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A journey into electrical standardization of shore power connections for bulk carriers

Development of a bulk carrier and general cargo ship standard for shore power connections in port

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In an attempt to facilitate the standardization of shore power for bulk carriers and general cargo ships, this article discusses the development trends around the electrical connection standardization of shore power for these two ship types. Shore power reduces emissions by supplying ships with clean electricity from the shore with an electrical connection so the ship's auxiliary engines can be switched off. In this period of high climate disturbances, the maritime industry intends to reduce its emissions as quickly as possible and shore power is the next logical step. However, the bulk carrier industry is urgently requesting the development of a specific shore power standard for global technology deployment. Therefore, this article addresses the key aspects of the standardization development for bulk carriers and general cargo ships such as the different ship-to-shore interfaces, the power demand of the world fleet, the cable management system, bulk berth frequentation, the connector, and safety.

Context and background

The maritime industry is making strides toward sustainability, but this shift is expected to take several decades. Five critical levers can drive the decarbonization of the industry: policy and regulations, technological advancements on ships, energy and fuel advancements, customer demand and pull, and finance sector mobilization. While only alternative fuels can lead to oceangoing zero-emission ships, the technologies currently available are not yet mature or present in sufficient quantities to decarbonize the entire fleet.

In the meantime, shore power, also known as cold ironing, alternative marine power, shore-side electricity, shore-to-ship electricity, or onshore power supply is a measure that can reduce GHG emissions now. However, the shore power standardization is not completed for the bulk carrier and general cargo shipping segments which undermines many decarbonization projects. Indeed, requests to add a bulk carrier standard have been made by many ports and shipowners to the Joint Working Group (JWG) 28 of the International Electrotechnical Commission (IEC). The JWG28 is in charge of shore power standards development and maintenance.

Figure 1 presents the decision tree for selecting a shore power connection based on the existing shore power standard of the IEC in collaboration with the Institute of Electrical and Electronics Engineers (IEEE) and the International Standard Organization (ISO).

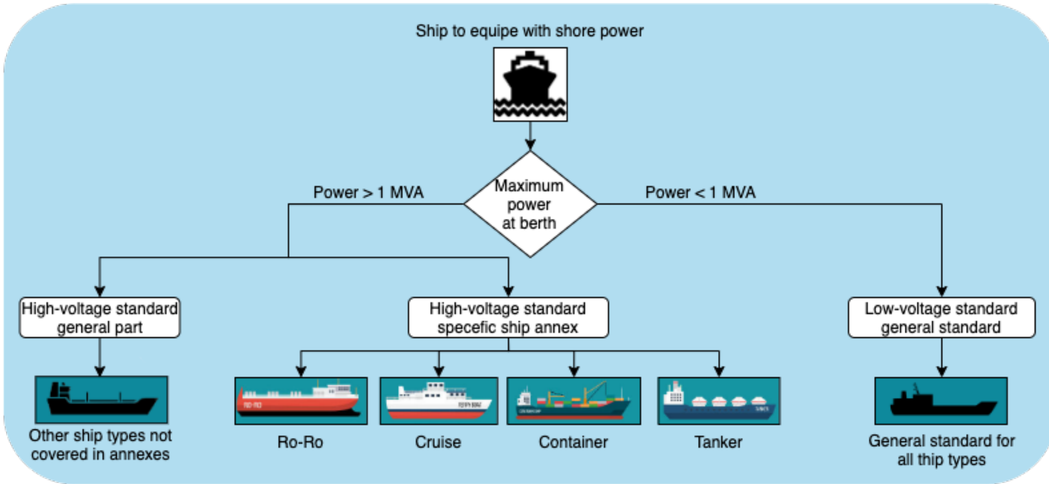


Figure 1: Layout of actual shore power standardization option for ships

If a ship requires more than 1 MVA at any berth it visits, it needs to use the high voltage (HV) standard IEC/IEEE/ISO 80005-1. Also, the IEC/IEEE/ISO 80005-1 standard includes specific ship annexes for cruise ships, container ships, Roll-on/Roll-off (Ro-Ro) ships, liquified natural gas carriers, pure cars and trucks carriers (PCTC), and tankers[1]. However, the bulk carrier annex is still missing. Then, if a ship requires less than 1 MVA in port, it is directed toward the current committee draft for vote (CDV) low-voltage (LV) standard: IEC/IEEE/ISO 80005-3 CDV1.

Technically, ships that have specifically defined sailing patterns such as ferries or liners could technically decide to use their own solution. However, it is not recommended if the ship fits into one of the categories as the standard ensures safety and compatibility with other similar ship types.

Apart from domestic bulk carriers in China and a few liner bulk carriers around the world, most of the bulk carrier and general cargo world fleets have not yet started to use shore power. Many challenges are slowing shore power adoption for this shipping segment and a universal standard is required to ensure all bulk carriers can share a common system regardless of the port they visit. Indeed, bulk carriers are ships that generally travel internationally and visit a large diversity of berths during their lifetime. If all ports have their own standard, the bulk carriers will not invest in multiple shore power connection systems as they often only visit the same port once a year.

Ship-to-shore interface for bulk carriers

In 2023, the world fleet of bulk carriers and general cargo ships consisted of 25,100 ships excluding ships smaller than 500 dead weight tonnage (DWT) and few specialized general cargo ship types. Together, they totalize a capacity of 894 M DWT which is the equivalent of transporting 88,500 times the Eiffel Tower. The smaller coastal bulk carriers and general cargo ships have a size below 10,000 DWT. The

[1] The tanker annex is not currently normative and is under review by the OCIMF and INTERTANKO

handy-size bulk carriers have a size that averages 40,000 DWT and the largest ore carriers even exceed 300,000 DWT.

