Hyper powered vessel battery charging system

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1. LIST OF ACRONYMS

Acronym	Name	Definition
AC	Alternating current	Current with alternating polarity as function of time
ACD	auto-connect charging device	Shore-side device for automated contacting with EV
BMS	Battery management system	Control system that manages the use of the batteries within the specifications set by the manufacturer
DC	Direct current	Fixed current amplitude and polarity as function of time
EV	Electric vehicle (vessel)	Battery powered, self-propelled movable object with EVSE contacting interface
EVSE	EV supply equipment	Shore-side charging system with EV contacting interface and infrastructure interface
IMD	insulation monitoring device	monitors the insulation of a circuit with respect to PE and reports back a warning or fault status when occurring
MACS	Maritime Automated Charging System	Object of this whitepaper
MCS	Mega-Watt charging system	Charging interface (CharIn) initiative MW charging plug-socket definition including communication, safety and dimensions
OCPP	Open charge point protocol	Standardized communication between the EVSE and the charge point operator
PA	Port Authority	
PE	Protected earth	Protection point of electrical equipment by a guaranteed connection to earth with a limited and defined impedance

2. EXECUTIVE SUMMARY

The European project HYPOBATT (Hyper powered vessel battery charging system) has brought together 18 key players from the European maritime sector. The aim is to develop a fast-charging system for ships with up to 5 MW of power charging capability. The applicable vessels are with a length of 45 m up to 110 m or travelling distance of 2 hours. A demonstration in real application has to be performed. HYPOBATT will provide an automated, scalable, modular, fast, with reduced cooling needs, and simple multi-megawatt charging system that will enable the ships to be automatically connected to the charging station and charged within a very short time after docking. Due to the intended modularity of the port-side charging stations, electrified port vehicles should also make use of this infrastructure in further steps, thus reducing the overall CO2 balance of a port. Further goals of the project are the proposals for standardization of the fast-charging system for ferries as well as the development of new business models for battery-powered boats, which should make electric ferry operations safer, faster, and more sustainable at other locations in the future.

During the activities performed up to now, several obstacles have been encountered due to the maritime application needs: vessels shall be equipped with two independent battery packs, no connection locking is permitted, no dedicated standard for DC charging systems [1] about voltages, power levels, ACD-vessels relative distances and movements, communications, max. length of wires, pushing forces for connection, EMC vs safety.

Introduction on the Why of the HYPOBATT whitepaper

To ensure Megawatt Charging System (MCS) becomes an interoperable, safe, and standardized solution in-line with all currently existing relevant standards, a descriptive summary has been written by the CharIN taskforce in the form of a whitepaper [2]. In this paper, numerous recommendations and requirements are given on several technical and non-technical aspects of the MCS. It is meant to provide information in a unified and cooperative manner to bridge the time gap until the requirements are defined in the relevant standards. Such a whitepaper is also under development for "Ruggedized MCS" (R-MCS). However, since there will be a main focus therein on making the regular MCS plug ruggedized for extremer conditions, the HYPOBATT consortium felt the need to publish this whitepaper for the Maritime Automated Charging System (MACS) solution, additionally covering specific aspects to the ACD (Automated Connecting Device) and the main markets for which it is envisioned, i.e. Marine and Heavy-Duty (HD) equipment. Therefore, the main addressed standards for which this whitepaper is intended are the IEC 80005 and the IEC 61851.

Within the first work package of the HYPOBATT project, an overview has been made on the three main aspects of the Marine charging market, i.e. High power charging technology, Marine hyper charging application overview covering vessel types, electric system architecture and energetic needs, and Port integration and grid interface requirements. This comprehensive set of application related specifications resulted in a requirements document. Based on this document and the CharIn's MCS whitepaper, the envisioned main requirements for MACS are presented in the following.

Keywords:

HYPOBATT project, vessel charging, conductive charging, standardization, marine, on shore power supply, automated connection device, high-power connector, scalability, interoperability, modularity, safety, MCS, MACS

3. INTRODUCTION

Main objective of this document is to present the major outcomes of the activities already performed in the HYPOBATT project.

Several topics related to the high-power charging in maritime sectors have been analysed and the differences respect other pioneers sectors have been highlighted. The performed tasks have given then a clear view of the new solutions needed and the lack of standardization in the 1 - 5 MW power range DC charging sector.

Where there was no adequate solutions or rules and standards in other sectors, dedicated proposals have been listed and, evaluating the relative pros/cons the most compliant to maritime needs, the considered best solutions have been identified.

The outcomes from current state of the work are a valuable input for other task forces working to cover the lack of standard solutions adequate to maritime sector.

Since in HYPOBATT project it is planned a demonstration activity with the construction of a real prototype with the proposed solutions applied, a plus value will come from the real product manufacturing and testing.

Considering the aim of HYPOBATT is to share all the collected information, evaluations and relative outcomes, all information can be reach by the website "https://www.hypobatt.eu/".

To better describe the outcomes in an organized way, the following deliverables have been already partially or completely published:

- D1.1: "***High power charging technology overview***". Complete document downloadable from the link below:
  https://www.hypobatt.eu/_files/ugd/7a4ebd_f37cc5204a0040d09a71741d573f68f3.pdf

- D1.2: "***Marine hyper charging application overview, KPI'S and specifications***". Complete document downloadable from the link below:
  (https://www.hypobatt.eu/_files/ugd/7a4ebd_d2382fe4a53a4b91b04d97d941312f31.pdf)

- D2.1: "***Report on digital twin of whole system***". Complete document downloadable from the link below:
  https://www.hypobatt.eu/_files/ugd/7a4ebd_cd72223033914350a69d3f45ec12141b.pdf

- D2.2: "***Report on software control unit***". Complete document downloadable from the link below:
  https://www.hypobatt.eu/_files/ugd/7a4ebd_baab4f09993a484a95499ef249ce6fd4.pdf

- ***Standardization topics*** will be available at link below:
  https://www.hypobatt.eu/kopie-von-wp6-results

- Other "coming soon" technical results will be available under the Menu "Results" of the HYPOBATT website reported above

An overview of the outcomes is presented in the following sections of this whitepaper but for the complete outcome description refer to project website mentioned above.

