery when the BSCL is connected directly to the DC link.

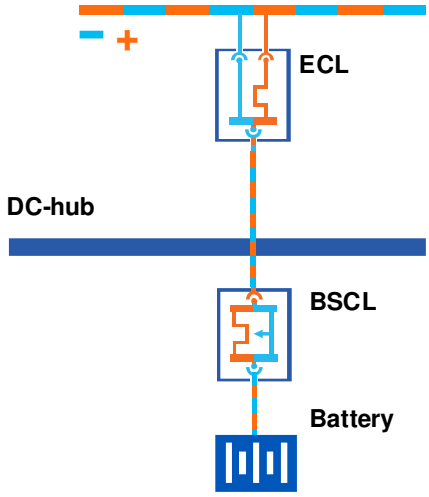


Figure 9-9 ECL - BSCL - battery single line diagram.

General cabling recommendation:

- The cable shall be a two or four-core symmetrical cable or other even number of conductors where plus and minus should be connected to equal number conductors each.
- It is important to allocate plus and minus to “diagonal conductors” to minimize stray inductance in four-core cables.
- With EMC screening.
- To check allowed total cable inductance.
- Total inductance depends on used cable type, length, and number of parallel cables.
- When renewing cables, the inductance must not increase, new cables shall be the same length as previous ones.
- The cable should comply with Classification Society rules or with IEC standards (IEC60092).

9.4.8 BSCL – battery interface

General cabling recommendation:

- The cable shall be a two or four-core symmetrical cable or other even number of conductors where plus and minus should be connected to equal number conductors each.
- It is important to allocate plus and minus to “diagonal conductors” to minimize stray inductance in four-core cables.
- With EMC screening.
- To check allowed total cable inductance.
- Total inductance depends on used cable type, length, and number of parallel cables.
- The maximum cable inductance is 25 µH. Deviation to the given limit may influence project specific functionality. Please confirm from The Switch.

- When renewing cables, the inductance must not increase, new cables shall be the same length as previous ones.
- The cable should comply with Classification Society rules or with IEC standards (IEC60092).
- Single core cables are **not** recommended for BSCL to battery connections.
  - ***NOTE!***
    Between the battery and the BSCL can be used a single core cable BUT it is the system integrators responsibility to ensure that:
    - Total inductance (cable + battery) is low enough (below 25 µH)
    - Proper EMC shielding.

9.4.9 EBL – EBL interface

The EBL is for connecting one DC-Hub together with another one.
Two or more DC-Hubs can be connected in either series or a ring configuration. The inter-connecting cables are then connected to the EBL on each DC-Hub.

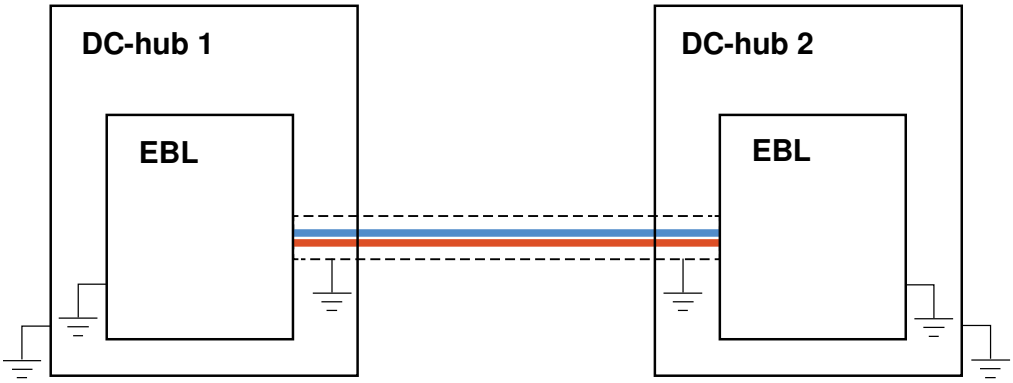


Figure 9-10 DC-Hub – DC-Hub power cable and grounding.

General cabling recommendation:

- The cable shall be a two or four-core symmetrical cable or other even number of conductors where plus and minus should be connected to equal number conductors each.
- It is important to allocate plus and minus to “diagonal conductors” to minimize stray inductance in four-core cables.
- With EMC screening.
- Allowed total cable inductance max 25 µH.
- When two pairs of EBL-EBL connection are used (i.e. 3600A), the cables must be individual and symmetrical for each pair of EBLs. That means that the EBL – EBL cable connection must be separate for the two pairs of 1800A EBLs, and symmetrical in terms of cable length, and number of parallel conductors/cables.
- Total inductance depends on used cable type, length, and number of parallel cables.
- When renewing cables, the inductance must not increase, new cables shall be the same length as previous ones.

- The cable should comply with Classification Society rules or with IEC standards (IEC60092).
- ***NOTE!*** It is the system integrator's responsibility to ensure that EQB is sufficient.

9.4.10 ECL – shore interface

General cabling recommendation:

- The cable shall be a two or four-core symmetrical cable or other even number of conductors where plus and minus should be connected to equal number conductors each.
- It is important to allocate plus and minus to "diagonal conductors" to minimize stray inductance in four-core cables.
- With EMC screening.
- To check allowed total cable inductance.
- Total inductance depends on used cable type, length, and number of parallel cables.
- When renewing cables, the inductance must not increase, new cables shall be the same length as previous ones.
- The cable should comply with Classification Society rules or with IEC standards (IEC60092).
- ***NOTE!***
  Between the 3 x ECLs on the DC-Hubs and the shore-side charging unit can be used as a single core cable. BUT it is the system integrators' responsibility to ensure that:
  - Total inductance is low enough (below 25 µH)
  - Appropriate current sharing
  - Proper EMC shielding.

9.5 Cabinet PE and HF –earthing

Each section with feeding cables shall be earthed separately. Sections shall be earthed a wire with finely stranded conductor (requirement IEC 60228 conductor stranding class 5 fine wire or higher) shall be connected between the PE bar and the conductive structure of the ship (a hull) with recommended maximum conductor length 600 mm. Wire size for earthing must comply with regulations and match with 50% of the total cross section of feeding phase cable(s). A finely stranded wire creates both low impedance EMC earthing path and PE (Protective Earth)-earthing. All earthing connectors of copper shall have sufficient cross-section to prevent exceeding 150 A/mm^2 at maximum earth fault currents that can pass through them.
For IT systems protective earthing conductors need not to be larger than 70 mm^2.

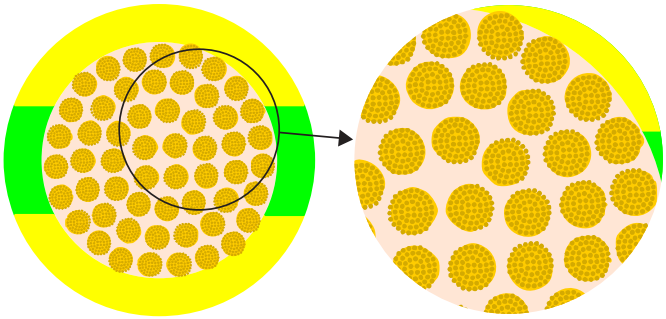


Figure 9-11 Example of finely stranded wire.

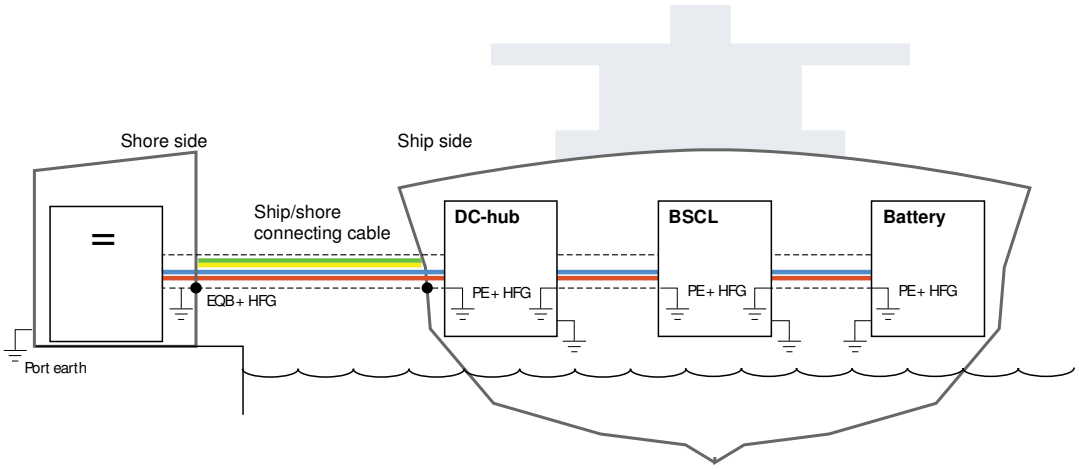


Figure 9-12 Shore connection (example).

PE = protective earth
HFG = high frequency ground

Equipotential bonding inside the ship or between the ship and the shore is to be provided by the system integrator. The equipotential bonding cable may be integrated into the shore power cable. When the equipotential bonding cable is intended to carry the shipboard earth fault current, the cable size is to be sufficient to carry the design maximum earth fault current.

9.6 Multi cable transit (MCT)

All cables between drive and motor must be earthed with high frequency ground in both ends. The standard drives are delivered with Roxtec MCT (multi cable transit) aluminum frames in both power and control sections. Open frame windows must be filled with blind EMC blocks.
Stainless steel is recommended as the material of the Stayplates and the Wedge ES. The Stayplates ensure a rectangular packing space and separate compression units. The Roxtec Wedge ES is used in frames with a rectangular packing space and seals the installation.



Figure 9-13 EMC Blocks for MCTs.

It is required that EMC blocks be used in all frames of power and control sections without exceptions. Even single core cables without braiding and blinding of unused MCT frame windows must use EMC blocks. This ensures that the power drive is properly EMC sealed.

Note the following only applies to armored cables:
Remove the cable outer shield without damaging the cable braid to ensure good contact with the conductive tin coated tape in the transit block. Do not remove isolation from un-shielded single core cables if these are used.

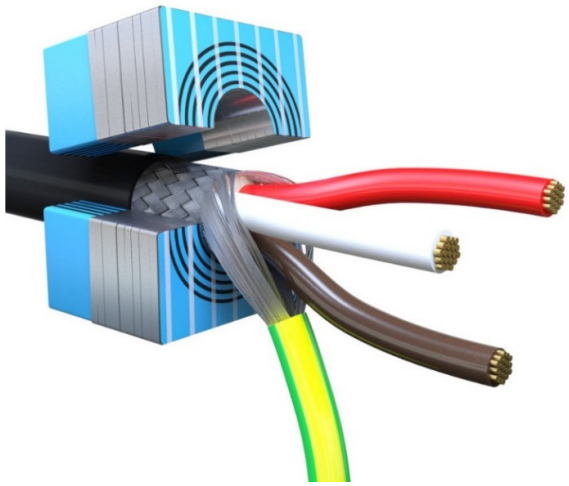


Figure 9-14 Armored cables must be used with Roxtec RM ES module.

It is important to ensure good electrical contact between the tin coating in the MCT blocks and cable braiding and to maintain the specified ingress protection degree. Avoid cable top entries as far as possible. If a top entry must be used, take extra precautions to maintain ingress protection.

After the cable has entered through the MCT, connect the cable braiding to the earth bar inside the drive. Keep the earthing as short as possible and with shrink tube installed.
For the cable entrance of the motor: Do not connect the cable braiding to the earth bar but use EMC MCT's in the cable transits to ensure proper HF earthing. For the rest of the

installation, the procedure is the same as for the drive end.
The cables should be cut to sufficient length and striped before being installed through EMC Roxtec blocks.

The illustration below shows an example of cable connections through EMC Roxtec blocks. Blocks without a cable going through them to be blind blocks. Refer to GA drawings for actual connection details.

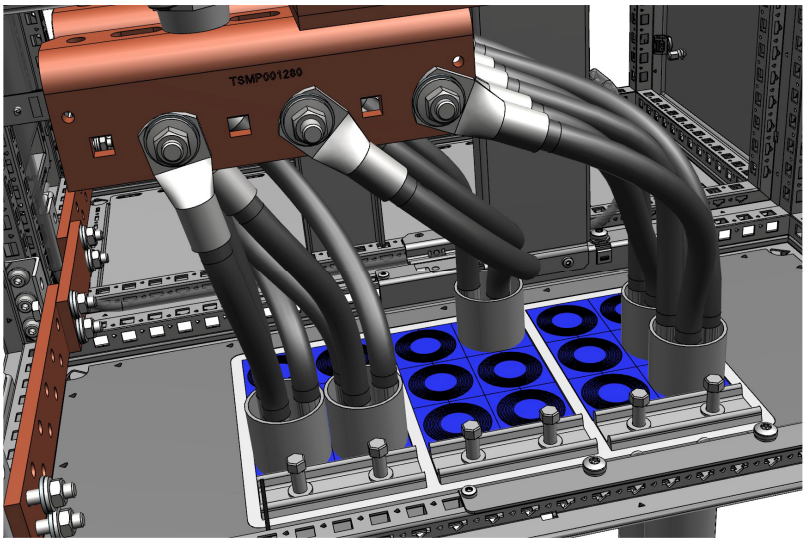


Figure 9-15 Roctec cable entry.

9.6.1 Multi cable transit (MCT) installation

To ensure an EMC compliant installation, the MCT frames must be packed properly with the correct block. In this manual, we will refer to Roxtec blocks, but other suppliers can be used if the blocks are EMC compliant. Refer to suppliers' installation instruction on how to install MCT blocks in the frames.

9.6.2 Blind plates

The blind plates are used to cover cable entries during transportation. They should be left in place on any cable entries that are not used.

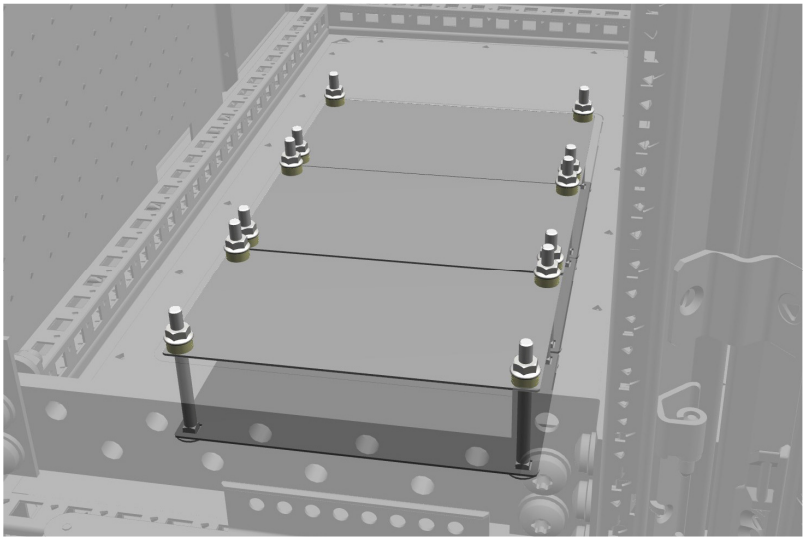


Figure 9-16 Cable entry blind plates.

9.7 Power cables connections

Connect the cable lugs to the appropriate terminals. Refer to the circuit diagram delivered. When mounting cable lugs of power cables side by side, ensure that the required air clearances and creepage distances are observed.

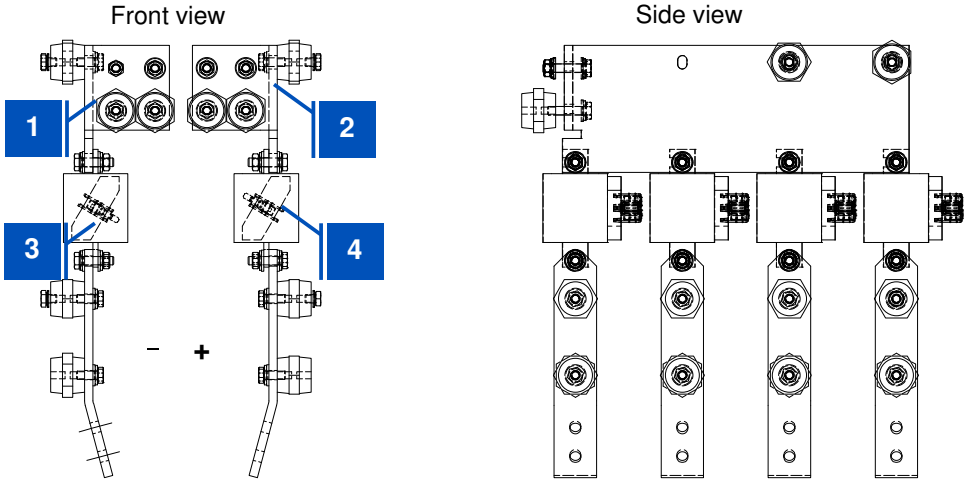


Figure 9-17 Battery connection (example).

1	(-) Neg. (4 pcs.)
2	(+) Pos. (4 pcs.)
3	Fuses (4 pcs.)
4	Fuses (4 pcs.)

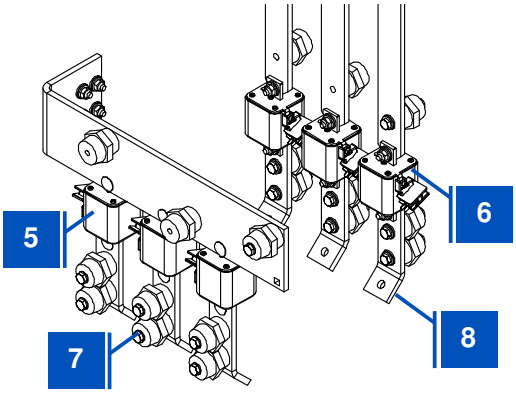


Figure 9-18 Fuel cell connection (example).

5	Fuses (3 pcs.)
6	Fuses (3 pcs.)
7	(+) Pos. (3 pcs.)
8	(-) Neg. (3 pcs.)

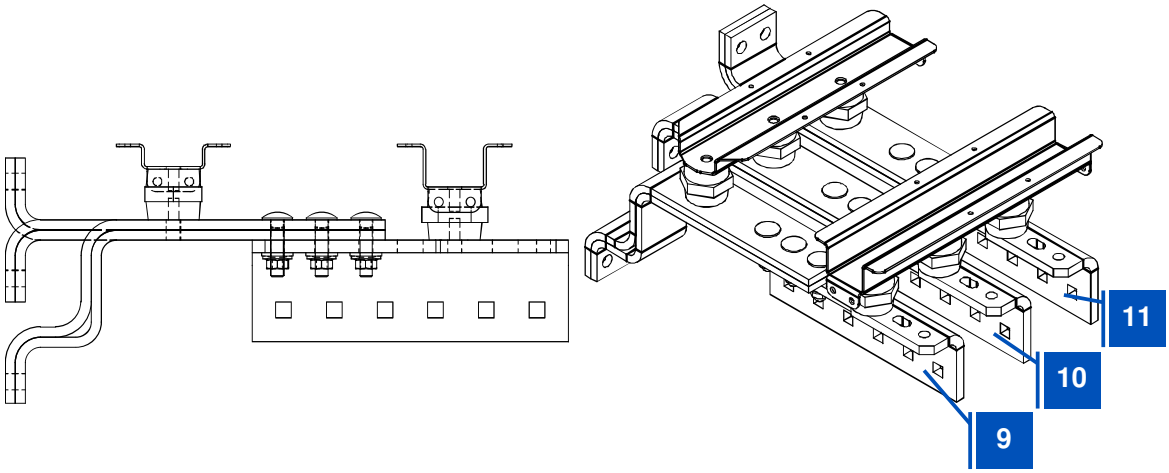


Figure 9-19 Grid connections (example).

9	L1
10	L2
11	L3
12	PE busbar

PE conductors of the power cable shall be connected to the PE busbars. Two lugged cables can be fastened per one Ø 11 mm through hole. The number of through holes varies depending on the width of the section: 800 mm - 25 pcs, 600 mm - 17 pcs, 400 mm - 9 pcs. If necessary, PE busbar in neighboring sections can be used, if that section allows it.

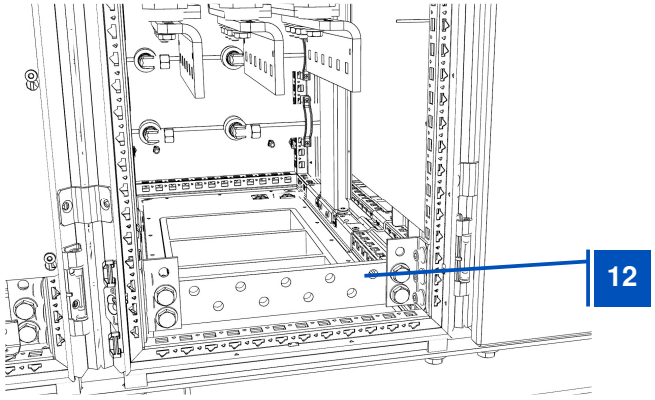


Figure 9-20 Nine through holes in the PE busbar, 400 mm wide section.

9.8 Signal/control cables

Follow the same guidelines for MCT packing as for power cables.
All signal cables must be shielded, as a minimum an overall screen is required. To get additional benefits, twisted pair cables will also reduce interference on the signals.
Wire dimensions do not need to be very large for 24 V digital signals, 4 - 20 mA analogue signals, and Ethernet cables must be minimum of CAT5 quality or better and shielded type.

9.8.1 Fiber connection between DC-Hubs

The fiber connection between the DC-Hubs shall be made using steel wire braided reinforced fiber cables (2 pcs.). Fiber optic connections are needed to synchronize applications. Fiber cable length is case-specific. The system integrator shall determine the fiber cables length. GFT CEL cards are all ways placed in the control cabinet (CC section).
Fiber type OM1
Reference cable: G4-62.5/OM1 AICI-I/O/RM

9.9 External interface

AUX, UPS, Ethernet and external process stop cable connections are in the control cabinet (CC section). Cables are routed via MCT (multi cable transit).
External process stop buttons (1- 4 pcs) can be connected to the process stop circuit.
External cable connections are project specified. Refer to the circuit diagram.

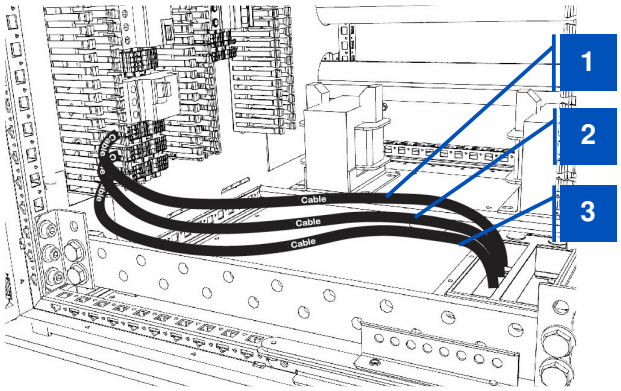


Figure 9-21 AUX and UPS cable connections at the control cabinet (example).

1	AUX 1
2	UPS
3	AUX 2 (optional)

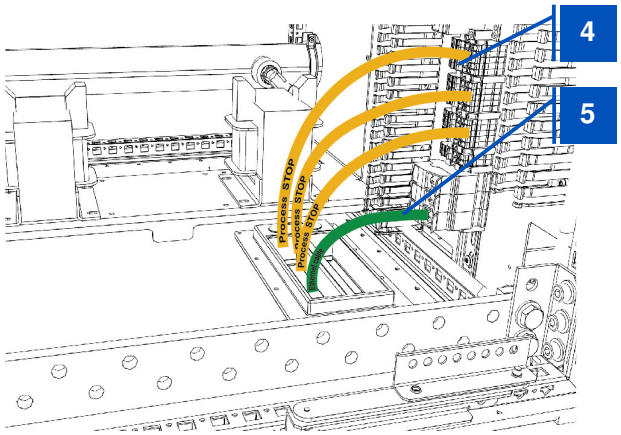


Figure 9-22 External process stop button and ethernet cable connection at the control cabinet (example).

4	External process STOP (optional)
5	Ethernet cable

10 Power modules

The Switch power module is designed with pluggable connections making it easy to replace in the field.
The power modules are replaceable modules, equipped with heavy-duty self-aligning fork plug connectors. All the power modules are connected by fork plugs and by flexible hoses for water cooling. They are controlled by Ethernet cable from the control section.
The power module dimensions: 1140 mm x 320 mm x 570 mm, (H x W x D).

10.1 Integrated EDCB

The Switch power modules provide an integrated EDCB (electronic DC breaker).
The purpose of the EDCB is to protect the other power module on a common DC link. EDCB disconnects the power module for a duration of 10 µs in case of a critical fault. This ensures very small voltage disturbance in DC link and allows all other applications, connected to the same DC-bus, to run continuously without being affected by a fault. With EBL and EDCB ultrafast protection DC-voltage does not drop (max drop 50 VDC) and keep operations running.

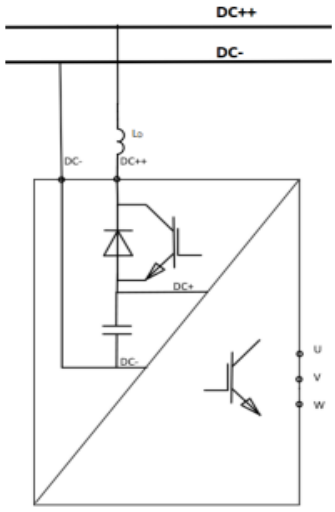


Figure 10-1 EDCB inverter module.

10.2 Power module external interface

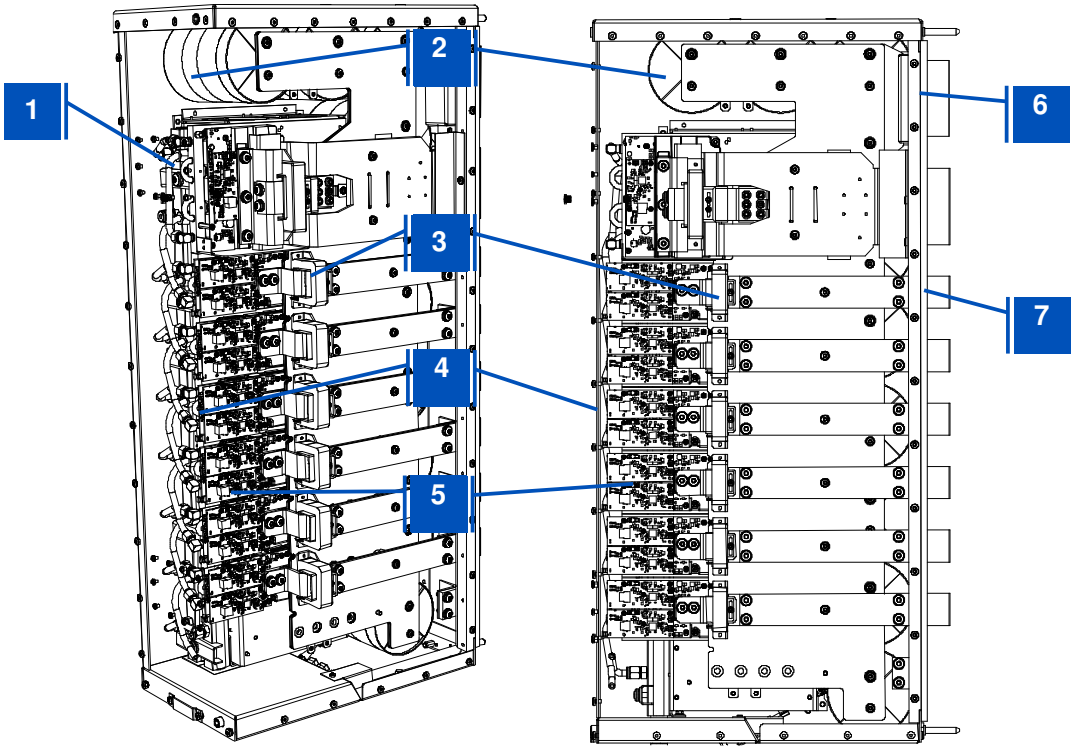


Figure 10-2 Power module (example).

1	Cooling liquid distribution block
2	Capacitors
3	Current measurement
4	IGBT´s on heatsink
5	Gate Drivers
6	DC-terminals
7	AC-terminals

10.2.1 Power terminals

The main power terminals are at the back of the module and are all aligned in a single column. Each terminal has a thickness of 10 mm and is made from silver plated copper.

The power terminals are split into two groups.

- Common DC bus.
  These are the two uppermost terminals with the DC- terminal on the top and the DC+ terminal below that. These terminals are used to exchange power between the power module and the main DC bus. Maximum continuous operating voltage is 1100 V DC, short-time overvoltage up to 1250 V is allowed.

- Load terminals (AC or DC).
  These are the output terminals of the IGBTs and are the controlled outputs from the module. Each output will be PWM modulated and may be used for both AC and DC.
- Water connections refer to chapter Internal cooling arrangement of the power module.

10.2.2 Control section

The interface towards the control section is at the bottom of the module and has multiple connectors.

- Auxiliary Power
  Dual 230 V AC
- 1x or 2x optical fibers (POF serial link)

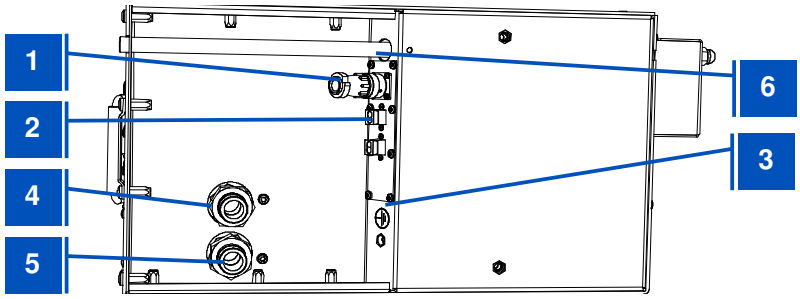


Figure 10-3 Bottom view of power module (example).

1	Power connector 230 VAC
2	Fiber connectors
3	Earthing
4	Cooling water inlet
5	Cooling water outlet
6	Guide spindle for pull-in

10.2.3 Power section

10.2.3.1 DC connection and output/ power terminals

The power module, the two DC terminals, DC- at the top and DC+ below DC-, are connected directly to the internal DC bus. The phase order is configurable.

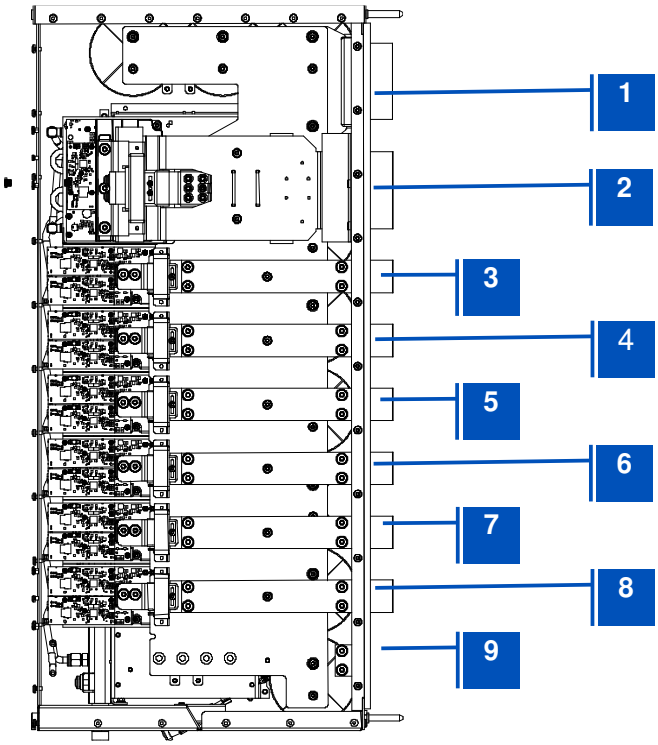


Figure 10-4 Inverter module power section (example).

