Shore Connection: Regulatory Developments and Best Practice in Port Operations

A PEMA Information Paper (revised August 2016)

This peer reviewed Information Paper provides an overview of current regulatory developments and best practice regarding electrical shore connection of ships in port and presents a number of practical examples of its introduction in container handling, ro-ro and ro-pax ferry, and cruise ship applications.

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INTRODUCTION

DOCUMENT PURPOSE

This peer reviewed Information Paper provides an overview of current regulatory developments and best practice regarding electrical shore connection of ships in port – shore power – and presents a number of practical examples of its introduction at container handling, ro-ro and ro-pax ferry, and cruise ship applications.

This paper focuses on the ISO/IEC/IEEE80005-1 standard that defines shore side electrical connection for larger vessels, and which entered into effect in 2012. While being covered by the above standard, this paper does not review shore connection for tanker vessels. The paper excludes bulk and inland vessels, and vessels with a power requirement of less than 1 Mega Volt Amp (MVA). Retrofitting of vessels for shore power also fall outside the scope of this paper.

It is within these parameters, and against a background of growing public awareness of emissions generated by shipping, that PEMA has produced this information paper with a view to providing a practical resource for decision makers and the global ports sector as a whole.

REGULATORY DEVELOPMENTS

In the first section of this paper, we outline the current state of legislative requirements and standards relating to the use of shore power internationally, and specifically in China, Europe and North America.

BEST PRACTICE

Section two discusses the ISO/IEC/IEEE80005-1 standard, and highlights practical considerations for port operators, shipping companies, and equipment manufacturers when implementing shore power at container, ro/ro, and cruise ship berths, and provides several examples of best practice at these applications.

PERSPECTIVES AND CONCLUSION

In the final section of this paper we review recent regulatory and technical developments in shore power, and briefly touch on selected recent developments in this area.

PEMA cannot advocate or decide which shore power solution is the right choice for any particular facility. However, the intent here is to contribute to industry awareness of the issues that ports and terminals should consider when making their selection.

ABOUT THIS DOCUMENT

This document is part of a series of Information Papers developed by the Safety & Environment Committee (SEC) of the Port Equipment Manufacturers Association (PEMA). The Safety & Environment series is intended to inform readers about the design and use of equipment and technology to improve the safety of people, equipment and cargo, and to improve the energy and environmental performance, of port and terminal operations.

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1 | BACKGROUND

Shore power is also known as cold ironing, SSE (Shore Side Electricity), high voltage shore connection (HVSC), onshore power supply (OPS) and Alternative Maritime Power (AMP). All these terms describe the same process: the connection of ships in port electrical grid in order to power onboard services, systems and equipment. This enables ships' diesel generators to be switched off with a resultant reduction in noise and emissions, such as particulate matter, nitrogen oxides, sulphur oxides, carbon oxides, and volatile organic compounds.

According to consultancy Ecofys, SSE delivers a number of benefits, including :

- Elimination of ship engine emissions in port areas (SOx, NOx, PM, CO_2)
- Elimination of noise and vibration caused by ships at berth
- Improvement of working conditions in ports
- Enabling maintenance of auxiliary engines while idle
- Compliance of vessels at berth with International Maritime Organization (IMO) requirements
- Fuel cost savings, as onshore electricity may be less costly than generator use, (although this is highly dependent upon the price of oil. At the time of writing, Brent Crude was at around USD 42 a barrel)
- Shore power may extend service life of auxiliary generators, reducing maintenance costs

SSE is emerging as one of a number of effective means of reducing pollution from ships in port. A variety of regulations are currently being implemented to reduce ship emissions in port and to support the development and wider use of SSE.

This peer reviewed information paper provides an overview of current regulatory developments and best practice regarding electrical shore connection of ships in port – shore power – and presents a number of practical examples of its introduction at container handling, ro-ro, and cruise ship applications.

This paper does not include tankers, bulk or inland vessels, nor vessels with a power requirement of less than 1MVA. Retrofitting of vessels for shore power also fall outside the scope of this paper. In terms of standards, this paper focuses on the ISO/IEC/IEEE80005-1 standard which regulates shore side connection for larger vessels, and that entered into effect in 2012. The International Electrotechnical Commission (IEC) is currently working on a standard for smaller vessels, (PAS 80005-3), such as offshore supply vessels, river cruisers, and larger fisheries vessels.

Separately, in addition to European Union (EU) funding for ports to introduce shore power technologies, the 28-member bloc introduced the Deployment of Alternative Fuel Infrastructures directive in October 2014 that makes the provision of shore side electricity, (SSE), mandatory in most cases for EU ports by 2025. These changes reflect the maturing regulatory framework that exists for electrical shore connection of ships in port.

