ANALYSIS OF LOW VOLTAGE SHORE POWER FOR VESSELS

Assessment of the current draft proposal on low voltage shore power standards

HAVENBEDRIJF ROTTERDAM N.V.

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Objective:

Provide quantitative and qualitative analysis of the low voltage data for the sea-going as well as provide insight to the relevant standards that is in progress of standardization for providing low voltage shore power to sea-going vessels. The assessment will help the consortium of Port of Amsterdam, Port of Rotterdam, KVNR (Dutch ship owners association) and Stena Line with consent of the Dutch IWT (Inland Waterway Transportation) association in developing recommendations on the topic of low voltage shore power standardization

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Keywords:

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List of Abbreviations

AC	Alternate Current
AFIR	Alternative Fuel Infrastructure Regulation
AIS	Automatic Identification System (ship position data)
BOG	Boil-off Gas
CDV	Committee Draft for Vote
CEN-CENELEC	Comité Européen de Normalisation Électrotechnique
CO_2	Carbon dioxide (greenhouse gas)
CV	Container vessel
DC	Direct Current
EICB	Expertise en InnovativeCentrum Binnenvaart
EN	European Norms
GHG	Greenhouse Gas
HV	High Voltage
HVSC	High Voltage Shore Connection
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IEV	International Electrotechnical Vocabulary
IHS	Information Handling Services
IMO	International Maritime Organisation
ISO	International Standardisation Organization
JWG	Joint Working Group
LNG	Liquefied Natural Gas
LV	Low Voltage
LVSC	Low Voltage Shore Connection
MGO	Marine Gasoil
Misc.	Miscellaneous
NC	National Committee
NEK	Norsk Elektroteknisk Komite
OPS	Onshore Power Supply
PoR	Port of Rotterdam
TEN-T	Trans European Transport
TEU	Twenty-foot Equivalent Unit
UPS	Uninterruptible Power Supply

1 EXECUTIVE SUMMARY

Main objective of the study is to provide an assessment on the standardization of low voltage shore power based on the analysis performed on the current power demand and voltage levels of sea-going vessels in relation to the IEC/IEEE 80005 standard for shore power connections.

IEC/IEEE 80005-1 high voltage shore connection cover containerships, cruise, oil, chemical and liquefied gas tankers, ro-ro cargo ships, ropax, vehicle carriers and ferry passenger ships but leaves out bulk carriers, refrigerated bulkers and general cargo ships, which use low voltage system onboard. IEC/IEEE 80005-3 defines low voltage shore connection requirements.

Quantitative analysis of voltage and frequency data is performed on the sea-going vessels. Different segments considered for the analysis includes bulk carrier, containership, cruise, oil tanker, chemical tanker, liquefied gas tanker, general cargo ship, ro-ro cargo ship, ropax, ferry-passenger ship, vehicle carrier, refrigerated bulker, other liquid tanker, other passenger/ferry, and miscellaneous vessel. Miscellaneous vessels consist of tugs and fishing vessels in majority.

Approximately 31% of voltage data is available for the existing world fleet, with low voltage data comprising approximately 30% and high voltage approximately 1%. Vessels with low voltage system for bulk carriers, containerships, oil, chemical and liquefied gas tankers mainly operate at a frequency of 60Hz, while the other segments have a comparable mix of both 50 and 60Hz operating frequency.

For the vessels whose low voltage data are available, approximately 60% of them are eligible for low voltage shore power as they do not need load reduction at 1 MVA. For the segments which will require load reduction at 1 MVA, vehicle carrier and containership top the list. Subtracting all vessel types already listed in IEC/IEEE 80005-1, which includes vehicle carriers and containerships, the number of vessels which do not require load reduction at 1 MVA, increases to 69.7%. The major vessel types still requiring load reduction are bulk carriers (35.4%) and general cargo ship (6.9%). With a high % of vessels under bulk carriers requiring load above 1 MVA, the bulk carrier segment is considering having a separate Annex in the high voltage standard.

The majority of LV sea-going vessels have a system voltage of 440V at 60Hz followed by 400V at 50Hz, the latter being more prominent in small vessels. Only 0.3% of the sea-going vessels with available low voltage system data uses 690V at 60Hz.

The current draft of IEC/IEEE 80005-3 is a complement to the already established HV-shore connection standard IEC/IEEE 80005-1. The draft standard defined by IEC/IEEE 80005-3, is restricted to maximum power transfer rating of 1 MVA. This restriction is based on the practical consideration of keeping the number of parallel cable connections between shore and ship controllable regarding space and handling. The upper limit of 1MVA also keeps a clean separation between LVSC and HVSC installations.