3.1 Maritime Automated Charging System Overview

The Maritime Automated Charging System shown in this chapter is based on the considerations performed in the HYPOBATT project as consequence of the State of Art analysis and the evaluation performed on the improvements proposed. The aim of this reporting is to share these with the standardization committees working for the maritime sectors in order to give the possibility to recommend or to define in the standardization some design constraint leading to enlarged interoperability, modularity and high efficiency performances as well.

The high-level view of the maritime charging system is in Figure 1, the following Figure 2 **Error! Reference source not found.**identifies the main functional blocks (modules) with relative main functions expected.

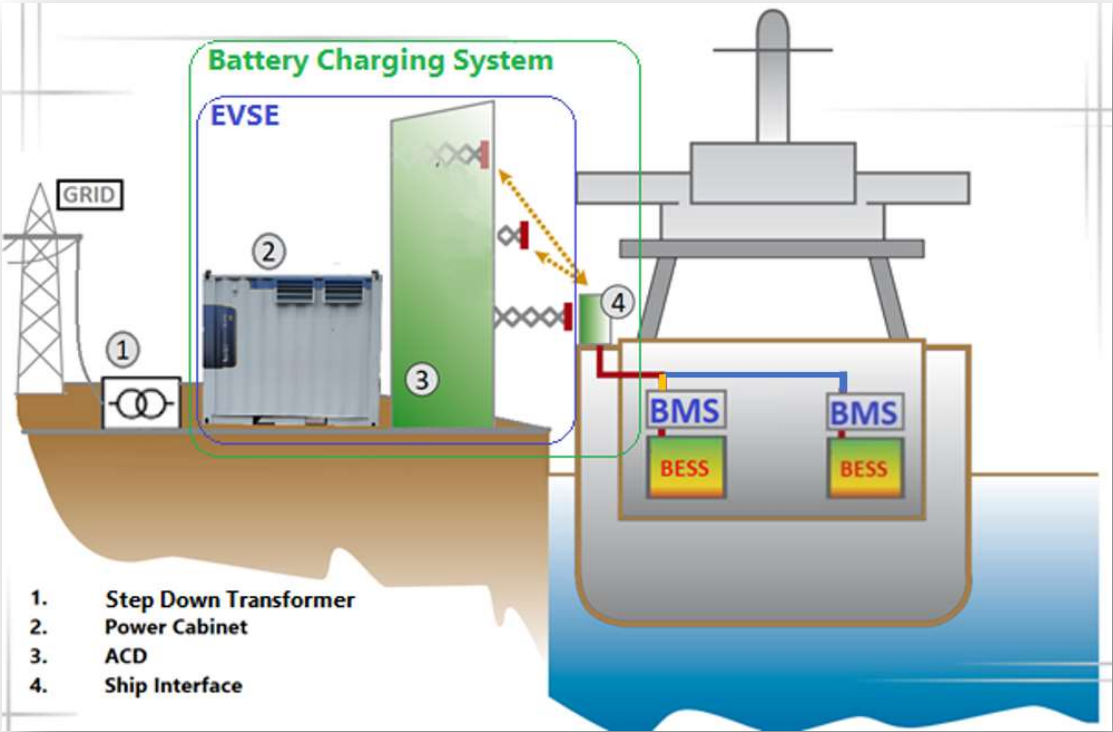

Figure 1 System Representation and Main Functional Blocks Identification

The high voltage (> 36 kV AC) to medium voltage (> 1 kV, < 36 kV) Step-Down Transformer (1.) is considered outside of the battery charging system because of usually already part of the port grid where other loads are connected as well and already covered by standards. EVSE input voltage is considered to be medium voltage (> 1 kV, < 36 kV).

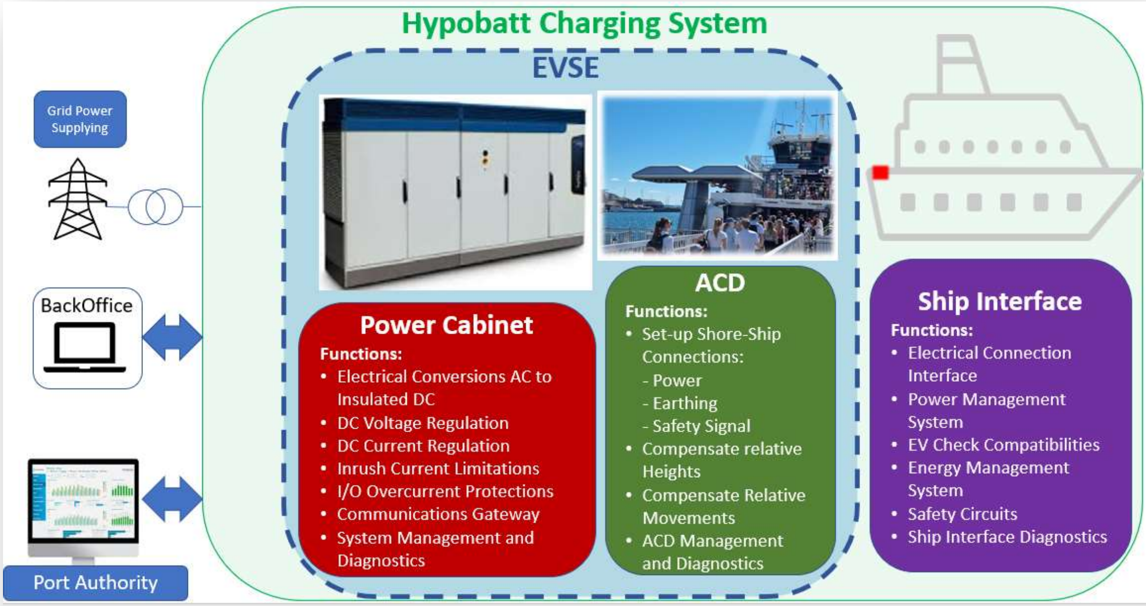

Figure 2 Functional Blocks Identification and main internal functions

4. Requirements

In this chapter, the requirements identified up to date in the HYPOBATT project with regards to safety, communications and hardware aspects are collected.

