Onshore Power Supply Systems

Preliminary Design Recommendations for Tankers and Terminals

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The Oil Companies International Marine Forum (OCIMF)
Founded in 1970, the Oil Companies International Marine Forum (OCIMF) is a voluntary association of oil companies having an interest in the shipment and terminalling of crude oil, oil products, petrochemicals and gas, and includes companies engaged in offshore marine operations supporting oil and gas exploration, development and production.

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Our mission is to lead the global marine industry in the promotion of safe and environmentally responsible transportation of crude oil, oil products, petrochemicals and gas, and to drive the same values in the management of related offshore marine operations. We do this by developing best practices in the design, construction and safe operation of tankers, barges and offshore vessels and their interfaces with terminals and considering human factors in everything we do.

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Glossary

Auxiliary systems Systems that support the primary operations of a tanker ship.

Berthing Bringing a ship to her berth until the ship is made fast. A berth could be any facility where a ship moors alongside, including a quay and a jetty.

Cable Management System (CMS) Equipment to control, monitor and handle the shore power cables on a terminal to ensure safe and efficient connectivity to the ship.

Cargo pumping system The system on a tanker used for loading and discharging liquid cargo.

Circuit breakers Automatically operated electrical switches designed to protect an electrical circuit from damage caused by overload or short circuit.

Deadweight (DWT) The difference between the displacement and the mass of the empty ship (lightweight). It may be defined for any load waterline from the ship's tables, but is usually referenced for ship comparative purposes to the summer deadweight.

Displacement The mass of water in tonnes displaced by a ship at a given draught.

Earthing Also referred to as 'grounding'. The electrical connection of equipment to the main body of the 'earth' to ensure that it is at earth potential. On board ship, the connection is made to the main metallic structure of the ship, which is at earth potential because of the conductivity of the sea.

Electrical load The amount of electrical power consumed by all equipment and devices in a system at any given time.

Equipotential bonding The connecting of metal parts to ensure electrical continuity, intended to achieve equipotentiality.

Frequency converter A device that converts the frequency of electrical energy.

Hazardous area An area in which an explosive atmosphere is present, or can be expected to be present, in quantities such that special precautions for the construction, installation and use of equipment are required.

High voltage Nominal voltage in range above 1,000 volts AC and up to and including 15 kilovolts AC.

Interlocks A safety device used to prevent undesired states in equipment, ensuring that operations happen in the right order.

Load factor A ratio that represents the relationship between actual power consumed and the maximum possible power that could be consumed (design load). It is used to estimate expected electrical loads.

Maximum Electrical Load The largest amount of electrical power that a system can demand or consume.

Nominal voltage The designated voltage of an electrical system or circuit.

Onboard ship frequency The standard frequency of the electrical power distribution system used on a ship.

Onshore Power Supply (OPS) The provision of shoreside electrical power to a ship when berthed.

Panamax, Aframax, Suezmax, VLCC Categories of tanker ships classified by their deadweight tonnage and physical dimensions, especially width restrictions for passing through the Panama and Suez Canals.

Phase In electrical engineering, this refers to the distribution of the load in an AC system. A 3-phase system divides the total electrical load across three conductors.

Pilot contact Low voltage contact in the shore power plug and socket outlet or inlet for equipment status and/or safety interlocking.

Ship connector High voltage shore power connector at ship end of cables on cable management systems, generally with 3 phase power and protective earth (ground) sleeves plus pilot wire sleeves.

Ship inlet High voltage shore power inlet at ship connection point, generally with 3-phase power and protective earth (ground) pins plus pilot wire pins.

Terminal Information Booklet (TIB) A document providing specific information about a terminal, including facilities, safety, and operational procedures.

Abbreviations

CMS	Cable Management System
DWT	Deadweight
GHG	Greenhouse Gas
Hz	Hertz
IAPH	International Association of Ports and Harbors
ICS	International Chamber of Shipping
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISGOTT	*International Safety Guide for Oil Tankers and Terminals*
kV	Kilovolt
MVA	Megavolt Amps
OPS	Onshore Power Supply
SIGTTO	Society of International Gas Tanker and Terminal Operators
TIB	Terminal Information Booklet

Bibliography

IEC/IEEE 80005-1:2019 – Utility Connections in Port

IEC 60092-502:1999 – Electrical Installations in Ships – Part 502: Tankers – Special features

International Safety Guide for Oil Tankers and Terminals (IAPH/ICS/OCIMF)

A Justification for the use of Insulation Flanges (and Electrically Discontinuous Hoses) at the Ship/Shore and Ship/Ship Interface (SIGTTO)

1 Introduction

The adoption of Onshore Power Supply (OPS), also known as cold ironing, brings environmental advantages to maritime operations in ports and terminals. By using shore-based electrical power while at berth, ships can reduce their emissions, contributing to improved local air quality, potential Greenhouse Gas (GHG) emissions reduction (depending on grid GHG intensity), and aiding in compliance with environmental regulations.