PEMA intends this information paper to function as reference tool for the global ports and shipping sector, specifically for those considering the adoption of shore power, and more broadly for policy makers, decision makers, members of the media, and other interested groups.

It should be noted that shore power is just one of a number of ways of reducing emissions from ships in port. Other technologies include "scrubbing" – using seawater to absorb carbon dioxide generated by ships – and vessels that are powered by liquefied natural gas (LNG). Both approaches substantially reduce emissions from vessels in port.

2 | REGULATORY DEVELOPMENTS

2.1 CALIFORNIA

The California Air Resources Board, (CARB), a department within the cabinet-level California Environmental Protection Agency, enforces a requirement for berthing ships in Californian harbours. Since 2014, 50 per cent of ships' power requirement at the berth is to be met by SSE. This ratio is to reach 70 per cent by 2017, and 80 per cent by 2020.

2.2 CHINA

Chinese decision-makers are increasingly realising the importance of ports and maritime shipping in improving air quality. In its 2011-15 five-year plan, China identified SSE as a key element of efforts to curb pollution in ports. Following recent amendments to China's Air Pollution Prevention and Control Law, effective January 1, 2016, vessels at berth will be required to use fuels that meet government emissions standards. Additionally, all new terminals should install shore side electric power facilities to encourage ships to turn off their diesel engines while at berth.

2.3 EUROPE

In Europe, various regulations and incentives have been progressively implemented to tackle ship emissions. Most recently, Article 5 of the directive on the deployment of alternative fuels infrastructure, (Directive 2014/94/EU), states: "Member states shall ensure that the need for shore-side electricity supply for inland waterway vessels and sea-going 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 December 31, 2025, unless there is no demand and the costs are disproportionate to the benefits, including environmental benefits."

Member states have until November 2016 to finalise their national policy frameworks in relation to this directive.

Furthermore, the Connecting Europe Facility (CEF) programme was established by the European Commission in 2006 (under TEN-T) to support the construction and upgrade of transport infrastructure across the EU. It is managed by the Innovation and Networks Executive Agency, (INEA).

The CEF defines SSE as eligible to receive funds in categories such as innovation and infrastructure. Between 2007 and 2013, the EU allocated €8 billion to this fund. Between 2014 and 2020, €26 billion has been secured for the EU core transport network. Ports and operators can apply for funding for up to 50 per cent of the cost of SSE studies, and between 10 to 80 per cent of the cost of implementing SSE.

Directive 2003/96/EC allows EU member states to exempt ship operators from tax on electricity provided to ships in port.

Vessels using SSE are also compliant with the IMO's MARPOL VI, which was among the first international mandatory measures to reduce emissions from ships, (adopted in 1997 and entered into force in 2005).

3 | BEST PRACTICE

3.1 INTERNATIONAL STANDARDS

The growth of SSE applications has led organisations such as the IEC and the Institute of Electrical and Electronics Engineers (IEEE) to develop common SSE standards. In 2012, the first standard was introduced – ISO/IEC/IEEE80005-1 – for vessels requiring high voltage power supply. It is designed to support the introduction of standardised connections, eliminating the need for SSE equipment on ships to be adapted for use at different ports.

SSE systems are used by a variety of ships, which differ in terms of power requirements, voltages and frequencies, (low and high voltage, 50 and 60Hz). ISO/IEC/IEEE80005-1 includes annexes according to ship type and details requirements in terms of equipment design and construction, safety, and requirements for compatibility between ships and shore systems.

The standard is complemented by IEC62613 that defines requirements for plugs, socket outlets and ship couplers for HVSC systems. Plugs included in these standards are shown in pictures 1 to 3 below.

Picture 1: Example 6.6kV plugs for container ships and tanker vessels

Picture 2: Example 11kV plugs for cruise vessels, (the same type can be used for 6.6kV cruise vessels), up to 20MVA power demand

Picture 3: Example 11 kV plug for Ro/Ro and LNG ships up to 6.5MVA with a single cable

Figure 2: IEC/IEEE80005-1 standard main requirements for container and passenger

Vessel type	Nominal SSE voltage	Maximum power requirement	Frequency	Number of MV cables to feed vessel	Cable Management System location
Ro/Ro Ro/Pax	11kV, 6.6Kv acceptable for waterborne transportation	6.5MVA	50Hz or 60Hz	1	Berth
Container	6.6kV	7.5MVA	50Hz or 60Hz	2	Ship
Cruise	6.6kV and/or 11kV	20MVA – (16MVA suggested)	50Hz or 60Hz	4	Berth

Under the standard, a compatibility assessment between ship and shore has to be carried out prior to implementation of an SSE project, and tests should also be conducted during the first connection to the vessel.

