ebalanceplus

Specification of power inverter interfaces

Deliverable D3.2

Date: 7/2/2022

Author(s):
Przemyslaw Lukasiak

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

Technical References

Project Acronym	ebalance-plus
Project Title	Energy balancing and resilience solutions to unlock the flexibility and increase market options for distribution grid
Project Coordinator	Juan Jacobo Peralta Escalante CEMOSA
Project Duration	42 months (1st February 2020 – 31st July 2023)

Deliverable No.	D3.2
Dissemination level [1]	PU
Work Package	WP3
Task	T3.2
Lead beneficiary	TPS
Contributing beneficiary(ies)	CEM, IHP, SOF, UNC, JUNIA
Due date of deliverable	31/01/2022
Actual submission date	07/02/2022

[1] PU = Public
PP = Restricted to other programme participants (including the Commission Services)
RE = Restricted to a group specified by the consortium (including the Commission Services)
CO = Confidential, only for members of the consortium (including the Commission Services)

Document history

V	Date	Beneficiary(ies)	Author(s)
1	05/01/2022	TPS	Przemyslaw Lukasiak
2	03/02/2022	TPS	Przemyslaw Lukasiak
3	04/02/2022	TPS	Przemyslaw Lukasiak
4	07/02/2022	CEM	Juan Jacobo Peralta Escalante

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

Summary

1.1 Summary of Deliverable

Part of the ebalance-plus platform is to design and develop Grid Tied Inverter and DC/DC converters (cooperating with PV panels and battery energy storage system) connected via DC-Link voltage which will be installed in the University of Malaga demo site.

The deliverable is described in separate sections:

- Product description with main parameters of the device
- Implemented protections (hardware and software)
- Mechanical design (modular design, cooling, dimensions, lifting points)
- Electrical interfaces
- Communications

Disclaimer

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

Table of Contents

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement N°864283

Table of tables

Table of figures

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement N°864283

1 Introduction

Ebalance-plus is a trial project of a DC smart grid consisting of Multi Input Multi Output Inverter (MIMO), ten 15kW EV chargers, 56.7kW PV panels, and 79kWh battery. The MIMO Inverter connects AC grid, PV canopies, battery racks and EV chargers to the common DC link as it is shown in Figure 1. The external supervisor controller will be responsible for controlling the power flow between the devices. The aim is to keep maximum energy usage of renewable sources and minimalize energy usage from the AC grid.

The MIMO inverter consists of:

- 125kVA GTI,
- 70kW unidirectional DC/DC converter for PV canopies,
- 70kW bidirectional DC/DC converter for Li-ion batteries,
- AC and DC switchgear.

2 Product description

The MIMO uses modern SiC (Silicon Carbide) semiconductor devices that have very low losses at high switching frequencies. High switching frequency operation results in low audible noise and potential for size reduction of the filter's passive components.

The GTI inverter is designed as a bidirectional inverter which means it can import or export power from and to grid terminals (L1, L2, L3) to the common DC link. This will allow the GTIs to perform the required functions:

- Bidirectional real power conversion between the grid and the DC-Link,
- Reactive power compensation,
- Phase imbalance improvement.

Although the DC/DC converters for PV canopies and batteries are designed as bidirectional buck-boost choppers, the battery converter will operate in bidirectional mode and the PV converter will operate in unidirectional mode. The DC/DC converter allows to:

- Bidirectional power conversion independent from the input and the output voltage,
- Control battery charging and discharging current (working as a current source),
- MPP tracking of the PV panels.

The GTI is equipped with all necessary protections to fulfil the following standards:

- Anti-islanding relay – according to NRZ 105
- RCD protection – according to EN 62109-1, EN 62109-2
- Insulation resistance measurement – according to EN 62109-2

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

2.1 Main Parameters of GTI

Table 1 Main parameters of MIMO Inverter

Parameter	Value
Electrical parameters of the GTI inverter	
Rated power	125kVA
Rated phase current	105 A
AC connection voltage	400V +10%, -6%
AC connection frequency	49.5Hz – 50.5Hz
AC connection power factor	-1 to +1, nominal operation at unity power factor
AC connection number of phases	3
AC connection neutral wire	Yes
Nominal DC-Link voltage	750-800V DC
Power transmission	Bidirectional
Dielectric voltage withstands	1.8kVrms, 50Hz, 1 minute
Switching frequency	20kHz
Efficiency	≥97%
Electrical parameters of Battery converter	
Rated power	70kW @ V_{IN}≥650V DC
Nominal Battery voltage range	614-797V DC
Nominal input voltage	700V DC @100A
Switching frequency	20kHz
Efficiency	≥96%
Power transmission	Bidirectional
Electrical parameters of the PV converter	
Rated power of PV converter	70kW @ V_{IN}=650V DC
Rated voltage of PV panels	722V DC
Rated current of PV panels	103A DC
PV panels MPPT tracker voltage range	200-725V DC
Switching frequency	20kHz
Efficiency	≥96%
Power transmission	Unidirectional

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

Mechanical and environmental parameters	
Ambient temperature operating conditions	-20°C – +45°C degrees Celsius
IP rating	IP56 Control/Power IP32 Cooling ducts
Cooling	Air forced
Installation	Outdoor
Altitude	<1000masl
Maximum noise level	60dB(A) @ 5m.
Dimensions (H x W x D)	1711mm (+150mm plinth) x 2548mm x 600mm
Weight	1100kg

2.1.1 Parameters of the Batteries pack (BESS)

Table 2 Main parameters of Battery pack

Parameter	Value
Electrical parameters	
Continuous power rating	70kW
Nominal Energy	79kWh
Battery chemistry	Li-ion NMC
Nominal battery voltage	700V DC
Battery voltage range	614-797V DC
Power transmission	Bidirectional
Mechanical and environmental parameters	
Cooling	Cooled by air conditioner
Ambient temperature range	-42°C – +45°C
IP rating	IP55
Cabinet	Coated, vandal resilient steel enclosure
Dimensions with air conditioner (H x W x D)	2180mm x 903mm x 2180mm
Weight	1083kg

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N°864283

2.2 Standard list

The MIMO inverter fulfil below list of the standards

Table 3 Fulfilled standards

Number	Title
IEC 62477-1: Edition 1.1 (2016-2017)	Safety requirements for power electronic converter systems and equipment – Part 1: General
BS EN 60529: 1992	Specification for degree of protection provided by enclosures (IP code)
BS EN ISO 9001:2015	Management and Quality Assurance Standards
EN 62109-1:2010	Safety of power converters for use in photovoltaic power systems - Part 1: General requirements
EN 62109-2:2011	Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters
EN 62116: 2014	Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures
IEC 61000-2-2: 2017	Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems
EN 61000-6-2:2005	Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environments
EN 61000-6-4: 2007	Electromagnetic compatibility (EMC) - Generic standards. Emission standard for industrial environments

2.3 Principle of operation

2.3.1 Main functionality

The MIMO is a multi-input and multi-output device. It means that the MIMO is connected to more than one power source. The MIMO is supplied from the AC grid, PV canopies and Battery storage system at the same time. Each of the power sources is connected to the separate power converter inside the MIMO via contactors and protection devices. All the power converters are connected to the common DC-Link bus which allows the transfer of power between different power sources and the external EVCP. The block diagram of the MIMO is shown in Figure 1. All stacks are described in sections 4.6, 4.7, 4.8