Within the power range of 1 MVA, ports and vessels have the freedom to tailor the number of socket connections based actual load requirements of vessels calling a specific berth. This allows ports and vessels alike to fit only the required number of connections. A further advantage is the utilization of one socket and plug layout regardless of ship type, allowing different vessel types to connect to the same berth.

Some European ports, especially seaports with inland navigation, may have berthing and mooring areas which are shared among inland navigation vessels and sea-going vessels. This circumstance suggests a possible utilization of a common shore power infrastructure for inland navigation vessels and sea-going vessels, however from a compatibility, scope of application and regulatory compliance point of view, it is suggested to keep shore connection supply for inland navigation vessels and sea-going vessels separate.

Selecting 690V 60Hz as the transmission voltage has benefits with respect to the number of parallel connections needed to supply. Weighing these benefits against the fact that many vessels operate on 440V 60Hz, would suggest selecting 440V 60Hz as the transmission voltage instead of 690V 60Hz.

Irrespectively of the above, providing different voltages in a (regional) trading area, for example between European ports is worth considering.

Most importantly, the current document on which this report is based is a draft, subject to changes based on feedback from stakeholders and interest groups. Forming the future standard is still possible by commenting on the CDV through the national committees or participation as a member of JWG-28.

2 INTRODUCTION

Shore power is currently an important aspect in shipping to reduce GHG emissions from ships. According to FuelEU Maritime, from 1st January 2030 container and passenger ships not using zero-emission technologies must connect to shore power while at berth in TEN-T ports for more than 2 hours. As for other vessel segments, no such regulation is yet imposed, but is of important consideration that they can be provided with shore power. Some other nations such as USA and China, have regulations in place for shore power connection at their ports.

IEC/IEEE 80005-1 describes the requirements including design, installation and testing for high voltage shore connections to ships at shore. This is suitable for vessels which require power greater than 1 MVA at port.

Under IEC/IEEE 80005-1, containerships, cruise, oil, chemical and liquefied gas tankers, ro-ro cargo ships, ropax, vehicle carriers and ferry passenger ships are covered, defining the requirements for such categories of vessels. But for general cargo ships and bulk carriers, which forms a considerable share of the world fleet, high voltage shore connection is not covered.

In order to standardize low voltage shore connection to vessels with low voltage system and requiring low power at port, IEC/IEEE 80005-3 is being drafted to provide the necessary guidelines.

The consortium of Port of Amsterdam, Port of Rotterdam, KVNR (Dutch ship owners association) and Stena Line with consent of the Dutch IWT (Inland Waterways Transportation) association wants to understand:

- What are the key aspects defined under IEC/IEEE 80005-3
- What are the constraints involved, both for ships and ports
- Limitations on the low voltage shore power supply
- Regulations applicable to inland navigation vessels and sea-going vessels and the differences involved

The Port of Rotterdam is conducting the project with DNV on behalf of the above-mentioned consortium.

The consortium also collaborated with the World Port Climate Action (WPCAP) Power-to-Ship (shore power) working group for better understanding of the different aspects related to low voltage shore connection. Furthermore, a workshop has been conducted including DNV, some port authorities of the WPCAP group and ship owners to provide further insight into the issues related to the low voltage shore connection standardization.

A quantitative and qualitative assessment is conducted by DNV to provide insight into the low voltage systems onboard and implications involved with low voltage shore connection

In order to understand which different low voltage levels and frequencies are being used in the existing sea-going fleet of the different vessel segments, a quantitative analysis is performed on the available voltage and frequency data of the existing world fleet and vessels on order. Furthermore, based on the auxiliary power availability and typical load utilized for various segments at ports, the power demands for the different vessel segments are calculated.

A qualitative assessment is conducted to better understand the compliance requirements of IEC/IEEE 80005-3 and technical requirements such as plug and socket connection for LVSC, different voltage levels used in LVSC systems and design consideration of a LVSC system. Also, whether there will be any special considerations depending on the different vessel type are also a part of the assessment.

Furthermore, the assessment also provides better understanding of the OPS requirements under the framework of FuelEU Maritime and Alternative Fuel Infrastructure Requirement.

The results are to be used to in the advocacy for standardization at IEC and potentially other relevant organizations.

