European Maritime Safety Agency

Shore-Side Electricity

Guidance to Port Authorities and Administrations

Part 2 - Planning, Operations and Safety

Version 2
August 2022

EMSA

Cover Image:

MV Ellen

Document history

Version	Date	Changes	Prepared	Approved
1	19/07/2022	Original release		
2	12/08/2022	Sections 4.4.1 and 4.4.2 modified		

Acknowledgements

The EMSA Guidance on Shore-Side Electricity for Port Authorities and Administrations was the result of a vote of confidence from the Sustainable Ports Subgroups of the European Ports Forum, and the active contribution from several stakeholders throughout its development. EMSA would like to acknowledge the Forum and its Subgroup for giving the Agency the objective, goal and continuous support in the development of this guidance document.

Particularly, EMSA would like to acknowledge the support and contribution from:

- European Sea Ports Organization (ESPO) and all its members
- National Technical University of Athens (NTUA), in particular to Professor John Prousalidis
- International Association of Classification Societies (IACS)
- American Bureau of Shipping (ABS)
- Det Norske Veritas (DNV)
- EURELECTRIC
- CINEA, for the important institutional cooperation and sharing of results/ deliverables from EU co-funded SSE/OPS projects.
- EALING project
- European Community Shipowners Association (ECSA)
- Cruise Lines International Association (CLIA)
- Hapag Lloyd
- ABB
- Holland America

Table of Contents

PART 2

List of Abbreviations and Acronyms in Part 2

CCNR	Central Commission for Navigation in the Rhine
CESNI	Comité européen pour l'élaboration de standards dans le domaine de la navigation intérieure
DWT	Deadweight tonnage
EAFO	European Alternative Fuels Observatory
EAM	Emission Abatement Method
EC	European Commission
ECA	Emission Control Area
EMSA	European Maritime Safety Agency
EPR	Emergency, Preparedness & Response
ERC	Emergency Release Couplings
ERS	Emergency Release System
ESD	Emergency Shutdown System
ES-TRIN	European Standard laying down technical requirements for Inland Navigation vessels
EU	European Union
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Modes, Effects and Criticality Analysis
GT	Gross Tonnage
HAZID	Hazard Identification
HAZOP	Hazard & Operability Study
HSE	Health & Safety Executive
HVSC	High Voltage Shore Connection
IACS	International Association of Classification Societies
IAPH	International Association of Ports and Harbours
IGCT	Integrated Gate-Commutated Thyristor
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMO	International Maritime Organization
ISO	International Standardization Organization
LVSC	Low Voltage Shore Connection
MARPOL	International Convention for the Prevention of Pollution from Ships
MGO	Marine Gasoil
OPS	Onshore Power Supply
PAA	Port Authorities & Administrations (used throughout the document for simplification in the text)
PLC	Programmable Logic Controller
PPE	Personal Protective Equipment
PSC	Port State Control
QRA	Quantitative Risk Assessment
QualRA	Qualitative Risk Assessment

RA	Risk Assessment
RO	Recognised Organisation
SBC	Shore-side Battery Charging
SoC	Statement of Compliance
SOx	Sulphur Oxides
SPB	Shore-side Power Bank
SSE	Shore-Side Electricity
SSL	Ship Shore Link
STCW	IMO Code for Seafarers’ Training, Certification and Watchkeeping
SWIFT	Structured What-If Checklist (SWIFT) technique
WPCI	World Ports Climate Initiative

4. Shore-Side Electricity Options

4.1 General

Shore-side electricity projects have the primary objective of providing a controlled interface between power supply from the utility grid or distributed power/microgeneration, to direct power supply for ships at berth.

The diagram below identifies the key infrastructure elements for SSE, Onshore Power Supply (OPS) and Shore-side Battery Charging (SBC) arrangements. The key elements are identified from a generic perspective. However, electrical power infrastructure can follow a variety of different architecture layouts. The legend identifies the key infrastructure/equipment elements:

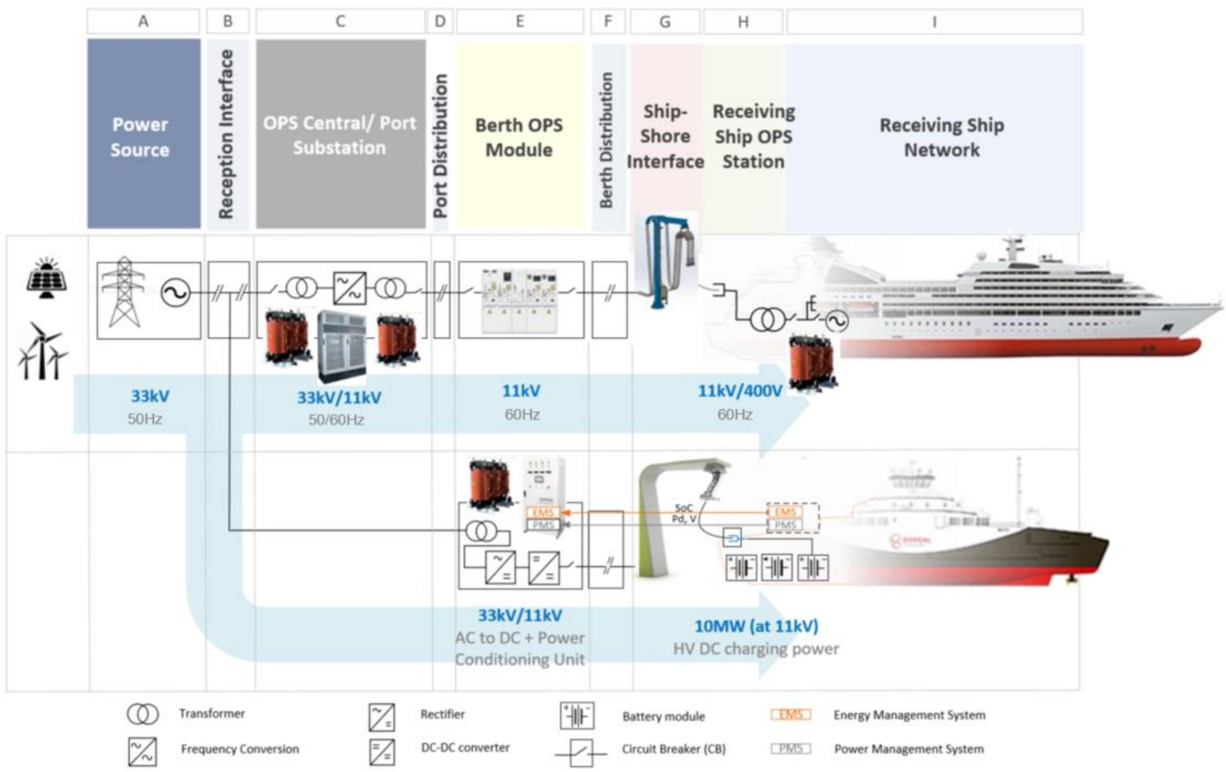


Figure 4.1 - Generic description of Onshore Power Supply (OPS) and Shore-side Battery Charging (SBC)

4.2 SSE Options

The present section includes general SSE systems architecture, including identification of the main infrastructure elements, examples of technological solutions and the different practical applications for OPS, SBC or SPB.

The different types of SSE arrangements are represented in Figure 4.2 and Figure 4.3 and described in Table 4.1. The list of SSE options presented is illustrative and non/exhaustive. Several combinations are possible in view of port/terminal/ship specific user requirements, both from a technical and operational perspective.

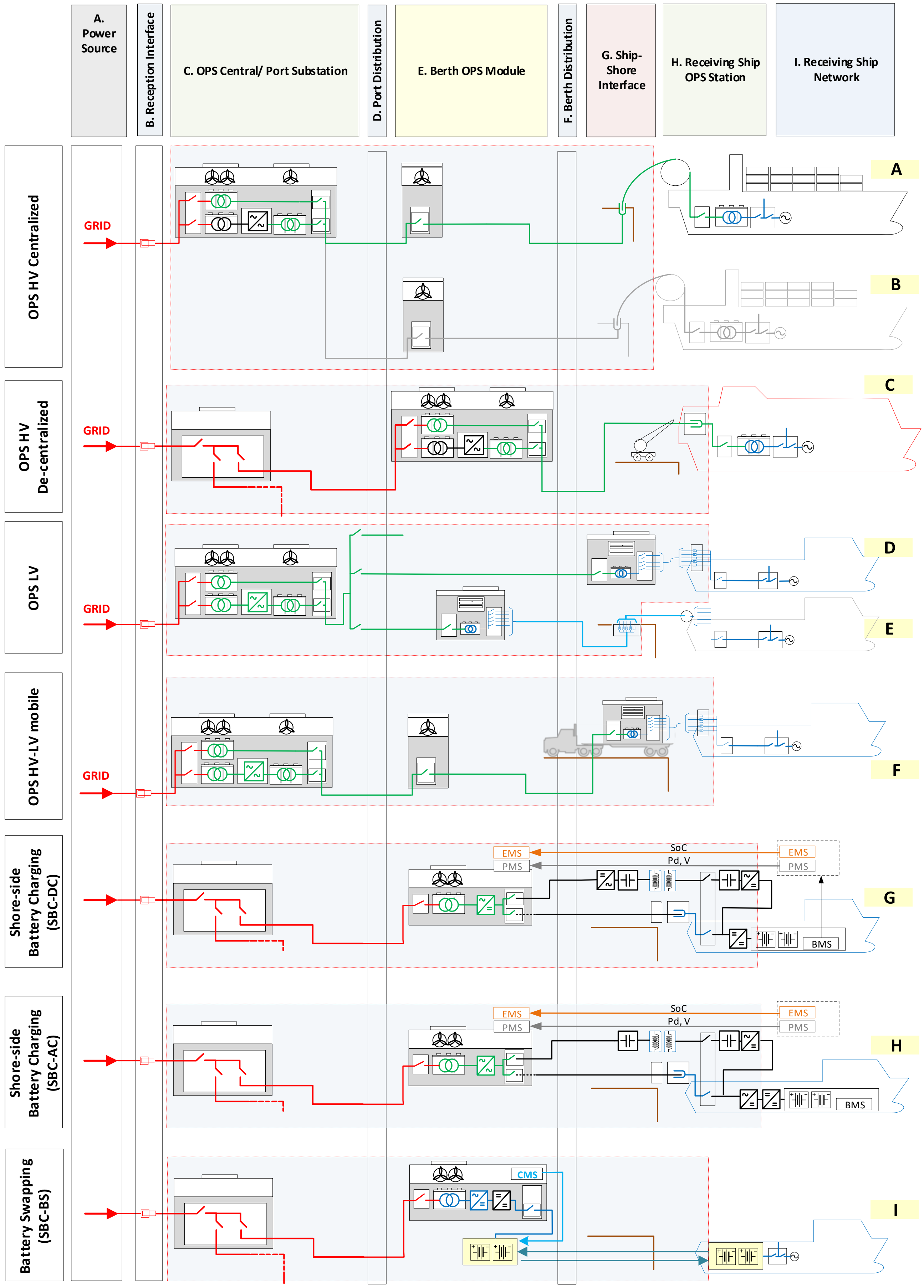


Figure 4.2 - SSE Types – Arrangements for SSE configuration “A” to “I”, (legend in figure 4.5).

Source: EMSA

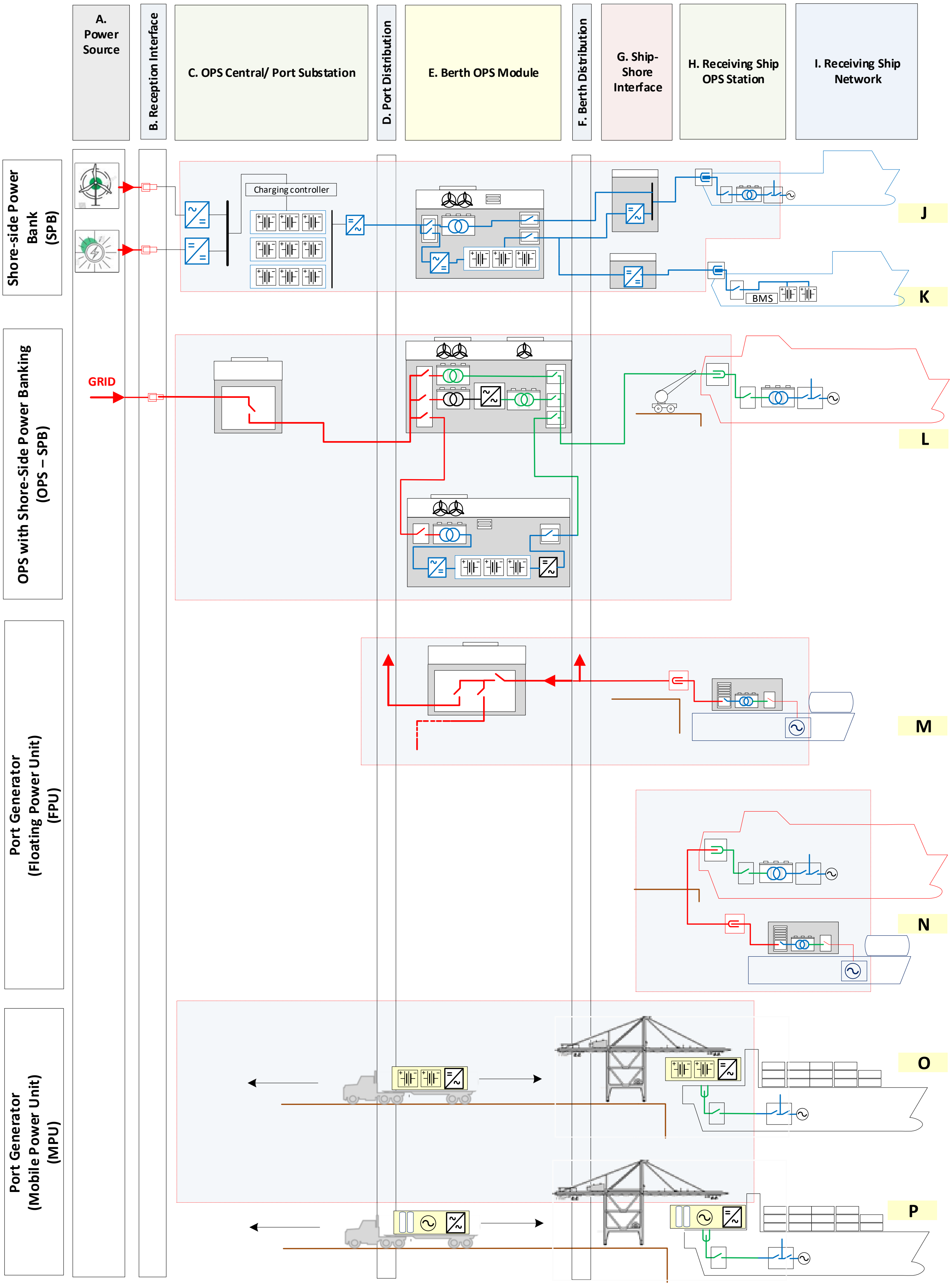


Figure 4.3 - SSE Types – Arrangements for SSE configuration “J” to “P” (legend in figure 4.5).

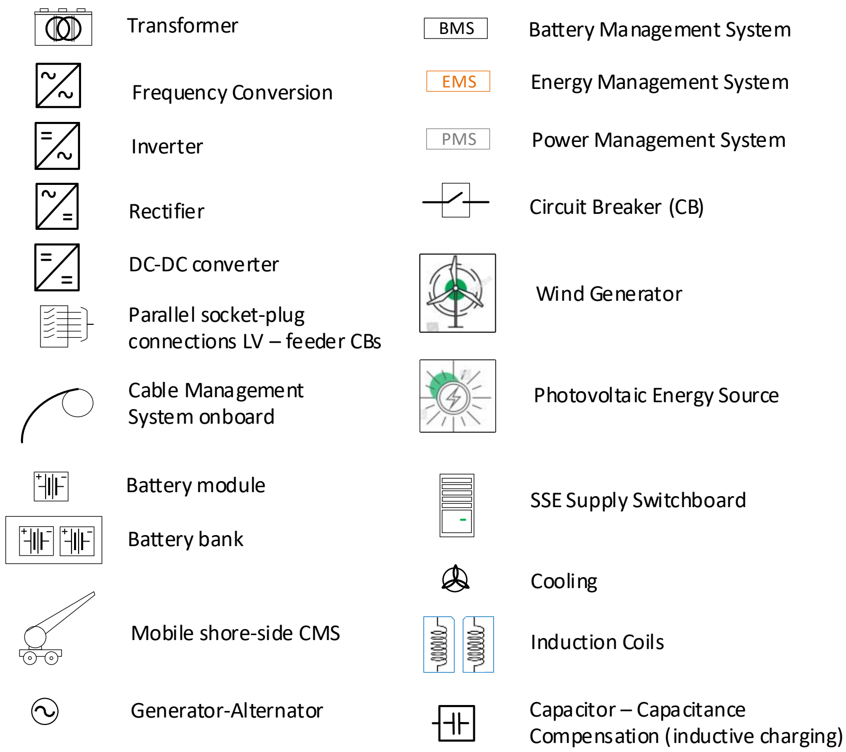
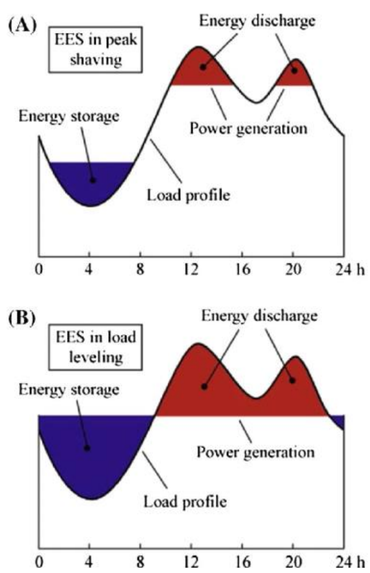


Figure 4.4 - Legend to diagrams in Figure 4.2 and Figure 4.3.

Table 4.1 – SSE Options – Different SSE types and possible configurations for Shore Side Electricity services.

Reference to diagrams in Figures 4.2 and 4.3	Designation	Brief	Short Description
A, B	High-Voltage Onshore Power Supply with Centralized Frequency Conversion	**HVSC** **HV-OPSc**	High Voltage Shore connection composed by connection to HV utility grid at a designated voltage and frequency. Frequency Conversion takes place at a centralized higher-level Port Substation. Multiple frequency converters can be used for increased redundancy. Distribution to different berth junction boxes with HV socket-outlets. Illustrated Containership case with Cable Management System onboard.
C	High-Voltage Onshore Power Supply with De-centralized Frequency Conversion	**HVSC** **HV-OPSd**	High Voltage Shore connection composed by connection to HV Utility Grid at a designated voltage and frequency. Frequency conversion takes place at a decentralized lower-level berth Substation. Multiple frequency converters can be used for increased redundancy. Designated distribution for large consumers (e.g. cruise ships). Illustrated cruise ship case with mobile Cable Management System ashore.
D	Low-Voltage Onshore Power Supply – without Cable Management System	**LVSC** **LV-OPS**	Low Voltage Shore Connection composed of HV Utility Grid at a designated voltage and frequency, followed by step down with frequency conversion at higher level Port Substation. Berth OPS module represented with transformer as an alternative location for shore-side transformer. Multiple cables are representative as a distinctive feature of LV connection, also represented corresponding parallel feeder circuit breakers. Cable Management System comprised on socket-outlet and ship-connector.

E	Low-Voltage Onshore Power Supply – with Cable Management System	**LVSC** **LV-OPSc**	Low Voltage Shore Connection composed of HV utility grid at a designated voltage and frequency, followed by step down with frequency conversion at higher level port substation. Berth OPS module represented with transformer as an optional alternative location for shore-side transformer. Multiple cables are representative as a distinctive feature of LV connection, also represented corresponding parallel feeder circuit breakers. Cable Management System comprised of cable reel onboard ship and socket-outlet arrangements.
F	Low-Voltage Onshore Power Supply by mobile step-down unit – from High Voltage installed supply infrastructure	**LVSC** **LV-OPS mobile**	Low Voltage Shore Connection in an otherwise high voltage supply infrastructure. Method relevant for OPS supply from a high voltage installation to OPS equipped ships which have no step-down OPS transformer onboard. Solution for relocation of OPS berth mobile unit can be diverse. Trailer-truck represented.
G	Shore-Side Battery Charging with Charger Unit ashore – DC charging	**SBC-DC**	DC Shore-side Battery Charging, supplied by HV utility grid supply, subject to power condition by step-down transformer and rectifier AC/DC converter. Wired and wireless inductive charging are both presented. For inductive charging are presented capacitance compensators adding reactive power consumed by the inductive charging coils. For wired connection the diagram shows a charging connector plugged in a connector-inlet arrangement. DC-DC converter presented installed onboard. Energy Management and Power Management Systems represented for communication across ship-shore interface (EMS, PMS).
H	Shore-Side Battery Charging with Charging Unit onboard – AC charging	**SBC-AC**	AC Shore-side Battery Charging, supplied by HV utility grid supply, subject to power condition by step-down transformer and frequency conversion if so necessary. Wired and wireless inductive charging are both presented. For inductive charging are presented capacitance compensators adding reactive power consumed by the inductive charging coils. For wired connection the diagram shows a charging connector plugged in a connector-inlet arrangement. DC-DC converter presented installed onboard. Energy Management and Power Management Systems represented for communication across ship-shore interface (EMS, PMS).
I	Shore-Side Battery Charging with Charger Unit ashore – Battery Swapping	**SBC-BS**	Swapping of batteries may represent an option for reduced turnaround times, especially for ships engaged in regular traffic with short periods at berth. Generic diagram represents a berth-level charging unit used for interchangeable batteries used to plug-in onboard battery powered vessel. Charging management Systems is represented.
J	Shore-side Power Banking as interface electrical energy storage for Renewable Production in port area – OPS supply	**SPB (OPS)**	Renewable energy resources integrated into port energy system, in particular directly integrated onto the shore-side electricity network. This can, in fact, be referred to as direct renewable. Indirect renewables are integrated indirectly through the electricity production mix at national/regional level. Technical solution comprises of AC-DC converters for wind generators and DC-DC for PV contribution. Other renewables may be possible, including the use of microgeneration with renewable and low carbon fuels. Option “J” presents renewable based SPB to OPS supply through the introduction of an Inverter unit for AC power supply at designated voltage and frequency.
K	Shore-side Power Banking as interface electrical energy storage for Renewable	**SPB (SBC)**	Renewable energy resources integrated into port energy system, in particular directly integrated onto the shore-side electricity network.

	Production in port area – SBC supply		This can, in fact, be referred to as direct renewable. Indirect renewables are integrated indirectly through the electricity production mix at national/regional level. Technical solution comprises of AC-DC converters for Wind generators and DC-DC for PV contribution. Other renewables may be possible, including the use of microgeneration with renewable and low carbon fuels. Option “K” presents renewable based SPB to battery charging supply through the introduction of an Inverter unit for AC power supply at designated voltage and frequency.
L	High-Voltage Onshore Power Supply with De-centralized Frequency Conversion, including Electrical Energy Storage module for Peak Shaving	**OPS-SPBps**	Onshore Power Supply (OPS) with Energy Storage Module for peak shaving and power backup. The battery system may assist in meeting power peaks during busy hours with multiple ships at berth, whilst storing energy at potentially more convenient hours (in price an operation cost).  **Figure 4.5 - Peak shaving and backup power.**
M	Port Generator (Floating Power Unit - FPU) – connected to the port grid	**PG-FPU**	Floating Power Generator presented with connection to shore-side grid, able to supply electricity to different OPS or battery charging points in the port area. Infrastructure on shore side may be limited in such cases to HV/LV cabling and shore-supply points at different berth locations. Supply to other port consumers also a technical possibility. Port generators may achieve equivalency to OPS if using renewable and low carbon fuels as per definitions in Renewable Energy Directive 2018/2001. Interconnection and Interoperability should follow similar standardisation references to OPS supplied by land-side infrastructure (IEC/IEEE 80005 series
N	Port Generator (Floating Power Unit - FPU) – connected directly to receiving ship grid	**PG-FPU**	Floating Power Generator presented with connection directly to ship grid. Operational advantage of such configuration presented by flexibility of OPS supply to different port/berthing locations. The figure depicts a supply directly to passenger ship, with the possibility of the Port generator FPU to be moored side-by-side. Onshore Power Supply by MPUs should comply with all relevant and applicable aspects of IEC/IEEE 80005 series. Port generators may achieve equivalency to OPS if using renewable and low carbon fuels as per definitions in Renewable Energy Directive (EU) 2018/2001.
O	Port Generator (Mobile Energy Storage Unit) – Mobile energy storage unit	**PG-MESU**	Mobile energy storage unit, consisting of a mobile battery bank equipped with Inverter for power supply at required voltage and frequency by receiving ship.

			Mobile energy storage units can also be used for direct battery charging if DC-DC charging unit is used to charge onboard secondary batteries. Mobile units can be charged within port infrastructure and be mobilized with a variety of logistical combinations. Connection of the mobile battery bank should follow an acceptable connection geometry which allows for electrical safe interconnectivity and interoperability.
P	Port Generator (Mobile Power Unit - MPU) – Mobile generator-alternator unit	**PG-MPU**	Mobile energy storage unit, consisting of a mobile battery bank equipped with inverter for power supply at required voltage and frequency by receiving ship. Connection of the mobile battery bank should follow an acceptable connection geometry which allows for electrical safe interconnectivity and interoperability. Onshore Power Supply by MPUs should comply with all relevant and applicable aspects of IEC/IEEE 80005 series.

4.3 Onshore Power Supply (OPS)

Onshore power supply is the SSE type where the largest experience has been gained, remarkably with the increased development of high-voltage shore connection solutions in the Unites States, following the introduction of the CARB “at berth” regulation, and also with a large number of EU projects. It consists of a controlled interface infrastructure, connecting and conditioning the power between the utility grid, or distributed. Below some benefits and highlights from OPS are summarized.

Onshore Power Supply (OPS)

- Key technology to mitigate ship’s emissions at berth.
- Availability of OPS is increasing as part of ports’ sustainability initiatives
- Supply of high voltage electricity is a key enabler for OPS of higher power demanding ships
- Feasibility of OPS projects requires involvement from many stakeholders
- Architecture of OPS systems is increasingly automated to allow for efficient operation.

- More ports are today offering OPS services, allowing ships to reduce emissions at berth, with benefits for local air quality, reduction of GHG emissions and noise.
- Ships at berth have significantly different operating profiles, imposing different requirements for power supply.
- High voltage supply (>1kV AC) enables more efficient connection,
- Matching AC frequency 50/60Hz is still an important aspect to consider for transoceanic ships.
- Standardization achieved by complete IEC/IEEE 80005 series.
- IMO Interim Guidelines for Safe OPS operation has been finalized on 1Q 2020.

The following diagram illustrates the relevant elements of an OPS infrastructure and connection arangement, with identification of detailed elements. All elements presented with reference to IEC/IEEE 80005 standards.

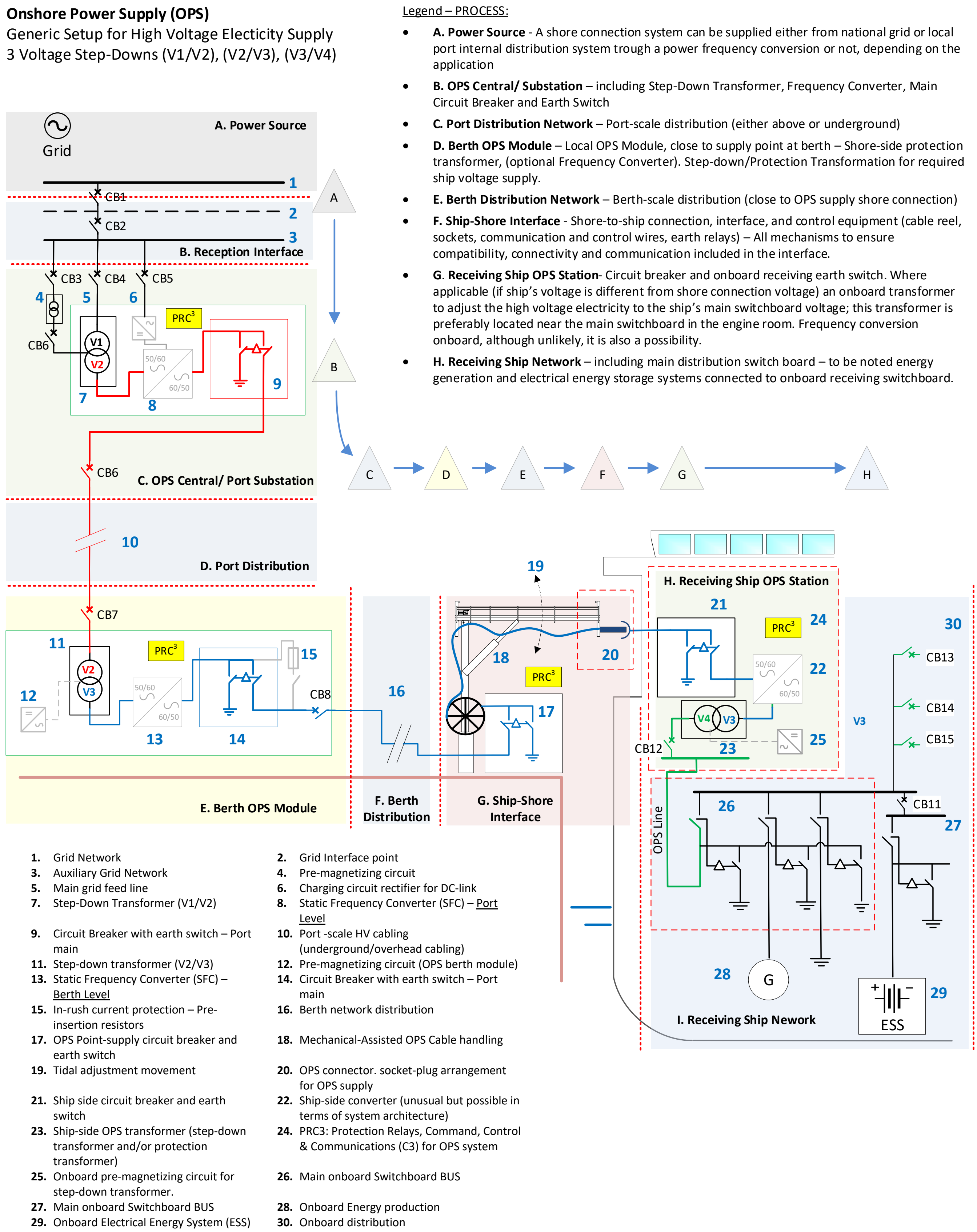


Figure 4.6 - OPS connection diagram – General architecture and functional elements.

Source: EMSA

4.3.1 High Voltage Shore Connection (HVSC)

High Voltage Shore Connection (HVSC) is the arrangement which can be considered more adequate to supply shore-power to ships with higher power demand requirements at berth. However, the use of HVSC requires that both shore and ship sides are prepared for such technical solution. On the shore side the supply should be done at voltage ratings of 6.6 kV or 11kV. Ships will have to be equipped with step-down transformers to adjust back the voltage to the onboard distribution grid.

The main advantages of the high-voltage connection to be considered by PAA are: 1) standardized connectivity, 2) the reduced number of OPS shore power cables (for the same power, with high voltages, the currents through the OPS cables are smaller, allowing for a reduced number of cables to be used); 3) less time in connection/disconnection; 4) safety in cable handling, connection and disconnection operation.

Figure 4.7 - HVSC with mobile CMS – High-voltage shore power supply to cruise ship – high power demand requirement.

Source: Siemens

Figure 4.8 - HV Shore Power cable reel onboard a containership.

Shore power cables are provided by containership for connection at equipped container terminal quays.

Source: Cavotec

Figure 4.9 – HV Shore Power solution from containership.

Source: CAVOTEC

Figure 4.10 – OPS connection to RO-Pax ship.

Fixed position for the CMS may be favoured by adequate knowledge.

Source: Port of Helsinki

4.3.1.1 Compatibility of voltage and frequency

When a vessel is powered by the shore power supply, the system voltage and frequency compatibility with the shore utility supply shall be ensured by provision of transformers or other relevant equipment to ensure compatibility.

Based on IEC/IEEE 80005-1:2019, the connections for selected ships with higher power demand should be made at a nominal voltage of 6.6 kV and/or 11 kV. The nominal voltage level onboard is normally 400/440 V AC. Some ships may also have 6.6 kV / 11.0 kV AC. A voltage transformer may be needed for transforming the voltage to be compatible with the ships' needs.

In terms of frequency, the largest number of ships engaged in worldwide trade use 60 Hz electricity. This is beneficial for visiting the US where 60 Hz electricity is used in the electrical grid. However, EU ports are equipped with electricity frequency of 50 Hz. The incompatibility on the power supply's frequency would have to be resolved by the installation of a frequency converter (on the shore side, as per standard IEC/IEEE 80005-1).

4.3.1.2 Power supply sufficiency and continuity

The shore power shall facilitate sufficient power supply for the normal at-berth operation. Further, the shore power shall facilitate power supply that is reliable and maintains the continuity.

4.3.1.3 Variation in voltage magnitude

The shore power's voltage and frequency should be stable. It should not cause malfunction of shipboard systems, e.g., ER/Cargo Control Room alarm and monitor system, gas detection, etc.

- The frequency shall not exceed the continuous tolerances ± 5% between no-load and nominal ratings
- For no-load conditions, the voltage at the supply point shall not exceed a voltage increase of 6% of nominal voltage
- For rated load conditions, the voltage at the supply point shall not exceed a voltage drop of -3.5% of nominal voltage

4.3.1.4 Voltage and frequency transients

The response of the voltage and frequency at the shore connection when subjected to an appropriate range of step changes in load shall be defined and documented for each high voltage shore supply installation. This should be ideally achieved through power quality monitoring devices (See SSE Guidance part 1) with the ability to record historic of transient events.

The maximum step change in load expected when connected to a high voltage shore supply shall be defined.

Based on the above, it should be verified that the voltage transients' limits of +20% and −15% and the frequency transients limits of ±10 % will not be exceeded.

4.3.1.5 Galvanic separation

The shore-side electrical system shall ensure that each connected ship is galvanically separated from other connected ships and consumers

4.3.1.6 Harmonic distortion

For no-load conditions, voltage harmonic distortion limits shall not exceed 3% for single harmonics and 5% for total harmonic distortion.

4.3.1.7 Electromagnetic compatibility

The shore power instrument should be compatible with (i.e., no interference is caused by) its electromagnetic environment and it should not emit levels of electromagnetic energy that cause electromagnetic interference in other devices in the vicinity.

Table 4.2 - OPS connection diagram.

Parameter	Reference(s)	**High Voltage Shore Connection (HVSC)**	**Low Voltage Shore** Connection (LVSC) (Refer
Voltage	IEC/IEEE 80005-1 IEC/IEEE DIS 80005-3 IACS Unified Requirements Electrical (Rev.1 Sept 2005)	**6.6 kV** **11 kV**	**400 V** **440 V** **690 V** **23 0V also possible for less demanding consumption <50 kW**
Voltage Tolerances		No-Load Conditions: **6% of nominal Voltage increase** Load Conditions: **3.5% max voltage drop**	No-Load Conditions: **6% of nominal Voltage increase** Load Conditions: **5% (3.5%)[1] max voltage drop**
Frequency	See section 3.9.1.1	50/60 Hz DC for Fast DC Charging systems	
Frequency Tolerances	IEC/IEEE 80005-1 IEC/IEEE DIS 80005-3 IACS Unified Requirements Electrical (Rev.1 Sept 2005)	Continuous tolerance: ±5%	
Transient Response		**dV** (voltage transient peak variation): -15% < dV < 20% (1.5sec) **df** (frequency transient variation): ±10% (5sec) Transient Response should be well known and documented for: 1. Shore side, for the voltage and frequency response, when subject to an appropriate range of different load step changes, 2. Ship side for the maximum step change in load expected (this can be an Air Conditioning compressor, electrical pump, crane or electrohydraulic group). The part of the system subjected to the largest voltage dip or peak in the event of the maximum step load being connected or disconnected shall be identified. Combining 1) and 2) it should be verified that the voltage transients limits of +20 % and −15 % and the frequency transients limits of ±10 % will not be exceeded.	
Harmonic Distortion		For no-load conditions, voltage harmonic distortion limits: < 3 % (single harmonics) < 5 % (for total harmonic distortion)	
Voltage variations for DC supply	IACS UR E5	Voltage tolerance (continuous) ±10% Voltage cyclic variation deviation 5% Voltage ripple (RMS over steady DC voltage): 10%	
Voltage variations for battery systems		Components connected to the battery during charging: +30%, -25% Components not connected to the battery during charging: +20%, -25% Note: Different voltage variations as determined by the charging/ discharging characteristics, including ripple voltage from the charging device, may be considered.	

In the next pages the different standardized ship types featured in IEC/IEEE 80005-1 are presented:

A. HVSC – RO-Pax (ref: IEC/IEEE 80005-1, Annex-B)
B. HVSC – Cruise ship (ref: IEC/IEEE 80005-1, Annex-C)
C. HVSC – Containership (ref: IEC/IEEE 80005-1, Annex-D)
D. HVSC – LNG Carrier (ref: IEC/IEEE 80005-1, Annex-E)
E. HVSC – Tanker (ref: IEC/IEEE 80005-1, Annex-F)

[1] IEC/IEEE DIS 80005-3 – mentions 3.5%, aligning the maximum voltage drop under loading conditions with the HVSC standard (IEC/IEEE 80005-1). Irrespective of the alignment between the standards, it is important to keep the voltage drop under the shore-power loading condition

Table 4.3 - HVSC – Ro-Pax.

HVSC – RO-Pax (ref: IEC/IEEE 80005-1, Annex-B)

Shore connection nominal voltage: 11 kV, accepted 6.6kV for regional waterborne transportation services

Shore connection earthing system: LRE with 335/200 Ohms NGR

Number of cables to feed the vessel: 1

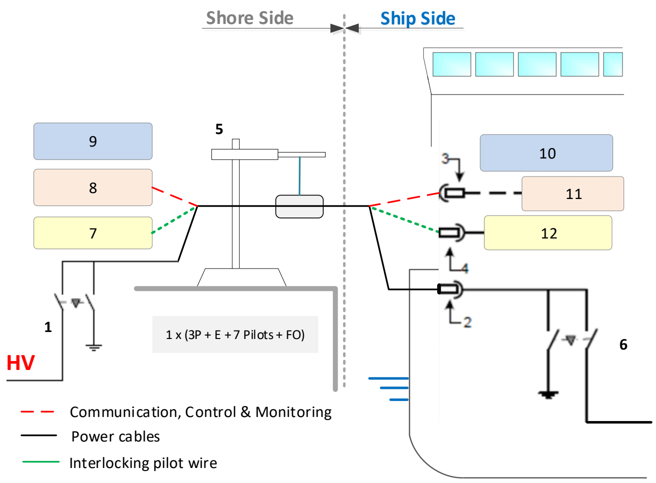
Location of the cable management system: berth

Most frequently used earthing system on ship: high-resistance earthing

Source: Stena AB

Source: Baleària

General system diagram



Source: IEC

Legend

1. Shore OPS Circuit-Breaker
2. Plug (shore-side) and socket-outlet (on-board)
3. Fibre optic communication for control and monitoring (integrated in power cable); socket-outlet (shore-side) and plug (on-board)
4. Pilot wires (integrated in plug and socket-outlet)
5. Cable management system, here shown as shore-side crane
6. Ship OPS Circuit-Breaker
7. Interlocks with pilot wire shore side
8. Control shore side
9. Protection relaying shore-side
10. Protection relaying ship-side
11. Control ship-side
12. Interlocks with pilot wire ship-side

Voltage/ Power rating	Ship ESD (minimum input)	Neutral Earthing resistor	Cables
11 kV AC and/or 6.6 kV AC Power rating: 6.5 MVA (see section 7)	No minimum input defined ESD function shall use the pilot contacts integrated in the single OPS cable.	Where a shore-side transformer is used, the star point shall be earthed through a neutral earthing resistor of 335 Ohms. Nominal voltage of 6.6 kV will require a 200-Ohms resistor.	• 1 cable

Safety Circuits	Shore ESD (minimum input)	Connector – Inlet standard
The control power voltage shall be less than 60 V DC or 25 V AC safety extra-low voltage type source as per IEC 60364-4-41 (refer to figure B.2 of IEC/IEEE 80005-1)	No minimum input defined in IEC/IEEE 80005-1 ESD function shall use the pilot contacts integrated in the single OPS cable.	• Connectors/ Inlet: IEC 62613-2:2016, Annex J (figure below) • Pilot contacts are part of the safety circuit • Data link (if provided) shall use Fibre Optic (IEC/IEEE80005-a - section 7.3.4, fig.5). • ESD functions shall be performed with pilot conductors (IEC 62613-1, IEC 62613-2:2016, IEC/IEEE80005-1 Annex A) • Short circuit withstand current: 16kA RMS 1 sec (max peak of 40kA (IEC 62613-1)

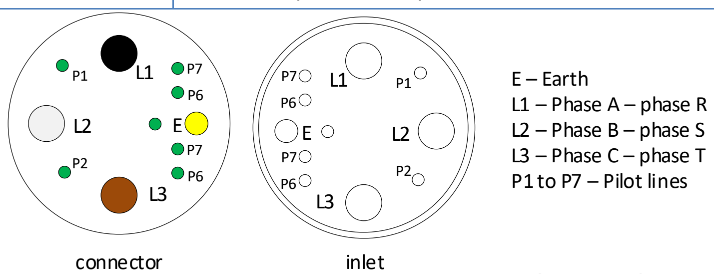
Compatibility Assessment before connection (ship-specific)

Assessment that the ship provides effective earthing

Equipotential Bonding

Not mandatory (see section 15)

Where applied, the requirements in IEC/IEEE80005-1, Annex B – section B.7.2.5 should be followed



Source: IEC

Table 4.4 –HVSC - Cruise ship.

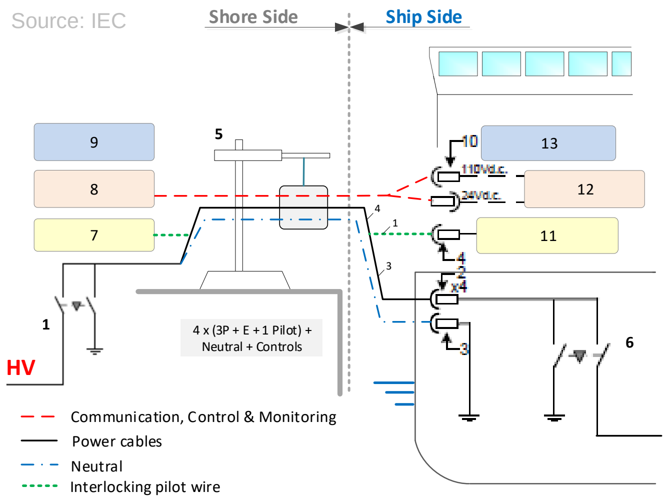
HVSC – Cruise ship (ref: IEC/IEEE 80005-1, Annex-C)

- Shore connection nominal voltage: 11kV and/or 6.6kV
- Shore connection earthing system: LRE with 540 Ohms NGR
- Number of cables to feed the vessel: 4 power cables, neutral distributed to ship
- Location of the cable management system: berth
- Most frequently used earthing system on ship: high-resistance earthing

Source: Holland America

Source: Royal Caribbean

General system diagram



Legend

1. Shore OPS Circuit-Breaker
2. Power ship connector (shore-side) and ship inlet (onboard), (four)
3. Neutral ship connector (shore-side) and ship inlet (onboard)
4. Pilot wires (integrated in connectors and inlets)
5. Cable management system, here shown as shore-side crane 13 Protection relaying onboard
6. Ship OPS Circuit-Breaker
7. Interlocks with pilot wire shore-side
8. Communication for control and monitoring shore-side
9. Protection relaying shore-side
10. Communication and control wires and connector (110 V DC and 24 V DC)
11. Interlocks with pilot wire on-board
12. Communication for control and monitoring on-board.
13. Protection relaying onboard

Voltage/ Power rating	Ship ESD (minimum input)	Neutral Earthing resistor	Cables
11 kV AC and/or 6,6 kV AC Power rating: 16MVA (20MVA recommended) (see section 7)	1.cable overtension alarm (if any) 2.socket limit switch	Neutral earthing resistor of 540 ohms and connected only to the ship side (see Figure C.2) (refer to figure C.2 of IEC/IEEE 80005-1).	• 4 power cables (rated 500A) • Neutral (rated 250A) • Control

Safety Circuits	Shore ESD (minimum input)	Connector – Inlet standard
• 110VDC Safety and Control circuit • 24VDC Safety and Control circuit • Ground Check circuit • SCADA circuit (refer to figure C.3 of IEC/IEEE 80005-1)	1.electrical protection tripping condition, 2.ground check trip, 3.ground monitoring trip, 4.shutdown order from PLC, 5.cable over tension alarm (if any).	• Connectors/ Inlet: IEC 62613-2:2016, Annex G • Neutral: IEC 62613-2:2016, Annex H • (4) power 3-phase connectors, each rated 500 A and one neutral single pole connector rated 250 A • Diagram of the connector plug, and inlet presented below (ref: IEC/IEEE80005-1, Annex-C + IEC 62613-2:2016, Annex G)

Compatibility Assessment before connection (ship-specific)

Assessment that the ship provides effective earthing

Equipotential Bonding Monitoring

Mandatory. Continuous monitoring of the electrical bonding is required (Annex-C section 4.2.2)

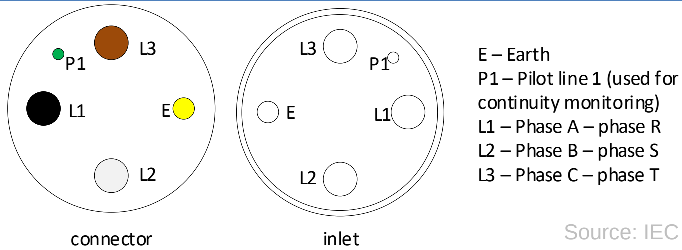


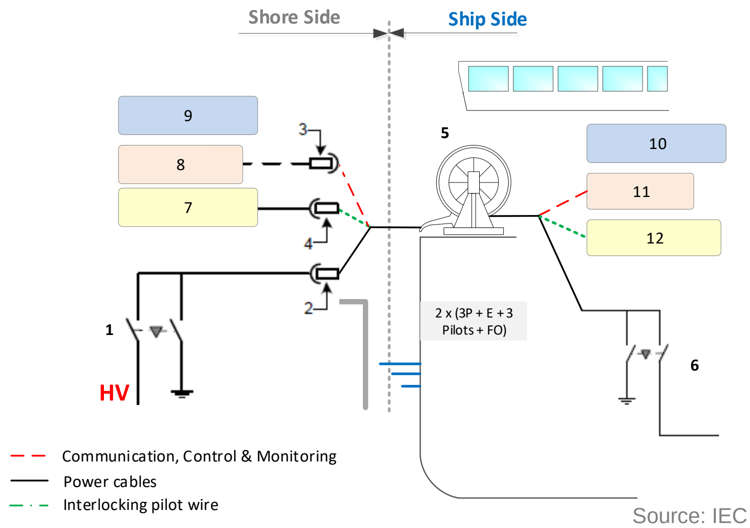
Table 4.5 – HVSC – Containership.

HVSC – Containership (ref: IEC/IEEE 80005-1, Annex-D)

- Shore connection nominal voltage: 6.6kV
- Shore connection earthing system: LRE with 200 Ohms NGR
- Number of cables to feed the vessel: 2
- Location of the cable management system: on ship
- Most frequently used earthing system on ship: high-resistance earthing

Source: A.P. Moller - Maersk

General system diagram



Source: IEC

Legend

1. Shore OPS Circuit-Breaker
2. Socket-outlet (shore-side) and plug (onboard)
3. Fibre optic communication for control and monitoring 8 Control shore-side (integrated in power cable); plug (shore-side) and socket-outlet (onboard)
4. Pilot wires (integrated in connectors and inlets)
5. Cable Management System (cable reel onboard)
6. Ship OPS Circuit-Breaker
7. Interlocks with pilot wires shore-side
8. Control shore-side
9. Protection relaying shore-side
10. Protection relaying onboard
11. Control onboard
12. Interlocks with pilot wires onboard

Voltage/ Power rating	Ship ESD (minimum input)	Neutral Earthing resistor	Cables
6,6 kV AC Power rating: 7.5MVA (see section 7)	. No minimum input defined ESD function shall use the pilot contacts integrated in the single OPS cable.	The shore side transformer star point shall be earthed through a neutral earthing resistor of 200 ohms.	• 2 power cables (in parallel)

Safety Circuits	Shore ESD (minimum input)	Connector – Inlet standard
• Safety Circuit is supported by Pilot contacts (IEC/IEEE80005-1, Annex D – Figure D.2). • The voltage used in the pilot circuit shall be less than 60 V DC or 25 V AC	No minimum input defined in IEC/IEEE 80005-1 ESD function shall use the pilot contacts integrated in the single OPS cable.	• Connectors/ Inlet: IEC 62613-2:2016, Annex II • Pilot contacts are part of the safety circuit • Data link (if provided) shall use Fibre Optic (IEC/IEEE80005-a - section 7.3.4, fig.5). • ESD functions shall be performed with pilot conductors (see IEC 62613-1, IEC 62613-2:2016, IEC/IEEE80005-1 Annex A) • Short circuit withstand current: 16kA RMS 1 sec (max peak of 40kA (IEC 62613-1)

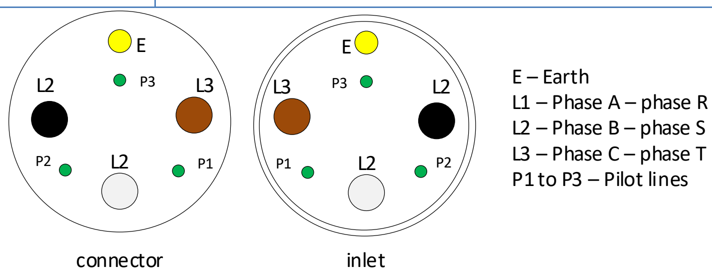
Compatibility Assessment before connection (ship-specific)

Cable length provided by ship must be sufficient (sufficient cable length to reach the shore-side supply point level +10m) (section D.4.3)

Equipotential Bonding Monitoring

Not mandatory.