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

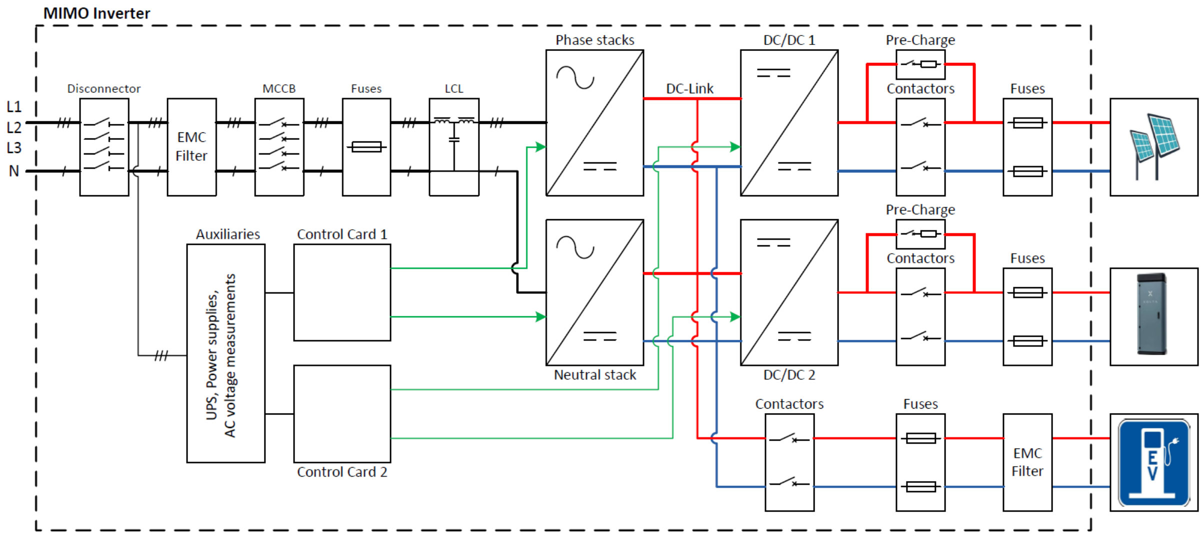

Figure 1 Block diagram of the MIMO inverter

The MIMO converter is equipped with two identical control cards based on tri-core micro-processor equipped with digital and analogue inputs and outputs to control all internal components. The first card (Control card 1) is responsible for controlling the GTI inverter and the second card (Control card 2) is responsible for controlling both DC/DC converters. To operate the MIMO requires AC voltage, which supplies all auxiliary circuits like auxiliary power supplies, MCCB, fans and anti-condensation heaters. Auxiliary voltage is taken from the main AC as a parallel path to the power circuit what is also shown in Figure 1.

When the power-up and self-check of the system is finished MIMO Inverter will stay in standby mode waiting for the commands from the supervisory controller. After receiving the start command from the supervisor, the system insulation measurement must be performed. The system pre-charges the PV canopies and BESS DC/DC converters after the contactors for the PV and BESS are closed while the GTI contactor remains open. Next, the insulation meter is checking the insulation resistance and if the resistance is lower than the limit the confirmation signal is sent to the control card. The Anti-islanding relay continuously monitors the amplitude and frequency of the AC grid and will open contactors and report the faults when the limits have been exceeded. If no errors have been reported that GTI inverter pre-charges the DC link and closes the grid contactor and starts the operation of the whole system awaiting the power demands.
The GTI inverter works in the DC link control mode and is responsible for keeping the DC-link voltage at a constant level. The BESS converter operates in power mode and PV converter in Maximum Power Point Tracking (MPPT). When the DC-Link voltage is stabilized supervisor controller can send demanded power to the BESS converter. Because power generated by the PV converter depends on the solar radiation the supervisory controller can only limit the maximum power of the PV converter. The supervisor controller cannot send active power demand to the GTI as it works in DC-Link mode and the power flowing through the GTI is given by an equation below.

$$P_{GTI} = P_{PV} + P_{BESS} + P_{EVCP} + P_{losses}$$

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

The supervisory controller controls the power flow based on the EVs charging power, power generated by the PV canopies, grid conditions and State of Charge (SoC) of the batteries.

NOTE: To transfer energy between inputs / outputs of the MIMO Inverter mains voltage is required as the GTI is responsible for stabilization of the DC-Link voltage.

2.3.2 Reactive power compensation and phase imbalance improvement

The GTI has additional functionalities like reactive power compensation and phase balance improvement of the substation transformer. The GTI has no knowledge about the power factor and current imbalance of the substation transformer therefore, both functionalities can be used only if the supervisor controller has such information. The supervisor controller can send to the GTI demanded reactive power to correct the power factor of the transformer or active power demand for specific phase(s) to balance the currents on each phase of the inverter. Reactive power compensation and phase imbalance compensation is limited by rated power per phase (when GTI is working with full active power it cannot compensate reactive power). These features are independent and can be used in parallel with the main functionality.

2.4 Control panel

The GTI is equipped with Control Panel which is installed behind the door in the switchgear compartment. The Control Panel contains:

- Manual switch to turn on and off supply voltage to the auxiliaries,
- Local/Remote switch for choosing the local or remote mode of operation. In remote mode, all control commands are taken from the supervisory controller, in Local mode, all commands are taken from USB or local Ethernet port.
- The USB terminal is for diagnostic and debugging purposes
- Ethernet port is for diagnostic and control purposes
- 13A RCD protected AC outlet to supply test equipment during commissioning.

The view of Control Panel is depicted in Figure 2.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

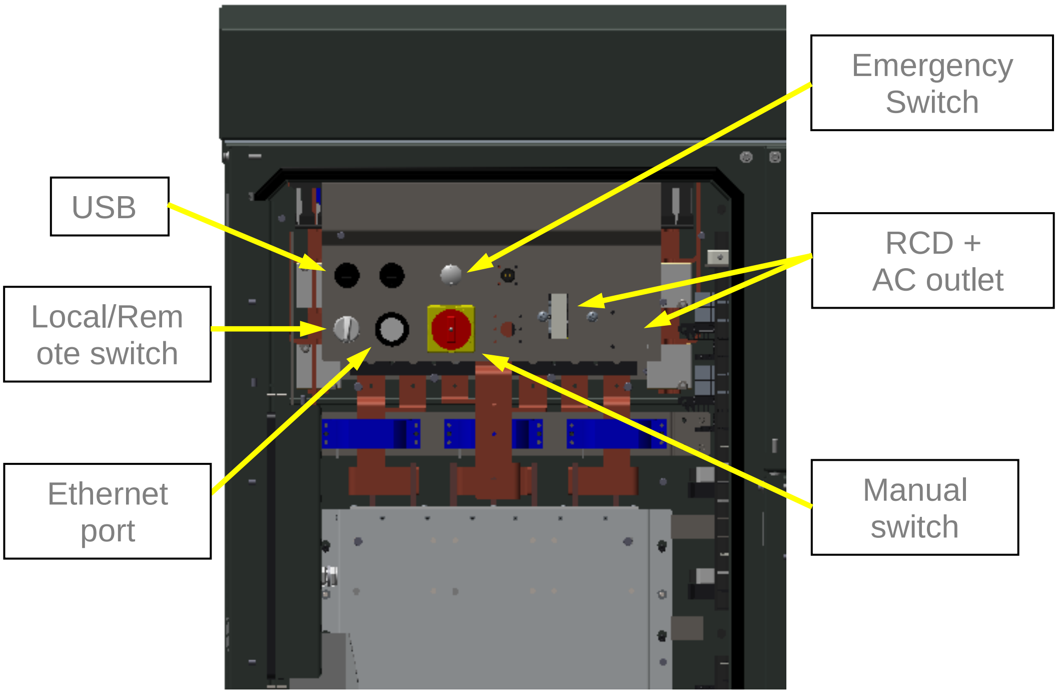

Figure 2 View of the Control Panel

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

3 Protection

3.1 Concept

Due to the sensitivity of the power electronic devices to both overvoltage and overcurrent, protection is implemented in:

- Hardware (providing a fail-safe operation); and
- Software acting on the hardware components for different periods and at different control layers.