There exist multiple ways to connect a bulk carrier to the shore and they all have benefits and drawbacks. From high-voltage cables to wireless systems, this section presents the different electrical interfaces that can be used for bulk carriers and general cargo ships to connect the ships to the shore.

Dry-docking connection

First, all bulk carriers have a low-power shore power connection available for dry-docking. This system generally consists of a 400 V or 440 V connection protected by a 400 A breaker for a handy-size bulk carriers or bigger. The dry-docking breaker is generally interlocked to the main switchboard, so the shore electrical network is not directly connected to the ship diesel generators (DG) while the signals are not synchronized. This means the ship needs to be entirely shut down each time it connects to the dry-docking connection. This situation can be forbidden by the port as the ship loses all means of control and safety during this time. It also shuts down all the electronics of the ship which can be damaging and requires the electrical officer to perform maintenance on all the electrical systems at each connection and disconnection. Also, the cables of dry-docking connections generally need to be bolted directly to a connection panel as there is no standard connector for this application. Figure 2 presents the general electrical diagram of such a system.

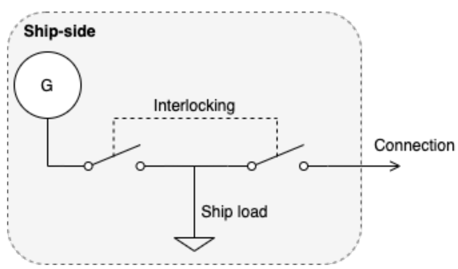


Figure 2: Simplified electrical diagram of a dry-docking shore power connection

One of the simplest forms of shore power consists of using the dry-docking connection while the ship is in port. However, there are two main issues with this method. First, the connection is low power (~300 kVA), which is not sufficient for commercial applications other than being at rest in port doing no cargo or ballasting operation. Second, the cables need to be bolted manually which is a long process and needs an electrician on the shore to coordinate the connection.

Because of these reasons, shore power has not been seriously used via the dry-docking connection. A standardized connection with a universal plug and socket and a higher power transfer rate is required to unlock shore power for bulk carriers.

Low-voltage standardized connection

Another way to connect bulk carriers and general cargo ships to the shore is by using a standardized LV shore connection. Now, the IEC/IEEE/ISO 80005-3 CDV1 covers all LV connections that are smaller than 1000 V and with a maximum power smaller than 1 MVA. The LV standard is not specific to bulk carriers or general cargo ships, but rather a general standard for ships using a low-power connection and locates the CMS on the shore for all ship types. Figure 3 presents the electrical diagram of a standardized LV system.

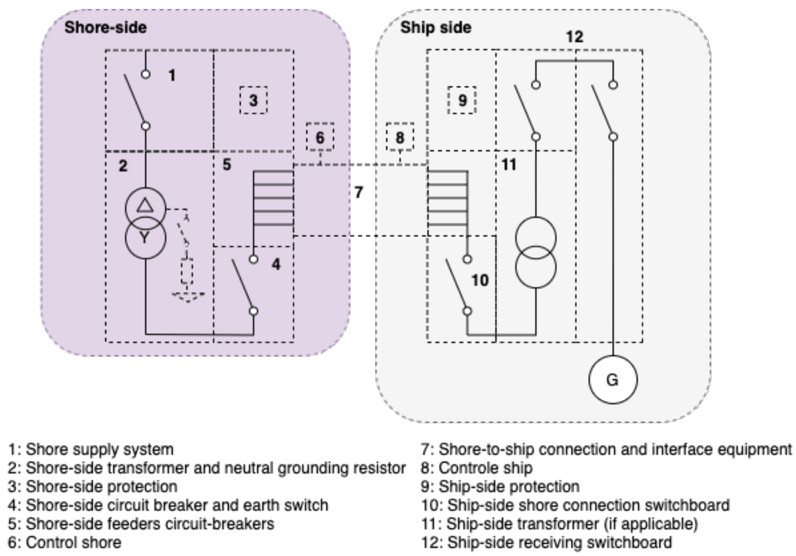


Figure 3: Block diagram of a low-voltage shore connection system from IEC/IEEE/ISO 80005-3 CDV1

One of the main advantages of IEC shore power standards is that they include a control system to do automatic synchronization i.e., to perform a load transfer between the ship DGs to shore power so there is no need to shut down the ship. Also, the connection is standardized so all ships are required to use the same plug. However, there are some practical issues with standardized LV systems. First, the size of the cables is important, and they are hard to handle manually. Indeed, the cables have three phases with a maximum size of 185 mm^2. To overcome this issue, some cable management system (CMS) suppliers offer a dynamic system that pushes the cables, so they are easier to handle manually. However, applications requiring a CMS system with a mobile crane to lift the cables to the ship are very complex and expensive due to the number of cables to manage.

Another issue is the different voltages that can be used. Indeed, typical voltages used for bulk carriers and general cargo ships vary between 400 V, 440 V and 690 V while typically available voltage levels on the shore vary between 240 V, 380 V, 400 V, 480 V, 600 V, and more. Also, the number of cables to put in parallel to supply the shipload varies based on the different voltage levels. While a 690 V connection can supply 1 MVA with three cables in parallel, 440 V requires 4 cables, and 400 V requires up to 5 cables based on IEC/IEEE/ISO 80005-3 CDV1. Bulk carrier owners who have experienced these systems for the bulk industry have expressed that LV systems with more than three cables in parallel become impracticable. However, it is not impossible as some ships are using this system, but at this point, it becomes a situation of case by case. Indeed, some shipowners have studied LV solutions for 5 MVA power demand and found out it would require a staggering amount of 32 LV cables in parallel to supply such a demand.