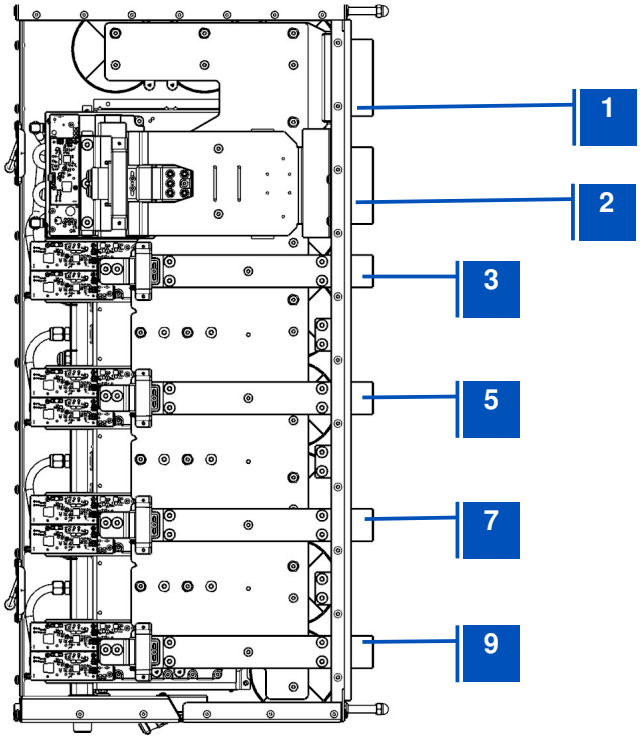


Figure 10-5 DC/DC module (example).

	2x840A AFE + EDCB	1600A MI+ BC + EDCB	840A DC/DC+EDCB
1	DC-	DC-	DC-
2	DC+	DC+	DC+
3	U1	U	DC+
4	U2		N/A
5	V1	V	DC+
6	V2		N/A
7	W1	W	DC+
8	W2		N/A
9	N/A	N/A	DC+

10.3 Isolating a power module from a main circuit

The Switch DC-Hub design provides features to isolate the power module from an electric main circuit in two levels in case of equipment failure.
Immediate disconnection by a cut off process is provided by a solid state switch called EDCB, consisting of detection electronics and current flow interrupting semiconductor, controlled with fast responding circuitry.
The EDCB is incorporated into construction of the power module.
Fast operation prevents other equipment on the same DC distribution to be influenced, since the voltage drop is negligible in the DC distribution under precisely controlled and limited fault current in the power module.
A fuse based fault current interruption would not be able to match with performance the EDCB provides.
In second phase, isolation from the main electricity after the immediate cut off is provided by a mechanism, which enables the power module to be repositioned to break electrical contacts to the system and locked securely into the safe isolated position.
In the isolated position, an electrical clearance is minimum of 25 mm from main circuit terminals to connecting tabs in the power module. Adequate isolation and securing to safe open position by applied locking techniques with associating hardware is achieved. Galvanic connection to PE bus bar from the power module remains intact.
Refer to chapter 10.5.7 Moving failed power module to disconnected position.

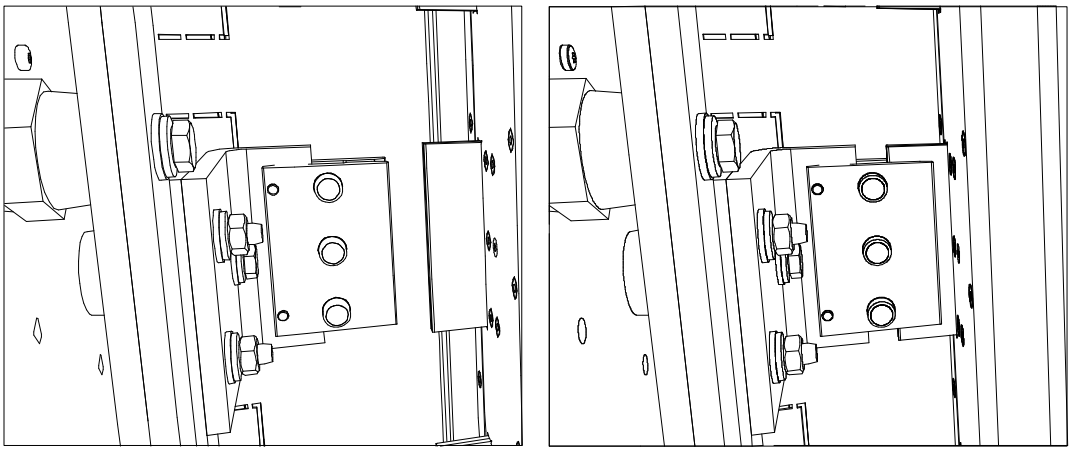


Figure 10-6 Power terminals of the power module DISCONNECTED / CONNECTED positions (example).

The power module must always be moved to the disconnected position if it fails, and it doesn't work. The need to move the power module to disconnected position may arise for e.g., the following reasons:

- Ground faults in the power module.
- Short-circuit in the power module.
- If a fault is detected in the operation of the power module that cannot be reset.
- The power module does not turn on as expected or repeatedly triggers failure(s).
- A local liquid leak in the power module, which is likely to cause a ground fault, or a serious equipment failure if it continues. The cooling water connection to the power module must be shut off in the event of a water leak.
- The DC-Hub can be used even if one power module has failed.

10.4 Power module handling

The power modules are factory cleaned and dried – and cooling water connections are capped. The modules have metal plates fastened directly to the framework of module for protection. The armored module is sealed within a 0,15 mm green, transparent, ESD safe PVC bag (VpCl – 125). Low density polystyrene is used for outer shock protection inside the wooden crate. Power modules must be kept in the original packaging until they are to be installed in the cabinets. The packing contains Vapor phase Corrosion Inhibitor (VpCI® – 111 emitter) plastic cups.



The power modules are highly sensitive to electrostatic discharge (ESD).



Warning!
Crushing hazard around the power module when moving it. The weight of a power module is approx.120 kg.



Always use safety boots when installing or removing power modules.

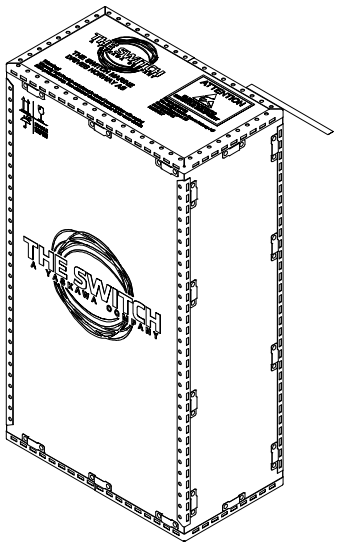


Figure 10-7 Transportation box of the power module.

Treat the modules with care. Keep dry and avoid impacts. The power modules must always be stored in original packaging and temperature variations should be limited to avoid risk of condensation. The transportation box of the power module is delivered to the customer on a Euro-pallet (EPAL).
Examine the module thoroughly when it is unpacked. The equipment must not be unpacked if there is any risk of electrically charged dust/particles in the air or if there is any risk of water condensation. ESD safety must always be maintained.
The modules must be protected from any environmental hazards. Use a fireproof cover to protect the modules if welding or other hot work is carried out nearby. Completely cover all surfaces and openings of the modules before starting sandblasting, spray painting, grinding or any other work that can lead to dust, particle, or chemical contamination. Do not perform any work inside the cabinets while there is a risk of exposure to such hazards. The cabinet doors and covers must always be kept closed and locked when work is not performed inside the cabinets.

10.5 Installing and removing the power module

This chapter covers the standard PD3.1 modules and PD4.1 protection device ECL, EBL and BSCL modules. All procedures are basically the same.

10.5.1 Tools and equipment required for installation and removal of the power module

The following equipment is required for installing and removing power modules.

- ESD travel kit including ESD wrist strap.
- Battery drill.
- 8 mm hex key for threaded rods for inclusion.
- T50 Torx key for the locking bracket.
- Grease for spindles and bolts, lubricant synthetic long-term grease e.g., *Isoflex topas NB 52 Kluber.*
- Lever handle for Slot Ballofix valve.
- Small cup for collecting water when removing the blind plugs.
- A funnel or a bucket for collecting water while the module is removed.
- 2 x blind plugs to prevent water spills.
- Lifting bracket.
- Torx key T40 for the lifting bracket bolts.
- Lifting device (lifting trolley) for the power module.
- Adjustable wrench with opening 36 mm short handle (8”) for connecting/disconnecting cooling hoses.

10.5.2 Preparation

- The power module is ESD sensitive, therefore it is recommended to make sure that all personnel who take part in the installation/removal must use correct ESD equipment, including clothing.
- Before starting this procedure, ensure that all the voltage sources of the Single Drive such as main power supply breaker and battery, are disconnected and locked.
- Always measure voltage on DC link and voltage between DC link and earth before proceeding with any work on the frequency converter. If voltage between earth and DC bus is above 50 VDC or 50 VAC keep the voltage instrument connected and observe if the voltage goes down. If so, wait until the level is less than 50 V and then short circuit earth and the DC bus. If the voltage level does not sink there is an earth fault present. Locate and fix before proceeding.



The power modules are highly sensitive to electrostatic discharge (ESD) Make sure that personnel, the power module and the cabinet have the same electrical potential.

Warning!
Make sure that all breakers and all pre-charge fuses are opened and then wait five minutes before opening the Single Drive cabinet door.

10.5.3 Power module first time installation into the Single Drive cabinet

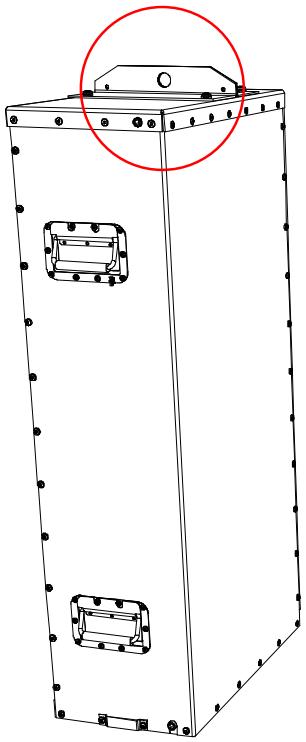


Figure 10-8 Use the lifting bracket to lift the power module its place and remove the bracket.

Before installing the power module in the Single Drive cabinet, make sure that.

- The cabinet must be clean, without dust and approved for the installation.
- Flushing is done according to the flushing procedure and is approved.
- Valves for the cooling water supply shall be closed.
- Power module is ESD sensitive equipment, therefore it is recommended to follow ESD precautions.
- The cables are tucked away so that they are not damaged when the power module is sliding into the section.

10.5.4 Installing the power module

- Unpack the power module from the wooden crate and check that the ESD plastic bag is intact and not opened. Carefully remove the ESD form to prevent buildup of static electricity. Continue to unpack the ESD plastic bag and unscrew the metal covers around the power module – always wear ESD strap while observing ESD precautions.

- Inspect the power module for any visible damage from transport, dirt and dust on the module. Use cotton fabric to remove any dirt or dust.
- Attach the lifting bracket to the top of the power module with four Torx screws.
- Grease the guide spindles.
- Grease the fork plug power terminals by assembly and sealing grease.
- Lift the power module by using a hydraulic crane or another type of lifting device with sufficient lifting capacity. Remember to properly connect the lifting equipment to earth.
- Use the lifting device as a support platform.
- Carefully lift the power module. Make sure that ESD precautions are followed, and the power module doesn't bump into anything. Use the handles to guide the spindles of the power modules for pull-in.
- Use a battery drill on the 8 mm hex screws to push the power module into operating position. This is done by alternating between turning the upper and lower screws on the module. When tightening, or untightening the hex screws, alternate often to avoid jamming the module and damaging the threads. No more than 3 turns at each place.
- Ensure that the CONNECTED/DISCONNECTED locking brackets on top and bottom are properly mounted. The CONNECTED text should appear in the gap when the power module is properly mounted.
- Tighten the locking screw.
- Connect the separate earthing cable at the bottom of the front panel.
- Connect the cooling water hoses to the power module.
  The connection of water-cooling hoses to the power module can be done in the following order:
  - Assemble the connection as shown Figure 10-9
  - Remove blind plugs from the inlet and outlet connections at the bottom of the power module.
  - Apply a small amount silicone or Teflon based lubricant to the O-ring of male fitting at the bottom of the power module.
  - Use 36 mm wrench tools to tighten the brass fitting nut (**1**) at the bottom of the power module into the fitting. Keep by hand the straight fitting exactly perpendicular to the joint. Tighten the joint sufficiently tight, do not overtighten!
  - Tighten the assemblies into inlet and outlet pipes at the bottom of the power module.
  - ***Note!*** When disconnecting the power module water connections unscrew the brass fitting nut (**1**). There is no need to loosen any other connections.

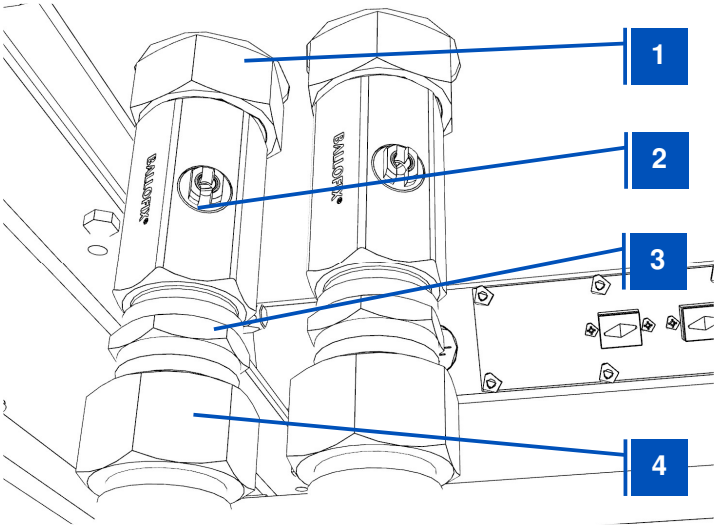


Figure 10-9 Power module water connections.

1	Fitting with hexagon nut with O-ring size 17,0x1,5mm, EPDM or Nitril material
2	Ball Valve G3/4" female threads
3	Hexagon Nipple outside threads 3/4"-3/4" koniske threads
4	Female fitting with hexagon nut

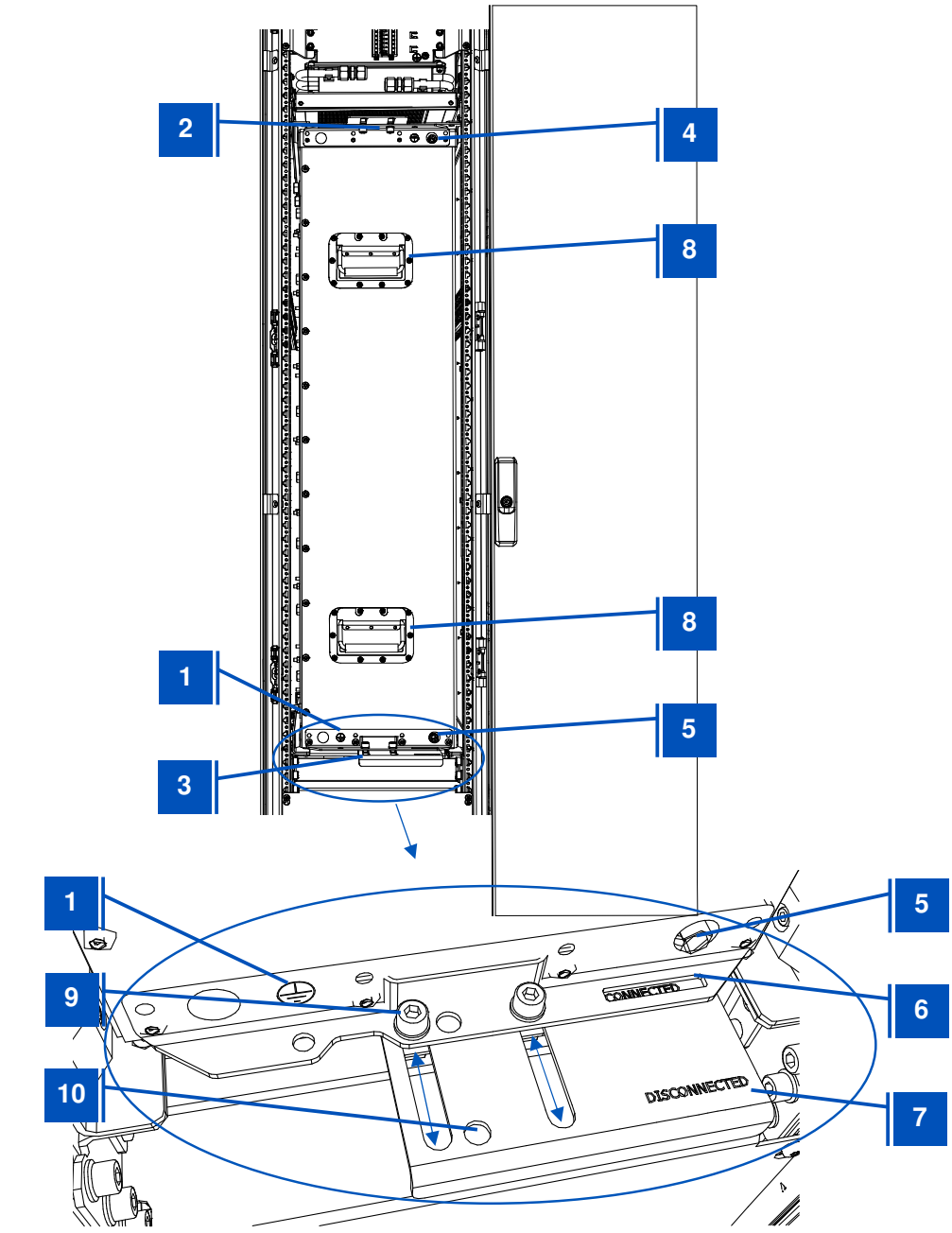


Figure 10-10 CONNECTED/DISCONNECTED locking bracket.

1	Earthing cable
2	Bracket locking upper, 6 mm hex key
3	Bracket locking lower, 6 mm hex key
4	Mounting screw upper, 8 mm hex key
5	Mounting screw lower, 8 mm hex key
6	CONNECTED position
7	DISCONNECTED position
8	Handles
9	Locking screws of the bracket
10	Bracket for padlock

Caution!
When installing the power module (PD4.1 protection devices), ensure that the cooling hose does not come into contact with the busbars.

- Install the cooling hoses. First start with the inlet then outlet.
- Start the external cooling system.
- In the bottom of the cabinet where the power module is mounted, there is inlet and outlet manifold for water cooling distribution. Open the outlet valve first and then the inlet.
- Check all the connections on the water-cooling piping inside the cabinet for leakages. Longer flushing time is needed if there are air bubbles in the piping. The system is self-ventilated, and the air bubbles will be flushed out.
- Let the water flow in the cooling system for 15 minutes, check the water leakage. If there is a water leakage, fix it before continuing to the next step.
- Connect the cables to the power module:
  - Power connector 230 VAC
  - Fiber connectors
- Disconnect the earthing cable at the bottom of the front panel of the power
- module.
- Check that all tools are removed before closing and locking the door.

10.5.5 Removing the power module

- Tools and equipment required for removing the power module are described in chapter 10.5.1, and preparation is described in chapter 10.5.2.
- Stop the Single Drive and open the main breakers and pre-charge breaker and lock them.
- Wait at least 5 minutes after opening the main breaker to ensure the power module has been fully discharged.
- Disconnect the control cables.
  - Power connector 230 VAC

- Fiber connector

- Disconnect the earthing cable at the bottom of the front panel of the power module.
- Remove locking bolts from the locking brackets.
- Close both the inlet and outlet valve of the manifold on the bottom of the cabinet.
- The disconnection of water-cooling hoses from the power module can be done in the following order.
  - Place a small bucket under the outlet water-cooling connection nuts then start to open the nuts, dry with cotton towels if necessary.
  - Put the blind plug on the outlet side and tighten it, this helps to avoid water spill when opening the inlet connection.
  - Place another small bucket under the bottom-left inlet water cooling hose's nuts then start to open the nuts. The water inside the module can be 0.5 - 1 liter.
  - When the water spilling has been finished, then put the blind plug on the inlet and outlet pipe of the module and tight it. Be careful not to let any water spill onto the module.
- Use a battery drill on the 8 mm hex screws to move the power module out of the operating position. This is done by alternately turning the upper and lower screws on the module. Stop drilling when the bolts become unscrewed.
- Mount the lifting bracket on the power module.
- Use the handles to pull the power module out.
- Check the voltage level on the power terminals of the pulled-out power module. Make sure there is no voltage on. Measure the DC voltage for safety reasons.



Warning!
In some abnormal situations, the discharge may take longer than 5 min.

- Lifting away: use a crane or other lifting arrangements. Remember to properly connect the lifting equipment to earth. Carefully lift the module out of the cabinet.
- Safe storage: the power modules that are removed from the section must be treated as new modules. To prevent frost damage, make sure cooling water has been drained off completely then put the blind plug on the inlet and outlet pipe of the module and tight it. Place the power module in ESD protective cover and then put it in a container or a pallet.

10.5.6 Moving the power module to disconnected position

The power modules are possible to move to the disconnected position if there is a need to operate the Single Drive without the power module.

- Stop the Single Drive and open the main breakers and pre-charge breaker and lock them.
- Wait at least 5 minutes after opening the main breaker to ensure the power module has been fully discharged.

- Do not disconnect the earthing cable.
- Do not disconnect the cooling hoses.
- Lose the bracket locking bolts.
- Use a battery drill on the 8 mm hex screws to move the power module out of the operating position. This is done by alternately turning the upper and lower screws on the module. Stop drilling when the bolts become unscrewed.
- Use the handles to pull the power module out against the bracket.
- The DISCONNECTED text should appear in the gap when the power module is securely disconnected.
- Tighten the bracket locking bolts.

10.5.7 Moving failed power module to disconnected position

The power modules are possible to move to the disconnected position if there is a need to operate the Single Drive without the power module.

- Stop the Single Drive and open the main breakers and pre-charge breaker and lock them.
- Wait at least 5 minutes after opening the main breaker to ensure the power module has been fully discharged.
- Confirm condition of safe voltage levels.
- Loosen four fastening screws in the locking mechanism by a tool for purpose.
- Drive the power module by a tool for purpose out from the position “CONNECTED” to position “DISCONNECTED” by built-in long stud bolts dedicated for the purpose in the power module.
- Pull the module from handles to the most outer position limited by the locking mechanism and secure in place by four screws in the locking mechanism.
- Use padlock (bracket Ø 10 mm) to secure to position DISCONNECTED.
- Close and lock the cabinet door with a key for purpose.

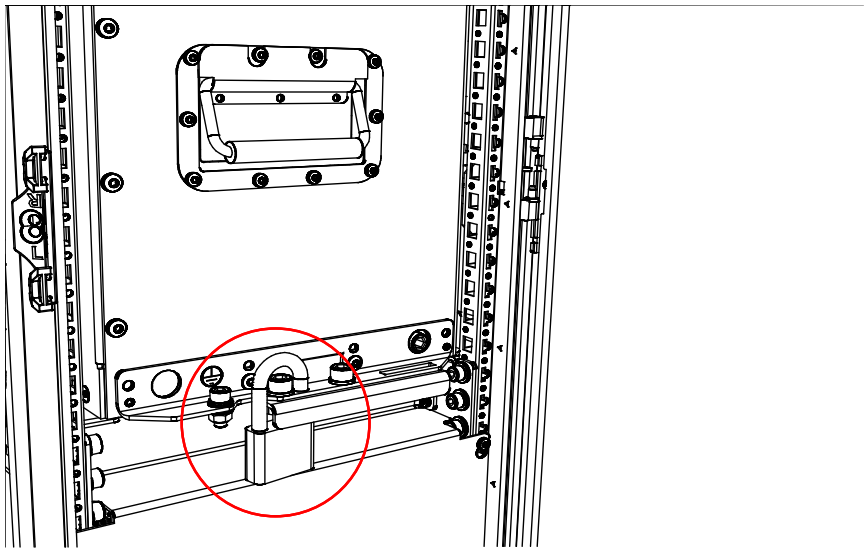
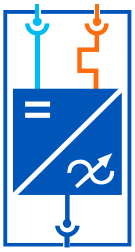


Figure 10-11 The power module is locked to DISCONNECTED position by using a padlock.

11 Active front end rectifier (AFE)



11.1 Active front end

An active front end converter (AFE) connects the DC link to an AC grid for bi-directional power flow. It means that when the power flows from the grid to the DC link, then the AFE behaves as a controlled rectifier. And when the power flows from DC link to the Grid, then AFE behaves as synchronized inverter.
The AFE can either be connected to shore or an on-board switchboard. The voltage and frequency are configurable.
The Switch AFE can be operated in two different modes, termed as load mode and source mode.
In load mode (AC frequency droop control), the AFE controls the amplitude & phase of voltage and current of the converter for a fixed grid frequency (50/60 Hz), It can synchronize to an existing grid or perform black-start and operate in island (off grid) mode. The power flow between AC grid and DC link can be controlled using frequency increase/decrease pulses.
In source mode (DC link voltage control), the AFE is responsible for controlling the DC link either solely or together with other units using droop. Reactive power control using a set-point is also possible while in this mode.
The AFEs are controlled remotely either the upper-level system by Modbus UDP-IP or application PLC – or locally by HMI display.
Various limiter and protection functions are implemented in the AFE to ensure safe operation.

11.2 AFE hardware and filter overview

The AFE has an LC-filter between the grid and the power module. The filter's reactors are air cooled with dedicated liquid to air heat exchangers. The temperatures of reactors are monitored.

11.3 AFE local process stop

The AFEs are equipped with AFE process stop push buttons, which shuts down the functions of that AFE – no MI or other AFE.

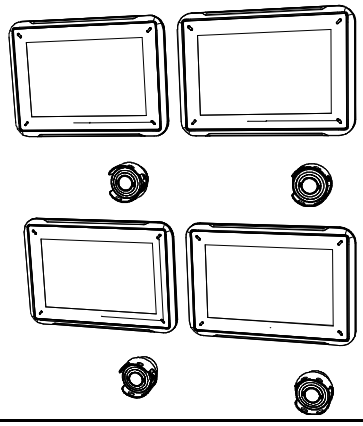


Figure 11-1 AFE and MI HMI local displays and process stop buttons (example).

11.4 AFE HMI local display

There is one HMI for each AFE application. The main page of each HMI shows the most important quantities measured by the converter (voltage, current and power).
Refer to chapter 6.5.1 Power module HMI for HMI menu bar and other background functions.
The AFEs can be operated and monitored both from the local touch display or remotely.



Warning!
Electrical hazard. Users should not trust overview indications of voltage if working inside cabinet.



Always use proper measuring tools to ensure there is no voltage present before work.

11.4.1 Home screen

The home screen will be used as a start-up screen. The home screen shows important information about the MI. Actual control mode in text format, power in both kW and percentage, speed in both rpm and percentage, DC link voltage in volts DC, current in ampere, frequency in Hertz. On the right-side there are external references in percentage. To access home screen from another screen press home icon in the menu bar (Figure 12-3).

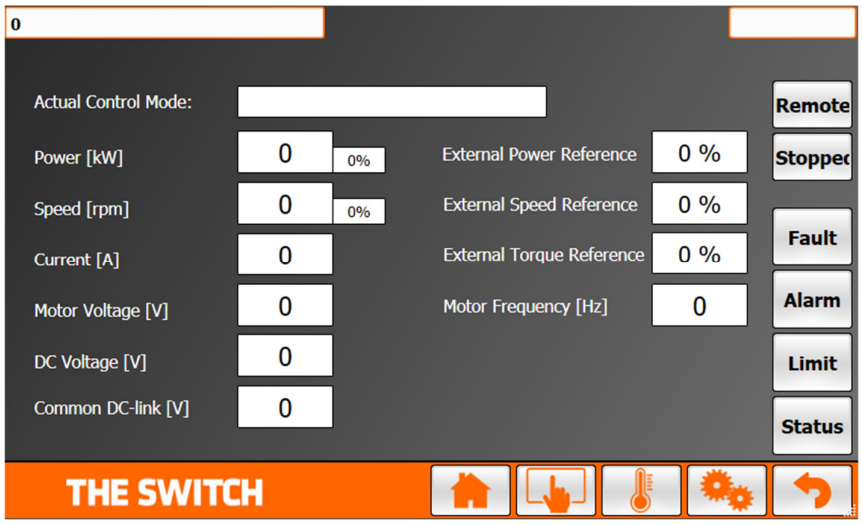


Figure 11-2 Home screen.

11.4.2 Local control screen

Local control screen is intended for manual control of the drive from the HMI display. You can get to the local control screen by pressing on the local control button in the menu bar second most to the left. In the top of the orange box, local control can be activated if pressing the green enable button. When local control is inactive, control buttons are greyed out and will have no actions if pressed (Figure 11-3). When the local control enable button is pressed an icon in the green box will show that local control is active (Figure 11-5).

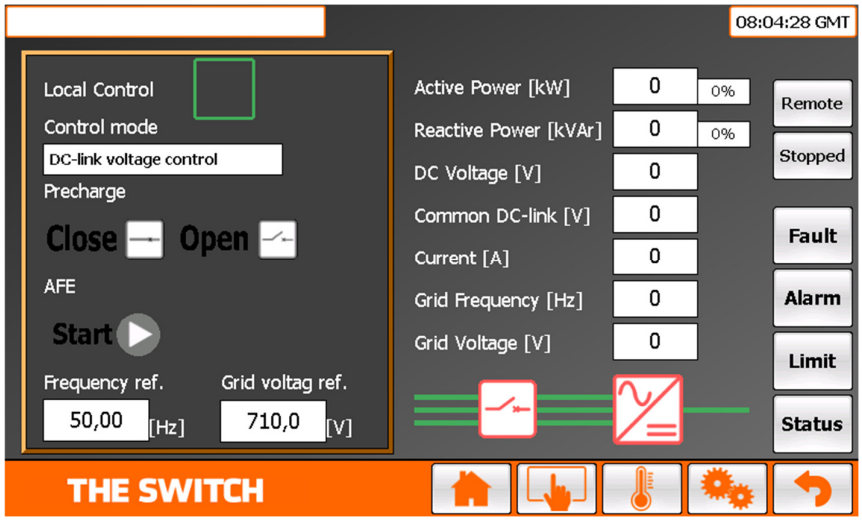


Figure 11-3 Local control screen OFF.