Before to go in the details of main topics in the following sub-chapters, some general key points have been here summarized.

Due to different technical constrains and boundaries those automotive existing and upcoming standards cannot be fully applied to maritime sector. Nevertheless, the basic principles of automotive standards can be transferred into the maritime application for the required electrical paths that needs to be connected conductively. Basically, in the standards transfer between the 2 sectors, considering the automated connection considered here, the following performances need shall be considered:

- Automated connector tolerances shall be defined considering the impact respect the behavior of moving interfaces to automatically connect (moored ships have anyway some movements on the three translational axis and on the three rotational ones)
- Distance between the ACD and the Power Cabinet shall be scalable as for application needs, ideally without limits
- No additional cooling system shall be required by the ACD to avoid cooling losses and reducing space needs on the quay (available space and automatic infrastructure allows solution with passive cooling)
- Design for maritime environment (e.g. air salinity)

4.1 Communications concept and requirements

The communication interfaces proposed for the maritime system are identified in the Figure 3 and where the MACS is already in advanced stage, the related requirements have been adopted.

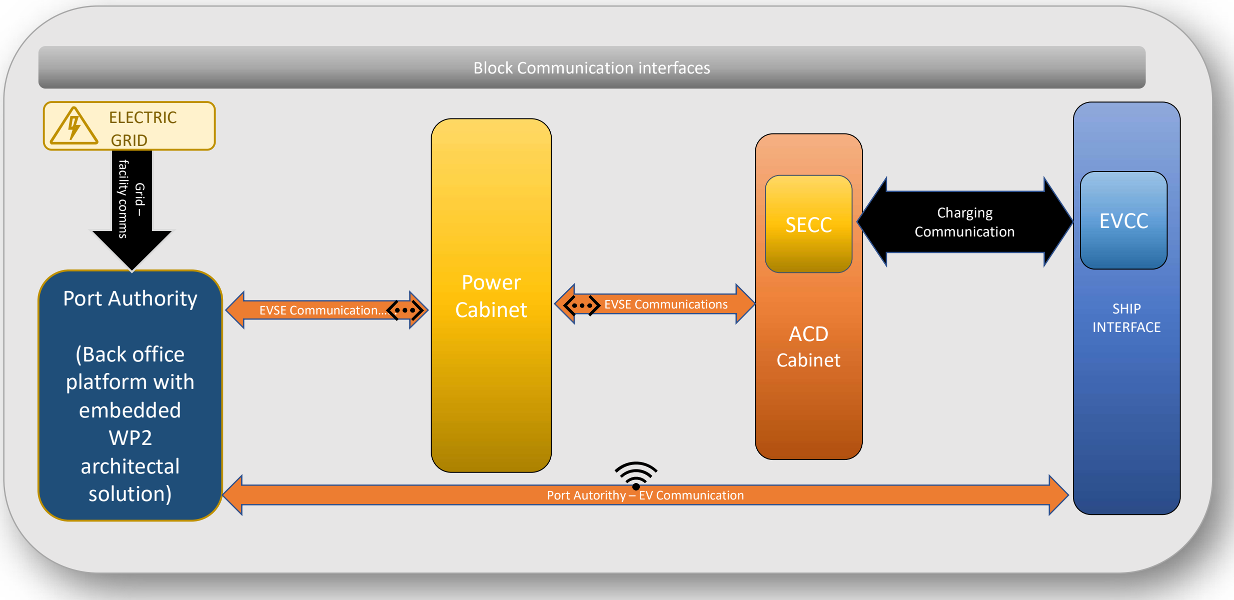

Figure 3 Communication Interfaces

About the "**Charging Communication**" between shore and EV charging controllers:

- the "Physical Layer" it has been considered as for the CharIN's suggestion "*a unified* ***differential signaling and native TCP/IP support*** *is of utmost importance for communication robustness and interoperability*" [2], lately shifted to 10BASE-T1S.
- the ISO 15118 protocol is considered to be robust and then compliant to maritime applications

About the "**EVSE Communication**" between charging system components, to lead to a wide interoperability between the charging system modules, the Ethernet standard shall be applicable. In case of long distances to cover, due to ports layouts, the Fiber Optic Ethernet link could be necessary and then applied. Obviously then the TCP / IP (IEC 60870-5-104) is expected to be standardized on this communication interface as well.

About the " **Port Autorithy – EV Communication"**, this link shall be established before the EVSE-EV connection so it can be only by wireless technology. At writing time, it has not yet definitively agreed in HYPOBATT project if Wi-Fi can be the best solution in term of reliability and cybersecurity considering ferries could transport several people carrying Wi-Fi devices, but it is the most probable anyway. The same obviously here about the TCP / IP protocols.

About the " **Grid – facility comms"** interface, the considered communication protocol is the OCPP which manages the communication between the EVSE and the CPO (Charge Point Operator) which is responsible for the operation of one or typically a lot of charge points.

4.2 Electricals

4.2.1 Electromagnetic compatibility (EMC)

Considering the non-existence of a dedicated Marine standard focussed on ports' installations, industry standards are proposed in relative section (IEC 61851-21, EN 61000 series and US FCC). It would be nice to have compliance to the most severe limits in emission (residentials) and immunity to the most severe levels of disturbances. Considering the automotive sector has already the dedicated standard *(IEC 61851-21),* where applicable, it shall be considered, and product compliance shall be reached. Here below in **Error! Reference source not found.** a more appropriate diagram of maritime applications respect usuals in other sectors.