A major advantage of LV connections is that they do not require a transformer on the ship if the supplied voltage matches the voltage of the ship, greatly reducing the investment. Since most bulk carriers are either 400 V or 440 V, the maximum power of a practical shore power connection would be around 750 kVA.

To mitigate the issue of the low power transfer rate of LV standardized connections, it is possible to couple the shore power system on the ship side with a battery or with the DGs to reduce the peak power demand. These options could enable bulk carriers to use a smaller shore power connection while still being able to perform any operations on shore power. Figure 4 presents the electrical diagram of the two hybrid shore power solutions.

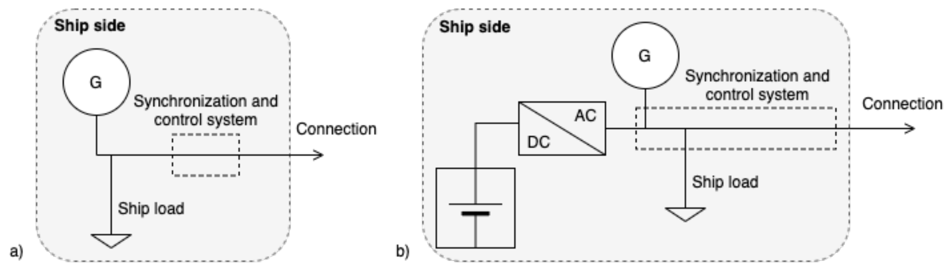


Figure 4: Simplified electrical diagram of a) Hybrid diesel generator-shore power system, b) Hybrid battery-shore power system

However, the disadvantage of the hybrid-DG shore power system is that the ship will still produce emissions because of the DG fuel consumption. As many current shore power regulations require the ship to be zero-emission while at berth, parallel use of the DGs would not be feasible. It also requires an additional control system for the synchronization of the frequency between the DG network and the shore network which increases the capital expenditure (CAPEX). For the hybrid battery-shore power solution, it requires the installation of a battery. While batteries might penetrate the bulk carrier and general cargo market because of the uptake of renewables and hybrid propulsion systems, this is not yet the case and it also means additional costs and system complexity.

Therefore, LV connections are a cost-effective avenue for small bulk carriers or bulk carriers with small power demand. However, the standard still needs to be completed to ensure all ships can use the same connection with the same voltage.

High-voltage standardized connection

The other standardized way to connect bulk carriers is to use the IEC/IEEE/ISO 80005-1 HV shore connection standard. The HV standard covers voltage levels higher than 1000 V and peak power demand greater than 1 MVA. Figure 5 presents the electrical diagram of a standardized HV system.

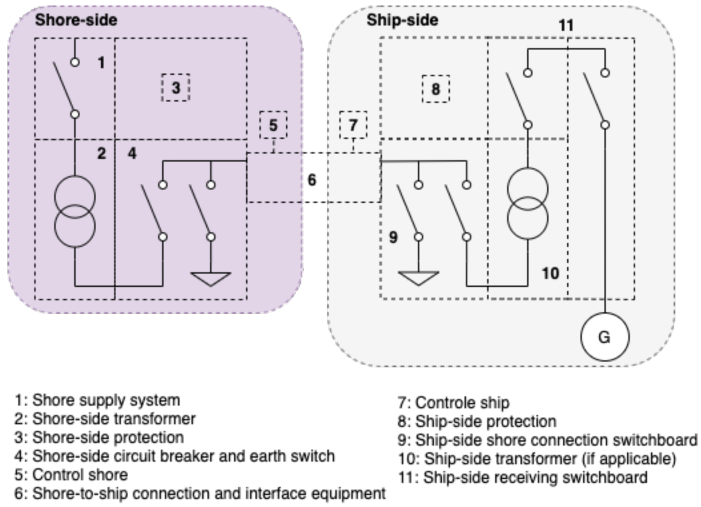


Figure 5: Block diagram of a high-voltage shore connection from IEC/IEEE/ISO 80005-1

The IEC/IEEE/ISO 80005-1 standard does not include an annex for bulk carriers as they do for cruise ships, tanker ships, container ships, roll-on/roll-off ships, and liquified natural gas carriers. Therefore, bulk carriers would fall into the general category. Typically, voltage levels used for HV systems are 11 kV for cruise ships as they can have peak power demands as high as 20 MVA and 6.6 kV for the other ship types. Nevertheless, with the rapid augmentation of the auxiliary electrical load, 11 kV connections are favoured for new shore power applications.

An advantage of HV systems is that the CMS is much smaller than its LV counterpart as the copper section does not need to be as large for the same amount of transferred power. Also, only one cable would be required to supply bulk carrier loads. Nevertheless, HV systems also have the drawback of requiring HV training for the ship crew so they can safely handle the equipment.

While HV connections are more expensive and take more space, they enable the transfer of more power to the ship, and they can be managed much easier making the solution future-proof. For these reasons, HV should become the norm in the industry for larger bulk carriers in the coming years.

Direct current connection

Since the IEC shore power working group has recently started to work on the DC shore power connection standard IEC 80005-4, there is no standard for DC connections yet. However, with the uptake of renewables, hybrid systems and autonomous ships, DC bus on ships are becoming more common. It is also expected that battery or hybrid battery-hydrogen ships will find practical applications for short-sea shipping ships. Therefore, some coastal bulk carriers and general cargo ships might prioritize DC connections as they can supply large amounts of power to recharge batteries. In some cases, DC grids present electrical benefits compared to AC connections. Figure 6 presents the electrical diagram of a DC connection for bulk carriers and general cargo ships.