Where applied, the requirements in IEC/IEEE80005-1, Annex D – section D.7.2.5 should be followed



Source: IEC

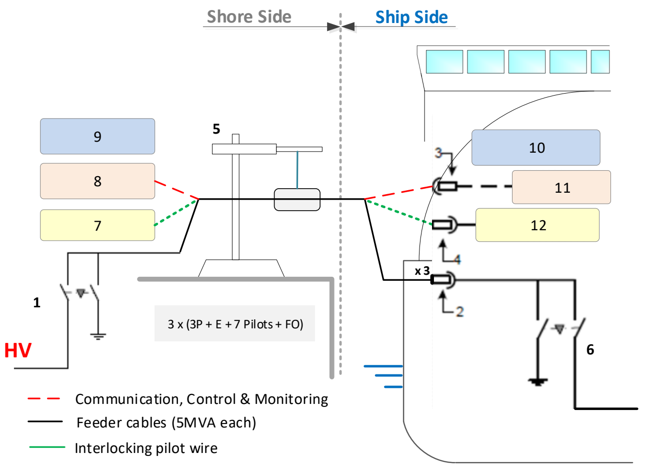
Table 4.6 – HVSC - LNG carrier.

HVSC – LNG Carrier (ref: IEC/IEEE 80005-1, Annex-E)

- Shore connection nominal voltage: 6.6kV
- Shore connection earthing system: unearthed
- Number of cables to feed the vessel: 3
- Location of the cable management system: berth
- Most frequently used earthing system on ship: unearthed or high-resistance earthing

Source: MOL LNG Transport

General system diagram



Source: IEC

Legend

1. Shore OPS Circuit-Breaker
2. Plug (shore-side) and socket-outlet (onboard)
3. Fibre-optic communication for control and monitoring (integrated in power cable); socket-outlet (shore-side) and plug (onboard)
4. Pilot wires (integrated in plug and socket-outlet)
5. Cable Management System (shown as crane on shore-side)
6. Ship OPS Circuit-Breaker
7. Interlocks with pilot wires shore-side
8. Control shore-side
9. Protection relaying shore-side
10. Protection relaying onboard
11. Control onboard
12. Interlocks with pilot wires onboard

Voltage/ Power rating	Ship ESD (minimum input)	Neutral Earthing resistor	Cables
6,6 kV AC Power rating: 10.8 MVA (see section 7)	ESD1 (ship moves past the warning range) - initiate automatic starting, synchronization and connection of the ship's main source of power followed by isolation and earthing of the shore power connection(s) both onshore and onboard ESD2 (ship moves past the maximum range of movement of the ship.) – trigger an emergency stop and earthing of the shore's power connection(s) both ashore and onboard.	Neutral point of the shore OPS transformer unearthed where the LNGC connected to the system is designed with an insulated or high-resistance earthed power system for compliance with the requirements of SOLAS, Ch II-1/D, Regulation 45.4.3, and IEC 60092-502.	• 3 cables (each with 3 Phases + Earth + 7 Pilots and (optional) Fibre Optic))

Safety Circuits

Connector – Inlet standard

- Connectors/ Inlet: IEC 62613-2:2016, Annex J (figure below)
- Data link (if provided) shall use Fibre Optic (IEC/IEEE80005-a - section 7.3.4, fig.5).
- Diagram of the connector plug, and inlet presented below (ref: IEC/IEEE80005-1, Annex-C + IEC 62613-2:2016, Annex G)
- Short-circuit contribution level from the HV shore limited by the shore-sided system to 25 kA RMS.
- The short-circuit withstand current is 25 kA for 1 s and the maximum peak short-circuit current is 63 kA.

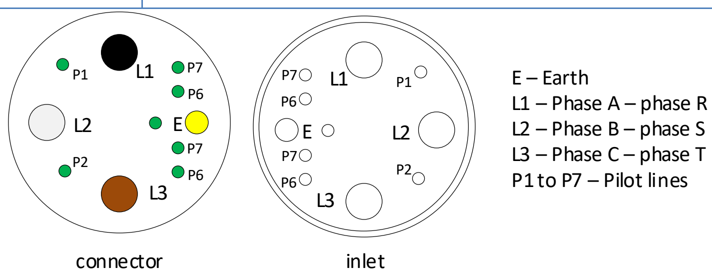
Compatibility Assessment before connection (ship-specific)

a) compatibility of shutdown system and disconnection equipment

b) availability of OPS power supply for cargo operations

Equipotential Bonding Monitoring

Not mandatory (see section 15) - Where applied, the requirements in IEC/IEEE80005-1, Annex D – section D.7.2.5 should be followed

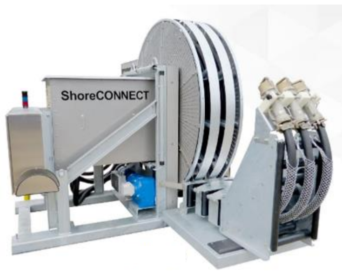


Source: IEC

Table 4.7 – HVSC – Tanker.

HVSC – Tanker (ref: IEC/IEEE 80005-1, Annex-F)

- Shore connection nominal voltage: 6.6kV
- Shore connection earthing system: unearthed
- Number of cables to feed the vessel: 3
- Location of the cable management system: berth
- Most frequently used earthing system on ship: unearthed or high-resistance earthing

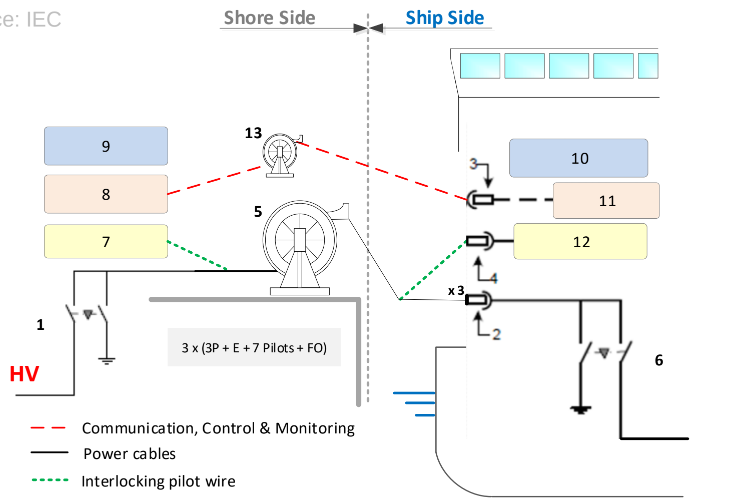


Source: WABTEC

Source: EURONAV

General system diagram

Source: IEC



Legend

1. Shore OPS Circuit-Breaker
2. Plug (shore-side) and socket-outlet (onboard)
3. Control and monitoring (separate cable management system with copper wires) - plug (shore-side) and socket-outlet (onboard)
4. Pilot wires (integrated in plug and socket-outlet)
5. Cable Management System (shown as crane on shore-side)
6. Ship OPS Circuit-Breaker
7. Interlocks with pilot wires shore-side
8. Control shore-side
9. Protection relaying shore-side
10. Protection relaying onboard
11. Control onboard
12. Interlocks with pilot wires onboard
13. Control cable management system

Voltage/ Power rating	Ship ESD (minimum input)	Neutral Earthing resistor	Cables
6,6 kV AC Power rating: 10.8 MVA (see section 7)	ESD strategy should be similar to the LNG presented with 2 Stage ESD. This is not detailed in IEC/IEEE80005-1 Annex-F. Primarily Section 4.9 of the standard should be observed. ESD1+ESD2 approach may be specially considered and always subjected to Compatibility Assessment.	Other earthing arrangements may be allowed because of the need to limit earth fault current in hazardous areas.	• 3 parallel cables (each with 3 Phases + Earth + 7 Pilots) Each power cable should be rated to 3.6 MVAc

Safety Circuits

No Safety Circuits are described in IEC/IEEE80005-1 Annex-F.

Pilot guides should be part of the safety circuit which should be based on continuity verification.

Compatibility with earthing strategy should be ensured

Connector – Inlet standard

- Connectors/ Inlet: IEC 62613-2:2016, Annex II (figure below)
- Certified intrinsically safe or fibre-optic systems can be a suitable means of communication.
- The prospective short-circuit contribution level from the HV shore distribution system should be limited by the shore-sided system to 16 kA RMS.

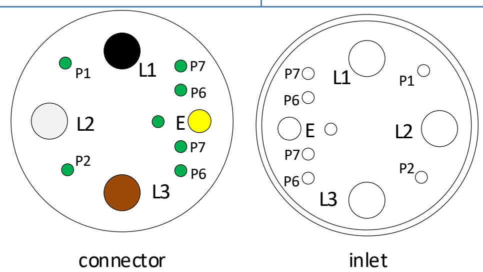
Compatibility Assessment before connection (ship-specific)

Special requirements apply to the distribution systems of tankers (see IEC 60092-502).

Equipotential Bonding Monitoring

Not mandatory

Should be considered as good/ precautionary practice for tankers.



E – Earth
L1 – Phase A – phase R
L2 – Phase B – phase S
L3 – Phase C – phase T
P1 to P7 – Pilot lines

Source: IEC

In addition, and support to table 4.6, the following elements are further detailed as a result of best experience from ports already with experience with OPS for tankers:

1. HVSC for Tankers means two significant differences / challenges compared to other SSE/OPS installations:
   - The HVSC system shall be able to connect to any tanker berthing at jetty - This is an aspect requiring more flexibility regarding cable management because; 1) the location of the on board connection point is ship-specific, 2) variation in vessel position along the jetty, depending on manifold combination in use, 3) level variation from different loading conditions during the call. There is a strong need for adaptation to specific ships.
   - ATEX - Both quay and vessel (tank deck) are classified as hazardous areas (Zone 1*) during loading /discharging operation. This increases the demand level on installations and procedures for handling of HVSC–equipment.
2. Equipotential bonding cable
   - HVSC standards (IEC/ISO 80005-1) demands equipotential bonding between shore and ship. Once the shore-side HV-cable is connected to the ship, connection/intake is secured. The HV-cable is always connected to shore-side earth.
   - Previous editions of ISGOTT[2] required use of bonding cables to avoid arc when connecting/disconnecting loading-arms/manifolds. This is now replaced by isolation flanges to avoid electrical contact. The equipotential bonding cable (EBC) introduced for HVSC above, does not replace the need for isolation flanges
3. Cable and power demand
   - Power rating 10,8 MVA, equip HVSC system based of use, calling vessel types, types of operation to avoid rising cost related to over dimension system of power demand. Do not require more cables then necessary according to ships power demand. In general, products tankers need max power during discharging >3 MVA which are possible to supply by one cable (3.6 MVA).
   - When using crane, the lifting point must be connected to earth. During lift operation the cable plug will be protected by a weather-proof end cap and the complete plug will be covered with anti-shock protection, to avoid damage during handling.
4. Compartment at shore and ship
   - CMS on shore side, place CMS close to shore centreline as possible, per today, HV-cable reels are not available for ATEX purpose. It is therefore also here necessary to use a CMS enclosure with overpressure (Explosion proof according to IEC60079-2) for the cable reel compartment of the container.
   - HV-connector components are currently not available in ATEX classification. It is therefore necessary to use an enclosure with overpressure (Explosion proof according to IEC60079-2) for the onboard connection point.
5. Shore side and Ship side safety functions
   - When HVSC Power On is established, it is interlocked by Safety Circuits. It is only possible to establish shore power electrical power feed if all conditions are fulfilled. There are two Safety Circuits, shore / ship. Respective circuit contain all the conditions that must apply for safe HVSC. Should one condition disappear, the Safety Circuit will trip, and HV-switch will cut the power supply immediately.
   - Shore-side safety circuit include e.g. HV switch status, earth coupler status, HVSC plug connected (pilot), overpressure above limit, doors closed, no smoke, no explosive gas inside EX-area, etc.
   - Ship-side safety circuit include e.g. HVSC plug connected (pilot), cable fix point clamped, cable tension inactive, overpressure above limit, doors closed, etc.

[2] International Safety Guide for Oil Tankers and Terminals (ISGOTT 6) - 6th Edition - https://www.ocimf.org/publications/books/international-safety-guide-for-tankers-and-terminals-1

4.3.2 Low Voltage Shore Connection (LVSC)

Low Voltage Shore Connection (LVSC) is another option for OPS which is suitable/applicable to supply electrical power to ships of less power demand or, in addition, to ships which are not equipped with onboard step-down transformers.

The LVSC international standard is currently under revision, but reference can be made to the existing standard (IEC / IEEE PAS 80005-3:2014, Low voltage shore connection). This is expected to be replaced by a new standard in due course.

The diagram below shows the different elements of a LVSC OPS solution.

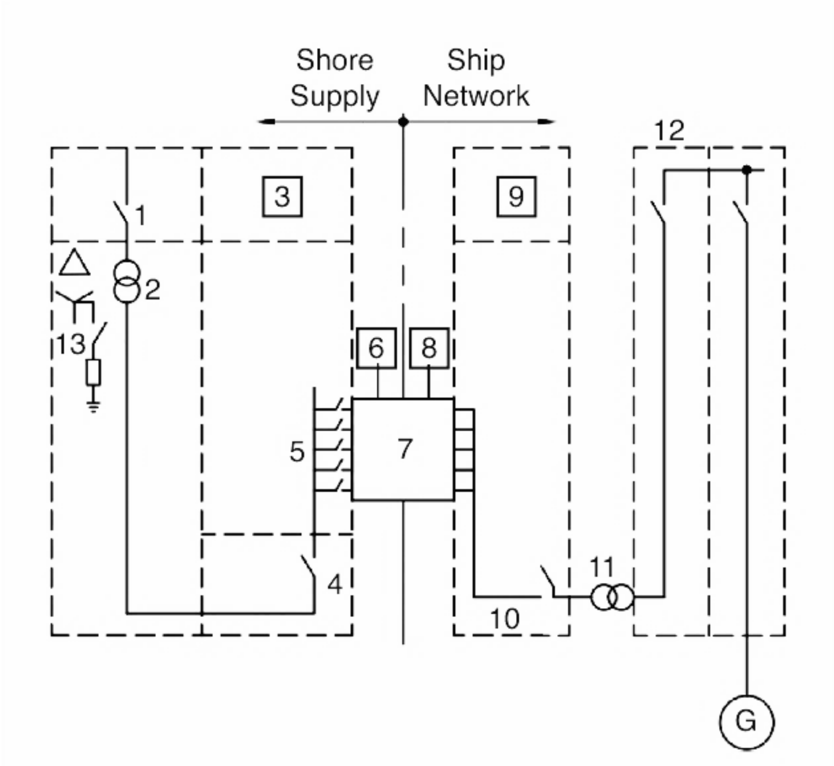


Figure 4.11 – Low Voltage Shore Connection – LVSC block diagram.

Legend for Figure 4.11: LVSC block diagram: the 1) primary breaker, 2) substation transformer, 3) LV switchgear, 4) main breaker, 5) feeder breakers, 6) feeder cables to power receptacles, 7) plug and receptacle assemblies, 8) plug with a flexible cable, 9) ship onboard shore power panel, 10) ship-side circuit breaker, 11) optional ship onboard transformer, 12) synchronizing breaker, and 13) neutral resistor disconnect switch. G) grounding.

Source: IEC

Low Voltage Shore Connection OPS have very specific challenges that should be considered by PAA in their development plans:

- Need to consider the **number of cables** for specific ship connections – Can go up to 5 (five) cables in case of 400 V connections to supplies of 1 MVA power demand.
- **Coordination between LV feeder Circuit Breakers (CB)** – the opening of one CB will lead to the overload on the other CBs. There may be a need to consider selectivity in adequate design to ensure reliability of LVSC systems.
- **Safety** – With a higher number of LVSC feeder cables it is important to consider the difficulties associated to handling of the cables, increasing potential probabilities for accidents.
- **Operation** – Higher “connection/disconnection” times, accounting for the number of cables to operate.

Table 4.8 - Low Voltage Shore Connection - Number of Connections as a function of power demand and voltage.

Power demand kVA	Voltage (V)					
	400		440		690	
	Nr Connections	I_max/cable (A)	Nr Connections	I_max/cable (A)	Nr Connections	I_max/cable (A)
Up to 250	**2**	180	**1**	328	**1**	209
251 – 500	**3**	241	**2**	328	**2**	209
501 – 750	**4**	271	**3**	328	**2**	314
751 - 1000	**5**	289	**4**	328	**3**	279

Low Voltage Shore Connection SSE options are presented in Figure 4.12. It can be noted the relevance of the shore-side step-down transformer which is required to match the HV shore side supply (when available) to the supply of electrical power to ships at berth.

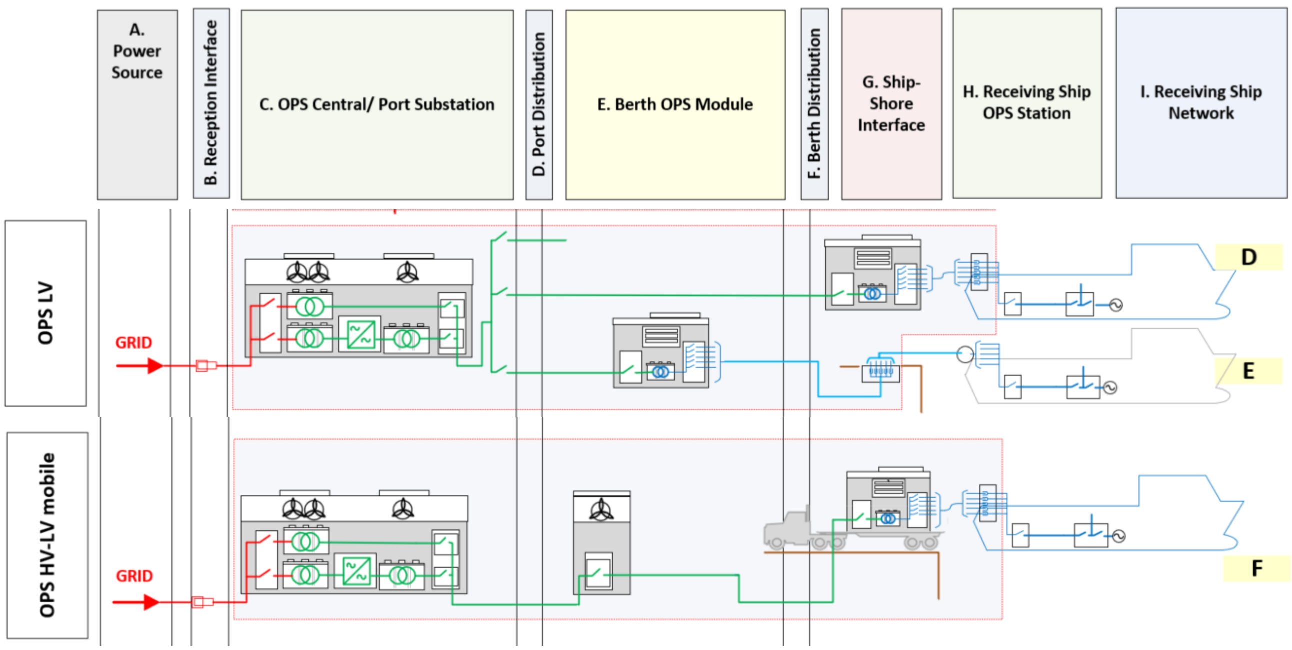


Figure 4.12 - Low Voltage Shore Connection – SSE arrangements possible for LVSC (legend in figure 4.4).

Source: EMSA

In the next pages the different standardized ship types featured in IEC/IEEE 80005-3 are presented:

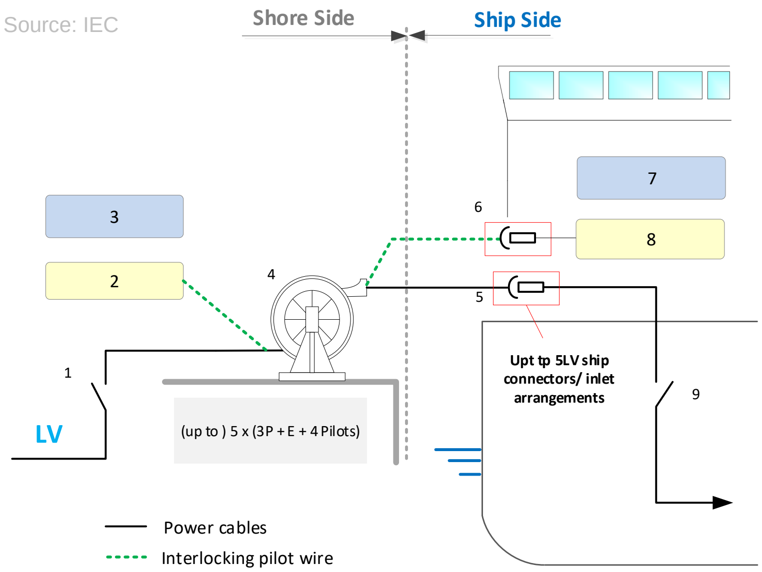
A. LVSC – OSV, Service and Working Vessels (ref: IEC/IEEE 80005-3, Annex-B)
B. LVSC – OSV, Service and Working Vessels (ref: IEC/IEEE 80005-3, Annex-C)
C. LVSC – Tankers (ref: IEC/IEEE 80005-3, Annex-D)

Table 4.9 – OSV - Service Vessels.

LVSC – OSV, Service and Working Vessels (ref: IEC/IEEE 80005-3, Annex-B)

- Shore connection nominal voltage: 400/440/690V
- Shore connection earthing system: LRE with 25 Ohms NGR
- Number of cables to feed the vessel: up to 5 cables
- Location of the cable management system: on shore

General system diagram



Legend

1. Shore side main or/and feeders circuit-breakers.
2. Interlocks with pilot wires shore side
3. Shore side protection relaying
4. Cable handling system, here shown as on shore cable reel
5. LV-plug
6. Pilot wires (integrated in Plug and Socket
7. Ship protection relaying
8. Interlocks with pilot wire ship side
9. Onboard OPS circuit breaker

Voltage/ Power rating	Ship ESD (minimum input)	Neutral Earthing resistor	Cables
400/440/690V AC Power rating: < 1 MVA (see section 7)	ESD facilities should be activated in case of occurrence of any of the events listed in IEC/IEEE80005-3, section 4.9.	Where applicable, shore-side transformer star point shall be earthed through a neutral earthing resistor rated 25 ohms	Up to 5 cables (rated 690V, 50/60Hz/ 350A)

Safety Circuits

Safety Loop circuit to be provided in accordance with IEC/IEEE80005-3, section 7.3.1.

Pilot guides should be part of the safety circuit which should be based on continuity verification.

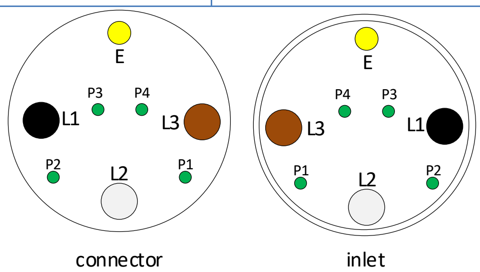
Connector – Inlet standard

- Connectors/ Inlet: IEC 60309-5 (figure below)
- Maximum short-circuit current 16 kA / 1 s and a maximum peak short-circuit current of 40 kA.

Compatibility Assessment before connection (ship-specific)

Equipotential Bonding

An equipotential bonding between the ship's hull and shore earthing electrode shall be established by the earth contacts of the plug, socket-outlet, ship connector and ship inlet.



E – Earth
L1 – Phase A – phase R
L2 – Phase B – phase S
L3 – Phase C – phase T
P1 to P4 – Pilot lines

Source: IEC

Table 4.10 – LVSC - Containerships

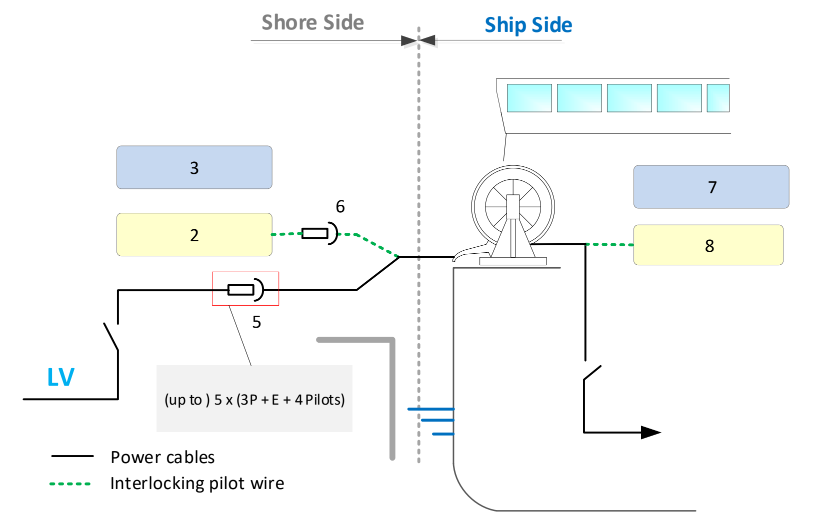
LVSC - Containerships (ref: IEC/IEEE 80005-3, Annex-C)

- Shore connection nominal voltage: 400/440/690V
- Shore connection earthing system: LRE with 25 Ohms NGR
- Number of cables to feed the vessel: up to 5 cables
- Location of the cable management system: on ship

Source: CAVOTEC

Source: Juergen Braker, FleetMon

General system diagram



Source: IEC

Legend

1. Shore side main or/and feeders circuit-breakers.
2. Interlocks with pilot wires shore side
3. Shore side protection relaying
4. Cable handling system, here shown as on shore cable reel
5. LV-plug
6. Pilot wires (integrated in Plug and Socket
7. Ship protection relaying
8. Interlocks with pilot wire ship side
9. Onboard OPS circuit breaker

NOTE: The location of LV cabling reels on the ship side, especially for higher power demands may be difficult to achieve due to space arrangement limitations. This is however the IEC/IEEE80005-3 standard annex for containerships to be followed.

Voltage/ Power rating	Ship ESD (minimum input)	Neutral Earthing resistor	Cables
400/440/690V AC Power rating: < 1 MVA (see section 7)	ESD facilities should be activated in case of occurrence of any of the events listed in IEC/IEEE80005-3, section 4.9.	Where applicable, shore-side transformer star point shall be earthed through a neutral earthing resistor rated 25 ohms	Up to 5 cables (rated 690V, 50/60Hz/ 350A)

Safety Circuits

Safety Loop circuit to be provided in accordance with IEC/IEEE80005-3, section 7.3.1.

Pilot guides should be part of the safety circuit which should be based on continuity verification.

Connector – Inlet standard

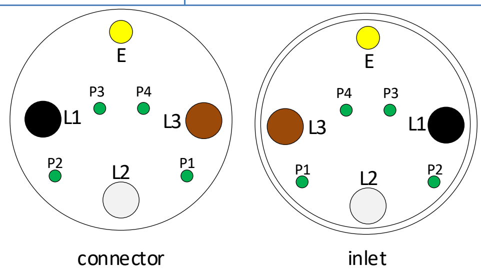
- Connectors/ Inlet: IEC 60309-5 (figure below)
- Maximum short-circuit current 16 kA / 1 s and a maximum peak short-circuit current of 40 kA.

Compatibility Assessment before connection (ship-specific)

Location of the CMS onboard may be subject to special consideration

Equipotential Bonding

An equipotential bonding between the ship's hull and shore earthing electrode shall be established by the earth contacts of the plug, socket-outlet, ship connector and ship inlet.



E – Earth
L1 – Phase A – phase R
L2 – Phase B – phase S
L3 – Phase C – phase T
P1 to P4 – Pilot lines

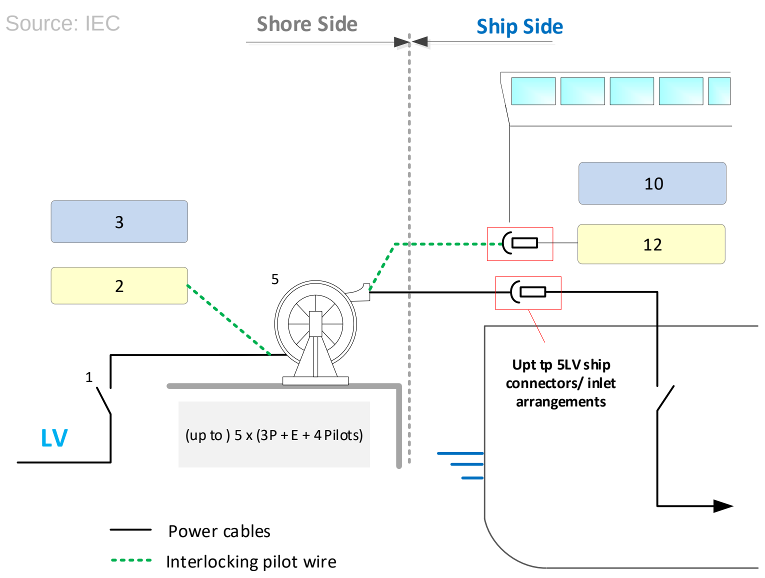
Source: IEC

Table 4.11 – LVSC – Tankers.

LVSC – Tankers (ref: IEC/IEEE 80005-3, Annex-D)

- Shore connection nominal voltage: 400/440/690V – 60Hz
- Shore connection earthing system: LRE with 25 Ohms NGR
- Number of cables to feed the vessel: up to 5 cables
- Location of the cable management system: on shore

General system diagram



Legend

1. Shore side main or/and feeders circuit-breakers.
2. Interlocks with pilot wires shore side
3. Shore side protection relaying
4. Cable handling system, here shown as on shore cable reel
5. LV-plug
6. Pilot wires (integrated in Plug and Socket
7. Ship protection relaying
8. Interlocks with pilot wire ship side
9. Onboard OPS circuit breaker

Voltage/ Power rating	Ship ESD (minimum input)	Neutral Earthing resistor	Cables
400/440/690V AC Power rating: < 1 MVA (see section 7)	ESD facilities should be activated in case of occurrence of any of the events listed in IEC/IEEE80005-3, section 4.9. Intrinsically safe (IS) barriers shall be provided on ship and on the shore for the safety 1291 circuits. The safety circuit shall be designed according to IEC 60079-11.	Shall be used IT system, so neutral earthing resistor shall be disconnected or may be omitted. Special cares should be taken during the design and operations phases related to IT systems 1302 (see IEC 60364).	Up to 5 cables (rated 690V, 50/60Hz/ 350A)

Safety Circuits

Safety Loop circuit to be provided in accordance with IEC/IEEE80005-3, section 7.3.1.

Pilot guides should be part of the safety circuit which should be based on continuity verification.

Connector – Inlet standard

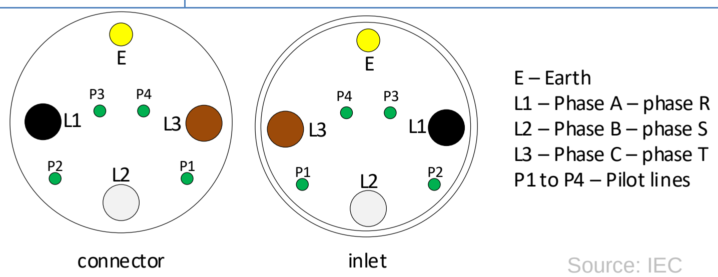
- Connectors/ Inlet: IEC 60309-5 (figure below)
- Maximum short-circuit current 16 kA / 1 s and a maximum peak short-circuit current of 40 kA.

Compatibility Assessment before connection (ship-specific)

Special requirements apply to the distribution systems of tankers (see IEC 60092-502).

Equipotential Bonding

An equipotential bonding between the ship's hull and shore earthing electrode shall be established by the earth contacts of the plug, socket-outlet, ship connector and ship inlet.



Source: IEC

4.3.3 Configuration and Optimization of OPS systems

The selection of the adequate OPS arrangement is dependent on 1) port/terminal-specific elements and 2) operating profile of ships at berth. The present section presents elements that PAA should take into consideration when assessing possible architectures for SSE OPS installations. Number and power rating for transformers and frequency conversion units, layout of the distribution network, reliability of the OPS system, amongst other aspects, are important factors to take into consideration in the selection of the specific arrangement/configuration/layout to follow.

The present section highlights possible configurations for SSE OPS systems.[3]

Configuration of OPS system – Option I

Figure 4.13 shows a high-power converter that can supply power to several quays at the same time. This is also called in some literature “Centralised OPS supply”.

The elements of the SSE/OPS system are located/centralized in the main OPS central/port substation which, due to its large dimensions, may be located away from quay, at a convenient location within the port. The substation will typically include: 1) frequency converter, with 2) associated “step-down” and “step-up” transformers, and 3) all necessary switchgear and main shore-side connection switchboard.

In Figure 4.13 it is possible to see that only one frequency converter is centralising the shore power supply which is provided to the ships by 2 distinct separated circuits. This configuration allows ships of different frequencies to be supplied at any berthing position.

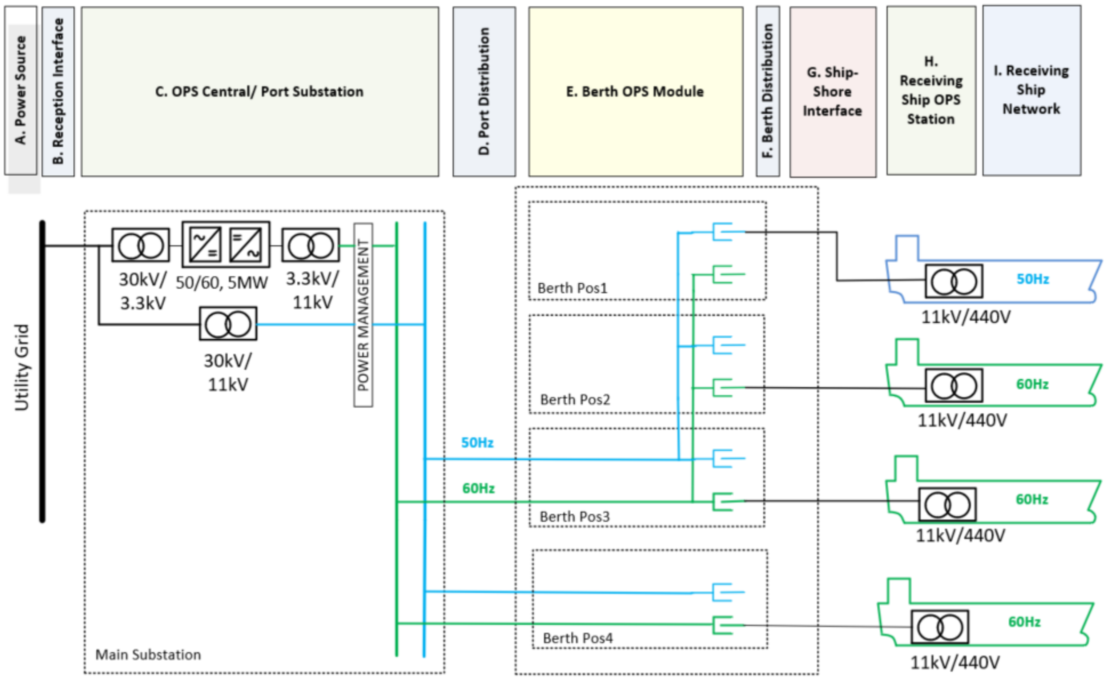


Figure 4.13 - Option 1 – high power frequency converter – Centralised OPS supply. Two AC BUS – 50 Hz or 60 Hz.

Source: EMSA

Frequency conversion supplies voltage transformers, which are located in the main distribution station. The power of the frequency inverter and associated transformers, depending on the installation, can go up to 10 MW (in Figure 4.13 the power indicating 5 MW). This level of power concentrated in one supply unit can however represent a challenge in terms of reliability of the whole system. Should any problem be induced in the OPS supply grid by any of the receiving ships, the whole supply may be affected and driven to blackout.

[3] Tarnapowicz, Dariusz, Analysis Of The Topology of „Shore To Ship” Systems – Power Electronic Connection Of Ships With Land, New Trends in Production Engineering, 2018 Volume 1 Issue 1

The reliance on one frequency converter and supply power-conditioning unit, despite being the simplest approach, and potentially more attractive from a capital investment perspective, may be one with great implications in terms of reliability. It may not be possible in all situations to guarantee uninterrupted operation of the system which may represent a serious limitation to the safety and operation of ships at berth. In addition, because of technological limitations of solid-state technology for higher power, the frequency converter is usually based on IGCT – this may have a detrimental effect on the quality of generated voltage flows.

Configuration of OPS system – Option II

The topology of Option II is presented in Figure 4.14, with the introduction of multiple lower power frequency conversion (in the presented example of 1 MW). Frequency converters and matching transformers are located in the main distribution station. In the first and second topology, connecting cables are distributed independently. As opposed to Option I, this approach is often referred to as "Decentralised OPS supply".

Option II allows the use of the frequency converters in parallel operation (assisted by a Power Management unit).

The main advantage of Option II is the ability to ensure an independent operation of systems for frequency conversion which significantly increases the reliability of the STS system. In this way the challenges presented by Option I are not present.

The main disadvantage of this solution, apart from possible cost, is the larger surface of the main station necessary for installation of more converters and transformers than in when compared to Option I.

However, there is the possibility for modular implementation of Option II with the use of containerised modules that are equipped with full power conditioning units (converter and matching transformers). This would allow the OPS infrastructure to be future proof, with the possibility to further grow and meet increasing demand from ships. Expansion of the OPS system with additional modules (converters) would in this way be a possibility, connection more units to the Power Management system. Modular concept enables the construction of converters of any power ranging from several hundred kVA to over 10 MVA.

Due to the parallel modular layout for the power conditioning units, it is possible to ensure the uninterrupted operation even with inoperative modules with slightly reduced parameters, thus ensuring redundancy and mitigating the risk of blackout in receiving ships.

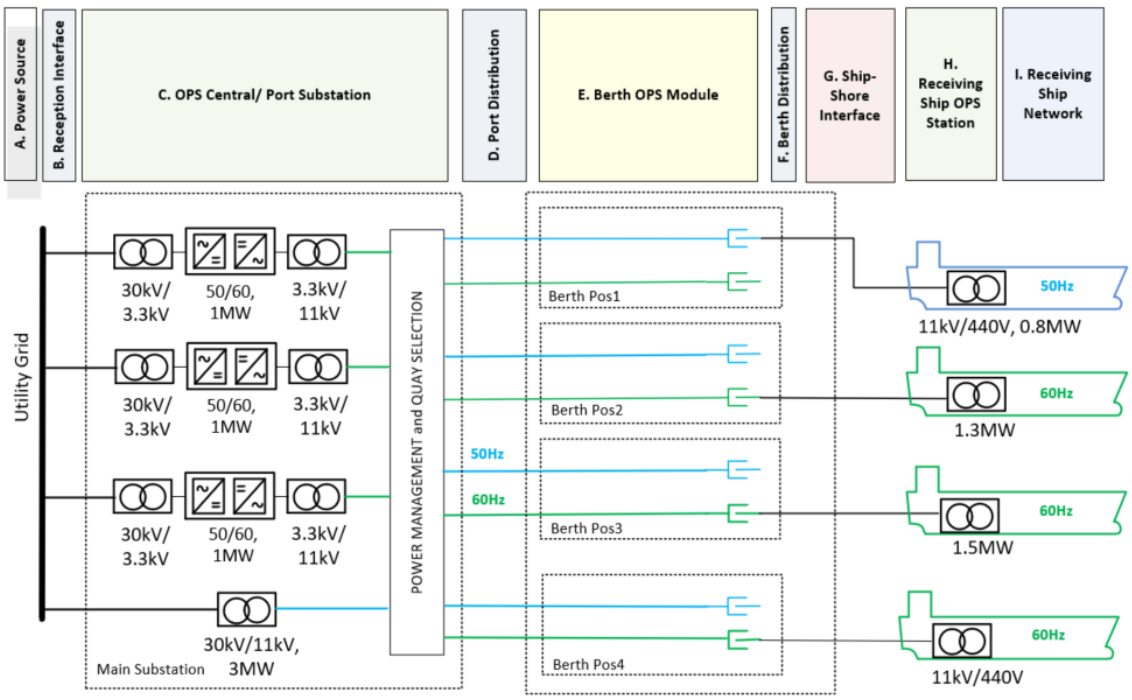


Figure 4.14 - Option II – a few converters of lower power. Two AC BUS - 50 Hz or 60 Hz.

Source: EMSA

Advanced redundancy in Option II allows:

- Continuous operation of the system with partially reduced power in case of failure of a single module
- The ability to build a system with a number of n+1 modules, resulting in further increase in the reliability and availability of power
- Flexible planning of repair or replacement of a single module during operation

Moreover, in accordance with the information from different manufacturers, it is possible, in Option II configuration, to explore the system in overload. From: 120% 10 min; 150% 30 sec.; 175% 2 sec. Higher overloads can be achieved by adding more modules.

A great advantage of Option II is the possibility of the synchronization of the ship power grid with the land network using control of dedicated frequency converters, which is not possible in Option I.

In Option II, it is also possible to save the number of connecting cables to the different quay locations by the installation of the frequency selector (Figure 4.15).

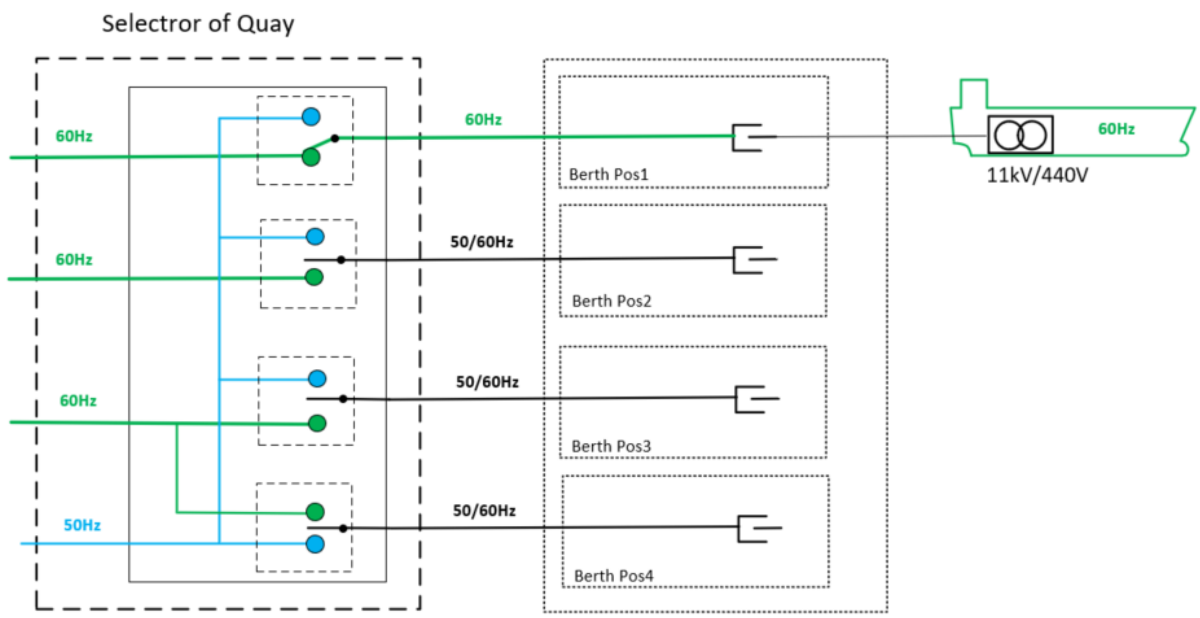


Figure 4.15 - Option II – Application of a frequency selector – saving connecting cables.

Source: EMSA

Configuration of OPS system – Option III

Option III, as presented in Figure 4.16, introduces an alternative approach, with the adoption of a DC transmission grid.

The main advantage of this layout is the ability to transfer energy between systems with different frequencies. In the main switchboard, AC voltage is rectified to DC voltage and in this form, it is transferred to local inverters, distributed in accordance with port-specific layout, where it is then changed back to AC voltage.

Advantages from the transfer of DC power are well known and can be briefly listed:

- Transfer losses are reduced by 33 percent
- Transfer power is independent of distance
- Transmission line does not require reactive power compensation
- HVDC systems can combine asynchronously operating power systems
- HVDC systems enable quick control of volumes and directions of power flow

One of the disadvantages of the topology shown in Figure 4.16 is a decrease in the reliability of the systems by suing one AC/DC converter in the main distribution station. The failure of this inverter disables the entire STS system. This can however be solved by adding additional redundancy at the rectifier unit level.

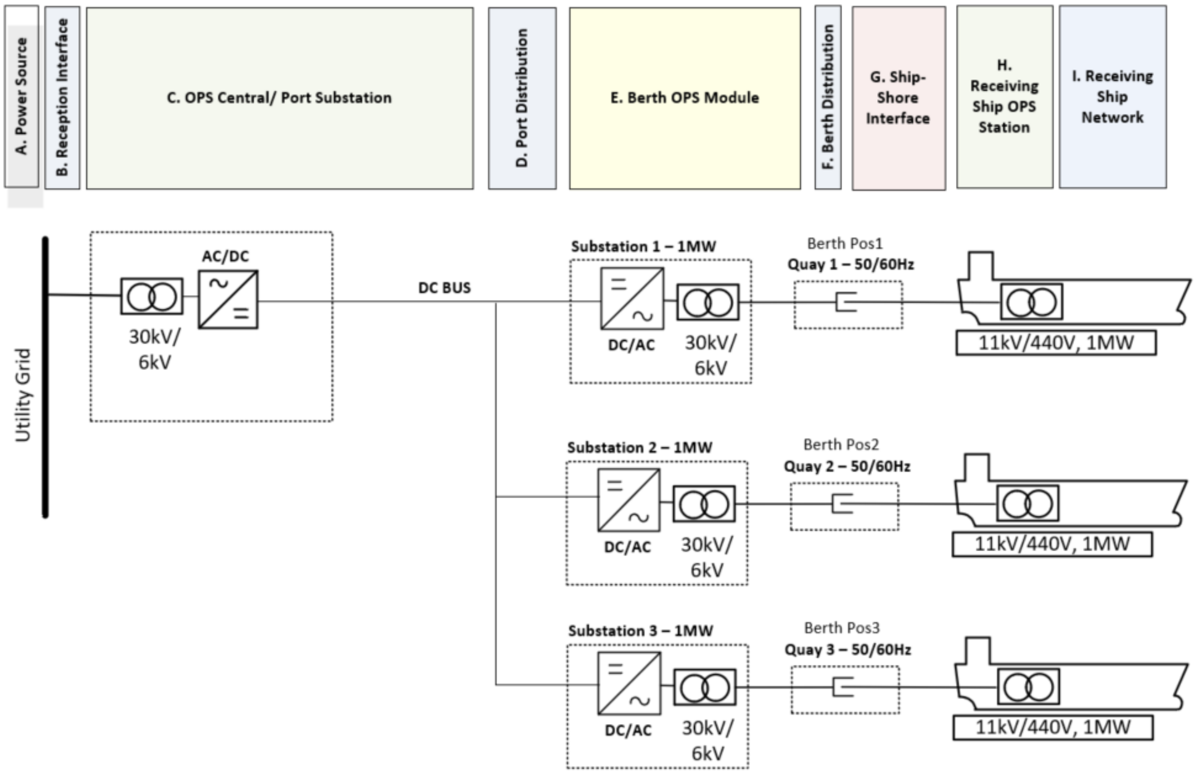


Figure 4.16 - Option III – HV power supply. (HVDC – Transmission).

Source: EMSA

The following table summarises the main advantages and disadvantages of the different configurations presented. It should be taken into consideration that any cost-benefit assessment to be made, when evaluating possible future options for OPS installation, a trade-off between investment cost and reliability of the whole system must be made. It is important to have early anticipation of the essential critical factors driving the SSE installation (reliability is critical for specific operations of ships at berth, e.g., for cruise ships and LNG carriers, even if for different underlying reasons).

Table 4.12 – Summary of advantages and challenges of different OPS configurations.

