Research on Onshore Power Supply System in Port for Ships

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Abstract. Due to various ship types, the shipboard devices which receive the shore power are varying. To ensure the safety of equipment and personnel in onshore power system (OPS) operation process during ship berthing at port, the global standards for the process of providing shoreside electrical power to a ship at berth is in high demand to be formulated. In this paper, the background of the OPS formulating, the composition of the OPS and existing problems when ship connect with the OPS are discussed firstly. Then, possible solutions have been proposed to determine the main content of the guideline. Finally, the significance of the guideline and the suggestion for the OPS development are given.

1. Background

1.1. Wide Attention Drawn by Ship Emission and Severe Pressure in Environment Protecting
There are more than 94,000 seagoing vessels in the world that consume billions of diesel fuel every year. The emission problems caused by intensive ship transportation activities and huge amount of energy consumption have attracted increasingly attention day by day. GHGs emissions and air pollutants generated from ships engaged on international voyage have aggravated air pollution in areas where shipping activities are concentrated, such as ports. The reason is the ships employ diesel fuel that produces high content of NOx, SOx, PM during all activities no matter in navigation or at port. The UN, North America, EU and several Asian countries such as China and Singapore have been aware of the impact of ship GHGs emissions and air pollutants on human health and the environment, and have taken relevant measures to tackle the threaten. For example, the IMO has set ship pollution standards in MAPOL which establish limits on PM, NOX and SOX emission from ship[1], the IMO also continues to increase control requirements. On 28th October 2016, The IMO 70th session of MEPC made the decision to cap marine fuels outside ECA limited to maximum 0.5% effective on 1/1/2020 rather than on 2050.

1.2. The continuous development of the OPS technology has become the main development trend of shipping in response to environmental pressure
There are several measures for ship to respond to the increasingly stringent environmental requirements, such as using low sulphur fuel, liquefied natural gas, retrofiting with SOx scrubbers and connecting to the OPS at port. Among them, the use of the OPS at port is one of the important tools for ship energy saving and emission reduction, and it is the most widely adopted measurement at present as major shipping ports in the United States, Europe and Asia have already employed. In addition, the ports authorities in the major emission control areas clearly propose that ships can use shore power as an
alternative measure to meet the emission requirements. Therefore, the OPS has become one of the main development trends in the future.

1.3. Prominent problems in the OPS standards and regulations in different ports appear with the application goes deeper

With the widely promotion and application of the OPS in the world, the problem of imperfect standards and norms has become increasingly prominent because the operational processes are formulated by each ship and port independently. The seagoing ships usually call at different types of ports while sea ports usually serve varying ships that have individual shipboard power equipment. Divergence in operation instructions or guidelines made by port or ship based on their own situation may cause risks in safe operation of the OPS. In 2016, when Ship A first connect to the OPS in Port B, due to poor communication between the ship and the shore about the ship's power supply safety information, the crew activated high-power ship equipment to maintain the main engine, which directly damaged the shore-side shore power conversion equipment and caused huge losses.

In order to solve the above-mentioned problem and avoid such accidents in the future, the China Maritime Safety Administration has proposed the proposal of formulating guidelines on safe operation of OPS service in port for ships engaged on international voyages to IMO and the proposal has been approved.

2. The composition of the OPS and the problems in application

2.1. The composition of the OPS

The construction plan of the OPS is depending on the type of ship calling at the port, the voltage and frequency of the marine electrical appliances and the power supply of the terminal. In most of regions and countries, the frequency of power supply and electrical equipment is 50 Hz, some are 60 Hz. The electrical frequency of most international ships is 60 Hz. As for inland and coastal ships, the electrical frequency is 50 Hz. Generally, there are three types of power supply forms in the OPS[2].

Form 1: High-voltage shore power to high-voltage ship (high-high). Ships using high-high OPS should be able to connect with high-voltage shore power directly. There are three type of powers that the high-high OPS could provide: AC 6.6kV / 60Hz, AC 11kV / 60Hz and AC 6kV / 50Hz.

Form 2: High-voltage shore power to low-voltage ship (high-low). Ships adopting high-low OPS need to be equipped with transformers to transform the high-voltage shore power to low voltage which is acceptable to the ship. The power type provided by the high-low OPS is AC 6.6kV / 60Hz or AC 6kV / 50Hz, which could serve low voltage ships with the power type of AC 440V / 60Hz or AC 400V / 50Hz.