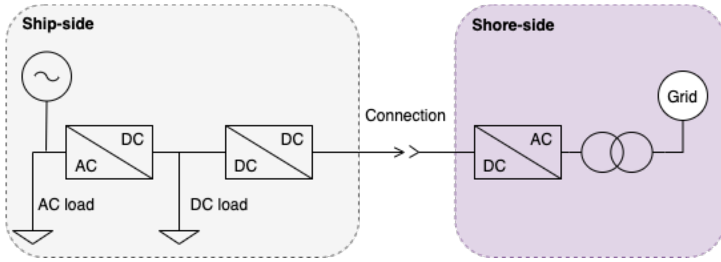


Figure 6: Simplified electrical diagram of a DC shore power connection

While being well suited for battery charging, DC shore power connections need additional power converters which augments the CAPEX on the ship side and on the shore side. While not currently prevalent, DC connections should be used for short-sea shipping applications, especially given their compatibility with battery-hybrid propulsion systems.

Wireless connection

Wireless connections are also considered to supply shore power to bulk carriers and general cargo ships in port. From a practical standpoint, it looks like a perfect situation where no cables are required to perform the connection. It is also useful in rough environments where electrical connections are exposed to salty water and cold/hot temperatures. There are two types of wireless shore power connections: electric field coupling and magnetic field coupling. Nowadays, most systems on the market are magnetic types. Figure 7 presents a wireless shore power connection system.

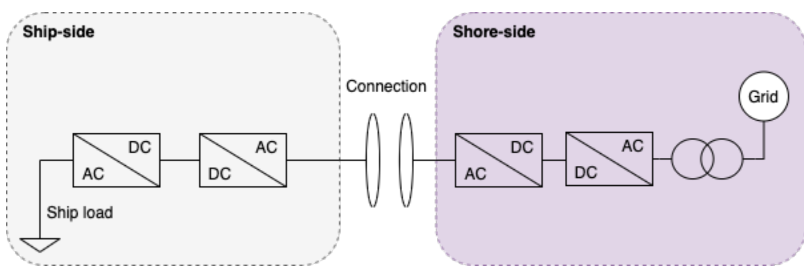


Figure 7: Simplified electrical diagram of wireless shore power connection

Yet, wireless connections also include many drawbacks. First, oceangoing ships generally dock in coastal ports where there is a tide which results in the ships moving vertically along the berths. Additionally, the draft of bulk carriers and general cargo ships changes a lot while the ship is loaded and unloaded. Therefore, the wireless shore system needs to be mounted on a level-varying infrastructure which is complex and CAPEX intensive. Second, wireless systems can have low efficiency which results in energy losses and increased operational expenditure (OPEX). This was one of the reasons the electric car industry did not use wireless charging systems and the issue is the same with shipping. Indeed, the efficiency of wireless connections varies between 60% to a theoretical maximum of 94%. To optimize the efficiency, the distance between the two inductors needs to be minimized and the frequency needs to be electrically augmented. Third, the wireless system requires an additional power converter to adapt the received electrical connection from the shore which augments the CAPEX on the shore side and on the ship side.

Nevertheless, the wireless connection is a promising technology, and more research must be done to improve the efficiency and diminish the costs.

In brief, the selection of the ship-to-shore connection interface will depend on four criteria: practicality, the power demand at berth, the cost, and the internal bus voltage and frequency of the ship. As for practicality, we just observed that standardized LV and HV solutions were the best options. For the costs, LV is less expensive. However, the cost is similar to HV when high-power demands are required which makes HV more practical and economical. Therefore, the next step is to look at the power demand of bulk carriers and general cargo ships at berth.

Electrical characteristics and power demand at berth

Based on an analysis of the Clarkson database, about half of bulk carriers and general cargo ships are very small general cargo ships, which only require a small shore power connection in port. Also, 70% of all the ships are gearless, which also means their power demand at berth is low since there are no cranes or boom conveyors causing high peak power demands. Then, most of the small bulk carriers and general cargo ships have an internal electric system working on 400 V/50 Hz. With the ships increasing in size, 440 V/60 Hz systems are dominant. Therefore, international berths visited by large ships might only need to provide 60 Hz power connections. Finally, self-unloaders (SUL) and heavy lifters are only a minor part of the ships (0.4%).

To determine the general power requirements of the world fleet regarding shore power, Figure 8 presents the average and peak power requirements of the different ship categories and types based on the results of a survey passed through the industry which integrates about 800 bulk carriers. The average power is given in kW and the peak power is given in kVA because volt-amps is the unit used to measure the maximum apparent power required for shore power.

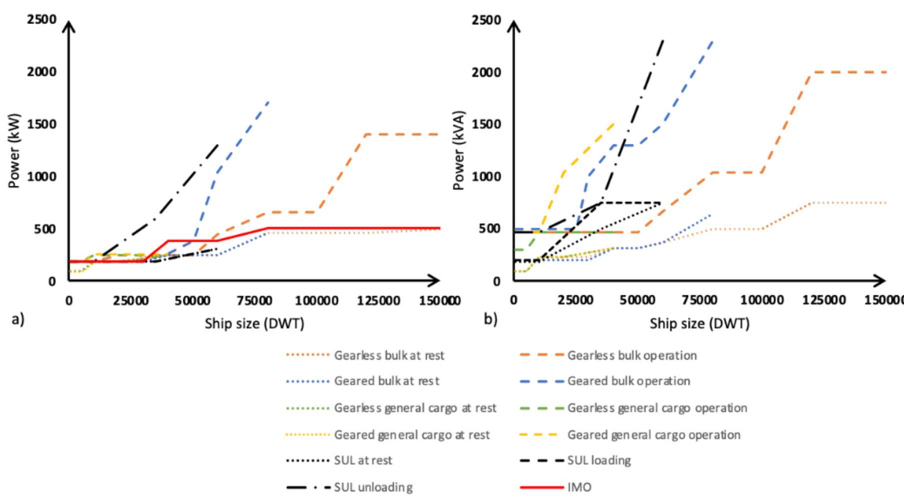


Figure 8: Bulk carrier power demand at berth when at rest and during loading and discharging operation for a) Average power demand b) Absolute apparent peak power demand