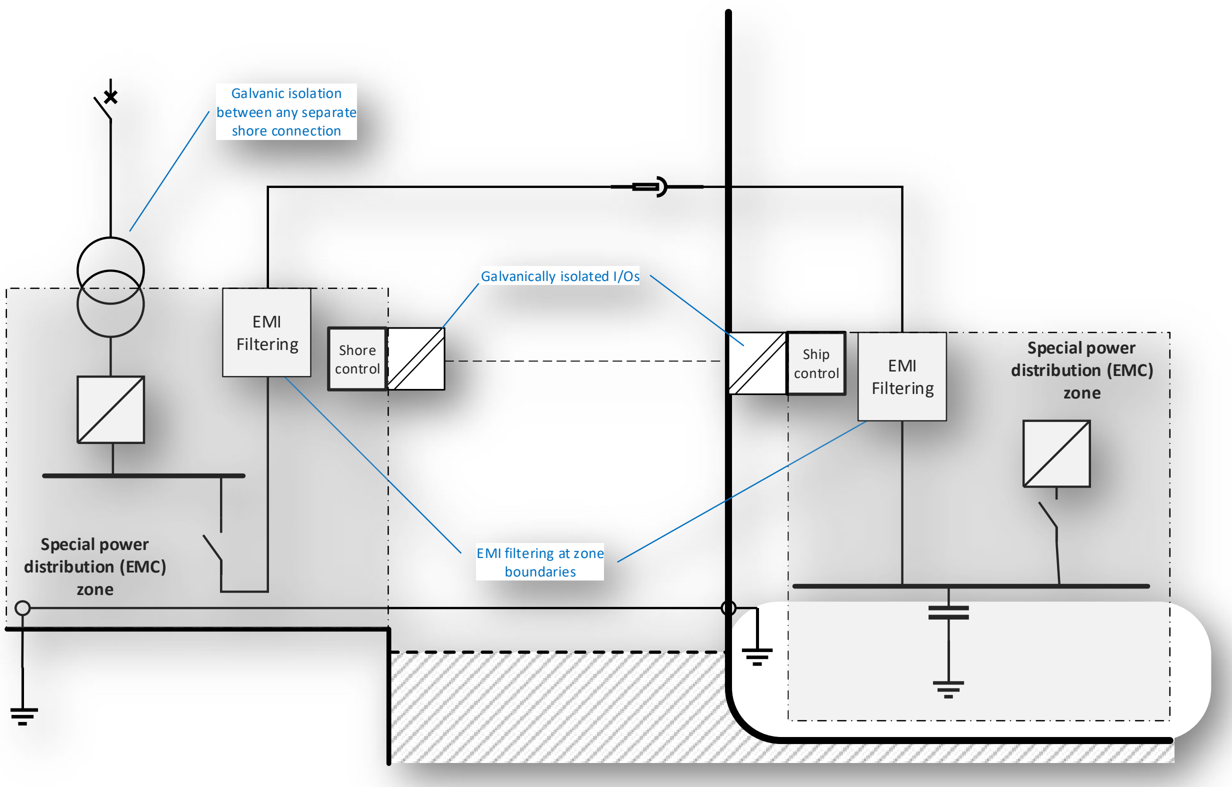

Figure 4 EMC zonal diagram

4.2.2 Isolation and safety

To reach the high electrical safety level required by the maritime system, following topics must be considered:

- ***Output Earthing System.*** The DC bus for the battery charging shall be floating (IT)
- ***Isolation Faults Protection.*** Power signal isolation w.r.t PE shall be monitored by IMDs.
- ***Run-Time Fault Conditions to Open the Circuit:***
    - Short Circuits
    - Isolation Faults
    - Earthing Fault
    - Excessive displacements / motions between the shore and ship interfaces
    - Emergency Push Buttons activations

4.2.3 Touch Safety

Safety aspects related to touching of high voltage or high temperature components is not contemplate in the HYPOBATT project because of the automated intention of the system imposes to keep out people and operator from the area.

4.2.4 Maximum temperatures (socket/pins and other components)

As the connection is automated the temperature of the contacts can be dimensioned as for the materials and reliability of the automated parts.

4.2.5 Short circuit protection

It shall be proven that the system can withstand a short circuit (on either side) of the connection (EV and EVSE).

4.2.6 Bus Voltage Range

The DC voltage range is ideally continuously adjustable over the full low-voltage directive range of 75-1500 V DC. However, this gives great complexity, size and reduced efficiency to the power conversion electronics. Considering the KPI on efficiency optimisation, next to a scalable power, also a scalable-voltage solution is therefore preferable. Based on the HYPOBATT market research inventory, an overall voltage range of 500-1500 V DC is required to accommodate for the existing and expected future electric vessels to be supplied. This is in-line with the voltage range defined in [2] for ACD devices. A strict 1500 V DC limit is posed by the Low Voltage Directive (2014/35/EU).

4.2.7 Current / Power Ranges and topologies

Electrical Vehicle Supply Equipment (EVSE) focus.

Currently, with the inexistence of defined overall DC current and power specifications of the Marine applications, a maximum overall power need of 20 MW is expected for Marine ACD. The intended HYPOBATT EVSE power range to be considered is 1-5 MW in sufficient steps to be able to make a prototype of 2 MW, preferably in even steps. A granularity of 1.25 MW would therefore be suitable to both achieve the envisioned maximum of CharIN's MCS (3.75 MW) and the HYPOBATT's MACS KPI maximum (5 MW) with one granularity. Resultantly, to achieve the complete expected Marine power need of 20 MW, 4 parallel chargers and connectors are required.