To aid the uptake of OPS, OCIMF has assembled a workgroup composed of industry experts from different organisations representing standardisation bodies, shipowners, ports and terminals, and classification societies. The workgroup is developing guidance for the safe application of OPS alongside the berth for tankers, the terminal, and their interface. Barges, gas carriers, gas terminals, and double-banking operations are out of the scope of this workgroup.

The workgroup has collected best practices of OPS systems and evaluated potential hazards to ensure the appropriate critical safeguards were considered in developing the guidance. One of the initial goals was to understand the power requirements onboard various types of tankers during their time at the berth in port. The workgroup conducted a survey of tanker owners and operators, with responses representing a total of 550 tankers. The survey provides insight into each ship's electrical installations, cargo systems, and power consumption patterns, including electrical loads when discharging and loading cargo.

Supported by the survey, this document outlines recommendations for standardised OPS system requirements for voltage, frequency, and number of cables. Other design and operational considerations are addressed, including the location on ships for connection to shore power, ship and shore electrical hazardous areas, the OPS system's ability to accommodate varying ship sizes and orientation, and the electrical isolation ship/shore cargo equipment.

This paper aims to deliver sufficient information promptly, enabling the industry to advance shore power projects. A full OCIMF information paper covering aspects of the safe application of OPS to tankers, the terminals and their interface will follow this paper.

1.1 Executive summary

- The shore power connection should follow IEC/IEEE 80005 Series Standards, as amended.
- The provision of OPS at 6.6 kilovolt (kV), 60 hertz (Hz) as standard is recommended.
- The OPS system may have 1 to 2 cables depending on the power demand of the typical design ship.
- A specific standardised plug and socket type will be recommended later in the full information paper to follow this one.
- The relative installation location of the ship/shore connection is not prescribed but is left to the involved parties' discretion based on case-specific evaluations.
- A risk assessment is critical, emphasising safety related to hazardous areas.

2 Maximum power requirements, voltage, frequency and cables

A survey was conducted to determine the actual power requirements onboard various types of tankers during their time at the berth. A total of 550 tankers participated in the survey, primarily INTERTANKO members. The results offer insights into their electrical installations, cargo systems, and power consumption patterns, including auxiliary loads while discharging and loading cargo.

The maximum electrical load for a tanker at berth occurs when it is discharging cargo. As part of the study, information on design loads and onboard ship measurements for auxiliary systems was collected. The auxiliary systems' electrical load and the cargo system's expected load were combined to estimate the total electric load during discharge.

It is worth noting that there are limited real-world reference points for an 'all-electric' cargo pumping system. A conceptual approach was employed to estimate the electrical load equivalent for the non-electric cargo systems. The power required to operate these non-electric cargo pumping systems (such as diesel-hydraulic or steam turbine systems) was converted into a theoretical electric motor-powered equivalent.

Calculating the cargo system's expected electrical load during discharge involved taking the theoretical rated load of an equivalent electric cargo pumping system and multiplying it by a load factor. This load factor is a ratio derived from the measured and design electrical loads.

The equivalent electrical loads of cargo pumping systems were determined by examining the drive ends of steam turbines and diesel-driven hydraulic pumps. While the survey captured data on these systems' capacities and configurations, external references were used to provide supplementary information on drive ends.

The shore power supply for tankers is recommended to be a nominal voltage of 6.6 kV AC, 3 phase, 3 wire, with protective earth and an operating frequency of 60 Hz at the terminal side. The use of a high-voltage system allows the number of cables required to be significantly reduced. The power quality is to be in accordance with the requirements of IEC/IEEE 80005-1.

The number of cables and connectors shall be project-specific, i.e. the terminal and the tanker will define this number based on their needs. Additional engineering barriers, such as circuit breakers and means of earthing for each cable/connection with interlocks, are recommended to prevent the threat of live connection ends.

Terminals, ship owners, and other stakeholders should work together to determine the adequate sizing of the OPS system. The survey data indicates a total power demand of under 5.7 Mega Volt Amps (MVA) during tanker loading operations for all tanker classes. Table 2.1 shows the power needed for a maximum discharge for different ship classes. The maximum total apparent power demand of the largest ship class operating in that terminal can be used as a reference for defining the OPS system capability. On some occasions, only one individual ship in the survey had the maximum demand displayed on the table.