Topology	Advantages	Challenges
Option I Centralised OPS with one high power Frequency Converter	• Small area of the main station and long distance from quays • Cost of installation is slightly lower than cost of other variants	• The less reliable system (failure of the inverter disables all terminals) • Limited availability of highly specialized service for high power converters • Low quality of electricity (high THD) – the need to use harmonic filters • No possibility of synchronizing systems using inverter control

Option II De-Centralised OPS with several lower power Frequency Converters	• Failure of one of the inverters disconnects only one terminal; other terminals work without any problems • Possibility to increase the reliability through the use of multi-level redundancy • Possibility of parallel operation of modules in order to ensure power for ships with high power requirements • Ease of access to service • High quality of generated voltages from inverters based on IGBT transistors • Possibility of placing autonomous installations in containers and thus increasing the possibilities for expansion of the STS system • Possibility of synchronizing systems using inverter control	• Higher cost of installation. • The use of double-busbar switchgears instead of standard switchgears will increase the cost of the installation.
Option III DC distribution with inverters at berth	• Surface of the main station is the smallest of all variants • High efficiency due to smaller losses in rail and DC cable lines • Modularity for easy expansion	• Limited technology availability • Placement of inverters in quays interferes with the port infrastructure • Failure of AC/DC converter in the main station prevents (need to be solved by introduction of additional rectifiers, adding to cost) • If a fault occurs in the centrally placed rectifier, or in the DC-link, no berth will be able to supply vessels alongside with onshore power supply.

The different configurations outlined above were analysed as a demonstration of the different arrangements possible in the development of SSE installations. For both OPS options I, II and III the different approaches with respect to the location, redundancy and power rating for the frequency converter are dictating the different topology arrangements. However, there are, at least, as many combinations as the different ports and specific port/ terminal/ ship requirements. It is important to ensure that SSE systems are reliable through adequate design of frequency conversion and transforming units. Also, with respect to the total length of HV distribution cabling in the port, it is important to note that some important choices, like the use of frequency selector units, will allow to save the duplication of busbars or distribution circuits, just for the purpose of supplying different frequencies.

In Figure 4.17, a possible shore power arrangement for a 36 MVA OPS installation is presented. 3x12 MVA static frequency conversion units ensure a total combined power of 36 MVA. Separating the frequency conversion in parallel units ensures the necessary reliability of the SSE system. To be noted that, at main substation level there is no voltage reduction – only frequency conversion takes place.

The supply of 50/60 Hz is made by a double BUS at port distribution level, with the possibility for selection of the frequency at a centralized unit, optimizing the cable length to be installed throughout the different quays.

The voltage reduction takes then place at berth OPS module level allowing the power supply need to be adjusted in accordance with quay or terminal specific operating aspects.

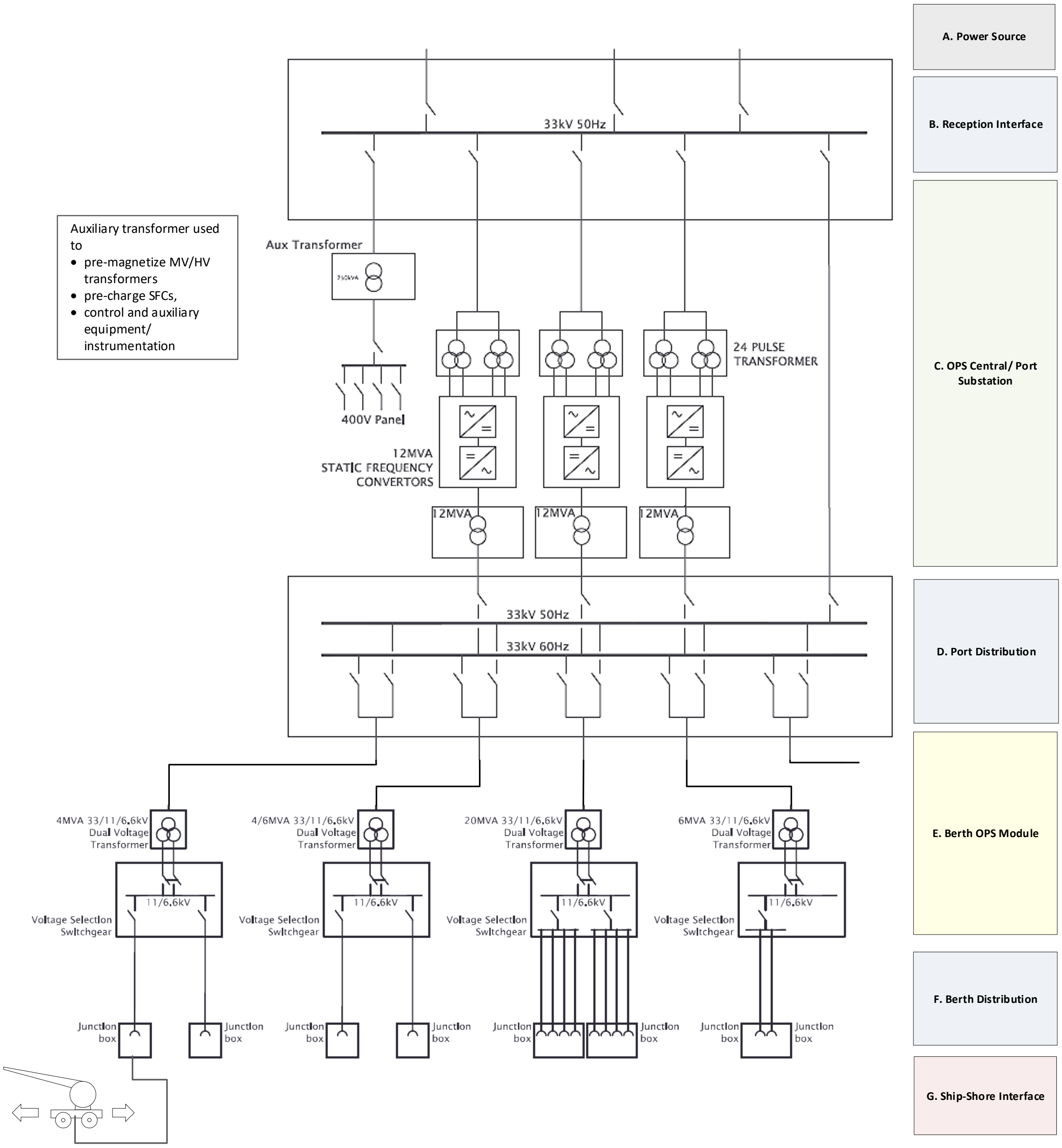


Figure 4.17 - SSE installation – OPS 36MVA installed capacity – example of structure layout for a redundant centralized OPS installation.

Source: EMSA

4.4 Shore-side Battery Charging (SBC)

Shore-Side Battery Charging (SBC) represents the SSE arrangement able to guarantee the charging of onboard Battery Energy Storage Systems (BESS) by shore power supply, either AC or DC, using a connection protocol suitable for the specific BESS onboard, at a specified charging power.

The key difference between the services provides in OPS and SBC are, in essence, related to need to ensure control across the battery charging process. Due to this need, it is important to have visibility/ communication between the charged ship BESS and the shore-side unit. This is one of the important challenges with SBC and, adding to that challenge, the aspect of interconnectivity and interoperability is of key relevance to address. The large majority of SBC installations today in operation are realisations of tailor-made solutions which are applicable to specific ships with connectivity arrangements highly specific. Unlike OPS, SBC has no standard for interconnectivity or interoperability.

In addition to the above challenge, another important difference can be identified in SBC, when comparing to OPS: the power demand is dictated by the ambition in the duration of the charging process. For fast charging very high power is required. Whereas in OPS the high power may be required by some ships with high hotel or service loads at berth, for SBC these high loads may be required by otherwise smaller ships which have however the ambition to charge “fast”. This paradigm of SBC is important to take into consideration for design of SSE/SBC installations and services.

There are several technical solutions for battery charging of electric/ hybrid electric ships. Figure 4.18, presents the 4 (four) generic cases that can be considered.

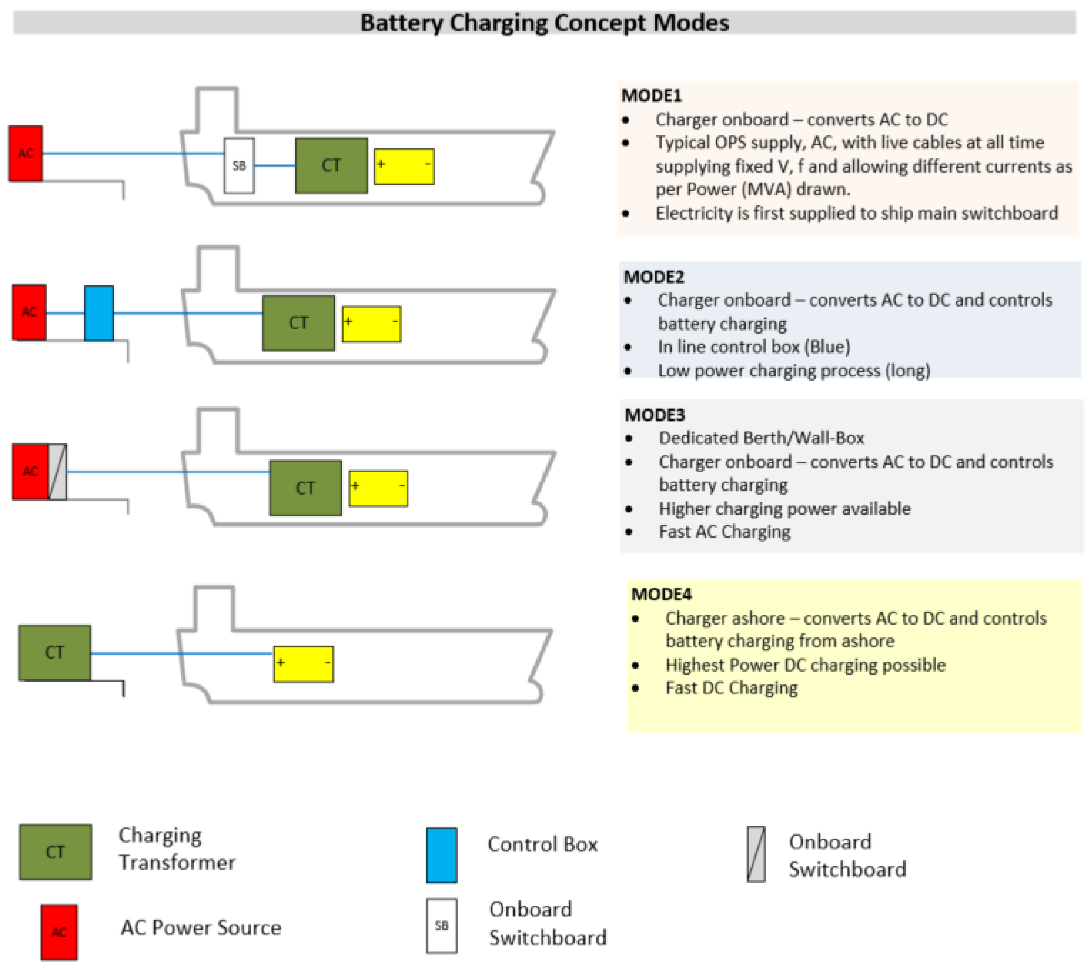


Figure 4.18 - Shore-side Battery Charging – 4 generic options AC and DC charging.

Source: EMSA

Without standardisation, SBC cable management systems/ connection solutions have developed specific solutions. From Figure 4.19 to Figure 4.22 it is possible to see some examples of SBC connectivity solutions.

Figure 4.19 - Shore-side Battery Charging – NORLED Ampere – CAVOTEC system with gravity driven charging cables falling into connection.

Source: Cavotec SA/NORLED

Figure 4.20 – Shore-side Battery Charging – MV Ellen shore-side fast charging transformer.

Source: Mobimar

Figure 4.21– Shore-side Battery Charging – induction charging connection.

Source: Wärtsilä Corporation

Figure 4.22 - Shore-side Battery Charging – Portico solution for battery charging connection. Several parallel cables grouped, with gravity connection.

Source: Zinus AS

The specificities of SBC projects are multi-dimensional, starting from the connectivity arrangement, and going up to the communications solution, both for system operability and for battery charging management. PAA should have in particular consideration the fact that any SBC project will impact the infrastructure differently, with power demand requirements which may be very high, as a function of fast charging requirements for RO-Pax ferries with short turn-around times at port.

The level of integration of charging systems into the overall SSE infrastructure is very important and the combined power demand effect of primary relevance to be addressed.

PAA should ensure with operators that there is a good level of predictability in the charging pattern of the vessels operating with SBC services in port.

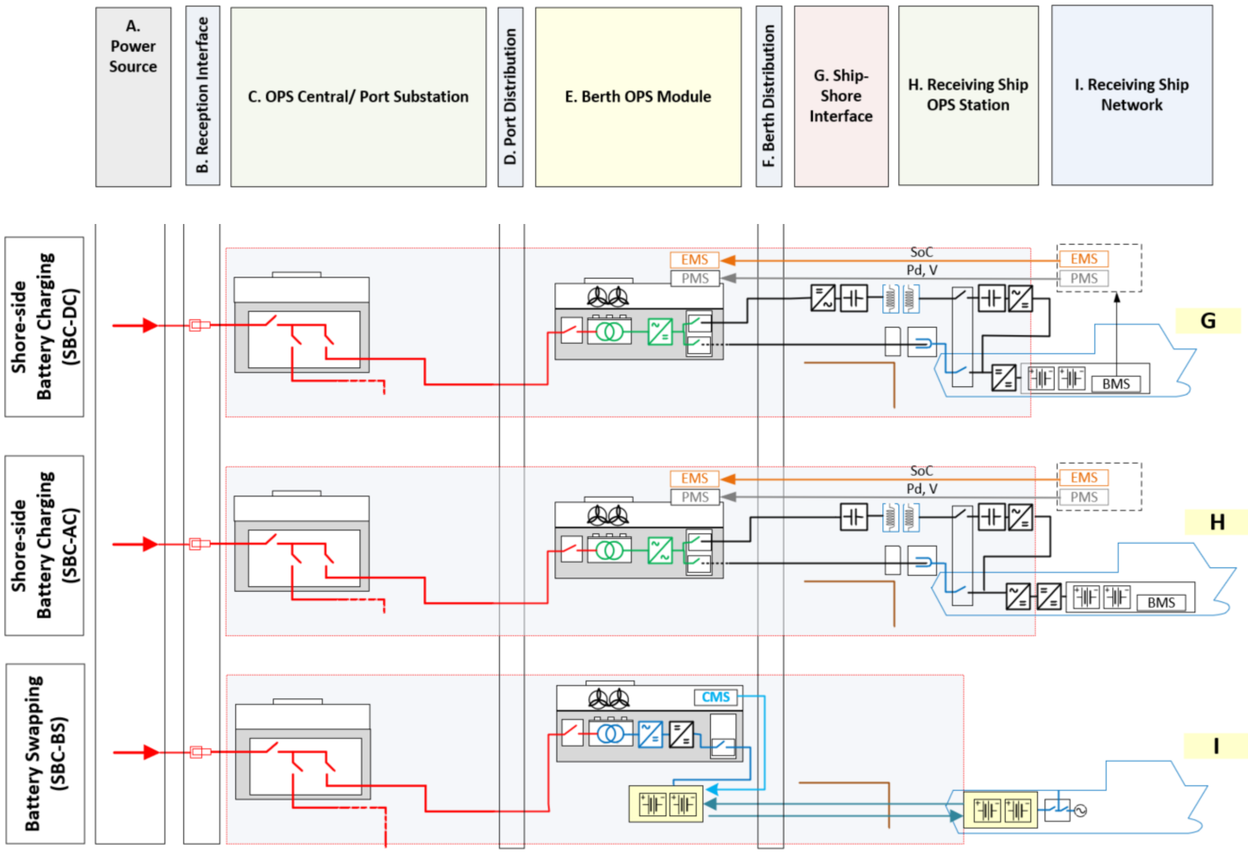


Figure 4.23 - Shore-side Battery Charging – DC, AC charging and battery swapping.

Source: EMSA

G	Shore-Side Battery Charging with Charger Unit ashore – DC charging	**SBC-DC**	DC Shore-side Battery Charging, supplied by HV utility grid supply, subject to power condition by step-down transformer and rectifier AC/DC converter. Wired and wireless inductive charging are both presented. For inductive charging are presented capacitance compensators adding reactive power consumed by the inductive charging coils. For wired connection, the diagram shows a charging connector plugged in a connector-inlet arrangement. DC-DC converter presented installed onboard. Energy Management and Power Management Systems represented for communication across ship-shore interface (EMS, PMS).
H	Shore-Side Battery Charging with Charging Unit onboard – AC charging	**SBC-AC**	AC Shore-side Battery Charging, supplied by HV utility grid supply, subject to power condition by step-down transformer and frequency conversion if so necessary. Wired and wireless inductive charging are both presented. For inductive charging are presented capacitance compensators adding reactive power consumed by the inductive charging coils. For wired connection the diagram shows a charging connector plugged in a connector-inlet arrangement. DC-DC converter presented installed onboard. Energy Management and Power Management Systems represented for communication across ship-shore interface (EMS, PMS).
I	Shore-Side Battery Charging with Charger Unit ashore – Battery Swapping	**SBC-BS**	Swapping of batteries may represent an option for reduced turnaround times, especially for ships engaged in regular traffic with short periods at berth. Generic diagram represents a berth-level charging unit used for interchangeable batteries used to plug-in onboard battery powered vessel. Charging management Systems is represented.

4.4.1 SBC System Architecture

The diagrams below present the different possible SBC charging modes, reflected in different system architectures[4]. Particular relevance given to the suitability of the different arrangements for fast charging.

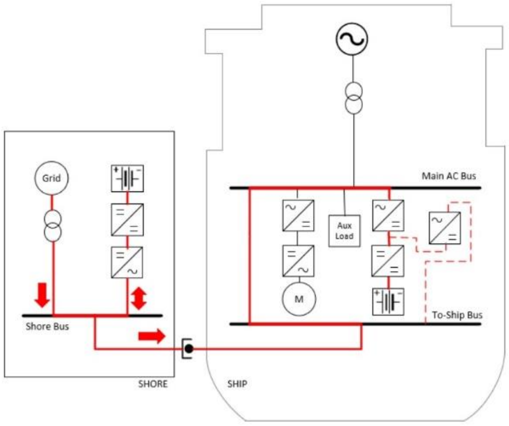
<table>
<tr><th colspan="2"></th><th colspan="2">Receiving Ship</th></tr>
<tr><th colspan="2"></th><th>AC</th><th>DC</th></tr>
<tr><th rowspan="2">Shore-Side Charging</th><th>AC</th>
<td>
- AC power source
- Onboard rectifier required
- AC-DC charger onboard – important
- Need for synchronization makes this arrangement unsuitable for fast charging
- Typical OPS connection arrangement


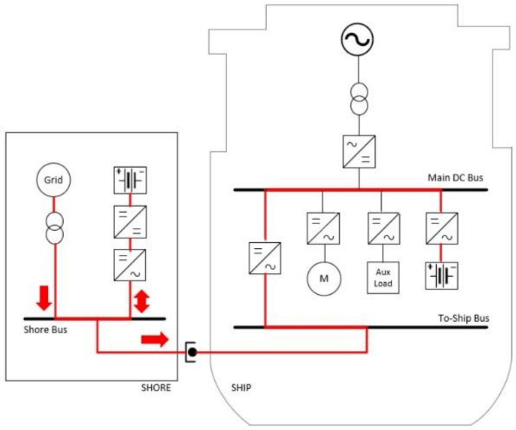
Figure 4.24 - SBC – AC shore-to-ship charging – AC-based ship grid.
Source: [1]
</td>
<td>
- AC power source ashore
- AC-DC converter charger (can be onboard or ashore) – onboard in the figure below
- Onshore battery for charging


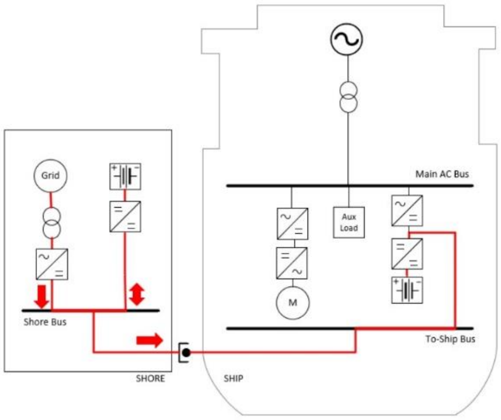
Figure 4.25 - SBC – AC shore-to-ship charging – DC-based ship grid.
Source: [1]
</td></tr>
<tr><th>DC</th>
<td>
- DC power source
- Onboard rectifier required
- Suitable for fast charging


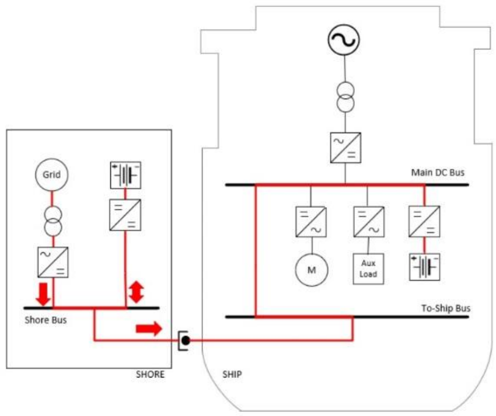
Figure 4.26 - SBC – DC shore-to-ship charging – DC-based ship grid.
Source: [1]
</td>
<td>
- DC power source
- DC based onshore energy system
- Charger-converter can be either ashore or onboard (as in the figure below)
- Suitable for fast charging


Figure 4.27 - SBC – AC shore-to-ship charging – DC-based ship grid.
Source: [1]
</td></tr>
</table>

[4] As in S. Karimi, M. Zadeh and J. A. Suul, "Shore Charging for Plug-In Battery-Powered Ships: Power System Architecture, infrastructure, and Control," in IEEE Electrification Magazine, vol. 8, no. 3, pp. 47-61, Sept. 2020, doi: 10.1109/MELE.2020.3005699.

4.4.2 Control and Power Management

Battery Charging is a time-variant process encompassing the need to monitor severable variables and control

Generally, two levels of control can be considered in a charging system [1]:

1) **Low-level control**, for control of power converters (Power Converter Control); including the following functions:
    a. Control of the Converters and respective modes of operation.
    b. Current control
    c. Control of power flows
    d. Voltage Control
    e. Power Variation control during charging process.
    f. Management of bidirectional current flow
2) **High-level control**, including
    a. Power and energy management system (PMS and EMS) that generate the power and voltage set points for stable and efficient operation of the power system during the charging process.
    b. Onshore and onboard battery management systems (BMS), which are responsible for estimation of the state of charge (SoC) and the state of health, thermal management, and cell balancing.

To illustrate the importance of these controls for battery charging and operation of an all/electric or hybrid/electric ship, Figure 4.28 includes both AC and DC charging versions, where PMS (Power Management System) and EMS (Energy Management System) are illustrated as functional components linking the ship to the shore side.

In addition to the EMS and PMS, also the Battery Management System (BMS) is illustrated. Together these three systems operate and interact to ensure the safety and operability of the battery energy system. It is important to ensure that compatibility of the low-level and high-level control systems are communicating adequately to contribute to the battery charging at berth.

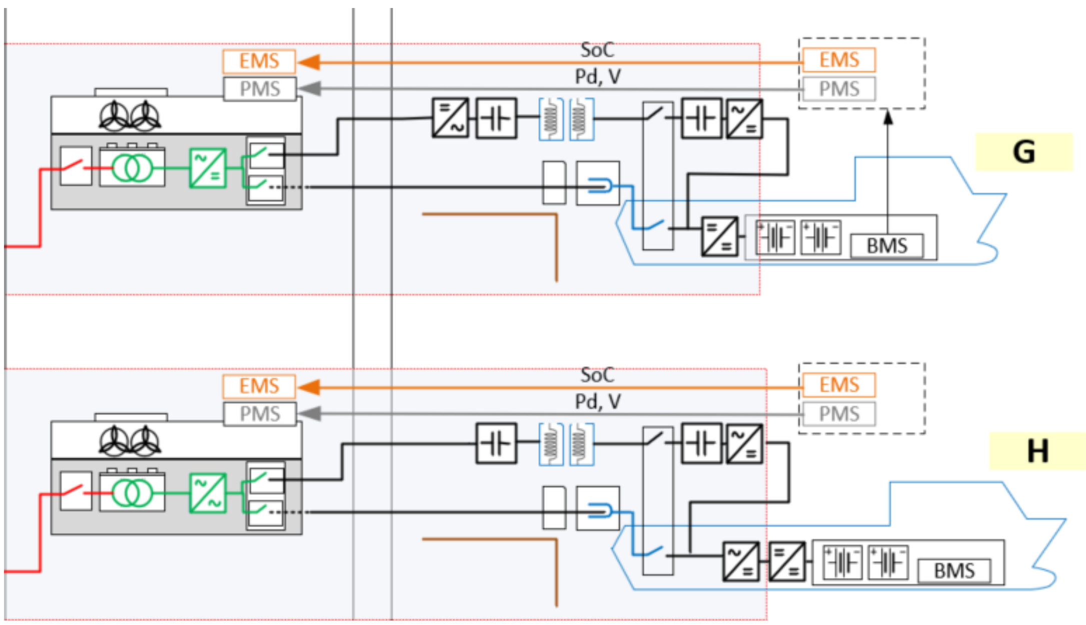


Figure 4.28 - SBC – DC and AC battery charging, respectively in “G” and “H”.

Source: EMSA

4.5 Shore-side Power Bank (SPB)

Shore-side power banking is an extension of the SBC concept and, to some extent, a combination of SBC and OPS. The central infrastructure element are battery banks and can be installed in different points of the SSE infrastructure. Figure 4.29, presents battery banks at central substation and at berth OPS modules.

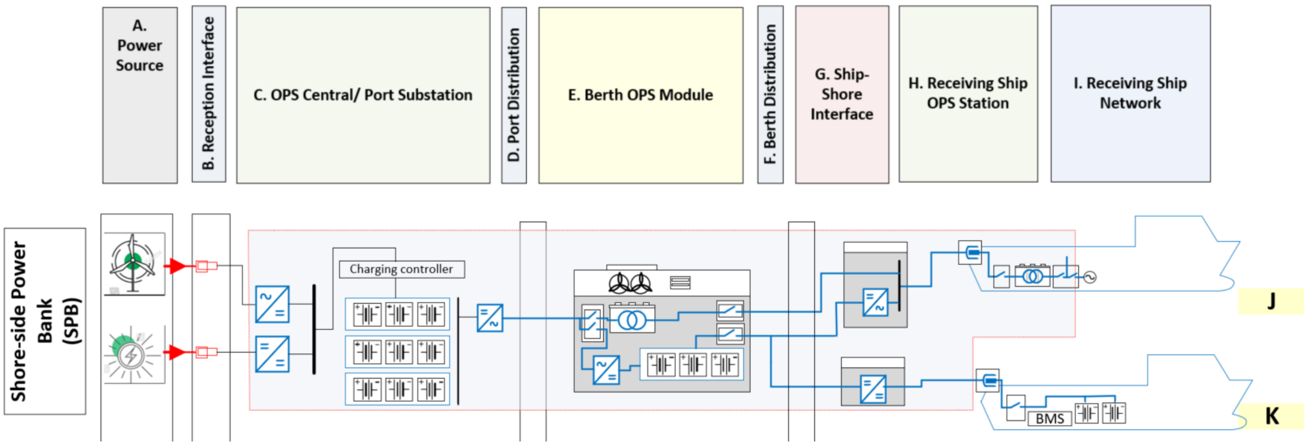


Figure 4.29 - SPB – Shore-side power banking.

Source: EMSA

Renewable energy resources integrated into port energy system, in particular directly integrated onto the shore-side electricity network can use battery banking infrastructure in order to store fluctuant/irregular energy production.

The technical solution comprises of AC-DC converters for wind generators and DC-DC for PV contribution. Other renewables may be possible, including the use of microgeneration with renewable and low carbon fuels.

Option "J" in Figure 4.29, presents renewable based SPB to OPS supply through the introduction of an Inverter unit for AC power supply at designated voltage and frequency. Option "K" illustrates the supply of battery charging service.

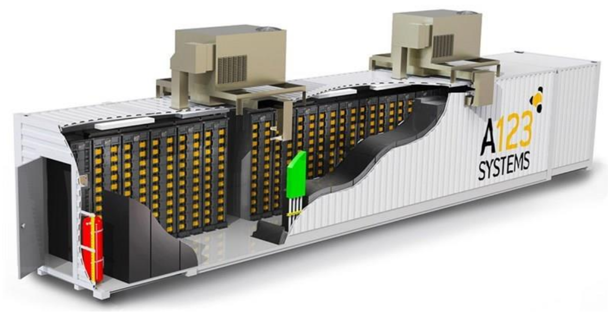


Figure 4.30 - Electrical energy storage site containerised unit.

Source: A123 systems, LLC

Figure 4.31 - Multi-MW battery bank – to be noted the refrigeration units for the cooling of battery modules.

Source: Samsung

Below it is possible to see the different levels at which power banking can play an important role in ports and in the context of SSE installations.

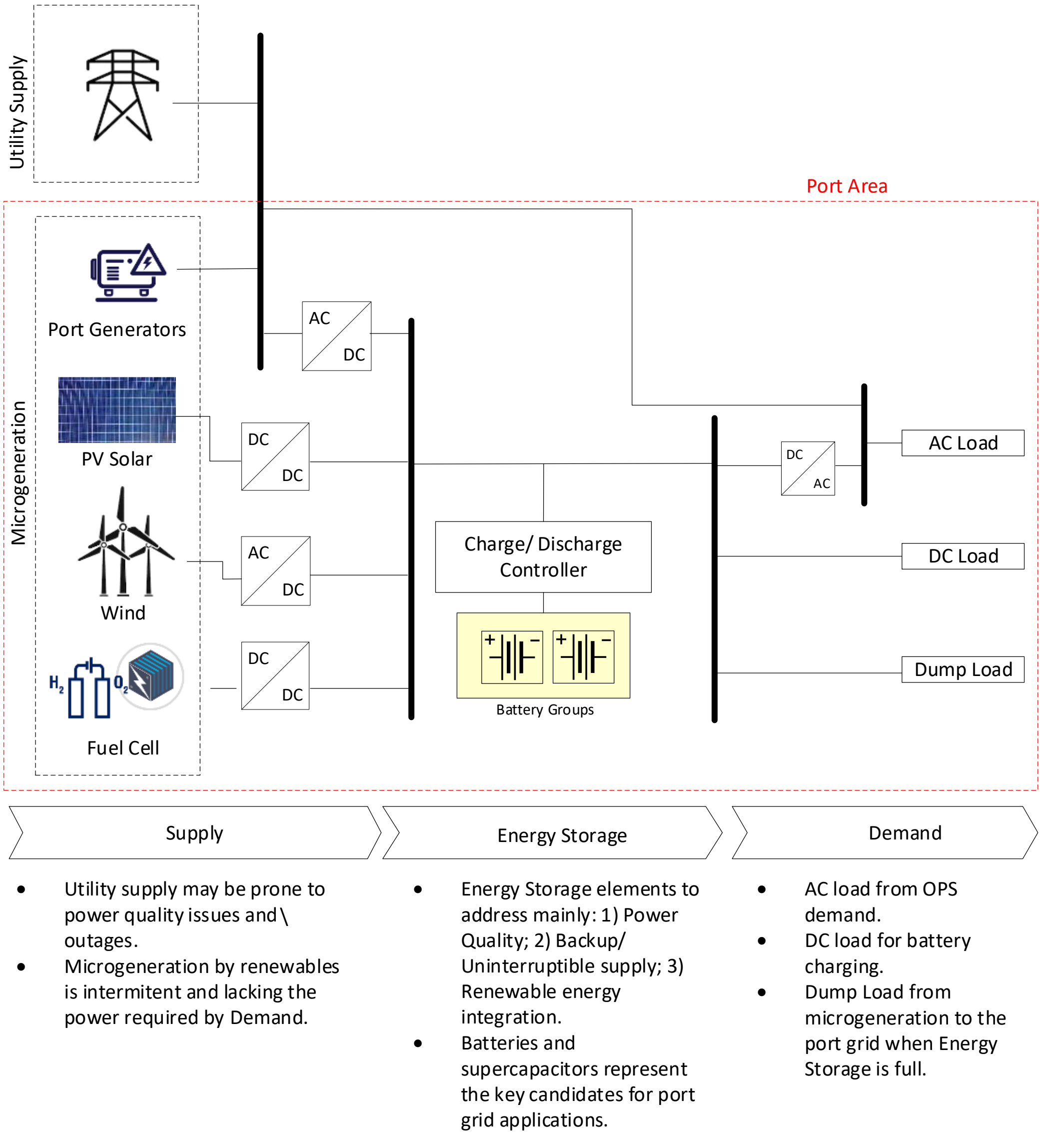


Figure 4.32 - SPB – Shore-side Power Banking – Different locations/roles in the SSE systems for electrical energy storage.

Source: EMSA

4.6 Port generators

Port generators are key building blocks in the construction of smart grids and microgeneration in ports. The possibility to provide electrical power production "on-spot" and with mobility/flexibility, is a possibility which will be important to consider in the development of sustainable solutions for ports with more difficult access to the utility grid.

Figure 4.33 – Becker LNG Hybrid power production barge – supply of OPS power supply at the Port of Hamburg – electricity supplied via shore-based installation.

Source: Becker Marine Systems

Figure 4.34 – 1.5MW containerized mobile LNG power production units – standard ISO container modular size allows intermodal mobility.

Source: Becker Marine Systems

Figure 4.35 – ABB concept for 3MW Fuel Cell module for microgeneration in ports – hydrogen fuel cells – increasing interest zero-emission power production. Modularity also facilitates the adaptation for operation onboard.

Source: ABB

PAA should assess the potential for microgeneration in accordance with a technical assessment and feasibility study taking the following elements in consideration: 1) Difficulties in access to the utility grid; 2) Insufficient power for the required demand; 3) Availability of floor area for installation of power production units; 4) Safety aspects (Hazardous areas, low flashpoint or toxic fuels) and 5) Sustainability of the energy options.

Careful consideration should be given in particular to spatial planning: with the space-critical requirements in ports and terminals, location or microgeneration units should be decided with due consideration to all other activity (cargo and passenger) flows in the port area.

5. Regulatory Framework

The regulatory framework for SSE/OPS infrastructure projects plan, development, and operation, needs to be assessed over the 3 dimensions: 1) Shore side; 2) Ship-shore interface and 3) Ship side. High-level instruments (International and EU), national law (for electrical and port regulatory aspects), standards, Class rules and guidance documents, can be considered altogether the key building blocks for SSE regulatory framework. The diagram below provides a representation of the inter-relations between the different instruments.

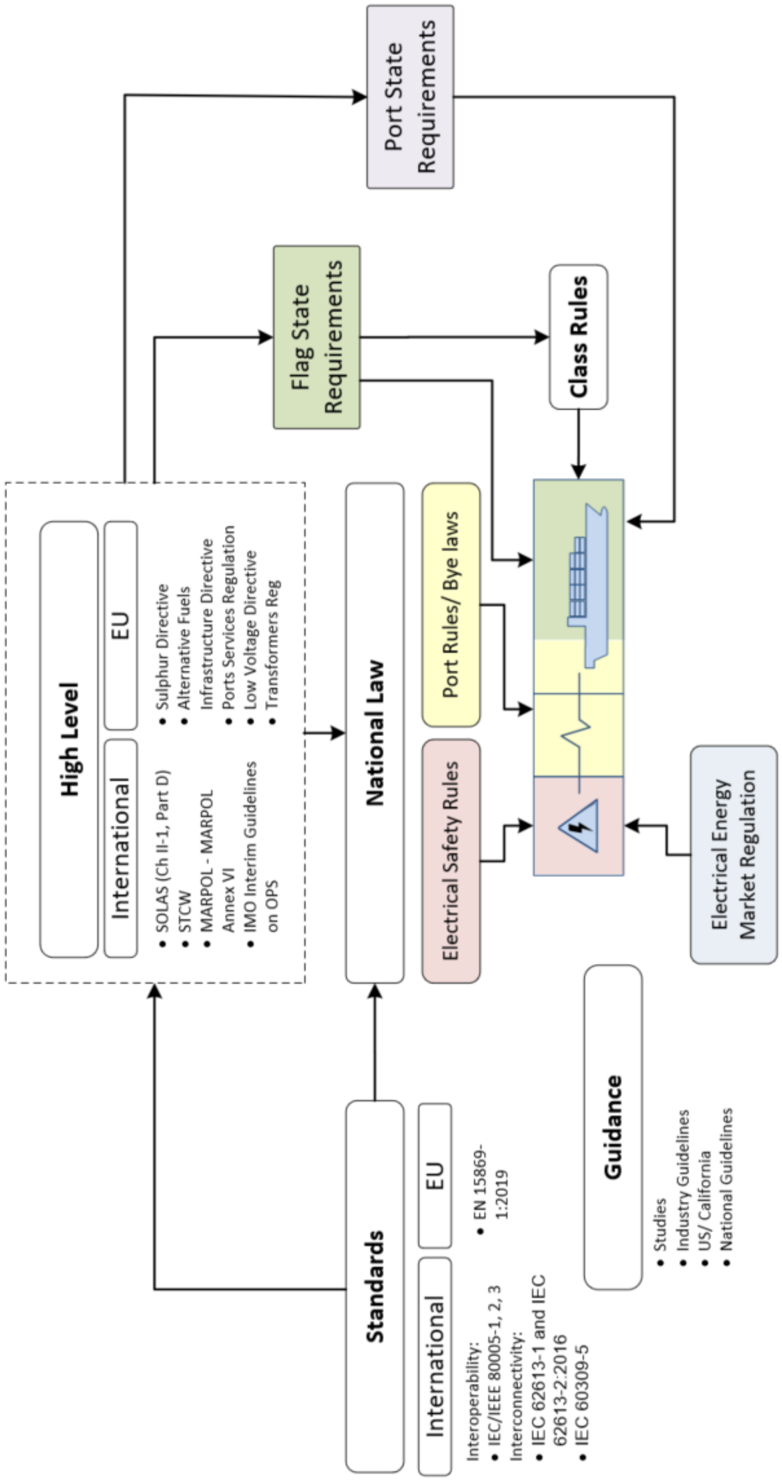


Figure 5.1 – SSE regulatory framework dimensions.

Source: EMSA

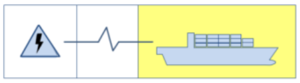
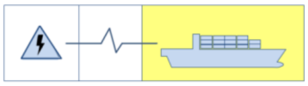
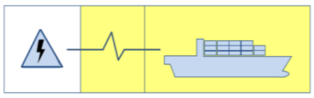
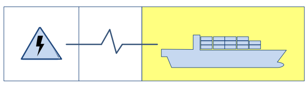
5.1 High-level instruments

The present section lists the relevant **high-level instruments** with relevance to the shore side, ship side and SSE interface.

5.1.1 International

The present section lists the relevant **high-level international instruments** with relevance to the shore side, ship side and OPS interface.

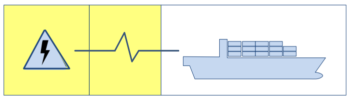
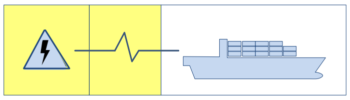
Table 5.1 - International high-level instruments.

Title	Organization	Type	Scope
SOLAS International convention for the Safety of Life at Sea (SOLAS)1974, as modified by the protocol of 1988 relating thereto 	IMO	Convention	Ships engaged in international voyages. Ships shall conform to: SOLAS Chapter II-1, Part-D Electrical Installations (Regulation 40-45).
MARPOL International Convention for the Prevention of Pollution from Ships 	IMO	Convention	Relevant for Annex VI, with limits on SO_x and NO_x Emissions, Energy Efficiency and EAMs. By establishing limits on air emissions, MARPOL Annex VI sets a standard requirement for the adoption of cleaner energy sources. Whilst at Port, in the EU, to the requirements set by MARPOL Annex VI, Regs 13 and 14, the Sulphur Directive adds the maximum limit of 0.10% sulphur content in fuels, at berth.
IMO OPS Guidelines Interim Guidelines on Safe Operation of Onshore Power Supply (OPS) Service in Port for Ships Engaged on International Voyages 	IMO	Guidelines	Interim Guidelines finalized at IMO, in March 2020, adopted in MSC103, focused on Operation of OPS systems for HVSC and LVSC, applicable to ships engaged in international voyages.
STCW International convention on standards of training, certification and watch keeping for seafarers 			Training, certification and qualification of seafarers serving on board sea-going ships. Minimum standards of competence for seafarers. Especially important for the competencies defined for the person in charge (for both HV and LV systems): Electro-technical officers holding a certificate of competency in accordance with the requirements of regulations III/6 of the STCW Convention. Chief engineer officers and second engineer officers on ships powered by main propulsion machinery of 3,000 kW propulsion power or more holding a certificate of competency in accordance with the requirements of regulations III/2 of the STCW Convention and who have completed training in accordance with section B-III/2 of the STCW Code.

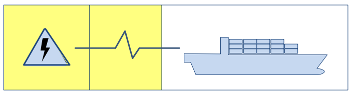
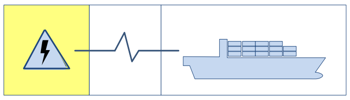
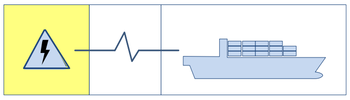
5.1.2 EU

In EU law it is first important to make the distinction between 1) regulations and 2) directives. Whereas **regulations** have binding legal force throughout every Member State and enter into force on a set date in all the Member States, **directives** lay down certain results that must be achieved but each Member State is free to decide how to transpose directives into national laws. This is an important note regarding the EU legislative framework since the present Guidance, whenever addressing directives, does not make distinction between different implementation exercises in each EU Member States[5].

Table 5.2 – EU high-level instruments.

Title	Organization	Type	Scope
EU Alternative Fuel Infrastructure Directive Directive 2014/94/EU on the deployment of alternative fuels infrastructure  **NOTE**: Currently under revision in the context of the Fit for 55 legislative package. Directive will become an EU Regulation with mandatory requirements for OPS infrastructure development	EC	European Directive	Directive 2014/94/EC on the deployment of alternative fuels infrastructure, [3], part of the EU Clean Power for Transport package, states in Article 4: *(…)* *5. Member States shall ensure that the need for shore-side electricity supply for inland waterway vessels and seagoing ships in maritime and inland ports is assessed in their national policy frameworks. Such shore-side electricity supply shall be installed as a priority in ports of the TEN-T Core Network, and in other ports, by 31 December 2025, unless there is no demand and the costs are disproportionate to the benefits, including environmental benefits.* *6. Member States shall ensure that shore-side electricity supply installations for maritime transport, deployed or renewed as from 18 November 2017, comply with the technical specifications set out in point 1.7 of Annex II.*
EU Machinery Directive – Directive 2006/42/EC 	EU	European Directive	Directive 2006/42/EC is a revised version of the Machinery Directive, the first version of which was adopted in 1989. The new Machinery Directive has been applicable since 29th December 2009. The Directive has the dual aim of harmonising the health and safety requirements applicable to machinery on the basis of a high level of protection of health and safety, while ensuring the free circulation of machinery on the EU market. Applicable to SSE infrastructure equipment, in particular where automated systems are included in the design.

[5] In this way there will be aspects from the different national instruments that will not be captured by the present Guidance. It is important to be mindful that, for each EU Member State there should be a national instrument correspondent to the implementation of a directive. In this Guidance, whenever Directives are addressed, for a complete evaluation of each EU MS context, the corresponding national law should be consulted.

COMMISSION DELEGATED **REGULATION (EU) 2019/1745** of 13.8.2019 supplementing and amending Directive 2014/94/EU of the European Parliament and of the Council as (…), **shore-side electricity supply for inland waterway vessels**, (…) and repealing Delegated Regulation (EU) 2018/674 	EU	EU secondary legislation	Delegated regulation to Directive 2014/94, defining the standards for OPS The shore-side electricity supply for inland waterway vessels shall comply with standard EN 15869-2 'Inland navigation vessels — Electrical shore connection, three phase current 400 V, up to 63 A, 50 Hz — Part 2: Onshore unit, safety requirements'.
EU Port Services Regulation Regulation (EU) 2017/352 Of the European Parliament and of the Council of 15 February 2017 establishing a framework for the provision of port services and common rules on the financial transparency of ports 	EU	European Regulation	EU Regulation establishing a framework for the provision of port services, and common rules for transparency and on port services. SSE is within the scope and applicability of this regulation, either inside the port area or on the waterway access to the port. OPS is considered as bunkering service
EU Sulphur Directive Directive 2016/802/EU relating to a reduction in the sulphur content of certain liquid fuels (*codifying Council Directive 1999/32/EC as regards the sulphur content of marine fuels, as amended by Directive 2012/33/EU*) 	EU	European Directive	Sulphur Directive includes reference to Shore-Power.
Directive (EU) 2016/1629 laying down technical requirements for inland waterway vessels, amending Directive 2009/100/EC and repealing Directive 2006/87/EC	EC	European Directive	Reference to technical requirements for Inland Navigation vessels. Certificates for the Inland Navigation vessels. Inspection of the Inland Navigation vessels. Reference is made to Technical Requirements within CESNI Standard ES-TRIN 2021 (https://www.cesni.eu/documents/es-trin-2021/).

5.2 Standards – SSE systems and operation

A standard is a “document, established by consensus and approved by a recognized body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context”.

Standards are fundamental to make the bridge between high level instruments, and the operational, or technical, implementation of their provisions. These documents are developed and defined through a process of sharing knowledge and building consensus among technical experts nominated by interested parties and other stakeholders - including businesses, consumers, and environmental groups, among others.

The importance of international standards in shore-side electricity, working together with global reaching regulations, is directly related to the promotion of safety and confidence in the development of SSE as a technology option for improved sustainability performance of both ships and ports. By setting out requirements for specific items, material, components, systems, or equipment, or describing in detail a particular method or procedure, international standards facilitate international trade by ensuring compatibility and interoperability of components, products and services. They bring benefits to operators and authorities in terms of reducing costs, enhancing performance, and improving safety.

The present section on standard has a focus on International and EU Standards, even though it is well recognized that other standards (regional or national) also play an important role in the characterization and certification of SSE systems. International standards mentioned are only the ones developed and published by international standardization bodies (ISO, CEN and IEC).

There are several different types of standards. Basically, standards include requirements and/or recommendations in relation to products, systems, processes, or services. Standards can also be a way to describe a measurement or test method or to establish a common terminology within a specific sector.

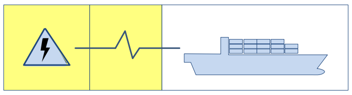
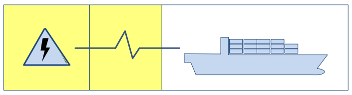
European Norms (ENs) are documents that have been ratified by one of the three European Standardization Organizations (ESOs), CEN, CENELEC or ETSI; recognized as competent in the area of voluntary technical standardization in line with EU Regulation 1025/2012.

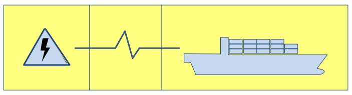
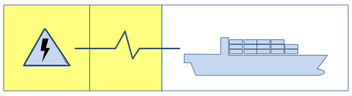
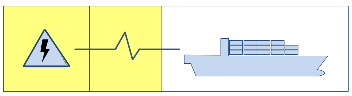
An EN (European Standard) “carries with it the obligation to be implemented at national level by being given the status of a national standard and by withdrawal of any conflicting national standard". Therefore, a European Standard (EN) automatically becomes a national standard in each of the 34 CEN-CENELEC member countries.

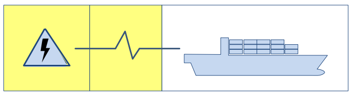
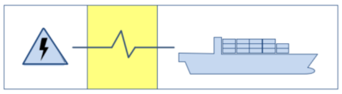
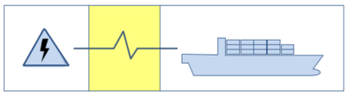
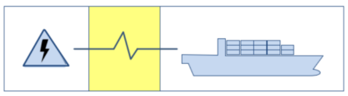
Standards are voluntary which means that there is no automatic legal obligation to apply them. However, laws and regulations may refer to standards and even make compliance with them compulsory. This is an important point for SSE development where it is essential to ensure interconnectivity and interoperability of the relevant SSE systems. Two relevant examples are The IMO OPS Guidelines and Directive 2014/94/EU where the IEEE/IEC 80005-1 is referred for High-Voltage Shore Connection (HVSC). By having a reference to the standard in the mentioned high-level instruments it is possible to enforce the application of the standards, in line with the application of those instruments.

The standards selected in this section are of particular relevance for interoperability of shore-side electricity systems. They are mainly designed for the supply of electricity in OPS mode but can also be relevant to SBC or SPB.

Table 5.3 - SSE Standards.

Title	Responsible	Type	Scope
IEC/IEEE 80005-1 **Utility connections in port – Part 1: High voltage shore connection (HVSC) systems – General requirements** 	IEC	International Standard	This part of IEC/IEEE 80005 series describes high-voltage shore connection (HVSC) systems, onboard the ship and on shore, to supply the ship with electrical power from shore. (Applicable for OPS systems above 1kV AC (1.5 kV DC) This document is applicable to the design, installation and testing of HVSC systems and addresses: • HV shore distribution systems, • shore-to-ship connection and interface equipment, • transformers/reactors, • semiconductor/rotating frequency convertors, • ship distribution systems, and • control, monitoring, interlocking and power management systems. It does not apply to the electrical power supply during docking periods, for example dry-docking and other out of service maintenance and repair. It is expected that HVSC systems will have practicable applications for ships requiring 1 MVA or more or ships with HV main supply.
IEC/IEEE 80005-3 **Low voltage shore connection (LVSC) systems – General requirements** 	IEC	International Standard	This part of IEC/IEEE 80005 series describes low-voltage shore connection (LVSC) systems, onboard the ship and on shore, to supply the ship with electrical power from shore. (Applicable for OPS systems above 400V AC (600 V DC) and up to 1000V AC (1500V DC) This document is applicable to the design, installation and testing of LVSC systems and addresses: • LV shore distribution systems, • shore-to-ship connection and interface equipment, • transformers/reactors, • semiconductor/rotating frequency convertors, • ship distribution systems, and • control, monitoring, interlocking and power management systems. It does not apply to the electrical power supply during docking periods, for example dry-docking and other out of service maintenance and repair. It is expected that LVSC systems will have practicable applications for ships requiring up to 1 MVA while at berth. Low-voltage shore connection systems exceeding 250 A, equal or exceeding 400 V AC. and up to 1000 V AC. nominal voltage are covered by this standard. High-voltage shore connection systems are covered by Part 1 of this standard.