Control buttons will be enabled for manual control of the drive. The actual control mode will be visible below the local control enable button. To change the control mode, press the Change button. A new popup window (Figure 11-4) will appear with the active control mode highlighted in orange. Click on the white colored control mode box to change it. The window can be closed from the red cross marker in the bottom right corner.

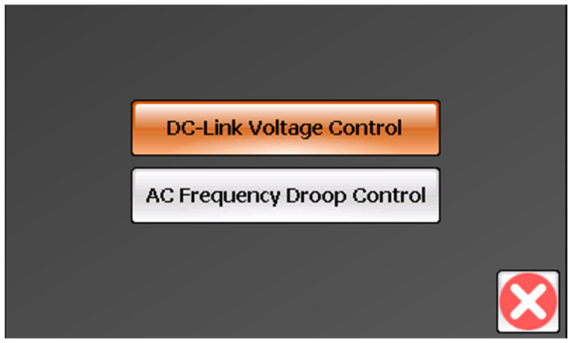


Figure 11-4 Popup window.

By pressing the close button, pre-charge will be executed and closing of E-DCB will take place. Open button will open E-DCB. When pressing the start button, the breaker will be closed and AFE will go into a running state. By pressing stop, modulation will stop, and breaker will be opened.

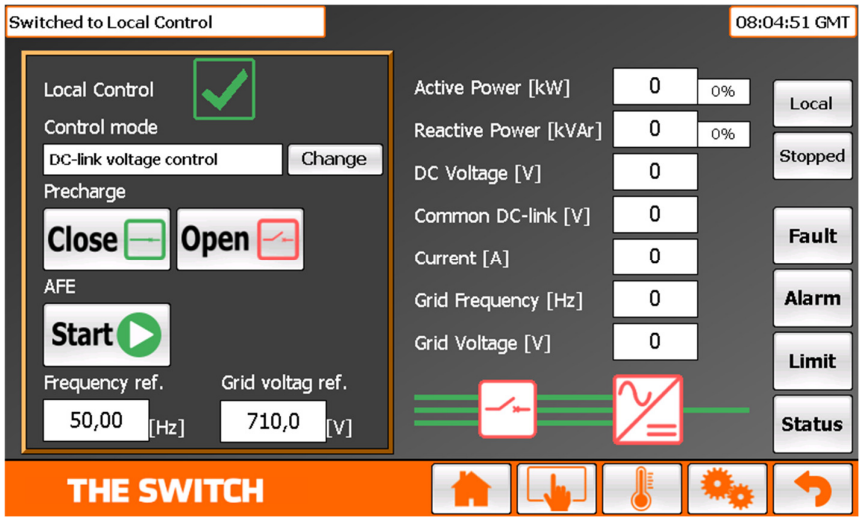


Figure 11-5 Local control screen ON.

In the bottom of the orange box, there are two reference values “Frequency reference” and “Grid voltage reference”. Initially these will show the actual value used by the control of AFE. When switching from remote to local, AFE will continue to use the value that was active in remote control to make a smooth changeover. The reference values can be adjusted by clicking inside the value box. A numpad popup screen will appear where a new value can be entered (Figure 11-6). Insert the wanted value and click on the enter icon. If the new value is inside the allowed range, the new value will be presented in the box. It’s important to note that the entered value will be scaled, and twice before being presented in the box and therefore it’s possible that the value has been rounded off. If a value outside the allowed range has been entered, a new popup window will appear to inform the user that the new value will not be accepted (Figure 11-7). The references are only used in AC frequency droop control mode.
On the right-hand side important information will be presented for the drive. In the lower right-side there is an overview of the drive. The breaker icon shows the status of the grid circuit breaker. Red means open and green closed status. The drive icon will give a status of the drives state, red means stopped and green running.

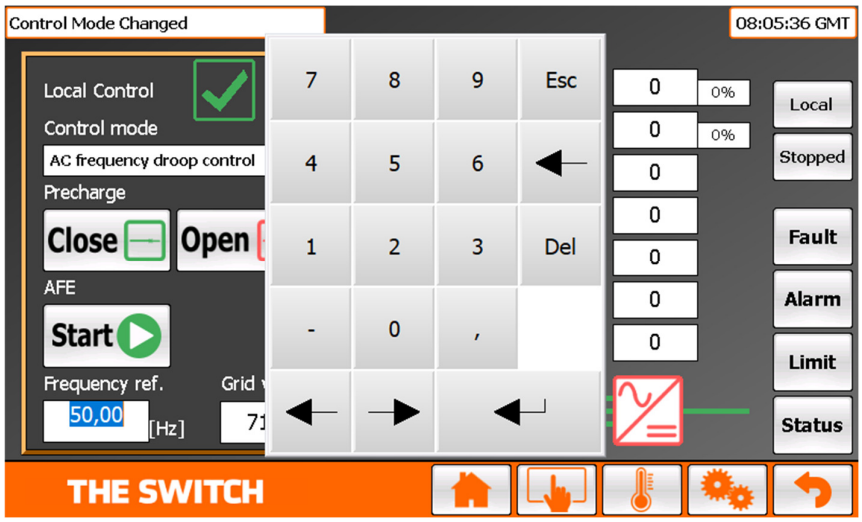


Figure 11-6 Numpad popup.



Figure 11-7 Popup input value out of range.

11.4.3 Temperatures screen

In temperatures screen cabinet and control related temperatures will be shown. Temperatures are presented in degrees Celsius. Utilization factors in percentage are shown on the right side per each bridge leg of the power module.

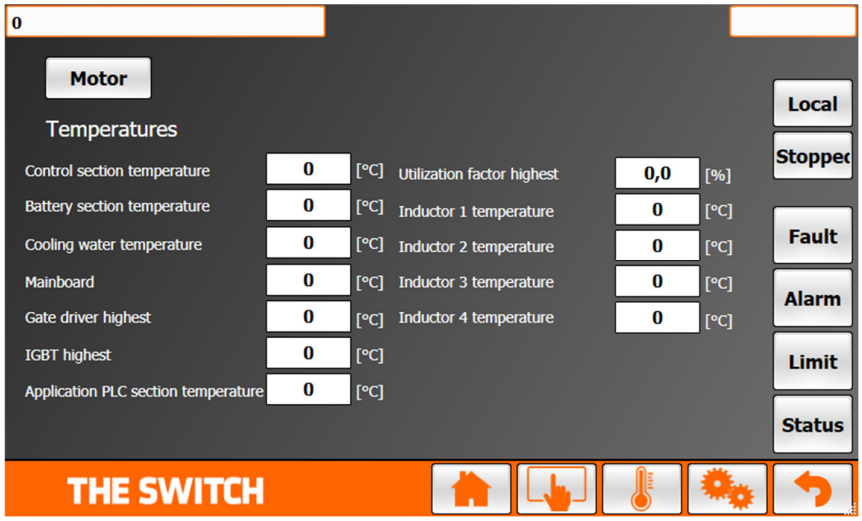


Figure 11-8 Temperatures screen.

11.5 AFE insulated measurement card (IVM) circuits

An insulated measurement card and a pre-charge circuit are installed next to the AFE converter. The IVM measures grid side voltage and frequency. The IVM communicates with its CCO (Central Control Board) via fiber optic cable.

11.6 AFE pre-charge system functionality

The pre-charge circuit consists of resistors, fuses, three diode bridges and a contactor which is controlled by the PLC.
The pre-charge arrangement limits the charging current of the DC link capacitor banks located on the power modules. The pre-charge supply is fed from the main supply via resistors and diode bridges. The resistors limit the inrush current to the desired value and the voltage builds up according to the time constant.
When the voltage level reaches a sufficient value, the main breaker is closed after some seconds and AFE enters in run-mode. The pre-charge circuit is protected by fuses. Refer to the circuit diagram for the detailed connections.
Each AFE has its own pre-charge unit as product option.

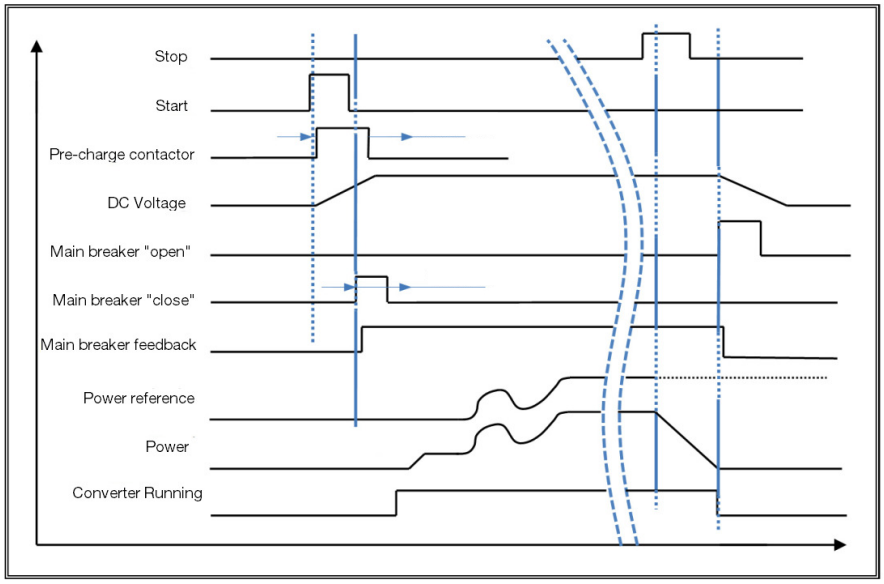


Figure 11-9: Pre-charge sequence.

Table 11-1.

Word used in Figure 11-9	Explanations of word
Stop	Stop signal coming from drive control system for the main breaker. Used to stop and de-energize the DC link.
Start	Start signal coming from the drive control system for the main breaker. Used to energize the DC link.
DC voltage	Voltage on DC link of converter. Can be monitored in display.

Word used in Figure 11-9	Explanations of word
“Open” breaker	Signal from the converter to open the internal breaker of AFE, or open breaker command on local panel.

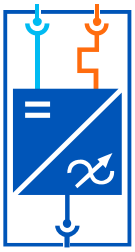
11.7 AFE tuning and troubleshooting

For AFE alarms and faults refer to the separate document The Switch DC-Hub Interface List Refer to the document list chapter 3.2



Caution!
Insulation alarm detected in converter, possible earth fault present in circuitry. The cause of the alarm must be clarified. Double earth fault can be hazardous. It is under the user’s responsibility if you decide to continue using the product.

12 Motor inverter (MI)



Motor inverters convert the DC voltage to the controllable AC voltage and frequency. By varying the voltage and frequency, the speed and torque of the e-motor (induction motor or permanent magnet synchronous motor) can be controlled.

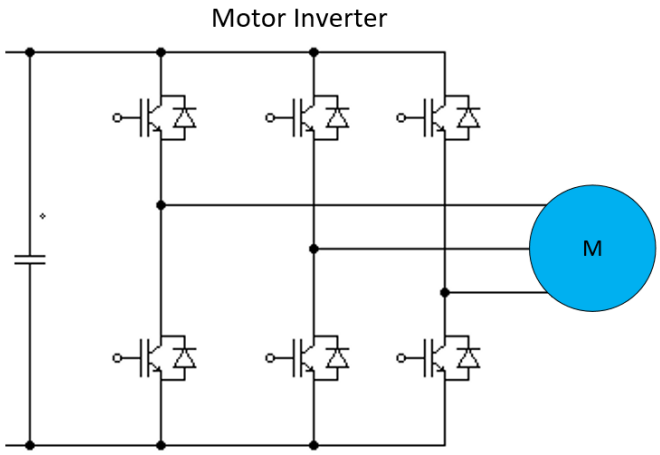


Figure 12-1 Electrical overview of the motor inverter (MI).

12.1 Motor inverter overview

MI converts the DC Voltage to the varying frequency and AC voltage, in other words MI controls the speed and torque of the e-motor.
Motor Inverter MI is directly connected to the motor.
The MI is controlled remotely either by the upper-level system (Modbus UDP/IP) or application PLC – or locally by HMI display.

12.2 MI local process stop

The MI is equipped with MI process stop button, which shuts down the functions of that MI application – not AFEs.

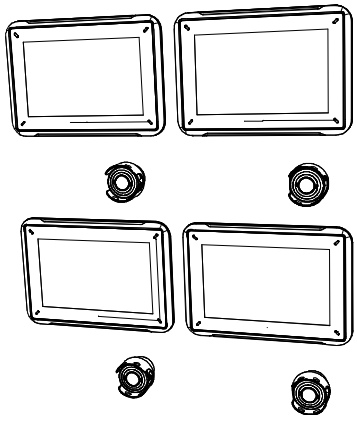


Figure 12-2 MI and AFE HMI local displays and process stop buttons (example).

12.3 MI HMI local display

The main page of HMI shows the most important quantities measured by the power module (power, speed, voltage, current and frequency).

Refer to chapter 6.5.1 Power module human machine interface for HMI menu bar and other background functions.



Warning!
Electrical hazard



Users should not trust overview indications of voltage if working inside cabinet. Always use proper measuring tools to ensure there is no voltage present before work.

12.3.1 Home screen

The home screen will be used as a start-up screen. The home screen shows important information about the MI. Actual control mode in text format, power in both kW and percentage, speed in both rpm and percentage, DC link voltage in volts DC, current in ampere, frequency in Hertz. On the right-side there are external references in percentage. To access home screen from another screen press home icon in the menu bar (Figure 12-3).

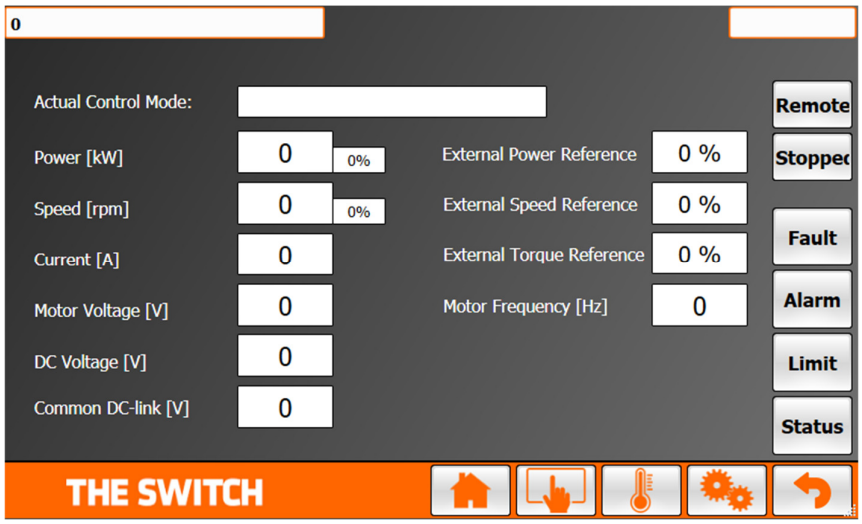


Figure 12-3 Home screen.

12.3.2 Local control screen

In local control screen (Figure 12-4) manual control of the drive is possible. If the local control is inactive, control buttons will be greyed and inhibited for further use. To activate local control the green box must be pushed. An indication that local control is active can be seen when the green box is marked (Figure 12-5). Depending on if a breaker is connected to the MI, Close and Open buttons will appear when local control is active. When pressing the Close button, a normal pre-charge will be executed, and the breaker will close. The open breaker will command the breaker to open even if the motor is running. The motor can be started by pressing the Start button. If the motor is running the start button will change to a stop button, from which the motor can be stopped. Arrows up and down are for increasing and decreasing reference. Depending on what control mode is active, different references will change. In the bottom right-side there is an overview of the MI. When the power module is stopped the icon will be red, and when the power module is running it will switch to green color. The lines represent cables and will be blue when no voltage is present. When voltage is above a certain limit, they will light up green.

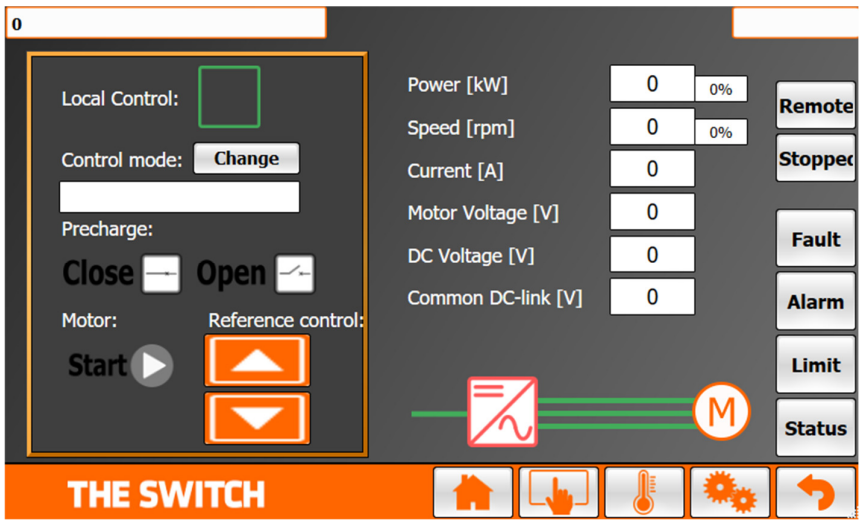


Figure 12-4 Local control screen OFF.

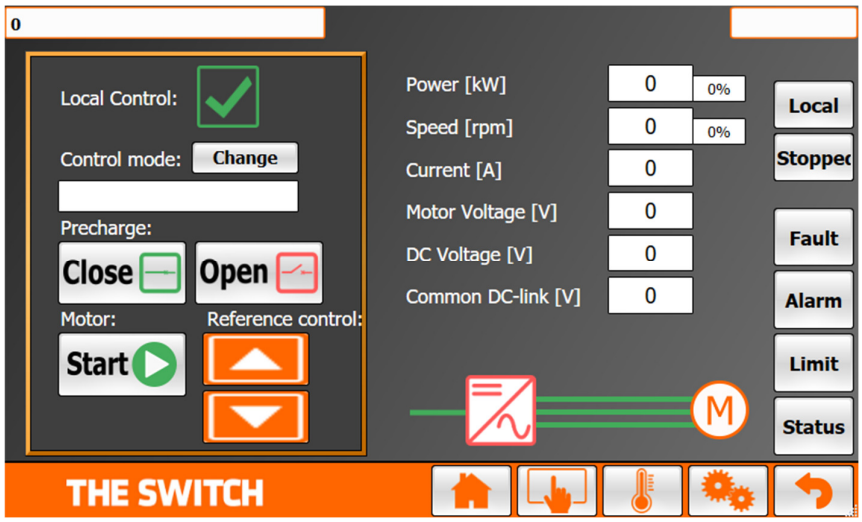


Figure 12-5 Local control ON.

12.3.3 Temperatures screen

In temperatures screen cabinet and control related temperatures will be shown. Temperatures are presented in degrees Celsius. Utilization factors in percentage are shown on the right side per each bridge leg of the power module.

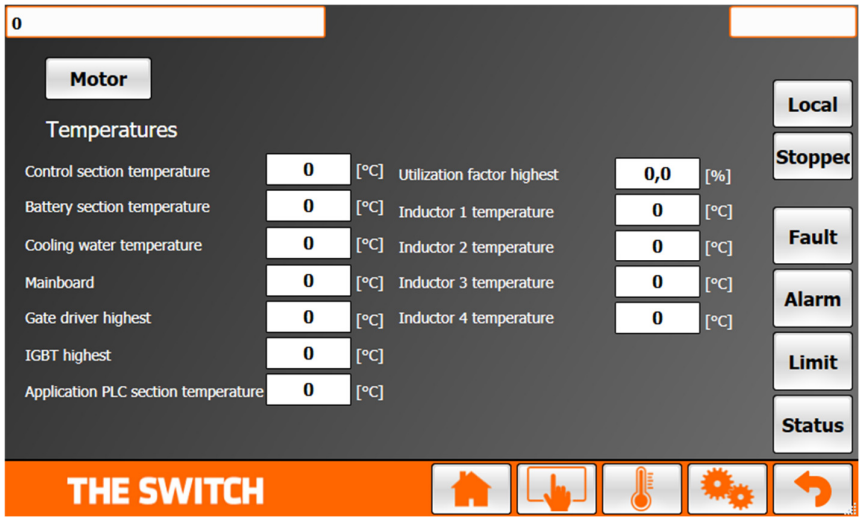


Figure 12-6 Temperatures screen.

12.4 MI power cable installation

Refer to chapter: General guidelines for power cable and MCT packing.

Motor inverter requires three core cables and a balanced connection on the inverter's output side to achieve proper current sharing.

12.5 MI control

Main components of the MI control are listed below:

- CCO, Central Control board.
- PLC, Programmable Logic Controller.
- HMI, Human Machine Interface, local touch display.
- Process stop button.

These components are connected to each other, and the external component as shown in figure below:

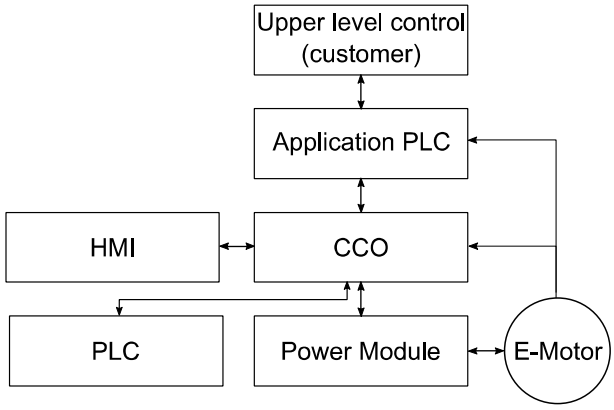


Figure 12-7 MI Control component interface.

The main task of the CCO is to control the motor drive, and to

- Communicate with PLC.
- Communicate with HMI.
- Communicate with the upper-level control (customer).
- Control the power module.
- Communicate with other MI if torque follower mode is enabled.

12.6 Motor parameter configuration

Before starting up e-motor parameters must be uploaded to the MI software. The e-motor parameters can be found from the e-motor nameplate. An example of an e-motor name plate is given in (Figure 12-8). Some of the parameters are set by using ID Run function.

MACHINE TYPE	**PMM0450H01**
MACHINE CODE	**PMM0450H01-01650-01800-00690-03-55-I-L-H-S**
MACHINE SERIAL Nº	XXG0XXX
POWER	1650 kW
TERMINAL VOLTAGE	690 V
CURRENT	1550 A
POWER FACTOR	0,92
RATED FREQUENCY	90 Hz
SPEED (RATED / MAX)	1800 rpm / max 2292 rpm
THERMAL CLASS	130
INSULATION CLASS	155
PROTECTION CLASS	IP54
DUTY CYCLE	S1
AMBIENT TEMPERATURE (MIN/MAX)	min 0 ºC / max. + 45 ºC
CONNECTION	STAR
NUMBER OF PHASES	3
WEIGHT	3850kg
COOLING	IC8A6W7
COOLING INLET TEMPERATURE	max. 38 ºC
MANUFACTURING YEAR	2017
OPEN CIRCUIT VOLTAGE AT MAX SPEED	750 V

Figure 12-8 Nameplate of e-motor where necessary parameters of the MI can be found.

Table 12-1

Parameter name	Description
Voltage rating (V)	The rated line-to-line voltage of the motor.
Current rating (A)	The rated current of the motor.
Frequency (Hz)	The rated frequency of the motor.
Speed rating (RPM)	The rated speed of the motor.
Power rating (MW)	The rated power of the motor.
Number of poles	The number of poles in the motor (see details below).
Stator resistance (Ohm)	The per-phase resistance in the stator windings. This value can usually be found in the motor test report, or the service tools can be used to automatically find this value.
Leakage reactance (%)	The total leakage reactance of both stator and rotor in an induction machine. ID run can be used to this value. Note that this value is only used for induction machines.
Magnetizing reactance (%)	Induction machine no-load magnetizing reactance.
Motor efficiency (%)	The rated power efficiency of the motor at nominal speed and load.
Power factor rating	The rated power factor of the motor.
Motor type 1	Induction Machine: Permanent Magnet Synchronous Machine (PMSM)
Rotor resistance ratio	The ratio between rotor and stator resistance. Only used for induction machines. This value can be calculated from the No-load and blocked rotor short-circuit tests for the machine.

The number of poles in the motor is usually not found on the e-motor nameplate but can be calculated from the rated frequency and rated speed using the following equation:
n = 2 * [Rated Frequency (Hz) / Rated Speed (RPM)] * 60
and round off to the nearest integer. To have the value calculated automatically this parameter can be set to zero.

12.6.1 Operations mode

The MI can operate in torque mode, speed mode, power mode and DC-voltage mode. Controlled mode is shown in the figure below.

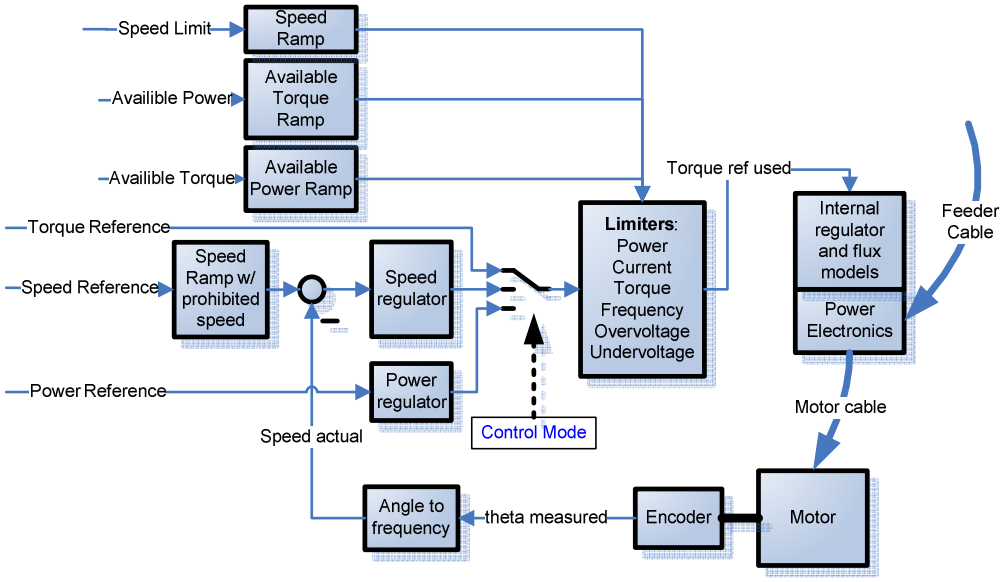


Figure 12-9 Control-mode of the MI.

Table 12-2 PID 418: Selector Motor Control Mode can be used to change the operation mode.

PID 418: Selector Motor Control Mode	
Actual Value	**Operation mode**
0	Torque Mode
1	Speed Control mode
3	Power Control mode
4	DC Voltage Control

Torque control
The most basic control mode is the Torque Control mode, in this mode the input reference is a torque reference, which is passed through an internal, configurable, ramp function before it is applied to the motor.

Speed control
When the control mode is set to speed control, the motor controller will try to keep the speed of the motor equal to the reference after some processing. A simplified block schematic of this process is shown in (Figure 12-10) below. The input is the external speed reference, and the output is the torque reference to the motor.

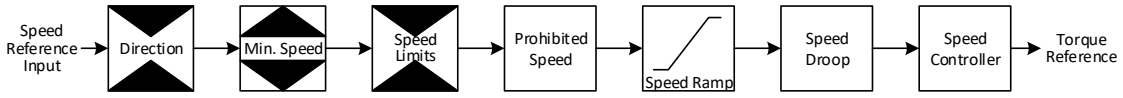


Figure 12-10 Simplified block schematics of the speed control process that is enabled when the control mode is set to Speed Control.

Power control

The power mode makes the use of the relation.

Power = Torque * Speed

The power reference is transformed to an internal torque reference based on the actual speed. All limits and protections valid in torque mode are also used in Power Mode.

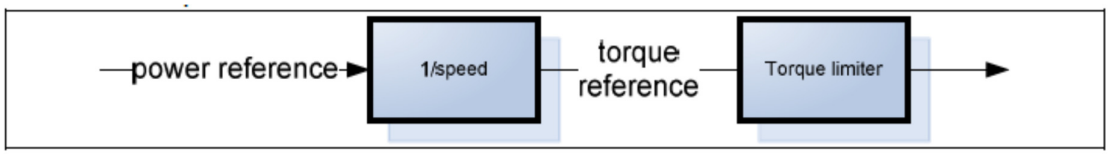


Figure 12-11 Power mode.

DC voltage control

When the motor control mode is set to DC Voltage Control, the motor controller will try to keep the DC Voltage of the inverter equal to given reference value. This mode is suitable for shaft generator operation when the motor inverter must be responsible for controlling the DC voltage. This is typically the case when the motor inverter is paired with an Active Front End converter that is running in Grid Control Mode (Load mode).

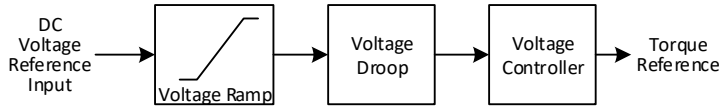


Figure 12-12 DC voltage control mode.

DC Voltage reference

The DC voltage reference is by default set in the parameter database using PID 487, Voltage Reference DC, and cannot be changed while the motor is running.
If an adjustable voltage reference is needed, release 1.73.0, there is also an option where the reference can be set from the PLC by writing to a signal parameter. To enable this function the configuration parameter PID 496 must be set to 1, signal parameter PID 2027 Voltage DC Reference PLC can then be used to set the reference.

Torque follower

Torque follower function is based upon having a fast, redundant intercommunication between all the mainboards that are controlling the same load. A master-slave principle is used whereas the master can be operated in any of the available control modes and the slave (follower) in torque mode.

To allow the MI PLC software to change the operation mode, PID 419 should be configured.

Table 12-3

PID 419: Selector Control Mode PLC	
Actual Value	**Operation mode**
0	Not allowed: MI PLC software cannot change the motor control mode
1	Allowed. MI PLC software can change the motor control mode.

Coast stop and ramp stop
Coast stop and ramp stop can be configured from PID 435: Selector Motor Stop Mode.

Table 12-4

PID 435: Selector Motor Stop Mode	
Actual Value	**Description**
0	Coast Stop: Disable the inverter when the stop command is given
1	Ramp Stop: Ramp down the motor speed down to 0 before disabling the inverter.

Direction of rotation
MI can rotate the e-motor in clockwise (positive) and counterclockwise (negative) direction. By default, the e-motor shaft rotates in a Clockwise (positive) direction, standing on the e-motor and looking toward the load. PID 470: Selector Speed sign Allowed is used to change the direction of the speed.

Table 12-5

PID 470: Selector Speed sign Allowed	
Actual Value	**Description**
0	Both directions
1	Only positive direction (Clockwise)
2	Only negative direction (Counter-Clockwise)

ID run
ID run tools is used to identify the stator resistance, leakage inductance and the magnetizing inductance of the induction/asynchronous motor, see figure below.

! ***Note!***
While measuring the motor stator resistance and leakage inductance, make sure that the motor is still and not rotating. Any rotation due to external forces will affect the measurements. It is normal that the stator resistance

measurement test causes some movement of the motor shaft, and these are considered during the measuring phase.