Additionally, software protection is implemented on more than one hardware platform with a degree of redundancy. A generic software protection architecture is shown in Figure 3 below.

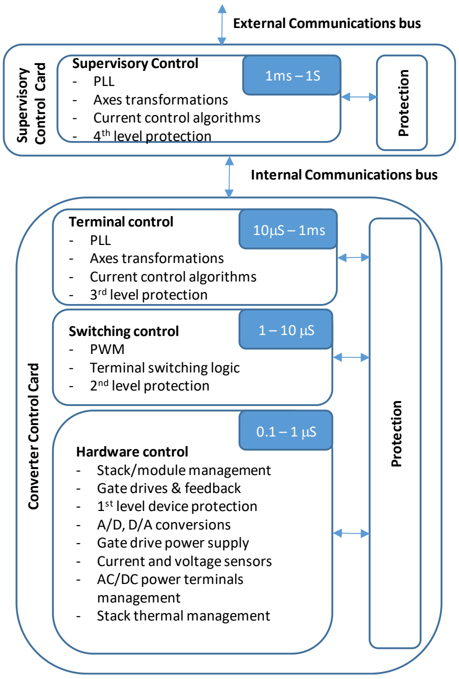

Figure 3 Generic software protection architecture for power electronic based equipment

3.2 Protection requirements

In general, the main electrical protection requirements of the MIMO Inverter are:

- Withstand abnormal LV distribution network conditions
- Protect the equipment from any damage
- Fail safe to protect the maintenance personnel

The design and selection of hardware and insulation follow the guidelines in IEC62477. Figure 4 is an extract from the standard that shows the different areas concerning the OVC requirements. Accordingly, the impulse withstand voltage applicable to the GTI components including the switchgear is:

- 2.5 kV for components in the OVC II area.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

- 4 kV for components in the OVC III area.

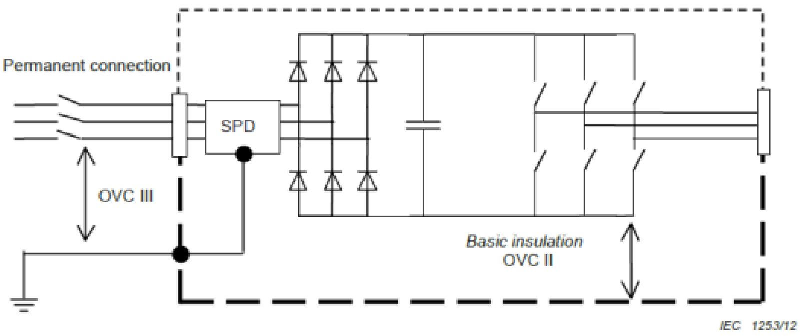

Figure 4 Extract from IEC 62477

3.3 Hardware protection

3.3.1 Input MCCB

The four poles moulded case circuit breaker (MCCB) rated at 320A forms the GTI first line protection.
The AC circuit breaker incorporates an electronic protection module type PR222DS/P with L, S, I and G current protection functions as described in Table 4.
The MCCB has double insulation between the live power parts (excluding the terminals) and the front parts, with accessories completely segregated from the power parts thereby preventing any risk of contact with live parts.

Table 4 Current protection modules for MCCB

ID	Description
L	Against overload with **long** inverse time delay trip and trip characteristic according to an inverse time curve ($I^2t=k$) according to IEC 60947-2 Standard
S	Against short-circuit with inverse **short** time delay trip and trip characteristic with inverse time ($I^2t=k$) or definite time
I	Against short-circuit with **instantaneous** trip <25ms

3.3.2 AC fuses

The MCCB is supported by 400A AC fuses. The aim of the fuses is redundant work to the MCCB. In case of failure of MCCB the fault still can be cleared by fuses.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N°864283

3.3.3 Battery, PV Panels and EV Chargers fuses

DC outputs/inputs of the converter are equipped with DC contactors in DC positive and DC negative wire. They can operate under the full power of the converter. Additionally, each output/input of the converter is protected by the DC fuses, which can clear short-circuit on the output/input.
PV canopies input and BESS input is protected by 160A DC fuse. EVCP outputs is protected by 250A DC fuse.

3.3.4 Over voltage surge protection device (SPD)

The converter is equipped with surge-trap modular surge protective device which is a 3 pole 480V device with an auxiliary microswitch for health monitoring. The GTI control card monitors the surge device for failure. The internal metal oxide varistors are self-protecting with individual thermal fuses.

3.3.5 Auxiliary supply MCB

The auxiliary power supply is taken from the incoming grid connection. It is protected by the three-phase Miniature Circuit Breaker (MCB) rated at 16A with class B characteristics.

3.3.6 UPS

The MIMO is equipped with UPS which keeps the control circuit alive for the next few minutes after occurring the loss of mains. The MIMO can communicate the loss of mains to the supervisor controller and can safely turn off all of power converters.

3.3.7 Pre-charge fuses

The MIMO Inverter is equipped with three pre-charge circuits. One pre-charge circuit is on the AC connection, and it is controlled by the GTO control card. The second is on the battery input and the third is on the PV input. Both are controlled by DC/DC converters control card. The pre-charge circuit contains resistors, contactor and fuses which are in parallel to the main contactors. The purpose of the pre-charge circuit is to protect components against inrush current during turning on of main contactors (MCCB). Control cards control pre-charge circuits via the contactors. The AC pre-charge circuit is protected by auxiliary supply MCB (see section 3.3.5) and 10A DC fuses on the output of pre-charge. The battery and PV panels pre-charge circuits are protected by 3A DC fuse.

3.4 Hardware trips and interrupts

Hardware trips and interrupts that directly trip the MCCB and the DC connectors as described below.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

3.4.1 Emergency Stop (E-Stop) and door open

For safety, the system is equipped with the Emergency stop and the door open switches.
In case any of the switches are tripped the system will open MCCB and DC contactors.

3.4.2 DC-link hardware overvoltage trip

To protect the electrical components of the DC link, a hardware comparator operates directly on the MCCB opening shunt trip coil. The levels associated with this hardware interrupt protection are given in Table 5

Table 5 Hardware interrupt protection for the DC-link

Trip	Measurement	Trip Level	Reset Level
DC Link Over Voltage	DC	880	800

3.4.3 RCD

The MIMO inverter is equipped with residual current protection type B (for AC and DC current). The RCD is checking residual current in all phases and neutral wire of the GTI and trips MCCB and DC contactors when leakage current according to the EN 62109-2 is higher than 1,25A.