In Figure 8 a), the average load demand of bulk carriers for different operating modes is presented and compared to the data provided by the Fourth International Maritime Organization (IMO) GHG study. Also, the auxiliary power of the boiler is aggregated to the total auxiliary engine load as boilers can be electrified and might be if the ships connect to shore power in the future. It can be observed that, in general, the average load demand in port follows IMO data. However, there are important differences to consider when the ships are in loading or unloading conditions combined with the ballasting operations. Figure 8 b) presents the peak apparent power demand. The power stays low for small ships, however, 25,000 DWT ships or more quickly start to require a very large peak power demand. For SUL and Supramax bulkers around 60,000 DWT and equipped with deck cranes, the power demand even reaches 2300 kVA. Furthermore, cement carriers can even reach 5 MVA of peak power demand in port.

Then, by combining the Clarkson database and electrical power consumption data of Figure 8's industry survey, it is possible to estimate the repartition of power requirements of the world fleet of bulk carriers and general cargo ships. The results are presented in Figure 9 but do not include the SUL, heavy lifters and cement carriers as they only present a small share of all ships and might be dealt with on a case by case for standardization purposes.

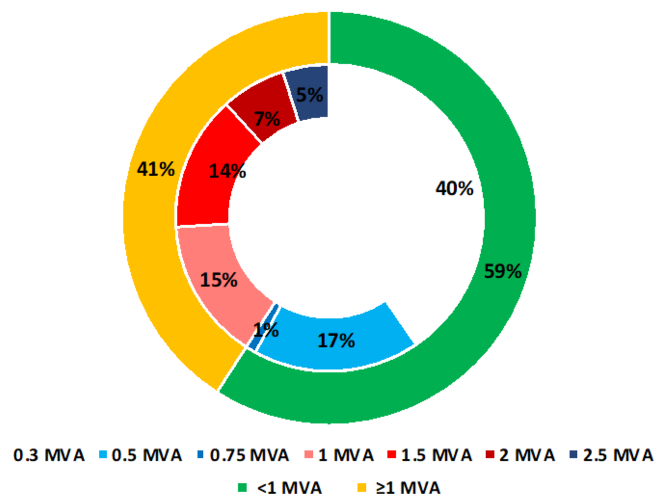


Figure 9: Share of the quantity of bulk carriers and general cargo ships per peak power demand in power

Figure 9 indicates that 59% of the bulk carriers and general cargo ships only require a peak power demand in port that is below 1 MVA and that could be supplied by a LV 750 KVA system with 1-4 cables. However, the rest of the ships would need a HV connection or a LV connection exceeding the limitation of the LV standard in many cases with multiple LV cables. It could be argued that small shore power connections will fit most of the vessels and that the selected shore power solution should be adapted for smaller vessels as they are the majority. However, the prime mover of shore power is decarbonization. Therefore, a look at the emissions of bulk carriers and general cargo ships at berth is required. Figure 5 presents the share of emissions at berth for bulk carriers and general cargo ships per peak power demand in port which is based on the average power demand of the ships at berth.

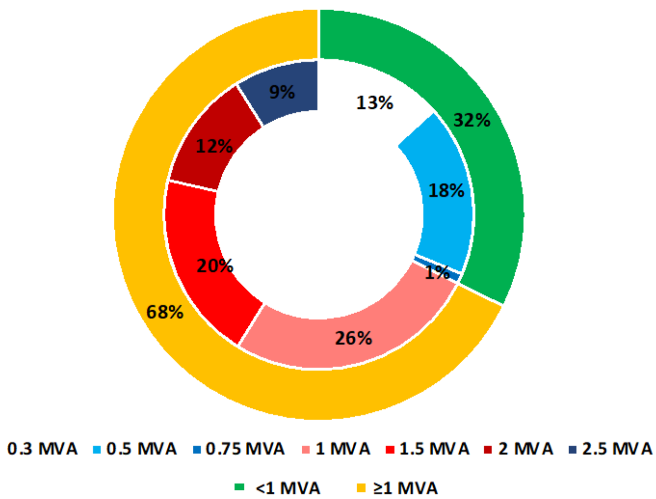


Figure 10: Share of the emissions of bulk carriers and general cargo ships per peak power requirements

In this case, the larger ships might be less numerous, but their average power demand at berth is larger which results in more emissions. Indeed, 68% of the emissions at berth are produced by ships requiring more than 1 MVA. Therefore, the bulk carrier shore power standard must prioritize a system that is best suited for larger ships.

Nevertheless, it is unlikely that the small coastal bulk carriers and general cargo ships will really invest in expensive HV systems unless fully electrified ships or battery-hydrogen ships become the norm for short-sea shipping. In the latter case, a HV port grid could also provide the required power for these ships to recharge their batteries while LV solutions risk lacking power for charging. However, this option is not feasible in the short term due to the typically slow progress rate of the maritime industry and electrical grid expansion. Therefore, it is possible that small ships will still use a LV solution to supply their power demand.