3 DEFINITIONS

Term	Definition
Plug and sockets	The term *plug and sockets* is substitutional for plugs, socket-outlets, ship connectors and ship inlets for low-voltage shore connection systems
Onboard system voltage	The onboard system voltage is normally the supply voltage of the onboard generators to the vessel's main switchboard
Transmission voltage	Describes the voltage level between the shore side and the vessel side power supply system
High voltage	Any voltage level greater or equal to 1000V AC or 1500V DC
Current draft of IEC/IEEE 80005-3	The draft for IEC/IEEE 80005-3 refers to the draft provided by the Port of Rotterdam dated on 27.06.2023

4 QUANTITATIVE ANALYSIS

4.1 Scope

The quantitative analysis for addressing the share of low voltage system onboard ships (with less than 1 kV) and power demand at port for the world fleet, excluding offshore and inland vessels, is done based on IHS Fairplay data. Both the existing fleet and vessels on order are taken into consideration. The different vessel segments considered for the quantitative analysis of low voltage share in the world fleet include:

- Bulk carrier
- Containership
- Cruise
- Oil tanker
- Chemical tanker
- Liquefied gas tanker
- General cargo ship
- Ro-ro cargo ship
- RoPax
- Ferry passenger ship
- Vehicle carrier
- Refrigerated bulk
- Other liquid tanker
- Other passenger/ferry
- Miscellaneous

Under the vessel segment "Miscellaneous", tugs, fishing vessels, landing crafts, dredgers, research vessels and other activity vessels are included. Offshore vessels are excluded from the study as they have unique requirements and do not come under the sea-going fleet.

Data availability for the entire world fleet is restricted, and therefore, assessment was done based on the share of data that was available for the world fleet. In figure 1, the share of voltage data for different vessel segments (only for the existing fleet) are reflected. The voltage data provided is the main switchboard voltage onboard vessels.

The red bars in figure 1 and figure 2 reflects the share of vessels for which we do not have any voltage data. No assumption was made for the unavailable data. The quantitative analysis was based only on the available data.

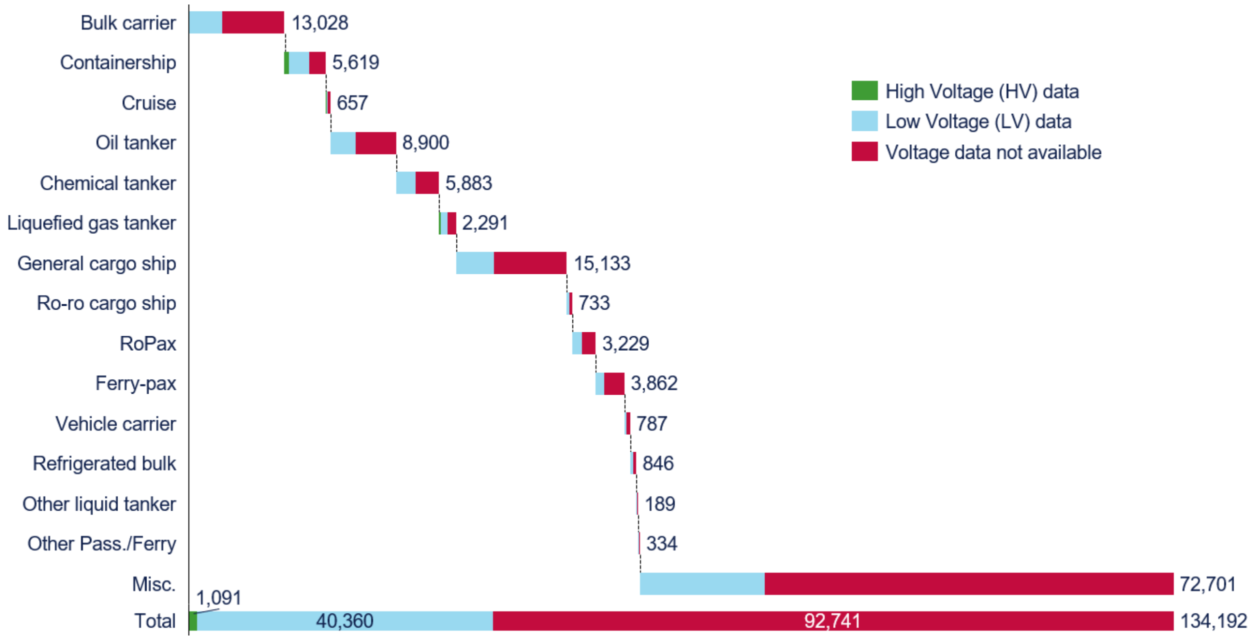


Figure 1: Voltage data availability for the existing world fleet (no. of vessels)

Figure 2 shows the voltage data availability for the newbuilds, i.e., vessels on order.