Form 3: Low-voltage shore power to low-voltage ship (low-low). This form usually employs in inland wharves to supply power for domestic ship. Few of coastal ships are also using low-low OPS for power supply. The power type provided by low-low OPS is 440V / 60Hz or 400V / 50Hz.

There are three main parts that consist the OPS [3-4]: power supply system based onshore, Ship-shore interactive equipment and shipboard power receiving system. The high-voltage power from the public power grid is supplied through substations to the port dock berth connection box to complete the conversion of shore power voltage and frequency. According to the different port power supply schemes, the power supply system based onshore can be divided into two types: frequency conversion shore-based power supply system and constant frequency shore-based power supply system. Ship-shore interactive equipment is used to connect the shore-based power supply system and the ship's power receiving system. Ship-shore interactive equipment is consisted of cables and related equipment, which can be configured by the ship or by the port side. Shipboard power receiving system is the part from the ship's shore power connection point to the ship's own power distribution board which usually includes a transfer screen, transformer, distribution box and other related electrical equipment. It can be divided into two types: high voltage shipboard power receiving system and low voltage shipboard power receiving system.
2.2. Main problems in the application of the OPS

2.2.1. Lack of operating standards for shipboard power receiving system. In the operation of power supply system based onshore, IEC/IEEE IEC/ISO/IEEE 80005-1:2019: Utility connections in port – Part 1: High Voltage Shore Connection (HVSC) Systems – General requirements is commonly referred by the OPS operator. However, as for ship side, there is no unified operation standards for ship board power receiving system. This adds the potential risk for ships connect to the OPS at port and hinder the development of clean port.

2.2.2. Compatibility of ships and shore-based systems. The inconsistency in the production, manufacturing and construction standards of the shipboard power receiving system and shore-based power supply system, as well as the certain differences in the power system of international sailing ships, together with no requirement that the ship needs to undergo a compatibility assessment before using the OPS result in the ship may encounter problems when using the OPS. For example, insufficient capacity of shore power supply system, mismatch of ship-shore communication protocol, inconsistent operation of power supply and receiving system and ship-shore interactive equipment, different frequency and phase sequence of ship and shore power system etc. can easily cause electricity accidents to ships and ports.

2.2.3. Inconsistent testing standards. In the inspection of shore-based power supply system, the IEC/IEEE IEC/ISO/IEEE 80005-1:2019: Utility connections in port – Part 1: High Voltage Shore Connection (HVSC) Systems – General requirements is commonly referred internationally, whereas for shipboard power receiving system, the ship and port side are refer to the specifications of the classification society in each county. The inspection system in each classification society is formulated on the base of ship condition in each country and includes different inspection requirements. Therefore, although the ship has gone through the test, the inconsistent between shipboard power receiving equipment and shore-based power supply system may still exist which leads to unsuccessful operation when ship connected to the OPS at port.

3. Possible solutions and the determination of the guideline main content

3.1. Possible solutions for the problems in the OPS

3.1.1. Joint inspection of the shipboard power receiving system. There are types of equipment in shipboard power receiving system. For the new built ship that already has or the ship that has been retrofitted with the onshore power receiving system, each equipment has to undergo relevant inspection to obtain a qualified marine product certificate before installed onboard. Besides, the electric equipment should be jointly adjusted after the onshore power receiving system completely installed before the ship connects to a shore supply point.

3.1.2. Carry out compatibility assessment. The shore installations and ship-side installations for the OPS adopt different construction standards respectively and usually the shore installations are fixed. The shipboard power receiving system varies from ship to ship so that the equipment performance and parameters and the electricity consumption are varying. International ports are exposed to more safety threatens in the OPS operation due to more internationally calling vessels with various electricity parameters. Therefore, before the ship arriving at the port, both ship and shore side should fully communicate and conduct a compatibility assessment to ensure the safety and success of the shore power supply operation.
3.1.3. **Carrying out inspection before ship-shore connection.** Before the OPS connection, the shore and ship-side should conduct visual inspection on the key equipment of the OPS to ensure the OPS facilities are in good working condition to prepare for the safe connection. Key equipment includes reverse power protection devices, grounding devices, protection devices, interlocking systems, and control equipment.