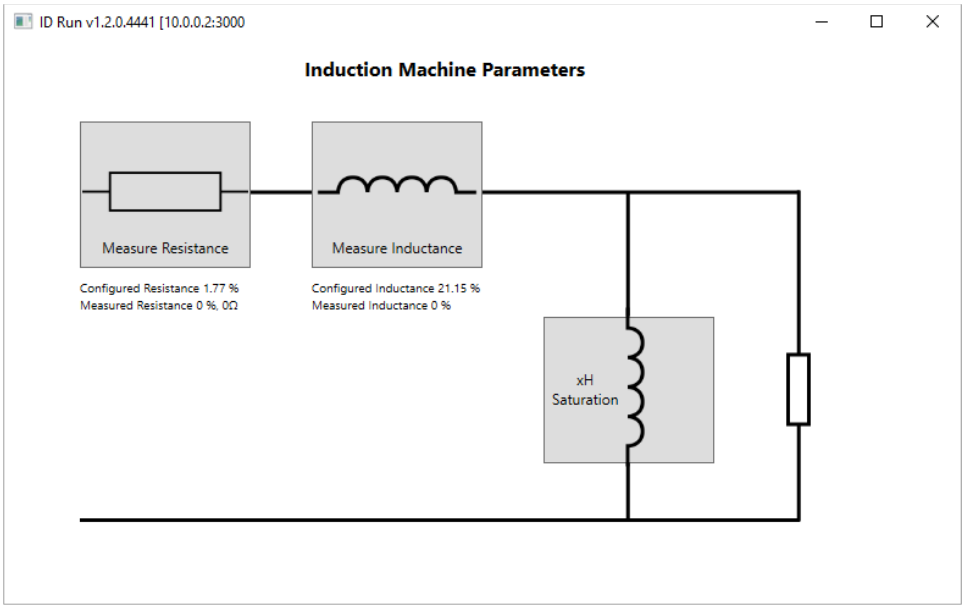


Figure 12-13 Parameter of the e-motor to be measured with ID RUN.

When the test is finished, the resulting measurements are shown in the Test Results table. All the measured values should be written to the parameter database at PID 206, PID 207 and PID 208 respectively. The measured unit for leakage inductance and magnetizing inductance is in per unit/percentage (%), whereas the parameter unit for leakage reactance and magnetizing reactance is also in per unit/percentage. After saving the parameter the drive must be rebooted for the changes to take effect.
See chapter 15.18. ID Run procedure.

Only perform ID Run procedure if told to do so by qualified service engineers.

Only perform the test on a disconnected motor with no load. Do not perform this procedure on a hot e-motor

12.7 Encoder (optional)

The Encoder Interface Board (EIB) gives speed-feedback from the motor rotor to the main control board. The EIB connects to the main control board (CEL) using glass fiber. The EIB itself shall be mounted close to the motor to keep the encoder cables as short as possible. External encoder cables and fibers are not in The Switch scope.

The following types of encoders are supported, depending on the machine type:

Induction Machines

- Only incremental, HTL[4] type, encoders are currently supported.
- Recommended pulse count is 1024-2048 for most applications
- Encoder power supply from EIB is 24 V (max 200 mA)

Permanent Magnet Synchronous Machines

- Only SSI and EnDat 2.1 or 2.2 are supported
- Recommended minimum number of pulses is 4096 (12-bit)
- Only single turn encoders are supported
- Encoder power supply from EIB is 12 V

The use of the EIB requires that the following things are in order:

- The CEL board is equipped with the optional Glass Fiber Transceiver (GFT) board.
- Industrial fiber is installed between the EIB and the control cabinet.
- Fiber splicing box is installed in the control cabinet of the DC-Hub or the Single Drive.
- Optical fibers with LC connectors are installed between the GFT and the splicing box.

[4] HC-HTL from Leine Linde is HTL compatible

12.7.1 Encoder installation

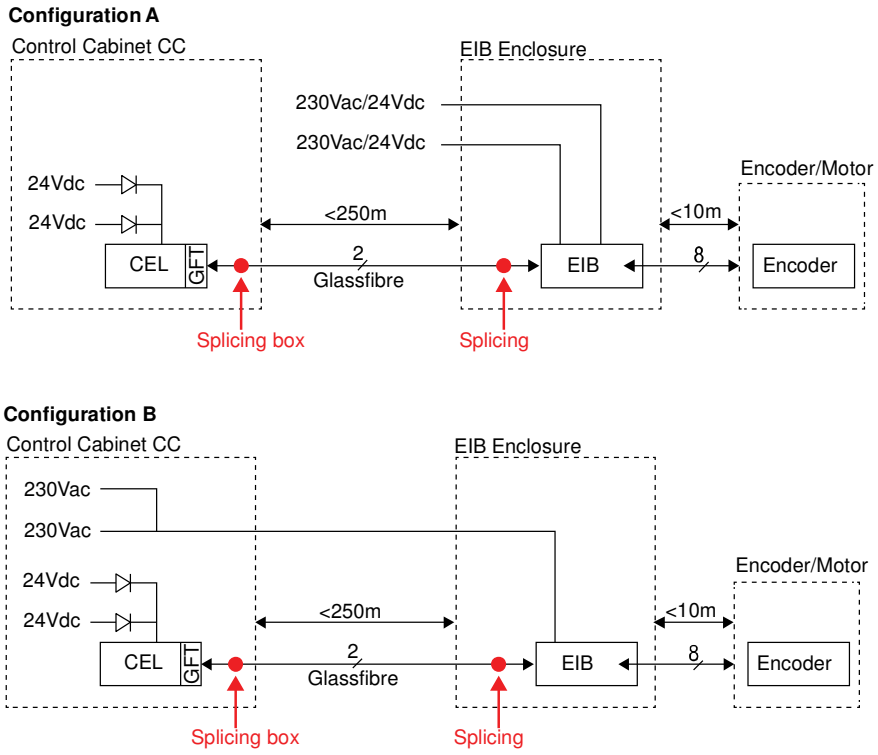


Figure 12-14 Fiber cable splicing points.

The board shall be mounted in several positions with regards to the encoder and the main control electronics. The default configuration is shown in Figure 12-14 Configuration **A.** This configuration will likely be used in most marine environments, where DC voltage is readily accessible, and the EIB is located close to the encoder/motor (<10 m). Two 110 Vac to 230 Vac supplies will supply the EIB Enclosure and will be converted by on/off board converters to two 24 Vdc supplies to power the board electronics and the encoder. The fiber link back to the control electronics can be up to 250 m. Figure 12-14 Configuration **B** shows a similar configuration to the one described in Configuration **A** but the EIB and encoder will have power supplied from the control cabinet.
The EIB enclosure shall be installed close enough to the encoder of the E-motor, the maximum cable length between them is 10 m.

Dimensions of cast aluminum enclosure are 232 mm x 202 mm x 113 mm (H x W x D).

The shipyard shall perform the installations according to this instruction. Only the Switch's authorized service personnel can perform configuration process.



Figure 12-15 Installed EIB enclosure.

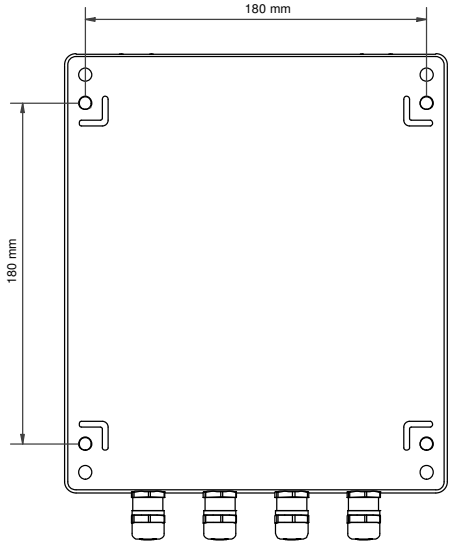


Figure 12-16 EIB enclosure fixing points.

The size of the hole for the fastening bolts are Ø 7 mm. 23 mm shall be added to the length of the bolts that will attach the EIB enclosure to the bulkhead.

12.7.1.1 Splicing box (control section)

The rugged fiber needs to be spliced/terminated in the control section to connect to the CEL board equipped with the optional GFT board. Two short (~1 m) pigtail cables with LC connectors on one end are spliced to the fibers using a fusion splicer. A splicing box is required to provide an anchor point for the rugged fiber and to provide space to protect and store the excess length of (thin = Ø0.9 mm) fiber.



Figure 12-17 Splicing box.

12.7.1.2 Fiber termination EIB enclosure

The rugged fiber needs to be spliced/terminated in the EIB enclosure to connect to the printed circuit board. Two short (~1 m) pigtail cables with LC connectors on one end are spliced to the fibers using a fusion splicer. The pigtail cables must match the fiber type in the rugged cable (Multimode 62.5/125 mm or 50/125 mm). The excess fiber is stored inside the enclosure as shown below.

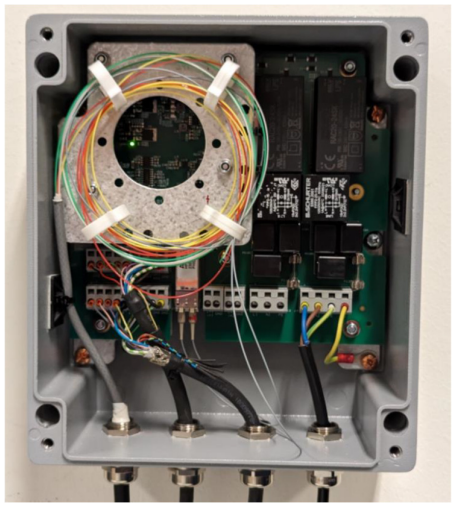


Figure 12-18 EIB enclosure with terminated fiber.

12.7.2 Encoder fiber cable type and length

Fiber cable length is case specific. The maximum fiber cable length is 250 m. It is the system integrator's responsibility to acquire a suitable fiber cable and connect it by using fusion splicing. Refer to the circuit diagram.

The encoder board enclosure will typically be mounted next to the motor. The fiber is routed from the encoder board enclosure to a splicing box in the control section of the drive. The cable needs to be of a rugged type and in accordance with [3] DNVGL-CP-0402 edition February 2016 Class program type approval optical fiber cables.

Fiber cable specification:

- Type: Multimode 62.5/125 mm or 50/125 mm

- Number of fibers: 2 or more
- Outer diameter: 4.5 to 10 mm (to fit cable gland LAPP 53112625)
- Secondary coating: 0.9 mm
- Tensile strength: >500 N
- Crush: 1000 N 3 test points, 0.5 m between test points

12.7.3 Encoder configuration parameters

Contact The Switch / Refer to the separate document how to make required configuration for different types of encoder and motors.

Table 12-6 Encoder configuration parameters

PID	Name	Description
980	Selector Encoder Interface Enable	Enable the Encoder Interface Board (EIB). This parameter must be set to 1 to use any type of encoder.
981	Selector EIB 24V Output Enable	Enable the 24 V supply voltage for HTL type incremental encoders.
982	Selector EIB 12V Output Enable	Enable the 12 V supply voltage for SSI and EnDat encoders.
983	Selector Encoder Interface Type	Select which type of encoder is connected to the EIB. 0: HTL type incremental encoder 1: EnDat 2.1 or 2.2 2: SSI
984	Incremental Encoder Pulse Count	The pulse count of the incremental encoder.
985	EIB Inverter Trip Mask	Configure which events shall cause an instantaneous trip of the inverter.
986	EIB E-DCB Trip Mask	Configure which events shall open the E-DCB
987	EIB Alarm Mask	Configure which events shall raise an alarm.

12.8 MI tuning and troubleshooting

For MI alarms and faults refer to separate documents The Switch DC-Hub Interface List Refer to the document list chapter 3.2



Caution!
Insulation alarm detected in converter, possible earth fault present in circuitry. The cause of the alarm must be clarified. Double earth fault can be hazardous. It is under the user's responsibility if you decide to continue using the product.

13 DC/DC converter



13.1 DC/DC overview

A DC-to-DC converter (DC/DC) converts one DC voltage level to another DC voltage level. The Switch DC/DC converter can connect a DC source (e.g., battery or fuel cell) to the DC link enabling bi-directional power flow. It can operate in either load mode or source mode. In load mode, there are two control modes that can be used. Power and current control. When power control mode is selected, a power reference set-point is used to control the power flow to or from the DC link. When the current control mode is selected, a current set-point is used to control the power flow to or from the DC link. This can be constant power or dynamic power for peak-shaving applications. This power reference, together with the instantaneous battery voltage, determines the battery charging/discharging current.
In source mode, the DC/DC is responsible for controlling the DC link either solely or together with other units using droop. The battery charging/discharging current is then dependent on the various units connected to the same DC link.
Limiter and protection functions are implemented in the DC/DC control to protect the power electronic converter itself and the battery from overcurrent, overvoltage or undervoltage during operation.

! ***Note!***
DC/DC is not reverse power protected, and a fuel cell cannot be directly connected to it.

Table 13-1 6 DC/DC functionality.

Variable	Type	Comment
Control modes	Source mode	DC voltage control
	Load mode	Grid frequency control
Source mode control	Fixed DC voltage control	
	DC voltage droop control	DC voltage controlled by actual power and grid voltage
	Reactive power control	Compensation or reference
	Grid voltage droop control	Grid voltage controlled by reactive power
Load mode control	Grid frequency control	
	Frequency droop control	Active power sharing with other sources. Linear or dynamic droop
	Black out start	Grid creation
	Island mode operation	Single source in grid
	Grid voltage droop control	Grid voltage-controlled by reactive power
	Grid oscillation damping	
Other main functionality	Grid synchronization	Synchronization to measured grid voltage before connecting

13.2 DC/DC local process stop

The DC/DC are equipped with process stop push buttons, which shuts down the functions of that DC/DC – no AFE or other application.

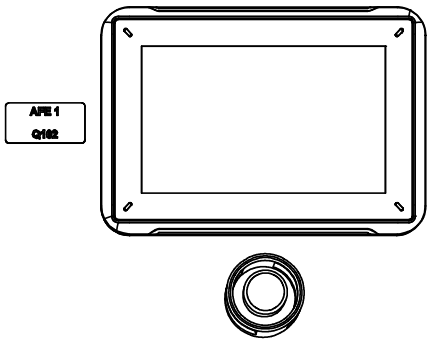


Figure 13-1 DC/DC HMI local display and process stop button (example).

13.3 DC/DC breaker

Each DC/DC application in a DC-Hub comes with a breaker between the power module and the DC link. The purpose of the breaker is to isolate the module completely from any voltage by disconnecting both the – and + pole between the DC link and power module. Additionally, the power module must be disconnected from the fast connectors on the back of the power module. This is normally only needed when any kind of service on the power module is required.
The breaker is controlled by the cabinet automation PLC. When auxiliary power is connected to the DC-Hub and the PLC is powered on, it will check the last breaker status before the PLC was powered off. If the breaker was closed then as soon as initialization is done, a close command will be sent to the breaker. If the breaker was open before the PLC was powered off, no commands will be given, and the breaker will remain open until a manual close command is given. For DC/DC applications located in a transport section where a remote IO fieldbus coupler is used, the communication between the fieldbus coupler and cabinet automation PLC must be alive before a close command will be given. It's important to note that the breaker will not open to any alarms or faults except if the process stop is activated.
The breaker can be controlled manually through the HMI display (see chapter 13.5). When the correct pin code is inserted, control buttons close and open will be visible. If the HMI display is not functioning, the switch breaker can be opened by pressing the process stop button.

13.4 DC/DC HMI local display

There is one HMI for each DC/DC application. The main page of each HMI shows the most important quantities measured by the converter (voltage, current and power).
Refer to chapter 6.5.1 Power module HMI for HMI menu bar and other background functions.
The DC/DCs can be operated and monitored both from the local touch display or remotely.

13.5 DC/DC HMI screens

13.5.1 Home screen

When the HMI starts up the home screen will appear first. Here you will be presented with important information such as:

- Actual control mode in text format
- Module DC voltage in volts
- Common DC link voltage in volts DC

For each bridge leg:

- Voltage Out DC
- Current in ampere
- Power in kW.

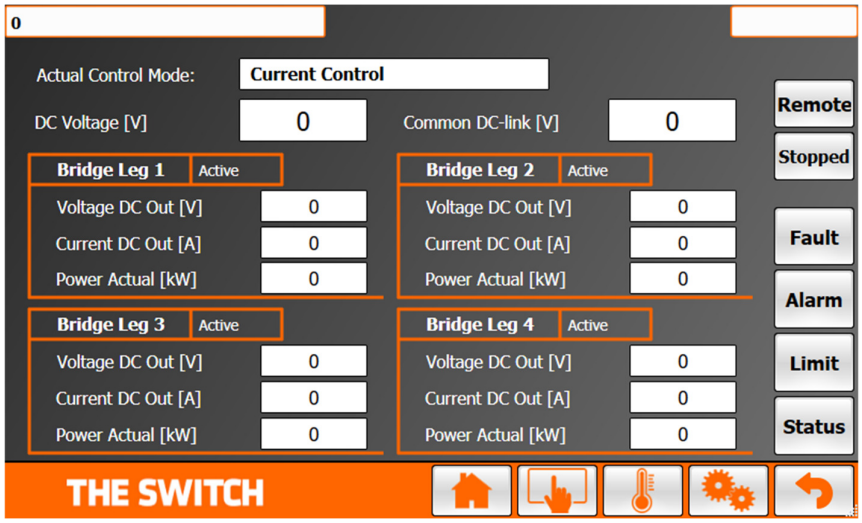


Figure 13-2 Home screen.

13.5.2 Local control screen

The local control screen is meant for manual control of the drive from the HMI display. You can get to the local control screen by pressing on the local control button in the menu bar second most to the left. In the top of the orange box local control can be activated if pressing the green enable button. When local control is inactive, control buttons are greyed and will have no actions if pressed (Figure 13-3). When the local control enable button is pressed an icon in the green box will show that local control is active ((Figure 13-4). Control buttons will be enabled for manual start and stop of the drive. The actual control mode is displayed in the text box inside the orange box. Control mode can be changed by pressing the Change button. By pressing close, pre-charge of the module and closing of E-DCB will be performed. Next step is to start the module by pressing Start button. Finally, each bridge leg group can be manually started by first selecting which bridge leg group to control. The selected bridge leg group will be highlighted in blue. To start the bridge leg group, press the Start Bridge Leg button. A stop sequence can be performed by reversing the steps. A reference can be set in the reference text box by pressing on it. A popup window with a keypad will open, where the wanted reference should be entered. On the right-hand side important information will be presented for the selected bridge leg group. In the lower right-side there is an overview of the drive. The breaker icon shows the status of the DC breaker. Red means open and green closed status. The drive icon will give a status of the drives state, red means stopped and green running. Control of the DC breaker can be accessed by pressing on the DC breaker icon.

Warning!
User should not trust overview indications of voltage if working inside cabinet. Always use proper measuring tools to ensure there is no voltage present before work.

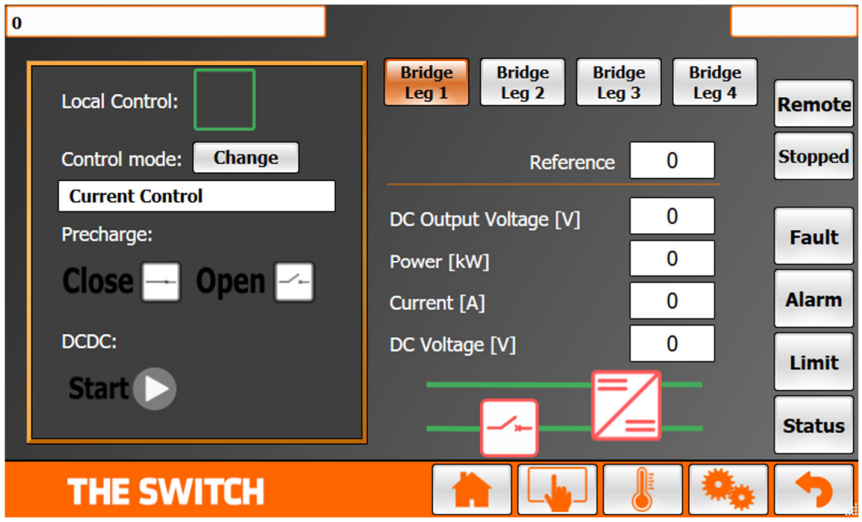


Figure 13-3 Local control screen.

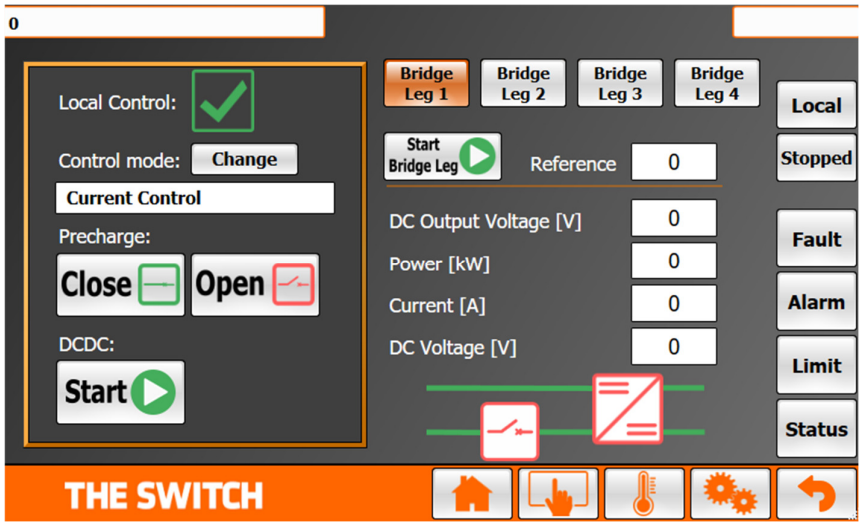


Figure 13-4 The green checkbox show that local control is active.

13.5.3 Control mode selection screen

When the change control mode button is pressed, a popup window with all existing control modes will be presented. The active control mode will be highlighted in blue. The control mode can be changed by pressing on one of the buttons (Figure 13-5).

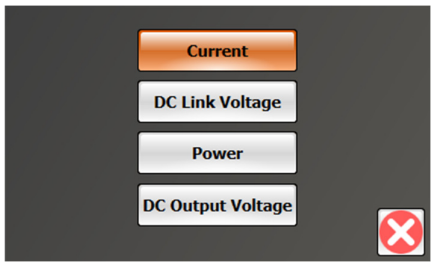


Figure 13-5 Control mode selection screen.

13.5.4 DC breaker control screen

When the DC breaker icon is pressed, a popup window asking for a pin code will appear. Control of the DC breaker is protected with a pin code so that only authorized personnel can open or close it. To enter a pin code, press on the text box and a keypad will appear. If the correct pin code is entered, Close and Open buttons will appear (Figure 13-6). Now the DC breaker can be manually controlled.

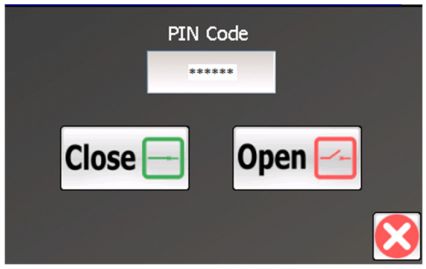


Figure 13-6

If the wrong pin code is entered, an error message will be displayed (Figure 13-7).

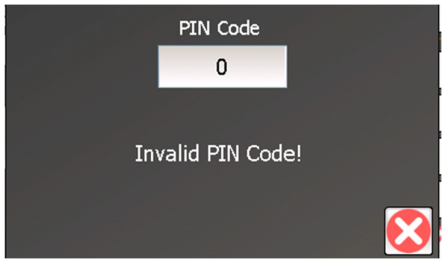


Figure 13-7

13.5.5 Temperature screen

In the temperature screen all temperatures regarding DCDC functionality and utilization factor, and cooling water temperature are presented. On the left side DC filter temperatures connected to the specific DCDC in question are shown. Temperatures are in degrees Celsius. On the right side there are drive module related temperatures. Temperature screen can be accessed from the menu bar by pressing the temperature icon third from the left (Figure 13-8).

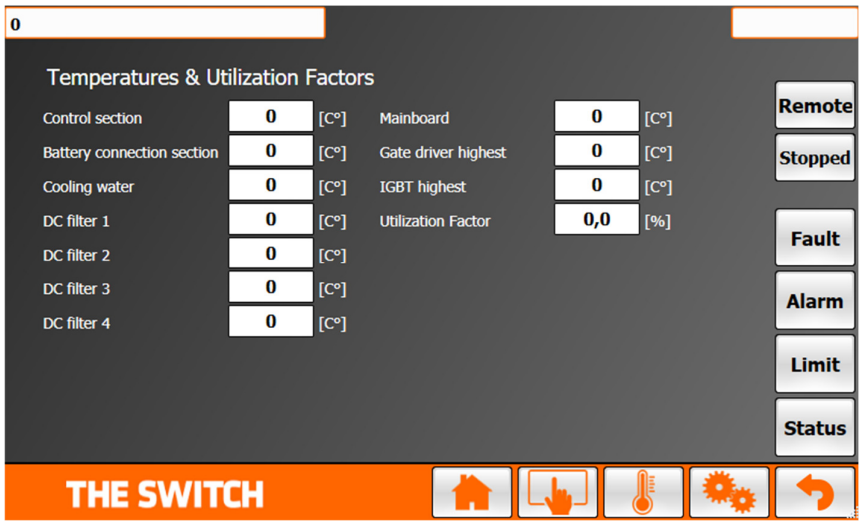


Figure 13-8

13.6 Hardware overview

The DC/DC converter can be configured for a different number of individual DC energy sources and a different number of parallel DC/DC outputs connected to a single energy source. Up to four energy sources can be connected to a single power module with one DC/DC output towards each energy source. These configurations are denoted as 1x1, 2x1, 3x1 and 4x1. Up to four parallel outputs can be connected to a single DC energy source. These configurations are denoted as 1x1, 1x2, 1x3 and 1x4. A configuration with two DC energy sources connected to the power module with two parallel DC/DC outputs towards each energy source also exists and is denoted as 2x2 configuration.

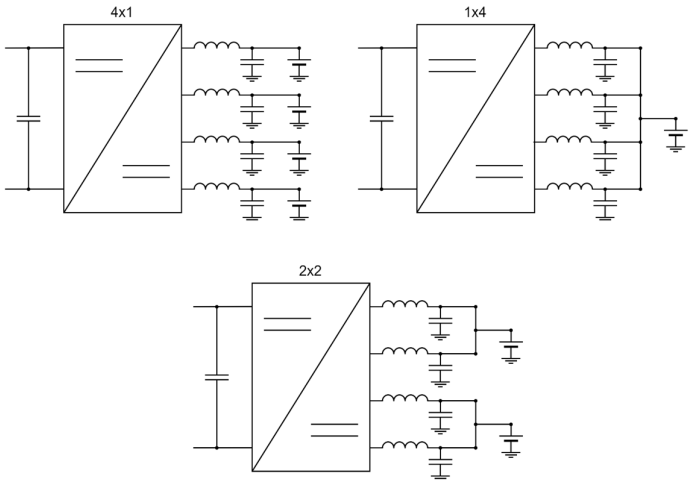


Figure 13-9 Different DC/DC configurations with varying amount of DC- energy sources connected to a single power module.

13.7 Operation Modes

The DC/DC converter can operate in source mode or in load mode. In the source mode the converter controls the DC-link voltage. This implies that the DC-link voltage control mode is selected. In the source mode the converter controls either the current or power flowing

to/from the DC energy source. This implies either current control mode or power control mode respectively.

Table 13-2 PID 575: Selector Control Mode can be used to change the operation mode.

PID 575: Selector Control Mode	
Actual Value	Operation Mode
0	Current Control Mode
1	DC-link Voltage Control Mode
2	Power Control Mode
3	DC Output Voltage Control Mode

Current Control

The most basic control mode is the current control mode, in this mode the input reference is a current reference, which is passed through an internal ramp function before it is applied to the current controller. In the current control mode, the current of each DC energy source is controlled independently.

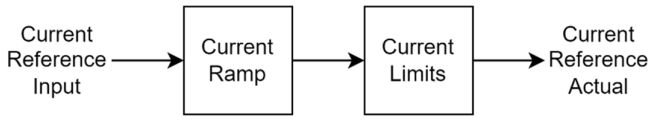


Figure 13-10 Current reference path.

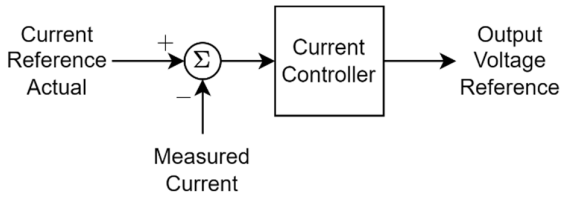


Figure 13-11 Current controller.

Power Control

The power control mode makes the use of the relation:

Power = Voltage*Current

The power reference is transformed into an internal current reference based on the actual DC output voltage. In the power control mode, the power of each DC energy source is controlled independently.

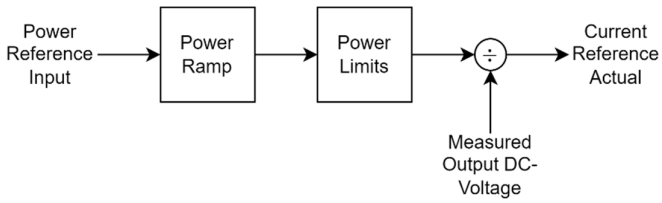


Figure 13-12 Power reference path.

DC-link Voltage Control

The DC-link voltage control mode is common for all DC energy sources connected to the same power module.

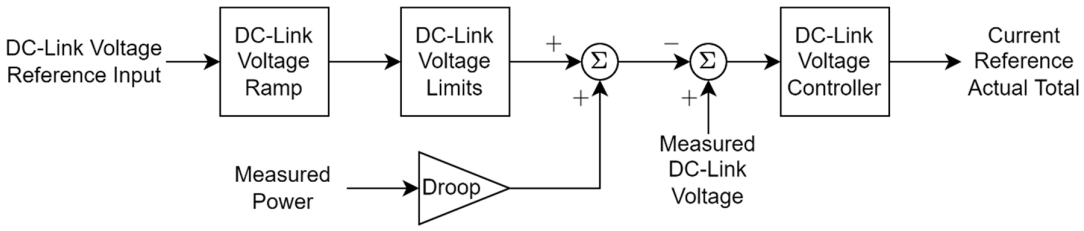


Figure 13-13 DC-link voltage reference path.

The external DC-link voltage reference is used to calculate an internal current reference which is shared between all the DC energy sources connected to the power module. The current sharing between the DC energy sources can be adjusted.

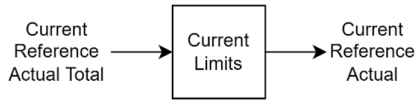


Figure 13-14 Current sharing with one DC energy source.

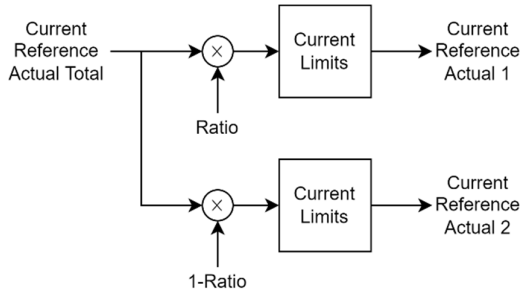


Figure 13-15 Current sharing with two DC energy sources.