As SSE systems develop, standardisation bodies update existing standards and develop new ones. A revised version of ISO/IEC/IEEE80005-1 is due to be published in 2017.

3.2 GENERAL OVERVIEW

To power vessels at berth, additional infrastructure on shore and onboard ships is required, because electrical power available from port grids is not adapted to vessels' requirements in terms of voltage, frequency and earthing. Furthermore, safety features need to be integrated, (all of which are standardised in ISO/IEC/IEEE80005-1). The necessary SSE infrastructure includes the elements described below (see also Figure 3).

3.2.1 On shore installation

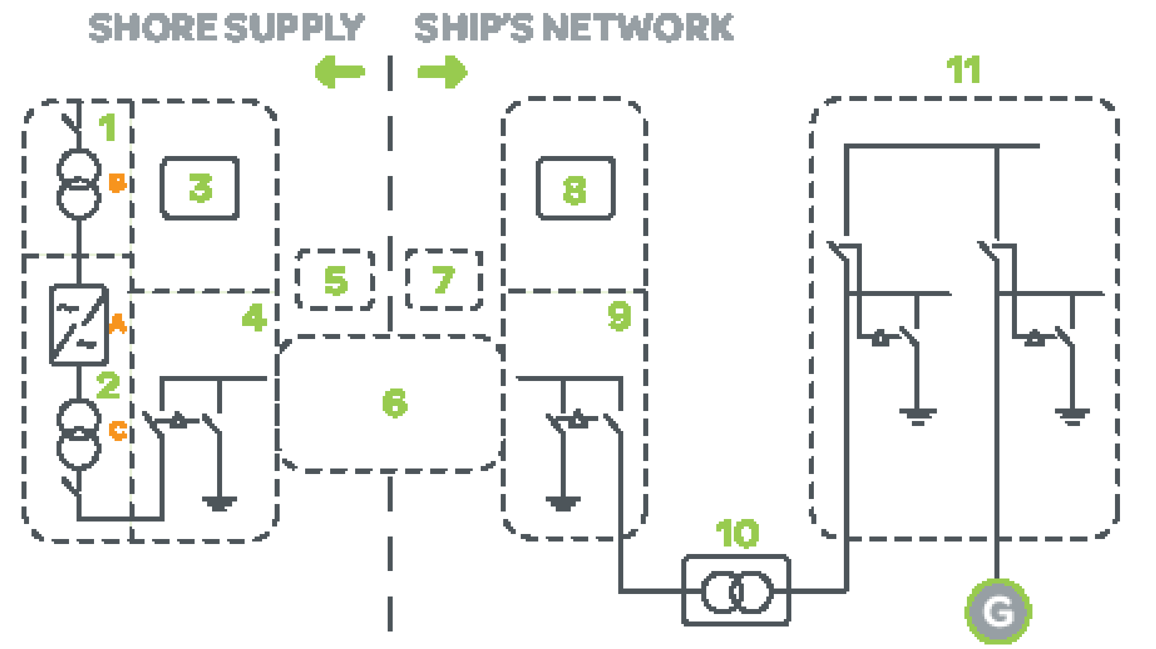
An electrical substation is required to convert voltage and frequency of the electrical grid to those required by vessels and specified by relevant standards, including electrical protection equipment. Upstream and downstream medium voltage (MV) cable connections from the grid to the power conversion system, and from the conversion system to the connection point on the vessel are also required.

3.2.2 Interface and equipment

A cable management system (CMS) ensures safe handling of cables during connection and disconnection procedures. The position of the CMS is also defined in the IEC standard: for all vessel types other than container ships, the CMS needs to be installed onshore. Container ships are required to have on board cable reels due to space constraints on the berth. Another key area to consider is choice of sockets, plugs and connectors.

3.2.3 On board installation

On board installations include a MV connection switchgear to manage power and ground connections; a step-down transformer to the vessel's voltage(s) level(s) as required; a receiving panel, which includes the adaptation of the existing MV or low voltage switchboard to receive shore power, and a synchronisation control device, (synchronisation being carried out on board, as per the standard). If required, a power management system adaptation on board the vessel to manage shore connection and disconnection operations. On board SSE systems are not detailed in this paper.



Power frequency conversion system:
Power converter (A) unit including
step down power transformer (B)
step-up power transformer (C)
The power frequency converter is either included in each shore connection system or centralized at port level for large power requirements.