3.4.4 Anti-islanding relay

The MIMO invert is equipped with an anti-islanding relay that trips MCCB when loss of mains occurs or deviation of the AC grid parameters are higher than allowable according to Spain Specific Specifications Endesa Distribución Eléctrica, S.L.U. - NRZ105

3.4.5 Insulation resistance meter

The MIMO is equipped with an isolation resistance meter. According to EN 62109-2 Insulation resistance measurement is checked always before putting the MIMO to the work. The insulation resistance measurement is done only in off-line mode due to the MIMO is not an isolated system.

3.5 Software protection

3.5.1 Overview

An overview of the software protection of the inverter is shown in Figure 5 and the overview of the software protection of the DC/DC converter is shown in Figure 6.
The MIMO will have its fast protection functions implemented locally on its control cards in C-code.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

The following subsections provide details on the settings of different software protection functions.

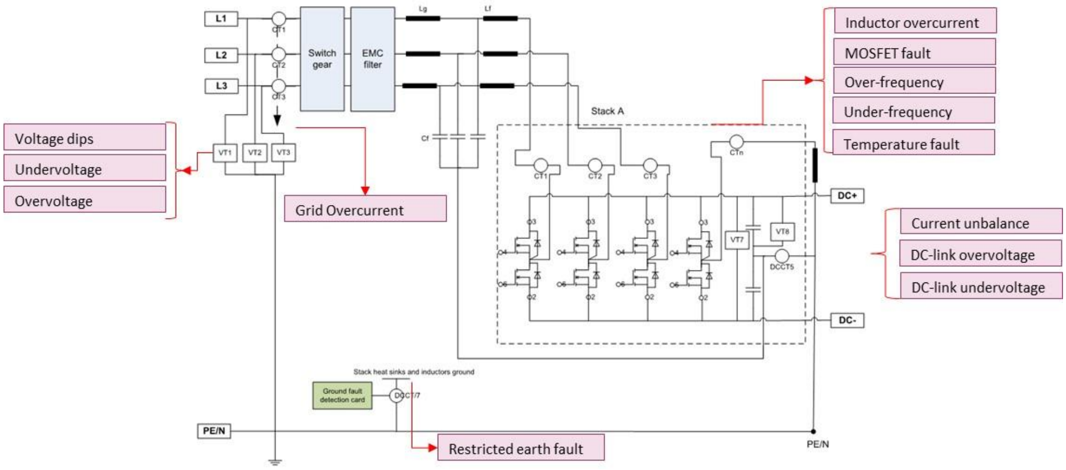

Figure 5 Software protection of the Inverter

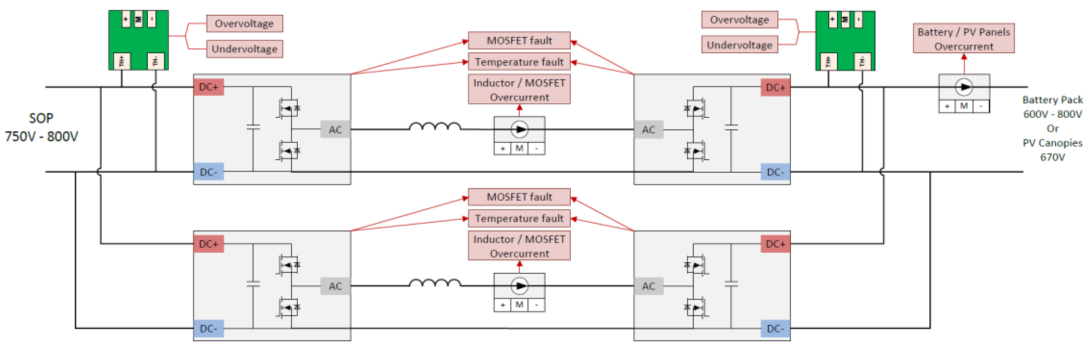

Figure 6 Software protection of the DC/DC converter

3.5.2 Faults, trips, and lockouts

Both control cards will provide the following functions for the processing of any defined fault:

- A fault flag,
- A fault counter,
- A decrement timer,
- A lockout flag.

When a fault occurs the fault flag is set, and the fault counter will be incremented by 1.

A fault flag will cause the state machine to enter the tripped state. In this state device is switched off (main contactors and MCCB are opened). Current and voltage measurements are performed continuously to determine a “healthy state” and indicate that a fault is cleared following a tripped state (which may be dependent on either measured values or timed). After 10s faults are cleared the MIMO enters in standby mode, if the fault is still present the MIMO will go to the trip state.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N°864283

When a fault counter reaches a pre-determined limit, an associated lockout flag will be set which will cause the state machine to go to the locked state and open the MCCB. Only a power cycle of the system will allow exit from this state to a normal operating state.

When a fault is cleared the decrementing timer will be started. When the decrementing timer reaches a configurable time limit the fault counter will be decremented by 1. The decrementing timer will be restarted and will continue to operate until the fault counter has reached 0. This mechanism is to stop occasional faults from building up over time and incorrectly leading to a lockout.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

4 Mechanical design

4.1 Construction

The MIMO is arranged as one multicompartment cubicle designed as outdoor street furniture. The compartment contains as follows:

- Switchgear
  - EMC filters
  - MCCB,
  - DC Circuit Braker,
  - Fuses,
  - Protection components,
  - Isolation switch,
  - DC/DC converters pre-charge circuits.
- Choke's compartment (compartment invisible from the front):
  - Inverter LCL filter (grid chokes, PWM chokes, filter capacitors),
  - Neutral leg choke,
  - DC\DC converter chokes.
- GTI compartment:
  - Three phase stacks (SiC modules, DC-Link capacitors, busbars, gate drivers),
  - Neutral stack (SiC modules, DC-Link capacitors, busbars, gate drivers),
  - Colling fans.
- DC/DC converters compartment
  - Two DC/DC converter stacks (SiC modules, DC-Link capacitors, busbars, gate drivers),
  - Colling fan,
  - Voltage and current transducers,
  - GTI pre-charge circuit.
- Control compartment
  - Control cards,
  - UPS,
  - Auxiliary power supplies,
  - Auxiliaries (relays, terminal blocks, etc),
  - Protections (insulation meter, RCD, Anti-islanding relay).
- Top cover
  - It is only cover of the device

The power electronics components are forced air-cooled with high-reliability fans. The rated lifetime of the fans is higher than 30khrs, but thanks to controllable speed the lifetime is expected to be higher than the rated value.