Ship class	DWT	Survey population	Total apparent power demand (MVA)	No. of standard cables and connectors at 6.6 kV, 500 A	Power cables capacity at 6.6kV, 500 A (MVA)
Product/ Chemical tankers	3k – 60k	70%	Average: 3.2	1	5.7
			Maximum: 6.4	2	11.4
Panamax	60k – 80k	6%	Average: 3.5	1	5.7
			Maximum: 4.0	1	5.7
Aframax	80k – 120k	16%	Average: 5.4	1	5.7
			Maximum: 5.8	2	11.4
Suezmax	120k – 200k	3%	Average: 6.9	2	11.4
			Maximum: 10.4	2	11.4
VLCC	200k – 320k	5%	Average: 8.2	2	11.4
			Maximum: 10.4	2	11.4

Table 2.1: *Total apparent power for cargo discharge from tanker survey and associated cables and connectors*

3 Frequency converter

The majority of tankers are designed and operated with 60 Hz internal power distribution systems. Of the vessels surveyed, 96% operate with 60 Hz. Table 3.1 outlines the requirements for the provision and location of a frequency converter based on the onboard ship frequency and the terminal grid frequency. Adherence to these guidelines ensures compatibility between the ship's electrical system and the terminal's shore power supply.

Onboard ship frequency	Terminal grid frequency	Recommended location of frequency converter	Notes
60Hz	50Hz	Terminal	Conversion is to be sized to the largest shore power load size for which the terminal is designed
50Hz	60Hz	Onboard the tanker	Terminal where 60Hz to 50Hz frequency converter is NOT available
50Hz	60Hz	Terminal	Terminal where there is already a frequency converter on the terminal side, which can adjust to provide 50Hz shore power. In that case, the terminal shall provide power at 50Hz
50Hz	50Hz	None	No frequency converter required
60Hz	60Hz	None	No frequency converter required

Table 3.1: *Frequency conversion requirements*

4 Accommodating varying ship sizes and orientation

A tanker's berthing orientation can be either port-side-to or starboard-side-to based on factors such as tide, current, berth configuration, and cargo requirements. Terminals should consider multiple variables such as ship size, relative berth position, and orientation when designing the OPS system.

It is recommended that the Cable Management System (CMS) be located onshore in accordance with IEC/IEEE 80005-1, while ships should be equipped with a socket box to accommodate the cables. The connection between the cable plugs and sockets shall be onboard the ship.

A ship and/or terminal may have multiple shore power connection points to provide flexibility in berthing orientation. In these cases, the high-voltage shore connection equipment should be interlocked such that only one connection point can be active at any time.

The high-voltage shore connection point may be located near the ship's side or the centreline. Smaller ships may favour a centreline location for the flexibility of a single connection point. Due to shore-based cable reach limitations, larger ships may require a connection point near the ship's side while ensuring a safe workspace for cable handling and protecting the shore connection equipment from the weather.

Flexible CMS, such as mobile or telescopic units, may accommodate a wide range of ships. Terminals may employ fixed or mobile cable management systems compliant with their hazardous zones.

Berthing requirements to match the shore CMS position should be stated in the Terminal Information Booklet (TIB) and to be considered during ship/shore compatibility checks.

Design and operational safety considerations for ship movements and emergency departures will be addressed in the upcoming OCIMF information paper.

5 Location of the shore power connection

Terminal and ship owners should work together to determine the best placements for the CMS equipment and onboard OPS connection points. A comprehensive terminal compatibility study and risk assessment are advisable for ship owners.

The OPS connection point should be outside a hazardous area or in a gas-free, safe, pressurised space. The relative position of ship/shore connection is not prescribed but is left to the involved parties' discretion based on case-specific evaluations.

Ship owners can position the connection point mid-ship above the cargo area or, alternatively, aft, outside the cargo area. Positioning the connection point mid-ship allows terminals to position their CMS near the cargo loading equipment and accommodate various tanker sizes. A significant drawback to the mid-ship position is the proximity to hazardous cargo, which demands extra precautions, tailored material specifications, and specialised engineering. See section 6 for further details.

The positioning of the CMS and onboard OPS connection points should be arranged to align with each other, considering three directions: vertical as measured by the elevation above the waterline, longitudinal along the forward/aft axis, and transversal along the port/starboard axis. The CMS may have limited movement and reach. Similarly, ships cannot be shifted down the berth due to the cargo transfer system's alignment needs. Also, the CMS must be strategically placed to prevent interference with fixed berth structures, ship equipment, and operational and escape routes.

When the connection point is not along the ship's centreline, it is recommended to place connection points at both the port and the starboard sides of the ship. For connections near the mid-ship, the CMS should be to the right of the cargo manifold when facing the tanker.

If the ship owner decides to position the connection point away from the cargo area, the logical spot is aft, above the main machinery space. This location is further from hazardous cargo and closer to the ship's electrical protective relays and switchgear. However, one limitation to an aft connection is the significant variation in tanker designs. The onshore CMS may need to reach far across the water with some ships.