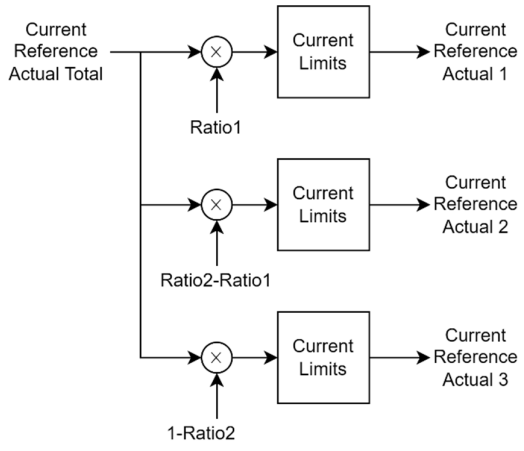


Figure 13-16 Current sharing with three DC energy sources

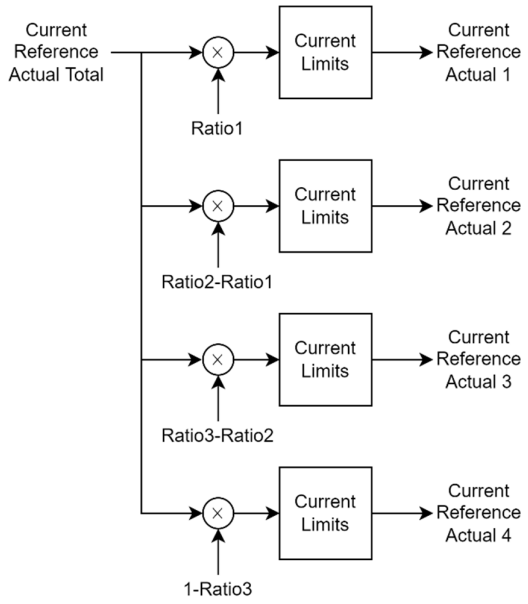


Figure 13-17 Current sharing with four DC energy sources.

Output voltage control
Output voltage control is used to provide a stable output voltage towards a DC energy source. The output voltage can be controlled with a voltage reference.

13.8 Pre-charging output filter capacitors

The LC-filter capacitors need to be pre-charged before the DC/DC converter can start to operate.

13.9 Sleep Mode

Outputs of the DC/DC converter can be commanded to enter a so-called sleep mode in which an output stops switching but is ready to quickly resume normal operation if the DC-link voltage drops or rises more than is allowed. The sleep mode is only available in the DC-link voltage control mode and can be used to minimize switching losses when the DC/DC.

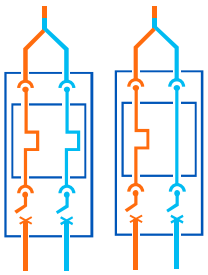
13.10 DC/DC tuning and troubleshooting

For DCDC alarms and faults refer to separate document The Switch DC-Hub Interface List Refer to the document list chapter 3.2

Caution!
Insulation alarm detected in converter, possible earth fault present in circuitry. The cause of the alarm must be clarified. Double earth fault can be hazardous. It is under the user's responsibility if decides to continue using the product.

14 Protection device

Protection devices include four types:



Electronic Bus Link (EBL), Semi-conductor switches in both poles (2P variant) or in positive pole (1P variant). EBL also includes a braker.



Battery short circuit limiter (BSCL), Semi-conductor switch only in the positive pole. Passive overvoltage clamping circuit allowing higher source inductance.
Standalone BSCL has a separate product manual.



Electronic current limiter (ECL) Semi-conductor switch only in the positive pole.

Electronic DC breaker (EDCB), integrated into standard power module

Protection device products have some common features:

- All products are a combination of a cabinet and a power module.
- Same pluggable power module electrical interface, two poles for input, two poles for output.
- All power modules have the same physical dimensions: 800 x 150 x 560 [mm] (H x W x D). Power terminals in the rear are 35 mm in addition. Pull-in bolts are 50 mm in addition to depth.
- The width of the cabinet structure is dependent on the configured application. The power sections are designed to house power modules and have a modular design.
- The cabinet consists of standard sections rated IP44 and is manufactured in steel. Vibration dampers are used between cabinet and foundation.
- All power cable entries are located at the rear bottom, and the cabinets must have access from the front.
- All cabinets have effective EMC shielding by EMC tight enclosure with EMC shielded multi cable transits.
- A cabinet cooling unit which includes water to air heat exchanger and fans is installed at the top back of each power section when needed.
- Process stop push buttons for each redundancy group (including DCDC or ECL at DC-Hub end) + possible to connect external push button.

14.1 Electronic bus link (EBL)

The main target of the EBL is for connecting one DC-Hub together with another one and maintaining the selectivity even with a major fault in one DC-Hub – and not pulling down the other, healthy DC-Hub.
The EBL reacts as a fuse but responds electronically within microseconds. While a fast thermal fuse or an electromechanical breaker acts within milliseconds.
With microseconds response the DC-link in the healthy DC-Hub typically drops less than 50 V (from around 1000 Vdc) with a full short circuit in the shorted DC-Hub, or in the cables interconnecting them. The EBL is a two-pole protective device, which means that it can interrupt the current bi-directionally.

- Electronic bus link (EBL) offers ultra-fast protection between DC-Hubs.
- EBL allows a ring network.
- EBL allows DP3 operation as an option.
- Improve redundancy while enabling fuel savings.
- Several units can be connected to a system.
- Connects The Switch DC-Hubs together.
- Critical faults are detected and disconnected in approximately 10 microseconds.
- DP3 tested and approved by DNV.

14.2 Electronic current limiter (ECL)

The main target of the ECL is the protection of the DC-Hub from short-circuits in a battery - DC-Hub connection. It is paired with a Battery Short Circuit Limiter (BSCL) module. The BSCL module will protect the battery from any short-circuits or overload scenarios that happen after the BSCL, such as a short-circuit on the cable or a failure inside of the DC hub that results in too high demand on current from the battery. The ECL module on the other hand will protect the DC hub from any short-circuit or faults happening on the cable, BSCL or in the battery. Besides the pair with ECL, BSCL may also be paired with a DCDC power converter to protect the DC-link.
The BSCL has a very short reaction time. When a short-circuit occurs in the battery or on the cable connection of the battery - BSCL, the BSCL will turn off the short-circuit current before the latter reaches the short-circuit current rating of the battery. This means that more batteries, with their own BSCLs (paired with ECLs or DCDC converters), can be connected to a DC hub without reaching intolerable short-circuit currents. Although the BSCL allows the DC current to flow bi-directionally, it can interrupt/limit the current only in one direction.
Multiple ECLs/BSCLs can be controlled by either a single, shared control board or each BSCL can have its own individual control board.
The BSCL module shall NEVER be combined with a mechanical breaker or switch.
No automatic electrical isolation (no breaker or similar). Electrical isolation between the DC-Hub and the load (cable) can only be achieved by pulling out the module.

ECL disconnects the battery from application and the rest of the system keeps running.

- ECL applications can be controlled locally from an HMI display screen.
- When the remote control is selected, local control buttons will be greyed out.

- When local control is selected, the application can be turned ON and OFF with buttons on the local control screen. Remote control is blocked while local is selected.
- The event log of the ECL application can be seen in the HMI display with faults, alarms, limits, and status events.

14.3 EBL and ECL power modules

The control interface towards the control section is at the bottom of the module and has multiple connectors. Refer to the circuit diagram when making connections.

- Auxiliary Power
- Dual 230 V AC
- 1x or 2x optical fibers (POF serial link)

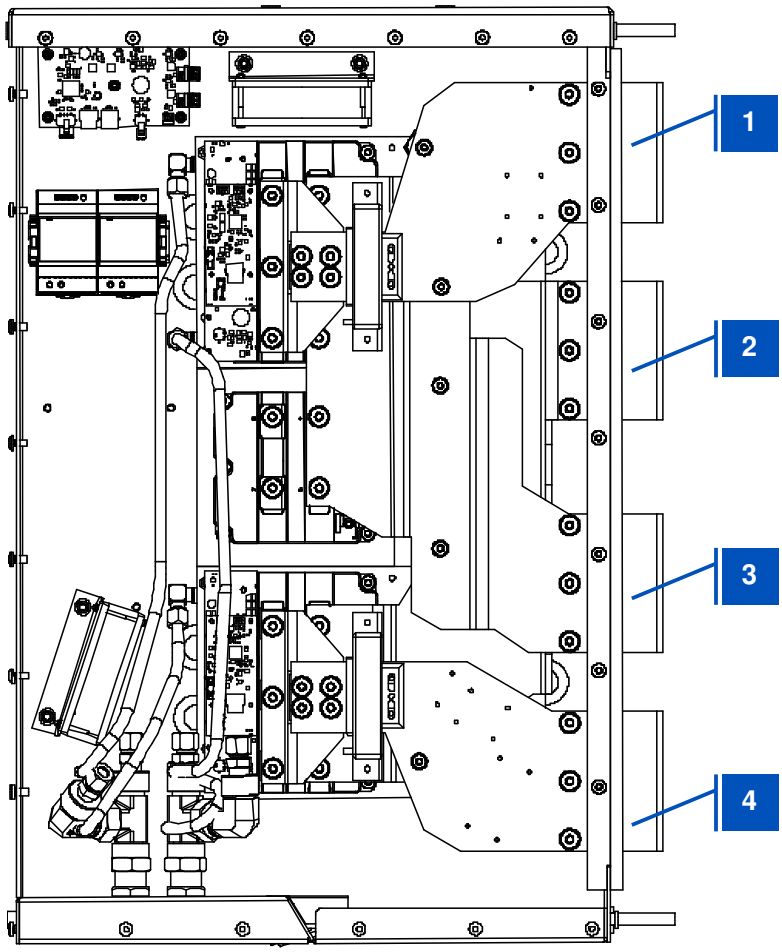


Figure 14-1 EBL 2P power modules shown without the side cover.

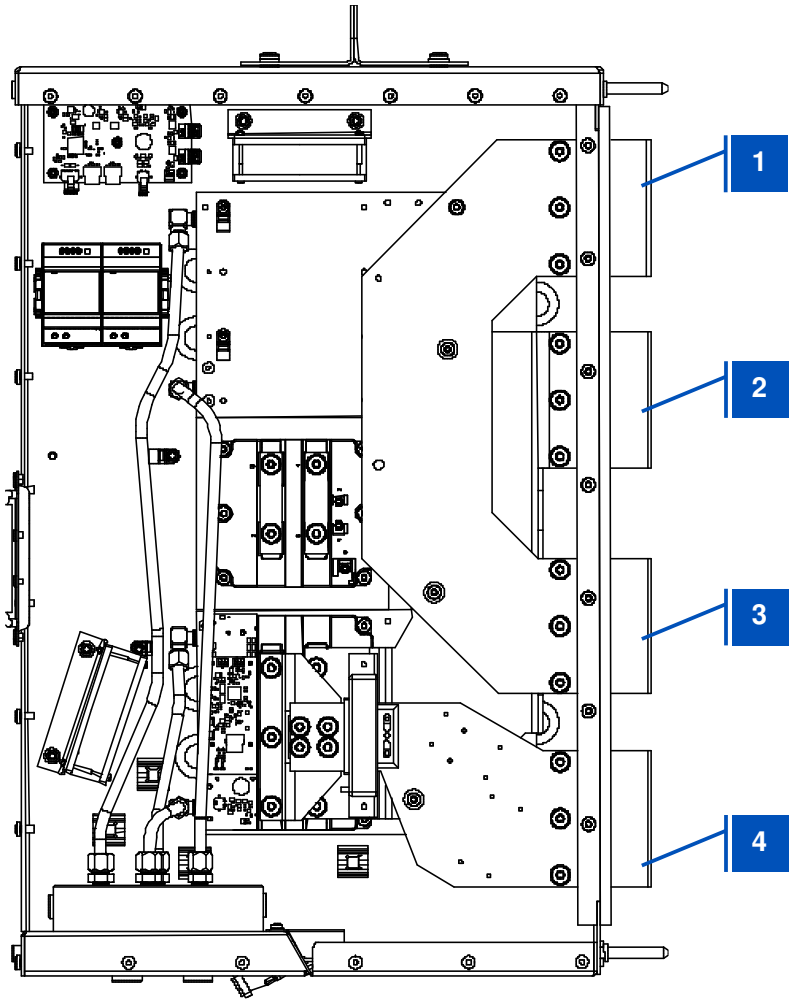


Figure 14-2 ECL power modules shown without the side cover.

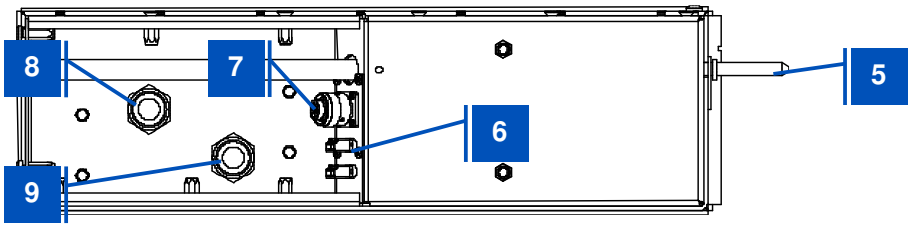


Figure 14-3 Bottom view of EBL power module.

1	DC-, DC-Hub
2	DC+, DC-Hub
3	DC-, BSCL/battery
4	DC+, BSCL/battery
5	Guide spindle for pull-in
6	Fiber connectors (ECL 1 pc and EBL 2 pc)
7	Power connector 230 VAC
8	Cooling water inlet
9	Cooling water outlet

14.4 Cabinet

All EBL cabinets have some common features:

- All power modules are water cooled.
- Control boards are outside of the module placed in the control section.
- Pull-in bolts for the power module.

For protection device cabinet handling and installation refer to the chapter 10.4 Power module handling. The installation shall be done in a similar way.

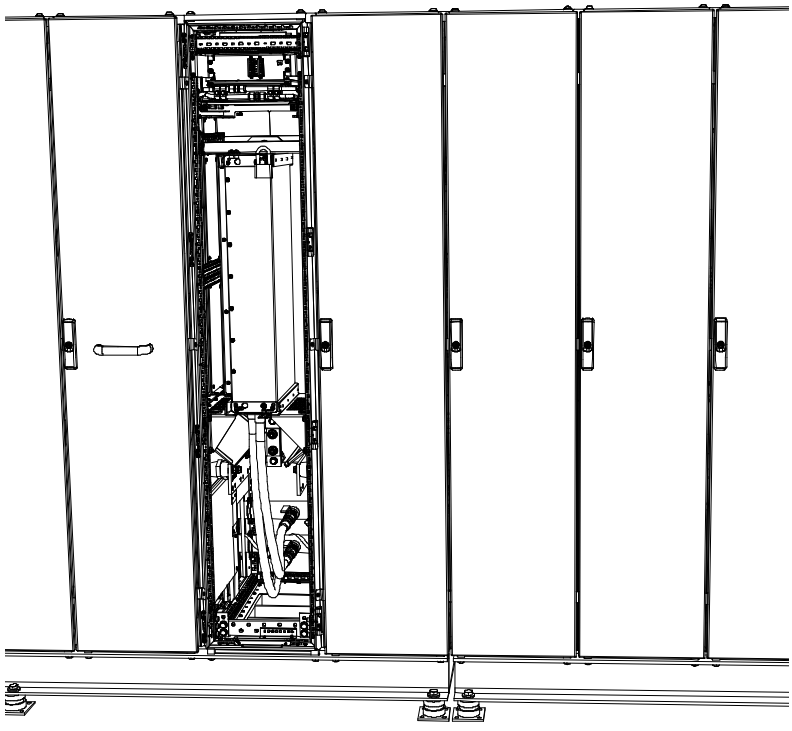


Figure 14-4 ECL section at the DC-Hub, the door removed (example).

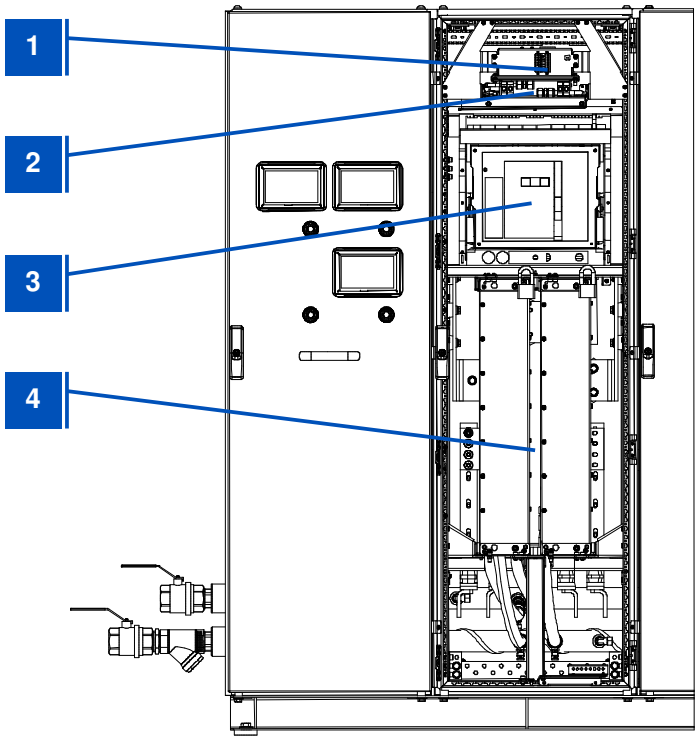


Figure 14-5 Double EBL at the DC-Hub cabinet, the door removed (example).

1	Cooling fan
2	Radiator
3	Circuit breaker
4	EBL power modules

14.5 Isolating a power module from a main circuit

EBL family protection devices provide features to isolate the power module from an electric main circuit in case of equipment failure.
In the isolated position, an electrical clearance is minimum of 25 mm from main circuit terminals to connecting tabs in the power module. Adequate isolation and securing a safe open position by applied locking techniques with associating hardware is achieved. Galvanic connection to PE bus bar from the power module remains intact.
Refer to chapter 10.5.7 Moving failed power module to disconnected position.
The power module could be locked to DISCONNECTED position by using a padlock.

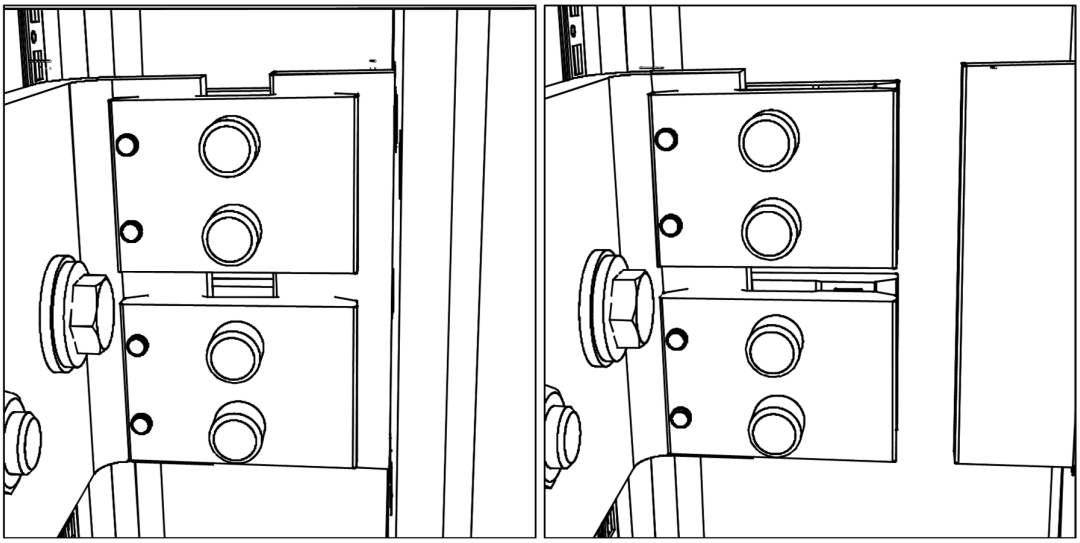


Figure 14-6 Power terminals of the power module CONNECTED/DISCONNECTED positions.

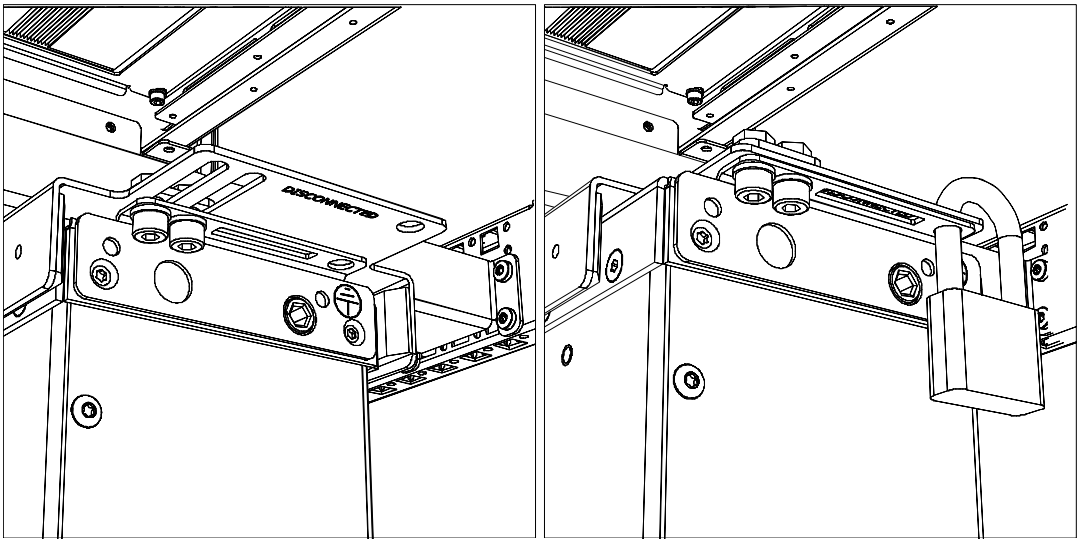


Figure 14-7 The power module is at the CONNECTED and the DISCONNECTED position, locked by using a padlock.

14.6 Communications

With the 2P variant design the IGBTs have 2 main boards (CEL- Central Electronic board) for the EBL power module. They are controlled by: Modbus TCP on dual optical fiber, one optical fiber pair for each pair. Single IGTB modules each have one main board and one optical fiber pair.

14.7 DC-cable specifications

Refer to the chapter 9 General guidelines for cables

14.8 Power module handling

Refer the chapter 10.4 Power module handling.

14.9 EBL controls

The control cabinet is equipped with:

- Process stop button, which shuts down the functions of EBL applications.
- Releasing the process stop button is required before restart.
- Local/Remote switch,
  When switching to local control, EBLs will keep same control commands as before. When local control is active, remote-control signals are ignored.
- Local control buttons: Close, Open and fault Reset buttons.
- Status lights: Closed, Open and Fault indicator lights.

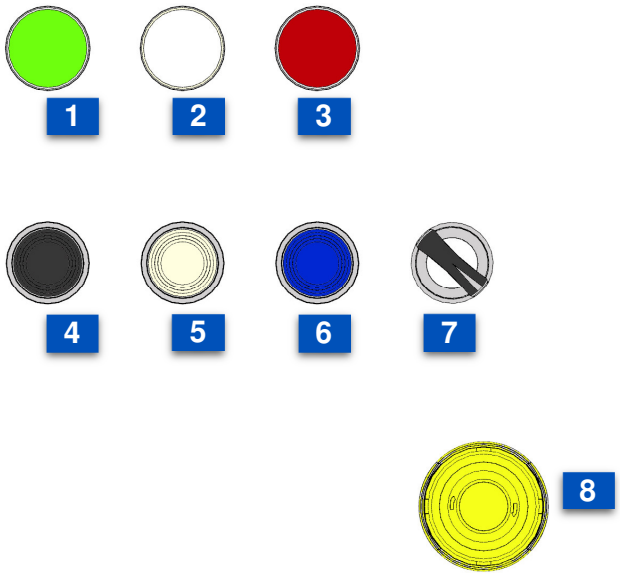


Figure 14-8 EBL controls and status lights.

1	Status light Closed
2	Status light Open
3	Status light Fault
4	Control button Close
5	Control button Open
6	Control button Reset
7	Local/Remote switch
8	Process stop button

14.10 EBL HMI

14.10.1 Home screen

The home screen (Figure 14-9) will be used as a start-up screen. The home screen shows important information about each EBL. Actual power in kW, current in ampere, input voltage in volts DC and output voltage in volts DC. Below each unit's measurements, there are status lights about the current status of EBL and its breaker. To access the home screen from another screen, press the home icon in the menu bar.

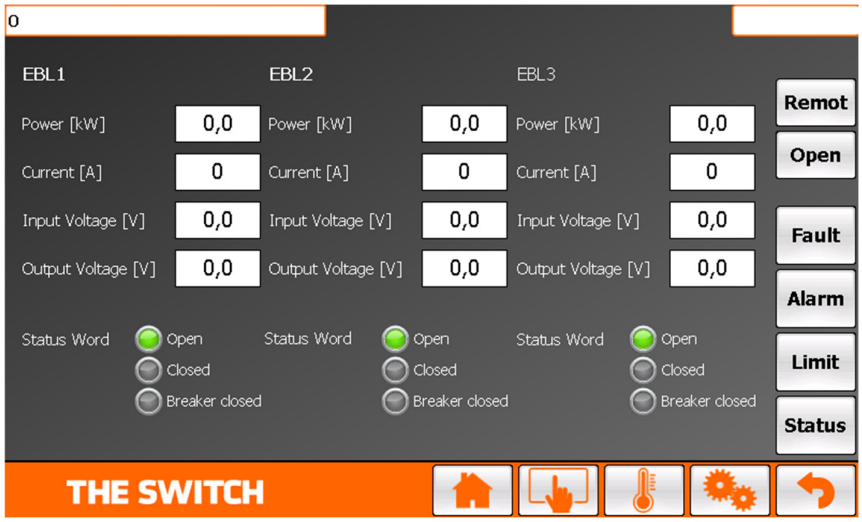


Figure 14-9 Home screen.

14.10.2 Local control screen

In local control screen (Figure 14-10) manual control the EBL is possible. Each unit can be controlled separately and the unit to control can be selected on the right side of the orange framed box. The currently selected unit is highlighted in orange. If local control is inactive, close and open buttons will be greyed out and cannot be used. When activating local control, buttons will become visible. The only exception is if there's an active fault on the unit selected in local control. Then the close button will stay greyed out. Next to the local control buttons, there are important measurements from the application. The measurements are related to the selected unit and by switching between them the measurement values will change to the next unit. In lower (Figure 14-11) the measurements are the actual status of the selected EBL (Closed/Open). On the right side, on the top is a point of control status box. When all applications are in remote control, the text will say Remote. When one or more is in local control, the text will change to Local. The box below shows the status of the applications. When all are in open position, the box will say Open. When one, but not all, is closed the box will change to green and blink while the text is saying Closed. The box will turn static when all applications are closed.

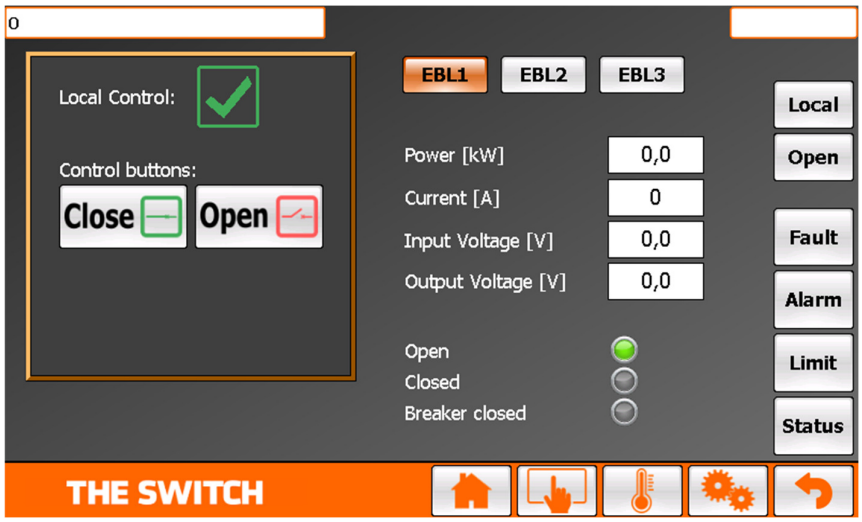


Figure 14-10 Local control screen.

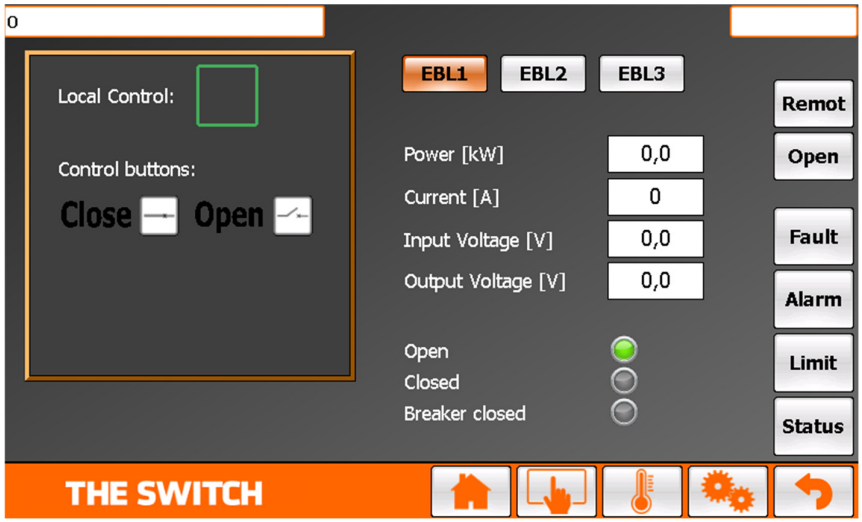


Figure 14-11 Local control screen – Local control on.

14.10.3 Temperature screen

In the temperature screen (Figure 14-12) cabinet and control related temperatures are presented. Unit is in degrees Celsius.

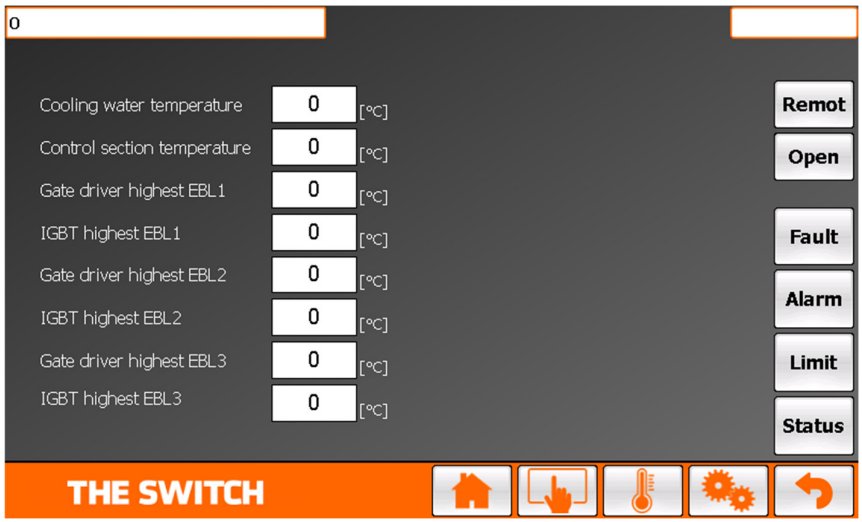


Figure 14-12 Temperature screen.