The placement of the compartments is presented in Figure 7. Chokes compartment is not visible on the figure, because it is located at the back of the MIMO Inverter.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

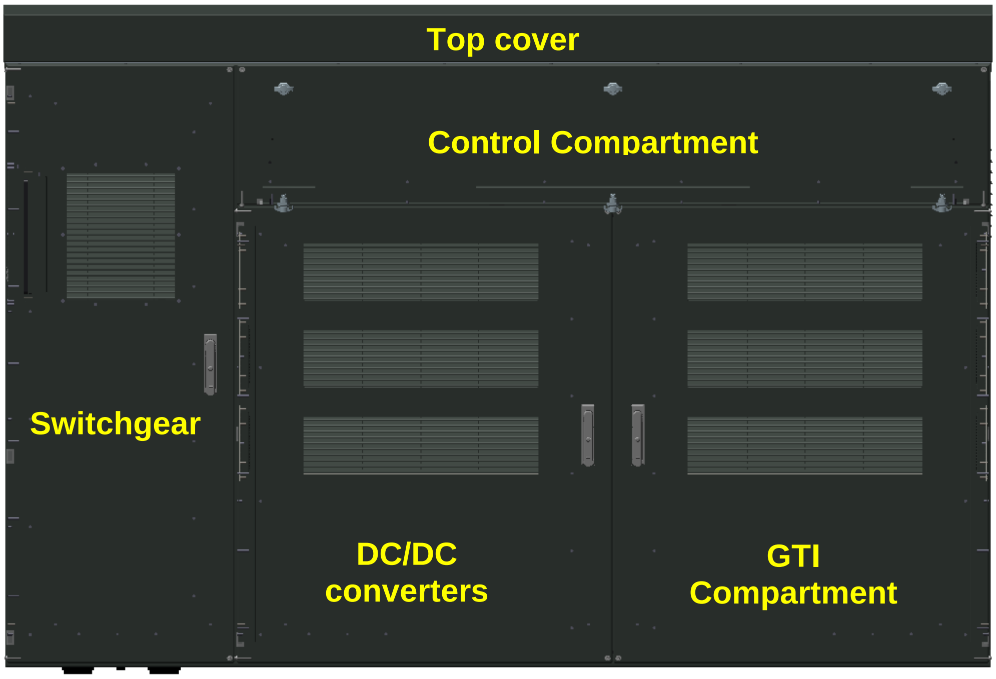

Figure 7 Compartments of the MIMO Inverter

4.2 MIMO enclosure

The enclosure is a bespoke design manufactured from mild steel and is powder-coated to eliminate corrosion. The enclosure's prime requirement is to manage the air cooling of the power stacks. A duct system is formed where the power stacks are bolted to the enclosure. The duct is positioned above a fan box that houses the single cooling fan. The fan is speed is controlled by the inverter control card. The dimensions (in mm) of the MIMO Inverter are shown in Figure 8

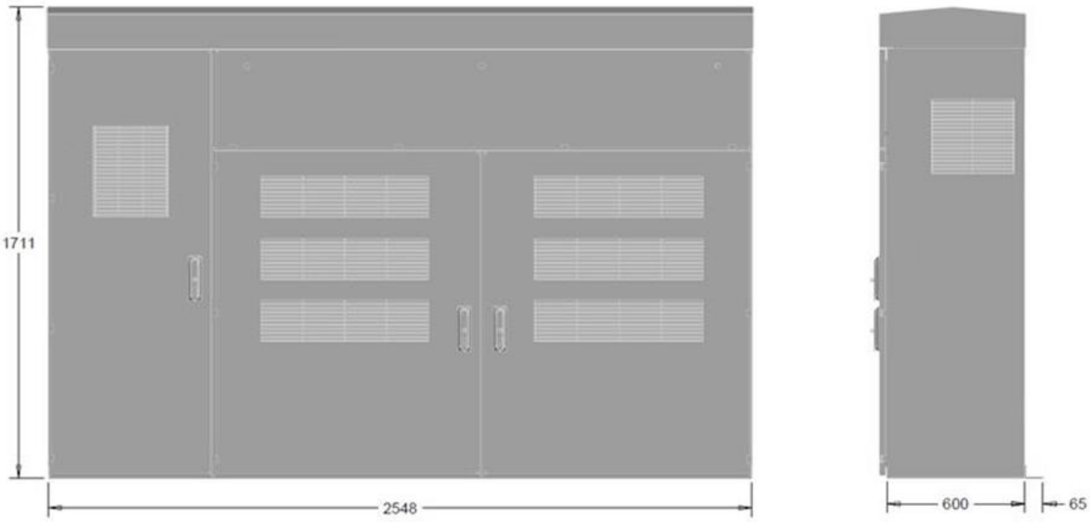

Figure 8 Dimensional drawing of the MIMO converter

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement N°864283

4.3 Enclosure lifting points

The enclosure is fitted with four lifting eyes positioned on the top corners to enable lifting for transport and installation. The position of the lifting is shown in Figure 9. The size of the opening is 12.5mm. It is recommended to use four lifting points (two on each side of the converter).

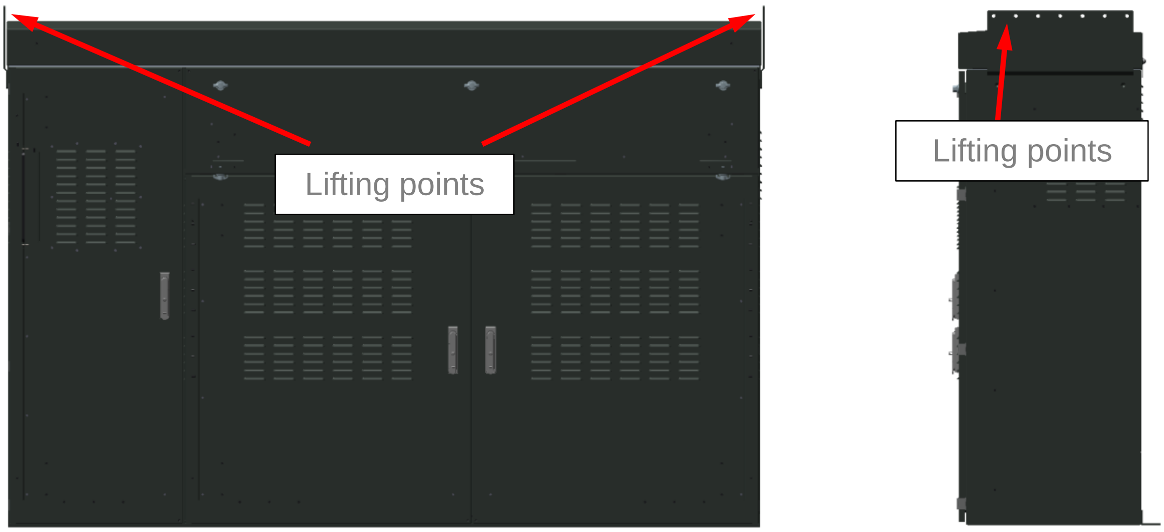

Figure 9 Lifting points of the MIMO Inverter

4.4 Floor mounting arrangement and forklift points

The MIMO Inverter has additional plinth which increase doors distance from the ground. Plinth has openings for forklift which allow transportation the MIMO Inverter. MIMO Inverter with plinth should be placed on the concrete base and should be bolted. MIMO Inverter with plinth and forklift openings is shown in the Figure 10. Mounting holes spacing is shown in Figure 11.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