1. Connection to the MV port's electrical network or to the local grid
2. Power frequency conversion system
3. Shoreside protection relays and interlocking system
4. Shoreside CB and earthing switch

5. 6. 7. Shore-to-ship connection, including: HV cables and cable reels, HV plug/socket-outlets with handling facilities, communication and control wires, equipotential bonding cable, etc.

8. Shipside protection relays and interlocking system
9. Shipside CB and earthing switch
10. Where applicable (ship voltage different from shore connection voltage), an onboard transformer is needed to adapt the high voltage supply to the ship's main switchboard voltage; this transformer is preferably located near the main switchboard in a dedicated room
11. Onboard receiving switchboard

Figure 3 Electrical diagram and components of a typical SSE system, as per ISO/IEC/IEEE80005-1

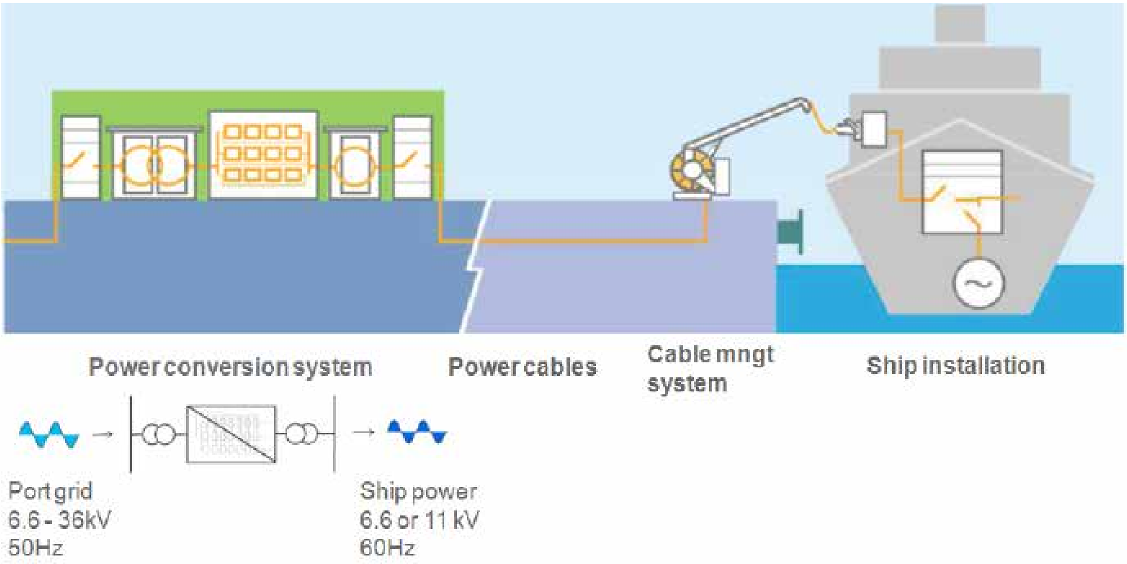


Figure 4 Example SSE system for vessels other than container ships and requiring frequency conversion

3.3 PRELIMINARY CONSIDERATIONS

To optimise the use of SSE systems, ports should target berths best suited to shore power:

- Berths with close proximity to urban areas: as SSE reduces vessel emissions, it tends to be most beneficial at berths located close to residential or commercial areas.

- Berths with regular and longer staying traffic: the busier a berth, and the longer vessels remain at berth, the greater the occupation rate of SSE. For example, connecting ferries that berth over night to SSE will generate a greater benefit than at a berth where a variety of vessels make short turnarounds.

- Berths welcoming vessels equipped with shore power: to optimise the use of SSE, ports should prioritise the installation of SSE at berths where SSE vessels make regular calls.

- Berths hosting vessels that consume a large amount of power: vessels that consume large amounts of power are the biggest polluters.

- Berths/terminals that have a MV substation being able to cover the power need of vessels: grid capacity is normally not a problem when connecting ferries or similar vessels to SSE because their power requirement at the berth tends to be low. However, to power large cruise ships, or container ships with significant numbers of refrigerated units, several additional megawatts per berth may be required. A port without sufficient power may have to add a grid extension to its SSE system, potentially adding considerable time and CAPEX.

- Berths supplied with electricity from renewable sources: the overall environmental benefit of SSE is higher if electricity for a given berth or port is produced with renewable energy.

To optimise the introduction of SSE, the following dimensioning criteria should be assessed and validated:

- Type of vessel to be connected: vessel type dictates voltage. power and frequency requirements. An accurate review of these requirements will avoid unnecessary costs and operational issues.

- MV substation: the voltage and frequency of the substation will be needed to dimension transformers and determine whether frequency conversion is required, (if vessels use a different frequency to that of the port's MV substation). The location of a substation also determines dimensions of cabling, trenches and civil works requirements.