While we start to see where the bulk carrier standard is going, there are still some important questions that need to be assessed for the shore power standardization such as berth utilization, the cable management system location, and the safety of the connection. Indeed, the CMS location, on the shore or on the ship, will have major impacts on costs and operation practicality and depends on the type and frequentation of the berths.

Overview of bulk berth utilization

Bulk carriers and general cargo berths vary tremendously in types of usage and this characteristic has an impact on the final decision on the CMS location. Indeed, these ships can visit bulk berths with heavy equipment on shore to transfer cargo, remote berths with very limited port infrastructure, general cargo berths where the cargo is loaded and unloaded by individual packages and more. In some cases, the ships even need to move while loading or unloading.

Based on information derived from the AXSMarine database, there were about 2232 ports and 10,707 terminals visited by bulk carriers and general cargo ships in 2022. Data on the frequentation of the berths enabled to identify that bulk carriers and general cargo ships spend on average 3.31 days at berth per voyage with a standard deviation of 2.47. With the same data, an analysis of the concentration of the time in port for each terminal was also realized and the results are presented in Figure 11.

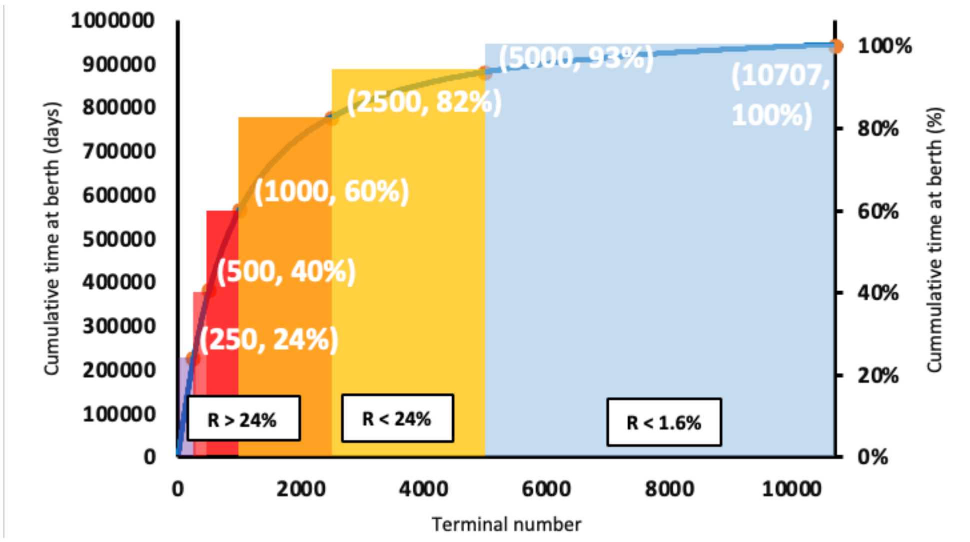


Figure 11: Analysis of bulk carrier and general cargo terminals frequentation and coefficient of utilization (R)

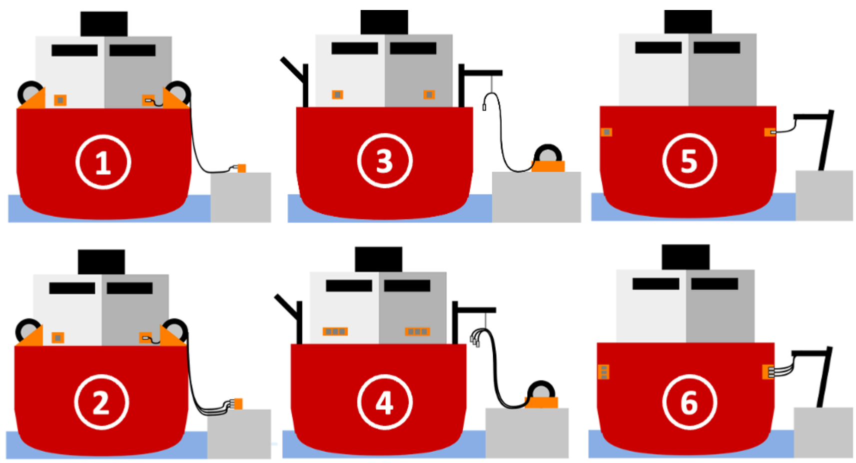
The results show that the most frequented 250 terminals in the world cover 24% of the time spent in port, the top 500 covers 40%, the top 1000 covers 60%, and so on. Therefore, a relatively low number of berths can cover most of the time spent in port by bulk carriers and general cargo ships.

Also, since the data is based on the time spent at berth for ships in a terminal, the coefficient of utilization of the terminal "R" varies a lot. Indeed, for the top 2500 berths, the utilization coefficient was larger than 24% which means there was at least one ship at berth one-quarter of the time for these terminals. However, this figure drops significantly for the berths with smaller utilization as they present a utilization coefficient smaller than 1.6 %.

Finally, the exact number of berths was not covered by the database. Yet, the inspection of the data made it possible to determine that there were about 2-3 berths per terminal. Therefore, it could be expected that the total number of berths to be equipped with a shore power system would be around 43,000 berths. However, if only the top 5000 terminals are equipped with a shore power system, it can be estimated that a total of 15,000 berths would need a shore power system. However, not all berths at a port will need to have a CMS since not all berths are occupied at the same time. It is complex to estimate the real quantity of CMS to plan but 15,000 is expected to be an absolute maximum. Compared to the number of ships, there are fewer berths to equip with a CMS that there are berths. In the end, the biggest challenge and CAPEX for the ports is not the CMS itself but rather to bring electrical power to each berth, and infrastructure.