Title	Responsible	Type	Scope
IEC/IEEE 80005-2 **Utility connections in port – Part 2: High and low voltage shore connection systems – Data communication for monitoring and control** 	IEC	International Standard	This part of IEC/IEEE 80005 describes the data interfaces of shore and ships as well as step by step procedures for low and high voltage shore connection systems communication for non-emergency functions, where required. It covers the requirements of the HVSC systems described in Part 1 and is also intended to cover the requirements of a forthcoming standard for LV shore connection systems (relation to IEC/IEEE 80005-3 is less imprinted in this standard). This standard specifies the interface descriptions, addresses and data type. This standard also specifies communication requirements on cruise ships, in Annex A. Application of this standard relates otherwise to annexes of IEC//IEEE 80005-1. This standard does not specify communication for emergency functions as described in IEC/IEEE 80005-1.
EN 15869-1:2019 **Inland navigation vessels - Electrical shore connection, three phase current 400 V, 50 Hz, up to 125 A –** **Part 1: General requirements** 	CENELEC	EN Standard	This document specifies requirements for electrical installations for the shore supply of berthing inland navigation vessels with electrical energy, three-phase current 400 V, 50 Hz with a rated current of up to 125 A. This document applies to the supply of inland navigation vessels in ports and moorings for commercial inland navigation. This document specifies general requirements and contains information on the billing procedure. For the supply of small craft and houseboats in marinas and similar installations the requirements of IEC 60364-7-709 apply. For electrical shore connections with a current rating more than 125 A, which are suitable for passenger ships with hotel operation, EN 16840 applies. The requirements for the IEC 60364 series and HD 384 series generally apply to low-voltage systems on shore.
EN 15869-2:2019 **Inland navigation vessels - Electrical shore connection, three phase current 400 V, 50 Hz, up to 125 A** **Part 2: Onshore unit, additional requirements** 	CENELEC	EN Standard	This European Standard applies in conjunction with EN 15869 to the shore supply of berthed inland navigation vessels with electrical energy. This part (2) of EN 15869 specifies additional requirements for the onshore unit of the electrical shore connection.

Title	Responsible	Type	Scope
IEC 60364-7-709:2007 +AMD1:2012 CSV Consolidated version 	IEC	International Standard	IEC 60364-7-709:2007+A1:2012 applies only to circuits intended to supply pleasure craft or houseboats in marinas and similar locations. The particular requirements do not apply to the supply of house boats if they are directly supplied from the public network. The particular requirements do not apply to the internal electrical installations of pleasure craft or house boats. For the remainder of the electrical installation of marinas and similar locations the general requirements of IEC 60364 together with the relevant particular requirements of IEC 60364-7 apply.
IEC 60309-5:2017 Plugs, socket-outlets and couplers for industrial purposes - Part 5: Dimensional compatibility and interchangeability requirements for plugs, socket-outlets, ship connectors and ship inlets for low-voltage shore connection systems (LVSC) 	IEC	International Standard	IEC 60309-5:2017 applies to a single type of plug, socket-outlet, ship connector and ship inlet, hereinafter referred to as accessories, intended to connect ships to dedicated shore supply systems described in IEC/IEEE 80005-3. This part of IEC 60309 applies to three-phase accessories with an earth contact and with four pilot contacts. This publication is to be read in conjunction with IEC 60309-1:2012.
IEC 62613-1:2019 Plugs, socket-outlets and ship couplers for high-voltage shore connection (HVSC) systems - Part 1: General requirements 	IEC	International Standard	IEC 62613-1:2019 applies to accessories with - three phases and earth with pilot contacts, - one pole for neutral. These accessories have rated currents not exceeding 500 A and rated operating voltages not exceeding 12 kV 50/60 Hz. This second edition cancels and replaces the first edition published in 2011. This edition constitutes a technical revision.
IEC 62613-2:2016 Plugs, socket-outlets and ship couplers for high-voltage shore connection systems (HVSC-systems) - Part 2: Dimensional compatibility and interchangeability requirements for accessories to be used by various types of ships 	IEC	International Standard	IEC 62613-2:2016 contains standard sheets for different configurations of (shore) socket-outlets, (shore) plugs, ship connectors and ship inlets, hereinafter referred to as accessories, up to 12 kV, 500 A, 50/60 Hz and with up to seven pilot/auxiliary contacts. General requirements are given in IEC 62613-1.
CESNI Standard ES-TRIN (latest version 2021**) - European standard laying down technical requirements for inland navigation vessels** **https://www.cesni.eu/documents/es-trin-2021/**	CESNI	European Inland Navigation Standard	Contains provisions on inland navigation vessel construction, arrangement and equipment, special provisions for certain categories of vessel such as passenger vessels, pushed convoys and containerships, as well as instructions on how to apply the technical standard. ES-TRIN also incorporates the new requirements governing the use of SSE. In order to ensure consistency of two existing legal regimes for technical requirements for inland navigation vessels (Rhine and EU) it is necessary to provide the same standards. Both EU law (Directive (EU) 2016/1629) and CCNR Regulation will be referring to ES-TRIN standards delivered by CESNI.

5.2.1 Standardization for Interconnectivity and Interoperability

Standardisation for interconnectivity and interoperability in SSE is not yet a reality harmonized across the different SSE options. In Table 5.4, the completeness of the standardization framework is presented.

Table 5.4 – Standards for interconnectivity and interoperability in different SSE options.

SSE Mode		Interconnectivity	Interoperability	Data Communication	Automation	International/EU Regulatory
OPS (Onshore Power Supply)	HVSC	IEC 62613-2:2016	IEC/IEEE 80005-1	IEC/IEEE 80005-1 (7.8) IEC/IEEE 80005-2 (normative requirements currently exist only for cruise ships)	Not yet standardized	IMO OPS Guidelines EU AFID
	LVSC	IEC 60309-5	IEC/IEEE 80005-3 (under development/ finalization)	IEC/IEEE 80005-2	Not yet standardized	IMO OPS Guidelines EU AFID
	LVSC - IW	EN 15869-2:2019 (up 125A) EN 16840: 2017 (above 250A)		Possible application of IEC/IEEE 80005-2	Not yet standardized	CCNR CESNI – ES-TRIN2019
SBC (Shore-side Battery Charging)	SBC-AC As OPS – ship-side charging.	IEC 60309-5/ IEC 62613-2 AC connection	IEC/IEEE 80005 series As OPS – ship-side charging.	Possibility for future development for IEC/IEEE 80005-2 or ISO15118	Not yet standardized	Not yet developed
	SBC-DC	Not yet standardized	Not yet standardized		Not yet standardized	Not yet developed

5.2.2 ISO/IEC 80005-1

Shore connection systems must comply with the standard **IEC/ISO/IEEE 80005-1** Ed.1: Utility Connections in Port - Part 1: High Voltage Shore Connection (HVSC) Systems.

The aim of the standard is to set forth:

- Requirements for shore connection design and construction
- Requirements to guarantee the safety of high-voltage shore connection systems
- Requirements for compatibility between ships and high-voltage shore connection systems

The goal is for the shipping industry and port facilities to cooperate to develop appropriate operating procedures for connecting ships to HVSC systems.

The standard is designed to guarantee standard, straightforward connection, eliminating the need for ships to make adaptations to their equipment at different ports. Ships that do not comply with the standard may find it impossible to connect to compliant shore supplies.

This standard is supported by **IEC 62613-1 & 2**, which sets standards for high-voltage plugs, socket-outlets, and ship couplers for HVSC systems.

The standard covers:

- Quality of the power supply
- Electrical requirements
- Environmental and mechanical requirements
- Safety
- Electrical equipment requirements
- Compatibility between ship and shore connection equipment
- Ship-to-shore connection and interface
- Plugs and socket-outlets
- Ship requirements
- Verification and testing

The diagram below provides an overview of the IEC/IEEE 80005-1 scope.

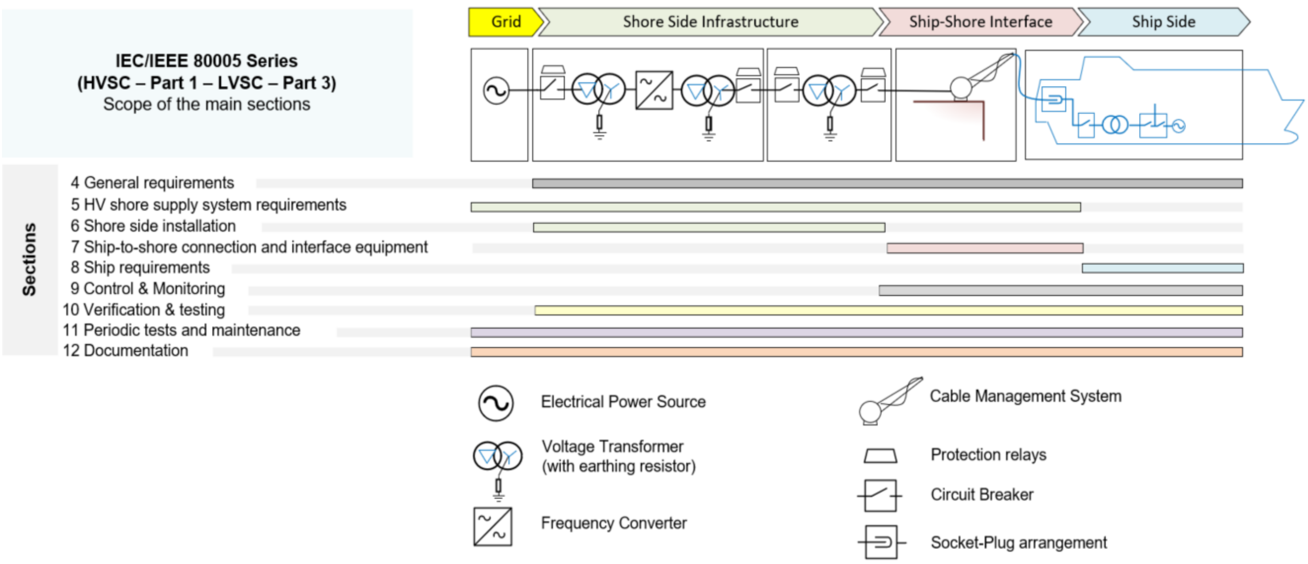


Figure 5.2 - Scope of IEC/IEEE 80005-1.

Source: EMSA

5.2.3 Standards for Battery Charging

Standardisation for interconnectivity and interoperability in SBC/ship battery charging has been referred to in section 5.2.1 as a gap to be addressed. There are in fact no standards for SBC at the date of 1st publication of this Guidance. For the sake of completeness, however, it is important to refer the framework for standardization based on existing electric ship charging. Figure 5.3, highlights the 3 main general references with respect to EV battery charging, covering supply stations, communication, and connector.

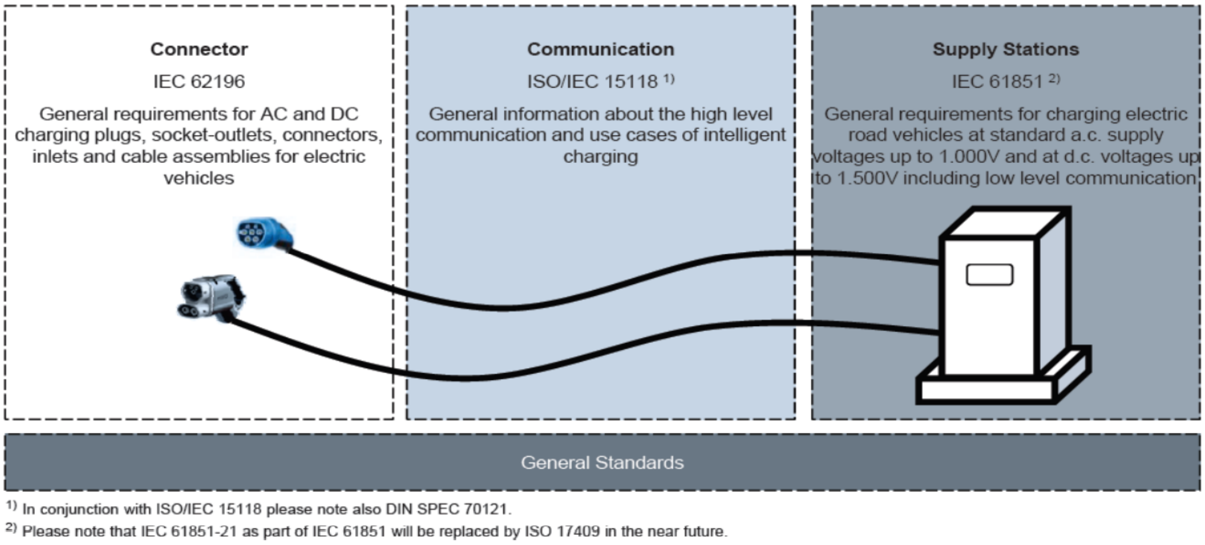


Figure 5.3 - General standards for battery charging.

Source: IEC

At first sight the applicability of the road EV charging standards would not be relevant to maritime applications due to the limited power rating for the connectors, especially in face of the high-power requirements for fast battery charging. It is nevertheless relevant to refer to this framework from a conceptual perspective, at least, for the definition of the time-steps associated to the shore-side battery charging process.

In Figure 5.4, the different standards are presented with correspondence to the different charging methods possible.

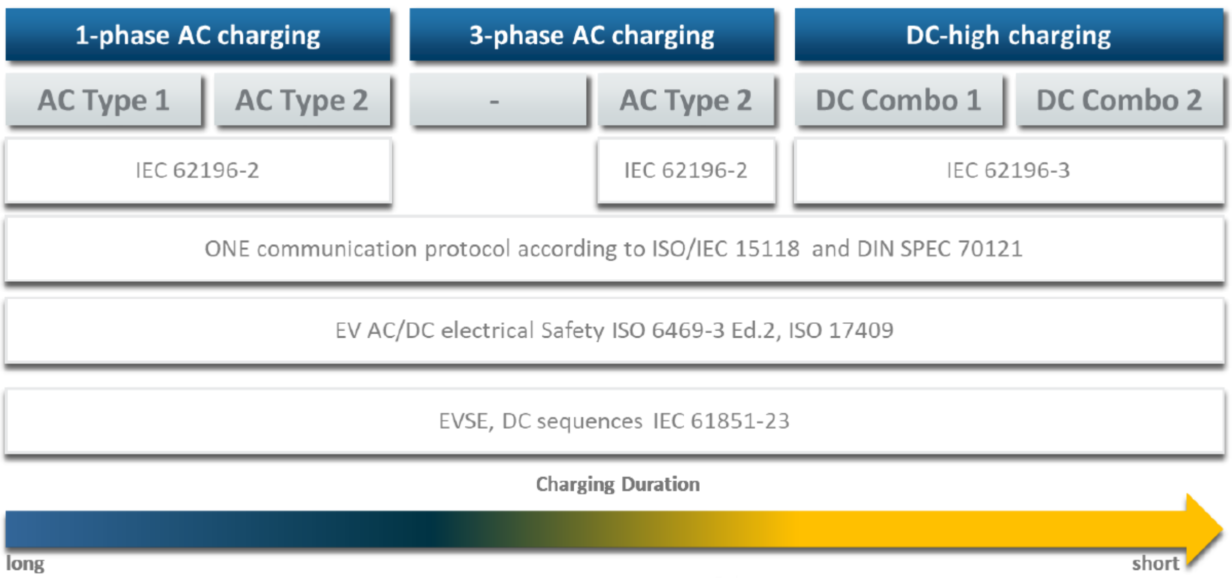


Figure 5.4 – General standards for battery charging – correspondence to charging method.

Source: IEC

The main limitation for the application of standard road EV battery charging lines and connectors is related to the limited power rating of the existing standards. CCS or other, of a few hundreds of kW. By increasing the standard to a value well above 3.5 MW, the MCS (Multi-MW Charging System) will address this barrier and, despite its direct applicability to heavy-duty trucks, it will offer also a potentially better application for small passenger ferries or other SBC applications.

Figure 5.5– Multi-MW Charging System (MCS) under development and under tests in laboratory. Designed to meet the needs of heavy-duty trucks.

Source: NREL

6. Responsibilities

The present section identifies the 1) different stakeholders involved in SSE projects and their roles, and 2) the main responsibilities that can be attributed to port authorities and administrations.

6.1 Stakeholders

Relevant Stakeholders can be identified playing a role in different stages of SSE infrastructure projects. These are presented below, in a non-exhaustive list. Central reference is made to the EU Regulation 2017/352 (Port Services Regulation), which includes within its scope the provision of shore-power in ports as a port service. Different combinations and port-specific arrangements are possible and both diagram and table below include generic references to possible stakeholders in SSE. Different port management arrangements are possible, being important to adapt/interpret the table/diagram below in due consideration for this fact.

Table 6.1 - Stakeholders (reference to Figure 6.1).

Stakeholders		Role in SSE context
TSO	Transmission System Operator	Transmission of electrical power at national/regional level, between generation plants (upstream) and distribution (downstream).
DSO	Distribution System Operator	Maintenance of both short- and long-term capability of equipment, installations, and networks to supply electricity in a continuous and reliable way while meeting the quality requirements in force.
CA/ **MBP**	(Port) Competent Authority/ Management Body of the Port	Ref. to Regulation 2017/352 - Port Services Regulation Articles 2(3) and 2(5) - organisation, administration, and management of the port infrastructure and one or more of the following tasks in the port concerned: the coordination and management of port traffic, the coordination and control of the activities of the operators.
RSO	Receiving Ship Operator	SSE Electricity ship consumer at berth, responsible to ensure interoperability and interconnectivity on the ship side. 1st connection certification and maintenance of conditions for connectivity. Responsible for keeping load.
OP	Intra-Port Operator	Port operators/port service operators responsible for maintenance of consumer side protection devices and electrical safety, in line with Intra-port electricity electrical grid requirements.
MG	Microgeneration	Any operator developing and operating units of microgeneration of electricity, integrated within the port, supplying electrical power to the port grid.
TO	Terminal Operator	Management and operation of terminal grids dedicated to the terminal operation. Development, management, and operation of terminal based SSE systems. Responsible for electrical safety of terminal grids.
PGO	Port Grid Operator	Management, development, and operation of intra-port electrical power grid, including SSE/OPS/SBS grid interface infrastructure.
EES	Electrical Energy Storage	Management, development, and operation of intra-port electrical power grid, including SSE/OPS/SBS grid interface infrastructure.
SSE OP	SSE Operator	Provision of electrical power to ships at berth, on OPS or SBC, AC or DC, including maintenance, development, and operation of SSE equipment
PSC	Port State Control	Verification/enforcement of compliance of RSO statutory obligations, remarkably in context of safety, including safety and certification of SSE equipment, onboard.
Flag	Flag State	
Class	Classification Society	Third-party verification of RSO statutory responsibilities, particularly in the context of safety, including SSE equipment safety certification.

Other	International Standardization Bodies	Definition of standard technical requirements for SSE interconnectivity and interoperability.
	Regulator/ Energy Competent Authority	Definition of minimum requirements to ensure safe and integrated deployment and operation by electrical power grid operators, including those in operation of SSE infrastructures.

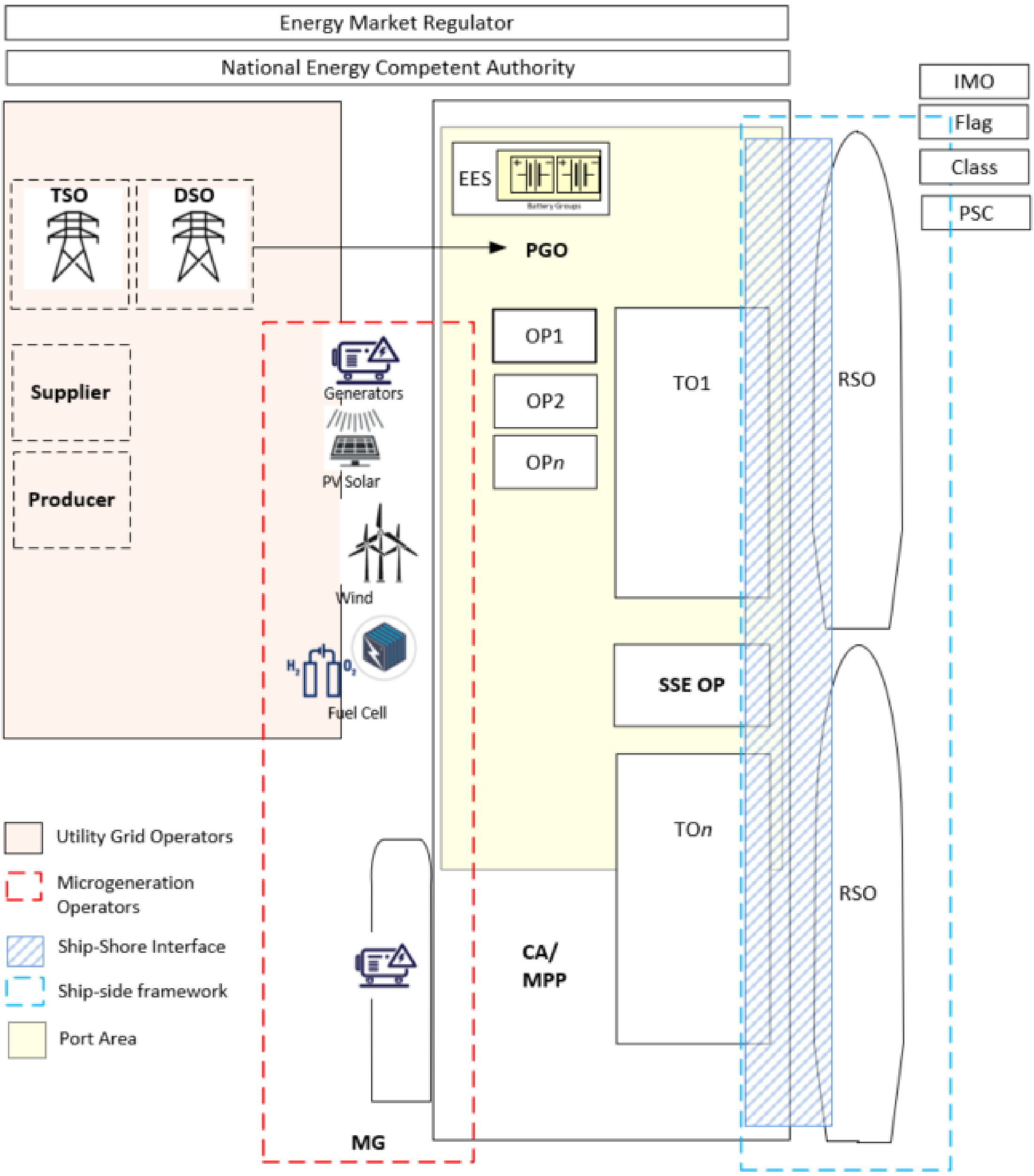


Figure 6.1 - Stakeholders in shore-side electricity context.

Source: EMSA

6.2 Port Roles and Responsibilities in SSE

Table 6.2, outlines the port's roles and responsibilities, in the context of SSE, integrating both "competent authority" and "administration" aspects and highlighting the challenges that should be met by PAA.

Port Authorities and Administrations (PAA) are here defined with reference to the definition of Competent Authority and Management Body of the Port - Ref. to Regulation 2017/352 - Port Services Regulation Articles 2(3) and 2(5) - organization, administration, and management of the port infrastructure and one or more of the following tasks in the port concerned: the coordination and management of port traffic, the coordination and control of the activities of the operators.

Table 6.2 - Port Authority and Port Administration roles and responsibilities in SSE.

	Port Role/Responsibility
Feasibility	**Participate and complement technical feasibility plans for SSE infrastructure** PAA should take an active role in the development or participation in feasibility projects for SSE infrastructure.
Power demand	**Estimation of power demand** Estimation of power demand is a critical element in the development of SSE infrastructure. See section 7.3.
Electricity – Access to Grid	**Define the model for development of access to grid** Decide whether the access is to be undertaken by the port or at 3rd party initiative. PAA should take a leading role in the contact with TSOs/DSOs, either assuming an active role or mediating.
Electricity – Distributed Production/ Microgeneration	**Develop a regulatory framework for OPS in the ports** Identify opportunities for distributed power production, in replacement or complementary to the utility grid supply.
Port rules	**Develop a regulatory framework for OPS in the ports** Safety and administrative rules with respect to the development, operation and maintenance of SSE systems should be included as part of the list of port rules. Ports should regulate at their level the development of the SSE projects and services.
SSE plans	**Publication of updated SSE availability plans (Good Practice)** This is presented as a good practice role/responsibility. The periodicity of the publication of such plan could be as applicable/adequate to each port context.
Restrictions	**Develop restrictions on SSE if necessary** Restrictions to the use of SSE should be developed considering grid behaviour specific elements (e.g. during high peak hours- with restriction on power available).
Compatibility	**Compatibility assessment** 1st Connections for ships calling for OPS will require a Compatibility Assessment (IEC/IEEE 80005). PAA should ensure that an adequate database is maintained where all OPS information is kept.
Safety/ Security zone	**Passive and active protection infrastructure for SSE** Definition of the necessary measures to mitigate the risk of damage/impact or other potentially affecting the integrity of SSE systems.
Security	**Definition of security zone around SSE infrastructure elements** Undertake this activity in coordination with ISPS security arrangements.
Communications	**Approve communications plan (operation and emergency)** Together with SSE operator and other stakeholders, PAA should ensure adequate communication plan is in place, both for normal operation and emergency.
Pass-by navigation	**Establish passing distances for other ships during SSE**

Mooring	Mooring requirements **Define requirements for mooring, taking into account the knowledge of passing by traffic or other factors to be considered. Mooring should be adequate to minimise relative motion of the ship.**
Checklist	**Implement procedure for active exchange and archive of SSE checklists** Implement checklists to assist procedures for 1) Request SSE service; 2) Prepare for connection; 3) Connection; 4) Disconnection. Ensure that SSE operator is supported by checklist procedures, effectively and adequately documented.
Spatial planning	**Support development and approve spatial planning and SSE locations** Develop spatial planning for the port area, taking into consideration the installation of main SSE infrastructure elements.
Traffic control	**Develop general procedures for traffic control (temporary or long-term/fixed)**
Organization	**Establish clarity on the roles/ responsibilities between the involved parties**
Safety	**Develop safety requirements** Ports should develop specific safety framework requirements, by referring to the relevant existing standards and IMO OPS Guidelines, mirroring at port level the necessary operational procedures for safe operation.
Emergency	**Emergency response plan (internal, external and training)** Ensure adequate preparedness for response in SSE emergency scenarios, in particular for: 1) Sustained Blackout; 2) Electrical Fire and 3) Electrical Shock/Arc – Emergency services (at port level or at local level) should be aware of the HV installation. Regular training of emergency response would be an important aspect to define.
Enforcement	**Build adequate enforcement capacity** PAA should be assisted with sufficient capacity to check and verify SSE installations – important to ensure that the necessary level of safety is in place.
Risk	**Risk acceptance criteria and develop systematic risk assessment capacity** PAA should develop capacity for risk assessment exercises with respect to SSE projects.
Accreditation	**Accreditation of the SSE SUPPLIER** PAA should be assisted with sufficient capacity to check and verify SSE installations.
Competencies	**Qualification of the port staff involved in SSE activities and evaluation of SSE plans and infrastructure**

7. Project Development

The present section refers to the central aspects related to the project development of SSE projects. The outline is focused on the engineering/technical feasibility and development, whereas financial, economic and social dimensions are not directly considered in this guidance."

7.1 OPS project dimensions for feasibility analysis

There are several distinct dimensions for an SSE project that need to be included into a feasibility study, as presented in the diagram in Figure 7.1.

A. Technical

- Concept design and engineering solution.
- Engineering development, approval, manufacturing, technical standards
- Optimization

B. Legal

- Regulatory framework for the proposed SSE solution.
- Regional/local/port rules
- Permitting
- Legal framework incentives

C. Operational

- Operational model.
- Ship demand Profile
- Operational resources
- Competencies and operational planning.

D. Market/Financial

- Demand evaluation
- Customized/tailored contract
- Electricity pricing and opportunities
- Competitors
- Market
- Financial evaluation

SSE Project - Feasibility

E. Economic

- Evaluation of economic cost-benefit.
- Impact assessment of SSE in port/local economic profile.

F. Social

- Social Acceptance for SSE solution.
- Social impact
- Public consultation

G. Safety

- Risk assessment for the proposed SSE solution.
- Mitigation of electrical risks
- Involvement of wider port community
- Integration of safety culture

H. Sustainability

- Environmental impact (comparison of onboard VS OPS emissions).
- Sustainability of the project.
- Socio-Economic-Environmental balance
- Impact on the sustainability profile for the port.

Figure 7.1– SSE project dimensions – feasibility analysis.

Aspects related to dimensions D, E, F and H are out of the scope of the present Guidance.

Source: EMSA

A complete feasibility analysis of SSE projects should be the analytical, qualitative and, where possible, quantitative, evaluation of proposed projects covering at least the dimensions presented in the diagram of Figure 7.1, all collectively contributing to the development and implementation of SSE projects and should be taken into consideration by PAA at the earliest possible moment from the presentation of the project.

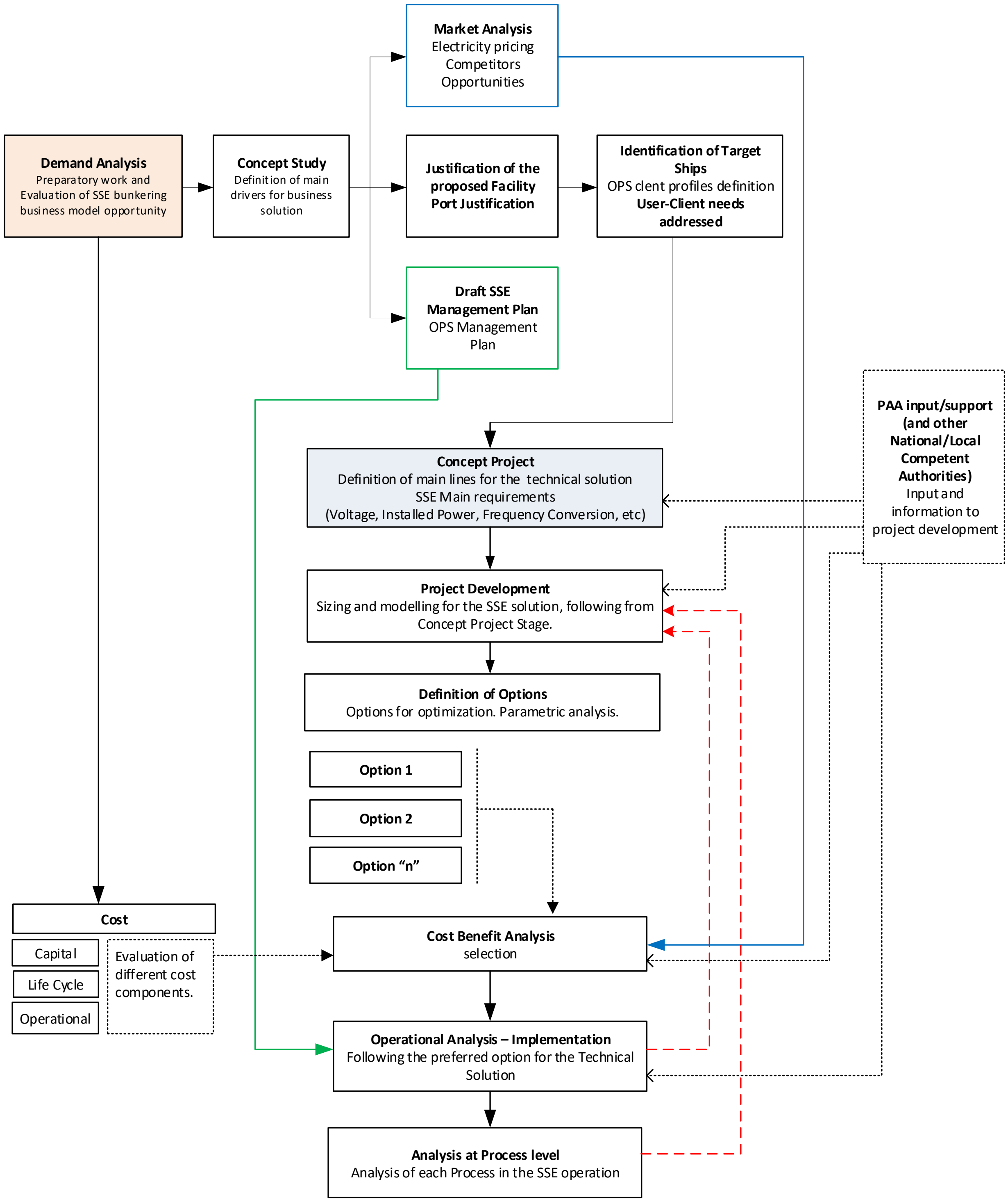


Figure 7.2 - SSE (OPS) project flow diagram.

Generic diagram representing the project development for SSE facilities, particularly for OPS, indicating the different points where PAA can support operators - involvement in different parts of the project will depend on the degree of involvement allowed by operators in advance to initiation of the permitting process.

Source: EMSA

Collaboration and integration are very likely to pay dividends to all parties even if it may be considered that commercial/industry sensitive information is sometimes not shared in advance. Information and transparency, together with non-disclosure agreements should be able to allow for the necessary early trust and engagement to be developed.

7.2 Elements for Feasibility Analysis

Following the different dimensions presented in Figure 7.1, defining SSE project dimensions, Table 7.1, lists some suggested elements that PAA may use not only in the support of feasibility analysis studies but also as a direct contribution to the feasibility prospects for any SSE project.

For each selected project dimension, the suggested elements indicate which aspects PAA may provide support with.

Table 7.1 - SSE projects – elements for feasibility analysis.

Project dimension (Figure 7.1)	**Elements for feasibility analysis** (elements that should be observed for feasibility analysis of SSE projects)	**Support from PAA** (elements where PAA support may have a direct impact in feasibility)
A. Technical	**Electricity source/availability** – distance to HV electricity source	• Mapping of existing SSE facilities, storage, and distribution infrastructure. • Facilitation in the development of the logistic chain.
	Communications – A variety of different options may be considered for communications during SSE.	• Communications are an important element for technical feasibility analysis, particularly with regards to the necessary communication channels for operational aspects such as authorization procedures. • Radio frequencies, encrypted data, digital, web-based communications, SATCOM, emergency communication, and any other technical aspects relevant for the technical/operational feasibility of the project. • PAA should make available all possible options for communications' planning within the context of any prospective SSE facility project. • An important aspect to consider is the interoperability of systems and, in the particular case of emergency, the possibility to have communication channels shared by the wider multi-operator community in the port area.
	Standardization – Are the different SSE solution elements to be certified according to relevant international standards?	• A key rule in the context of certification for a prospective SSE facility will be standardization. • PAA should consider the identification of standardization elements as positive aspects towards feasibility of a given SSE project. • The relevant standards for SSE facilities and operations are listed and summarized in Section 0 underlining suggest good practice in the reference to these standards. • PAA should make clear reference to the relevant standards for SSE in their requirements for certification of SSE facilities. Legally binding requirements for standardization must be inscribed either in national legislation of port-specific regulations.
	Certification – will the SSE facility proposed meet all the requirements for certification?	• PAA should adopt structured certification schemes for SSE projects and operations. With guidance for certification, referring to specific standards it will be, in principle, easier to assess the feasibility for a prospective project.
	Technical Maturity of the proposed project – Has the solution presented for implementation been tested in operation before? For how long? For solutions that have already been implemented, prospective SSE projects should	• For solutions that have already been implemented it is important to check for evidence and elements of reference projects. • For new technology elements, to support technical maturity for a prospective SSE project PAA can, as appropriate, establish connection points with other

Project dimension (Figure 7.1)	Elements for feasibility analysis (elements that should be observed for feasibility analysis of SSE projects)	Support from PAA (elements where PAA support may have a direct impact in feasibility)
	provide as many elements as necessary to support in the evaluation of their technical feasibility.	ports and initiatives, seeking for any possibility of technology transfer. • In the case of public funded projects, it should be possible for prospective SSE initiatives to get information and demonstrated results which belong partially[6] to the public domain. PAA may play an important role in the dissemination and availability of these results, establishing the link with the public funding competent authorities.
	Automation – What is the degree of automation in the proposed SSE solution? Is supervision considered?	• Automation elements may be present in some SSE projects. The degree of automation, however, will inevitably be different from project to project, with SSE via rigid/automated arms being likely to incorporate elements of automation for reduced human intervention. • It is important, in this context, that PAA may define what the minimum requirements are for manning of SSE installations, even in the case where full automation is considered. • Any automated elements in SSE solutions must be provided for with manual over-ride options that allow for manned operation.
B. Legal	**National legislation** – What are the applicable legislative references to the proposed SSE solution? Consideration to be made to any legal requirements for the use of OPS. **Port regulations** – Are any specific requirements for SSE inscribed in the port regulations?	• PAA should, as appropriate and reasonably possible, provide an information package to prospective SSE operators including all legal references that may be relevant for the definition of the concept project, supporting from an early stage in the definition of a feasible solution. • In the case of early consultation by prospective SSE supplier/operators, PAA should assess any specific details of the proposed SSE project and provide the relevant legal references applicable to that case. • From the early evaluation of the proposed project, along with the relevant legal references, PAA may issue a first indication regarding the feasibility for the presented solution.
	Permitting – Are all steps for permitting being observed? Permitting can represent a significantly burdensome process if all aspects are not accounted for in a preliminary phase. Feasibility of any SSE projects should address, in advance, all different parts of the permitting process to ensure that no major obstacles are posed to the good realization of the project.	• Provide operators with all the relevant elements for permitting, making them available in a transparent and informative manner. • Assuming the position of a “facilitator” in the permitting process, PAA should provide operators with the relevant mapping and points of contact for the different parts of the permitting process. • The establishment of a “single-desk” approach, where all relevant permits could be initiated and monitored, would be a highly relevant initiative. One of the main factors of success for such measure would be the level of collaboration between different competent authorities.
C. Operational	**Operational Restrictions**. The adequate design of operations should consider any restrictions possible/likely to be imposed by any given PAA.	• Operational restrictions should be clearly expressed in port regulations. • In addition, as a way to support the feasibility of prospective SSE projects, PAA should also consider alternative options, possibly risk-based, where excursions beyond the operational restrictions would be possible.

<table>
<tr><th>Project dimension
(Figure 7.1)</th><th>Elements for feasibility analysis
(elements that should be observed for feasibility analysis of SSE projects)</th><th>Support from PAA
(elements where PAA support may have a direct impact in feasibility)</th></tr>
<tr><td></td><td>Operational Envelopes. Similarly to the operational restrictions, the feasibility analysis of SSE projects should consider the operational envelopes imposed by possible local weather restrictions (wind/ temperature/ other)</td><td>Provide information to operators on local conditions that may result in operational envelopes to be accounted for in SSE operations.
Inform on the local characteristic weather patterns, with local weather office data for a typical year-round chart (wind, temperature)
Make available to operators all operational information found relevant to the feasibility analysis of new SSE projects.
PAA should also consider alternative options, possibly risk-based, where excursions beyond the operational envelope restrictions/limitations would be possible. Justification to be presented based on specific risk assessment.</td></tr>
<tr><td><u>D. Market/ Financial</u></td><td colspan="2">Aspect not considered within the scope of the present Guidance document.</td></tr>
<tr><td><u>E. Economical</u></td><td colspan="2">Aspect not considered within the scope of the present Guidance document.</td></tr>
<tr><td><u>F. Social</u></td><td colspan="2">Aspect not considered within the scope of the present Guidance document.</td></tr>
<tr><td><u>G. Safety</u></td><td>Risk Assessment. The evaluation of risk for an SSE project is likely to be the most relevant document to be used not only for permitting but also, especially in the initial stages of concept or project development, an important tool to reassess the concept or project in itself.

Risk assessment is more likely to introduce modification into the proposed solution than to deem it to a negative feasibility prospect. It will be able to introduce elements which can then be used to detail the engineering solution, inclusive of any identified necessary safeguards to improve the evaluated safety risk level for the proposed project.

Assessment of risk will be made either following a quantitative or qualitative approach. In both cases there are elements that can be considered <u>fundamental drivers for an adequate feasibility evaluation</u> derived from a risk assessment:
Adequate representation of the SSE facility and operation in the risk assessment.
HAZID team composition (experience, proven competency, number of participants)
Number of different risk case scenarios considered (including the complete scope of operations).</td><td>Risk Criteria - PAA must clearly define risk criteria wherever Quantitative Risk Assessment is required.

There must be a clear understanding, promoted by PAA, that the usefulness of QRAs is only best explored with SSE risk criteria.

In the absence of national framework for such risk criteria, ISO/TS 18683:2015 suggested risk criteria example (Annex-A) should be taken as the biding reference.
Participate in HAZID workshops. Participation in HAZID workshops for prospective SSE projects will give PAA the possibility to support operators in the definition of risk scenarios, underlining the most critical situations and supporting, through the drafting of relevant safeguards, the project feasibility.
Data on Incidents and near-misses related to bunkering, eventually held by PAA, should be used to draft recommendations or specific requirements for PAA, improving in this way the feasibility prospects for the project.
Should the HAZID represent the first step before the development of more thorough risk assessment (QualRA or QRA), PAA should take the opportunity of participation to provide elements considered relevant for feasibility.
Involvement of third-party risk evaluation professionals should be regarded positively by PAA, as an indication of transparency in the risk study/assessment process.

For prospective SSE projects PAA should underline the need for independent risk study (at least as much as reasonably possible). In this regard “independency” is to be understood as a good guarantee for feasibility of the prospective SSE project.</td></tr>
</table>

Project dimension (Figure 7.1)	**Elements for feasibility analysis** (elements that should be observed for feasibility analysis of SSE projects)	**Support from PAA** (elements where PAA support may have a direct impact in feasibility)
	Safety Distances/Control Zones. One of the direct results of risk assessment will be the definition of the safety zone and additional control zones (such as the security zone or navigation exclusion zone). Focusing primarily on the Safety Zone it is important to evaluate if the intended location, adjacent infrastructure, and proposed safety distance are compatible. If not entirely possible to eliminate potential ignition sources, gas trapping spots and conflicting activities, within the proposed Safety Zone, the feasibility of the project will be inevitably affected. <u>This should be subject to continuous review.</u> Since the Safety Zone, by definition, should encompass the elimination of potential ignition sources and other activities/ operations inside the defined zone, it will be important to ensure that no conflicts arise.	• As a first principle in the interpretation of proposed safety distances PAA should consider that no safety distance is the “right” safety distance. • PAA should provide support with the indication of any baseline minimum required safety distances for SSE, underlining the concept of meaningful protection. • Feasibility analysis, based on suggested safety distances, should be based on the evaluation of meaningful protection for persons and infrastructure. • Dispersion studies should be regarded as a good indication on positive risk feasibility, resulting, in principle, in the definition of more realistic safety distances, based in numeric gas dispersion calculations. • Assumptions used in all numeric/computational gas dispersion calculations should be assessed by PAA as indicators on how accurate is modelling of local conditions
<u>**H. Sustainability**</u>	Aspect not considered within the scope of the present Guidance document.	

All elements from the table above should be addressed in the context of the desired earliest involvement of PAA in the feasibility discussion of prospective SSE projects. This may not always be possible, and SSE proposed solutions may be presented in a stage of development such that less flexibility to accommodate proposed recommendations may become a problem in the permitting and/or implementation stages. PAA have here an opportunity to engage early, participate and through collaborative support be able to potentiate the SSE project as a port service adding value to a specific port economy profile.

7.3 Power demand

7.3.1 Power demand estimation

The present section includes guidance for power demand calculations.

Power demand estimation is an important task that should take part in two moments of the SSE life cycle plan:

1. Initial design
2. In-operation

Whilst the **initial design** power demand estimation is relevant for the whole SSE system and component sizing, with a view to define required installed power, the **in-operation** power demand is variable and a function of daily activity.

Table 7.2 - SSE projects – Power demand estimation strategies.

Power Demand Estimation Strategies			
Initial Design	Identification of port call history associated with survey/actual measurement of the energy used at berth (fuel consumption per hour) IDEAL	Identification of port call history associated with Information on estimated specific fuel consumption: Info on powerplant installed onboard POSSIBLE	Reference to IEC/IEEE 80005 Annexes indicative power demand by ship type LEAST PREFERRED
In-Operation	Normal operation Power demand < Installed power Managed Operation Power demand > Installed power POSSIBLE	Restrictions to power usage based on identification of individual ship operating profile LEAST PREFERRED	Power management assisted by artificial intelligence in stochastic process approach Machine learning for power management IDEAL

In Figure 7.3 a diagram is presented with a procedure for energy/fuel consumption-based calculations. The process requires detailed survey of fuel consumption from a selected group of representative ship types to allow for the calculation of actual energy consumption, determination of the power demand and load duration curves.

ESTIMATING SSE INSTALED POWER

Step 1 – Identify Ships at berth for SSE

Identify the number and characteristics of ships to connect to SSE taking into account:
- Ship Type
- Gross Tonnage
- Berthing locations
- Requests for OPS operation from ships
- Preliminary agreements with Operators with a view to develop SSE/OPS.

FINAL RESULT from Step 1:
- Identification of the TYPE and NUMBER of ships to consider for SSE/OPS development on a GIVEN LOCATION (terminal/ berth)

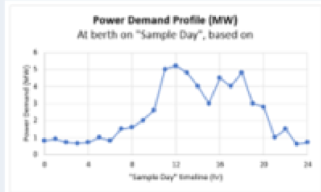
Step 2 – Gather data from operating profile at berth

Data form Operating Profile at berth includes: Energy Consumption at berth, on an hourly basis (fuel or electrical energy consumption)
The following methods can be used:
1. Target surveys for fuel consumption at berth (on a selected universe of ships)
2. Using measured fuel consumption data, when made available.
3. Available Performance Records for individual ships.

FINAL RESULT from Step 2:
- Structured data for ENERGY CONSUMPTION at berth, for individual ships, over a defined period of time (ton of fuel consumption/ hour)

Step 3 – Power Demand Curves

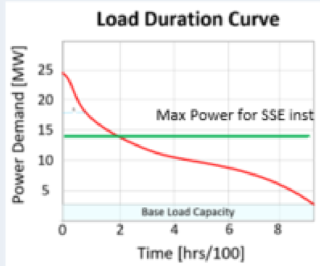
With the set of ships identified (**Step 1**) and with the energy consumption at berth, consumed per hour by individual ships (**Step 2**), develop a distribution of the power Demand in relation to a selected time scale of observation.
In the diagram below it is possible to see this power demand distribution for one ship during 24hrs.



FINAL RESULT from Step 3:
- Identification of the POWER DEMAND curves for the different ships calling at that port, under the survey/analysis.

Step 4 – Load Duration Curve

With the information from all ships at berth over a given observation period it is possible to develop the Load Duration Curves for the intended ships in observation.



FINAL RESULT from Step 4:
- Plotting of the LOAD DURATION CURVE for the port, over a well defined duration of time.
Determination of how long/ concentrated is peak demand.

Step 5 – Determine Design Factors

At this stage it is important to determine at which point should the **green** line in Step 4 should be located.
In order to assist the decision on the installed power to project for a given SSE installation it is important to determine the relevant Design Factors.
These will allow to understand that in the majority of the cases the maximum power to install is not the sum of max power demand from ships at berth.
The following factor must be determined:
1. Power Demand Factor
2. Diversity Factor/ Simultaneity Factor (ks)
3. Load Factor
4. Utilization Factor (ku)

FINAL RESULT from Step 5:
- Determination of the maximum design power for the SSE installation

Figure 7.3 – Estimation of installed power demand in SSE projects.

Source: EMSA

Expedite calculations are possible, based on either hourly averaging o fuel consumption for ships at berth or, alternatively, based on information on installed auxiliary/power production plant

Examples of simplified calculations for power demand (for individual ship) based on fuel consumption information (OPTION 1 – Survey based, OPTION 2 – Engine consumption info) are in Table 7.3.