14.11 ECL HMI

14.11.1 Home screen

The home screen (Figure 14-13) will be used as a start-up screen. The home screen shows important information about each ECL. Actual power in kW, current in ampere, input voltage in volts DC and output voltage in volts DC. Below each unit's measurements, there are status lights about the current status of ECL. To access home screen from another screen press home icon in the menu bar.

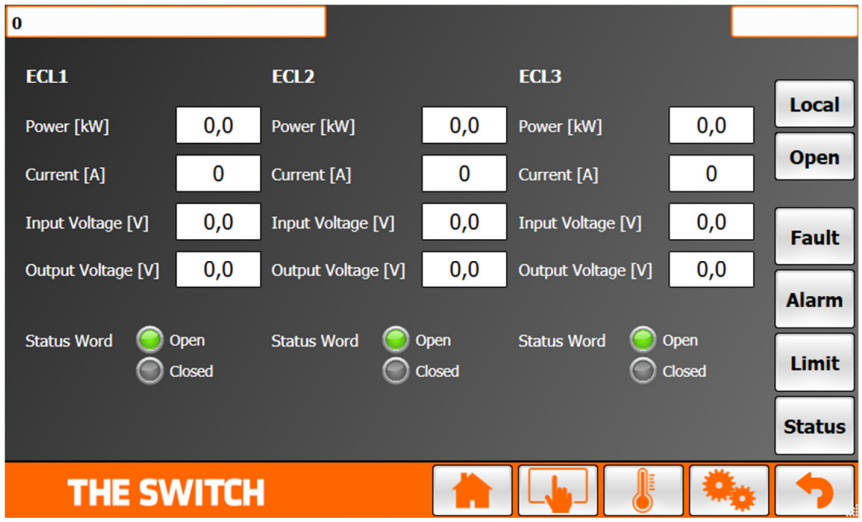


Figure 14-13 Home screen.

14.11.2 Local control screen

In the local control screen (Figure 14-14) manual control the ECL is possible. Each unit can be controlled separately and the unit to control can be selected on the right side of the orange framed box. The currently selected unit is highlighted in orange. If local control is inactive, close and open buttons will be greyed out and cannot be used. When activating

local control, buttons will become visible. The only exception is if there's an active fault on the unit selected in local control. Then the close button will stay greyed out. Next to the local control buttons, there are important measurements from the application. The measurements are related to the selected unit and by switching between them the measurement values will change to the next unit. In lower (Figure 14-15) the measurements are the actual status of the selected ECL (Closed/Open). On the right side, on the top is a point of control status box. When all applications are in remote control, the text will say Remote. When one or more is in local control, the text will change to Local. The box below shows the status of the applications. When all are in open position, the box will say Open. When one, but not all, is closed the box will change to green and blink while the text is saying Closed. The box will turn static when all applications are closed.

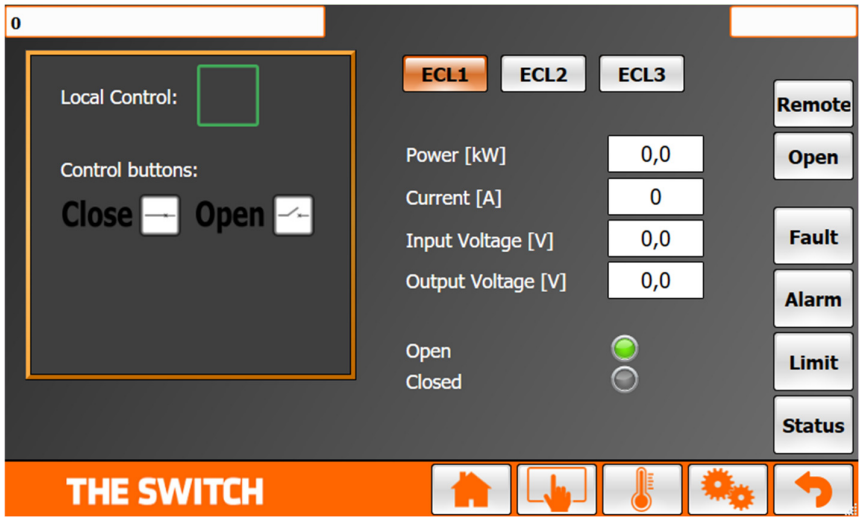


Figure 14-14 Local control screen.

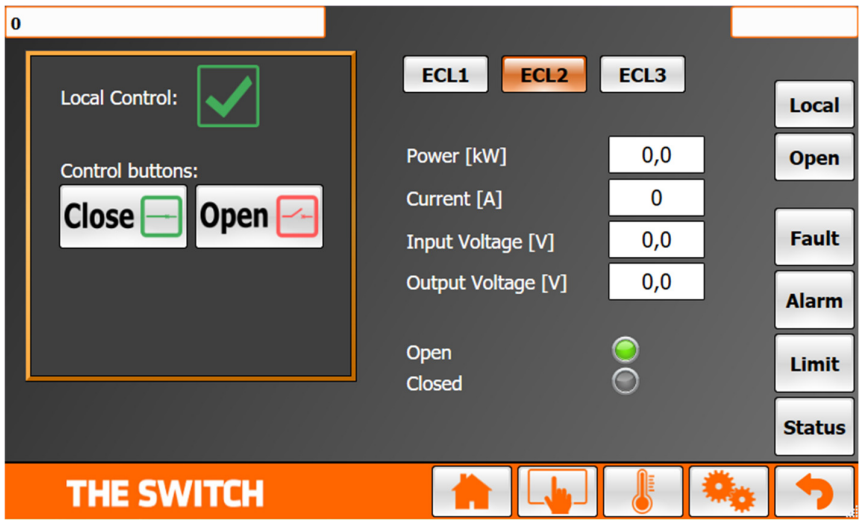


Figure 14-15 Local control screen – Local control on.

14.11.3 Temperature screen

In the temperature screen (Figure 14-16) cabinet and control related temperatures are presented. Unit is in degrees Celsius.

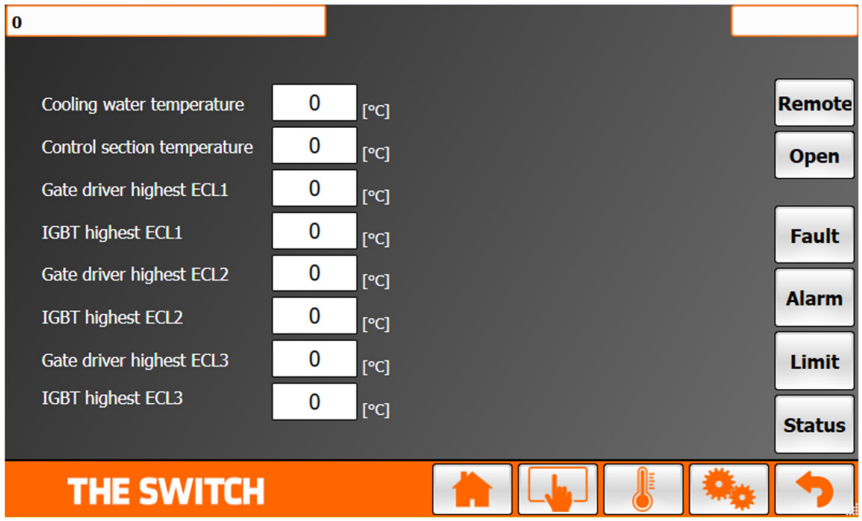


Figure 14-16 Temperature screen.

15 Maintenance

This chapter provides a detailed description of the maintenance procedures that operators or trained service personnel can perform on the DC-Hub.
The DC-Hub features a modular design that greatly simplifies maintenance procedures. Once a fault has been located using the diagnostics procedures, the affected module can be removed and replaced.



Warning!
There is a risk of serious injury to personnel or equipment if these procedures are not followed correctly.



Do not undertake any of these procedures unless properly qualified.



The power modules and the control card at the control section are ESD sensitive parts that can be damaged by ESD.
Make sure that all personnel who take part in the installation and maintenance use correct ESD equipment including clothing, as described in chapter 5.9 Electrostatic discharge (ESD) protection.

15.1 Required service tools

Most maintenance, troubleshooting, and commissioning procedures can be done with the standard electro-mechanical service tools. Some procedures require special tools which are listed below. Torx screws are mainly used in installation, but some components may contain other screw heads. Always refer to the installation instruction for the component to be installed.

Table 15-1 Special tools

Procedure	Required special tools
General	Multimeters CAT III 1000V, ESD wrist strap, proper work clothes and shoes, Rittal enclosure key[5], SZ 2531.000, battery drills, multiple size torque wrenches to cover range 5 – 90 Nm, Torx bits set up to T50.
Cabinet installation	Lifting crane, forklift.
Water connections, Y-filters, and ball valves	Big plier wrench, pair of adjustable wrenches 0 – 70 mm gap.
Power module installation	Lifting bracket, hoist, Lifting device (lifting trolley) for the power module.
Power module water connection	Adjustable wrench with opening 36 mm short handle (8”) for connecting/disconnecting cooling hoses.

[5] One double-bit key is supplied with every enclosure.

15.2 Scheduled maintenance

Scheduled maintenance aims to minimize equipment failure, maintenance backlogs, and reactive maintenance.

15.2.1 Interval: Variable

Table 15-2

Part or system	Procedure	Description
Water cooling system	Flushing if needed. It is always needed prior to commissioning.	See chapter 15.8 Flushing.

15.2.2 Interval: 6 Month

Table 15-3

Part or system	Procedure	Description
The fan-and-filter unit of Output Disconnector Cabinet (ODC) Starpoint Disconnector Cabinet (SDC)	Check /clean. Replace filters if needed.	See chapter 15.24 Inspect the condition of the fan-and-filter unit.

15.2.3 Interval: 1 Year

Table 15-4

Part or system	Procedure	Description
Water cooling system	Test cooling water quality	See chapter 15.6 Cooling water quality.
Water cooling system	Adding inhibitor	See chapter 15.6 Cooling water quality.
Water cooling system	External strainer inspection	See chapter 15.7 External strainer inspection (not in The Switch ‘s scope).
Water cooling system	Cooling system inspection	See chapter 15.9 Cooling system inspection (not in The Switch ‘s scope).
Cabinet cooling water Y-filter	Check /clean	See chapter 15.10 Cooling water inlet Y-filter cleaning.
Cabinet and overall mechanical construction	Check the cabinet and clean it if required	See chapter 15.14 Check /clean cabinet.
Fans and air cooling	Check /clean radiator	See chapter 15.15 Check/clean radiator.
Control section Power section	Check cable screws	See chapter 15.16 Check control cable connector screws.
Power section	Check power cable connection	See chapter 15.17 Check power cable connection.
Water cooling system	Test water leakage sensor	See chapter 15.19 .
Water cooling system	Test valves	See chapter 15.20 Testing valves.
AC capacitors	Check	See chapter 15.21 Inspect the condition of AC capacitors.
Breakers/ Switches	Check	See chapter 15.22 Check the condition of breakers and switches.

15.2.4 Interval: 5 Years

Table 15-5

Part or system	Procedure	Description
Fans and air cooling	Replace cooling fans	See chapter 15.11 Cabinet cooling fan replacement procedure.
Cooling system	Wash the internal cooling system with dedicated washing and flushing apparatus.	Contact the Switch.
Cabinet	Inspect polycarbonate protection	See chapter 15.13 Check polycarbonate protection.
Vibration dampers	Inspect the condition of vibration dampers and floor fastenings.	See chapter 15.23.
Power module	Replace cooling fans.	See chapter 15.25
Power module	Checking measurement for discharge resistors and capacitors.	Contact the Switch.



The power modules must be treated as ESD sensitive material. Always ask a service engineer for help if you are not trained or if you are unsure about this procedure.

15.3 Stop and disconnect the main sources of the voltages of the DC-Hub



Warning!
Electrical hazard.
Touching live parts, busbars and cables results in death or lethal injuries due to electric shock.



Live working is not allowed in the power sections. Do not open the door of the section when DC-Hub is energized.

Several of the procedures in this chapter require the DC-Hub's electrical systems to be safely disconnected. Follow this work sequence before performing any internal maintenance tasks:

1. Stop the DC-Hub (MI, AFE) and disconnect all the main power sources.
2. Open breakers. The DC connection to other DC-Hub buses must be open as well.
3. Make sure the main breakers are isolated and locked.
4. Isolate pre-charge supply fuses of AFEs by opening the fuses.
5. Wait at least 5 minutes after stopping the DC-Hub before working on the power module to ensure it has been fully discharged.

6. Check the voltage level on the DC bus. Make sure there is no voltage on DC bus DC+ to DC-, DC+ to the cabinet (PE connection ground), DC- to the cabinet (PE connection ground). Measure the DC and AC voltage for safety reasons.
7. If the voltage between earth and DC bus is above 50 VDC or 50 VAC, keep the voltage instrument connected and observe if the voltage goes down. If so, wait until the level is less than 50 V and then short circuit earth and the DC bus. If the voltage level does not sink, there is an earth fault present. Locate and correct before proceeding.
8. Follow the earthing procedure.

15.3.1 Earthing procedure



Warning!
Electrical hazard.

Prior internal maintenance work of the DC-Hub this earthing (In North America, earthing is called grounding) procedure must be followed so that maintenance work may be performed without danger of electric shock:

- De-energize the DC-Hub in accordance with follow the work sequence described at chapter 15.3.
- Use portable earthing equipment for discharging and grounding of the dead DC-Hub (IEC 61230).
- Test the circuit for voltage. Do not assume that the circuit has been de-energized just because it has been turned off.
- **Apply ground-end clamps (PE connections) first and remove them last.**
- Apply other connections, GI grid interfaces (L1, L2, L3), MI interfaces (U1, V1, W1) and BC battery connections (+ Pos, - Neg).
- Conductor-end clamps must be applied and disconnected by insulation sticks of adequate rating and length.
- After maintenance work remove earthing equipment – PE-connection last and proceed normal DC-Hub start -up.

15.4 DC circuit fuses replacement

Before any maintenance or replacement measures follow the work sequence described at chapter 15.3. Make sure the main breakers are isolated and locked, including isolation equipment in the battery unit.



Warning!
Electrical hazard



Make sure the breakers and pre-charge fuses are opened and secured with a personal padlock. Always measure voltage with a CAT III 1000V multimeter before touching electrical parts.



Do not alter the state of the main breakers during the service measures.

15.5 Disconnecting the cooling water supply

Several of the procedures in this chapter require the DC-Hub's cooling water supply to be safely disconnected. Follow this work sequence before performing any internal maintenance tasks that involve the cooling water system.



Caution!
Be careful not to spill any water on the power module.

- Stop the cooling pump.
- Disconnect cooling water supply by closing the external valves outside the cabinet.
- Close the high-pressure upper inlet valves first. Then close the lower low-pressure outlet valves. It is only necessary to close the valves in the cabinet section where maintenance work is performed.

15.6 Cooling water quality

The cooling water systems are designed for tap water quality, and a mix of adequate percentage (%) water/inhibitor agent. The precise percentage mix is decided by the ship owner.
It is recommended to use `*Monopropylene glycol*´ or similar. Different types of glycols should not be mixed. Refer to the technical specification of the DC-Hub.

15.7 External strainer inspection

The external strainer not included/supplied with the DC-Hub is mounted on the manifold inlet pipes. This strainer removes harmful particles from the cooling water. Regular inspection of the strainer is necessary to maintain cooling water quality and prevent clogging. Refer to manufacturer's documentation for strainer maintenance and for details on cleaning the strainer.

15.8 Flushing

The cooling water system connected to the DC-Hub must be flushed during the commissioning. The DC-Hub supplier is not responsible for the execution of the flushing of the installation's cooling system. However, the requirements in this description must be fulfilled prior to connecting the equipment. The Switch offers equipment and personnel that can perform the flushing procedure if required.
Periodic cleaning of the cooling water and cooling water system is recommended.
The water should always be free from significant impurities such as oil or grease, mud and foam forming particles, rust and metallic parts, sand and other garbage particles which can cause problems in effective heat transfer from the equipment to water. It is the customers' responsibility to decide the cleaning technique and method.
The inlet of the cabinet is equipped with the Y-filters, which must be inspected/cleaned during the flushing procedure.
If additives are used in the water, they must be non-reactive to the following materials:

- PEX tubes
- EPDM hoses
- Stainless steel, brass, nickel, copper

Please refer to datasheets to determine the amount of cooling water flow needed for each DC-Hub application.

15.9 Cooling system inspection

Proper cooling water flow is required to keep the DC-Hub operating at the correct temperatures. The cooling water flow may be interrupted for several reasons such as

1. Clogged strainers.
2. Sudden interruption of cooling water.
3. Gradual decrease in water flow.

The procedure for cooling system inspection:

1. Visually check for leakages.
2. Visually check for clogged pipes.
3. The transparent PEX tubes will appear darker than normal if accumulation of dirt and particles occur. In case of clogging, take immediate action such as flushing to clear the affected pipes.
4. Inspect the cooling water strainers.
5. Water quality will be affected by dirty strainers. Check all strainers on every installation for any accumulated particles.
6. Flow measurement.
7. Flushing.
   Consider flushing if any impurities are present in the system.

! ***Note!***
Any additions to the cooling water (like corrosion inhibitors or flushing additives) must be non-reactive.

15.10 Cooling water inlet Y-filter cleaning

The Y-filter must always be cleaned when the cooling system of the cabinet or cooling system of a vessel is flushed or serviced.

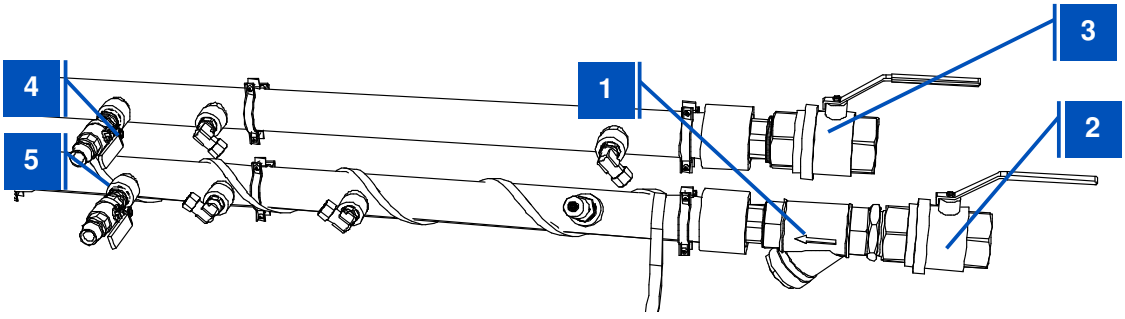


Figure 15-1 Y-filter cleaning (example).

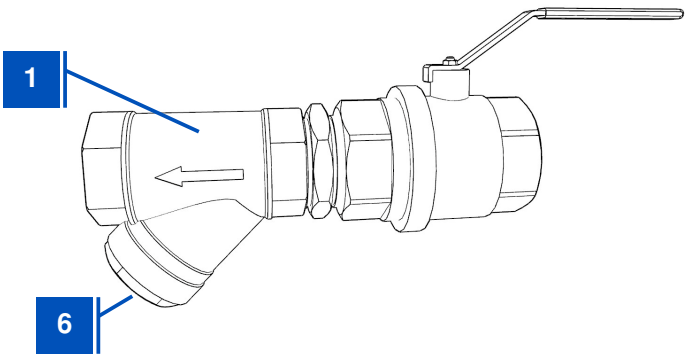


Figure 15-2 Bolted lid for filter insert access.

1	Y-filter
2	Cooling water inlet ball valve
3	Cooling water outlet ball valve
4	Cooling water outlet ball valve power module
5	Cooling water inlet ball valve power module
6	Bolted lid for filter insert

When the Y-filter is cleaned during flushing. Drain the whole cooling system of the cabinet, refer to chapter 15.8 Flushing. For the Y-filter service follow this procedure:

1. Close the valves (**4** and **5**) for the power modules inside the cabinet.
2. Close the inlet and the outlet valve (**2** and **3**) on the outside of the DC-Hub.
3. Open bolted lid for the filter insert (**6**).
4. Empty the internal system, be prepared to collect the liquid in a container large enough.
5. Clean the filter insert or replace it if needed.
6. Assemble the filter insert.
7. Close the bolted lid for the filter insert (**6**).
8. Open the inlet and the outlet valve (**2** and **3**) on the outside of the cabinet.
9. Flush the internal system.
10. Open the valves (**4** and **5**) for the power modules inside the cabinet.

15.11 Cabinet cooling fan replacement procedure

The fans need to be replaced as described in the maintenance schedule. If audible noise, or rotational speed does not follow given command cooling fan must replace immediately. Life expectancy is 60 000 h in average 40°C.

Warning!
Electrical hazard

Make sure the breakers and pre-charge fuses are opened and secured with a personal padlock. Always measure voltage with a CAT III 1000V multimeter before touching electrical parts.

Caution!
Be careful not to damage the copper pipes of the radiator.

Caution!
Risk of water leakage and damage to electrical components. Only skilled personnel familiar with the cooling water system may carry out the replacement of the cooling fan.

15.11.1 Cabinet cooling fans replacement procedure

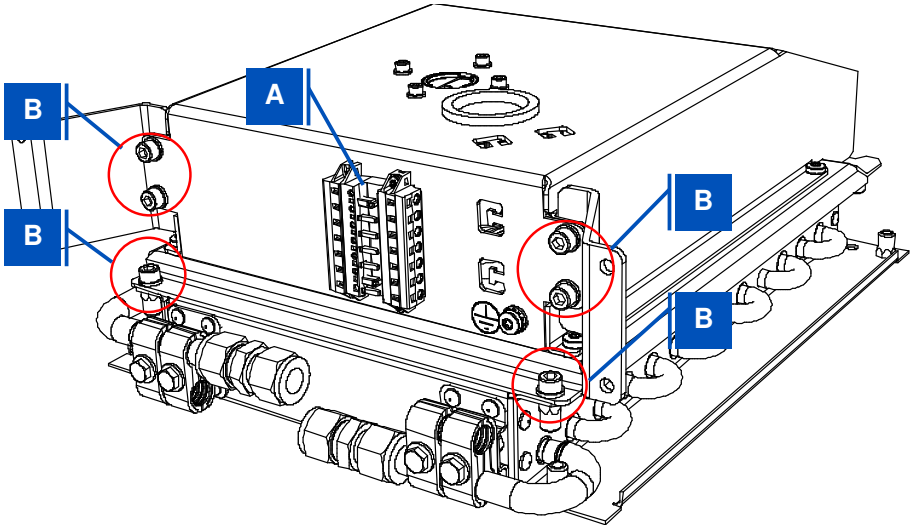


Figure 15-3 Cooling fan assembly (example).

1. Stop the DC-Hub and open breakers refer to chapter 15.3 Stop and disconnect the main sources of the voltages of the DC-Hub.
2. Disconnect AUX feed to fans.
3. Disconnect the plug of the cooling fan (**A**).
4. Remove the screws 6 pcs (**B**) that fasten the cooling fan assembly and slide it from the fan radiator assembly. The radiator leaves in place.
5. Replace the cooling fan in the cooling fan assembly. Look at the spare part list.
6. Fasten the screws (**B**).
7. Connect plugs (**A**).
8. Start up the DC-Hub.

This procedure is intended for replacing only a fan subassembly, but if the entire cooling assembly, including the radiator, is to be replaced, the cooling water system must be depressurized and drained, and the pipe fittings must be disconnected.

15.11.2 Cooling fan PEX pipe replacement

The tube fittings and PEX-pipe should be checked for leaks during other maintenance work or if the water leak sensor alarm occurs. Leaks shall be repaired immediately. The PEX pipes of all fans are interchangeable through the front of the cabinet section.

1. Stop the DC-Hub and open breakers refer to chapter 15.3 Stop and disconnect the main sources of the voltages of the DC-Hub.
2. Disconnect cabinet auxiliary supply/s.
3. Separate the DC-Hub from the cooling water system of the ship.
4. Depressurize and drain the cooling water system of the DC-Hub.
5. Disconnect the tube fittings (**C**) and the fitting of cooling manifold.
6. The old PEX pipe should be cut off in plain sight. The old piece of PEX pipe can be left in place.
7. The new PEX pipe shall be rerouted. It shall be installed to pass through the front of the cabinet section. Avoid blocking the power module movement.
8. Replace the tube fitting.
9. Install the new tube fitting (**C**). Note direction, radiator tube is 12.7 mm (1/2”) and PEX pipe is 12 mm. **DO NOT OVER THIGHT THE TUBE FITTING!**
10. Connect the PEX pipe to the cooling manifold.
11. Connect the DC-Hub to the cooling water system of the ship.
12. Fill and pressurize the cooling water system of the DC-Hub. Ensure that there is no water leakage.
13. Start up the DC-Hub.

15.11.3 LC-filter cooling fans replacement

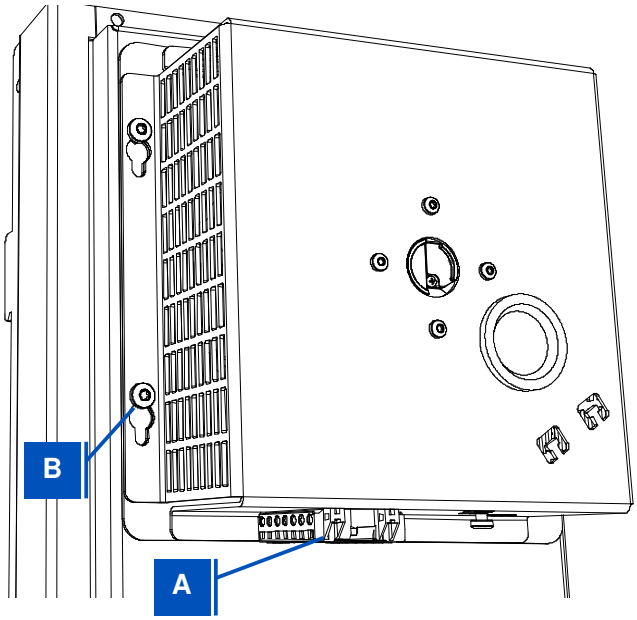


Figure 15-4 LC-filter cooling fan assembly.

1. Stop the DC-Hub and open breakers refer to chapter 15.3 Stop and disconnect the main sources of the voltages of the DC-Hub.
2. Disconnect cabinet auxiliary supply/s.
3. Disconnect the plug of the cooling fan (**A**).
4. Remove the 4 screws that fasten the cooling fan assembly and slide it from the frame (**B**).
5. Replace the cooling fans in the cooling fan assembly. Look at the spare part list.
6. Re-attach the cooling fan assembly.
7. Connect the cable.
8. Start up the DC-Hub.

15.12 Replace HMI touch display

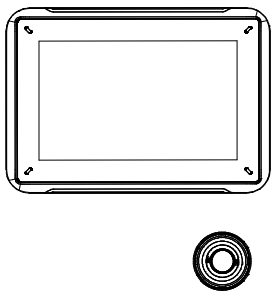


Figure 15-5 Touch screen display.

11. Turn off the 230 V power supplies.
12. Remove the 24 V power connector from the display.
13. Remove the Ethernet cable from the display.
14. Disconnect screws connecting the display to the control panel plate.
15. Remove the damaged display.
16. Install the new original display.
17. Reconnect screws to fasten display to the control panel.
18. Reconnect Ethernet cable to the socket marked "Ethernet or LAN A", NOT the socket marked "COM".
19. Reconnect 24 V power connector.
20. Turn on 230 V power supplies.
21. Reprogram the display if not pre-programmed. This must be performed by trained service personnel.

15.13 Check polycarbonate protection plates

The transparent polycarbonate protection covers protect components from damage and prevent touch. Any damage to the covers could indicate a serious fault with its neighboring component.



Caution!
Be careful not to overtighten the screws, as this can damage the components or screw heads.



Warning!
Electrical hazard



Make sure the breakers and pre-charge fuses are opened and secured with a personal padlock. Always measure voltage with a CAT III 1000V multimeter before touching electrical parts.



Make sure that all personnel who take part in the installation use correct ESD equipment, including clothing, as described in the Safety chapter.



The power modules must be treated as ESD sensitive material. Always ask a service engineer for help if you are not trained or if you are unsure about this procedure

1. Stop the DC-Hub and open breakers refer to chapter 15.3 Stop and disconnect the main sources of the voltages of the DC-Hub.
2. Open the front doors of a section.
3. Inspect polycarbonate plates for cracks, discoloration, heat damage or water spills.
4. If any of these are discovered, contact the service for assistance.

15.14 Check /clean cabinet

The cabinet shall be inspected for overall mechanical construction and all equipment, especially power modules fastened properly in places. Under vibrations generated forces fastening hardware may get loosened.
If the cabinet is dirty, it must be cleaned.



Warning!
Electrical hazard



Make sure the breakers and pre-charge fuses are opened and secured with a personal padlock. Always measure voltage with a CAT III 1000V multimeter before touching electrical parts.



Make sure that all personnel who take part in the installation use correct ESD equipment, including clothing, as described in the Safety chapter.



Caution!
Be careful not to overtighten the screws, as this can damage the components or screw heads.

1. Stop the DC-Hub and open breakers refer to chapter 15.3 Stop and disconnect the main sources of the voltages of the DC-Hub.
2. Disconnect the cooling water supply refer to chapter 15.5 Disconnecting the cooling water supply.
3. Open front the cabinet doors.
4. Inspect for dirt or signs of leaks.
5. Inspect for abnormalities in cabinet structure and loose items.
6. Clean the cabinet of dirt.
7. Use appropriate cleaning methods, equipment, and agents.
8. Dry the cabinet thoroughly.
9. Start up the DC-Hub.

15.15 Check/clean radiator

The internal fans pull air through the radiators so that they can gather dust and lose effectiveness over time. Regular cleaning is necessary to keep the radiators clean and function properly.



Warning!
Electrical hazard



Make sure the breakers and pre-charge fuses are opened and secured with a personal padlock. Always measure voltage with a CAT III 1000V multimeter before touching electrical parts.



Make sure that all personnel who take part in the installation use correct ESD equipment, including clothing, as described in the Safety chapter.



Caution!
Be careful not to damage the copper pipes of the radiator.

1. Stop the DC-Hub and open breakers refer to chapter 15.3 Stop and disconnect the main sources of the voltages of the DC-Hub.
2. Disconnect the cooling water supply refer to chapter 15.5 Disconnecting the cooling water supply.
3. Disconnect cooling water pipes from radiator assemblies. Use a suitable size bucket to collect any water drops.
4. Remove fan assemblies with metal plates.
5. Remove radiator assemblies.
6. Clean radiator assembly.
7. Reassemble in reverse order.
8. Start up the DC-Hub.

15.16 Check control cable connector screws

Some of the electrical wires to the control components are fastened with standard screw connectors, but most of the terminals are with cage clamp terminals. In a maritime environment, vibration, temperature changes and corrosion can cause screw connectors to loosen over time. To prevent this, the wire connector screws need to be tightened at regular intervals.
Make sure that the screws are tight enough to prevent any movement of the wires, but not so tight as to cause damage to the wire or the connector.