- Available space: while implementing SSE, especially in brownfield terminals, the footprint of the SSE system should be optimised to minimise impact on operations.

Clearly, power system sizing should be planned and scaled from the outset of an SSE project, including factors such as berths and terminals to be equipped, vessels' power needs, frequency of port calls and duration of stay at berth – currently and based on forecasts of future use and operational patterns.

3.4 ELECTRICAL SUBSTATIONS

3.4.1 Frequency conversion

The majority of large vessels considered in this paper require more than 1MVA, and operate 60Hz onboard, whereas local power grids in many parts of the world use 50Hz. In such cases, frequency conversion is required. Standard practice in the industry is to include the necessary equipments to handle frequency conversion on shore, rather than conducting conversion on board ships.

The primary reasons for this are:

- The risk of using existing frequency converter equipment dedicated to the navigation of the vessel for shore connection

- Lack of available space on board vessels for additional equipment

- To avoid potential technical problems due to vibration associated with onboard operation

There are currently two main frequency conversion technologies used for shore connection applications: static and rotary. Rotary frequency conversion is a proven technology that has been used successfully for many years.

The more recent static technology offers advances in power electronics, providing benefits in terms of reduced installation and maintenance costs and greater efficiency, (see Picture 4/5).

Picture 4: A 2MVA substation for a container vessel with static frequency conversion.

Picture 5: 12MVA Substation for cruise vessels at the Port of Hamburg. (Input: 10kV-50Hz, output: 6.6kV/11kv-60Hz).

3.4.2 Implementing a safe and protected system

Shore connection substations are required to operate with complex electrical power systems:

- Multiple sources (utility delivery substation and onboard generators)
- Power conversion for frequency conversion
- Mobile equipment (MV cable and plug) for shore-to-ship electrical connection, potentially for frequent daily use

Consequently, the ISO/IEC/IEEE80005-1 standard should be followed, especially in terms of:

- Implementing adequate protection. Figure 5 illustrates the protection plan for a shore connection system without frequency conversion for a container ship, including the protection functions embedded in each relay.
- Ensuring safe connection and disconnection: as shown in Figure 6, when performing a connection or disconnection, the operator has access to power connectors and can be exposed to a shock hazard if power connectors are not disconnected and earthed.