When aft connection is selected, in cases with a significant variance in ship dimensions, it is recognised that it may be impractical to reach aft with a single CMS.

The variation of the tanker's freeboard during loaded and unloaded states should be considered. It is vital that the onshore CMS can always connect to the ship without any undue strain on the cable.

Considerations should be made for the shore power connection points' elevation and interference with mooring systems. Additional guidance on CMS and its interaction with mooring systems, gangways, and cargo equipment will be covered in the upcoming information paper.

6 Ship and shore electrical hazardous areas

6.1 Location of connection points

The OPS connection point (shipside sockets) shall be located in a non-hazardous area or in a gas-free, safe, pressurised space.

If the shore power connection is in an on-deck connection compartment equipped with systems that create and maintain a non-hazardous boundary within a hazardous area, the compartment must be in a verified safe condition before any power circuits are connected or energised.

6.2 Hazardous area classification and associated equipment

It is important to be aware that a ship's hazardous area classification may differ from that of the terminal. A connection point may be outside the ship's hazardous area but still considered within a hazardous area by the terminal. The terminal may require additional protection onboard the ship before permitting OPS operations. Terminal owners may need to revisit their hazardous area classifications where these overlap with tankers.

During the design stages the hazardous area classifications for foreseen berth-tanker combinations are to be aligned, and the OPS positioned and designed accordingly.

The OPS installation onboard the ship shall be reviewed and approved by the ship's classification society.

The OPS onshore shall be approved according to port state requirements and national standards.

Ships fitted with OPS shall carry marine classification society notation for High Voltage Shore Power. Components that pass through hazardous areas onboard the ship shall meet classification society requirements for hazardous areas and the installation shall meet the requirements of IEC 60092-502. OPS components that pass through hazardous areas onshore shall meet port state requirements and national standards.

The ship/shore compatibility should be checked before the ship is cleared for OPS operations in a specific terminal.

6.3 Connection, disconnection, earthing and equipotential bonding

The connection location should be confirmed gas-free before connecting or disconnecting shore power cables.

While the shore-side cables (power, control cables, and communication) are being connected to the ship-side sockets, the cables shall be de-energised. While de-energised, the power cables' power conductors should be earthed at the shore end. The de-energised power conductors should be earthed to the ship's hull through an earthing switch on the ship.

The power cable circuit breakers shall be interlocked with the earthing switches. The earthing switches at both ends of the power cables should be open before the power cables are energised. Manual or automatic operation of earthing switches shall be subject to class requirements.

Equipotential bonding is provided through the earth conductors of the shore power cables. No separate bonding cable is required.

6.4 Hazards and equipment failure mitigation

Ignition risks may not solely stem from powered sources. Metal-on-metal contact or static electricity may generate sparks.

If the shore power connections are made in an area that might become hazardous, the pilot wires, control cables, and communication cables should be capable of being de-energised and isolated. Power cables shall be earthed.

Damaged cables are a significant threat to the safety of operations. Therefore, cables require appropriate protection, inspection and maintenance, which will be covered in the future information paper.

7 Ship/shore cargo equipment electrical isolation

The interface between a ship and its berth is a potential pathway for electrical current flow, posing risks such as electrical ignition of hydrocarbon vapours. Hazards can arise from phenomena such as static electricity, stray currents, and galvanic potential difference from tanker to terminal.

Stray currents and galvanic currents can also produce arcing, which occurs when there is an abrupt interruption in an electrically continuous path. For instance, a spark might be generated when a non-insulated loading arm disconnects from a ship manifold. To mitigate this, terminals should continue to use electrical isolation measures in hazardous areas such as insulating flanges or non-conductive hose lengths.

When passing, connecting, or disconnecting an earthed connector from shore to ship, there is a risk of sparking from making/breaking galvanic currents when it contacts the ship's hull, which should be considered and mitigated. Further information can be found in *International Safety Guide for Oil Tankers and Terminals* (*ISGOTT*) and in the SIGTTO paper *A Justification for the use of Insulation Flanges (and Electrically Discontinuous Hoses) at the Ship/Shore and Ship/Ship Interface*.

Shore power cables and their mechanical construction or protection should be suitable for the hazardous area classification they may pass through during handling into position for use and during use.

OPS cables should be kept well away from cargo transfer equipment to avoid incidental contact between statically charged piping and earthed OPS conductors.

Assuming insulating flanges or electrically discontinuous hoses are installed, introducing equipotential bonding with a high-voltage shore connection should not elevate risks related to losing ship/shore isolation. This maintains protective measures during hose and loading arm connections and disconnections.

8 Next steps

A full OCIMF information paper covering aspects of the safe application of OPS to tankers, terminals and their interface will follow this paper.

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