Warning!
Electrical hazard



Make sure the breakers and pre-charge fuses are opened and secured with a personal padlock. Always measure voltage with a CAT III 1000V multimeter before touching electrical parts.



Caution!
Be careful not to overtighten the screws, as this can damage the components or screw heads.

1. Stop the DC-Hub and open breakers refer to chapter 15.3 Stop and disconnect the main sources of the voltages of the DC-Hub.
2. Open the control cabinet doors.
3. Go over the components and tighten their connector screws if necessary.
4. Reconnect electrical supply.
5. Start up the DC-Hub.

15.17 Check power cable connection

Check the power cable connection to the busbars.
Check the earthing cable connection to the PE busbar. Note discoloration on connection points. If necessary, tighten the connections. Refer to chapter 9.3 Cable termination.



Warning!
Electrical hazard



Make sure the breakers and pre-charge fuses are opened and secured with a personal padlock. Always measure voltage with a CAT III 1000V multimeter before touching electrical parts.

1. Stop the DC-Hub and open breakers refer to chapter 15.3 Stop and disconnect the main sources of the voltages of the DC-Hub.
2. Open the power section doors.
3. Go over the connections and tighten if necessary.
4. Reconnect electrical supply.
5. Start up the DC-Hub.

15.18 ID Run procedure

If an electrical machine connected to the DC-Hub is changed or replaced, an ID Run procedure should be performed to measure some of electrical machine parameters.



Only perform ID Run procedure if told to do so by qualified service engineers.

Only perform the test on a disconnected electrical machine with no load. Do not perform this procedure on a hot electrical machine.
The service tool used for this procedure is the PowerDrive ID Run tool. Please refer to the separate PowerDrive ID Run tool manual that shows how to use this tool and perform the ID Run procedure.
After completing the procedure, the measured values must be manually entered into the electrical machine parameter database. The parameters are PID 206 (resistance stator), PID 207 (leakage inductance) and PID 208 (magnetizing inductance).

15.19 Testing water leakage sensor

The DC-Hub is equipped with water leakage sensors. The sensor is mounted inside on the floor of the control section. The sensor wire runs all the way through the sections and will give an alarm if the sensor wire is exposed to water.
The sensor can easily be tested whenever the sensor is in contact with the water. The water can be removed by applying dry cloth or similar. PLC creates alarm in case of leakage detected. Refer to the circuit diagram (water leakage sensor).

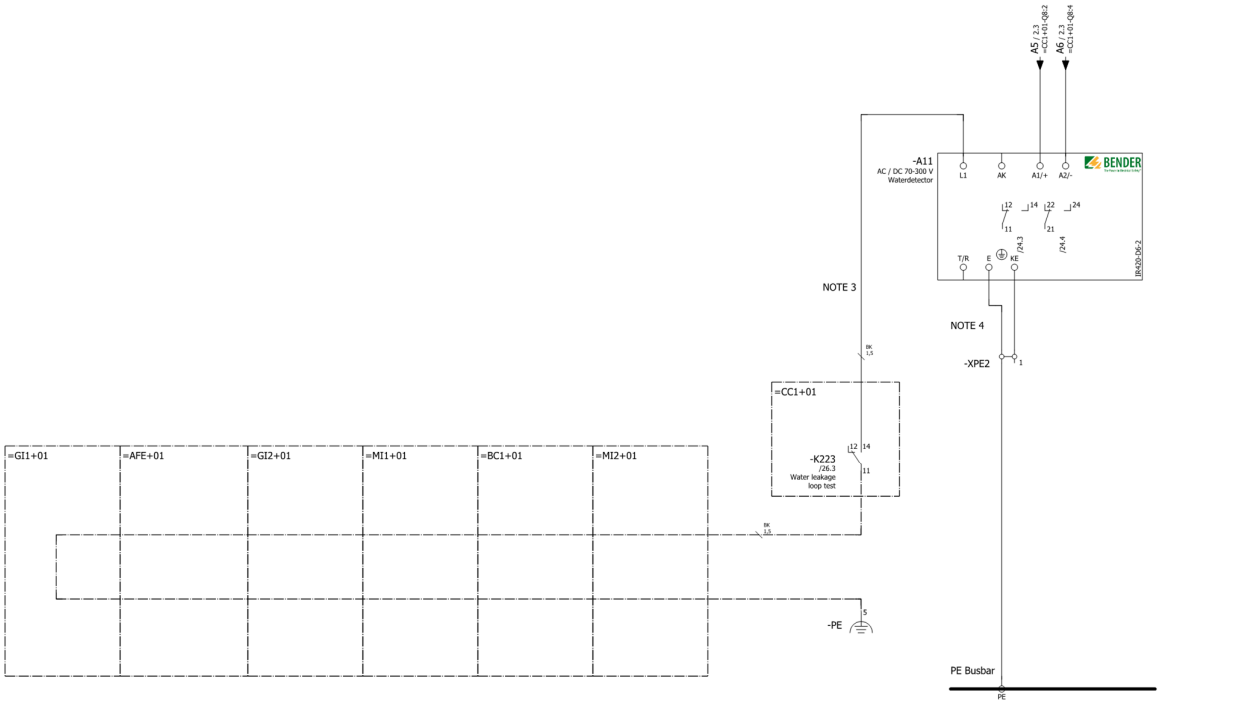


Figure 15-6 Water leakage sensor (example).

Warning!
Electrical hazard. Be careful not to spill any water on any internal components.

Warning!
Electrical hazard Do not come into contact with the test equipment while test is running. Always make sure the area is secured before testing begins.

Make sure the breakers and pre-charge fuses are opened and secured with a personal padlock. Always measure voltage with a CAT III 1000V multimeter before touching electrical parts.

1. Stop the DC-Hub and open breakers refer to chapter 15.3 Stop and disconnect the main sources of the voltages of the DC-Hub.
2. Locate the water leakage sensor cable in the bottom of the cabinet.
3. Wet a rag or piece of cloth in water.
4. Place wet rag over leakage sensor cable at bottom of cabinet.
5. Verify that the alarm: "Water leakage cabinet" appears on the touch displays.
6. Carefully dry the sensor and the area around it.

7. Reset the alarm display.
8. Start up the DC-Hub.

15.20 Testing valves

The cooling water valves must be tested regularly to prevent cooling water impurities or other factors from causing them to become stuck.



Warning!
Electrical hazard. Do not come into contact with the test equipment while the test is running. Always make sure the area is secured before testing begins.



Make sure the breakers and pre-charge fuses are opened and secured with a personal padlock. Always measure voltage with a CAT III 1000V multimeter before touching electrical parts.

1. Stop the DC-Hub and open breakers refer to chapter 15.3 Stop and disconnect the main sources of the voltages of the DC-Hub.
2. Move the cooling valves from the open to the closed position and back again. Make sure the valves move smoothly.
3. Start up the DC-Hub.

15.21 Inspect the condition of AC capacitors

In preventive maintenance the value of actual capacitance shall be verified, if reduced 10% or more from initial value, the capacitor must be changed.
Internal pressure been excessive inducing a bulging case can be detected by visual inspection. Ultimately the build in feature isolates the capacitor coils from terminals resulting in expanded casing and zero in capacitance value in testing. Typical life expectancy of applied capacitors is >200 000 h. Refer to the separate manufacturer's service notes for capacitors.



Warning!
Electrical hazard. Do not come into contact with the test equipment while the test is running. Always make sure the area is secured before testing begins.



Make sure the breakers and pre-charge fuses are opened and secured with a personal padlock. Always measure voltage with a CAT III 1000V multimeter before touching electrical parts.

1. Stop the DC-Hub and open breakers refer to chapter 15.3 Stop and disconnect the main sources of the voltages of the DC-Hub.
2. Make visual checking and proceed with necessary electrical measurements to ensure the correct operation of the AC capacitors. Replace it if necessary.
3. Start up the DC-Hub.

15.22 Check the condition of breakers and switches



Warning!
Electrical hazard. Do not come into contact with the test equipment while the test is running. Always make sure the area is secured before testing begins.



Make sure the breakers and pre-charge fuses are opened and secured with a personal padlock. Always measure voltage with a CAT III 1000V multimeter before touching electrical parts.

1. Stop the DC-Hub and open breakers refer to chapter 15.3 Stop and disconnect the main sources of the voltages of the DC-Hub.
2. Refer to the service notes and proceed with necessary measures to ensure the correct operation of the brakers. Replace it if necessary.
3. Start up the DC-Hub.

15.22.1 Breaker checking after short circuit current

A general inspection of the circuit breaker must be performed after any event that causes the circuit breaker to open with a short-circuit current. Follow the manufacturer's instructions for a general inspection of the circuit breaker.

15.22.2 Breaker maintenance schedule

Refer to the separate manufacturer’s service note for circuit breakers for detailed service program. Flow the manufacturer’s maintenance schedule.

15.23 Inspect the condition of vibration dampers and fastening to floor

Tighten bolts if needed. Replace the damper if needed.
The DC-Hub is fastened to the floor through the dampers at base of the cabinet using e.g., M12 lubricated bolts with spring washer, 4 pcs per damper. Recommended tightening torque is 40 Nm.

15.24 Inspect the condition of the fan-and-filter unit of disconnector cabinets

Warning!
Electrical hazard

Make sure the breakers and pre-charge fuses are opened and secured with a personal padlock. Always measure voltage with a CAT III 1000V multimeter before touching electrical parts.

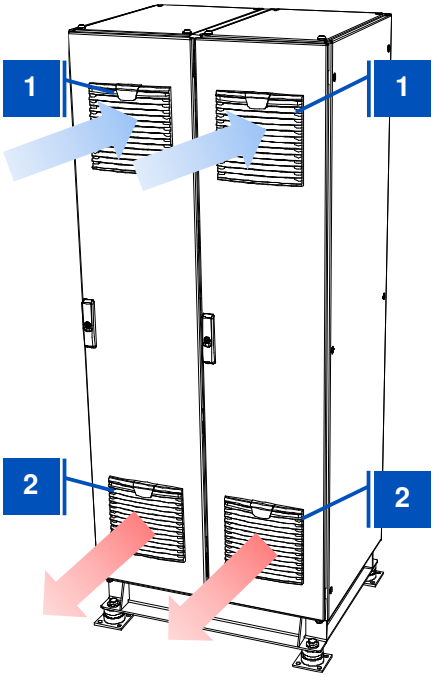


Figure 15-7 Air flow through the disconnector cabinets. Output Disconnector Cabinet (ODC) and Starpoint Disconnector Cabinet (SDC).

1	Inlet, fan-and-filter unit
2	Outlet, filter unit

The fan and filter unit (2 pcs) are located at the top of the disconnector cabinets. Lower ones are equipped with only outlet filter.
From time to time, the components may need to be cleaned using a vacuum cleaner or compressed air if they become visibly dirty. Any stubborn, oily stains may be removed using a non-flammable detergent, such as degreaser.
Sequence of maintenance measures: The filter should be checked at regular intervals in accordance with the level of dust exposure and replaced as necessary.
For cleaning/replacing the filter or replacing the fan see the EC fan-and-filter unit Assembly and operating instructions

1. Stop the DC-Hub and open breakers refer to chapter 15.3 Stop and disconnect the main sources of the voltages of the DC-Hub.
2. Open front the cabinet doors.

3. Check the level of dirt at the fan-and-filter unit.
    a. Filter soiling? Clean/replace.
    b. Are fan membranes soiled? Compressed air cleaning.
    c. Check the noise generation of the fan.
4. Start up the DC-Hub.

15.25 Power module cooling fans replacement

If a power module fan alarm is detected. A possible reason for this could be a faulty fan that needs to be replaced.

- Follow procedure described in chapter 10.5 Installing and removing the power module.
- Place the power module on sturdy work surface.
- Open the left side panel of the power module. Unscrew hex nuts by using a wrench 10 mm.
- Disconnect fan cables (3 Abico connectors per fan).
- Unscrew mounting bolts (M3x45) of fan by using Torx head T9. The right-side fan shall be removed first (4 Torx-bolts), and then the left-side fan (2 Torx-bolts) shall slide over the frame to right so that it can be removed.
- Replace the fan and connect the cables.
- Mount the side panel.
- Install the power module into the cabinet.



Caution!
Only the Switch's authorized service personnel can open the power module. There is a risk of equipment damage.



Caution!
Only the Switch's authorized service personnel can open the power module. There is a risk of equipment damage.



Make sure that all personnel who take part in the installation use correct ESD equipment including clothing, as described in chapter 5.9 Electrostatic discharge (ESD) protection.

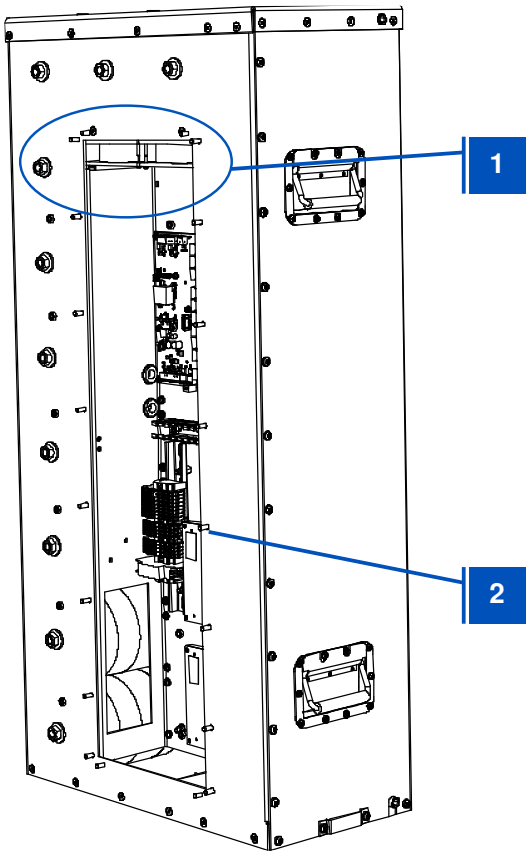


Figure 15-8 The left side panel is removed.

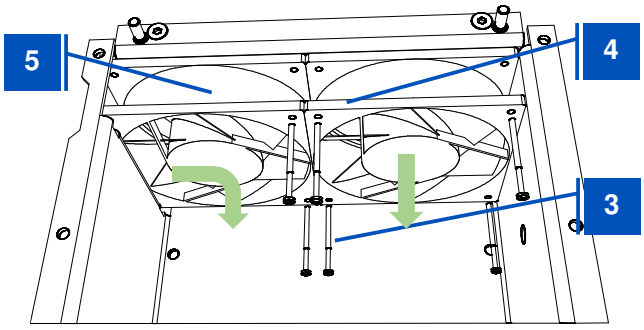


Figure 15-9 Fans removal.

1	Fan location
2	Panel fastening hex nuts 10 mm
3	Fan mounting Torx-Screw (4 + 2 psc) Torx head T9
4	Fan first to be removed
5	Fan slide aside

16 Cyber security

16.1 Foundational requirement

In the following, the capabilities of the control system are described from the viewpoint of each foundational requirement according to IEC 62443.
The Switch DC-Hubs and Single Drives fulfill IEC security level (SL) - SL1. Protection against casual or coincidental violation.

16.1.1 Identification and authentication

All users shall be identified and authenticated before given access to the system. There are three kinds of interfaces to control system:

- maintenance access
  - user level
  - admin level
- diagnostic access
- fieldbus access

Maintenance access uses secure shell (ssh) protocol to access the system. Password authentication is not permitted by the ssh server on the control system. Only public key authentication is possible. Identification of users is made based on different keys.

16.1.2 Use control

Enforce user's privileges and monitor these.
Wireless access is not provided by the control system.
Specific portable or mobile interfaces are not provided.
The PLC is password protected and only The Switch will have written access to the code. Customers will receive an upload password which allows them to download the software to the PLC if needed.
Cabinet automation PLC inside the control section. Application PLC The application can be used as an alternative interface towards external control systems.
The managed switch username and password are changed from default to restrict unwanted access.

The Switch DC-Hubs and Single Drives are located e.g., in an engine room or in a container on a ship's deck and an upper-level remote control system are in a control room or a bridge. Accessible to these rooms shall be restricted during commissioning, normal operation, and maintenance works.
Means to restrict access in case the control room is unattended should be addressed.
The ship owner shall do a cyber security risk assessment to define the needed risk reduction measures for these functions.

16.1.3 System integrity

Ensure system integrity from unauthorized manipulation.
The control system provides a software update facility. The software update facility allows to upload a new software package (“release package”) to the system. The release packages are digitally signed by The Switch using an asymmetric cryptography algorithm. When software from a release package is extracted, the signature of the package is checked using the public part of the signing key. If the signature does not match, the release package

is not accepted and software from the package is not executed. The private signing key is only in the possession of The Switch, valid software packages can only be created by The Switch.
The release packages are also encrypted further increasing the protection against malicious code.

16.1.4 Data confidentiality

Ensure confidentiality and prevent unauthorized disclosure of system communication.
The control system provides a backup facility. The backup files can be downloaded from the system to the host computer.

16.1.5 Restricted data flow

Limit unnecessary data flow by segmenting.
Since the control system is part of a single zone, these requirements do not have any effect into the cyber security functionality of the system.
The managed switch is configured with virtual LANs to isolate data traffic between the internal and external network. With its built-in firewall, port forwarding is used to allow specific data transmission from one VLAN to another. The data is mapped and forwarded to a given destination.

16.1.6 Timely response to events

Respond to incidents and evidence of violations, and correct action when incidents are discovered.
The control system provides read-only access to logs described earlier in this chapter.

16.1.7 Resource availability

Ensure the availability of the system in case of cyber security incident.
The control system provides system backup and system restore functionalities. System backup backups the following files:

- Maintenance and diagnostic access user databases and Ssh public keys
- Network configuration (IP address)
- Active release package (can be optionally left out, since available from The Switch)

17 Recycling instructions

The following describes specific end-of-life recommendations and safety instructions for the DC-Hub. These recommendations consider the material content of the products and the level of hazard their end-of-life treatment may cause.



Warning!
Ensure that the DC-Hub is separated from all electric power supplies.



Warning!
Secure safety in capacitor decommissioning by measuring that there is no remaining voltage. If voltage remains, discharge capacitors safely and measure again.



After decommissioning make sure that all materials are disposed of and recycled according to local regulation.

Summary of recommendations for different materials.

1. Much of the DC-Hub consists of different basic metals (iron, steel, aluminum, copper etc.). In metal recycling, it is recommended to follow the sequence presented below.
2.
   a. There are some chemicals with hazardous properties used in the assembly and operation of the DC-Hub, such as cooling liquid. These hazardous substances must be completely separated from the DC-Hub and disposed according to local instruction via a specialized company to avoid health and environmental damages. Material safety data sheets should be available for the user of the converter to secure safe handling of each hazardous substance.
   b. Metal parts that have been in contact with hazardous chemicals must be carefully cleaned before separation. If hazardous chemicals cannot be removed from these parts, the part must be separated to hazardous waste and disposed of according to local instruction by a specialized hazardous waste company.
   c. If the material content of the metal includes a significant portion of heavy metals, such as lead, the part in question should not be recycled along with other metals. Instead, it should be separately collected and handled in a hazardous waste management facility.
   d. Reuse opportunities for all metal components must be considered. If there is no opportunity for reuse, separate all metals (primary option) or collect them together to metal waste (secondary option). All non-heavy metals can be recycled by melting.
   e. If it is possible and economically reasonable, remove impurities (rubber, plastic, glass fiber) from metal parts before collection as well as possible. There is **copper** in multiple parts of the DC-Hub (e.g., cables). Copper parts should be disconnected from other parts of the product and collected separately. Plastics should be peeled off the copper wires either on site or in a waste management facility. If the peeling is done on site, copper should be

collected separately or placed into metal waste and plastics to either separate plastic collection, mixed waste or burnable (energy) waste according to the local waste management instructions.

3. All **electrical parts** should be separated and placed into electric waste.
   a. Capacitors need to be short-circuited in a safe manner before decommissioning and placement among waste.
   b. Circuit boards (PCBAs) can also be placed among electric waste, even old ones that may contain lead and other heavy metals restricted by RoHS directive.
4. The product also may contain smaller amounts of other substances, such as rubber, plastic (PA, PE and PP), composites and other insulation materials. If separate collection of these parts is possible, it is recommended otherwise, these materials should be recycled according to local waste regulations. Note that incineration of some substances, such as rubber or insulation materials, will lead to toxic gases, which is why they should not be burned or separated along other burnable waste components.

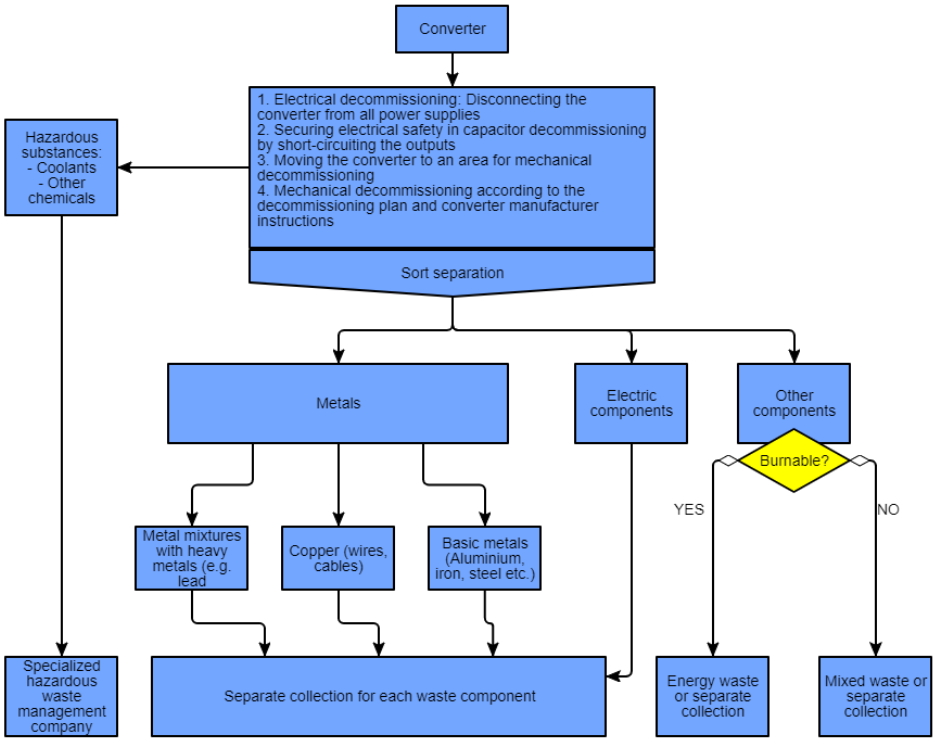
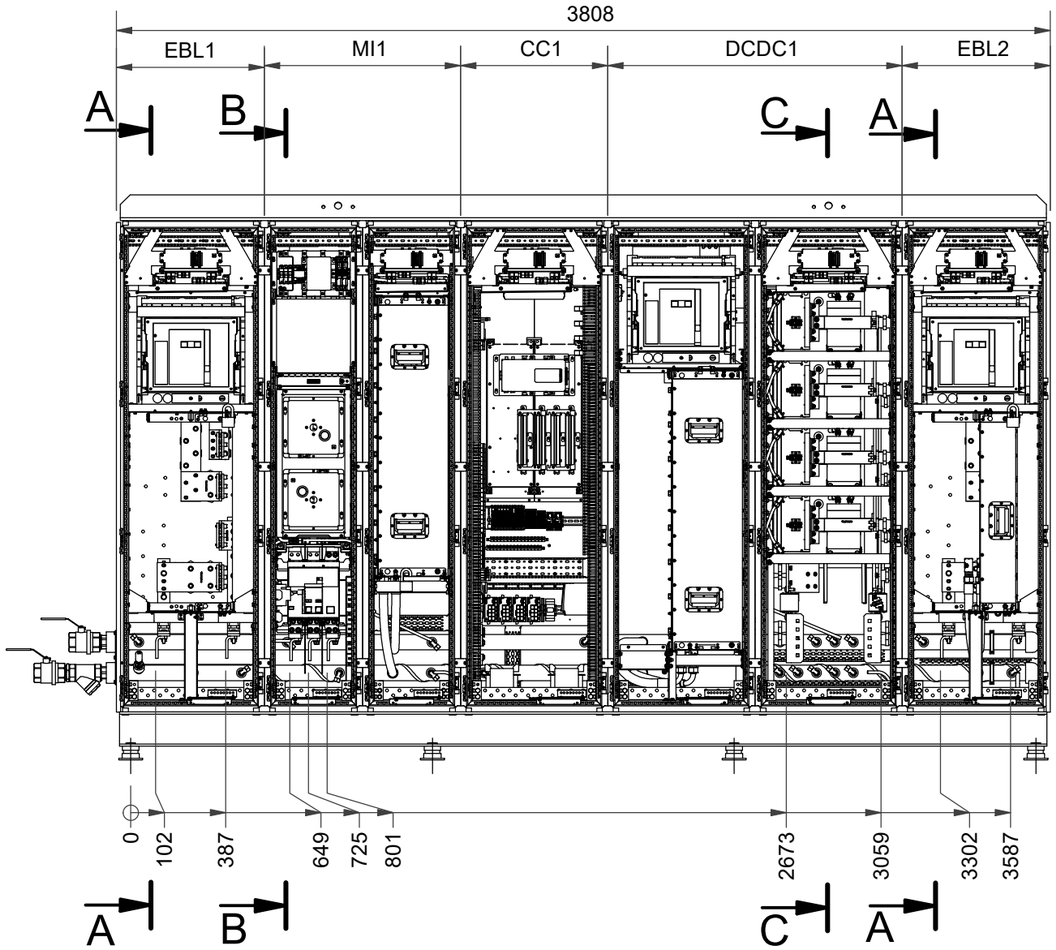


Figure 17-1 Summary of recycling recommendations.

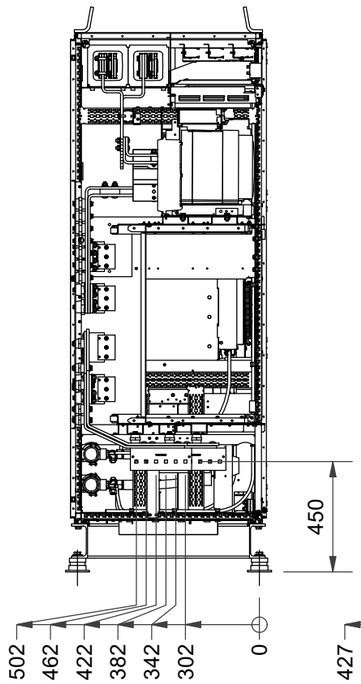


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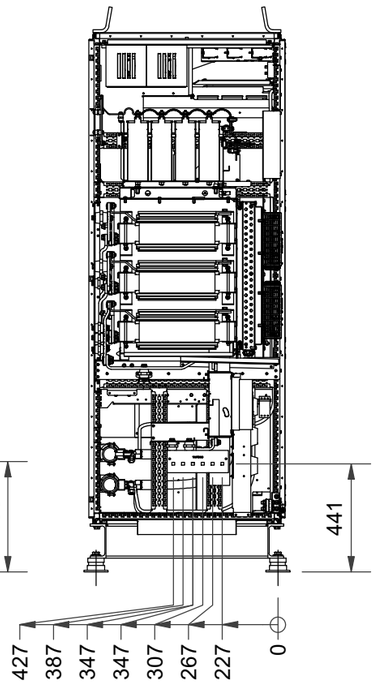
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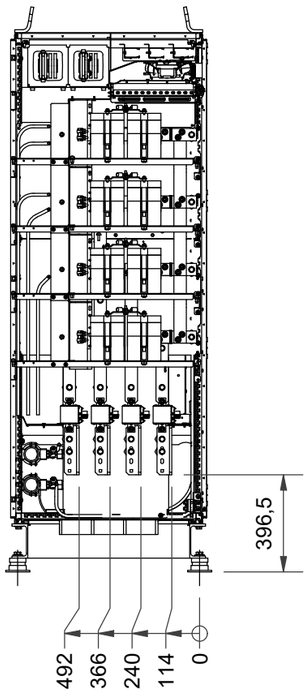
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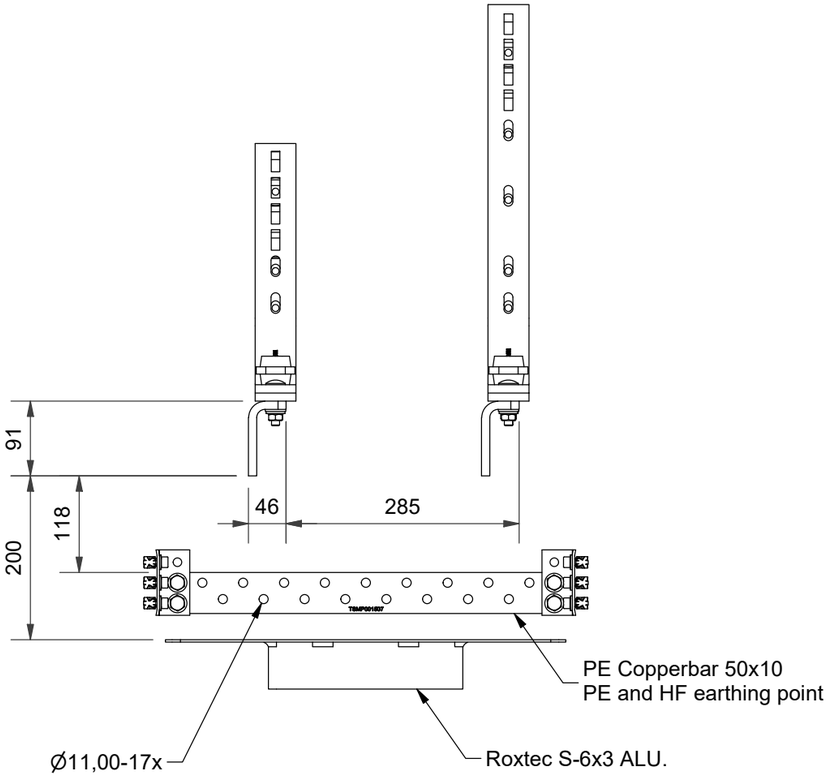