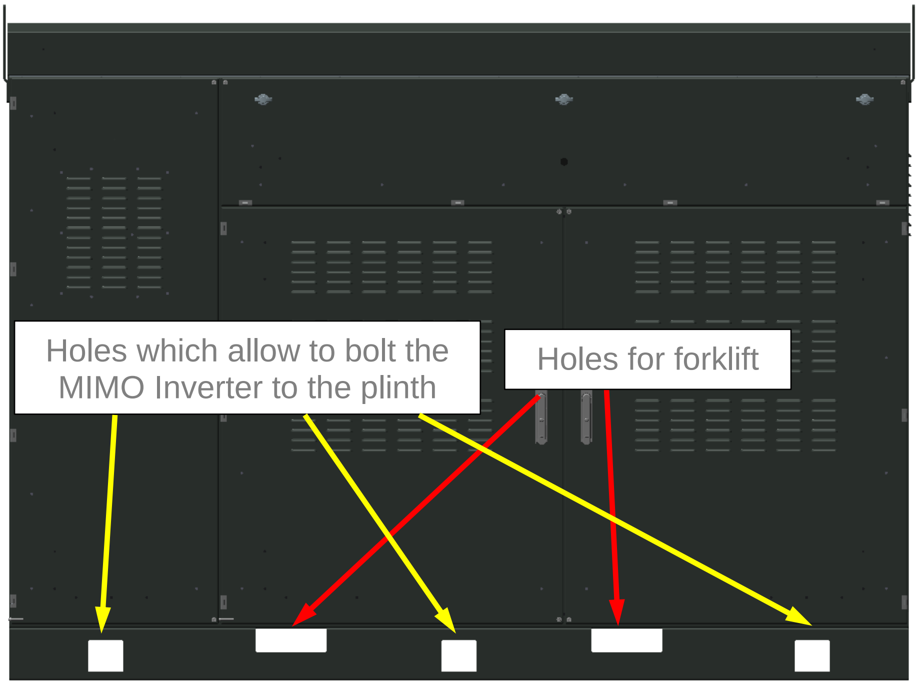

Figure 10 MIMO Inverter with a plinth (with forklift points)

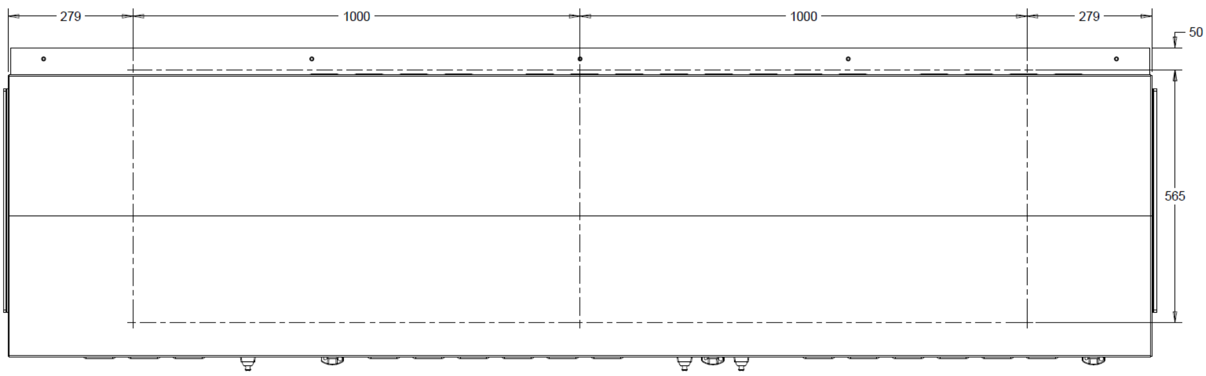

Figure 11 Mounting points of the MIMO Inverter (view from the top).

4.5 Cooling system and anti-condensation system

4.5.1 Cooling system

The MIMO Inverter has forced air cooling. The cooling system is divided into two independent systems:

- Cooling of SiC modules,
- Cooling of switchgear and other power components.

Inlet grill for cooling SiC modules is placed on the front doors of DC/DC converter compartment and GTI compartment. The air is sucked through the inlet grill by fans placed on the bottom of the cubicle and then pushed through the heatsink fins placed in the air duct. Next, the air goes through the choke compartment cooling all the

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

inductors inside and exits through the outlet grill which is placed on the back wall of the MIMO Inverter. Air flow path is given in the Figure 12.

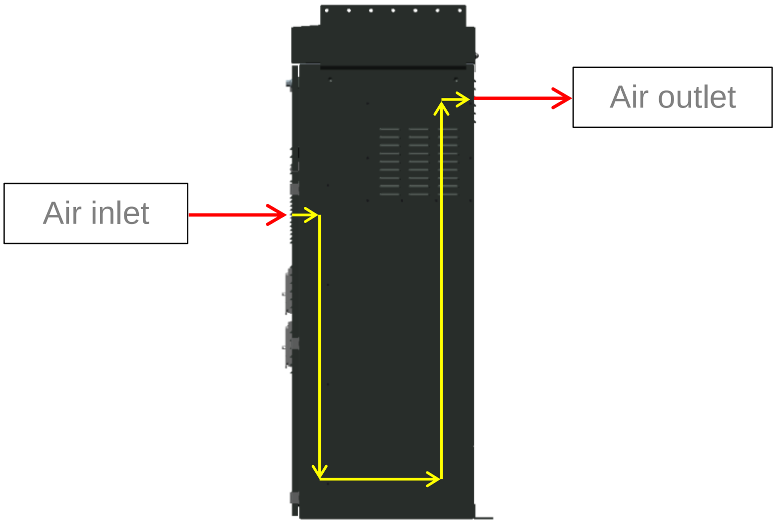

Figure 12 SiC modules cooling airflow path

Cooling of the switchgear and other power compartments is provided by an additional fan placed on the wall between Switchgear and DC/DC converters compartment. Air is sucked through the inlet grill placed on the switchgear compartment door. The air is cooling components inside the switchgear, goes through the fan and is cooling all power components inside DC/DC converters compartment and GTI compartment. Finally, air exits through the air outlet grill placed on the right wall of the MIMO Inverter. Airflow path is given in Figure 13.

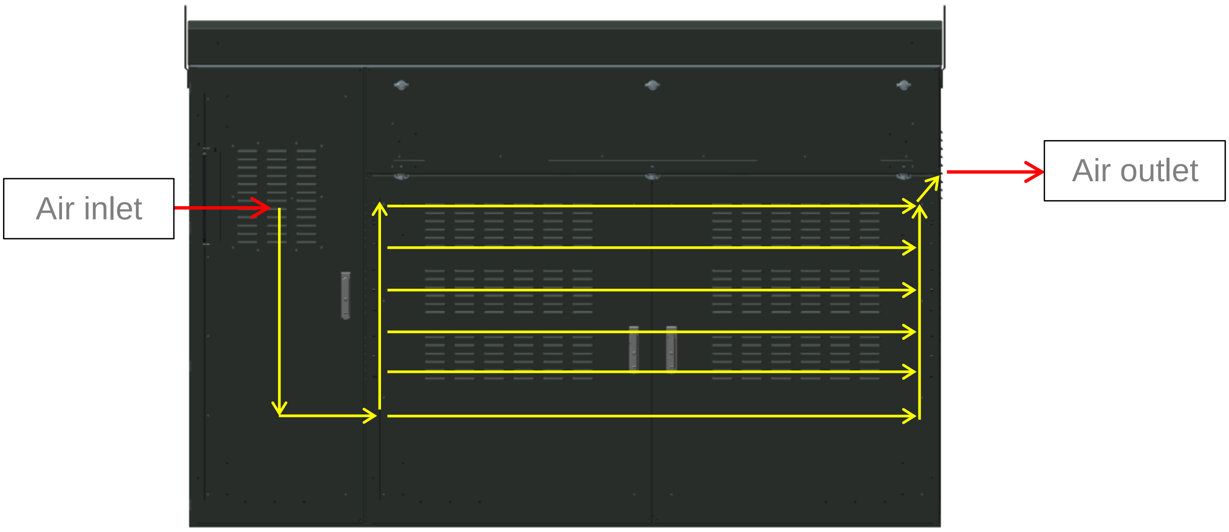

Figure 13 Switch gear and power compartment cooling air flow path

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

4.5.2 Anti-condensation system

The MIMO Inverter is equipped with an anti-condensation system consisting of a thermostat and two heaters. When temperature or humidity inside DC/DC converters compartment and GTI compartment go below the set level the thermostat turns on the heaters to increase the temperature and decrease the humidity inside the compartment.