The DC output power definition as a function of the DC voltage and current is depicted for the general case in Figure 5**Error! Reference source not found.**, wherein the complete area within the envelope of DC power as a function of DC voltage vs. current with corner operating points (OP) can be produced by the EVSE and supplied based on the set-points requested by the EV during the charging process. Subsequently, in Table 1, for each of the power levels (1,25/2,5/3,75/5 MW), the operating point values are listed for the 4 current ranges (I_{max} - 1,2,3,4) being 1250, 2500, 3750, and 5000 A, respectively as derived from the required power granularity.

In case of multiple separated batteries, either cascaded charging (D1.2, Figure 37a) or combined connectors for direct charging (D1.2, Figure 35a) are to be considered as specified. The latter requires galvanically separated LV DC fields, thereby leading to multiple ACD connectors, or 1 connector with multiple DC+ and DC- pins. Main requirement from modularity perspective is that an ACD with 2 separate fields of 1x nominal current (I_N) can be made in an equal manner as an ACD with 1 field of 2x nominal current (2 I_N). EVSE-EV communication control must be implemented with one SECC-EVCC set per ACD.

DC output power definition

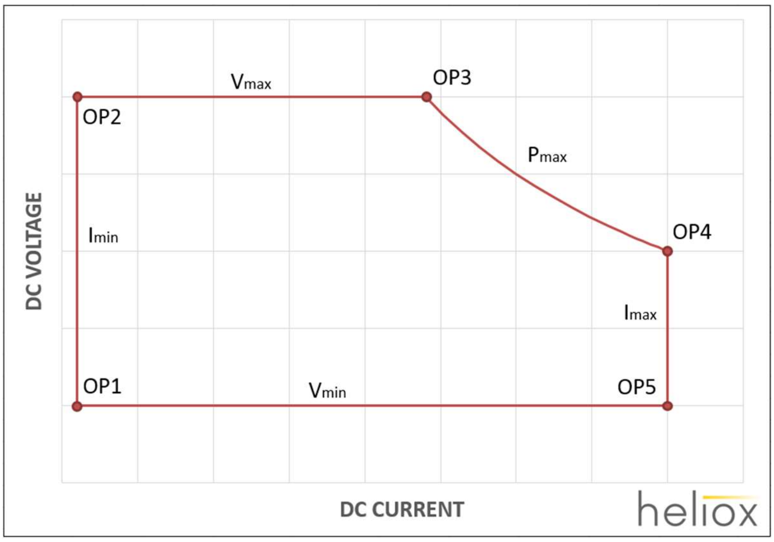

Figure 5 Envelope of DC power as a function of DC voltage vs. current with corner operating points (OP)

Table 1 DC current and voltage values for MACS definitions per operating point

DC power (P_{max}) [MW]	Operating point OP, (V,I); DC voltage in [V] , DC current in [A]				
	1	2	3	4	5
Maritime Automated Charging System (MACS) Standard Levels					
1.25	500,25	1500,25	1500,833	1000,1250	500,1250
2.5	500,50	1500,50	1500,1667	1000,2500	500,2500
3.75	500,75	1500,75	1500,2500	1000,3750	500,3750
5	500,100	1500,100	1500,3333	1000,5000	500,5000

Electrical Vessel focus

For redundancy reasons an electric ship will have (as a minimum) two battery systems, and because of the high energy rating, battery systems consist of multiple strings and packs (See Figure 1: from the Ship connector, 2 DC lines are linking the 2 BMS and battery packs). These batteries can be connected directly to a primary DC system, or via power converters to an AC or DC primary system. Another variable is the presence of a bus-tie between the primary busses. These variables can be sketched in 4 electric ship power configurations. In Figure 6 these topologies are shown with also the charger options indicated. Where the chargers are connected to the primary busses. In Figure 7 an alternative topology is given with batteries connected via converters, but with direct charging.

As can be concluded form the topologies, having two chargers will cover all options. With two chargers also redundancy will be created. Where in case of failure of one charger the other can (at half power) still charge the ship.

Having two chargers as a standard for charging of electric ship comes possibly with challenges on the MCS standard. The following challenges are now identified:

- Direct paralleling of chargers for close bus topologies (Figure 6 (b) and (d))

- Constant voltage mode (optional with droop) needs to be implemented for fix DC bus option (Figure 6 (c) and (d))