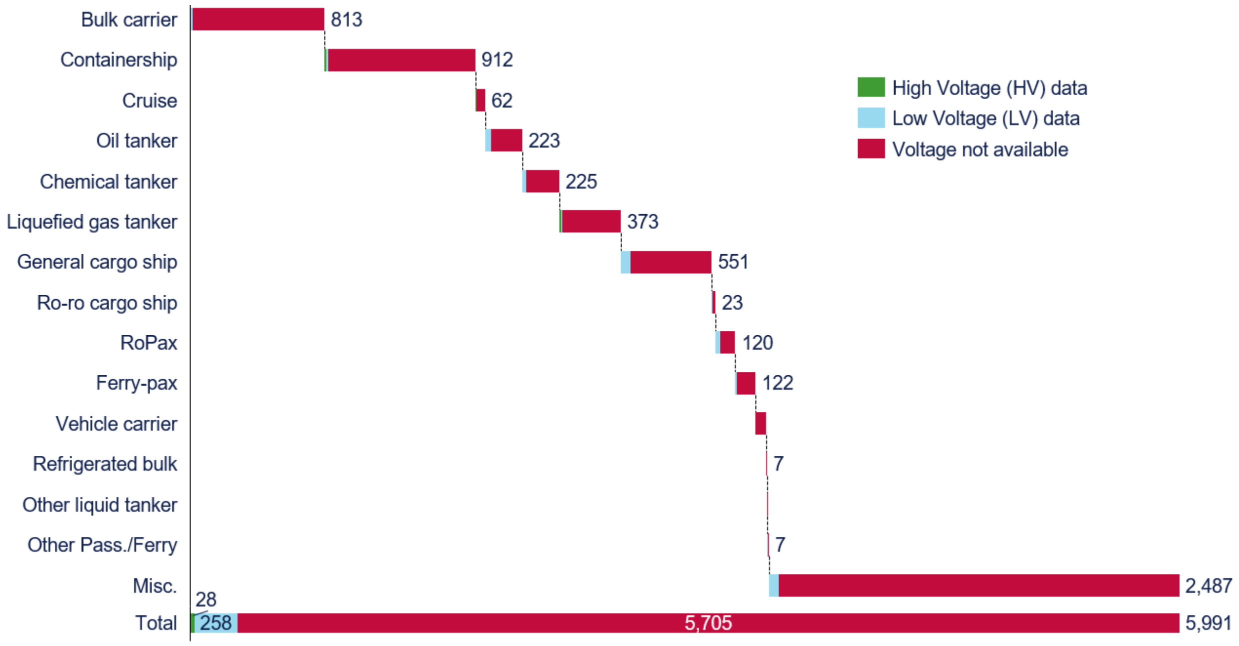


Figure 2: Voltage data availability for the vessels newbuild (no. of vessels)

Further analysis is conducted on the share of frequency data available for the low voltage system onboard ship, i.e., 50Hz and 60Hz. The share of different standard low voltage data such as 400V, 440V and 690V is also provided. The results of these analyses are provided in section 4.3.1 and 4.3.2.

Analysis of power demand at port for the different vessel segments is conducted to provide an estimation of the number of vessels that will requires less power than 1 MVA at port. For low voltage shore connection, the electric load on the vessel should not exceed 1MVA, and thus the power demand at port provides insight into the fact that even if many vessel segments have low voltage system onboard, they may have a high-power demand at port and thus may requiring capping at 1 MVA. The outcome of this analysis is provided in section 4.3.3.

Furthermore, the vessels which are too small and have an auxiliary power installation less than 100 kW, as well as vessels with direct current (DC) power supply are also categorized in this analysis.

Another assessment was conducted to provide insight on the vessel segments and corresponding number of vessels that are already covered and not covered by IEC/IEEE 80005-1.

4.2 Methodology

The voltage and frequency categorization and power demand modelling has been performed in 3 steps.

- Phase 1: Extraction of data from IHS Fairplay and analysis
- Phase 2: Data validation and quality assessment
- Phase 3: Model refinement

4.2.1 Phase 1: Extraction of data from IHS Fairplay and analysis process

The raw vessel data is taken from IHS Fairplay, which includes the vessel segment it falls under, the size category, voltage and frequency used onboard the ship and the total auxiliary power available for the vessel. Apparently, only 31% of the existing world fleet voltage data and 5% of the vessels on order voltage data are available.

Figure 3 shows the number of vessels for which low voltage data is available.