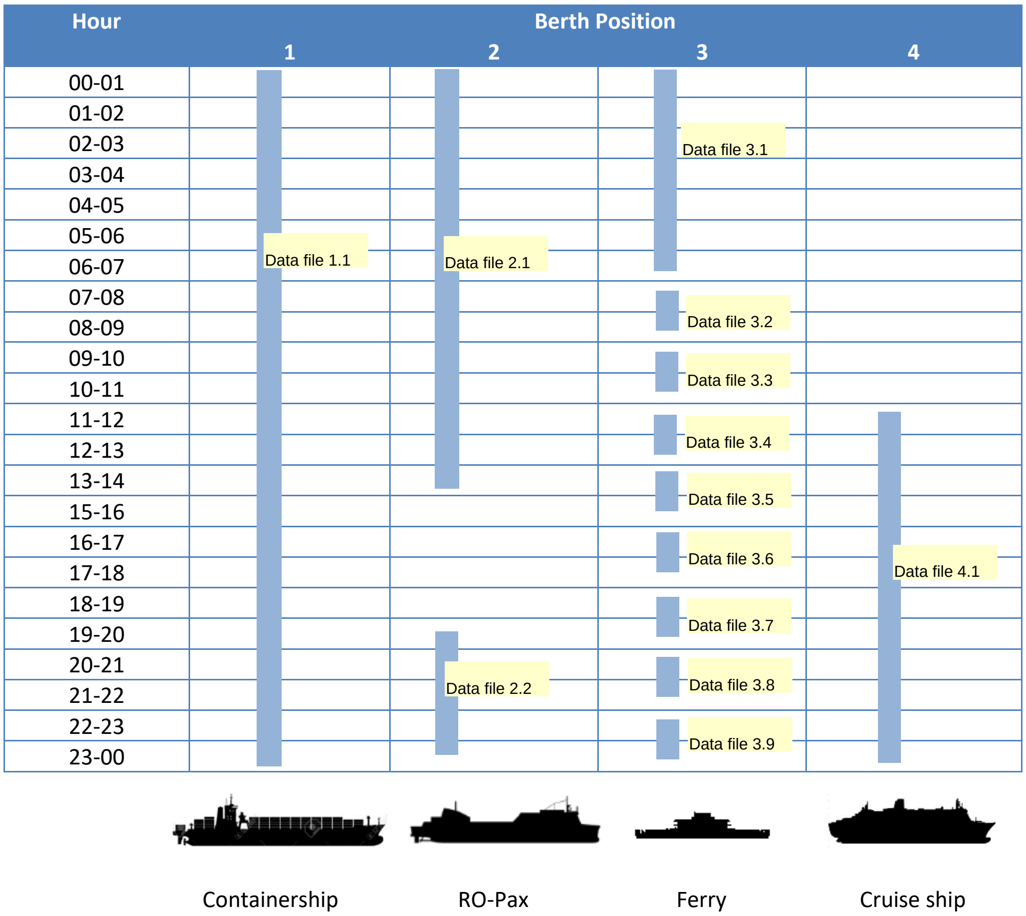
Table 7.3 - Power demand calculation example.

Step	Calculation	
1. Fuel consumption data	**OPTION 1** Survey/ actual measurement: - Selected reporting of fuel consumption at berth (**ton_fuel**) over a given period of time: Example: - Containership reported consumption of **2.5 ton** of MGO over a period of 24 h - Fuel consumption: **105 kg/h**	**OPTION 2** Information on estimated specific fuel consumption: - Info on powerplant installed onboard Example: - Containership known to have an installed group of 3 gensets of 1000 kW each. 1 generator at half load - Fuel consumption: **125 kg/h** Note: From literature, average consumptions: Generator 1000kW (average consumption MDO) 25% load = 75kg/hr 50% load = 125kg/hr 75% load = 175kg/hr 100% load = 240kg/hr
2. Conversion to energy	Low calorific value/ energy content (kJ/kg) for MDO: **44.1 kJ/g** Example: - Fuel consumption: **105 kg/h** - Energy consumption (kJ/hr): **4,630,500 kJ/h**	
3. Conversion to power	1 kJ = 0.000277777778 kWh Engine thermal efficiency av. 50% Example: - Energy consumption (kJ/hr): **4,630,500 kJ/hr** - Energy consumption (kWh): **1,286.3 kWh** - (shaft) power (kW): **1,286.3 kW x 0.5 = 643 kW**	
4. Factor for peak consumption	When calculating power demand based on fuel (energy) consumption the result will be an averaged based power figure. This may not be sufficient to cope with momentary or short-termed peak consumption. Each ship type will have a different peak factor which should be considered when designing shore-power infrastructure. It may be a design decision to be taken together with operators whether to design for average or peak (or any design point in between). Example: - Considering a containership operating profile, the need to account for peak consumption may be high, depending on the number of reefers. - For example: peak factor **1.5** - **Peak power: 643 kW x 1.5 = 96 4kW** - Rounding up: 1,000 kW = **1 MW** (real power)	

Step	Calculation
5. Power factor	Due to typical inductive load by pumps and compressors onboard a power factor between 0.8 (conservative) and 0.9 should be considered. Example: Calculation of Apparent Power: - (design) Power Factor = 0.8 - Power (apparent) = **Power/0.8 = 1.25MVA**
5. Final result (design order)	Should be listed: - Power (apparent) - Power factor used for design - Voltage (440, 690, 6,600 or 11,000 kV) - Frequency

Below, another practical example shows a daily port call information for different ships using SSE from the same port grid installation. Total power demand histogram is produced highlighting overall peak demand for the period when most ships are simultaneously at berth.

Table 7.4 - SSE projects – Power demand estimation for multiple ships/port calls.



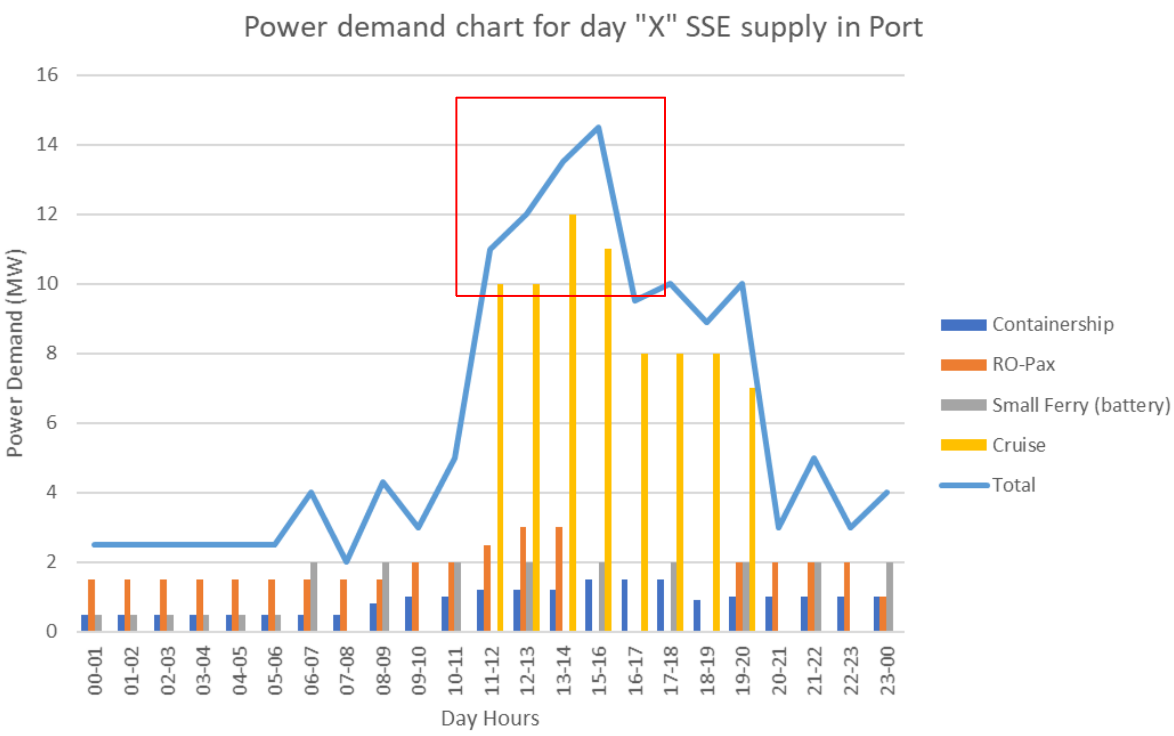


Figure 7.4 - Power demand estimation for multiple ships/port calls.

Source: EMSA

A possibility to cope with the power demand would be to make use of energy storage/ power banking connected to the port SSE infrastructure. A cost-benefit calculation, in the context of initial feasibility studies, should be able to identify the opportunities for peak shaving, load levelling/compensation strategies in the context of installed power sizing/estimations.

Challenges to power demand estimation are, as presented above, to be taken in consideration both during the planning phase and in operation. Multiple ships at berth, at the same terminal or distributed across different terminal will require form the grid a variable amount of power, mainly as a function of the operational activity of the ship at berth (hotel + services).

Whilst Table 7.4 and Figure 7.4 present an example for illustration, Figure 7.5 and Figure 7.6 show a power demand curve histogram for a yearly record, considering maximum power demand from ships at berth, considering record of hourly energy consumption.

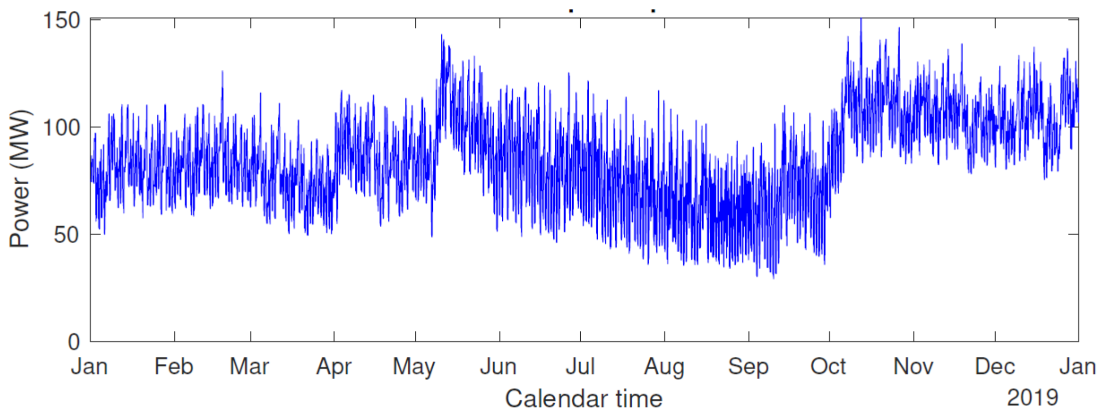


Figure 7.5 - Power demand record ships/port calls.

Source: EMSA

Figure 7.6, built from the power demand curve for containerships and passenger ships, over one year, presents the Load Duration Curve for the respective ships in one port, superimposed to compare the difference between load duration profile.

Whilst passenger ships consume large amount of power at berth, they have a peak load duration which is relatively limited.

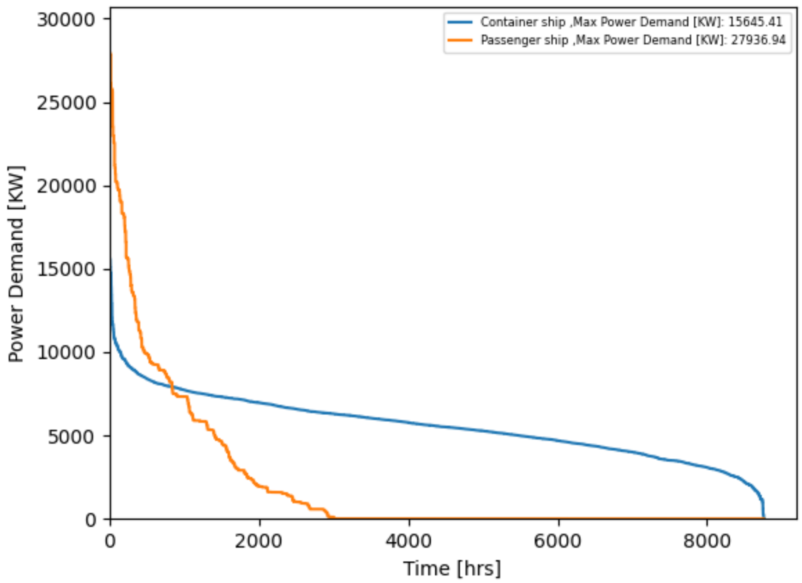


Figure 7.6 - Power Demand estimation for multiple ships/port calls.

Source: NTUA

7.3.2 Measures to Reduce Power Demand Unpredictability

The following measures should be taken into consideration by PAA in order to reduce the unpredictability associated to power demand from ships at berth:

- Apply energy survey-based power demand estimation, including a representative set of port calls in advance to the SSE design phase
- Confirm with representative ships their operating profile at berth, making use of questionnaires and taking into consideration the approved electric load balance of the different ships, for reference maximum electrical power demand at berth.
- Build power demand curves and load duration curves for the different representative ships.
- Decide on design factors (diversity factor/ simultaneity factor) based on documented exchange with operators.
- Apply power allocation to specific ships, with maximum power allocation associated to the compatibility assessment file.

7.4 Ship-specific considerations

The present section includes several ship-specific aspects of primary relevance for planning SSE infrastructure, including design requirements at ship level and port call activity.

The feasibility of OPS for different ships will have different factors to take into consideration as indicated in the table below:

Table 7.5 - OPS assessment elements.

<table>
<tr><th colspan="2">Ship-specific assessment elements for OPS</th></tr>
<tr><td>Power demand at berth</td><td>Power requirements (or peak load requirements) may represent a challenge for OPS option for larger and more power critical ships, requiring for higher power supply at berth.

Not only the average power is important but, remarkably, also the peak power requirements, often associated to the operation of heavy-duty equipment onboard, such as cranes, 3 phase engine start-up and other equipment.

Higher power demanding ships are best served by High-Voltage Shore Connections (HVSC). However, the availability of HVSC is currently limited to ports which have more recently developed OPS for ships with higher power requirements. HVSC of 6.6 kV up to 11 kV is made available and, for ships operating between ports with different voltage supply, there is the need to consider installation of OPS transforming units, a cost incurred in CAPEX investment figures.</td></tr>
<tr><td>Operating profile at berth</td><td>Use of energy/power intensive equipment. The average and peak power demand for operations at berth may in some cases affect the feasibility of OPS.

For assessment of peak power demand there are 2 different types of peaks to consider which may affect the feasibility of OPS:
1. <u>Transient peak</u>: Current increase over a very short peak time window (typically in the order of very few seconds
Transient peaks require engineering aspects to be in place (such as adequate circuit-breakers and 3-phase electric motors soft starters) in order to smoothen the start-up of heavy-duty electrical equipment.
2. <u>Consumption peak</u>: Sustained consumption level over a period of time, associated with a period of higher electrical consumption demand.
Consumption peak periods are especially relevant to address when assessing the impact of OPEX for OPS.
High power consumption periods should be subject to special consideration in the context of electricity supply contracts, with tariffs applied adjusted in particular situations.</td></tr>
<tr><td>Time at berth</td><td>Some ships, as part of their operational profile, spend limited time at berth. OPS connection/disconnection may represent a large share of the time at berth leading to reduced feasibility and cost-benefit for OPS.

The time at berth and its predictability will largely depend on the ship operational profile and whether it is engaged in regular traffic. Time at berth is important for operations but tends to be minimized in a context of OPEX optimization, for all ship types.

Average time for connection of OPS is:
• Blackout connection (total power by OPS): 30min, including handling of cabling, connection, frequency adjustment, safety checks
• Parallel connection (power shared onboard + OPS): 30min + 15min stabilization
• Fully automated: 10 min

Given that for ships engaged in regular traffic, under normal conditions, the average period at berth ranges from approximately 1 day up to 3 days, the time for connection of shore-power can be neglected.</td></tr>
</table>

Ship-specific assessment elements for OPS	
Safety	Safety aspects, and the need to mitigate certain safety risks during operations at berth may impose restrictions to the adoption of OPS by some ship types (such as tankers or LNG carriers). From an engineering perspective there may be even the possibility to develop solutions that can be demonstrated as safe, as may demonstrated by a Risk Assessment. The cost-benefit of such solutions may however deem such options as unfeasible. In the case of safety or hazardous areas in the ship-shore interface, careful consideration must be given to OPS feasibility, especially if explosion mitigation measures/ ignition prevention leads to OPS concepts with unacceptable CAPEX in result of EX-proof components. Another safety aspect to consider, contributing to the evaluation of OPS feasibility, is the need for onboard readiness of incident response systems, such as firefighting equipment and other emergency systems, which full availability is required in a context of handling hazardous cargo, either in bulk or parcel.
Security	Security sensitive operations may deem OPS unfeasible for different ships types. Energy security may need to be considered on the ship side, especially in case of more sensitive operations in cargo load-on/load-off (such as heavy lift cargo)- or passenger embarkation/ disembarkation. Security related aspects will also need to take into consideration the Operation Profile of the ship, especially the ports called and local ISPS requirements for the type of ship, cargo and operation intended. Port facility security plans need to be taken into consideration.
Cost	Despite being technically feasible, the conversion CAPEX cost for some ships may deem the installation more challenging from an economic perspective. This however may significantly change in view of possible future fuel price developments and increased regulatory certainty. Furthermore, an important aspect to consider with regards to Cost, is the need to assess the adequate framework for the Cost Benefit Analysis (CBA) and, in particular, how external costs are quantified. CBA OPS projects need an adequate framework for the assessment and quantification of economic and social costs/benefits.

It is important to make the note that the elements selected for feasibility of OPS shipboard installations do not include elements of connectivity (such as voltage, frequency, standard connectors).

Table 7.6, spread over the next pages, includes a colour code, and comments, for feasibility of OPS in different ship types, taking only into account ship specific considerations. The coloured cells highlight the criticality of the different aspects for feasibility of OPS for the selected ships types (‘Red, ‘Yellow’, ‘Green’, for ‘High’, ‘Moderate’, ‘Low’, respectively)

Table 7.6 - OPS for different ship types.

Type of vessel	Power demand at berth	Operating profile at berth	Average time at berth	Safety	Security	Cost
Cruise ships	**High** power and energy demand with large hotel load requirements at berth Main driving loads at berth: 1) hoteling; 2) onboard Services; 3) maintenance	Power demand variations but with **low** peak power requirements **Low** transient and consumption peak variations	**≈ 1 day**	**Moderate** criticality Emergency response load may be granted by onboard stand-by generator In some specific cases it is possible to have OPS in parallel with onboard generators, giving the possibility to have 1) power distribution and 2) emergency readiness	**Not critical** Largely depending on local-specific security restrictions	**High** cost If not already fitted of "OPS ready" Main drivers: Power, switchboard, HV transformer(s) onboard, converter if needed and integration arrangements)
Container ships	**Moderate** power requirements at berth moderate and Main driving loads at berth: 1) crane operations (if fitted – geared ships) and 2) number of refrigerated containers	Operating profile may contain **several moderate-to-high power peaks** **High** transient peak variation **Moderate** consumption peak variation In absolute terms the power peaks will be related to crane operation, reefer units and ballast/deballasting operation.	**1 day**	**Not critical**	**Not critical** Largely depending on local-specific security **May be critical if hazardous substances are handled**	**Moderate** conversion cost Main drivers: Power, switchboard and cable reel, HV transformer(s), converter if needed Typically, containerized unit fitted in one 40ft container slot space – modularization
RO-Pax	**Moderate-to-high** power requirements at berth Main driving loads at berth: 1) hoteling load (in particular for RO-Pax with large commercial and restaurant facilities); 2) cargo rolling/support platforms such as movable (hanging) decks	**Moderate** peak requirements **Moderate** transient peak variation **Low** consumption peak variation Power peaks will be related to cargo deck operations, hoteling and services, reefer units	**6 to 12 h**	**Moderate** criticality Emergency response load may be granted by onboard stand-by generator	**Moderate** criticality During embarking/ disembarking operations	**Moderate** cost If not already fitted of "OPS ready" Main drivers: Power, switchboard, HV transformer(s) onboard (converter typically not required as routes are not trans-oceanic) Can use cargo/ship deck space for retrofit with OPS power modular unit

Table 7.6 - OPS for different ship types.

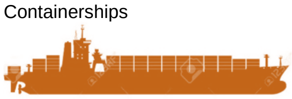
Type of vessel	Power demand at berth	Operating profile at berth	Average time at berth	Safety	Security	Cost
RO-RO, Car carriers	**Low-to-moderate** power requirements at berth Main driving loads at berth: 1) cargo rolling/support platforms such as movable (hanging) decks - particularly for PCC (Pure Car Carriers)/ ship carriers. 2) reefer units if fitted (RO-RO)	**Low-to-moderate** peak requirements **Moderate** transient peak variation **Low** consumption peak variation Power peaks will be related to cargo deck operations	**1 day (2 days for PCCs)**	**Not critical**	**Not critical**	**Moderate** cost If not already fitted of “OPS ready” Main drivers: Power, switchboard, HV transformer(s) onboard (may require converter) Can use cargo/ship deck space for retrofit with OPS power modular unit
General Cargo/ Break-Bulk	**Moderate** power requirements at berth Main driving loads at berth: 1) cranes/geared lift-on/ lift-off operations. 2) ballast/deballasting operations in conjunction with LO-LO operations	**Moderate** peak requirements **Moderate** transient peak variation **Low** consumption peak variation Power peaks will be related to cargo deck operations	**1.5 days**	**Not critical**	**Not critical**	**Low-to-moderate** cost If not already fitted of “OPS ready” Main drivers: Power, switchboard, HV transformer(s) onboard if needed
Bulk (Dry Bulk)	**Low** power requirements at berth Main driving loads at berth: 1) ballast/deballasting operation. 2) reefer units if fitted (RO-RO)	**Low-to-Moderate** peak requirements **Moderate** transient peak variation **Low** consumption peak variation Power peaks will be related to cargo deck operations	**2 to 3 days**	**Not critical**	**Not critical**	**Low-to-moderate** cost If not already fitted of “OPS ready” Main drivers: Power, switchboard, HV transformer(s) onboard if needed
Chemical/ Product Tankers	**Moderate-to-high** power requirements at berth Main driving loads at berth: 1) cargo pumping operations. 2) heating/cooling (as applicable to the cargo) 3) inert gas generation (if required)	**Operating profile will be strongly dependent on the type of cargo loading/offloading requirements** Heating/cooling may apply depending on the type of cargo	**1 to 2 days**	**Safety critical**	**Security critical**	**Moderate** cost Typically, available main deck space for modular OPS equipment Cost may rise if Ex-proof protection for OPS station onboard is required

Table 7.6 - OPS for different ship types.

Type of vessel	Power demand at berth	Operating profile at berth	Average time at berth	Safety	Security	Cost
		Inert gas generators may induce relevant peaks, when fitted.				IEC/IEEE 80051/1 (2019) includes relevant requirements specific for tankers.
Tankers (crude oil)	**High** power requirements at berth Main driving loads at berth: 1) cargo pumping operations. 2) heating cargo 3) inerting (Note: the large majority of heavy-duty equipment onboard oil tankers is powered by steam generated in oil fired boilers – the energy production and distribution has therefore no electrical distribution phase that could be made to allow for shore-power intake)	**High** peak requirements **High** transient peak variation **Low** consumption peak variation**.** Power peaks will be related to cargo deck operations (Note: peak requirements based on load profile if electrical equipment would be installed in replacement of steam)	**3 to 4 days**	**Safety critical**	**Security critical**	**High** conversion cost accounting for high power requirement – high voltage transforming requirements – high current cabling (NOTE: cost of converting tank heating to electric (very high) and that at sea steam tank heating using waste heat recovery is very efficient Cost of conversion for oil/ crude oil tankers is very likely to deem unfeasible OPS for such ships. IEC/IEEE 80051/1 (2019) includes relevant requirements specific for tankers.
LNG carriers	**High** power requirements at berth For loading: Onboard energy required for 1) cooling by nitrogen, 2) full inerting of tanks and lines, 3) filling sequence with bottom/top filling by onboard compressors; 4) boil-off re-liquefaction For unloading: Onboard energy required for 1) pumping and recirculation for temperature and pressure maintenance; 2) re-liquefaction of vapour return; 3) nitrogen punch for purging lines and, finally 4) inerting of lines and tanks	**Moderate** peak requirements **Moderate** transient peak variation **Low** consumption peak variation**.** Power peaks will be related to cargo deck operations	**2 to 3 days**	**Safety critical**	**Security critical**	**High** conversion cost IEC/IEEE 80051/1 (2019) includes relevant requirements specific for LNG carriers.

When it comes to power requirements at berth, it is possible to extract from available literature the estimated average power requirements by ship type – peak power indication is based on the assessment of different ship-specific operating profiles, also available in the listed references.

Table 7.7 - OPS typical requirements and standards for different ship types.

Ship Type	GT	Voltage (kV)	Power Demand Average (Peak), MW	IEC/IEEE Standards (Operability); Connectivity LVSC	IEC/IEEE Standards (Operability); Connectivity HVSC	Power Demand drivers/ Operating Profile/ Safety
Oil tankers 	<5,000	0.4/0.44/0.69	4 (6)	(80005-3 - annex-D) IEC 60309-5	(80005-1 - annex-F) 62613-2 - annex I	Power demand driven by cargo pumps and auxiliary systems. (majority of oil tankers use steam driven pumps/systems) Hazardous Areas in the ship-shore interface challenge the use of SSE. Critical safety and reliability of SSE during cargo operations.
	<10,000	0.69/6.6/11	6 (8)			
	>10,000	0.69/6.6/11	8 (10)			
Chemical/product tankers 	<5,000	0.4/0.44/0.69	6 (9)	(80005-3 - annex-D) IEC 60309-5	(80005-1 - annex-F) 62613-2 - annex I	
	<10,000	6.6/11	9 (12)			
	>10,000	6.6/11	10 (20)			
Gas tankers 	<5,000	0.4/0.44/0.69	5 (8)	(not defined) IEC 60309-5	(80005-1 - annex-E) 62613-2 - annex I	Cargo pumps and auxiliary systems drive the load. Critical system reliability during cargo pumping operations.
	>5,000	6.6/11	9 (12)			
Bulk carriers 	<50,000	0.4/0.44/0.69	0.5 (0.7)	(not defined) IEC 60309-5	(80005-1 - annex-E) 62613-2 - annex I	Cranes, where fitted, hydraulic systems and hatches operation.
	>50,000	0.69/6.6/11	2 (2.8)			
General cargo 	<25,000	0.4/0.44/0.69	1.5 (3)	(not defined) IEC 60309-5	(not defined) 62613-2 – as appropriate	Cranes, where fitted, hydraulic systems and hatches operation.
	>25,000	0.69/6.6/11	3 (5)			
Containerships 	<10,000	0.4/0.44/0.69	1.5 (2)	(80005-3 - annex-C) IEC 60309-5	(80005-1 - annex-D) 62613-2 - annex I	Cranes, where fitted, hydraulic systems, hatches operation, refrigerated containers. Reduced space at quay due to cargo terminal cranes pedestals.
	<50,000	0.69/6.6/11	2 (5)			
	>50,000	6.6/11	4 (6)			
RO-Pax 	<20,000	0.4/0.44/0.69	2 (4)	(not defined) IEC 60309-5	(80005-1 - annex-B) 62613-2 - annex J	Predominant Hotel loads and displacement of ship ramps. Short turn-around times at berth.
	>20,000	0.69/6.6/11	5 (6.5)			
Cruise ships 	<50,000	0.4/0.44/0.69	4 (4.5)	(not defined) IEC 60309-5	(80005-1 - annex-B) 62613-2 - annex H	Large Hotel load driving the power requirements Safety and Reliability of SSE is critical for operation
	<100,000	0.69/6.6/11	9 (12)			
	>150,000	6.6/11	18 (20)			
Offshore supply vessel 	<5,000	0.4/0.44/0.69	1 (1.5)	(80005/3 - annex-B) [IEC 60309-5]	(not defined) 62613-2 – as appropriate	Load from hydraulic systems, possible refrigerated module connections. Modest hotel load.
	>5,000	6.6/11	2 (3)			
Fishing vessels 	<5,000	0.4/0.44/0.69	0.5 (0.7)	(not defined) IEC 60309-5	(not defined) 62613-2 – as appropriate	Refrigerated systems and possible hydraulic/cranes operation
	>5,000	6.6/11	2 (3)			

From the numbers and ship types presented below, a considerable number of ships are already fitted and prepared for OPS:

1. **Containerships**, with a total number of almost 500 ships. The adoption of OPS by containerships is largely associated to the mandatory regime (since 2012) for these ships to connect to OPS in California Ports (Ports of Los Angeles (POLA), Long Beach (POLB), Oakland, San Francisco, San Diego, and Hueneme).

   Notwithstanding the reasoning associated with the California mandatory regime, containerships also enjoy of a particular facilitating condition for conversion/installation of an onshore power system. Taking advantage of modularization, containerships can expend one 40ft container slot to install a modular OPS unit. This modular unit contains all necessary control systems, circuit breakers, cable reel, and, whenever necessary, transformers and frequency converters.

   Considering the flexibility provided by modularization, added to the definite “incentive” provided by a mandatory requirement to connect to OPS, containerships take the lead in the number of individual ships equipped for OPS.

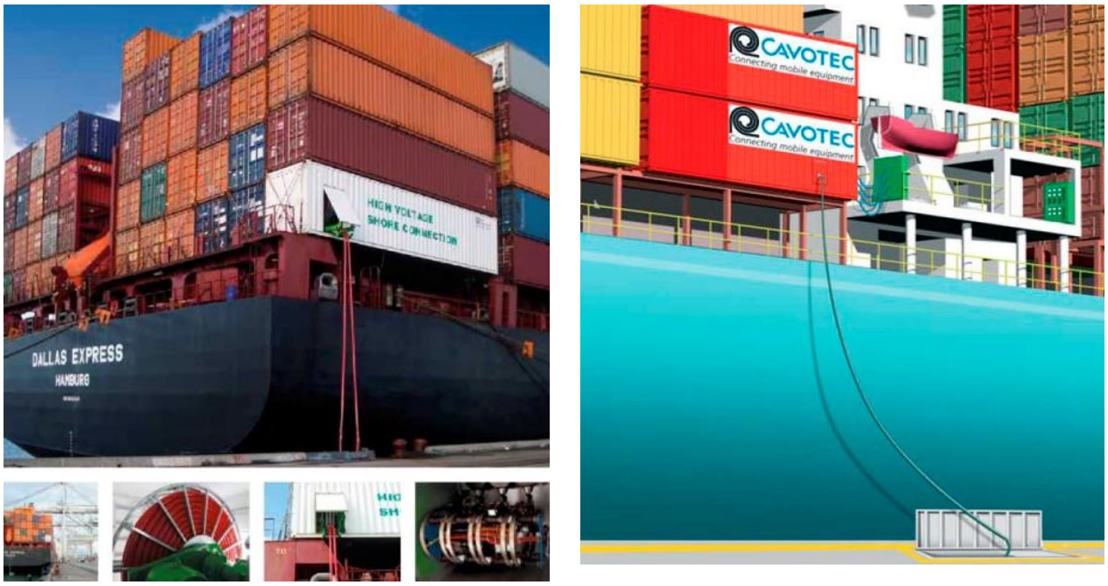


Figure 7.7 a) and b) - Modular OPS installation onboard containerships equipped with OPS.

Note: One 40ft container slot is lost to provide for the shore-power connection installation. The loss of 1 containerized unit is a minor cost reflected in the overall project externalities for the installation and use of OPS by containerships.

   In addition to the reasoning above, it is important to note that most of the high-power demanding containerships are equipped with no cranes (the main equipment that would impose higher peak power requirements). The baseload is strongly dictated by the total number of refrigerated containers.

2. **Cruise ships**, notwithstanding being the ship type with the typically higher power demand at berth, due to large share of Hotel Load (power needed for hoteling auxiliary requirements such as AC, heating, lighting, etc.), cruise ships have also developed OPS functionality due to the mandatory requirements in the Ports of California. According to MARINFO, currently there are 54 cruise ships equipped with OPS.

   OPS is also largely seen as an opportunity for cruise ships calling at ports where mitigation of emissions is currently an important factor for success of attractiveness in the cruise ship business industry.

3. **RO-Pax/ RO-RO,** in particular when operating in Emission Control Areas, counting also with 54 ships in total, are identified as particular candidates for OPS due to one particular contributing factor: the predictability of the port calls. The business case can be favoured by long term contracts, over a fixed route and operating profile with fairly good estimation on the number of shore-connections/year and also the possibility to have customized arrangements almost down to ship-specific

For all ships equipped with OPS we can safely assume that pre-arranged OPS connection has been established. The investment in the OPS equipment onboard is typically either 1) an investment for return, through the consumption of negotiated electricity prices, at berth or 2) through the enforcement of port-specific requirements to connect to OPS (e.g., California or China). Current ships equipped with OPS can therefore be assumed to have addressed all relevant technical challenges for connectivity/compatibility.

For ships not yet equipped with OPS, a newbuild installation, or existing ship conversion, should follow the technical requirements in IEC/IEEE 80051/1 (2019). The likelihood of installation of OPS in existing ships shall address all factors addressed in this Guidance, with a particular focus on the safety aspects. To this end the following ship types present specific challenges regarding the adoption of OPS for alternative supply of energy at berth to the following ship types:

1. **Chemical tankers (ammonia, vinyl chloride), ethane and LPG carriers:** With typical demand for cargo cooling below -50ºC, pumps and inert gas generation onboard, the family of chemical tankers may represent one of the ship types where OPS connection may be discouraged. In addition to the operational aspects, also the criticality of loading/offloading operation would represent the need to always ensure energy for emergency response. Even though OPS can be fed in parallel with onboard generator, the cost-benefit for such operation would be reduced.

   For some types of chemical carriers, where cargo can be carried at atmospheric pressure and temperature, the use of OPS can be considered without special concerns.

   In addition, chemical carriers are usually at berth in petrochemical terminals, or refineries, with a high-risk safety classification, including some probability for the presence of hazardous atmospheres. This would lead to the need to consider special protection of electrical equipment for operation in those areas. Considering the probability for earthing failures and arcing in connection-disconnection, OPS operation where hazardous zones are present should be discouraged.

2. **Oil tankers:** particularly those carrying crude oil typically make use of steam-driven power plant i.e. oil-fired boilers, simultaneously heating the cargo to allow for the steam-driven cargo pumps to load-offload crude while providing the result of such inert combustion exhaust gas to those cargo tanks being unloaded for safety reasons.

   These heating systems are typically boiler-based steam system. Converting into electrical based systems would lead to a significant conversion, accounting for technical and safety aspects. In addition, at sea cargo tanks heating using waste heat recovery is a highly efficient process, converting to electrical systems would inevitably represent a degradation of the energy efficiency of the ships at sea.

3. **LNG carriers**: with power requirements at berth highly driven by onboard re-liquefaction units, cooling requirements and inerting, LNG carriers are also ships involved in safety critical loading-offloading operations. Cryogenic compressors are high energy consumers used to re-liquefy boil-off-gas and which are typically installed on all LNG carriers.

   LNG carriers also make use of Boil-Off Gas for energy production, taken from natural cargo evaporation. The fraction that is not re-liquefied is used to either feed steam-based energy production or to directly feed cargo evaporators wherever needed for cargo control. There are, therefore, important energy efficiency gains from BOG which would be eliminated by electrification of some processes.

   In addition to the above, LNG loading/offloading operations typically involve the definition of a ship-shore hazardous zone and wider safety area to mitigate the risks of ignition following a potential leakage of LNG. Any electrical equipment (such as OPS connection, junction box, converter, transformers, or circuit breakers would have to be fully protected on both ship and terminal side, involving substantial added costs.

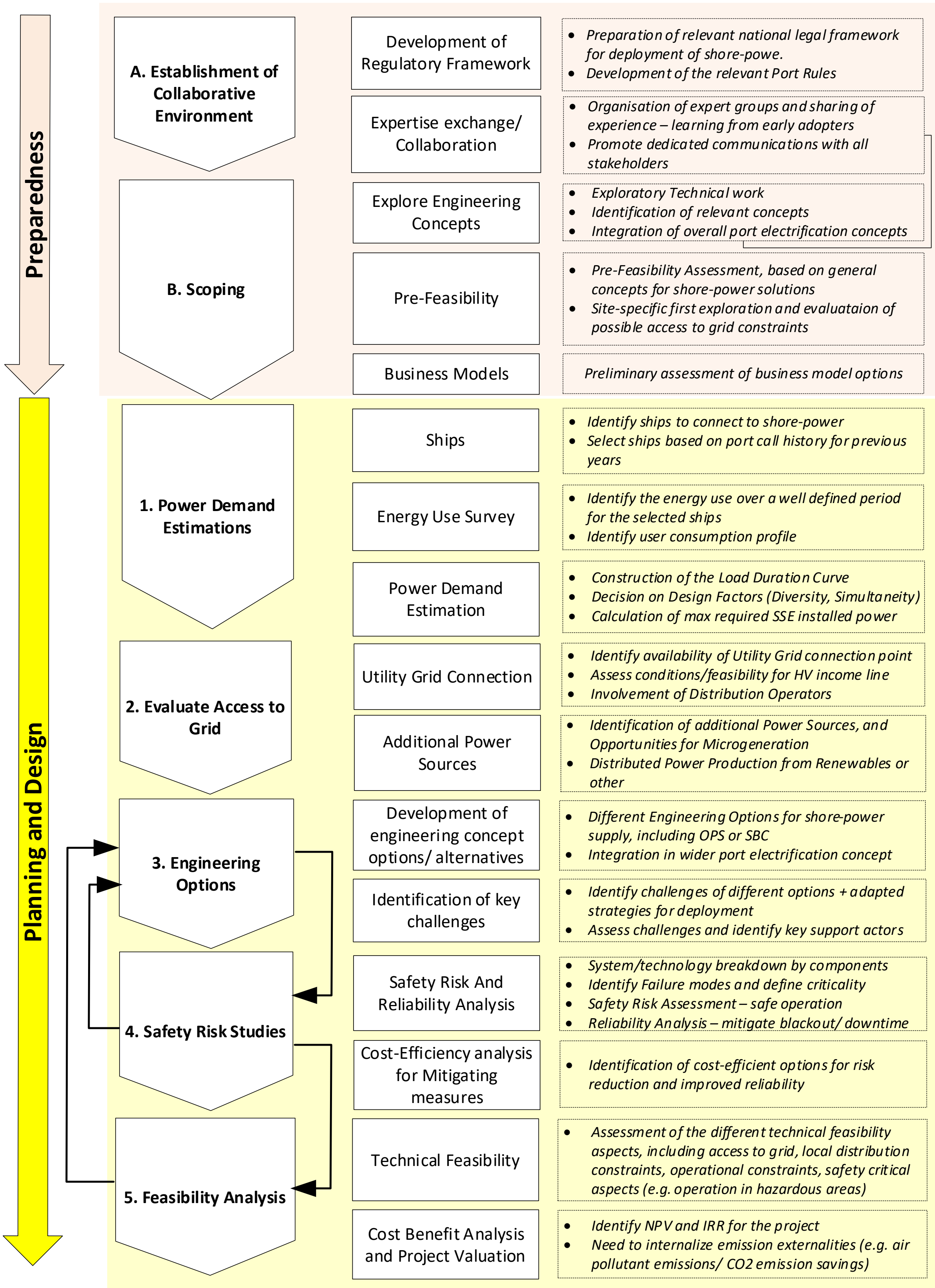
In addition to the above, it is important also to note that IEC/IEEE 80051/1 (2019) – High Voltage Shore Connection (HVSC) [1] and the IMO Safety Guidelines on OPS (2020) [2] are very recent references. Ships equipped with OPS systems compliant with either the previous version of the IEC standard (2012) or with other best practice/standard reference will be also operating and requiring to be brought into the new technical/reference framework. There is currently no indication of how many ships are, or may be, unable to comply with the new IEC/IEEE standard (2019) but, in due course, this is an element for harmonization that will be ensured when the IMO OPS Guidelines enter into force. The most recent version of the standard is clearly indicated to ensure the setup of an equal technical and safety reference for all ships using OPS.

7.5 Technical life-cycle of SSE projects

Figure 7.8 identifies the different life-cycle steps for SSE projects. Overall, the process can be divided into 4 main stages: Preparation, Planning and Design, Engineering/ Procurement/ Contracting/ Construction and Operation.

Within these 4 main stages, the structure presented follows the typical engineering development process, with: 1) identification of initial requisites, 2) study of options, followed by 3) feasibility analysis and project evaluation. Following the identification of a preferred option, the deployment of the project takes place with all detailed engineering drawings, procurement, contracting and construction and finally the operation of the system.

The structure below should not be understood as a rigid construction but rather as a good practice based on the structured engineering project development. Specific aspect of the shore side electricity context shall be emphasised, such as the establishment of a collaborative environment, corresponding to Step “A”. This step is one that should be understood as taking place irrespective of a specific decision for project development.


Preparedness
A. Establishment of Collaborative Environment
Development of Regulatory Framework
Preparation of relevant national legal framework for deployment of shore-powe.
Development of the relevant Port Rules
Expertise exchange/ Collaboration
Organisation of expert groups and sharing of experience – learning from early adopters
Promote dedicated communications with all stakeholders
B. Scoping
Explore Engineering Concepts
Exploratory Technical work
Identification of relevant concepts
Integration of overall port electrification concepts
Pre-Feasibility
Pre-Feasibility Assessment, based on general concepts for shore-power solutions
Site-specific first exploration and evaluataion of possible access to grid constraints
Business Models
Preliminary assessment of business model options
Planning and Design
1. Power Demand Estimations
Ships
Identify ships to connect to shore-power
Select ships based on port call history for previous years
Energy Use Survey
Identify the energy use over a well defined period for the selected ships
Identify user consumption profile
Power Demand Estimation
Construction of the Load Duration Curve
Decision on Design Factors (Diversity, Simultaneity)
Calculation of max required SSE installed power
2. Evaluate Access to Grid
Utility Grid Connection
Identify availability of Utility Grid connection point
Assess conditions/feasibility for HV income line
Involvement of Distribution Operators
Additional Power Sources
Identification of additional Power Sources, and Opportunities for Microgeneration
Distributed Power Production from Renewables or other
3. Engineering Options
Development of engineering concept options/ alternatives
Different Engineering Options for shore-power supply, including OPS or SBC
Integration in wider port electrification concept
Identification of key challenges
Identify challenges of different options + adapted strategies for deployment
Assess challenges and identify key support actors
4. Safety Risk Studies
Safety Risk And Reliability Analysis
System/technology breakdown by components
Identify Failure modes and define criticality
Safety Risk Assessment – safe operation
Reliability Analysis – mitigate blackout/ downtime
Cost-Efficiency analysis for Mitigating measures
Identification of cost-efficient options for risk reduction and improved reliability
5. Feasibility Analysis
Technical Feasibility
Assessment of the different technical feasibility aspects, including access to grid, local distribution constraints, operational constraints, safety critical aspects (e.g. operation in hazardous areas)
Cost Benefit Analysis and Project Valuation
Identify NPV and IRR for the project
Need to internalize emission externalities (e.g. air pollutant emissions/ CO2 emission savings)

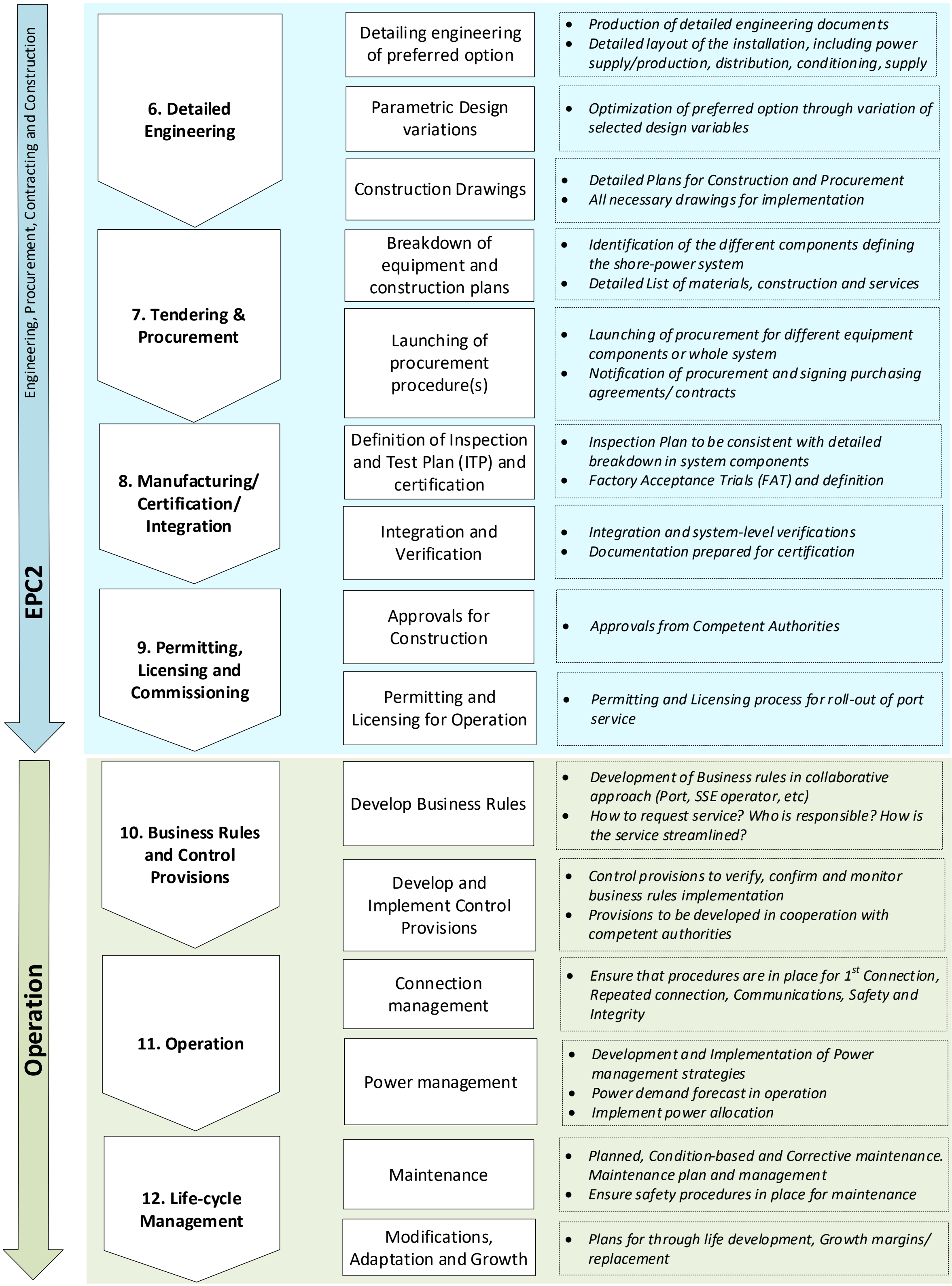


Figure 7.8 – Technical life-cycle of SSE projects.

Source: EMSA

8. SSE Operation

The present section is focused on operation of Onshore Power Supply (OPS) and Shore-side Battery Charging (SBC) systems, including reference to the different concept/modes of operation.

Section 8.1 highlights the different processes with functional flow-charts to illustrate the key differences between OPS and SBC. Section 8.2 is dedicated to preparation for operation, including the different tests and verifications that should precede operations. Section 8.3 is dedicated to OPS and Section 8.4 to SBC.

As far as the contents are concerned, the part on **OPS** is mainly focused in complementing and supporting the existing international guidance framework for operation of OPS. To this end the main provisions for OPS Operation can be found on the following references:

- IMO Interim Guidelines on Safe Operation of Onshore Power Supply (OPS) Service in Port for Ships Engaged on International Voyages
- IEC/IEEE 80005-1: High Voltage Shore Connection
- IEC/IEEE 80005-3: Low Voltage Shore Connection

Based on the outline of the IMO Interim Guidelines on OPS, together with requirements for Compatibility Assessment in IEC/IEEE 80005-1, section 4.3, the present section of the Guidance includes good practice elements suggested to PAA with respect to:

1. **OPS Compatibility Assessment** – With the suggested introduction of the concept of "connection certificate".
2. **Operation Flowchart** for OPS Connection – as complement to the IMO Interim Guidelines on OPS, including elements of good practice and other references to IEC/IEEE 80005
3. **Checklists** for OPS Operation (Annex)

The main principle followed in the present section is the one of "no duplication" of the provisions for operation outlined in the IMO Guidelines on OPS and only the aspects of compatibility assessment are included for reference and support to the proposal for a 1st connection certification.

As far as **SBC** is concerned the interoperability and interconnectivity framework for the operation is not as widespread or mature as the OPS, with battery charging mainly developed in several port/ship-specific applications. The different battery charging solutions for ships are also based in automated or semi-automated systems with cable management often based in designs optimized for minimum turnaround times in port. Cable handling, connection/disconnection, communications, and safety procedures are embedded in the design of SBC systems.

For outlining the operational concept for SBC, the present Guidance makes use of the described lithium-ion DC fast battery charging standard description in IEC 61851-23[7]. Different battery technologies and charging methods will have different durations for some steps and different charging current and voltage curves. The main steps are however the same in the different battery charging processes.

In addition to the operational process for SBC, also the main functional elements of the matted Supply Charging Station ashore and receiving Ship are presented in general with indication of their relevance in the process.

From an operational perspective, charging electric or hybrid-electric ships, encompasses different challenges when compared with OPS.

[7] IEC 61851-23:2014 - Electric ship conductive charging system - Part 23: DC electric ship charging station

8.1 Operation Concepts – OPS and SBC

The operation concept for both OPS and SBC is presented in Figure 8.1 and Figure 8.2. The block generic flow-chart presents only the main functional blocks in the definition of the concept of operations.