3.1.4. **Carrying out daily maintenance.** The daily maintenance of equipment is one of the important processes to ensure the normal operation of the OPS. Ship and shore sides should formulate manuals for daily maintenance of the OPS and regularly maintain the key equipment to keep the equipment in an immediately available state. In addition, they also need to record the maintenance time and status.

3.1.5. **Strengthen the management of operating personnel.** The failure of the OPS operation will pose a potential threat to personal safety especially in the high-voltage shore power system. The non-professional operation is very likely to cause safety accidents. Therefore, the shore power system operators should be strictly managed and have to possess certain required qualifications before employed. Meanwhile, a duty system has to be formulated to ensure the safety of the OPS operation.

3.2. **Main content of the Guideline**

Based on the above research, China cooperates with several IMO member countries to determine the framework and main contents of the Guidelines on Safe Operation of OPS Service In Port For Ships Engaged On International Voyages, including at least the following 4 parts.

3.2.1. **General.** It specifies the scope of application, general requirements and terms and definitions of the guidelines. The guidelines apply to the use of AC shore power by international ships but do not apply to the electrical power supply during docking periods, e.g. dry docking and other out of service maintenance and repair.

3.2.2. **Compatibility assessment.** The guidelines divide the use of the OPS for ships into two forms: the first calling at a shore supply point and the repeated calling of a shore supply point. Different requirements in compatibility assessment have been formulated according to the actual needs in two types of calling.

3.2.3. **Equipment.** The Guideline stipulates the system layout, equipment and communication requirements of the OPS facilities. It is required that the design of ship's shore power system should consider the influence of the surrounding environment and set up corresponding preventive measures. At the same time, reliable communication should be established for the entire process of using shore power by ships to ensure the smooth communication of information between the two parties.

3.2.4. **Operation.** The Guideline provides the inspection, connection and disconnection, operation manual, regular inspection and maintenance of the OPS, which are the core parts of this guideline. Restricting items have been put forward on the content of the test that the ship should carry out after the OPS installation completely, the safety inspection work for the first and repeated connections of the ship, the process of connecting and disconnecting the OPS for the first and repeated connections of the ship, regular inspection and maintenance procedure etc. to ensure the safe operation of the OPS.

4. **Significance of the Guideline and suggestions for the development of the OPS**

4.1. **Significance of the Guideline**

4.1.1. **Assist to promote the implementation of global ship emission control.** The use of shore power supply for ships could effectively reduce the emission of atmospheric pollutants and reduce the impact on the urban atmospheric environment in the port area. The OPS has become the main technical means for shipping to respond to increasingly stringent environmental protection requirements, and has become
the main development trend in the future. Research on OPS technology, promote the formulation and improvement of the OPS standards can continuously promote the application of shore power on ships, in line with the global policy guidelines for encouraging ship energy conservation and emission reduction.

4.1.2. Improve the utilization rate of the OPS. Although the application of OPS to ships has been continuously promoted in the world, the utilization rate of shore installations is less than 20%. Lack of safety operation standards for the OPS should be the main reason for this situation. Therefore, by formulating unified requirements for the ships and ports for ships at ports, the problem of low utilization rate of the OPS will be solved from a large extent and contribute to the development of green shipping.

4.2. Suggestions for the development of the OPS

4.2.1. Increasing the policy support. The governments have to maintain and increase policy support for the port industry which install the OPS by means of financial subsidies or taxes and fees adjustment. Support the ships to install onshore power receiving systems and ports to build the OPS. In addition, provide priority for the ships that use the OPS at ports with preferential berthing plan should be a possible way to encourage ships with on shore power receiving capabilities to use the OPS during port calling period.

4.2.2. Further improve the OPS standard system. Speed up the formulation of standards for testing and inspection of shore installations, construction and inspection regulations for ship-side installations, ship-to-shore communications and other standards to establish and improve shore power application standards system. Strengthen the promotion and implementation of standards are also important to promote the OPS in the future development.

4.2.3. Improving the technical level of shore power facilities and equipment. Increase the scientific and technological research investment in the use of shore power technology for ships calling at ports under the guidance of the market. Strengthen the technical research on ship-to-shore grid connection systems, encourage the research and development of the OPS complete equipment, and strengthen the inspection, testing and maintenance of the connection between shore and ship-side installations to improve the stability and safety of the OPS technology.

Acknowledgments
This work was financially supported by Ship-tech Scientific Research Project of Ministry of Industry and Information Technology (MC-201902-C02) fund.

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