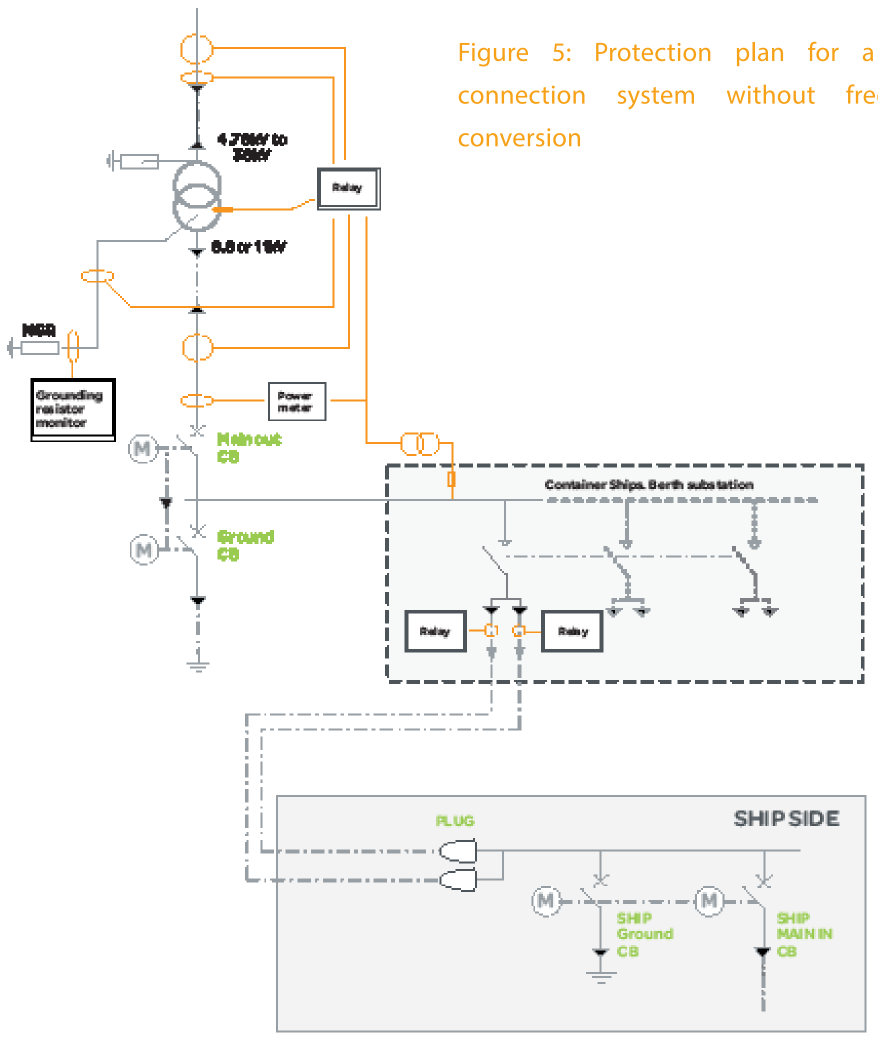


Figure 5: Protection plan for a shore connection system without frequency conversion

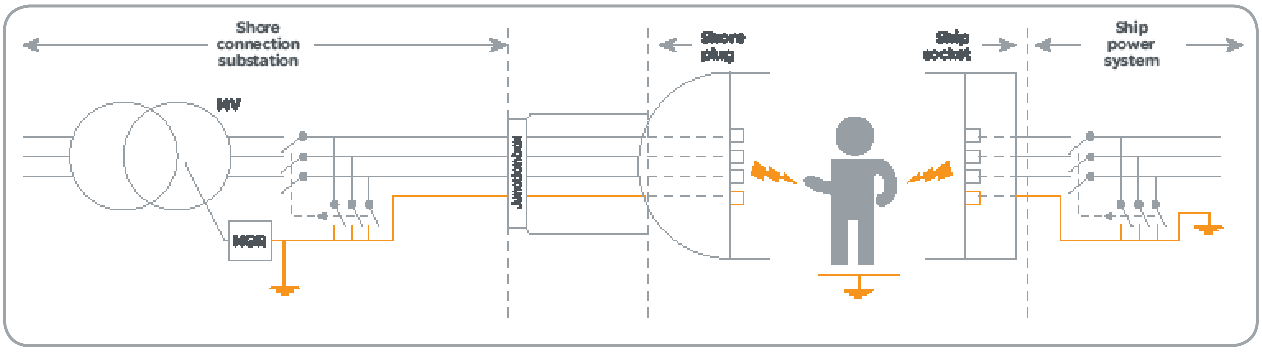


Figure 6: Electrical hazards during connection/ disconnection

Possible risks include f.1 failure to disconnect from the shore substation, f.2 failure to discharge the MV cable, and f.3 failure to disconnect from ship power system.

ISO/IEC/IEEE80005-1 sets specific measures to prevent the above risks. The recommended measures are described in the standard as:

- 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)

Safety conditions must be continually monitored on both ship and shore sides, through the safety loop formed by pilot wires. As per the standard, there is a specific safety loop for each type of vessel. Figure 7 summarises the mandatory safety functions to be implemented on a shore-to-ship system, (left), and the related safety conditions checked along the loop, (right).