Cable management system

The CMS is responsible for handling and delivering the cables. It is one of the critical components of the shore power system. Nowadays, different ship types are using different configurations based on their needs. For instance, electric ferries use automatic connection systems to maximize the charging time for their batteries. However, the bulk trade is much different. As the average turning time of a bulk carrier is about 3 days, it is less critical to have a connection process that is slow. Also, bulk berths are generally long enough to accommodate ships with different sizes to connect, and the ships are never berthed in the same position. Figure 12 presents the different cable management options for bulk carriers.



1. Fixed cable management system on ship with a high-voltage connection
2. Fixed cable management system on ship with a low-voltage connection
3. Mobile cable management system on shore with a high-voltage connection
4. Mobile cable management system on shore with a low-voltage connection
5. Fixed cable management system on shore with a high-voltage connection
6. Fixed cable management system on shore with a low-voltage connection

Figure 12: Cable management system different layout options

As discussed previously, there are two voltage categories of CMS: HV and LV. Then, the system can be fixed or mobile and, located on the ship or on the shore. Also, additional requirements exist for specialized berths such as tracking systems if the ship needs to move while loading or unloading cargo.

The HV and LV systems located on the ship are the most flexible solutions providing easy handling. However, they are more expensive for the shipowners as it is required to install two CMS instead of one: one starboard and one port side. Since there are about 15,000 CMS to plan for the world berths and about 50,000 CMS for the ships, it is much more cost-effective and intuitive to put the CMS on the shore. Moreover, shipowners have expressed their concerns with CMS on the ship as the components will suffer greatly from marine harsh conditions, cargo fine dust, ultraviolet radiations, and mechanical fatigue due to heavy weather, and easier to manage and maintain on shore.

Then shore fixed CMS are the less expensive to install and manage. However, bulk carriers rarely berth at the same position which makes fixed CMS viable for only a few specialized cases. Furthermore, many ports have highlighted the issue of berth space to put the CMS on the shore. While only specialized terminals equipped with gantry cranes might be affected, this lack of space could force the CMS to be located on the ship. An alternative option for berths with gantry cranes is to lift the CMS on the ship with the CMS.

In brief, the selection of the CMS is a critical step of the standardization process since the industry requires a uniform approach to CMS. Indeed, if both the ship and the berth are not equipped with a CMS or if the CMS is not accessible, the shore power connection will not be possible. It goes the same with the connector to use if the shipping industry does not want to struggle with multiple connector standards such as the electric car industry did. Therefore, the industry needs to determine which option they will select so the final solution can be uniform throughout the world fleet.

Connector

For ships using the LV standard, only connectors following IEC 60309-5 are allowed enabling compatibility in all cases. However, the bulk carriers still need to define their standard connector for the HV standard. Two options both following IEC 62613-2:2016 are on the table for bulk carriers and general cargo ships: the container ship plug with three pilot lines and the Ro-Ro plug with seven pilot lines. Figure 13 presents the layout of the two different plugs.

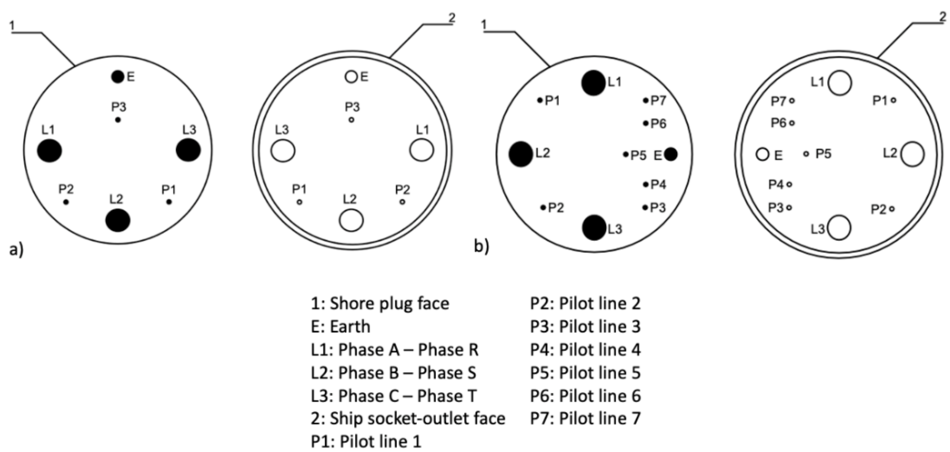


Figure 13: Possible connectors layout for bulk carrier and general cargo ships a) Container ship connector: Annex D of IEC/IEEE/ISO 80005-1, b) Ro-Ro ship connector: Annex B IEC/IEEE/ISO 80005-1

If the containership connector is used, this will ensure compatibility between the container berths and the bulk carrier berths. While most container ships only visit specialized container terminals and most bulk carriers only visit specialized bulk terminals, some ships might visit both terminals. This is especially the case of general cargo ships. However, general cargo ships often share berths with Ro-Ro ships which would enable these ships to share the Ro-Ro plug. Ultimately, a HV shore power connection for bulk carriers should only require one cable based on Figure 9 which can be provided by the Ro-Ro plug.

Safety

Firstly, all shore power connection events it is now recommended to follow the safety procedure of the IMO: *Interim Guidelines on safe operation of onshore power supply service in port for ships engaged on* *international voyages*. The document details the process of connecting the ship from the ship to the shore, the labor training requirements, the communication, and maintenance to ensure safety. Also, local authorities may have further requirements to follow.