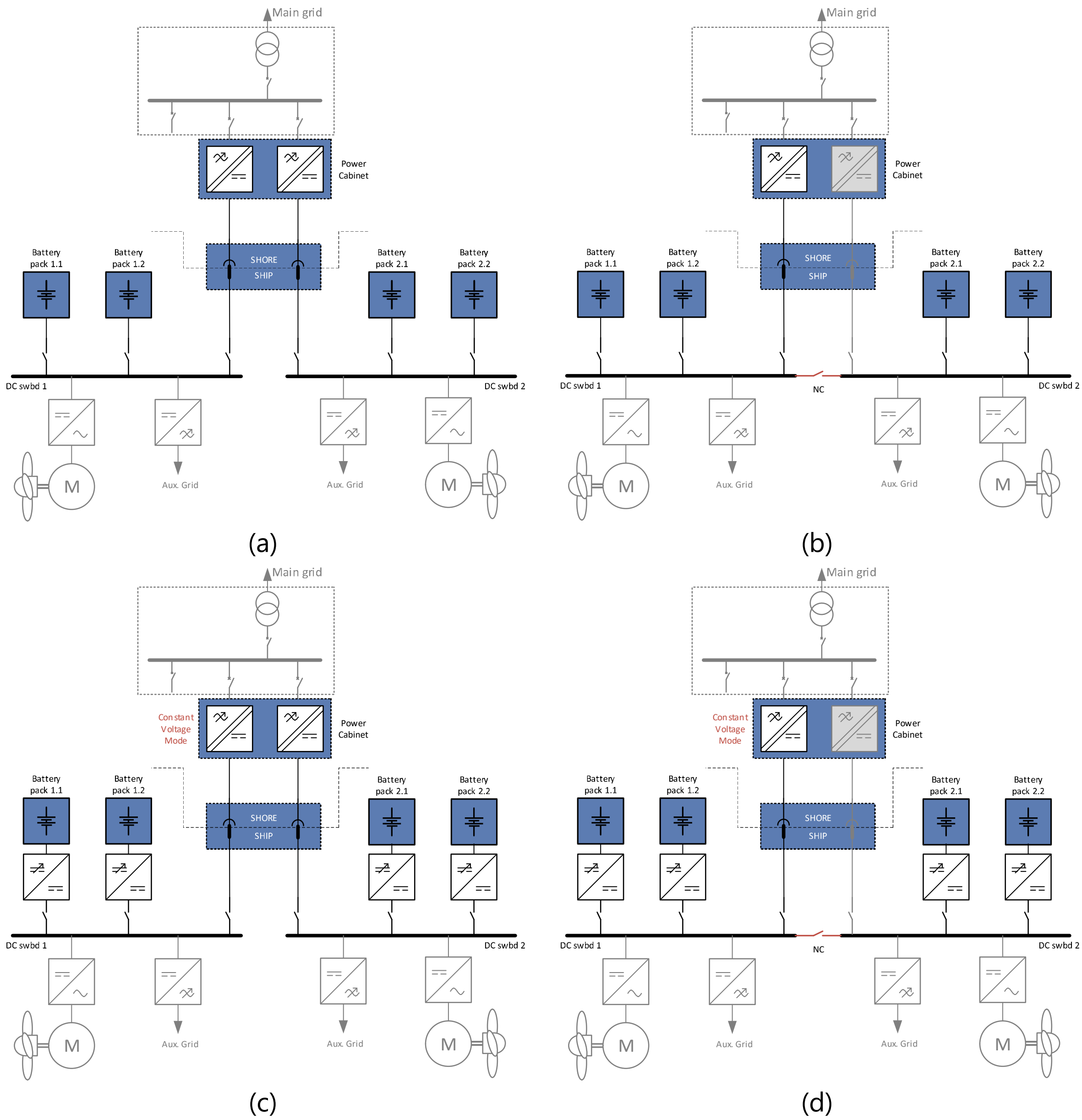

Figure 6. Suggested topologies for electric ship chargers, with (a) and (b) direct battery charging via DC-bus, and (c) and (d) DC-shore supply with onboard chargers.

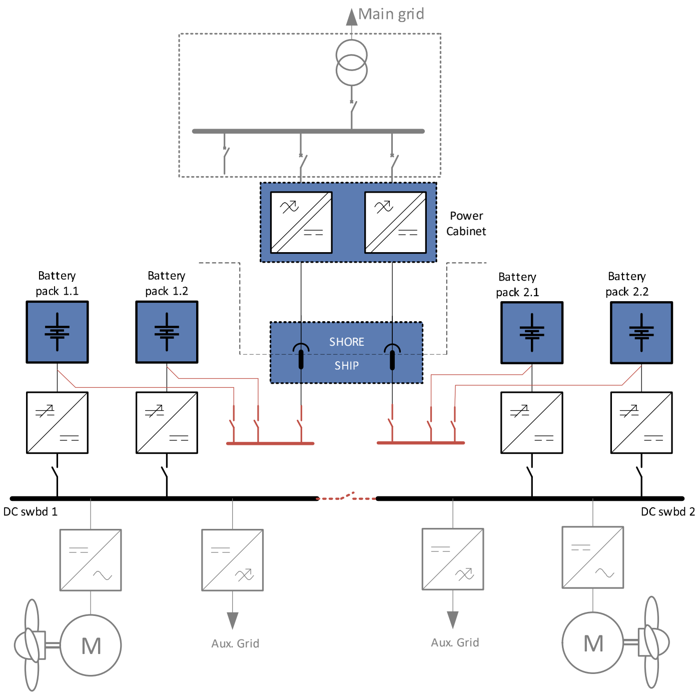

Figure 7. Topology with direct (fast) battery charging, can be used for primary AC and DC systems (bus-tie is optional).

4.2.8 Other Requirements

- ***EV-EVSE Connection Signals***
  - For the power transfer:
    - "DC+"
    - "DC- "
  - For safety reasons:
    - "PE" connection
    - "Low-level communication" can be in the form of Control Pilot (CCS) or Charge Enable as proposed in MCS. At least 1 circuit composed of 2 contacts/wires acting as a safety loop between EV and EVSE which will also be used for high-level communication.
- ***Input Voltage***
  - ***Grid Interface Input.*** An input step down transformer, tailored per application, should be foreseen (as part of the charging system or not) to accommodate a medium input voltage in the range 3-35 kV AC +/- 2,5 % (3P + PE) with frequency in the range 47-63 Hz. In this way also, the 6.6 kV or 11 kV nominal voltages, as for IEC80005-1, can be supplied.

4.3 Hardware

4.3.1 Coupler Retention shall be avoided

The connection EVSE-EV, also if automated, shall not be locked and free to be disconnected in case of the captain of vessels would decide to leave without waiting for disconnection.

No damages shall occur to the connector and the EV then the automated connector shall provide an autonomous automated disconnection in case of the EV is in "out of ranges" about distances and speed of the movements.

4.3.2 EVSE / Port Location Recommendations

Ships are very diverse in their appearance, which means that it is impossible to define an exact connection location, even more so due to tidal or other variations the water level is not constant. Furthermore, because ships are floating on the water, these can be moving during the charging process. Because it is economical impossible to define a set of specifications for the inlet location and movements tolerances covering all electric-ship types it was decided in the HYPOBATT project to define a limited movement space for the ACD, this means that other movements like tidal or location of the connector on the ship should be compensated by application. As an example, the ACD can be installed on a pontoon to compensate for tidal, or on rails for sideways compensation.