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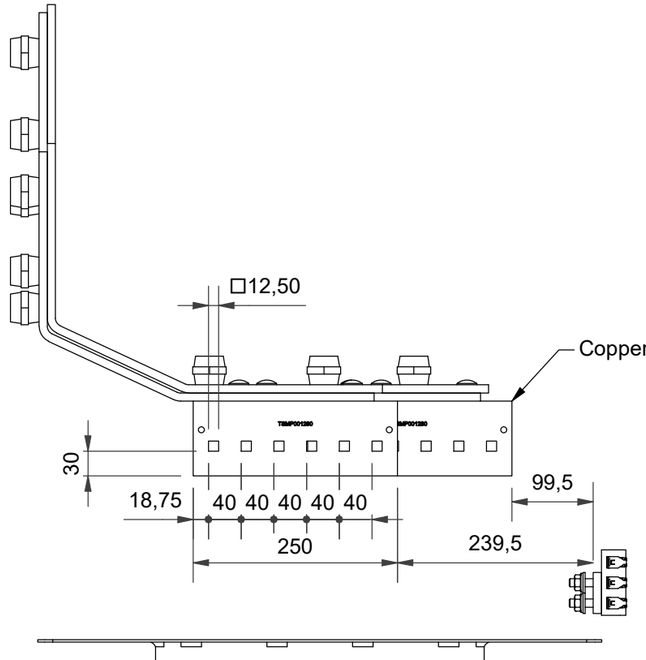
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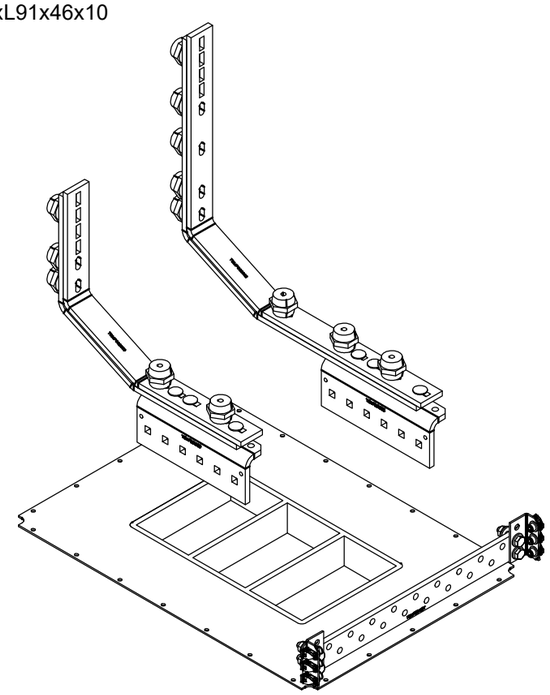
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FRONT VIEW



SIDE VIEW





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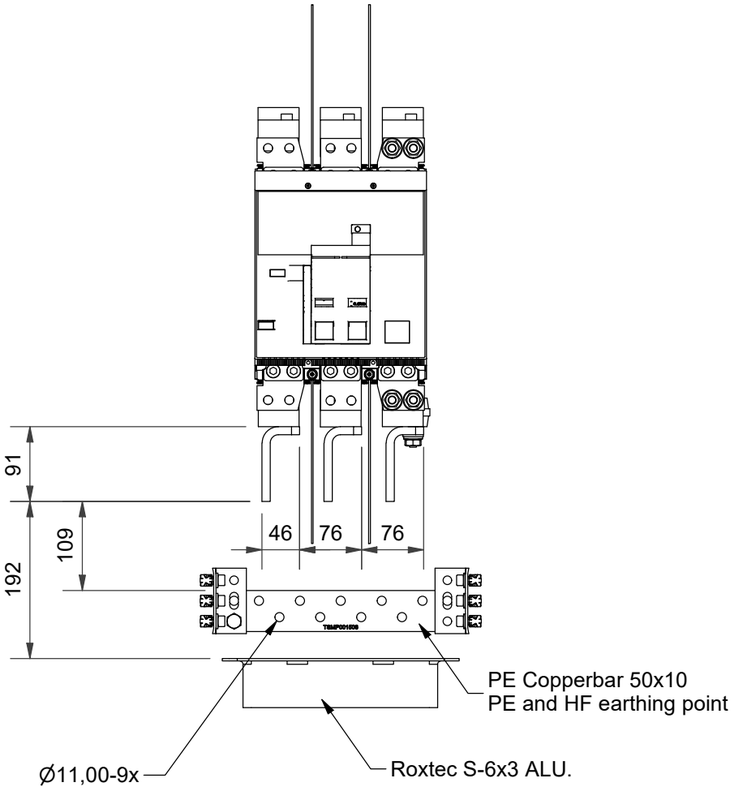
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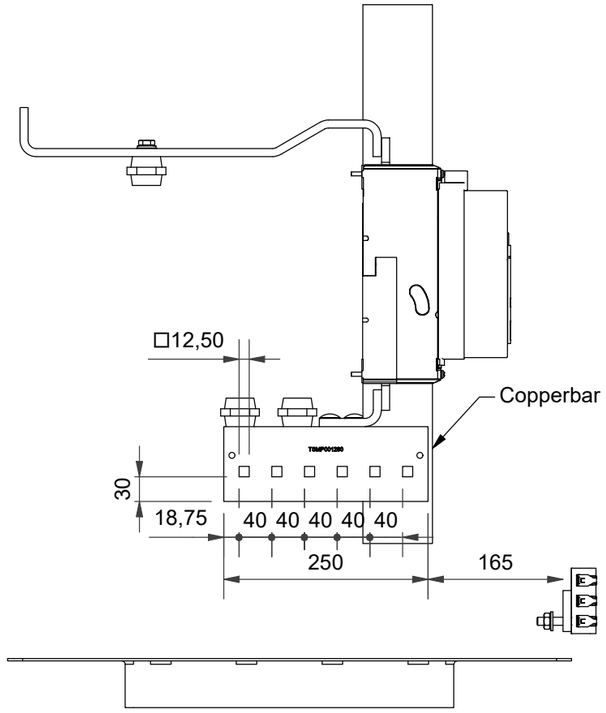
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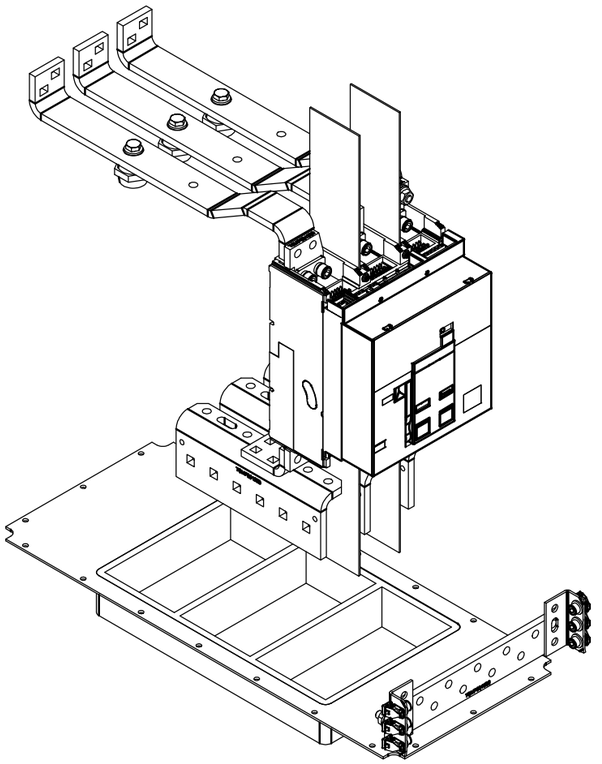
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FRONT VIEW



SIDE VIEW





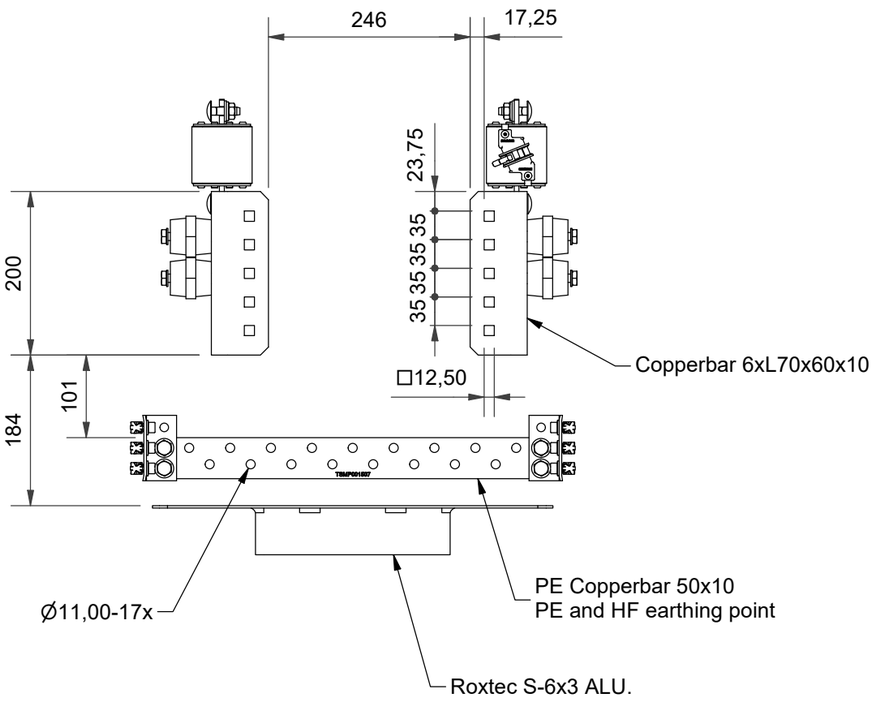
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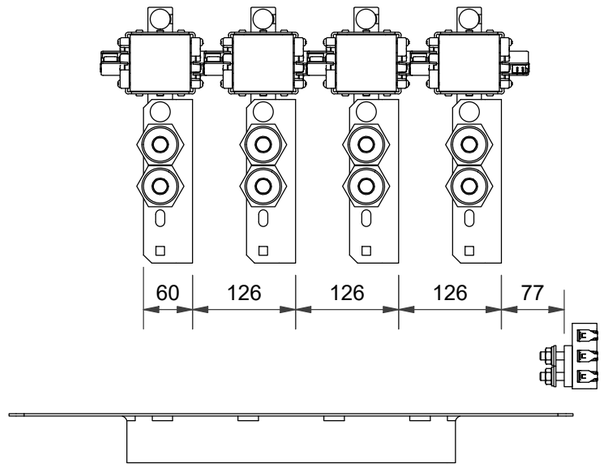
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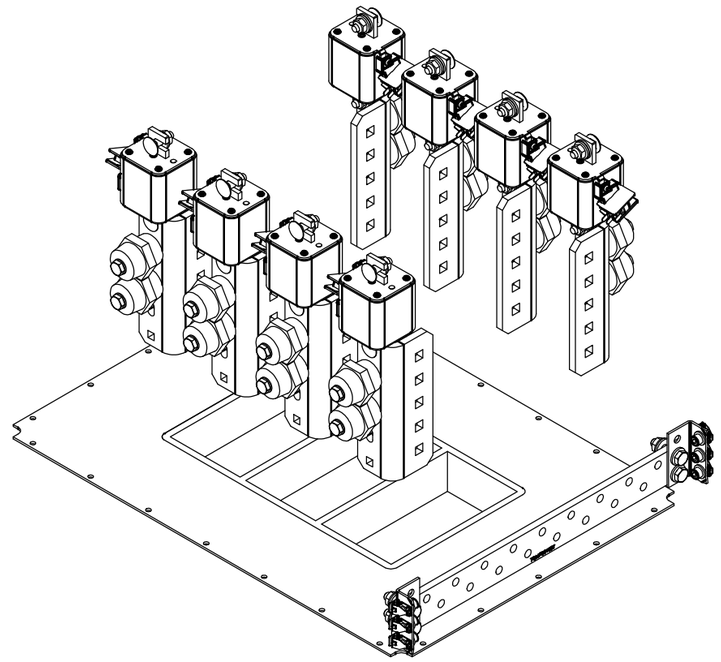
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FRONT VIEW



SIDE VIEW





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Technical Specification

The Switch DC-Hub

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Product type	The Switch DC-Hub
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DC-Hub Technical Specification

Version	Date	Prepared	Description	Approved	Date
R1	02.05.2025	RouEe	First release		
R2	10.10.2025	MarNi	Updated to match SLD		
R3	20.11.2025	MarNi	Updated DC source & removed seaworthy packaging & Added EBL module		

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1 Naming logic of applications

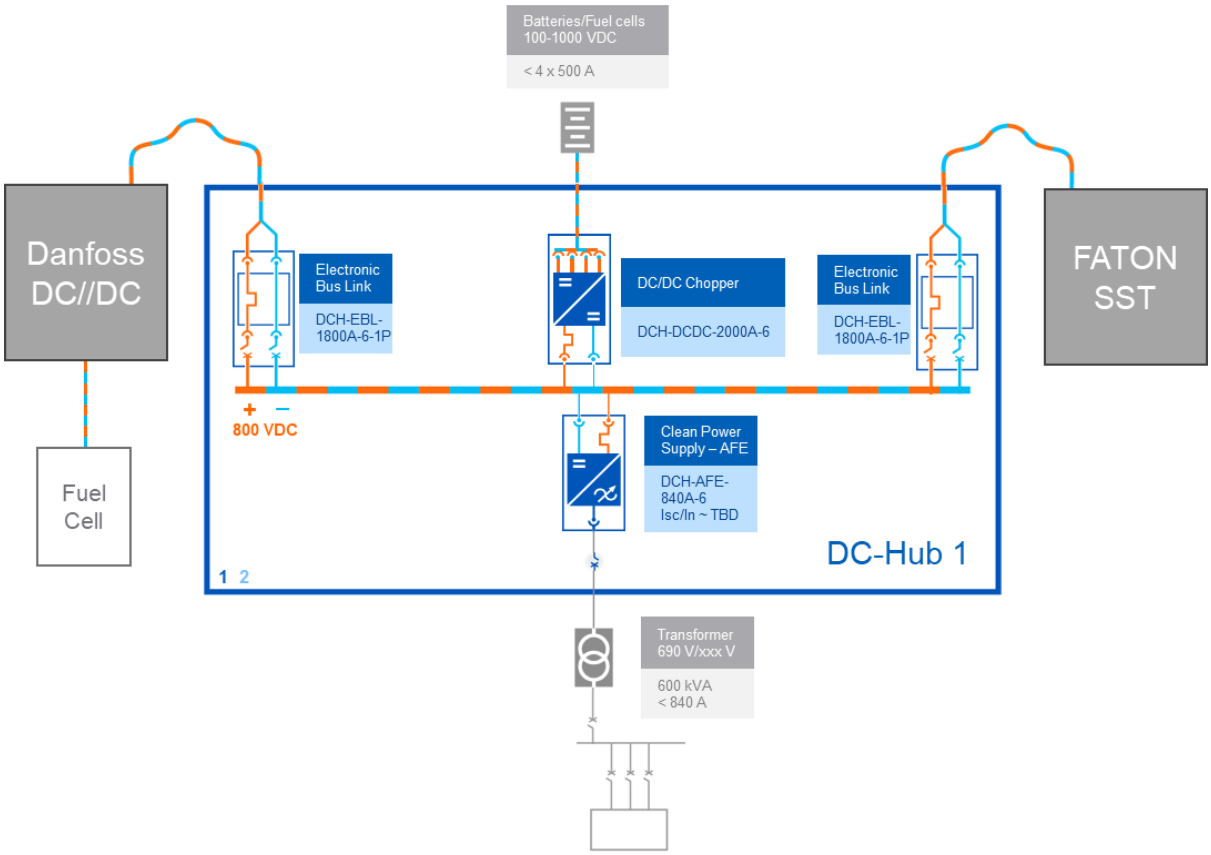
Type	-	**Application**	-	**Nominal Current limit [A]**	-	**Nominal Voltage level**
SD = Single Drive DCH = DC-Hub	-	AFE = Active Front End MI = Motor Inverter PR = Passive Rectifier DCDC = DC/DC Chopper DCF = DC connection with fuses EBL = Electronic Bus Link ECL = Electronic Current Limiter BSCL = Battery Short-Circuit Limiter CC = Control Cabinet EC = Empty cabinet (customizable) AC = Application Cabinet ODC = Output Disconnector Cabinet SDC = Starpoint Disconnector Cabinet	-	xxxxA E.g. 1600A = Limit of 1600 A E.g. 4x500A = 4 separate connections of 500 A each.	-	y E.g. 6 = Voltage level between 600 and 699 V_{AC}

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2 Project specific description

2.1 DC-Hub 1

2.1.1 DC-Hub 1 Single Line Diagram



2.1.2 DC-Hub 1 configuration

Before binding quote building blocks to be labeled and organized.

Label	Customer Label	Application	Material Name
		Transport section 1	
EBL1	-	Electronic Bus Link to another DC-Hub	DCH-EBL-1800A-6-1P
AFE1	-	Active Front End to transformer	DCH-AFE-840A-6
CC1	-	Control cabinet	DCH-CC-600
DCDC1	-	DC/DC chopper to battery/fuel cell	DCH-DCDC-2000A-6
EBL2	-	Electronic Bus Link to another DC-Hub	DCH-EBL-1800A-6-1P

*Customer labeling needs to decided before PO. Labeling location under global option.

2.1.3 DC-Hub 1 options

EBL1	**DCH-EBL-1800A-6-1P**		
	DC link Pre-charge	----	☒ (No, standard)

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		+P02	☐ (Yes)
	Cabling length to other DC-Hub	3	[m]
	Local control	+X03 +X02	☒ (Indication lights + buttons, standard) ☐ (HMI, Mandatory with option +P02)
AFE1	**DCH-AFE-840A-6**		
	Application PLC	---- +A01	☒ (No, standard) ☐ (Yes)
	DC link pre-charge	---- +P01	☐ (No, standard) ☒ (Yes)
	Grid side filtering	----- +G01	☒ (LC, standard) ☐ (LCL)
	Electronic DC Breaker (EDCB)		☐ (No) ☒ (Yes, standard)
	Transformer specifications	N/A	No transformer
	Type	N/A	[Step up; step down; isolation]
	Voltage on AFE side	N/A	[V_{AC}]
	Rated power	N/A	[kVA]
	Number of AFE side windings	N/A	[1; 2; 3; 4]
	Prospective SC current at DC-Hub terminals	N/A	[kA] Note: Please see application limits
	Winding and cabling minimum inductance	N/A	[µH] Note: see AFE electrical rating paragraph
CC1	**DCH-CC-600**		
	EDCB capacitors	----- +E02	☐ (No, standard) ☒ (Yes)
	Number of applications	+C01 +C02 +C03 +C04	☐ (1 application) ☐ (2 applications) ☐ (3 applications) ☒ (4 applications)
	Number of HMIs	+C11 +C12 +C13 +C14	☐ (1 HMI) ☒ (2 HMIs) ☐ (3 HMIs) ☐ (4 HMIs)
DCDC1	**DCH-DCDC-2000A-6**		
	Application PLC	---- +A01	☒ (No, standard) ☐ (Yes)
	DC link pre-charge	---- +P02	☒ (No, standard) ☐ (Yes)
	Cables per terminal	----	☒ (1-4 cables per terminal, standard) ☐ (Customized)
	Electronic DC Breaker (EDCB)		☐ (No) ☒ (Yes, standard)
	DC Source		

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	Source type		[Battery]
	Number of strings/cables	8	
	Capacity (if battery)	1000	[kWh]
	C rating (if battery)	0.7	
	Used SoC range (if battery)	30-80	%
	Used voltage range	100-750	[V_{DC}]
	Prospective SC current at DC-Hub terminals	10	[kA per string]
	Isolation at source end	No	[Yes; No]
	Cabling length	5	[m]
EBL2	**DCH-EBL-1800A-6-1P**		
	DC link Pre-charge	---- +P02	☒ (No, standard) ☐ (Yes)
	Cabling length to other DC-Hub	3	[m]
	Local control	+X03 +X02	☒ (Indication lights + buttons, standard) ☐ (HMI, Mandatory with option +P02)
General	**General options for DC-Hub**		
	Main inlet valve(s) with particle Y-filter for Ø≥1mm particles	---- +B01 +B02	☒ (None, standard) ☐ (Yes, valves and filters) ☐ (Yes, valves) Note: valves and filters recommended for maintenance purpose, filter must be installed horizontally
	Cooling manifold connection	+B11 +B12 +B13	☒ (Left) ☐ (Bottom) ☐ (Right, if only 1 transport section)
	Vibration dampeners	-O00 ----	☐ (No) ☒ (Yes, standard)
	Flexible top fixing	---- +O11	☒ (No, standard) ☐ (Yes)
	UPS fed circuits	-O80 -----	☐ (Cabinet fans excluded) ☒ (All aux circuits, standard)
	Isolation monitoring	-O20 ----	☐ (No) ☒ (Yes, standard)
	Leakage detection	-O30 ----	☐ (No) ☒ (Yes, standard)
	Anti-condensation heating	-O40 ----	☐ (No) ☒ (Yes, standard)
	Network topology	---- +O50	☒ (Star, standard) ☐ (Ring)
Global	**Global options for project**		
	Cyber security	-O61 ----	☐ (None) ☒ (IEC security level: SL1, standard)
	Lifting equipment for power modules	---- +O71	☒ (No, standard) ☐ (Yes)

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	Seaworthy packaging	-O72 ----	☒ (No) ☐ (Yes, standard)
	Customer labeling	---- +L01 +L02 +L03	☒ (The Switch labels, standard) ☐ (Cabinet section label) ☐ (Documentation[1]) ☐ (Device designation, IEC 81346-1 compatible labels required)
	Customized product branding	---- +L04	☒ (No, standard The Switch branding) ☐ (Yes, separate agreement needed)

[1] General arrangement drawings and circuit diagrams

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3 General DC-Hub data

3.1 DC-Hub voltage ratings

AFE/MI AC voltage	690 (max 0,97*lowest DC voltage/sqrt(2))	V_{AC}
DC nominal voltage	1050	V_{DC}
DC operating range	900…1100	V_{DC}

3.2 Electrical interface

Terminals	Ref GA02, issued during project phase
Power Cabling direction	Bottom entry
Power Cabling let-through	MCT frame (MCT modules not included)
Power Cabling information	Ref product manual
Power Cabling connections	Busbar connection with M12 holes
Control cabling direction	Bottom entry
Control cabling let through	MCT frame (MCT modules included for CC)

3.3 Mechanical data

Dimensions	(Note: Height and depth fixed, width varying)	
Height	2198 w/o lifting bars, 2298 w/	mm
Depth	800	mm
DC-Hub 1 width	3800	mm
Cabinet access	Front	
Cabinet access type	Doors	
Cabinet door key type	SZ Enclosure key, double bit No. 5	
Doors position lock	Included	
Service space (front/back)	1000/100	mm
DC-Hub 1 (left/right)	700/100	mm
Service space (top)	100	mm
DC-Hub color	RAL 7035	
Weight		
DC-Hub 1	ca 3000	kg
Enclosure ingress class	IP44	

3.4 Cooling and Anti-condensation heating

See product manual for detailed information.

Cooling method	Liquid	
Coolant temperature (operation)	22…38	°C
Cooling medium	Freshwater with possible corrosion inhibitors	
Cooling manifold size IN/OUT	2"	
Cooling manifold type IN/OUT	PP-R, 2” male thread	

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Coolant flow rate		
DC-Hub 1 (EBL1 included?)	149	l/min
System max pressure	6	bar
Coolant pressure drop, inlet - outlet	2[2]	bar
System test pressure	9	bar
Anti-condensation heating	Included in all DC-Hubs	
Heating cable type	Self-regulating heating cable	

3.5 Auxiliary, UPS and Anti-condensation heating power supply

Cabling direction	Bottom entry	
Cabling terminals	1-phase, 1 x AUX + 1 x UPS supply + 1 x Condensation preventing heating supply per DC-Hub	
AC voltage nominal	230	V_{AC}
Voltage error at steady state	< ±10	%
Frequency range	47…63	Hz
Auxiliary connection short circuit rating	15	kA
Maximum power rating		
DC-Hub 1		
AUX input	ca 2000	VA
UPS input	ca 2000	VA
Anti-condensation heating	ca 171	W

3.6 Heat dissipation

Total losses @nominal operation point		
DC-Hub 1	36	kW
To liquid	90	%
To air	10	%

3.7 Standards and classification

Classification society, rulebook, and version	TBD by customer
Class notations	TBD by customer
DC-Hub classified as main switchboard	No
General design power modules	IEC 61800-5-1, IEC 60146-1-1
Operation conditions	IEC 60721-3-6
Storage conditions	IEC 60721-3-1
Transportation conditions	IEC 60721-3-2
EMC	IEC 61800-3
Switchgear	IEC 61439-1, -2
UPS and battery	IEC 62040-1
Degrees of protection (IP code)	IEC 60529

[2] Pressure drop from inlet to outlet at nominal flow rate

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3.8 Environmental requirements

3.8.1 Operation conditions

Ambient temperature	0…45	°C
Ambient relative humidity	25…95, No condensation allowed	%
Climatic condition	6K1	IEC 60721-3-6
Biological conditions	6B1	IEC 60721-3-6
Chemically active substances	6C1	IEC 60721-3-6
Mechanically active substances	6S1	IEC 60721-3-6
Mechanical conditions	6M2	IEC 60721-3-6
EMC category	C4	IEC 61800-3
Altitude maximum	3000 m (Derating 1 %/100 m above 1000 m)	
Vibration	Vibration velocity amplitude 20 mm/s in the frequency range 5 to 50 Hz	
Inclination[3]	static 0±15°, dynamic 0±22.5°	

3.8.2 Storage conditions

Storage temperature	+5…+55	°C
Ambient absolute humidity maximum	25	g/m^3
Ambient relative humidity maximum	85, No condensation allowed	%
Climatic condition	1K2	IEC 60721-3-1
Biological conditions	1B1	IEC 60721-3-1
Chemically active substances	1C2	IEC 60721-3-1
Mechanically active substances	1S2	IEC 60721-3-1
Mechanical conditions	1M2	IEC 60721-3-1

3.8.3 Transportation conditions

Transportation temperature	-25…+60	°C
Ambient absolute humidity maximum	25	g/m^3
Ambient relative humidity maximum	85, No condensation allowed	%
Climatic condition	2K2	IEC 60721-3-2
Biological conditions	2B1	IEC 60721-3-2
Chemically active substances	2C2	IEC 60721-3-2
Mechanically active substances	2S2	IEC 60721-3-2
Mechanical conditions	2M2	IEC 60721-3-2

[3] See product manual

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4 Active Front End (AFE) description

4.1 Power module

Application type	Module type
DCH-AFE-840A-6	1 x PD3.1-840A-(0+3+0)xT4+EDCB
DCH-AFE-1600A-6	1 x PD3.1-1600A-(6+0)xT4+EDCB

4.2 Electrical rating DCH-AFE-xxxxA-6

Variable	DCH-AFE-xxxxA-6		Comments
	840	1600	
Grid type	IT, 3-phase		
Nominal grid side current (I_{ND}) [A_{AC}]	840	1600	Continuous current
Heavy duty grid side current (I_{HD}) [A_{AC}]	700	1333	Heavy duty
Grid side current overload (I_{OL}) [A_{AC}]	1050	2000	150% * I_{HD} 8 minutes below I_{HD} followed by 2 minutes overload
Short circuit current contribution grid (I_{SC}), 500 ms [A_{AC}]	1250	2500	Drive must operate without alarms. Continuous current I_{ND}. Nominal heavy-duty cycle available. Overload current 150% * I_{HD} for 2 minutes followed by I_{HD} for 2 minutes.
Short circuit current contribution grid (I_{SC}), 2 s [A_{AC}]	1250	2500	Drive must operate without alarms. Continuous operation with I_{HD}. Derated heavy-duty cycle available. Overload current 133% * I_{HD} for 2 minutes followed by I_{HD} for 2 minutes.
Breaker SC rating [kA] / peak [kA]	30 / 64	66/ 145	
Short circuit rating	I_{cw} = 36 kA/1s I_{pk} = 80 kA	I_{cw} = 34 kA/1s I_{pk} = 75 kA	
Grid frequency range (f_r) [Hz]	50 / 60		
THD_U [%]	< 5		
Allowed voltage error at steady state [%]	< ±2,5		
Allowed voltage error at transient state [%]	< +20/-15		
Allowed frequency error at steady state [%]	< ±5		
Allowed frequency	< ±10		

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error at transient state [%]			
Nominal grid side switching frequency average (f_{sw}) [kHz]	3		
Filter type	LC (standard) or LCL		See option list
Winding and Cabling minimum inductance	80	40	[µH]
Circuit breaker	Included to all AFEs		
Frame type	Roxtec S-6x3		

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5 DC/DC chopper description

5.1 Power module

Application type	Module type
DCH-DCDC-2x500A-6	1 x PD3.1-840A-(2+0+0)xT4+EDCB
DCH-DCDC-1000A-6	1 x PD3.1-840A-(2+0+0)xT4+EDCB
DCH-DCDC-3x500A-6	1 x PD3.1-840A-(3+0+0)xT4+EDCB
DCH-DCDC-1500A-6	1 x PD3.1-840A-(3+0+0)xT4+EDCB
DCH-DCDC-2x1000A-6	1 x PD3.1-840A-(4+0)xT4+EDCB
DCH-DCDC-4x500A-6	1 x PD3.1-840A-(4+0)xT4+EDCB
DCH-DCDC-2000A-6	1 x PD3.1-840A-(4+0)xT4+EDCB

5.2 Electrical rating DCH-DCDC-xxxxA-6

Variable	DCH-DCDC-xxxxA-6							Comments
	2x500	1000	3x500	1500	2x1000	4x500	2000	
Nominal load/ source side current (I_{ND}) [A_{DC}]	2x500	1000	3x500	1500	2x1000	4x500	2000	Continuous current. No overload. Maximum current to/from DC link is 1800 A.
Input/output bridge legs per chopper	2	1	3	1	2	4	1	
Max voltage input/ output [V_{DC}]	1000							DC link voltage must always be 50V higher that output voltage, see product manual
Min voltage input/ output [V_{DC}]	600							
Nominal switching frequency (f_r) [kHz]	3							
Filter type	LC							Included to all DC/DC choppers
Short circuit rating per terminal pair	Icw = 30 kA/1s Ipk = 30 kA							Maximum SC rating 120 kA assumed 2000A DCDC with 4 terminal pair
Frame type	Roxtec S-6x3							

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6 Control cabinet & App PLC cabinet description

Type	Information			Comment
DCH-CC-600				width: 600 mm
	Max. Application amount	6	pcs	If over 4 Application, need to be reviewed case by case
	EDCB Capacitors	Possible option		
	Frame type	Roxtec Comseal 32/M		
DCH-AC-400				width: 400 mm
	Max. Application amount	3	pcs	
	Frame type	Roxtec Comseal 32/M		
DCH-AC-600				width: 600 mm
	Max. Application amount	5	pcs	
	Frame type	Roxtec Comseal 32/M		

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7 Electronic Bus Link (EBL) description

7.1 Power module

Application type	Module type
DCH-EBL-1800A-6-1P	1 x PD4.1-ECL-1800A-(1)xT3
DCH-EBL-3600A-6-1P	2 x PD4.1-ECL-1800A-(1)xT3
DCH-EBL-1800A-6-2P	1 x PD4.1-EBL-1800A-(2)xT3
DCH-EBL-3600A-6-2P	2 x PD4.1-EBL-1800A-(2)xT3

7.2 Electrical rating DCH-EBL-xxxxA-6

Variable	DCH-EBL-xxxxA-6-1P		DCH-EBL-xxxxA-6-2P		Comments
	1800	3600	1800	3600	
Nominal current (I_{ND}) [A_{DC}]	1800	3600	1800	3600	Continuous current
Heavy duty current (I_{HD}) [A_{DC}]	1500	3000	1500	3000	Heavy duty
Current overload (I_{OL}) [A_{DC}]	2250	4500	2250	4500	150 % * IHD. 8 min below I_{HD} → 2 min I_{OL}
Dynamic Positioning (DP class)	DP2	DP2	DP3	DP3	Note: Depending on class and system design
Circuit breaker	Included				On DC link side
Frame type	Roxtec S-8x3				

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