Secondly, the IEC/IEEE/ISO 80005-1 standard and IEC/IEEE/ISO 80005-3 CDV1 standard cover the mechanical and electrical safety requirements that should be followed for the design and maintenance of shore power connections. One of the key mechanical safety measures is the requirement of an automatic cable tensioning system to ensure cables are always in a safe position. While hazardous risks are covered by the standard, specific risks related to bulk carrier operations such as the risks caused by explosive mixtures originating from the transported cargo should be integrated. Finally, grounding requirements are extensively covered by the current shore power standards to ensure system integrity even if ships operate on different systems and ensure safety in all cases. Bonding monitoring devices and regular inspection of the grounding are included in the standard.

Thirdly, on the electrical side, the IEC standards include safety loops passing through the pilot pins of the connector as presented in Figure 14. The layout of the safety loops is critical because it will determine the number of pilot pins needed in the plug, and therefore, it affects compatibility between the different plugs. The goal of the safety loops is to detect any broken cables or unplanned disconnections of the cables. They are also connected to safety disconnection buttons placed on the ship and onshore.

Finally, the standard requires the installation of an equipotential bound monitoring device or to regularly checking the integrity of the grounding. This is to ensure the integrity of the grounding and therefore the safety of the equipment and personnel.

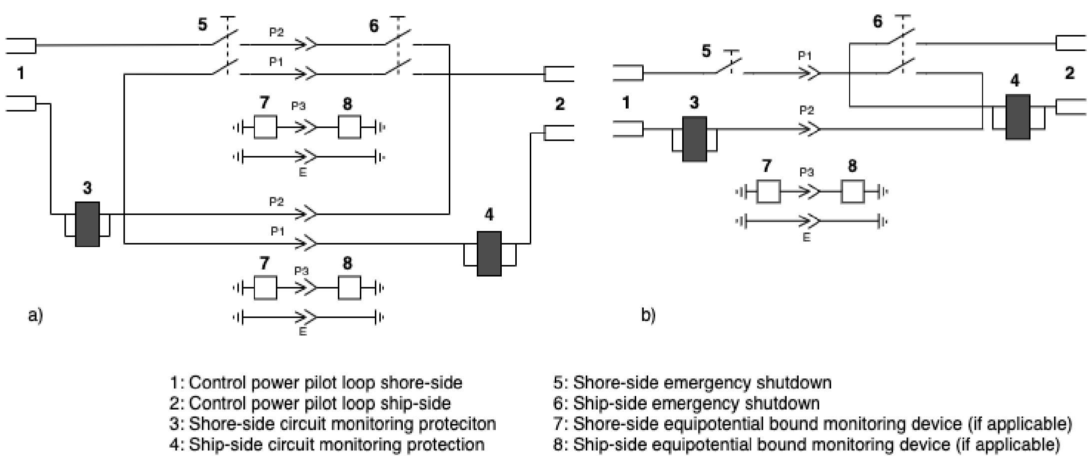


Figure 14: Simplified safety loop circuit a) IEC standard for container ships IEC/IEEE/ISO 80005-1 Annex D b) GB national Chinese standard for bulk carriers GB-T 36028.1 Annex A

As per Figure 14 a), container ships are currently referring to the IEC standard which requires two power cables in parallel to complete the two safety loops. The Ro-Ro safety loop circuit is the same but through only one cable with more pilot pins.

On the other hand, the Chinese GB national standard for bulk carriers in Figure 14 b) is slightly different. When China decided to make shore power mandatory, they had to propose a standard for shore power connections for bulk carriers since there was no specific bulk carrier annex at this time in the IEC standard. To follow the IEC general standard, they proposed a single safety loop circuit using the same plug that was used on container ships but with only one cable. Consequently, only one safety loop was possible as there were not enough pilot pins in the container plug to have two safety loops with one connector. For safety reasons, the future IEC shore power standard for bulk carriers cannot adopt the GB standard, as it fails to detect certain failure scenarios. In its current format, the GB standard would not meet the national regulations of many countries.

Consequently, the bulk industry has the choice to use either the IEC container ships' plug or the IEC Ro-Ro plug. As this is one of the main obstacles faced by the development of the standard, the industry should organize a working group to discuss this matter and agree on a solution.

Future recommendations

In summary, this article presents the trends in bulk carriers and general cargo ships' shore power standardization based on the power demand, berth usage and qualitative analysis of shore power systems. This work has highlighted different aspects and obstacles to standardization for these ships. Firstly, the large variety of ship sizes for bulk carriers and general cargo ships makes it practically impossible to find one standard that will cover all ships. However, larger ships cover a larger share of the emissions. Since emission reduction is the prime mover of shore power, a solution that is appropriate for larger bulk carriers such as the standardized high-voltage solution is preferred. For smaller coastal bulk carriers and general cargo ships, the less expensive and complex low-voltage system could be used as they will generally operate in local areas. Secondly, the location of the cable management system is an obstacle to the development of the standard. It was highlighted that installing the cable management system on the shore will result in a much smaller quantity of units to install. Also, the use of a HV CMS enables to use more compact CMS allowing more flexibility. Finally, two options are available for the connector type to use: either the container ship connector with two supply cables or the Ro-Ro ship connector with one supply cable. While both options have pros and cons, safety is ensured in both cases. Therefore, future work needs to be done by the industry and the research sector to agree on the location of the cable management system and the type of connector to use for the future bulk carrier and general cargo ship shore power standard.

To meet the future requirements of bulk carriers and general cargo ships, it is crucial to meticulously design the shore power standard. This involves thoughtful consideration of the anticipated rise in electrical demand due to the integration of electrical systems, batteries, and other technologies. The goal is to create a forward-looking standard that, at the same time, acknowledges the current context.

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