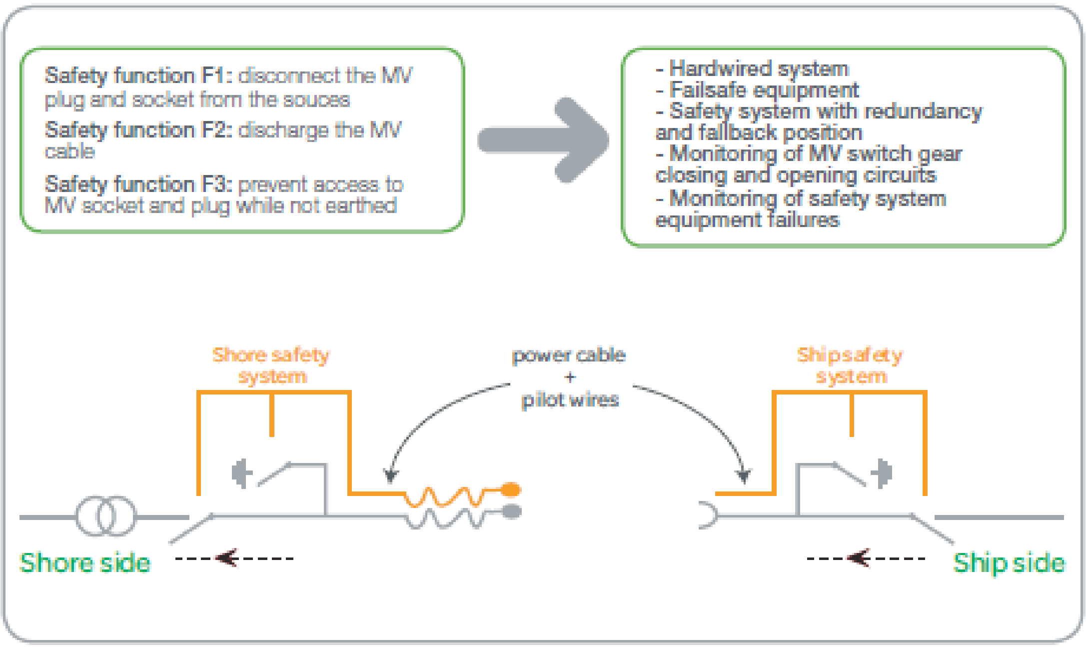


Figure 7: Mandatory safety functions to be implemented on a shore-to-ship system

3.4.3 Integrated and modular systems

To reduce installation time, minimise disruption of port operations, and reduce engineering costs, fully integrated shore substations are available, either in shelters or in concrete. These options can make it easier for operators to adapt SSE systems to changes in their terminal, such as traffic growth or a change of ownership.

Picture 6: SSE substation at the Port of Los Angeles

3.5 CABLE MANAGEMENT SYSTEMS

Cable Management Systems (cable reels, cranes, festoon and chain systems) handle cables and connectors that connect ships to SSE. CMS are also required to maintain the correct length of cable despite ship movement; maintain the correct cable radius to avoid cable wearing; provide a two-step alarm to identify hazards and start ESD procedures.

There are currently a variety of technologies and equipment that meet requirements for different ship types, although there are two primary CMS types:

- Onshore that handle cables from the shore to the socket outlet onboard the vessel. Onshore CMS can be mobile, installed at one location, attached to the quay but movable along the quay.
- Onboard, normally installed at a fixed location, and used to connect cables from the ship to the shore socket outlet.

Under ISO/IEC/IEEE80005-1, for cruise, ro-ro and ro-pax vessels, CMS are located ashore with sockets on board. For container vessels, CMS are onboard with sockets ashore.

The function and layout of CMS depends on specific characteristics, such as ship type and power requirements, terminal and quayside infrastructure, docking patterns, handling and security issues, as well as climatic and tidal conditions. All these points require detailed on site analysis.

3.5.1 Shore based CMS

Shore based CMS are available as mobile units, as movable systems attached to the quay, or fixed units installed at a single position. The selection of CMS type is primarily determined by the following:

- Type and size of vessel, and berthing position
- Public access or multipurpose terminals: equipment shall be positioned for operation and stored afterwards in a non accessible position in order to avoid accidents, or to avoid interference with other terminal operations
- Seasonal use of the shore connection: In the period when shore connection is not used the CMS can be stored in a protected area
- Future development of the terminal

Various technologies and equipment are suitable to ensure movable- mobile-customised solution:

- Mobile
- Movable systems attached to the quay

Picture 7: A cable reel system and crane device mounted on a trailer

Picture 8: An alternative trailer chain system where a chain mechanism is rolled out along the quay, and moved away from the quay after use

Movable systems allow adaption to different berthing positions.

Picture 9: A festoon system mounted on a stilt structure

Alternatively, the CMS can be combined with a chain system installed in a trench or on stilts.

Units that are fixed in a single position generally incorporate a crane or other cable dispensing mechanism to ensure that cables reach the connection point on board the vessel.

3.5.2 Ship based CMS

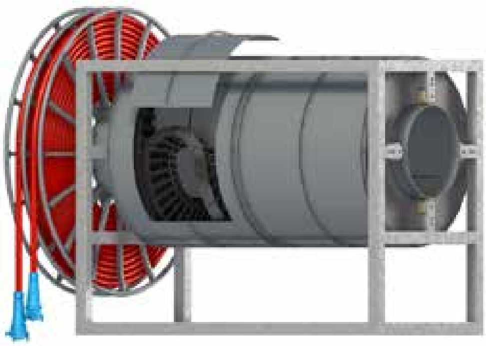
For container terminals, CMS need to be installed onboard ship and the cable handled at the shore connection point.

Onboard system design: The design of the ship based CMS depends on the following:

- Ship type and size and terminal design
- Tidal/weather conditions

The most common CMS for these applications are cable reels, although other technologies can be deployed, for example jib cranes and other cranes devices, or cable chains.