Connection Interface Position on the Ship

- To reach a high level of interoperability maintaining low costs, it would be **preferable to have a *side connection*** to the ship, along the shore edge (see Figure 8, left picture).
- It would be better to have the connection in the leaving direction to avoid damage to the ACD or the ship in case of vessel leaving before connectors are properly disconnected.
- A side connection is easy for vessels with high sides but, **in case of low vessel heights**, ***the connection is preferred from the top*** (see Figure 8, right picture).

Figure 8 Contacting Layouts: Side (left-hand side) and Top (right-hand side)

4.3.3 Insertion / Extraction Force

Considering the HYPOBATT connection study is related to automated solution, the insertion and extraction forces are not related to manual operation. Anyway, a minimum force shall be applied to have a successful connection.

About the "Side" connection, since the berthing mode are different and with diverse features the pushing force shall be minimized. Up to now it was not possible yet to define a maximum value.

About the connection from the "Top", the force is more tolerable but again since it is strictly related to the EV features, up to now it was not possible yet to define a maximum value.

4.3.4 Other: ACD–EV distances and relative movements

The ACD shall be capable to compensate ACD–EV distances and relative movements at least as for the following indication, at connecting time and when connected.

Considering axis as for Figure 29 in the HYPOBATT D1.2, the minimum performances for typical ACD connecting with moving vessels shall be:

- with SIDE connecting option:
  - Reach a ship interface at 1500mm from the quay on Y axis
  - Compensate relative movements on X axis of ± 100mm
  - Compensate relative movements on Z axis of ± 500mm
  - Compensate around X axis rotational up to ± 3°
  - Compensate around Y axis rotational up to ± 1° (connecting/disconnecting) and ± 3° when ACD connected
  - Compensate around Z axis rotational up to ± 2°
- with TOP connecting option; as SIDE, but exchanging axis Y and Z

Tolerance to vessel motions

During the connecting, charging and disconnecting process

Speed (Y-direction, telescopic distance) .... 0,02 m/s
Speed (X- and Z-direction, vertical plane) .... 0,03 m/s
Acceleration 0,005 m/s^2

4.4 Environmental

Considering that the most common location for installing the battery charger system is outdoors, the environmental requirements below shall be met:

- ***Operating Ambient Temperature Range:*** -25°C / +45°C. Output power derating could be allowed outside the range as for application needs.
- ***Operating Humidity Values and Duration***
    - yearly average: ≤ 75 % relative humidity
    - on 30 d in the year continuously: between 75 % and 95 % relative humidity
    - occasionally: between 95 % and 100 % relative humidity
- ***Operating in High Salinity Air.*** The system shall be designed for Category C5-M (Marine) of ISO 12944.
- ***Operating under Snow Load & Ice*** (as for application needs)
- ***Operating Solar radiation & UV.*** Materials shall be evaluated as ISO 4892 and ISO 16747.
- ***Operating Wind.*** Wind up to 20m/s shall be tolerated without misfunctioning.
- All components shall be designed to be compliant to the expected ***Pollution Degree*** related to the relative ***IP*** of enclosures. Although EMSA recommends "***For all shore power applications IP67 is the mandatory water protection index***" [3], after design justification and counter measurement taken, a lower IP level could be accepted.
- ***Maximum Acoustic Noise.*** Best should be reaching a low noise level in average and peak:< 80 dB(A) @ 5 m (see standards section) but during ACD movement could be allowed short time higher. Decision shall be taken by application considering passengers and operators' distances.
- ***Operating Vibrations.*** No requirements for land installation but for pontoon ones it shall comply to the ***pontoon movements dynamics***.
- ***Operating Impacts.*** Define for application the level of robustness and apply protections as for IEC 62262.
- ***Health and Environment.*** compliant to REACH regulation of the European Union.

4.5 Applicable Standards, Regulations and safety rules

Standards and Regulations

Due to the lack of dedicated standards, where it is possible, as usual practice in maritime applications, as reference, standard listed below are applied. It is desirable the maritime dedicated standard is considering and treating all the topics in the standards listed in this chapter.

The maritime ISO 80005-2 (High and low voltage shore connection systems – Data communication for monitoring and control) recommends:

- for the Physical Layer a Fiber optic connection but it is not adequated to the automated connection
- for the protocol the Modbus TCP/IP that could be evaluated also if not introduced for charging systems.

Applicability of standards of other industry sectors: not devoted to maritime sector standard shall be ***assessed to demonstrate their suitability for marine use. In case of gaps*** in the applicable rules and standards for the installations, ***risk analysis and technology qualification process are necessary***.

Other sectors standards:

- ***Medium Voltage Connection:*** IEC 80005-1, IEC 62613-1, MEPC.1/Circ.794, IEC 61936-1, RINA Rules Part-F Chapter 13 Section 15, DNVGL-RU-SHIP-Pt4Ch8
- ***Low Voltage Connection:*** IEC 80005-3, IEC 60364-4-41, IEC 60364-5-52, IEC 60664-1, 60664-3, IEC 61140, Low voltage directive (2014/35/EU), DNVGL-RU-SHIP-Pt4Ch8.
- ***Industrial Electric Standards:*** IEC 62271-200, IEC 60071-1, IEC 60270-1 and -2
- ***Ingress Protection Standard Reference.*** The reference standard is IEC 60529, but the IP index shall be defined per application. For US markets the reference is ANSI / NEMA 250.
- ***External Mechanical Impacts protection.*** The reference standard is IEC 62262, but the IK code shall be defined per application.
- ***General Construction rules:*** DIN 18299.
- ***Solar radiation & UV.*** ISO 4892 shall be considered for Plastic Materials.
- ***EMC Standards:*** IEC 61000 series; US FCC Part 15, subpart B, class A; NTH compliance also to IEC 61851-21-2
- ***Acoustic Noise.*** Reference standards are:
  - European Directive 2006/42/EC:
  - European Directive 2003/10/EC
  - US OSHA 1910.95
- ***Protection Painting***: ISO 12944

- ***Cathodic protection.*** Related standards to consider are ISO 12473, EN 12495, ISO 13174, EN 13173
- ***Guidelines evaluating metals and alloys in surface sea water:*** ISO 11306
- ***Automated connection devices.*** Automotive devices could be useful or to use or to study as for standards: IEC 61851-23-3 and SAE J3105.
- ***Safety of machinery:*** IEC 62061, Safety of machinery - Functional safety of safety-related control systems
- ***Charging Communication Standards:*** IEC 61851-24 and ISO 15118-20.