4.6 Inverter stack

The inverter is formed from three identical stacks which are shown in the Figure 14. The inverter stacks incorporate the following parts:

- Heatsink and mounting frame,
- Temperature sensor,
- SiC MOSFET power devices,
- DC link capacitors,
- Gate drive card,
- DC link discharge resistor.

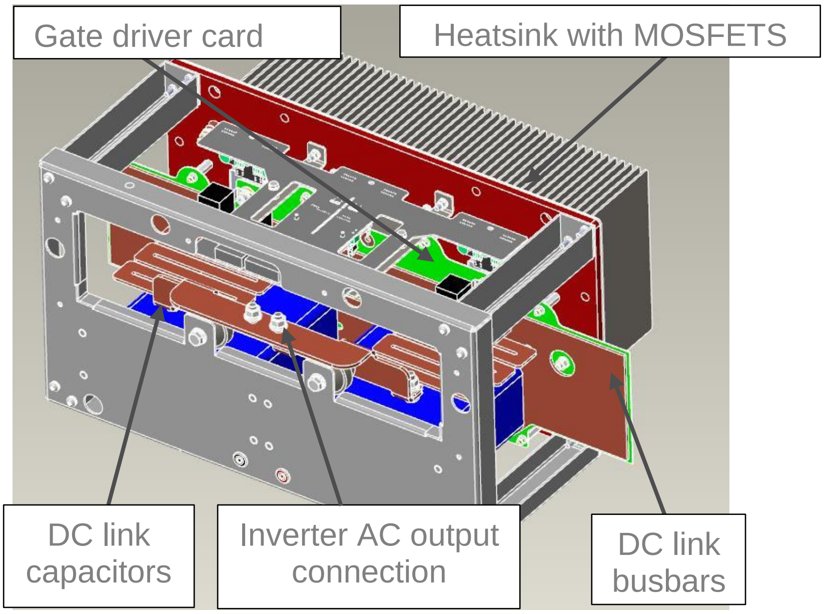

Figure 14 Inverter Stack (1 leg module)

4.7 Neutral stack

The neutral stack is shown in Figure 15. The neutral stack incorporates the following parts:

- Heatsink and mounting frame,
- Temperature sensor,
- SiC MOSFET power devices,
- DC link capacitors with DC midpoint,
- Gate drive card,
- DC link discharge resistors.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

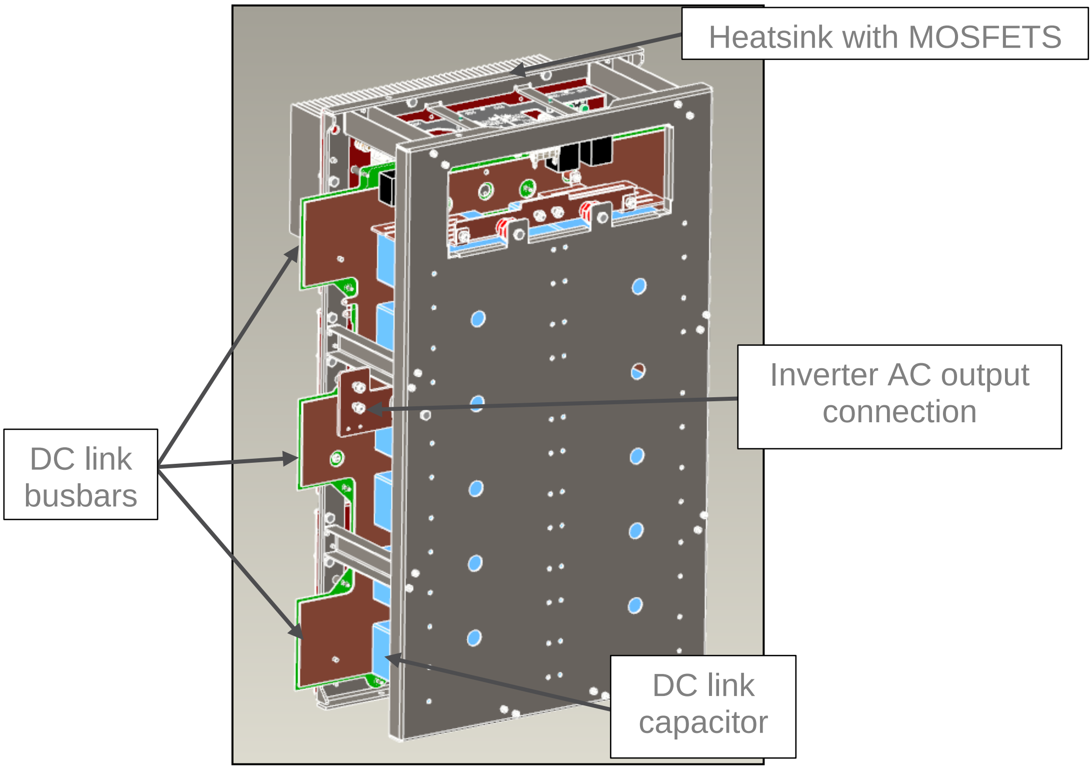

Figure 15 Neutral Stack (1 leg module)

4.8 DC/DC Converter stack

The DC/DC converters stack is shown in Figure 16. The DC/DC converters stack incorporates the following parts:

- Heatsink and mounting frame,
- Temperature sensor,
- SiC MOSFET power devices,
- DC link PCB busbars with DC link capacitors and discharge resistors,
- Gate drive cards.

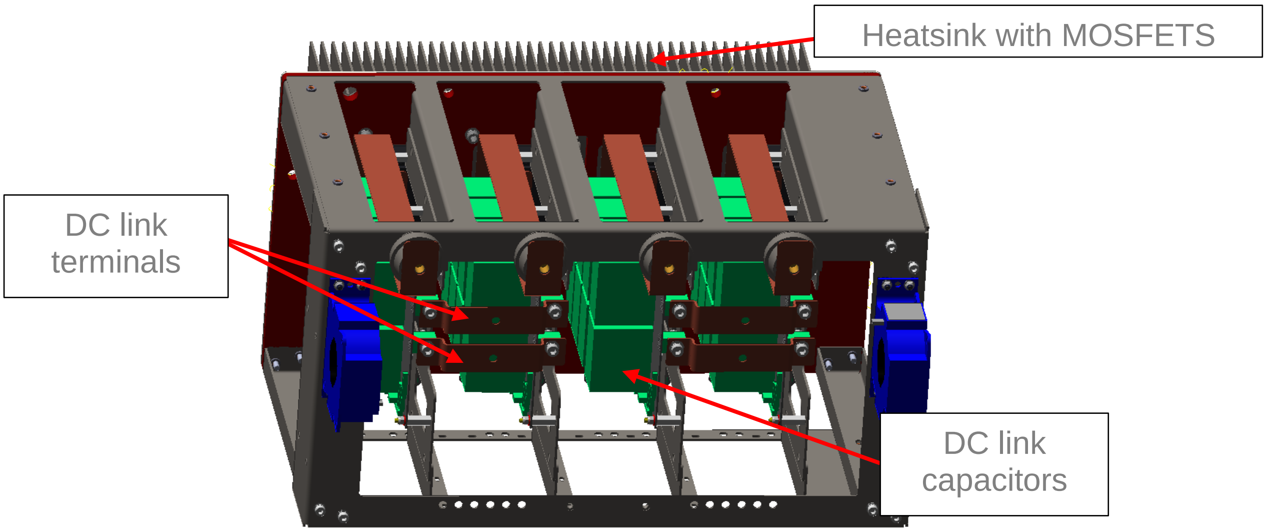

Figure 16 DC/DC Converter Stack (4 legs module)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

5 Electrical interfaces

All electrical connections are inside at the bottom of switchgear compartment, and they are shown in Figure 17. Cable entries are from the bottom, through the removable cover. All cables will be sealed by glands.