Picture 10: Cable reel using a slip ring

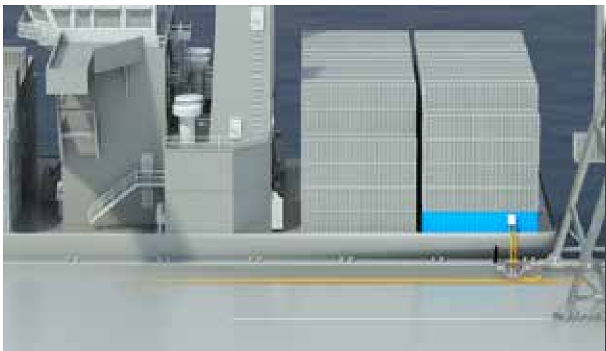


Picture 11: Cable ring without a slip ring

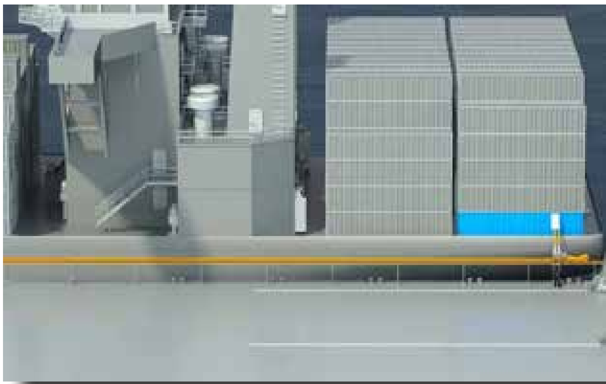
For container application, the The shore connection point tends to be a socket outlet embedded in the quay to minimise disruption to operations, (see Picture 12).

Picture 12: Fixed socket: in-ground socket outlet Junction Box with easy lift covers

The shore connection point may also be designed using moveable socket outlet JB with cable chains and other devices such as cable reels and festoons.



Picture 13a: Movable socket: outlet Junction Box with a cable chain in a trench



Picture 13b: Movable socket: outlet JB with a cable chain on a stilt structure

3.5.3 Example of CMS for ship connection per ship type

3.5.3.1 Ro-ro and ro-pax application

Picture 14: A CMS for ro-pax applications using a crane system to reach the ship's connection point, and a chain system to adjust to tidal and weather conditions

3.5.3.2 Cruise applications

Picture 15: A CMS for cruise applications using a telescopic bridge system to reach the connection point, and a chain system to adjust to tidal and weather conditions

Picture 16: An alternative CMS for cruise ships incorporating a large saddle for cables that are hooked on a small crane. The plugs are caught from the vessel and pulled inside for connection

Picture 17: Mobile CMS for cruise ships equipped with a 5-monospiral reel for movement alongside, and a telescopic boom for extending the cable to the ship connection point. Such systems can be removed from the berth when no vessel is connected, thereby minimising civil works costs

3.5.3.3 Container handling applications

For container applications, a spooled chain system can be placed on board the ship, or fitted inside a container. The system provides accurate, controlled guidance of cables for improved winding, (preventing tangles), and protection against wear.

- CMS in semi-mobile container
- CMS on deck

Picture 18: CMS on deck

Picture 19: CMS integrated into a semi-movable container

4 | PERSPECTIVES AND CONCLUSIONS

The past five years have seen a number of improvements in the application of shore power: the first international standard, ISO/IEC/IEEE80005-1, has been introduced, regulations to reduce emissions from shipping have been strengthened, and SSE technologies have improved.

As a result, shore power is increasingly being deployed in ports worldwide, and new-build terminals are taking steps to be shore power-ready. Furthermore, the number of vessels fitted with, or retrofitted for, shore power connection equipment continues to grow.

Work on further standardisation within the industry continues, with an update of ISO/IEC/IEEE80005-1 expected in 2017, and a new standard for vessels requiring less than 1MVA, (PAS/IEC80005-3).

As the use of shore power grows, so do its technological variations. In Norway, shore power connection is being used to charge the world's first battery powered car and passenger ferry. And in Germany, to manage the considerable power demand of cruise vessels, and the lack of sufficient electrical infrastructure at the Port of Hamburg, a hybrid LNG barge has been introduced that provides electrical power supply to cruise vessels, and to the local electrical grid during the winter months when fewer cruise vessels are in port.

In addition to the technical considerations outlined in this information paper, a successful implementation of shore power is also determined by all parties involved – ship owners, terminal operators, port authorities, utilities and manufacturers – being willing and able to co-operate towards a shared goal. This should be the first step of any shore power project.

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ABOUT PEMA

Founded in 2004, PEMA provides a forum and public voice for the global port equipment and technology sectors. The Association has seen strong growth in recent years, and now over 100 member companies representing all facets of the industry, including crane, equipment and component manufacturers, automation, software and technology providers, consultants and other experts.

Chief among the aims of the Association is to provide a forum for the exchange of views on trends in the design, manufacture and operation of port equipment and technology worldwide.

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