Safety aspects

The safety requirements shall be aligned with the local, national, and European regulation.

System Safe State Considerations

As for the application features, a safe state shall be defined for each block, and this shall be targeted in case of:

- Defined safety related alarm (e.g., Emergency Button, short circuit detected, PE connection lost, Emergency Stop)
- Communication is lost between blocks

In case some operation is needed before reaching safe state, the system shall be designed with the correct timing.

The Safe State could be conditioned and differentiated by different contexts and shall be defined in design stage.

Moving Mechanisms and Voltage Hazards Protection

To minimize the risks of injury, the areas with moving mechanisms or unsafe voltages, that could be touched, must be inaccessible. These areas must be clearly declared in the Installation manual.

Emergency Push Buttons

Safely accessible "e-stops" should be located at least close to the ACD and at vessel’s bridge. Another one will be allocated on the Port office (cloud-based software) in case the port operators need to shut down the whole process.

Fire prevention

The lack of standardization in this sector for charging application leads to consider local regulation and local fire brigade’s considerations.

Connectors shall be sufficiently resistant to the relative heat and risk of fire

5. CONCLUSIONS

As emerged in the analyses carried out in the first part of the project**,** hyper-power DC chargers for electric ships are still novel and dedicated designs, and there are no detailed and comprehensive requirements available. Detailed information and standards are not always available for all issues raising, but a basic set of requirements and standards have been determined to be used by the project partners to develop the planned technologies. Some of the analysed standards could be applied, at least partially, e.g. IEC 61851-23, ISO 15118 and ISO 80005. The gaps identified in specific regulatory marine provisions can be, at least partially, bridged by application of guidelines and standards derived from other industrial shore-based applications, or using the principles of Technology Qualification Process for innovative technologies.

The experience that will be gained in the development of the HYPOBATT Maritime Automated Charging Systems for electric ships will be noted and will become the input for the identification of additional prescriptive criteria and standards, framed into a goal-based methodology, to be applied for the regulatory compliance of safe, efficient, and reliable systems.

In general, it cannot be excluded that some instances, both in port grid and main power grid connections, will remain subject to location specific requirements (power quality, voltage levels, equipment standards, environmental conditions, data infrastructure, maintenance requirements, etc.), and local regulatory provisions and regulations from port authorities. Therefore case-by-case analyses and risk assessments are likely to remain part of the design and implementation process.

To date, the following gaps have been identified and respective solutions have been proposed:

Topic 1: Voltages and Power ranges.

Context. The Maritime sector is supported on the port side from the IEC 80005 series standards about the Onshore Power Supply and Shore-side Battery charging only for AC system.

Solution proposed. Focussing on most adequate vessel electrification currently on the water and the having a look on the market evolutions, the range 1 - 5 MW has been identified as the first right step to propose for standardization. Considering the MCS voltage and power levels, and to remain in low voltage directive as well, the upper limit of 1.5kV has been selected for the voltage and a step of 1.25 MW has been chosen for the scalability of the charging systems.

Topic 2: Two separated battery systems need on the vessels

Context. Due to the redundancy needs on vessels, (a minimum of) two independent battery systems are required as well.

Solution proposed. Considering the redundancy needed for service time (and not for charging time) some proposals have been provided by splitting the input power from 1 charger (and 1 ship connector) between the 2 battery systems or in different time slots or setting in parallel the batteries with a safe intelligent switchboard. An obvious solution, but more expensive in term of cost and space, could be having two half chargers the doubling charging connection and paths.

Options b) or d) in Figure 6 are the 2 best fitting for the HYPOBATT system, having only one charger.

Topic 3: Communication of arriving vessels.

Context. The connection of the EVs takes places after the vessels have been docked. Then before a conducted communication, a wireless one is necessary between vessels and PA to check the compliances and establish the docking pier, for example.

Solution proposed. To be implemented in HYPOBATT, up to now the proposed connection is "by internet", does not care what the wireless channel used to stablish communication between the E-Vessel and PA, and secured by VPN (Standards protocol are under definition). Needed data is itemized and structured (packaging, purpose, data latency, etc) to identify all key parameters that need to be shared (from EV to PA and the other way around) to make possible a digitally enhanced arrival and docking. At docking time, all Charging System modules needed at a specific pier have been pre-tested, switched-on and provided of the specific charging profile for that charging action.

Topic 4: ACD-vessels distances and relative movements.

Context. The diverse shapes and dimensions encountered in the vessels and diverse piers layout have not permitted to reach a cost-effective solution for the auto-connecting task, more, the continuous relative movements between the ACD and the vessels has prevented the use of an already proposed connector.

Solution proposed. It has been decided in the HYPOBATT project to define: a) a limited movement space for the ACD; b) a distance range for the ship interface to reach; c) movements limit; d) a connecting interface between ship and ACD adequate to the previous definitions; e) the connector pushing force to be as low as possible. The solutions proposed let the connection direction free to be from the Top or from the Side of the vessel but anyway aided from a port infrastructure compensating the relative gaps in terms of distances, positioning, berthing force resistance.

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