A shore connection system must include procedures to be followed by port and onboard maintenance staff for:

- High-Voltage (HV) cable connection and disconnection, safety hazards are managed by automatic and/or key interlocks and safety checks by maintenance operators
- As generally connection and disconnection of the ship's power supply is done without blackout, coupling between the shore substation and onboard generators must be synchronized

These procedures may depend on the ship type, the shore substation design, and port maintenance requirements, but should be compatible with IMO Interim Guidelines on OPS and IEC/IEEE 80005-1:

- Power architecture (cable to connect, switchboard architecture)
- Interlocking systems (automatic interlocking and/or key interlocking)
- Operators involved in the procedure (onboard operators, port authorities, onshore operators)

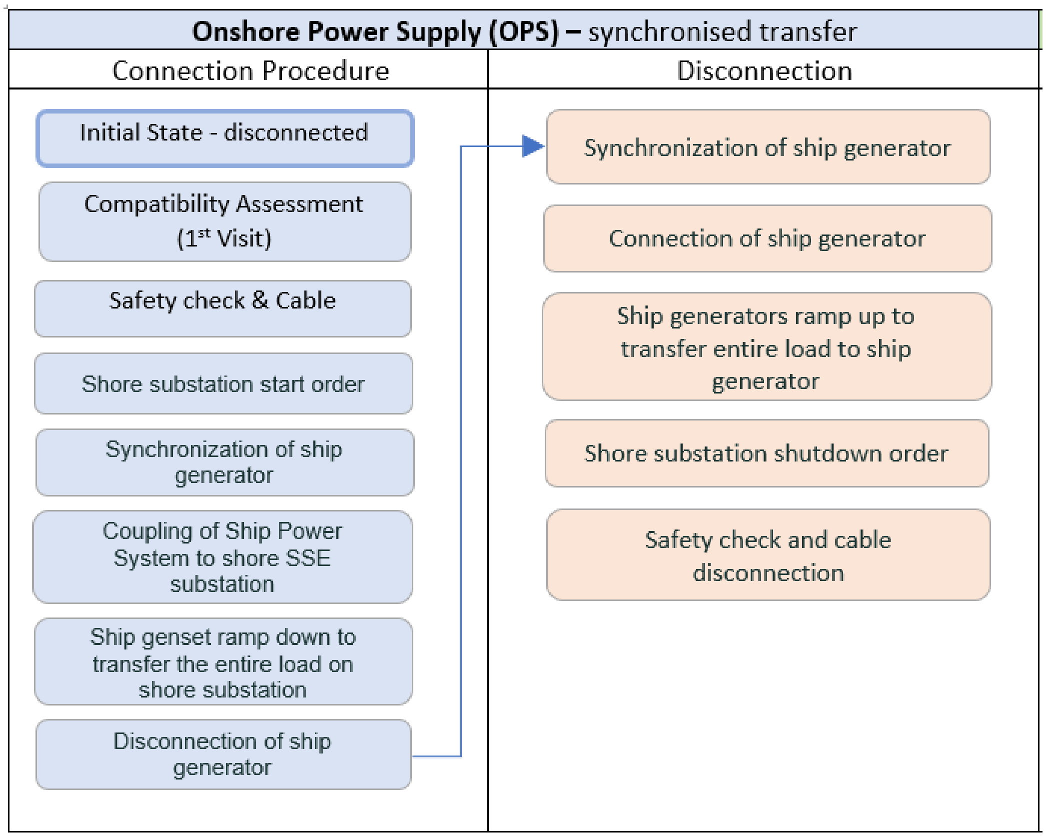


Figure 8.1 - OPS concept of operation – synchronised transfer.

Source: EMSA

SBC is generally supported by automated control and coordination of the different stages involved throughout the charging process.

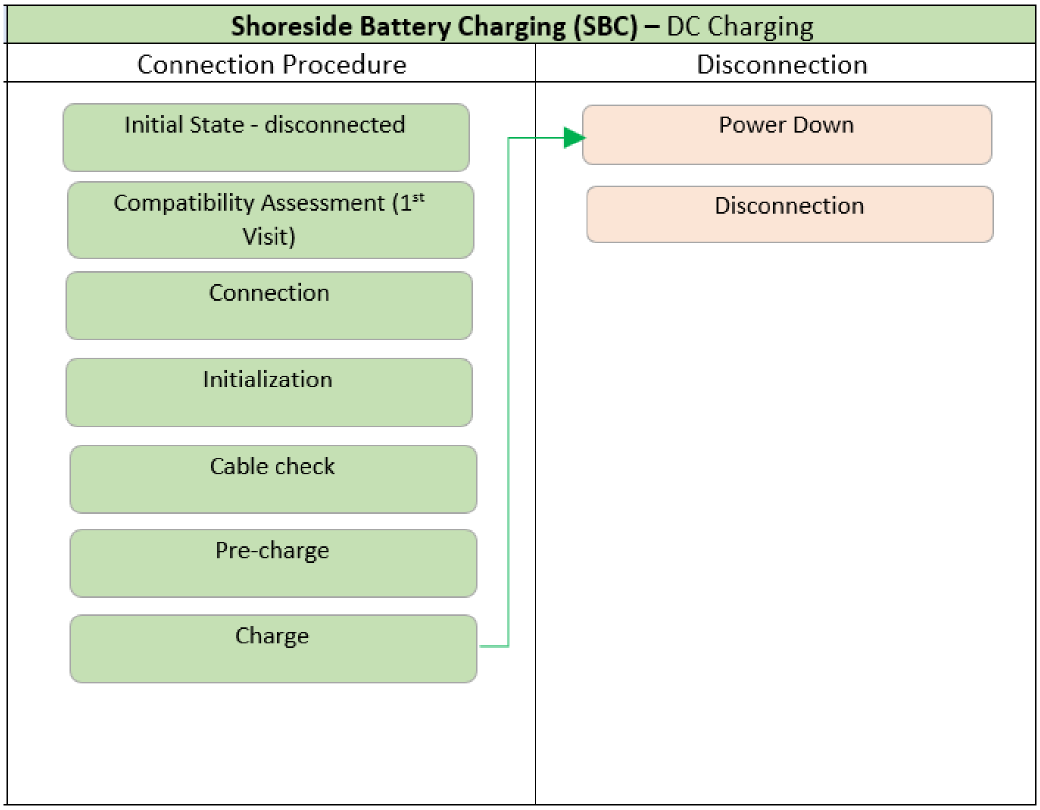


Figure 8.2 - SBC concept of operation – DC Charging.

Source: EMSA

8.2 Preparation for Operation

The present section outlines the different procedures and tests/verifications required before connecting to shore power. The compatibility assessment ensures that both ship and shore sides are ready to connect.

8.2.1 Tests and Verification

The present section outlines the different procedures and tests/verifications required before connecting to shore-power. The compatibility assessment ensures that both ship and shore sides are ready to connect.

Table 8.1 - Tests and Verifications prior to operation.

What	What should be covered?	When?
Compatibility assessment before connection **(Section 4.3 of IEC/IEEE 80005-1)**	Compatibility assessment shall be performed to verify the possibility to connect the ship to shore HV supply. Compatibility assessment shall be performed prior to the first arrival at a terminal. Assessment of compatibility shall be performed to determine the following (with reference to the relevant sections of the IEC/IEEE 80005-1): a) compliance with the requirements of this document and any deviations from the recommendations. b) minimum and maximum prospective short-circuit current (Section 4.7 and 4.8). c) nominal ratings of the shore supply, ship to shore connection and ship connection (Section 5.1).	**Prior to the 1st Visit** Prior to conducting the test referred to in this paragraph, the compatibility assessment or technical analysis, as appropriate, should be performed. Both shore and ship sides should cross-review the initial test reports before the tests at the first call at a shore supply point.

What	What should be covered?	When?
	d) any de-rating for cable coiling or other factors (see 7.2.1). e) acceptable voltage variations at ship switchboards between no-load and nominal rating (Section 5.2). f) steady-state and transient ship load demands when connected to a HV shore supply, HV shore supply response to step changes in load (Section 5.2). g) system study and calculations (Section 4.8). h) verification of ship equipment impulse withstand voltage. i) compatibility of shore and ship side control voltages, where applicable. j) compatibility of communication method and means. k) distribution system compatibility assessment (shore power transformer neutral earthing). l) functioning of ship earth fault protection, monitoring and alarms when connected to an HVSC supply (Section 8.2.2). m) sufficient cable length. n) compatibility of safety circuits. o) total harmonic distortion (THD) (Section 5.2). p) consideration of hazardous areas, where applicable (Section 4.6.4). q) when a HV supply system is connected, consideration shall be given to provide means to reduce current in-rush and/or inhibit the starting of large loads that would result in failure, overloading or activation of automatic load reduction measures. r) consideration of electrochemical corrosion due to equipotential bonding. s) utility interconnection requirements for load transfer parallel connection. t) equipotential bond monitoring (Section 4.2.2).	The initial tests for high voltage should meet standard **IEC/IEEE 80005-1** requirements. (similar requirement
Integration Tests <u>IMO OPS Guidelines, Section 2.1.3</u>	The following should be performed as an integration test by shore- and ship-sides before the OPS connection: 1. visual inspection, 2. power frequency test for switchgear assemblies and voltage test for cable, 3. insulation resistance measurement, 4. measurement of the earthing resistance, 5. function test of the protection devices, 6. function test of the interlocking system, 7. function test of the control equipment, 8. equipotential bond monitoring test or equivalent, 9. phase-sequence test, 10. function test of the cable management system, 11. integration tests to demonstrate that the shore- and ship-side installations work properly together, and 12. function test of the emergency stops.	**<u>At 1st Visit</u>** In accordance with <u>IMO OPS Guidelines, Section 2.1.3</u> the tests in 2) and 4) should be performed only if either of the installations, shore- or ship-side, has been out of service or not in use for more than 30 months.

Routine Tests	1. visual inspection. 2. confirmation that no earth fault is present. 3. statement of voltage and frequency. 4. an authorized switching and connection procedure; and 5. function test of the emergency stops.	**<u>At all subsequent visits</u>** If the time between port calls (the same shore supply point) does not exceed 12 months and if no modifications have been performed either on the shore- or ship-side installations, this verification should be conducted.

8.2.2 Connection Certification

Following compatibility assessment, the possibility of a ship to connect to an OPS system is confirmed. This, in itself, is not enough to ensure that a ship will successfully be able to receive OPS supply at any given port. An integration test is then needed for the 1st connection. For all subsequent visits to the same port/berth/OPS facility, the results of the integration test, in addition to more expedite and simple routine tests, should provide sufficient evidence that it is safe to connect.

For subsequent visits for OPS connection the routine tests are considered sufficient, provided that the exact same conditions are maintained from the integration tests.

PAA should, in light of the above, have the necessary provisions and measures in place to document and trace the historic file of OPS compatibility assessment, integration tests and routine tests, as applicable.

The diagram below outlines a possible <u>Certification of Connection</u> structure.

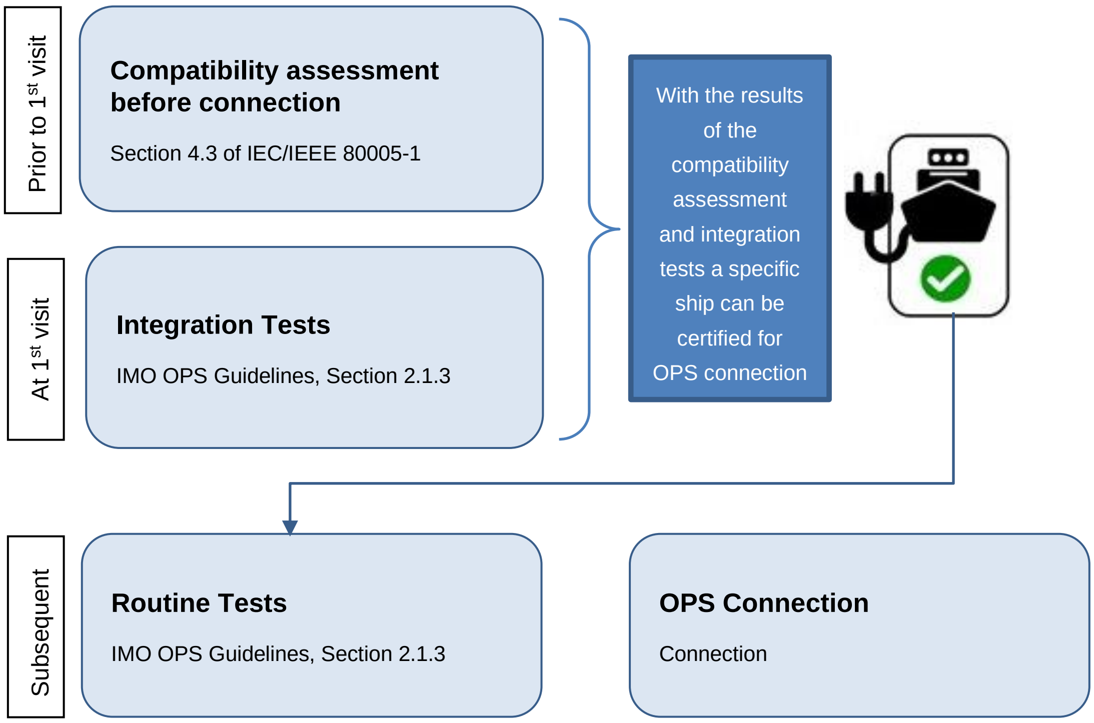


Figure 8.3 - Connection certification.

8.3 OPS Operation

The diagram below presents the general operational concept for onshore power supply, including both ship-side and shore-side general steps in the operation flow, with reference to the IMO Interim Guidelines on OPS and, where relevant, to the IEC/IEEE 80005 series.

	References	Ship side	Shore side
Compatibility Assessment	• IMO Guidelines 1.3.3, 2.1.1 • ISO 80005-1 (Section 4.3) - HV • ISO 80005-3 (Section 4.3) - LV (technical analysis)	• Requests 1st Connection • Provides complete information to PAA on required voltage and frequency • Informs load profile in port	• OPS supplier opens ship file • Contacts OPS supplier for coordination • Allocates slot for 1st connection procedure – load variation/ safety tests
1st Connection Integration Test	• IMO Guidelines 2.1.2 • Repeated Connection Cerificate on the basis of First Connection.	• Following compatibility assessment **and** 1st connection ship should be issued a Connection Certificate (CC) • Validity to be agreed	• PAA issues CC • OPS supplier includes ship file into the SSE management plan • Allocates slot for 1st connection procedure – load variation/ safety
Repeated Connection Verification	• IMO Guidelines 2.2.2 (HV) • IMO Guidelines 3.2.2 (LV)	• At repeated connections, ship holding a CC should have only to ensure that no modifications have taken place on ship side • Verifications to be documented	• Verifications on shore side • OPS supply adjusted for specific ships to connect as per CC file • OPS supplier includes ship file into the SSE management plan
Pre-Connection	• IMO Guidelines 3.2.1 (HV) • IMO Guidelines 3.3.2 (LV)	Safety Checks Ensure shore-side circuit breaker is open and isolated, and circuit is earthed <u>Ground switch - Safety tag</u> (DO NOT OPERATE)	• Ensure shore-side circuit breaker is open and isolated, and circuit is earthed • <u>Lock and safety tag</u> (DO NOT OPERATE) • Prove cables de-energised
Connection	• IMO Guidelines 3.2.1 (HV) • IMO Guidelines 3.3.2 (LV)	• Prove cables de-energised • Connect cables and secure connection • <u>Remove safety tag</u> – open ground switch • Rack-in circuit breaker	• Prove cables de-energised • Connect cables and secure connection • <u>Remove Lock and Safety Tag</u> – Open Ground Switch • Rack-in Circuit Breaker
Supply	• IMO Guidelines 3.2.2 (HV) • IMO Guidelines 3.3.3 (LV)	• Confirm connection and sequence for switching operations • Ship person in charge communicate to shore it is SAFE to close CB • Parallel connection of black-out	• Close CB for supply • Ensure adequate monitoring of power quality supply
Disconnection	• IMO Guidelines 3.2.3 (HV) • IMO Guidelines 3.3.4 (LV)	• Safety checks • Confirm no safety-critical operations onboard prior do switchover • Procedures for changeover to onboard supply • Request for disconnection	• Disconnect on request • Ensure adequate monitoring of Power quality supply
Completion	• IMO Guidelines 5.2	• Checklists documented • Secure equipment • OPS receipt received and archived together with checklist • Incident reporting	• Checklists documented • Secure equipment • OPS receipt received and archived together with checklist • Incident reporting

Figure 8.4– OPS Operation – References.

Further to the above, in Figure 8.5 to Figure 8.8, the flow chart diagram describes the OPS operation, from early request to connect to disconnection, including compatibility/integration/verification and safety procedures.

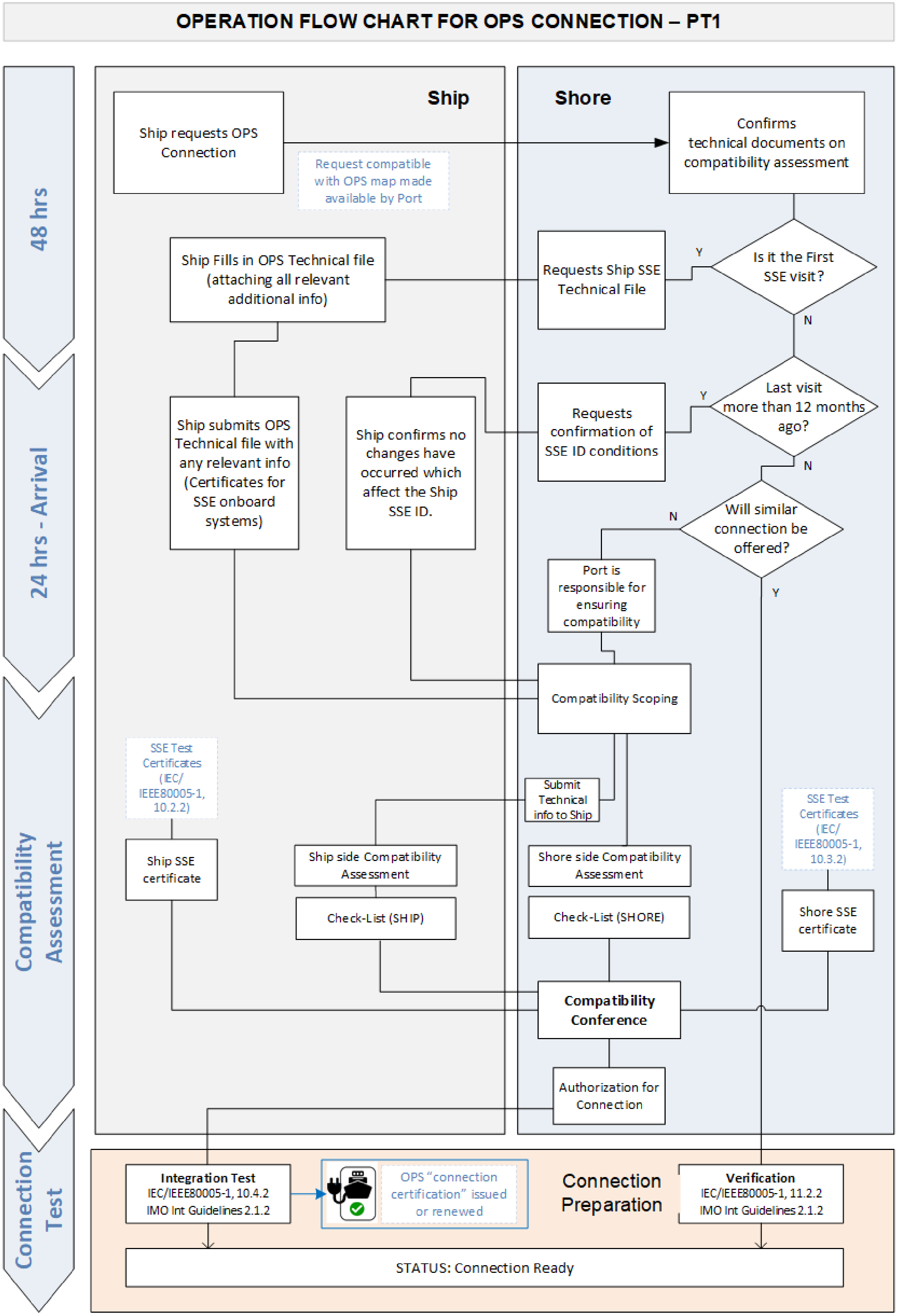


Figure 8.5 - OPS Operation – Flow Chart diagram PT1.

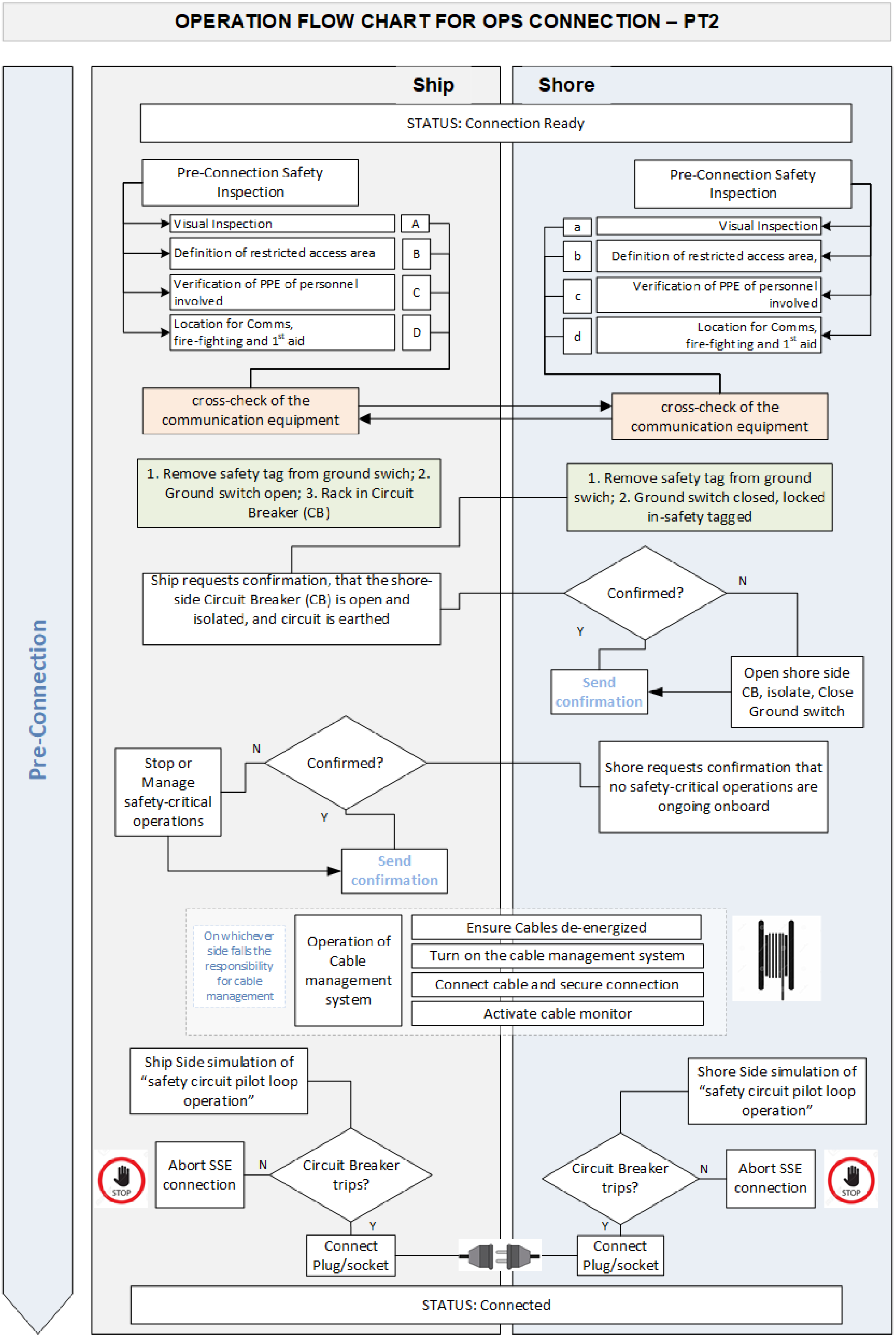


Figure 8.6 - OPS Operation – Flow Chart diagram PT2.

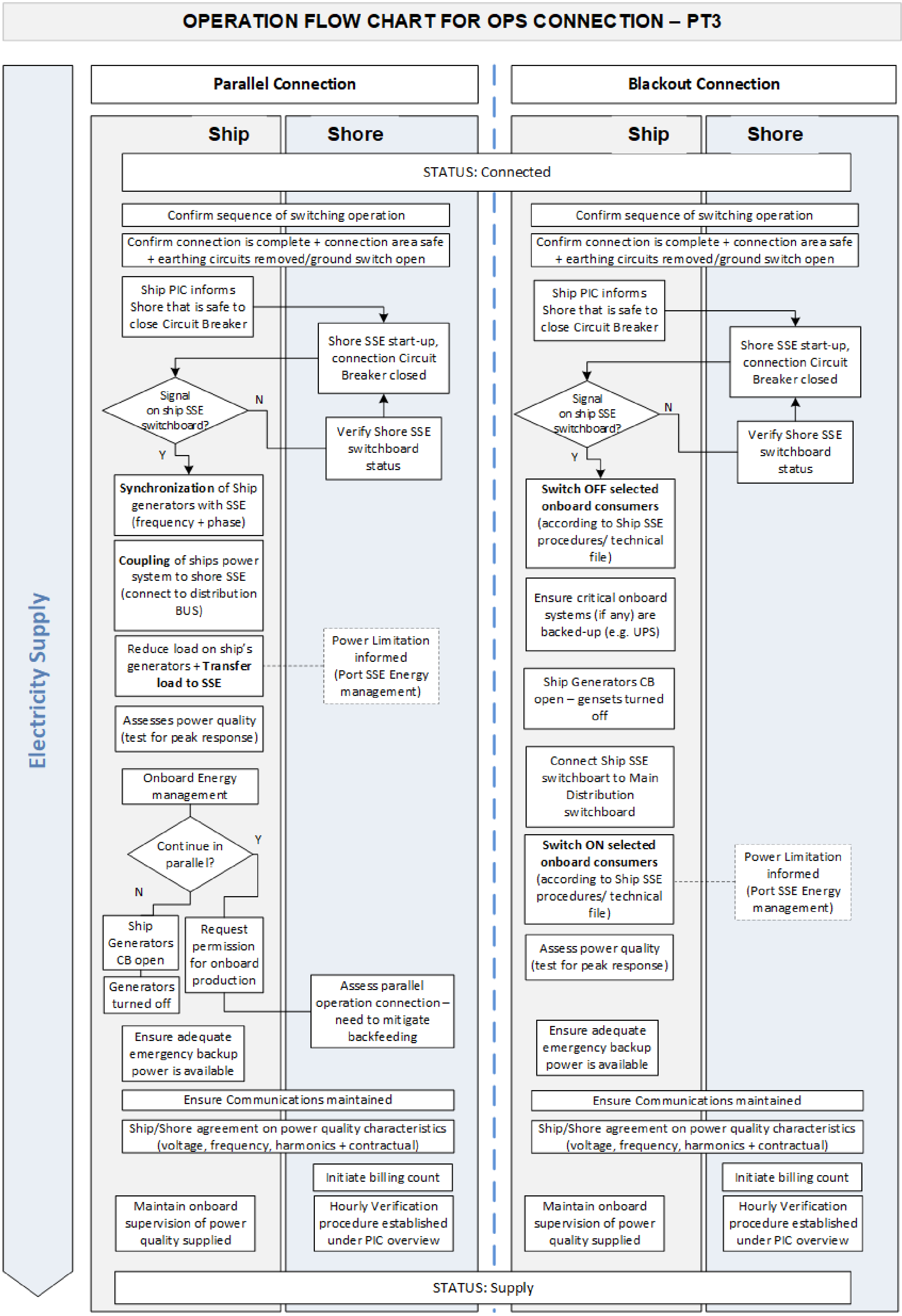


Figure 8.7 - OPS Operation – Flow Chart diagram PT4.

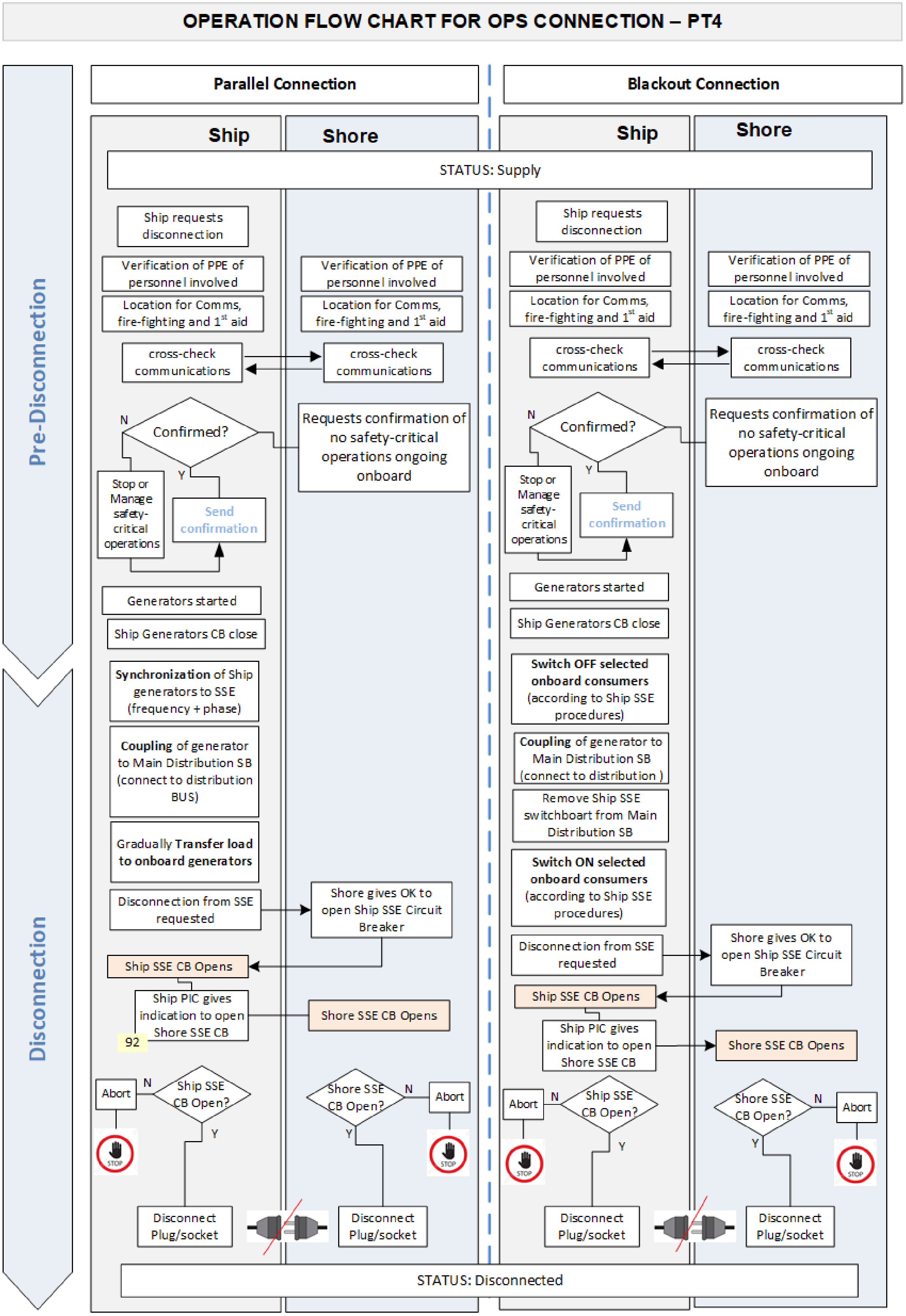


Figure 8.8 - OPS Operation – Flow Chart diagram PT4.

8.4 SBC Operation

Shore-side battery charging operation is largely dictated by **1**) the battery chemistry (NMC, LTO, other); **2**) the charging process (AC-AC; DC-AC, etc); **3**) the charging speed (slow/overnight, fast, other) and **4**) the power management system used and the associated charging parameters variation (voltage, current).

Figure 8.9 (a) and (b) – MINE Smart Ferry – Thailand- use of 26 CCS type charger connectors for fast charging of a passenger ferry.

To be noted the operational implications of using low power standard battery charger connectors used for road EVs. The example is shown as a demonstration that new, high charging power rated connections are needed to avoid the operational challenges of sequential connection of multiple charging cables.

Source: MINE Smart Ferry

Figure 8.10 – NORLED MV Ampere – Dedicated cable management systems for fast DC battery charging.
The connectors are driven to the receptable onboard, by gravity, falling into connected status.
Charging time: 10 min and overnight; Battery capacity: 1,040 kWh Charging power: 1.2 MW; Current: 1,250–1,650 A
Source: NORLED and **C**avotec SA

Figure 8.11 – AERO MV Ellen – Fast DC charging by the bow. Different connection solution.
Charging time: 20 min and overnight; Battery Capacity: 4.3 MWh; Charging Power 4 MW at 1,000 V

Source: Mobimar Ltd and Ærø

Figure 8.12 – Wireless charging system based on inductive power transfer.

Source: Wärtsilä Corporation and Cavotec SA

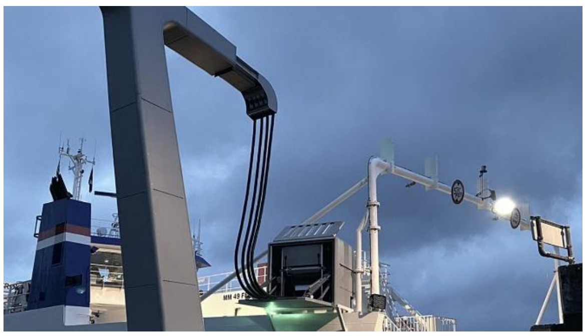


Figure 8.13– Battery charging cable management system with multi-degree of flexibility /motion.

Easier adjustable solution.

Source: Zinus AS

8.4.1 Charging Methods

The high energy and power density, low memory effect and resulting capacity loss, of lithium-ion batteries over other types of energy storage devices, make this type of battery the best candidate for the field of electric ships. However, li-ion battery charging must be carried out very carefully, since the charging method greatly affects how actively electrochemical side reactions occur inside the battery, and hence the cycle life of the battery itself. For this reason, finding the optimal technique to charge a battery in the shortest period of time with high efficiency, without damaging the cells, is a key driver for the design of the operational concept.

The main charging methods are presented in the following sub-sections, identifying the relevant variation in parameters, dictating the charging approach and, therefore, with influence in the operational concept model.

8.4.1.1 Constant Current-Constant Voltage (CC–CV)

In this method, represented in Figure 8.14, both an initial constant current and a final constant voltage are used. The charging process start with a constant current until a certain voltage value, known as cut-off voltage, is reached.

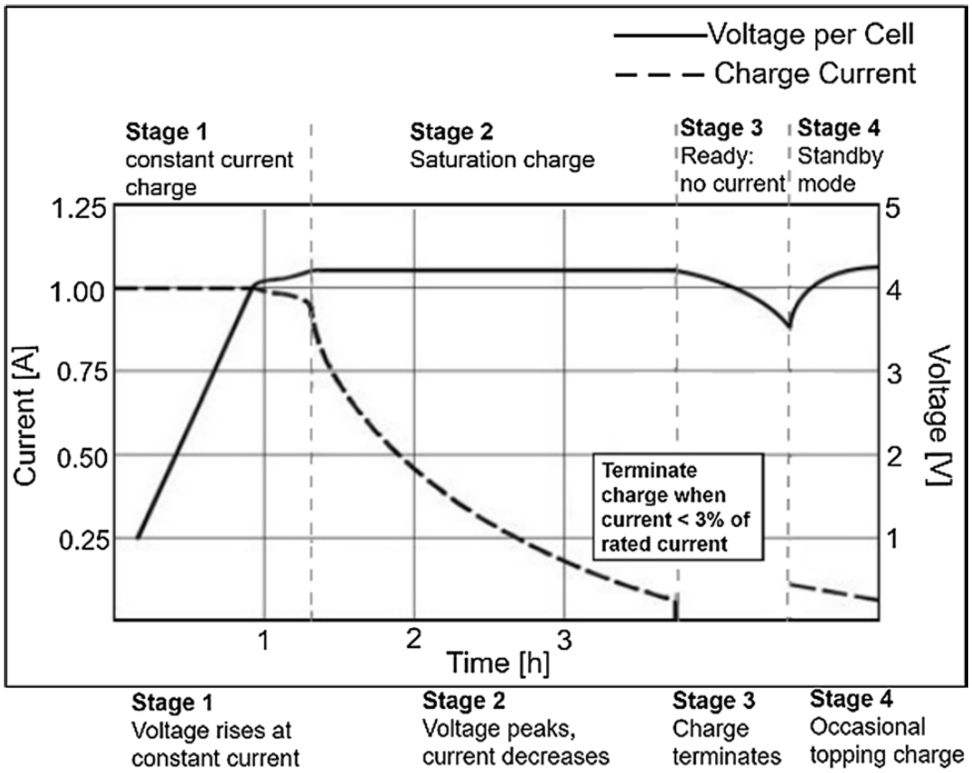


Figure 8.14 - CC–CV charge stages for a li-ion battery.

Source: https://batteryuniversity.com/

For li-ion with the traditional cathode materials of cobalt, nickel, manganese and aluminium typically the cut-off voltage value is around 4.20 V/cell. The tolerance is ± 50 mV/cell. Battery charging continues with a constant voltage just equal to the cut-off value. Full charge is reached when the current decreases to between 3 and 5% of the rated current.

Trickle or float charge at full charge is not suitable for a li-ion battery, since it would cause plating of metallic lithium and compromise safety. Instead of trickle charge, a topping charge can be applied when the voltage drops below a set value.

In some existing references, a little bit different variant is proposed, in fact the first stage consists now in a trickle charge. This stage is activated only if the battery is deeply discharged, i.e., the cell voltage is below 3.0 V and after it the CC–CV method keeps place with the aforementioned way.

8.4.1.2 Five-step charging

An alternative method is here described in order to obtain faster and safer charging and longer battery cycle life. The five-step charging pattern consists in a multistage (five stages) constant-current charging method, in which the charging time is divided into five steps. In each stage, the charging current is set to a constant threshold value. During charging, the voltage of the battery will increase and when it reaches the pre-set limit voltage, the stage number will increase, and a new charging current set value will be applied accordingly. This process will continue until the stage number reaches 5. Figure 8.15 illustrates the concept of the five-step constant current charging pattern. To find the charging current in each step different algorithms can be used, however it could be difficult and time ineffective find the optimal charging pattern.

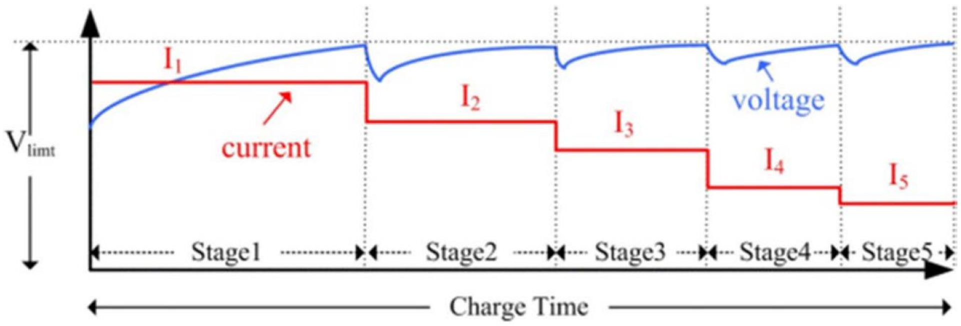


Figure 8.15 - Five-step charging pattern for a Li-ion battery[8].

8.4.1.3 Pulse charging method

With this charging strategy the charging current is injected into the battery in form of pulses, so that a rest period is provided for the ions to diffuse and neutralize. The charging rate, which depends on the average current, can be controlled by varying the width of the pulses. It is claimed that this method can really speed up the charging process, slow down the polarization effect and increase life cycles. As shown in Figure 8.16, every pulse charge current that is applied to the battery is characterized by the following factors: peak amplitude *Ipk*, a duty cycle *D* = *ton/Tp*, and frequency *f*.

Two different pulse charging methods exist: duty-fixed and duty-varied pulse-charge strategy. The duty-varied strategy can increase the charging speed and the charging efficiency with respect to the conventional duty fixed method.

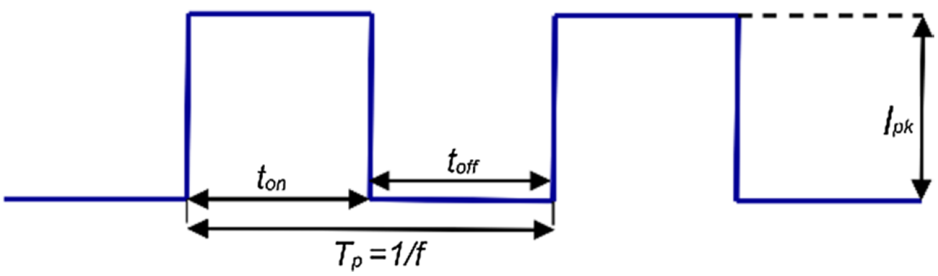


Figure 8.16 - Pulse charge current parameters[9].

[8] Brenna, Morris; Foiadelli, Federica; Leone, Carola; Longo, Michela - Electric Vehicles Charging Technology Review and Optimal Size Estimation - Journal of Electrical Engineering & Technology (2020) 15:2539–2552

8.4.2 System components for Shore-side Battery Charging system

The diagram in Figure 8.17, below, illustrates the main functional elements involved in battery charging operation.

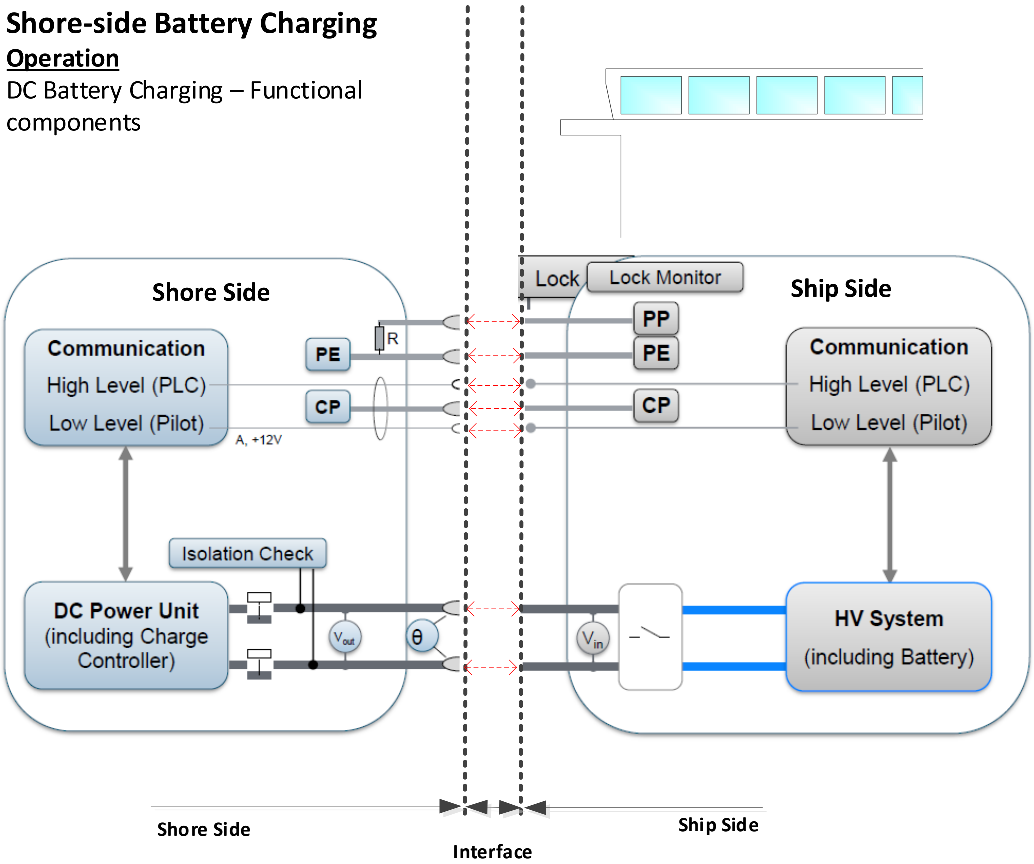


Figure 8.17 - System Components involved in SBC-DC.

Legend:
PE – Protective Earth
Vin – Ship Voltage input
Vout – Supply Volage Output
θ - Temperature sensors
PLC – Power Line Communication
CP – Charging Plug/Connector Pilot

Source: CharIN e.V.

8.4.3 SBC Operational Concept

Battery charging operational concept is described in Table 8.2, with reference to the time steps described in standard IEC 61851-23, for DC charging.

Different steps can be considered for other battery charging modes and the steps described should be considered only as general, non-exhaustive, reference.

Table 8.2 - SBC process – ref: IEC 61851-23.

Phase	Time Step	Description
Connection	**t (0)**	• Connector plugged into Receiving Ship (RS). • Immobilization of connected system.
Initialisation	**t (1) → t (2)**	• Establish PLC (Power Line Communication) communication: Exchange operating limits and parameters of charging. Important to ensure adequate compatible PLC modems operating on both supply and ship sides. • Shutdown if DC Voltage > 60 V or incompatibility of RS and DC supply is detected.
Cable check	**t (3)**	• RS changes CP state from B to C/D and sets RS status “Ready”. After connector lock has been confirmed • DC supply starts checking HV system isolation and continuously reports isolation state.
	t (4)	• DC supply determines that isolation resistance of system is above 100 kΩ. After successful isolation check, DC. supply indicates status ”Valid” and changes status to “Ready” with Cable Check Response.
Pre-charge	**t (5)**	• RS sends Pre-Charge Request, which contains both requested RS current <2A (maximum inrush current) and requested DC voltage.
	t (6)	• DC supply adapts DC output voltage within tolerances and limits current to maximum value of 2 A.
	t (7)	• RS closes disconnecting device after deviation of DC output voltage from RS battery voltage is less than 20 V.
	t (8)	• RS sends Power Delivery Request to enable DC power supply output. After DC supply gives feedback that it is ready for energy transfer RS sets DC current request to start energy transfer phase.
Charge	**t (9)**	• RS initiates message cycles by requesting voltage/current. • Shore-side supply responds with voltage/current adjustment as well as present limit and status values (voltage, current, isolation). • Continuous monitoring of lock, isolation, voltage, current and temperature
	t (10)	• RS reduces the current request to complete the energy transfer. The DC supply follows the current request with a time delay and reduces the output current to less than 1A before disabling its output.
Power down	**t (11)**	• RS sends a message to DC supply to disable its power output. After current is below 1 A the RS opens its disconnection device.
	t (12)	• DC supply disables its output and opens contactors, if any.
	t (13)	• DC supply reports status code ”Not Ready” with a message to indicate it has disabled its output.
	t (14) → t (15)	• RS changes CP state to B after receiving message or after timeout.
	t (16)	• RS unlocks the connector after DC output has dropped below 60 V. The DC supply continues isolation monitoring dependant on DC supply strategy. • Session Stop Request with a message and terminates digital communication (PLC).
Disconnection	**t (17)**	• EV and Supply disconnected. • Shore-side supply disables DC output. • Lock is disabled. • PLC is terminated. • Disconnecting of ship connector changes CP state from B to A.

9. Safety

The present section addresses the different dimensions of safety in design and operation of shore-side electricity systems.

Hazards and Failure Modes (Section 9.1)	**Risk Assessment** (Section 9.2)	**Risk management** (section 9.3)	**Safety Checks** for Operation (section 9.4)
Section covering general description of the different types of general hazards and failure modes in SSE systems and operations	Different possible good-practice approached for assessment of safety risk and reliability of SSE systems and operations	Different electrical protection strategies and equipment for mitigation of incidents in the operation of SSE systems	General safety checks to be conducted prior and during SSE/ OPS supply operation.

Safety for maintenance operations and for design or conduction of emergency procedures is not covered under the present section.

9.1 Hazards and failure modes

SSE systems require high safety and reliability levels with a view to mitigate the risks of 1) electrical fire/ explosion; 2) occupational incident/shock/arcing and 3) blackout during shore power supply.

Figure 9.1 presents a list of possible failure modes in different points of an SSE system installation and operation. The following sub-sections present different aspects to be considered in OPS and SBC safety.