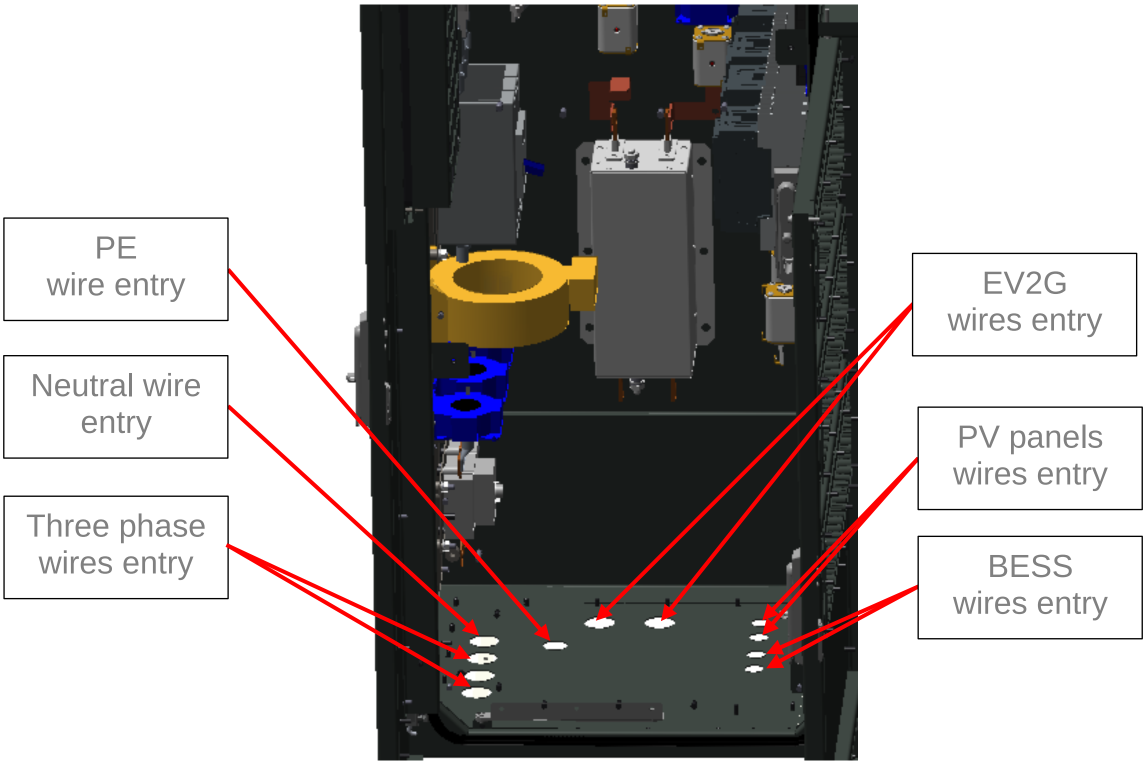

Figure 17 View of all power wires entry of the MIMO Inverter

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement N°864283

6 Communication

The MIMO Inverter is controlled by the DERMU (Distributed Energy Resources Management Unit) which sets the power flow between the terminals of the MIMO. The DERMU is the component in the ebalance-plus architecture that manages distributed energy resources (DER) at buildings or district level, providing both flexibility and resilience services (for further details about the system architecture, see project ebalance-plus deliverables D1.2 and D6.1). There are three communication slave nodes: the MIMO (two nodes GTI and DC\DC converters – Battery and PV) and the BESS. All the nodes use MODBUS TCP/IP communication protocol. Simplified control architecture is shown in Figure 18. The MIMO sends back to DERMU voltages, currents, power, status, and trip signals. All the nodes are working in Modbus slave mode, therefore the data from BESS must be sent to the MIMO from DERMU.

Detailed communication information is included in IO Schedule [324-047a, 324-047b, 324-047c].

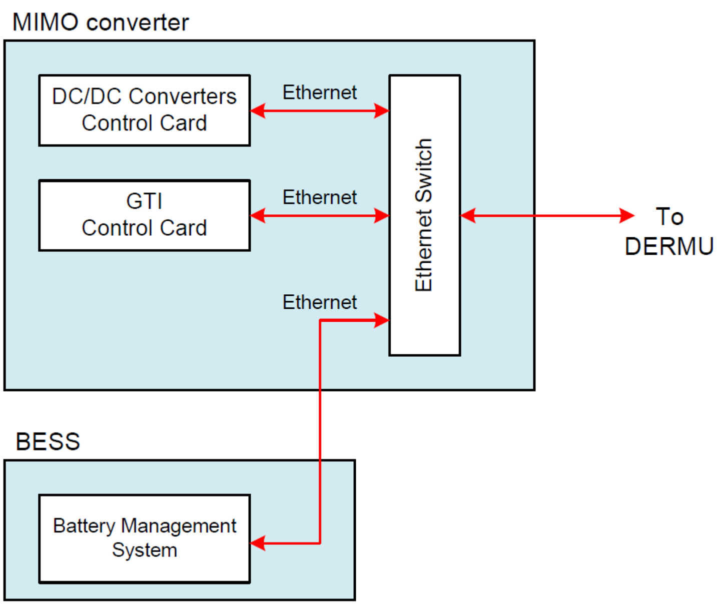

Figure 18 Simplified communication architecture

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283

Annex 1: Abbreviations

A.1 Abbreviations

Table 6 Abbreviations

Term	Definition
AC	Alternating Current
CT	Current Transformer
BESS	Battery Energy Storage System
DC	Direct Current
DERMU	Distributed Energy Resources Management Unit
DS	Disconnect Switch
EMC	Electro Magnetic Compatibility
EV	Electric Vehicle
GTI	Grid Tied Inverter
kVA	Kilovolt Amps (apparent power)
LCL	Third order passive filter (Inductance, Capacitance, Inductance)
LV	Low Voltage
MCB	Miniature Circuit Breaker
MCCB	Moulded Case Circuit Breaker
MIMO	Multi Input Multi Output
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
N/A	Not Applicable
OC	Open Circuit
OVC	Over Voltage Category
PE	Protective Earth
PLL	Phase Locked Loop
PV	Photovoltaic
RMS	Root Mean Square
SiC	Silicon Carbide
SOP	Soft Open Point
TPS	Turbo Power Systems

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°864283