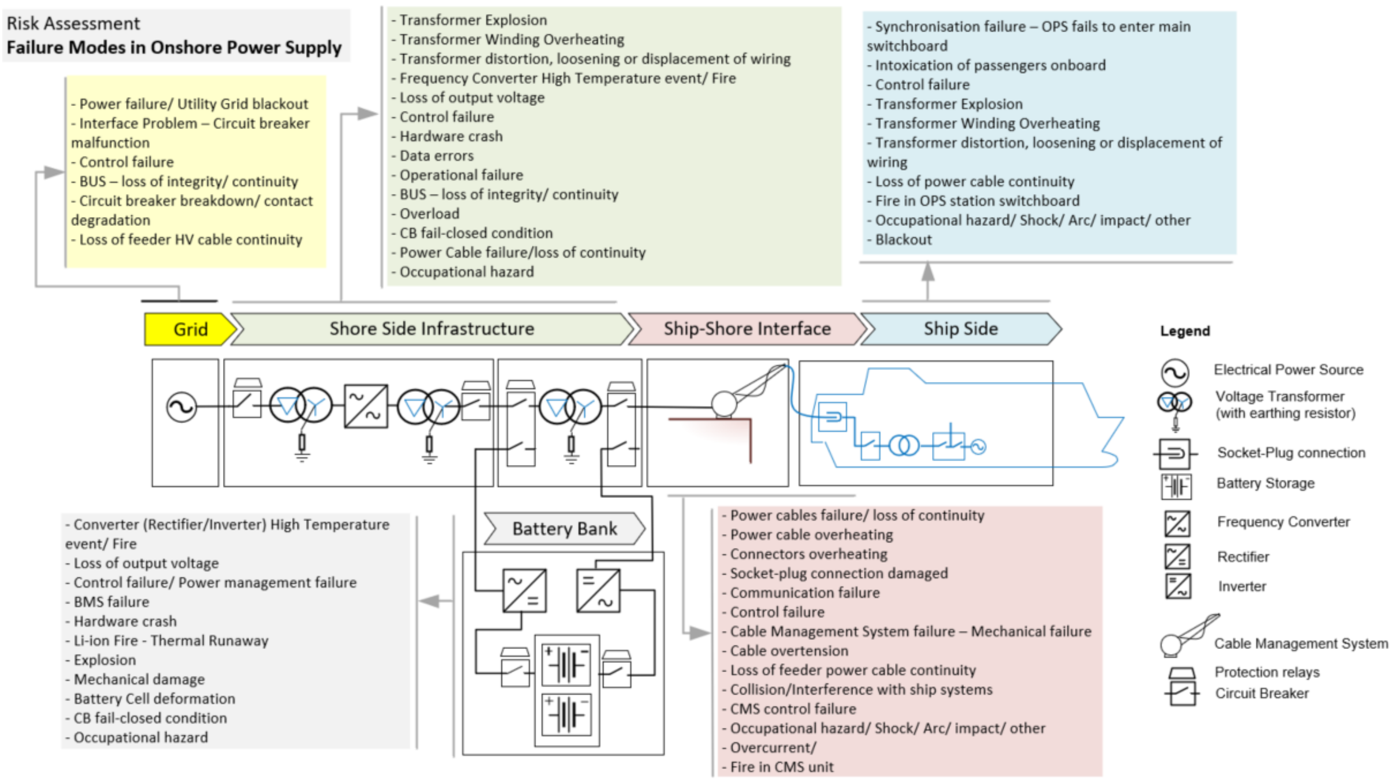


Figure 9.1 - Possible failure modes in shore-power/SSE systems and operation.

Source EMSA

9.1.1 Onshore Power Supply – Failure Modes

Table 9.1, below, lists different failure modes possible to consider in OPS systems. The system component breakdown follows that of Figure 9.1.

Table 9.1– Failure Modes in Shore-Power/ OPS systems and operation[9][10].

System	Failure mode	Cause	Effect/ Consequences	Mitigation/ Recommended Action
Power source	Electrical failure -power shortage	The electrical grid is not able to provide sufficient power supply.	Overlapping of contacts not sufficient, reduced current capability	The energy supply stakeholders (TSO/DSO) will need to be involved to review the feasibility and planning of providing the additional power load with the consideration for local grid specific variations. Consideration for installation of distributed power supply. Backup energy (battery pack systems or other).
	Quality of electricity (voltage variation, voltage and current transient, harmonic distortion)	During starting of the onboard high peak/consuming equipment, voltage may decrease during a short interval. When calculating power demand based on fuel (energy) consumption, the result will be an averaged based power figure. This may not be sufficient to cope with discrete short-termed peak consumption.	Trip of overload protection systems leading to blackout	Each ship type will have a different peak factor, which should be considered when designing shore power infrastructure. During the design stage, the decision is recommended to be taken together with operators whether to design for average power demand, peak power demand, or any design point in between.
	Electrical failure - high inrush current	High inrush current may occur when starting a high-capacity consumer, e.g., electrical driven high-capacity pumps, fast charging systems onboard, electro-hydraulic systems.	Voltage dip	It is recommended to: - size the transformer according to the terminal's traffic and potential peak load from the visiting ships, - establish a communication procedure beforehand between the ship and terminal about if there are load restrictions from the shore power system and the ship's required average and peak load, - perform the start-up of electrical machinery onboard the tankers in a manner that will limit the peak currents, e.g., using a soft start or frequency-controlled motor.
	Electrical failure	Lighting strike – atmospheric electrostatic discharge	Physical system disruption Integrity affected Damage of the consumers onboard the ship	Insulation in place for overvoltage protection. Ensure the design and installation of shore power system are following the relevant local standards and codes.

[9] DNV-GL

[10] Zuniga et al., Classical Failure Modes and Effects analysis in the Context of Smart Grid Cyber-Physical Systems, Energies, 13(5):1215, 2020

System	Failure mode	Cause	Effect/ Consequences	Mitigation/ Recommended Action
Main incoming substation	Electrical failure	Shipboard electrical frequency and voltage may not be compatible with the shore power.		Voltage step down transformers and frequency converter to be installed when needed.
	Electrical failure - overheating	The extreme environmental temperature may induce overheating of the main incoming station.		Consider implementing climate control for the main incoming station.
	Electrical failure - fail to start	Fault in the control system.	Unable to supply power to receiving ship	Ship will continue to use auxiliary engines to provide power. Procedure for fast power restoration must be in place. At least one ship generator ready to be connected for onboard main power restoration.
	Electrical failure - fail to stop	Fault in the control system.	Cannot disconnect the shore power when it has power on.	Incorporate a mechanical tripping of the circuit breaker for bypassing the main incoming station control system.
Power Equipment **(at main Substation or berth substations**	**Busbar** Loss of structural integrity Loss of electrical continuity Loss of electrical efficiency Electrical operation failure	The metallic strip can lose its mechanical integrity due to support insulators breakdown, cracking of welds and fracture of the copper bar. The occurrence of arc flashes degrades the copper bar. Moisture and humidity can lead to short circuits. Short circuits between buses and harmonics can lead to ohmic heating.	Power failure Blackout in OPS supply Fire Occupational hazard Equipment degradation due to short-circuit currents	Adequate design. Regular maintenance, including thermographic detection of hot spots.
	Circuit Breaker Insulation failure Wrong operation Bushing breakdown Bushing terminal hotspot Loss of dielectric strength in bushings Mechanical failure in the operating mechanism Contact's degradation	Loss of dielectric properties can damage the CB. Improper parameterization or manual installation leads to spurious opening or closures. Lightning or external short circuits can damage the bushing. Moisture can increase ohmic resistance in bushing terminals, resulting in bushing damage. Heat, oxidation, acidity, and moisture can lead to bushing degradation. Lack of lubrication, contamination or	Blackout event Failure to disconnect Fire	Signal analysis optimization in order to find opening patterns. Establish preventive cleaning and terminal verification routines.

System	Failure mode	Cause	Effect/ Consequences	Mitigation/ Recommended Action
		corrosion prevents CB from acting when necessary. Contact wear and electrical treeing can damage the equipment.		
	Power Transformer Bushing breakdown Bushing terminal hot spot Loss of dielectric strength in bushings	Lightning or external short circuits can damage transformer bushings. Moisture can increase ohmic resistance in bushing terminals, resulting in bushing damage. Heat, oxidation, acidity, and moisture can lead to bushing degradation.	Power quality degradation Fire Blackout in shore power supply	Real Time Signal analysis. Adequate design/ installation. Environmental conditions addressed. Adequate moisture, thermal, RH control.
	Power Transformer Magnetic-core delamination Tap changer mechanical failure in the drive mechanism Tap changer contacts degradation Windings isolation degradation or breakdown	Harmonics or corrosion can induce core degradation.	Contact wear and electrical treeing can lead to transformer unstable operation. Corrosion, friction or contamination can lead to transformer unstable operation.	Real Time Signal analysis. Implement hot spot alert strategies.
	Power Transformer Tank rupture	Vibration-induced damage, corrosion or cracking of welds result in oil leakage and possible catastrophic event. Oil contamination, oil moisture or short circuits and overloads can damage transformer windings.	Fire Explosion Equipment integrity disruption	Implement hot spot strategies.
	Power Transformer Cooling System failure	Fan degradation Refrigerating system failure	Transformer core overheating Fire Degradation	Cooling systems redundancy. Periodic cooling system maintenance (Check for leaks, rust or accumulation of dirt).
Frequency Conversion	**IGBT Power Module** Thermal runway	High operating temperature	Cracks formation and delamination formation in solder layers.	Lowering thermal resistance between IGBT and heat sink.

System	Failure mode	Cause	Effect/ Consequences	Mitigation/ Recommended Action
			Damage of IGBT power module and power interruption Blackout	
	Capacitor Capacitor open circuit.	Capacitor open circuit	Moisture absorption Replacing DC link capacitor	A proper overload protection scheme.
	AC/DC contactors Fails to open or open late.	Bad system configuration	During ON-state: high power losses & degradation of contactor Overheating, arcs, and fire	Periodic visual inspection.
	Cooling fans Mechanical failure	Fan mechanical failure	Overheating of frequency conversion unit Thermal failure Fire	Cooling systems redundancy.
Power cable	Mechanical failure - structural failure	The strength of the pier may not be sufficient to carry the extra load from the power cable.	Structural damage of the pier	A structural evaluation, including seismic analysis, shall be performed following MOTEMS to evaluate if upgrades of the structural system of the causeway and terminal is needed.
	Mechanical failure - Rupture	Cable might be damaged from the traffic on the wharf and earthquake. Inadequate CMS support	Shore supply failure Blackout Occupational incident	Perform electrical relay coordination study.
	Mechanical failure - Flooding	Flooding in the duct may damage the power cable.	Degradation of cable and connections	Ensure using waterproof typed power cable.
	Mechanical failure – degradation of insulation	Loss of isolation resistance The aging process results in the eventual failure of the insulating and sheathing materials.		Regular inspection. Adequate storage and handling of cables in operation. Avoid extended exposure to UNV light.
Onshore installations (excluding CMS)	Electrical failure - Overheating	Switchgear could be overheated due to high atmospheric temperature.		Consider implementing climate control for the switchgear.
	Electrical failure - Fail to start	Fault in the cable, switchgear, etc. at the onshore installation	Unable to supply power to the ship	Ship will continue to use auxiliary engines to provide power. Procedure for fast power restoration must be in place. At least one ship generator ready to be connected for onboard main power restoration.

System	Failure mode	Cause	Effect/ Consequences	Mitigation/ Recommended Action
	Electrical failure - Fail to stop	Fault in the control system.	Cannot disconnect the shore power when it has power on.	Regular maintenance required. Inspection
	Design challenge	The terminals may not have sufficient space for the shore power installation.		- Easy access and minimizing the distance between ship and pier is preferred. - Evaluate if an upgrade of the terminal is needed for accommodating the pier side shore power equipment.
	Mechanical damage	Wake from channel, provision loading, ship traffic, dropped objects may cause damage.		- Review the traffic design to introduce safety barriers, e.g. armour, at the high-risk locations.
	Electrical failure - Internal short circuit or arc	Internal short circuit or arc	Injury of personnel during operation.	-Perform an arc study and internal arc test -Following the local code to identify the design requirements, e.g. use arc-proof switchgear. The code may include: IEEE 1584-2018 - IEEE Guide for Performing Arc-Flash Hazard Calculations
Equipotential Bonding Connection	Failure of equipotential bonding	Mechanical damage of equipotential bonding cable	Potential injury of personnel during operation	Ensure adequate quality and good status of the equipotential bonding cable. Use a continuous equipotential bonding monitor device.
Cable Management System **(CMS)**	Mismatch between CMS OPS location on shore and receiving OPS station on ship side	Wide range of ship length and several scenarios of berthing arrangements	Impossibility to connect due to wide separate relative locations for supply/reception of shore-power	A standardized solution on the installation location of the Shore power connection location would be ideal but not available. Need to be investigated at ship-specific and terminal-specific levels. For containerships it is possible to have socket pit boxes at shore side at regular intervals (e.g. 50 m) – mobile socket boxes are also a possible technical solution – shore side is however typically constrained by cargo crane footprint area and trailing rails. For cruise ships it should be analysed on a case-by-case – mobile CMS on shore side may be the best option For RO-Pax, especially on dedicated terminals/ regular service it may be easier to consider fixed CMS solutions – compatible with regular RO-Pax ships. For ships involving handling of hazardous cargoes/substances, with potential presence of hazardous zones, the location of shore-power supply should be carefully considered and subject to Risk Assessment.

System	Failure mode	Cause	Effect/ Consequences	Mitigation/ Recommended Action
		Lifting heavy materials	Injury of personnel during operation	Locate/ install a suitable crane for handling the cables.
		Handling high voltage cables		-Ensure the shore power design and installation follow relevant standards, e.g. IEC standards and Class society standards. - Provide high-voltage operation and shore power usage safety trainings for the relevant personnel
		Unawareness of the potential conflicts during the design and operation	Interference the normal operation of ships and specific terminal, e.g. cargo discharging, provision loading, etc.	- Perform traffic study and develop an operation procedure to avoid conflictions - Awareness of port operations in the vicinity, to and from receiving ship
	Mechanical damage due to tidal relative motion	Tidal relative motion not sufficiently safeguarded	Over tension in power cables CMS damaged Ship structural damage Blackout in shore power supply.	Adequate design Cable tension alarm

Table 9.1 is not exhaustive and, depending on the OPS system actual components and local-specific elements, it is possible to have different equipment and operational considerations.

The table is presented to assist with safety and risk-based discussion in the analysis of generic SSE systems.

9.1.2 Shore-side battery charging – failure modes

Table 9.2, below, list different failure modes possible to consider in SBC systems. The system component breakdown follows that of Figure 8.17 and the operational concept of section 8.4.3, for a fast DC-DC charging system and process.

Table 9.2– Failure Modes in Shore-Power/ Shore-side Battery Charging (SBC)[11].

Phase	High Level Function	Potential Failure	Consequences	Mitigation
Connection	Establish electric connection	Incomplete mating	Potential Effect: Overlapping of contacts not sufficient, reduced current capability	No charging started
		Water, Dirt / Dust intrusion	Potential Effect: Insulation resistance decreases	Ensure Detection: Isolation Check is performed by Supply Station including self-test Isolation Check = fault --> no charging started Standard Ref.: Isolation Check IEC 61851 23, CC.5.1, IP44 IEC 62196 1 11.3.1

[11] CharIN e.V, Design Guide for Combined Charging System V7 2019-05-08

Phase	High Level Function	Potential Failure	Consequences	Mitigation
		Degradation of contacts or cable attachment (increased resistance and resulting overheating	Potential Effect: Isolation damage of insolation material supporting live parts	Detection: Temperature monitoring of connector contacts Mitigation: Temperature limited by Supply Station. Supply Station will initiate normal shutdown. Standard Ref.: IEC 61851 23, Annex CC.5.2, IEC 61851 23, CC.4.2 and ISO 17409, 9.6
Initialisation	Hand Shaking / Compatibility Assessment	Pilot signal not set or wrong value	Potential Effects: No or invalid pilot signal	Detection: Ship validates signal against standardized definitions Mitigation: No charging started Standard Ref.: IEC 61851 23, CC.1a time stamp t0/t4 and IEC61851 23 CC.1, CC.2, CC.3, CC.4
		PLC communication failed such that supply assumes request for DC charging instead of AC or no valid PLC communication established	Potential Effects: Misinterpretation or incompatibility of PLC information	Detection: Compatibility check (version based) Mitigation: No charging started Standard Ref.: ISO/IEC 15118 2
	Locking Connector	Locking failed	Potential Effect: Connector is not locked and can be removed	Detection: Lock monitoring signals error Mitigation: No charging started Standard Ref.: IEC 62196 3, 16.301, ISO 17409 Clause 9, IEC 61851 23 CC.5.3
	Exchange operating limits and parameters of charging	Misinterpretation of parameters and limits, supply operates with wrong voltage and/or current limits or parameters	Potential Effects: Later during charging: 1) Overvoltage, 2) Overcurrent, 3) Reverse current	1&2) Voltage and current measurement during charging Mitigation: 1&2) EV initiated emergency shutdown. 3) Prohibited and ensured by supply Standard Ref.: IEC 61851 23 CC for 1 and 2, IEC 61851 23 101.1.5 for 3
Cable Check	Supply enables isolation check	Isolation initially corrupt	Potential Effects: Connection between HV system and supply may lead to strike or arc	Perform initial isolation check at 500V (mandatory for supply, optional for ship) Mitigation: No charging started Standard Ref.: IEC 61851 23, CC5.1
		Isolation monitor malfunction	Potential Effects: Corrupted isolation not detected.	Detection: Perform isolation monitor self-test Mitigation: No charging started Standard Ref.: IEC 61851 23, CC5.1
Pre-charge	Supply enables High Voltage DC output	No / low voltage due to short circuit or broken wire, timeout.	Potential Effect: Precharge voltage cannot be established	Detection: Voltage measurement Mitigation: Timeout error, no charging started Standard Ref.: ISO 17409 13.4.1, IEC 61851 23, 6.4.3.110

Phase	High Level Function	Potential Failure	Consequences	Mitigation
	Voltage Synchronization	Mismatch between requested and delivered voltage	Potential Effects: Pre-charge Voltage incorrect. High power inrush current	Detection: Ship input voltage measurement and consistency check with requested supply voltage Mitigation: Ship disconnecting device still open. No charging started. Implemented in ISO/IEC 15118 2 1) 8.7.2.2, ISO 17409 5.6.2, ISO 17409, 9.1 last paragraph
		Voltage shift referred to ground	Potential Effects: Isolation breakdown/stress caused by excessive voltage	Mitigation: Limit voltage shift (V shift) caused by Supply Station Standard Ref.: IEC 61851 23 6.4.3.113, IEC 61851 23, 6.4.3.113
		Communication error	Potential Effects: Incorrect voltage supplied; Timeout	Detection: Input voltage measurement and consistency check with requested supply voltage Mitigation: Ship disconnecting device still open, no charging started Standard Ref.: ISO/IEC15118 2 1)1), 8.7.2.2, ISO 17409, 9.1 last paragraph
Charge	Supply transfers energy per EV request	Overheating of ship coupler	Potential Effect: Isolation damage of insolation material supporting live parts	Detection: Temperature monitoring of connector contacts Mitigation: Temperature limited by Supply Station. Supply Station will initiate normal shutdown. Standard Ref.: IEC 61851 23, Annex CC.5.2, IEC 61851 23, CC.4.2 and ISO 17409, 9.6
		Insulation corrupted during charging	Isolation fault	Detection: Continuous isolation monitoring at station (<1(<100kOhms) Mitigation: Fault state of isolation monitor and supply initiated normal shutdown Standard Ref.: IEC 61851 23, Annex CC.5.1
		of DC+ and DC output circuit	Potential Effects: Overheating, Arching	Detection: EV and EVSE voltage measurement recognises low voltage Mitigation: Ship over current protection, ship initiated normal shutdown Standard Ref.: ISO 17409 Clause 6.
		Unintended disconnect	Potential Effect: Hot disconnect with arc	Detection: None required Mitigation: Locking of connector (752N) Standard: IEC 62196 3 26.302, ISO 17409 Clause 9, IEC 61851 23 6.4.3.104

Phase	High Level Function	Potential Failure	Consequences	Mitigation
				Detection: Interlocking Interruption of Charging Process (state change from C2 Mitigation: CP lost shutdown (<5 A within 30 ms, <60 V within 100 ms) Standard Ref.: IEC 61851 23 9.4, IEC 61851 23 Annex CC.5.4
			Potential Effect: Connector can be unplugged under load	Detection: Lock monitor has status fault Mitigation: Ship initiated emergency shutdown Standard Ref.: ISO 17409 Clause 9
		Wrong output voltage at station (but within maximum voltage rating)	Potential Effect: Higher voltage at output than requested or lower voltage (may lead to reverse power flow)	Detection: Voltage measurement within EV and consistency check with requested voltage Mitigation: 1. Voltage change request if no reaction: 2. Normal shutdown Standard Ref: ISO 17409, 9.4
		Wrong output current	Potential Effect: Overcurrent, overheating of components in ship due to high current	Detection: Current measurement within EV Mitigation: Entry point Safe State: Ship initiated normal shutdown, ship fuse within HV system breaks Standard Ref: ISO17409, Third paragraph
Power Down	Supply reduces output current to 0A	Supply does not ramp down the current.	Potential Effects: Overvoltage, overcurrent	Detection: Receiving ship input voltage measurement, current derived Mitigation: Ship disconnecting device opens, Ship initiated emergency shutdown Standard Ref: ISO/IEC 15118 2 1)1), 8.7.2.2, ISO17409, third paragraph
	Deenergizing of Supply output (reduce output voltage to	Remaining high voltage on connector	Potential Effects: Overvoltage	Detection: Ship input voltage measurement Mitigation: Sequence stopped, next function cannot be entered (unlocking), **keep lock** Standard Ref: ISO/IEC 15118 2 1)1), 8.7.2.2, ISO 17409, 5.5.3
Disconnection	Unlocking of connector	No HV Safety Risk		
	Unplug connector	Connector cannot be unplugged no HV Safety Risk		

Table 9.2 is not exhaustive and, depending on the SBC system, charging mode, actual components and local-specific elements, it is possible to have different equipment and operational considerations.

The table is presented to assist with safety and risk-based discussion in the analysis of generic SSE systems.

9.2 SSE Risk Assessment

The assessment of safety risk for SSE system is usually performed through a combination of different methodologies. Whilst some may be more classical and allow for a "single-failure" risk-based calculation approach, where safety risk and reliability analysis can be combined, others can be more sophisticated in the possibility to integrate both very low-probability events and, also, the possibility for "multiple failure scenarios".

The combination of 4 (four) methods can be a possible solution to assess and visualize the relevant safety risk of SSE Systems and operations:

1. **HAZID** (Hazard Identification) exercise

   Hazard Identification Study (HAZID) is systematic, multi-disciplinary reviews carried out to determine potential hazards that may arise during operation of a process design, or execution of a work project, such as shore-side electricity infrastructure.

   A team of experts, over one or more guided/oriented and documented workshops are able to identify failure modes and qualitative safety risk of different systems, based on an equipment and component breakdown, together with a well-defined set of guidewords.

   Matrix in Figure 9.2 presents a HAZID matrix that is typically used, along with agreed qualitative criteria for probability and consequence.

2. **FMECA** (Failure Modes, Effects, and Criticality Analysis)

   FMECA is composed of two separate analyses, the Failure Mode and Effects Analysis (FMEA) and the Criticality Analysis (CA).

   IEC-60182 defines FMEA as a systematic procedure for the analysis of a system which target is the identification of the potential failure modes, their causes and effects on system performance.

   CA is necessary to plan and focus the efforts according to set of priorities in order to reduce the risk of failures and give to failures with the highest risk the highest priority.

   Risk Priority Number (RPN) to each failure mode: $RPN=S\times O\times D$, Where S (Severity) represents the severity on the base of the assessment of the worst potential consequences resulting from an item failure, O (Occurrence) denotes the probability of failure mode occurrence and D (Detection) represents the chance to identify and eliminate the failure before the system or customer is affected.

   Matrix in Figure 9.3 presents the FMECA process.

3. **HAZOP** (Hazards and Operability Analysis)

   Hazard and Operability Analysis (HAZOP) is a structured and systematic technique for system examination and risk management. In particular, HAZOP is often used as a technique for identifying potential hazards in a system and identifying operability problems likely to lead to nonconforming products. HAZOP is based on a theory that assumes risk events are caused by deviations from design or operating intentions.

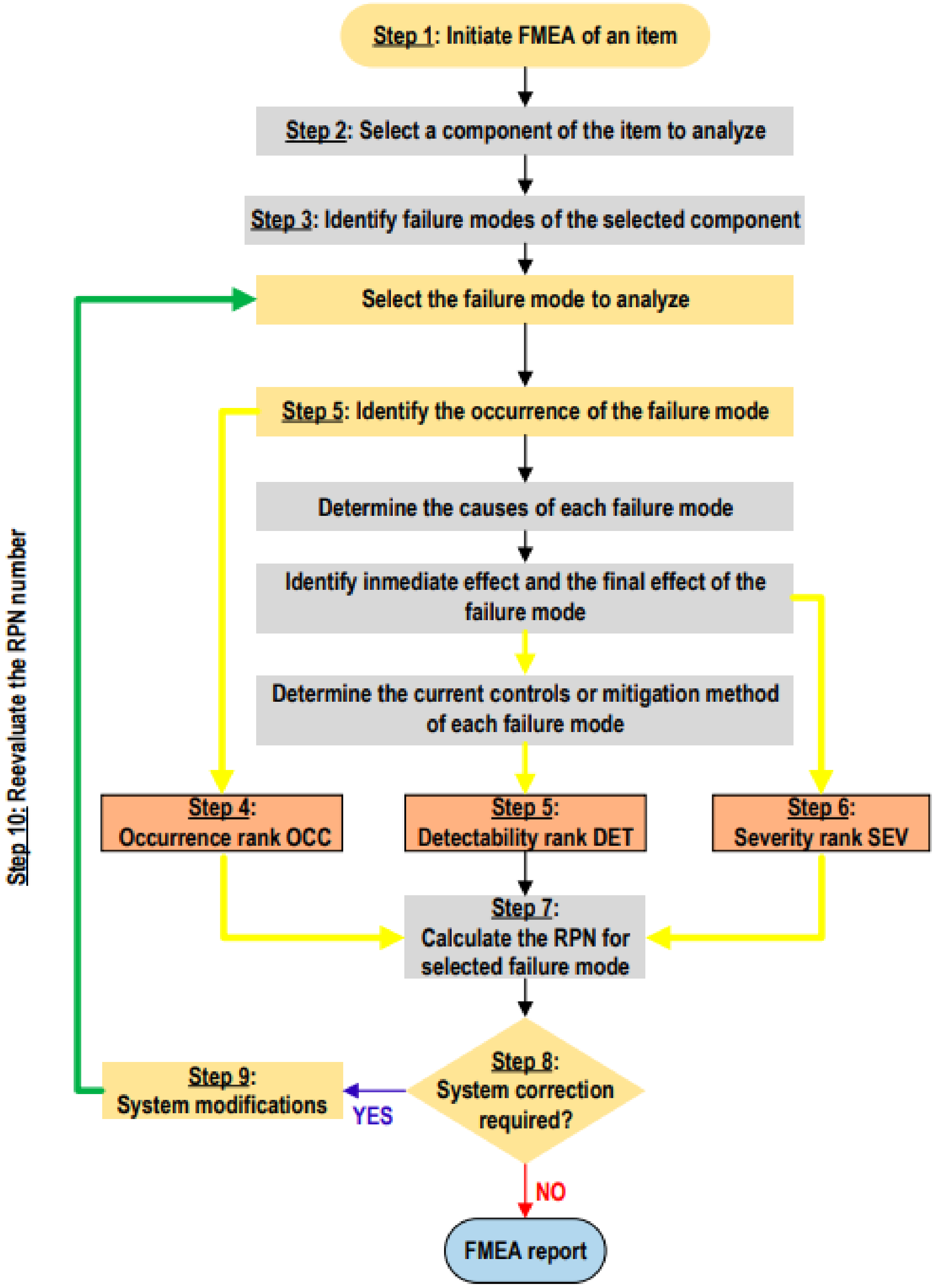
4. **Bow-Tie**

   Risk Presentation (not a risk assessment methodology *per se,* rather presented as a facilitated way to present the structure of causes, contributions, mitigating measures and consequences). A Bow-Tie analysis for "shore-power supply black-out" is presented in Figure 9.4.

Consequence	Personnel safety	Environment	Impact on vessel, terminal or its operation		Probability: Rare Technically to be excluded, or a failure can only occur by combination of two causes 1	Infrequent Not probable, to be expected that failure does not occur during lifetime of vessel/component under consideration (once in 100yrs) 2	Moderate Remotely probable, to be expected that failure can occur during lifetime of vessel/component under consideration (once in 10 years) 3	Frequent and high Probable, to be expected that failure occurs once per year of operation (1 year) 4	Very high Highly probable, to be expected failure occurs more often than once/yr of operation (<1yr) 5
	No impact on persons	None	No damage / undisturbed operation	1	L	L	L	M	M
	Single severe or few minor injuries	Minor effect, non-compliance event	Local damage/Operation of non-essential systems disturbed	2	L	L	M	M	M
	Multiple severe injuries	Localized effect, response required	Non-severe ship damage/Failure of non-essential systems	3	L	M	M	M	H
	One fatality	Major effect, significant response required	Severe damage to asset/ops of essential systems disturbed for <1h	4	M	M	M	H	H
	Multiple fatalities	Massive effect damage over large areas	Loss of vessel/Failure of essential systems	5	M	M	H	H	H

Figure 9.2 - HAZID matrix, with ranking criteria.

Source: DNV



(a)

Item / Function	Potential Failure Mode	Potential Cause(s) of Failure	Potential Consequence(s) /Mechanism(s) Of Failure	Detection Methods	Recommended Actions	Ratings of risk factors			
						SEV	OCC	DET	RPN

Figure 9.3 - FMECA process diagram[12].

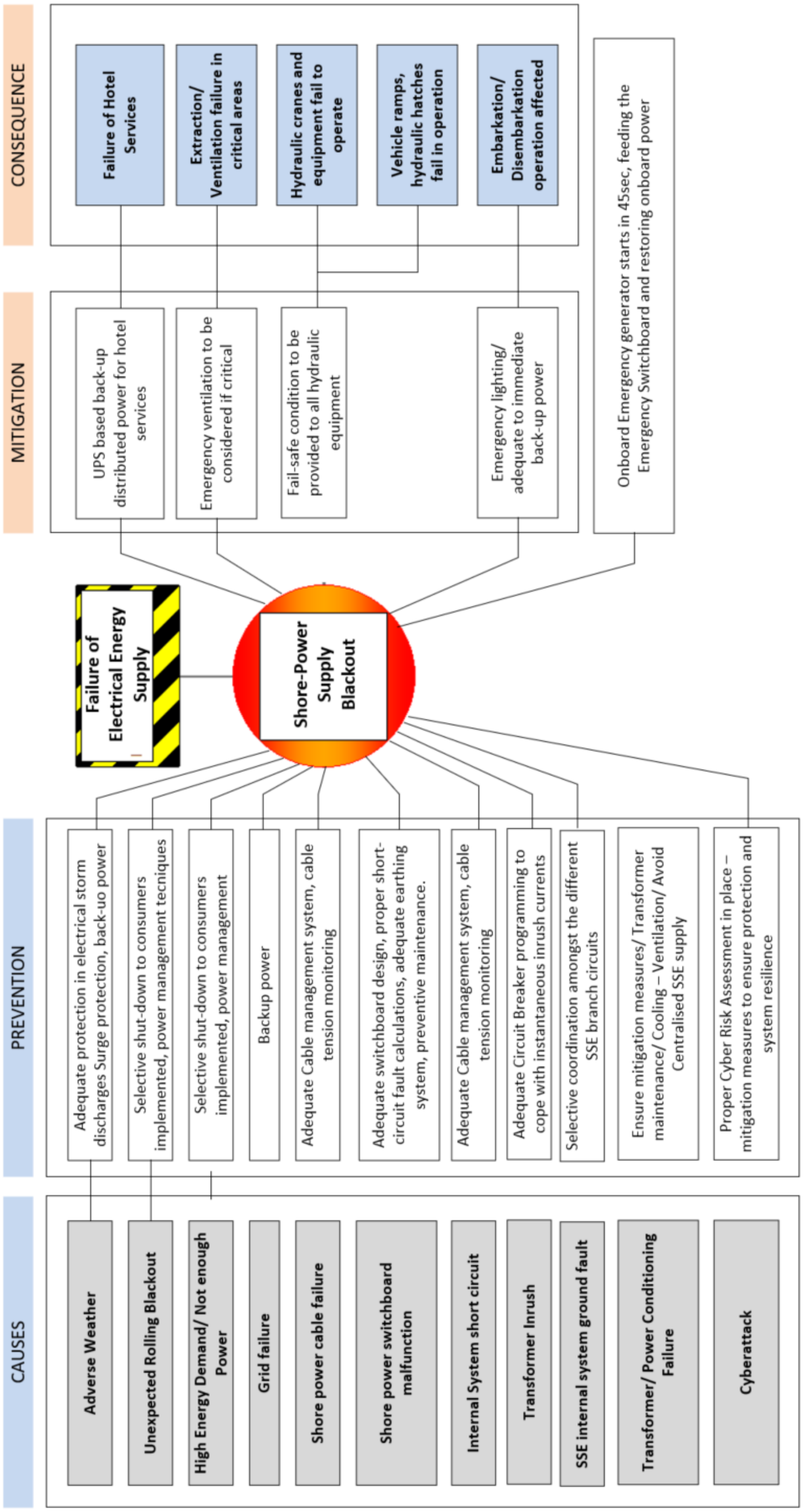


Figure 9.4 - Bow-tie risk representation – shore power supply blackout.

Source: EMSA

9.3 SSE Risk Management - Protections

The present section lists the possible SSE equipment protections that are present in SSE systems with a view to mitigate the risk for operators and increase the reliability of SSE systems.

9.3.1 Neutral earthing systems

In HV and LV installations, the neutral may or may not be earthed. The commonly used term is system earthing (also called system grounding), which determines how the neutral point of a transformer or generator and the exposed conductive parts (ECP) of the user's installation are earthed.

There are different solutions for earthing. Selecting the right one is a determining factor in terms of continuity of service, trouble-free operation, and protection against overloads and faults. A poor choice may result in damage to equipment, malfunctions, or hazardous situations. Installations where the type of earthing has been poorly selected or even worse, poorly implemented, may result in damage and electric shocks—or worse—electrocution.

Each earthing method affects network electrical parameters differently and determines the operating conditions of the installation in the event of a phase-to-earth fault. During an insulation fault or a phase-to-earth fault, fault currents, touch voltages, and overvoltages depend to a large degree on the type of earthing. A directly-earthed neutral helps limit overvoltages but is characterized by high fault currents. Conversely, an isolated system limits fault currents, but favours high overvoltages.

In all installations, when an insulation fault occurs, continuity of service also depends on the type of earthing. An isolated neutral enhances continuity of service in LV and even HV systems, on the condition that worker safety regulations are observed. On the other hand, a directly earthed or somewhat impedant neutral results in tripping when the first insulation fault occurs.

The type of earthing also determines the degree of damage suffered by certain loads (e.g. rotating AC machines, transformers) when an internal insulation fault occurs. When the neutral is directly earthed, an insulation fault causes severe damage due to the high fault currents. In installations with an isolated or highly impedant neutral, damage is limited, but equipment must have insulation levels compatible with the overvoltages that can occur in this type of system.

The type of earthing significantly influences the type and level of electromagnetic disturbances arising in an installation. Earthing that favours high fault currents and their flow in the metal structures of buildings causes major disturbances.

Conversely, earthing that limits fault currents and ensures good equipotential levelling does not cause significant disturbances.

For both LV and HV installations the type of earthing depends on the type of installation and type of network. It is also influenced by the types of loads, the need for continuity of service, and limits to disturbances for sensitive equipment.

9.3.2 Overview of earthing methods and implementation on ships

This section covers the impact of the earthing system on earth fault current, over voltages, and earth fault detection and clearing.

The contribution to the earth fault current of the capacitive leakage current (charging current) of HV cables must be carefully estimated for all ship operating conditions and for all load situations when at berth.

A ship could use different earthing methods on board for different areas (machine rooms, cargo holds, passenger cabins), for example. A comparative overview is presented in Table 9.3.

9.3.2.1 Solid earthing

- The transformer neutral is directly connected to the earth
- The earth-fault current is comparable to three-phase fault current and is easily detectable even if the fault occurs close to the neutral point of a star winding
- The level of transient overvoltages is low; the increase of the voltage between the earth and the two healthy phases remains low, thus no over-insulation is required
- Tripping is mandatory at the first earth fault
- According to the applicable class standards (BV, DNV, LRS, ABS, IRS, etc.) the system allowed for ships in this case is three-phase, three-wire (or four-wire in LV) with neutral directly earthed
- This arrangement is generally not used for ship power plant generation; however, hotel space for cruise ships can use a low-voltage three-phase system with the neutral directly earthed, a TT or TN-S system (5 wires: 3 phase conductors (L1, L2, L3), neutral conductor (N), protective earth (PE).

9.3.2.2 Low-resistance earthing

- The transformer neutral is connected to the earth via a low-resistance, faults being generally limited above 50A
- Like for solid earthing, earth fault detection is performed without any difficulties
- Transient overvoltages are well-controlled; the increase of voltage between the earth and the two healthy phases remains acceptable and does not require any improvement to the insulation of electrical equipment
- Tripping is mandatory at the first earth fault
- According to the applicable class standards (BV, DNV, LRS, ABS, IRS etc.) the system allowed for ships in this case is three-phase, three-wire (or four-wire in LV) with neutral directly earthed through a low-resistance
- This arrangement is generally not used for ship generators

9.3.2.3 High-resistance earthing

- The transformer neutral is connected to the earth via a high-resistance; the maximum single-phase-to-earth fault current is limited to a value in the range of approximately 5 A to 25 A primary current, depending on the value of capacitive leakage current of the network and the current through resistor
- The charging current (capacitive leakage current) of cables must be estimated for all ship situations, this value is used to determine the maximum earth fault current within the ship; the typical cable charging current for ships with HV systems is 5 A to 10 A depending on the size of the ship, with the exception of big cruise ships, where the charging current may reach a maximum value of 15 A to 20 A
- The level of transient over-voltages is linked to the value of the current limited by the neutral earthing resistance; with a primary earthing resistive current of 2 times the cable charging current, the peak value of the transient over voltages will never exceed 240% of the nominal voltage
- Due to the low value of the fault current, tripping at the first insulation fault is not mandatory and the operation of the installation may continue; nevertheless, the measurement of the residual current of each HV feeder allows the fault to be located rapidly for maintenance staff to clear it within a reasonably short time
- When a second fault occurs prior to the first fault clearing, the fault current reaches the value of the phase-to-phase short circuit and requires immediate tripping by the phase-to-phase overcurrent protections

- When a phase-to-earth fault occurs, the voltage between the earth and the two healthy phases reaches a value close to the phase-to-phase voltage, so over-insulation of electrical equipment is required
- According to the applicable class standards (BV, DNV, LRS, ABS, IRS etc.) the system allowed for ships in this case is three-phase, three-wire with a high-resistance earthing
- This method is very widely used on bulk carrier ships, chemical ships, cargo ships, container ships, Ro-Ro ships, reefer ships, tankers, cruise liners, offshore supply ships, recreational vessels, coast guard ships, frigates, destroyers, supply ships, and aircraft carriers.

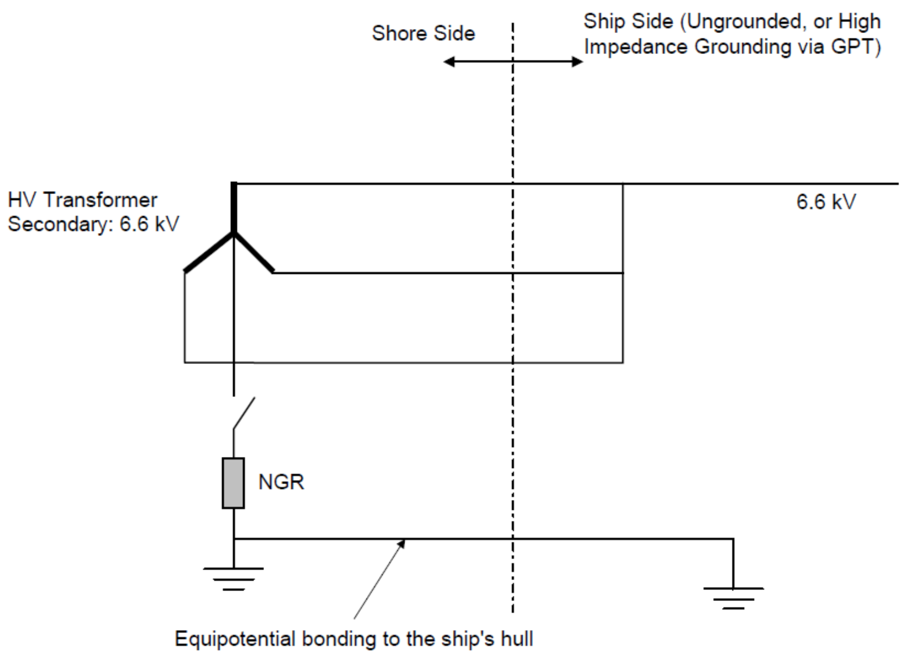


Figure 9.5 - Ungrounded Ship's System where shore-side Option for Ungrounded Neutral is Available[12]

Source: ABS

9.3.2.4 Unearthed systems

- No resistance is connected between the transformer neutral and the earth; the earth fault is equal to the cable charging current (2 A in LV up to 20 A in HV as mentioned above)
- As for high-resistance earthing, in the event of a phase-to-earth fault the voltage between the two healthy phases and the earth reaches the phase-to-phase voltage and requires improvement of the insulation of electrical equipment
- Tripping at the first fault is not mandatory; it becomes mandatory at the second fault, the fault becoming a phase-to-phase fault
- The level of insulation of any unearthed distribution system must be permanently monitored by an appropriate device (IMD, Insulation Monitoring Device) providing an audible or visual alarm when an unacceptable level of network insulation is detected (for HV systems the alarm must be both audible and visual (IACS E11 2); the fault must be located and eliminated by a maintenance team within a reasonably short time
- According to the applicable class standards (BV, DNV, LRS, ABS, etc.) the system allowed for ships in this case is three-phase, three-wire neutral insulated system; for small LV ships like recreational and sailing ships, it is a single-phase two-wire neutral-insulated system

[12] ABS Guide for High Voltage Shore Connection – November 2011

- As per high-resistance earthing systems, widely used on ships, unearthed systems are also found on a wide range of ship types.

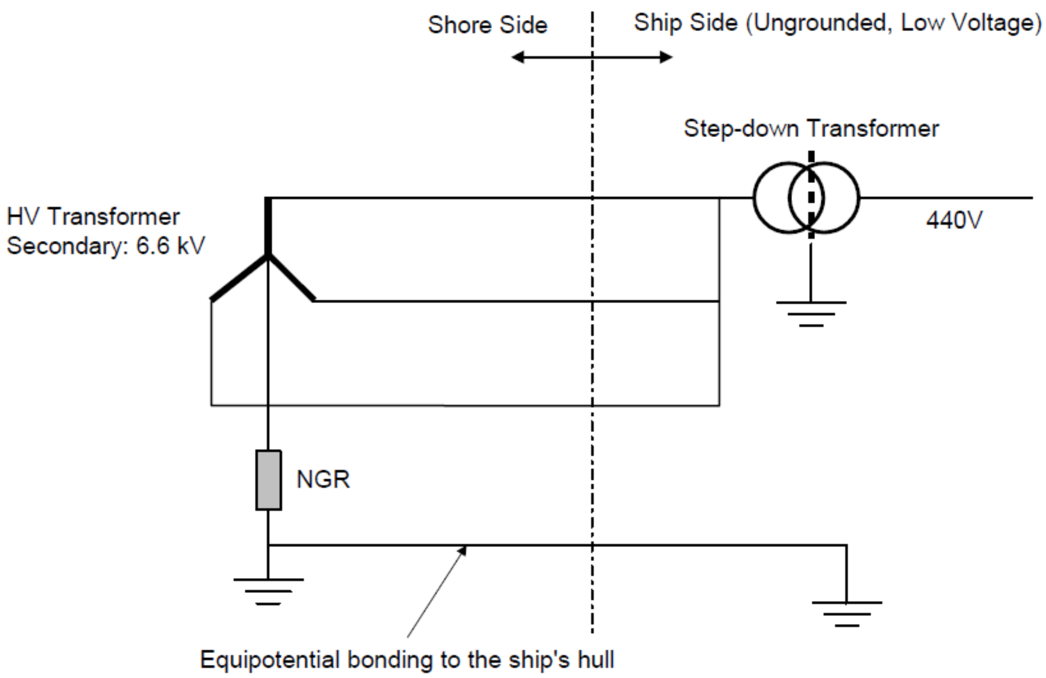


Figure 9.6 – Ungrounded LV Ship's System

Source: ABS

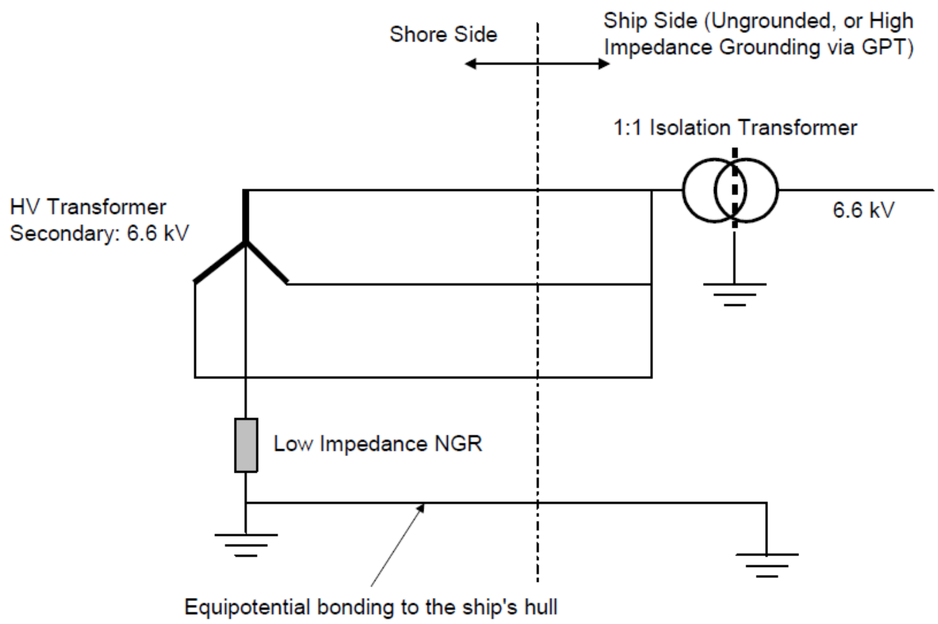


Figure 9.7 - Example for Ungrounded Ship's System (tanker, gas carrier).

Source: ABS

9.3.2.5 Earthing/Grounding - Summary

Below, a summary of the different possible earthing systems is presented.

Table 9.3 - Comparison of the different earthing systems.

Earthing System	Earth fault current	Damage	Transient overvoltages	Phase-to-earth overvoltage healthy phase	Tripping at the first fault
Solid earthing	High, 3-phase fault current	Very high	Low	Very low	Mandatory
Low-resistance Earthing	Medium, above 50A	High	Controlled	Low	Mandatory
High-resistance earthing	Low, up to 25A Charging current increase the current limited by the resistance	Low	Limited if the current limited by the resistance is higher than 2 times the charging current	The phase-to earth voltage is close to the phase-to phase voltage Insulation level needs to be improved	Not Mandatory Location and elimination of the fault are mandatory
Unearthed	Equal to the charging current	Low	High	The phase-to earth voltage is close to the phase-to phase voltage Insulation level needs to be improved	Not Mandatory Location and elimination of the fault are mandatory

9.3.3 Shore Connection Protection System

9.3.3.1 Protection Plan

Shore connection substations must be able to cope with a complex electrical power system:

- Multiple sources (utility delivery substation and onboard generators)
- Power conversion for frequency conversion
- Mobile equipment (HV cable and plug) for shore-to-ship electrical connection, which can be used several times a day

Considering the complexity of the installation, additional risks must be managed by implementing adequate protections. As example, this section will provide an overview of the protections that must be set in the main output HV switchboard, for container ship applications.

Figure 9.8 illustrates the overall architecture of the main output HV switchboard for container ship applications, including the protection functions embedded in each relay.

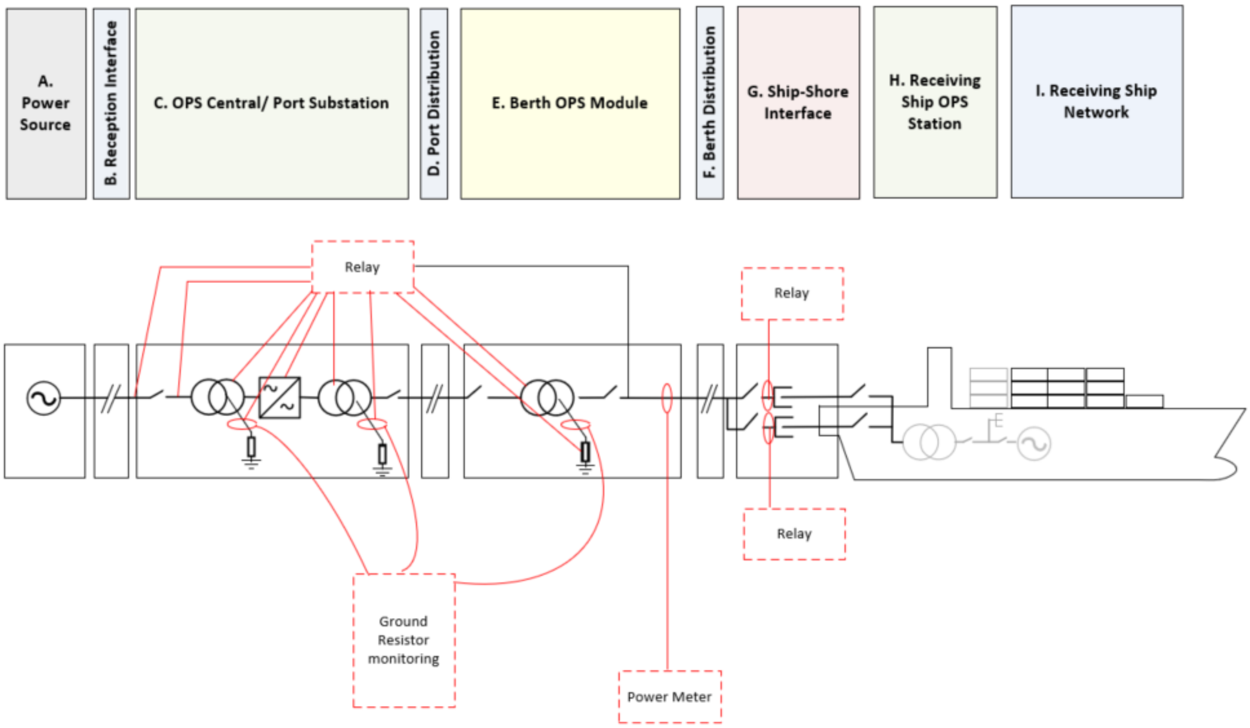


Figure 9.8 - Protection plan for a shore connection system without frequency conversion.

Source: EMSA

Protections embedded in the Relay (Ref to ANSI/IEEE Std. C37.2):

Protection Function	Description
87T	Transformer Differential
51G	Ground Time Overcurrent
51	AC Time Overcurrent Relay
50G	Ground Instantaneous Overcurrent
50	Instantaneous Overcurrent Relay
32	Directional Power Relay
27	Under voltage relay
59	Overvoltage Relay
81R	Rate-of-Change Frequency
84	Operating Mechanism
81	Frequency Relay
67	AC Directional Overcurrent Relay
67N	Neutral Directional Overcurrent
49	Machine or Transformer Thermal Relay / Thermal Overload
46	Reverse-Phase or Phase Balance Current Relay or Stator Current Unbalance

The protections detailed and associated to Figure 9.7 above can however be different depending on the exact configuration of the SSE system.

In Figure 9.9 the protection systems are also distributed per switchboard involved in the SSE-OPS connection.

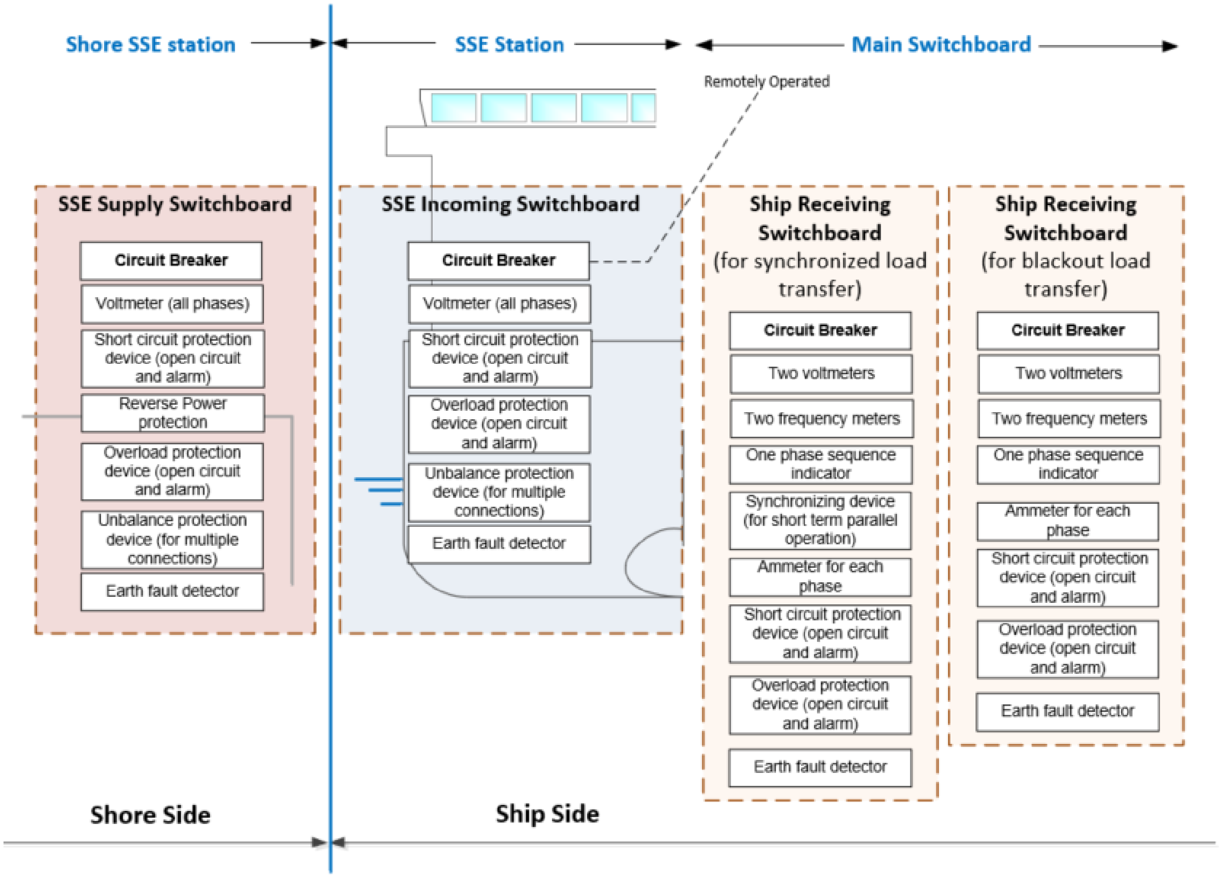


Figure 9.9 -Instruments and protections in OPS connection arrangement.

Source: EMSA

9.3.3.2 Protection against shore substation internal faults

Protection against an internal fault (earth or phase-to-phase faults) is provided by maximum overcurrent protections (ANSI 50/51 and 50/51 N), which are set to trip both input and output circuit breakers.

Particular attention should be given to internal faults within the shore system. Transformer internal faults such as inter-turn faults may be difficult to detect due to the low level of the corresponding line current (Figure 9.10). On the other hand, with frequency power conversion the limited value of the short-circuit current, with possible shutdown time generally between 0.5 s to 1 s, must be considered.

Consequently, for transformers, the use of two winding differential relays (ANSI 87T protection) and restrained earth fault protection are a reliable solution for internal faults. To secure the system, additional protections such as thermal overload (ANSI 49T) should also be installed.

In the event of a utility voltage interruption or collapse of frequency conversion units, an under-voltage protection (ANSI 59) trips the shore main output CB and then allows the ship to restart its own generators without any risk of inadvertent coupling with the shore substation.

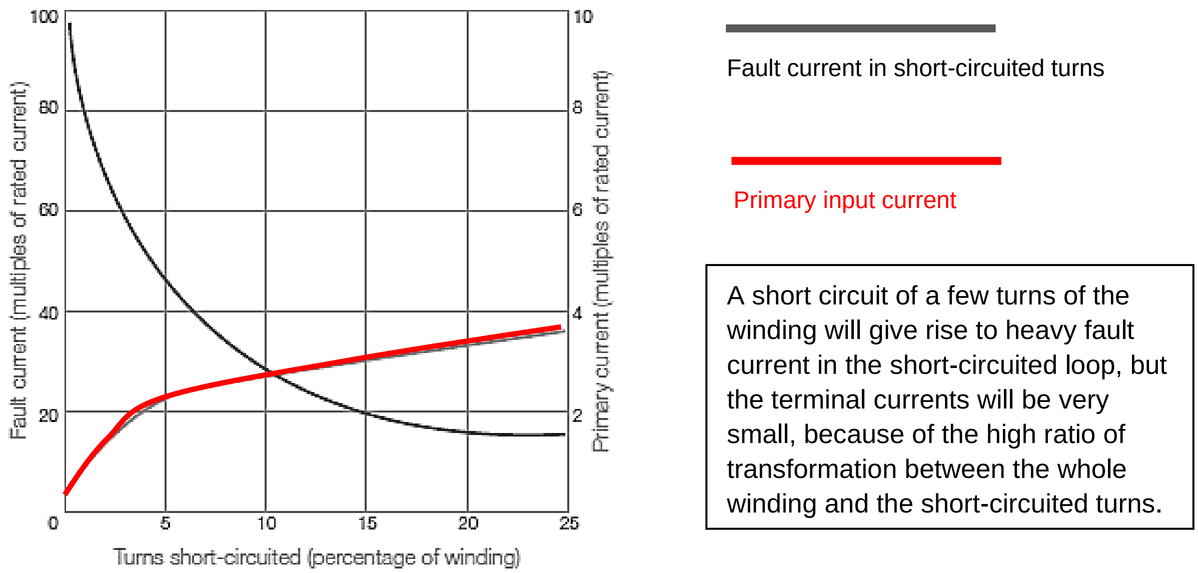


Figure 9.10 - Transformer inter-turn faults current/number of turns short circuited.

Source: Schneider Electric

9.3.3.3 Shore output protections

For earthing and phase-to-phase fault detection downstream of the shore installation, output maximum overcurrent protections (ANSI 50/51 and 50/51 N) are set to trip the output circuit breaker.

As the system can be supplied by both shore and ship side, directional protections (ANSI 67 and 67N) are set to trip on reverse overcurrent, coordinating protection and facilitating fault troubleshooting.

As the neutral earthing resistor could experience failures like connection resistance deviations or connection breakdowns, a specific relay is set to provide monitoring, detect possible failures, and guarantee that the installation will operate with the right neutral earthing system.

9.3.3.4 Parallel operation

During the shore start sequence, there is a risk that shore substation will close its main output breaker once the ship has already energized the connection cable. To prevent the shore from being connected to a ship without synchronization, a dead bus verification (ANSI 84) is set up on the main output breaker.

This protection enables the closing of the main output breaker only if no voltage is detected downstream.

During the parallel operation of the shore substation with ship generators, a reverse power protection (ANSI 32P) is placed on the main output breaker of the shore substation to prevent the ship from providing power to the grid.

To guarantee the acceptable voltage tolerance to ship loads, under/overvoltage protection (ANSI 27 and 59) and under/over-frequency protection (ANSI 81U/O) are also set up on the main shore output breaker.

9.3.3.5 Connection cable continuity monitoring

In the event of a breakdown or high impedance (poor contact) of the shore-to-ship earthing conductor, the bonding potential between the shore and the ship could exceed 30 V during an earth fault and present a danger to operators (Figure 9.11).

As the shore-to-ship cable is handled many times for each ship connection, this risk is not minor. Hence, an earthing check system is installed between the shore and ship to detect an earthing conductor failure (Figure 9.12). A current is injected into an additional pilot wire and passes through the earthing conductor; if a failure occurs on the earthing conductor, the earthing check system will trip the main circuit breakers on both sides.

There is also the potential risk of a power connector resistance deviation (due to poor contact) that could result in plug arcing phenomena. To detect this kind of failure, a negative sequence overcurrent protection (ANSI 46) is placed on the shore-side main output relay.

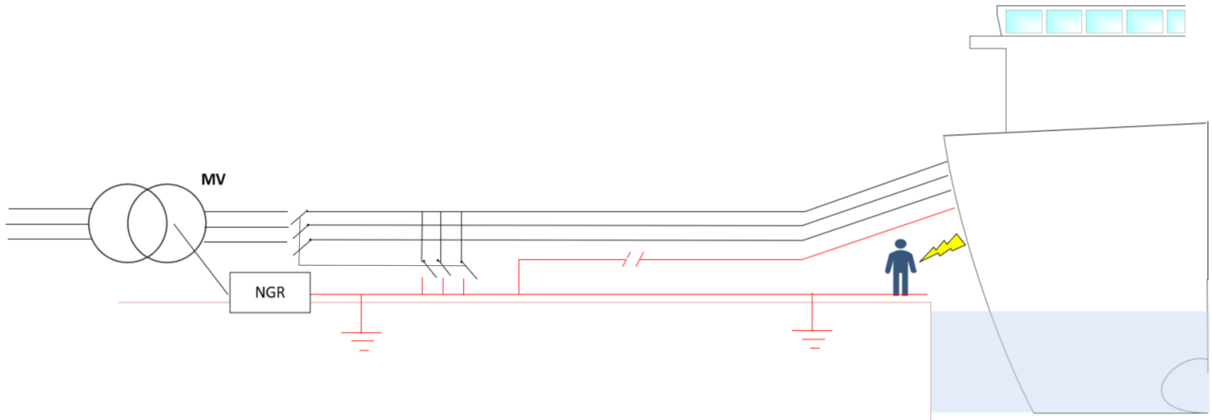


Figure 9.11 - Earthing conductor failure.

Source: EMSA

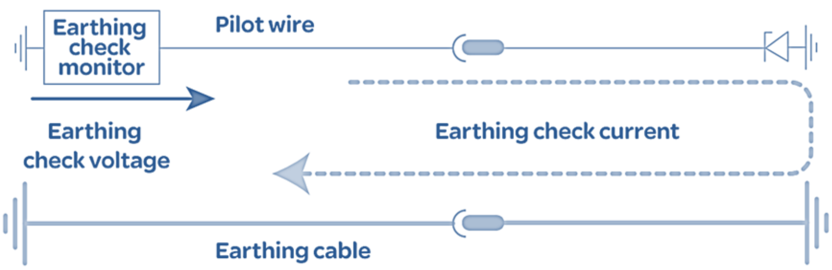


Figure 9.12 - Earthing check system.

Source: Schneider Electric

9.3.4 Protection Coordination

9.3.4.1 Earth fault coordination

The IEC/ISO/IEEE 80005-1 standard requires a galvanic separation between the shore connection and the onboard electrical network. A shore-side delta-star power transformer is used to meet this requirement. The star point of the transformer needs to be earthed through a resistance or remains isolated as defined above for each type of vessel.

As the voltages of the shore connection system are 6.6 kV or 11 kV, the system could require a delta-star transformer installed on board for ship voltage adaptation; in this case we would be dealing with two separate systems regarding earth faults. The shore-side earth fault protections do not need to be coordinated with those of the ship, which may maintain their existing settings.

Without an onboard transformer earthing protection must be coordinated. The difficulty lies in knowing the settings of the earth fault protection installed onboard. The best policy would be to set the shore earth fault protection below the minimum realistic earth fault current, taking into account resistive earth faults, and with a long time lapse exceeding the maximum time lapse met on board.

Hence, any fault not cleared by the onboard earth fault system will be detected and cleared by the onshore system. This solution does not reduce the availability of the loading/unloading operation, and the 80005-1 standard allows restoring ship power as specified by SOLAS CH II-1/D Reg. 42 or 43 after a blackout.

With the above solution, if the onboard earth fault relay does not trip, the shore earth-fault relay will trip as a back-up relay (Figure 9.13).

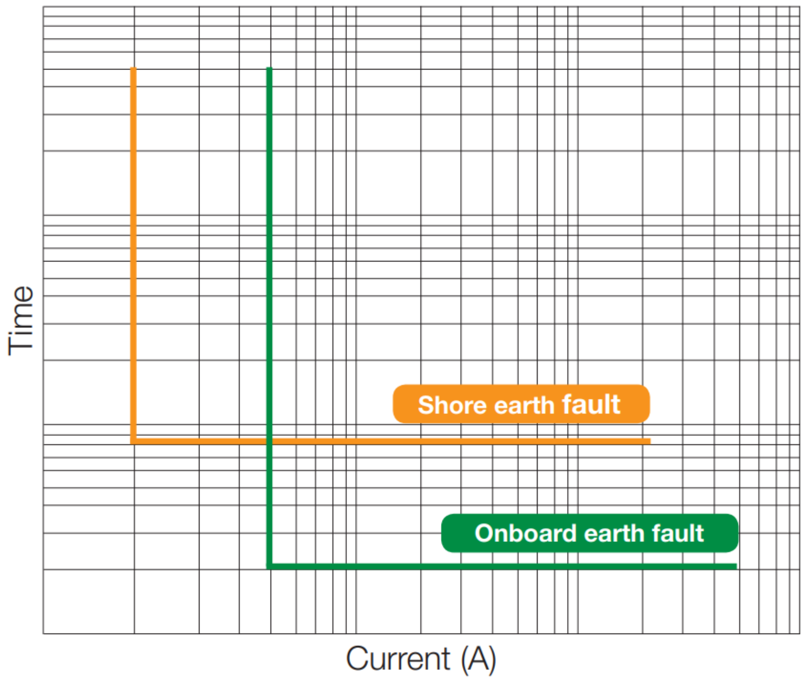


Figure 9.13 - Earth fault coordination in a shore connection system[13].

9.3.4.2 Phase-to-phase fault coordination

The major concern relative to the detection and clearing of phase-to-phase faults is the level of the expected short-circuit current. Currently, on the ship side, the expected short-circuit currents are very high due to the presence of several power generators on the main bus bars. The protection systems are set in accordance with these currents.

With power frequency conversion, the short-circuit current can be low and may collapse rapidly (depending on the frequency converter technology with LV or HV conversion; for HV conversion no overload capacity is available). In such situations, the coordination of shore protection with the onboard protection system becomes sensitive, and practically unachievable. In addition, when the ship is connected to the shore, onboard protections may not work properly because their settings are adjusted according to the minimum short-circuit current of the power generator and the largest onboard load. Standard 80005-1 requires shore substations to provide enough short-circuit current to trip the protection relay of the biggest load on the ship, in the case of a ship-side short circuit. Particular attention has to be paid to ANSI 50/51 protection coordination requirements, considering the limited level of short-circuit currents provided by the static frequency converters and the requirement that a shore protection system be set according to each ship.

[13] D. Radu - R. Jeannot - M. Megdiche - J. P. Sorrel, Shore connection applications, Main Challenges, July 2013

Whatever fault occurs onboard, the solutions generally consist of:

- Providing enough short-circuit current for enough time by using proper frequency converter technology or over-sizing the installation to ensure the selectivity of the largest onboard load as required by IEC/ISO/IEEE 80005-1
- Ensuring that setting time and current of the shore-side CB are coordinated with the frequency converters' total current time limitation; there is a general onshore trip, followed by a shore connection system blackout, and, finally, onboard ship power is restored.

9.4 Power Cable Handling Safety

There are electrical hazards inherent to the handling, connection, and disconnection of HV plugs. As shown in Figure 9.14, when performing a connection/ disconnection, the operator has access to power connectors and can be exposed to a shock hazard if the power connectors are not disconnected and earthed.

The possible risks are:

- Failure to disconnect from the shore substation
- Failure to disconnect from ship power system
- Failure to discharge the HV cable

All basic operations must be simple and secure, designed for complete protection of operators. Shore connection and disconnection safety is then achieved by adhering to two basic concepts:

1. Operating instructions and procedures
2. Automatic interlocks managed by a safety system (Figure 9.15)

IEC/ISO/IEEE 80005-1 sets forth specific measures to prevent the risks presented previously. The recommended measures are classified as follows in the standard:

- Emergency shutdown
- Conditions for the shore connection start sequence (conditions for main breaker closing and earthing switch opening)
- Conditions for plug handling during plugging and unplugging (opening the disconnector and closing the earthing switch on both sides).

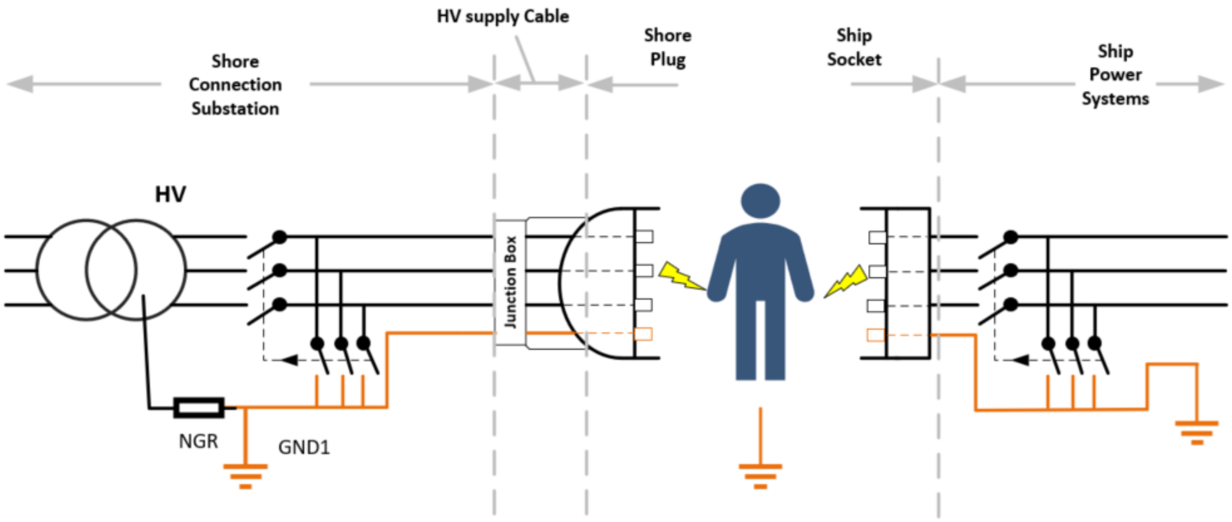


Figure 9.14 - Electrical hazard during connection/disconnection.

Source Schneider Electric

The purpose of automatic interlocks is to prevent all the risks intrinsic to HV plug handling during plugging and unplugging. The main safety requirements are:

- While not connected, on shore side (ship side for container ships case): - Allow access to and handling of the plug only when the shore circuit breaker is locked opened and when the earthing switch is locked in closed position
- While not connected, on ship side (shore side for container ship case) can be: - Prevent access to the HV socket while not earthed
- For disconnection: - Allow plug disconnection only if the HV plug & socket are isolated from the sources (shore and ship circuit breakers open) then the earthing switch of the shore side is locked in the closed position to discharge the HV cable and the earthing switch of the ship side is locked in the closed position

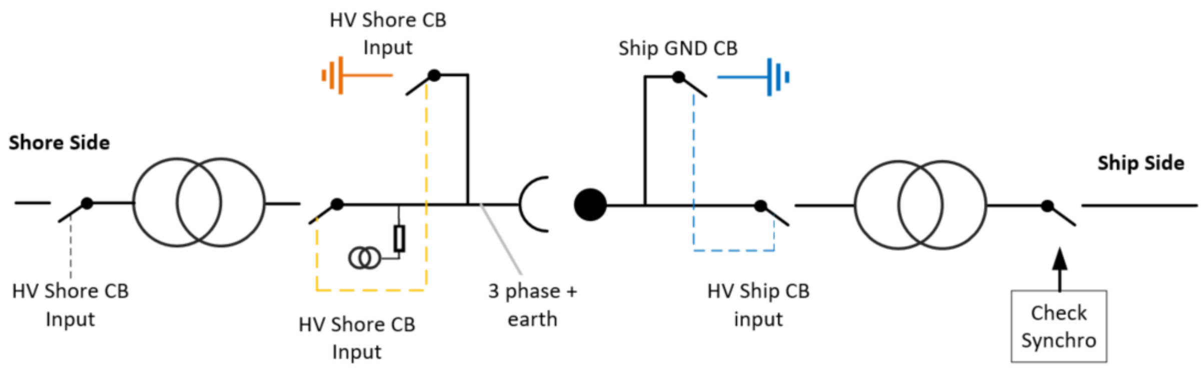


Figure 9.15 - HV shore to-ship connection architecture.

Source Schneider Electric

9.5 Safety Verification

Safety verifications can be defined with a view to ensure repeatability and standardization in safety procedures.

This system safety verification procedure should be completed for all IEC/ISO/IEEE 80005-1 compliant ships that have not previously successfully transferred to and from high voltage shore power or have not successfully transferred to and from high voltage shore power within the last 12-months.

A safety verification form aligned with the processes described in 8.2.2 to be checked and signed by the persons in charge on each side.

The elements below should be considered as minimum contents for the Safety Verification Form.

Table 9.4 - Safety Verifications elements.

Certificate Compliance	Ship HVSC designed/ built in compliance with IEC/ISO/IEEE 80005-1, with valid approval certificate.
Cable Insulation Resistance and Voltage Testing	Reviewed insulation resistance measurement and voltage test of cables. NOTE: Only required for initial shore or ship commissioning, 1st Connection certification, or in excess of **12-month** period from last successful transfer to high voltage IEC/IEEE 80005-1 indicates shall be performed only if one of the installations, shore-side or ship-side, has been out of service or not in use for more than 30 months. This represents a minimum standard. PAA/Operators may consider reducing this interval, especially for insulation resistance measurements.
Visual Inspection	Performed visual inspection of HVSC system in general
Earthing	Performed visual inspection of earthing resistance (shore only)
Phase Sequence	Visually verified phase sequence: Specified Frequency 50/60Hz HZ, A-B-C anti-clockwise (IEC/IEEE 80005 Section 5)
Equipotential Bonding	Visually verified equipotential bond monitoring: no signs of rust or wear of ship plugs, all pins, receptacles, plugs or cables
Interlocking	Function test of Interlocking
Cable Management System	Verified function of cable management system.
Integration	Integration testing to demonstrate that shore and ship-side installations work properly together, including protection devices and control equipment. Verification of Circuit Breaker tripping
Selectivity	Check Shore-side Feeder Circuit Breaker adjustment of programmable functions for electrical protection selectivity adequate to receiving ship characteristics The use of HVSC system shall not compromise the electrical protection selectivity of the largest on-board load (IEC/IEEE 80005-1 Section 6.1)
ESD verification	Emergency Shutdown System Verification • All individual emergency push buttons (e-stop) on ship tested. • All individual emergency push buttons (e-stop) on shore tested

References for Part 2

[1] S. Karimi, M. Zadeh and J. Suul, Shore Charging for Plug-In Battery-Powered Ships: Power System Architecture, infrastructure, and Control, Vols. vol. 8, no. 3, pp. 47-61, IEEE Electrification Magazine,, 2020.

[2] IEC/IEEE, IEC/IEEE 80005-1 - Utility connections in port – Part 1: High voltage shore connection (HVSC) systems – General requirements, IEC/IEEE, 2019.

[3] IMO, Draft Interim Guidelines On Safe Operation Of Onshore Power Supply (OPS) Service in Port for Ships Engaged on International Voyages, IMO, 2020.

[4] DNVGL, Rules for classification: Ships — RU-SHIP Pt.6 Ch.7. Edition July 2019, 2019.

[5] IEC, IEC 60079-10-1 (2015). Explosive atmospheres – Part 10-1: Classification of areas - Explosive gas atmospheres., IEC, 2015.

[6] EC, EU general risk assessment methodology (Action 5 of Multi-Annual Action Plan for the surveillance of products in the EU (COM (2013)76) – Document 2015-IMP-MSG-15 - 16 October 2015, 2015.

[7] EU, Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure, 2014.

[8] EC, Directive 1999/92/EC - ATEX of the European Parliament and of the Council of 16 December 1999 on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres, 1999.

[9] API, API RP-505. 1997, Recommended practice for classification of locations at petroleum facilities classified as Class I, Zone 0, Zone 1 and Zone 2. Washington, D.C. API., 1997.

[10] API, API RP-500. 1997. Recommended practice for classification of locations for electrical installations at petroleum facilities classified as Class 1, Division 1 and Division 2. Washington. D.C: API, 1997.

[11] EC, COMMISSION RECOMMENDATION of 8 May 2006 on the promotion of shore-side electricity for use by ships at berth in Community ports (Text with EEA relevance) (2006/339/EC), EC, 2006.

[12] ENTEC, European Commission DG-ENV Service Contract on Ship Emissions: Assignment, Abatement and Market-based Instruments - Task 2 Shore-side Electricity, 2005.

[13] EC, C(2019) 5960 final COMMISSION DELEGATED REGULATION (EU) supplementing and amending Directive 2014/94/EU of the European Parliament and of the Council as regards recharging points for L-category motor vehicles, shore-side electricity supply for inland wate, EC, 2019.

[14] IEC/IEEE, IEC/IEEE DIS 80005-3 - Utility connections in port — Part 3 Low voltage shore connection (LVSC) systems — General requirements, IEC/IEEE.

[15] CESA, MEPC 69/5/8 - Promoting the use of onshore power supply - Submission to MEPC69, IMO, 2016.

[16] EPA, Shore Power Technology Assessment at US Ports - EPA-420-R-17-004, United States Environmental Protection Agency, 2017.

[17] CARB, Technical support document: Initial statment of reasons for the proposed rulemaking - Regulations to reduce emissions from diesel auxiliary engines on oceangoing vessels while at-berth at a California port, Sacramento, CA: California Air Resources Board, 2007.

[18] CARB, Initial statement of reasons for proposed rulemaking - Proposed amendments to the regulations "fuel sulfur and other operational requirements for ocean-going vessels within California waters and 24 nautical miles of the California baseline, Sacramento, CA: California Air Resources Board, 2011.

[19] C.-C. &. W. C.-M. Chang, Evaluating the effects of green port policy: Case study of Kaohsiung harbor in Taiwan, Transportation Research Part D: Transport and Environment, 17(3), 185-189, 2012.

[20] J. J. &. C. B. Corbett, Clearing the air: Would shoreside power reduce air pollution emissions from cruise ships calling on the Port of Charleston, SC?, Pittsford, NY: Energy and Environmental Research Associates, 2013.

[21] E. A. Z. B. A. D. J. J. A. &. S. A. Sciberras, Cold ironing and onshore generation for airborne emission reductions in ports. Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment, 2014.

[22] IEC/IEEE, IEC/IEEE 80005-2 Utility connections in port – Part 2: High and low voltage shore connection systems – Data communication for monitoring and control, IEC/IEEE, 2016.

[23] D. R. -. L. Grandidier, Shore Connection Technology - Environmental Benefits and Best Practices - SE July 2012, Schneider Electric, 2012.

[24] IEC, IEC 60034 (all parts), Rotating electrical machines, IEC.

[25] IEC, IEC 60050-151:2001, International Electrotechnical Vocabulary – Part 151: Electrical and magnetic devices, IEC, 2001.

[26] IEC, IEC 60092-350:2008, Electrical installations in ships – Part 350: General construction and test methods of power, control and instrumentation cables for shipboard and offshore applications, IEC, 2008.

[27] IEC, IEC 60092-353, Electrical installations in ships – Part 353: Power cables for rated voltages 1 kV and 3 kV, IEC, 2014.

[28] IEC, IEC 60092-354:2014, Electrical installations in ships – Part 354: Single- and three-core power cables with extruded solid insulation for rated voltages 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV), IEC, 2014.

[29] IEC, IEC 60092-360, Electrical installations in ships – Part 360: Insulating and sheathing materials for shipboard and offshore units, power, control, instrumentation and telecommunication cables, IEC, 2014.

[30] IEC, IEC 60092-376, Electrical installations in ships – Part 376: Cables for control and instrumentation circuits 150/250 V (300 V), IEC, 2017.

[31] IEC, IEC 60092-502, Electrical installations in ships – Part 502: Tankers – Special features, IEC, 1999.

[32] IEC, IEC 60092-509, Electrical installations in ships – Part 509: Operation of electrical installations, IEC, 2011.

[33] IEC, IEC 60228:2004, Conductors of insulated cables, IEC, 2004.

[34] IEC, IEC 60793-2, Optical fibres – Part 2: Product specifications – General, IEC, 2019.

[35] IEC, IEC 60793-2-10, Optical fibres – Part 2-10: Product specifications – Sectional specification for category A1 multimode fibres, IEC, 2019.

[36] EEA, Overview of electricity production and use in Europe, 2018.

[37] Hitachi/ ABB, https://www.hitachiabb-powergrids.com/references/substation-automation/uk-national-grid-rewards-exceptional-performance-with-contract-e.

[38] Schneider Electric, Guide to energy measurement applications and standards - White Paper Number 998-19721656_GMA-US, Schneider Electric, 2016.

[39] IEEE, IEEE Std 1100-1992, "Recommended Practice for Powering and Grounding of Sensitive Electronic Equipment.", IEEE, 1992.

[40] E. Csanyi, Reactive power and PF correction @ https://electrical-engineering-portal.com/, EEP, 2019.

[41] EATON Technical, Power factor correction: a guide for the plant engineer - Technical Data SA02607001E, EATON, 2014.

[42] ABB , Shore connection solutions - shaping a sustainable world - MARINE & PORTS | SERVICE, ABB, 2019.

[43] DNV-GL, Recommended practice — DNVGL-RP-0043. Edition September 2017 - Safety, operation and performance of grid-connected energy storage systems, DNV-GL, 2017.

[44] Battery, https://batteryuniversity.com, 2020.

[45] IRS, Guidelines on High Voltage Shore Connection Systems for Ships 2020, IRS, 2020.

[46] BV, Rule Note NR 557 DT R00 E - High Voltage Shore Connection, BV, 2010.

Links for figures in Part 2

Figure 4.5 - https://www.researchgate.net/publication/332072567_Modelling_and_development_of_thermo-mechanical_energy_storage Last accessed in 19/05/2022

Figure 4.9 - https://slowboattochina2013.files.wordpress.com/2014/12/cold-ironing-cma-cgm-2.jpg Last accessed in 16/03/2022

ANNEX-A

Checklist OPS

Checklist – ONSHORE POWER SUPPLY

Planned Date and time: ______________________________

Port and Berth: ______________________________

Terminal receiving ship: ______________________________

Ship name/IMO Nr: ______________________________

	Check	Ship side	Shore side	IEC/IEEE 80005-1 2019	IMO OPS Guidelines	Remarks
	Onshore Power Supply					
A	**General**					
1	A compatibility assessment (for high voltage, see standard IEC/IEEE 80005-1) or technical analysis (for low voltage) of the OPS system should be available to verify the possibility of connecting the ship electrical system to the shore's installations			4.3	1.3.3	
2	An equipotential bonding between the ship hull and shore grounding electrode should be established				1.3.4	
3	Specify responsibilities and assignments, including the person in charge of the operation				1.3.5	
4	Complete a pre-connection checklist prior to the ship's arrival and connection at a shore supply point.				1.3.6	
5	Person in charge should confirm that there are no safety-critical operations on the ship prior to connecting to the shore power supply				1.3.7	
B	**Communication**				1.3.8	
6	A voice communication link, e.g. communication devices or other equivalents, should be provided to facilitate the communication between the operational personnel from the shore- and ship- side				1.3.8.1	
7	Equipment for voice communication should be functional				1.3.8.2	
8	In case of any VHF or UHF voice communications, the ITU Maritime Mobile Services frequencies should be used				1.3.8.3	VHF / UHF Channel: ____________ Primary System:

	Check	Ship side	Shore side	IEC/IEEE 80005-1 2019	IMO OPS Guidelines	Remarks
						____________ Backup System: ____________
9	Voice communications should be carried out in the common working language of the terminal and the ship or in English				1.3.8.4	Language: ____________
10	The ship should make a public address announcement advising the crew prior to OPS connection or disconnection				1.3.8.5	
C	**Verification and testing**				2.1	**FIRST CALL OR** if the time between port calls (the same shore supply point) exceeds 12 months
	INITIAL TEST SHORE SIDE INSTALLATION					
11	Visual inspection			10.2.2.a	2.1.2.1	
12	Power frequency test for switchgear assemblies and voltage test for cable in accordance with IEC 62271-200 and IEC 60502-2			10.2.2.b	2.1.2.2	Only if either of the installations, shore- or ship-side, has been out of service or not in use for more than 30 months.
13	Insulation resistance measurement			10.2.2.c	2.1.2.3	Only if either of the installations, shore- or ship-side, has been out of service or not in use for more than 30 months.
14	Measurement of the earthing resistor, including connection cables into star point and earthing bus			10.2.2.d	2.1.2.4	Only if either of the installations, shore- or ship-side, has been out of service or not in use for more than 30 months.
15	Shore-side bonding connection resistance from earthing bus of primary shore power switchboard terminal to connection point shore side			10.2.2.e		
16	Function test including correct settings of the protection devices			10.2.2.f	2.1.2.5	
17	Function test of the interlocking system			10.2.2.g	2.1.2.6	

	Check	Ship side	Shore side	IEC/IEEE 80005-1 2019	IMO OPS Guidelines	Remarks
18	Function test of the control equipment			10.2.2.h	2.1.2.7	
19	Equipotential bond monitoring test or equivalent				2.1.2.8	
20	Phase-sequence test			10.2.2.i	2.1.2.9	
21	Function test of the cable management system			10.2.2.j	2.1.2.10	Where applicable
22	Integration tests to demonstrate that the shore- and ship-side installations work properly together				2.1.2.11	
23	Function test of the emergency stops				2.1.2.12	
24	Additional tests if required by national regulations			10.2.2.k		
	INITIAL TEST SHIP-SIDE INSTALLATION					
25	Visual inspection			10.3.2.a	2.1.2.1	
26	Power frequency test for HV switchgear assemblies and voltage test for cables in accordance with IEC 62271-200 and IEC 60502-2			10.3.2.b	2.1.2.2	Only if either of the installations, shore- or ship-side, has been out of service or not in use for more than 30 months.
27	Insulation resistance measurement			10.3.2.c	2.1.2.3	Only if either of the installations, shore- or ship-side, has been out of service or not in use for more than 30 months.
28	Ship-side bonding connection resistance			10.2.2.d	2.1.2.4	Only if either of the installations, shore- or ship-side, has been out of service or not in use for more than 30 months.
29	Function test including correct settings of the protection devices			10.3.2.e	2.1.2.5	
30	Function test of the interlocking system			10.3.2.f	2.1.2.6	
31	Function test of the control equipment			10.3.2.g	2.1.2.7	
32	phase-sequence test			10.3.2.h	2.1.2.9	
33	Function test of the cable management system where applicable			10.3.2.i	2.1.2.10	

	Check	Ship side	Shore side	IEC/IEEE 80005-1 2019	IMO OPS Guidelines	Remarks
34	Integration tests to demonstrate that the ship-side installations such as the power management system, integrated alarm, monitoring and control system work properly together with the new installation			10.3.2.	2.1.2.11	
35	Function test of the emergency stops				2.1.2.12	
36	Additional tests if required by national regulations.			10.2.2.k		
37	Power frequency test for HV switchgear assemblies and voltage test for cables in accordance with IEC 62271-200 and IEC 60502-2. Insulation resistance measurement.					
	Tests at first call of a shore supply point			10.4		
38	Visual inspection.			10.4.2.a		
39	Power frequency test for HV switchgear assemblies and voltage test for cables in accordance with IEC 62271-200 and IEC 60502-2			10.4.2.b		
40	Measurement of the earthing resistance.			10.4.2.c		
41	Function test of the protection devices.			10.4.2.d		
42	Function test of the interlocking system.			10.4.2.e		
43	Function test of the control equipment.			10.4.2.f		
44	Equipotential bond monitoring test, where utilized, or manual override test			10.4.2.g		
45	Phase-sequence test.			10.4.2.h		
46	Function test of the cable management system.			10.4.2.i		
47	Integration tests to demonstrate that the shore- and ship-side installations work properly together			10.4.2.j		
	Tests at repeated calls of a shore supply point				2.2	
	VERIFICATION			11.2.2		
48	Visual inspection			11.2.2a	2.2.2.1	
49	Confirmation that no earth fault is present			11.2.2.b	2.2.2.2	
50	Statement of voltage and frequency.			11.2.2.c	2.2.2.3	

	Check	Ship side	Shore side	IEC/IEEE 80005-1 2019	IMO OPS Guidelines	Remarks
51	An authorized switching and connection procedure.			11.2.2.d	2.2.2.4	
52	Function test of the emergency stops.				2.2.2.5	
53	Appropriate procedures for ensuring the integrity of any isolations, such as a "lock out/tag out" system.				2.2.3	
54	Procedures should include an approved "Lock-out, Tag-out" system that is jointly controlled by the ship's and shore's persons in charge.			note		
	EARTH BONDING CONNECTION			113		Where equipotential bonding is not continuously monitored
55	Physical connection points shall be inspected at a frequency not exceeding 12 months.			11.3.a		
56	Shore-side bonding connection resistance shall be measured at a frequency not exceeding 12 months. Results shall not exceed 1 Ω.			11.3.b		
57	Ship-side bonding connection resistance shall be measured at a frequency not exceeding 6 months. Results shall not exceed 1 Ω.			11.3.c		
D	**Operation**					
	High voltage (HV)				3.2	
	Pre connection and connection				3.2.1	
58	Pre-connection safety inspection				3.2.1.1.1	
59	Visual inspection				3.2.1.1.2	
60	Definition of restricted access areas on both ship-side and shore-side connection				3.2.1.1.3	
61	Verification of the locations of the communication devices, i.e. walkie-talkie and telephone, fire-fighting equipment and first aid devices.				3.2.1.1.4	
62	Verification of the PPE of the personnel involved				3.2.1.1.5	
63	Confirmation that the shore-side circuit breaker is open and isolated, and circuit is earthed				3.2.1.1.6	
64	Cross-check of the communication equipment				3.2.1.2	
65	Confirmation that there are no safety-critical operations on the ship, prior to connecting to the shore power supply				3.2.1.3	
66	Operation of the cable management system:				3.2.1.4	

	Check	Ship side	Shore side	IEC/IEEE 80005-1 2019	IMO OPS Guidelines	Remarks
67	Ensure the power cables are de-energized				3.2.1.4.1	
68	Turn on the cable management system and deploy the cable(s)				3.2.1.4.2	
69	Connect the cable and secure the connection				3.2.1.4.3	
70	Activate the cable monitor systems to automatically observe the cable tension and length, and adjust, as necessary				3.2.1.2.4	
71	Simulation of the "safety circuit pilot loop operation" by shore- and ship- sides to confirm the appropriate breakers will trip				3.2.1.2.5	
	Supply of power				3.2.2	
72	Confirmation of the sequence of all switching operations				3.2.2.1.1	
73	Confirmation that the connection has been completed, connection area made safe and earthing circuits are removed				3.2.2.1.2	
74	The ship-side should communicate with the person in charge indicating that it is safe to close the shore-side circuit breaker				3.2.2.1.3	
75	<u>The shore power transfer by the ship-side should be, as follows:</u>				3.2.2.1.4	
	Ship's generator should synchronize with the shore-side grid				3.2.2.1.4.1	
76	Following synchronization, the load should be transferred between the shore supply and the ship source(s) of electrical power				3.2.2.1.4.2	
77	The ship-side should gradually reduce the load for the ship's generators and transfer the load to the shore system				3.2.2.1.4.3	
78	Once the ship's generators have reduced the load sufficiently, the generator breaker should be opened and the generator engine can then be shut down				3.2.2.1.4.4	
	Disconnection				3.2.3	
79	<u>Shore power disconnection via parallel connection from OPS should include the following detailed procedures:</u>				3.2.3.1	
80	Verification of the locations of communication devices				3.2.3.1.1.1	i.e. walkie-talkie and telephone, fire-fighting equipment and first aid devices
81	Verification of the PPE of the personnel involved				3.2.3.1.1.2	

	Check	Ship side	Shore side	IEC/IEEE 80005-1 2019	IMO OPS Guidelines	Remarks
82	Confirmation that there are no safety-critical operations on the ship prior to disconnecting from the shore power supply				3.2.3.1.2	
83	The shore power transfer by the ship-side, which should be as follows:				3.2.3.1.3	
84	Ship-side should start ship generator(s)				3.2.3.1.3.1	
85	Ship's generator should synchronize with the shore-side grid				3.2.3.1.3.2	
86	Following synchronization, the load should be transferred between the shore supply and the ship source(s) of electrical power;				3.2.3.1.3.3	
87	The ship-side should gradually increase the load for the ship's generators;				3.2.3.1.3.4	
88	The ship-side requires disconnection from OPS				3.2.3.1.4	
89	The ship-side may open the ship-side circuit breaker				3.2.3.1.5	
90	The ship-side should communicate with person in charge indicating that it is safe to open the shore-side circuit breaker				3.2.3.1.6	
91	Both parties should confirm that the ship-side and shore-side circuit breakers are isolated, connection area made safe and earthing circuits are completed;				3.2.3.1.7	
92	The power and control cable should be disconnected				3.2.3.1.8	(if applicable)
93	when the cable management system is installed onboard, it should be operated to collect and store the shore cable as per the applicable procedures.				3.2.3.1.9	
94	Shore power disconnection via a blackout connection should be in accordance with points 3.2.3.1				3.2.3.2	Except for points 3.2.3.1.3.2 to 3.2.3.1.3.4.
	Low voltage (LV)				3.3	
95	A technical analysis should be conducted to confirm the suitability of the ship- and shore-side OPS arrangements				3.3.1	
96	Pre-connection and connection Shore power transfer via parallel and via a blackout connection should include the following detailed procedures:				3.3.2	
97	A pre-connection safety inspection, which in turn should include:				3.3.2.1	
98	A visual inspection				3.3.2.1.1	
99	The definition of restricted access areas on both ship-side and shore-side connection				3.3.2.1.2	

	Check	Ship side	Shore side	IEC/IEEE 80005-1 2019	IMO OPS Guidelines	Remarks
100	A verification of the locations of the communication devices, i.e. walkie-talkie and telephone, fire-fighting equipment and first aid devices				3.3.2.1.3	
101	a verification of the PPE of the personnel involved; and				3.3.2.1.4	
102	a confirmation that the shore-side circuit breaker is open and power circuit is de-energized;				3.3.2.1.5	
103	cross-check of the communication equipment;				3.3.2.2	
104	Person in charge should confirm that there are no safety-critical operations on the ship prior to connecting to the shore power supply (see paragraph 1.3.7);				3.3.2.3	
105	operation of the cable management system fit for the intended purpose;				3.3.2.4	
106	simulation of the "safety circuit pilot loop operation" by shore- and ship-sides to confirm the appropriate breakers will trip.				3.3.2.5	
	Supply of power				3.3.3	
107	Where the shipboard generator is intended to run in parallel with the shore power for a period of time specified in the technical analysis (see point 3.3.1.1), the operation procedure may include but not limited to the following:				3.3.3.1	
108	Where the load transfer is executed via blackout, operation procedure should be in accordance with points 3.3.3.1.1 to 3.3.3.1.3.				3.3.3.2	
109	confirmation of the sequence of all switching operations;				3.3.3.1.1	
110	Both parties should confirm that the connection has been completed, connection area made safe and, if applicable, earthing circuits are removed;				3.3.3.1.2	
111	The ship-side should communicate with person in charge indicating that it is safe to close the shore-side circuit breaker				3.3.3.1.3	
112	The shore power transfer by the ship-side should be as follows:				3.3.3.1.4.	
113	Ship's generator should synchronize with the shore-side grid;				3.3.3.1.4.1	
114	Following synchronization, the load should be transferred between the shore supply and the ship source(s) of electrical power				3.3.3.1.4.2	

	Check	Ship side	Shore side	IEC/IEEE 80005-1 2019	IMO OPS Guidelines	Remarks
115	The ship-side should gradually reduce the load for the ship's generators and transfer the load to the shore system;				3.3.3.1.4.3	
116	Once the ship's generators have reduced the load sufficiently, the generator breaker should be opened and the generator engine can then be shut down				3.3.3.1.4.4	
	Disconnection				3.3.4	
117	Shore power disconnection via parallel connection from OPS should include the following detailed procedure:				3.3.4.1	
118	A safety inspection, which in turn should include:				3.3.4.1.1.1	
119	A verification of the locations of communication devices				3.3.4.1.1.1.1	i.e. walkie-talkie and telephone, fire-fighting equipment and first aid devices
120	A verification of the PPE of the personnel involved				3.3.4.1.1.1.2	
121	Person in charge should confirm that there are no safety-critical operations on the ship prior to disconnecting from the shore power supply				3.3.4.1.1.2	
122	The shore power transfer by the ship-side, which should be, as follows:				3.3.4.1.1.3	
123	Ship-side should start ship generator(s)				3.3.4.1.1.3.1	
124	Ship's generator should synchronize with the shore-side grid				3.3.4.1.1.3.2	
125	Following synchronization, the load should be transferred between the shore supply and the ship source(s) of electrical power				3.3.4.1.1.3.3	
126	The ship-side should gradually increase the load for the ship’s generators				3.3.4.1.1.3.4	
127	The ship-side requires disconnection from OPS				3.3.4.1.1.4	
128	The ship-side may open the ship-side circuit breaker				3.3.4.1.1.5	
129	The ship-side should communicate with person in charge indicating that it is safe to open the shore-side circuit breaker;				3.3.4.1.1.6	
130	To ensure that the power circuit is de energized, both parties should confirm that the ship-side and shore-side circuit breakers are open, circuits are isolated, and, if applicable, earthed				3.3.4.1.1.7	

	Check	Ship side	Shore side	IEC/IEEE 80005-1 2019	IMO OPS Guidelines	Remarks
131	The power and control cable (if applicable) should be disconnected; and				3.3.4.1.1.8	
132	When the cable management system is installed onboard, it should be operated to collect and store the OPS cable as per the applicable procedures.				3.3.4.1.1.9	

Agreed activities

XXXXXXXXXXXXXXXXXX	Ship	Terminal

Declaration

We, the undersigned, have checked the above items in accordance with the instructions and have satisfied ourselves that the entries we have made are correct.

If, to our knowledge, the status of any item changes, we will immediately inform the other party.

Ship	Terminal
Name	Name
Rank	Position
Signature	Signature
Date	Date
Time	Time

Record of repetitive checks								
Date								
Time								
Initials for ship								
Initials for bunker station								
Initials for terminal								

The joint declaration should not be signed until both parties have checked and accepted their assigned responsibilities and accountabilities. When duly signed, this document is to be kept on board.

European Maritime Safety Agency
Praça Europa 4
1249-206 Lisbon, Portugal
Tel +351 21 1209 200
Fax +351 21 1209 210
emsa.europa.eu