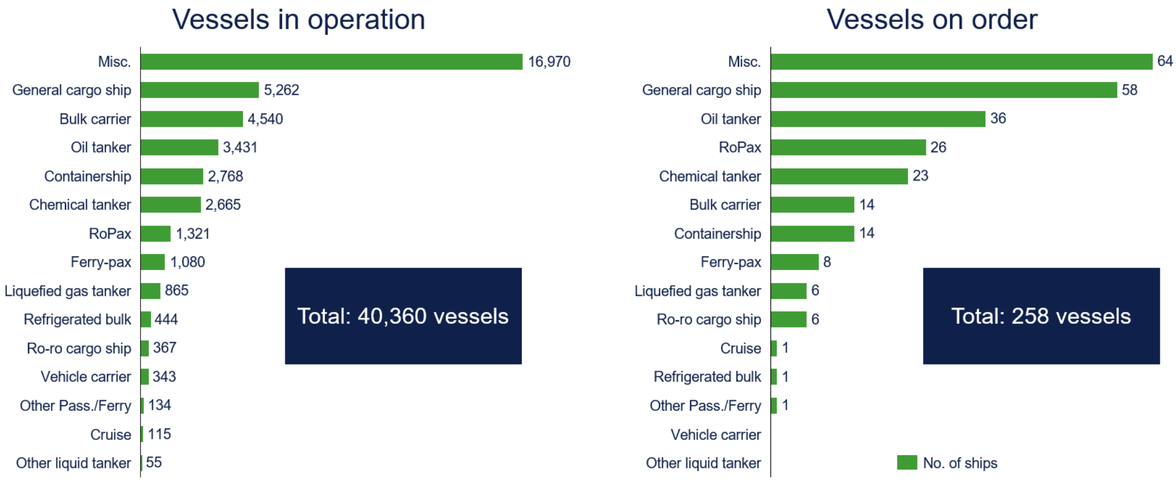


Figure 3: Breakdown of existing world fleet and orderbook for vessels with LV system

Analysis of the low voltage system onboard vessels is based on the available data points for the vessels segments in figure 3. The average power demand of different vessel segments at port is calculated based on the minimum required hotel load [1], load required for cargo maintenance or operation and any other specific load pertaining to a vessel type. For example, in containerships, along with hotel load, reefer load contributes to the total auxiliary power required onboard. Such factors are used to calculate the power demand at port and checked how many vessels remain below the 1MVA apparent power mark.

As the vessel segment “Misc.” is the largest segment, it was further divided into sub-segments.

4.2.2 Phase 2: Data Validation and quality assessment

Auxiliary power installed onboard ships and voltage data validation is conducted to check whether the numbers are realistic and minimize data errors as much as possible.

Verification of auxiliary power installation on vessels is conducted based on the average auxiliary power installation of the corresponding peer group. For example, a bulk carrier of size category 35000 – 59999 deadweight tonnes usually has an average of 1770 kW auxiliary power installed onboard, provided it is not equipped with unique machinery for specific requirements. Now, if according to the available data, the auxiliary power available onboard deviates too much from average auxiliary power installed onboard in the peer group, validation is done to understand why the auxiliary power deviates (e.g., cranes) and whether it is justified based on the vessel specific credentials, and potentially corrected accordingly. This is important, because the average power required at port is a function of the total auxiliary power installed onboard a ship.

As for the voltage data verification, the combination of voltage and frequency system installed onboard a ship is checked and ensured whether it is correct. For example, a vessel with 440V voltage system will have a frequency of 60Hz. If a vessel data shows any other frequency data, it was corrected accordingly.

4.2.3 Phase 3: Model refinement

The data model created after the validation phase was further refined to include voltage and frequency data for different size segments under the defined vessel segments. It is further refined to show the number of vessels under different low voltage levels (ex: 400V, 440V etc) and the corresponding frequency data for both the existing fleet as well as the vessels on order. Similarly, the power demand at port was refined to show the number of vessels requiring or not requiring load reduction at port and also categorizing the small vessels with less than 100 kW installation and vessels with DC power supply.

4.3 Results

4.3.1 LV data analysis for different vessel segments

According to IHS Fairplay, the low voltage level data is available for approximately 30% of the existing world fleet and 4% of the vessels on order. Data availability for vessels on order is worse, owing to the fact they are under construction and the machinery and electrical systems may or may not be in place and reported yet.

The available data share of low voltage system installed onboard for different vessel segments is represented in figure 4 for existing fleet and figure 5 for the fleet on order. In figure 4 and 5, the % represents the share of low voltage data available for each segment with respect to the total number of vessels in operation for that particular segment. The data represented in these figures are for low voltage only and does not include vessels with high voltage.

For existing fleet, refrigerated bulkers and ro-ro cargo ships tops the list, with more than 50% low voltage data available, whereas for fleet on order, maximum low voltage data is available for ro-ro cargo ship, followed by RoPax. Lower percentage of low voltage data share does not necessarily refer to increase in high voltage system usage preference.

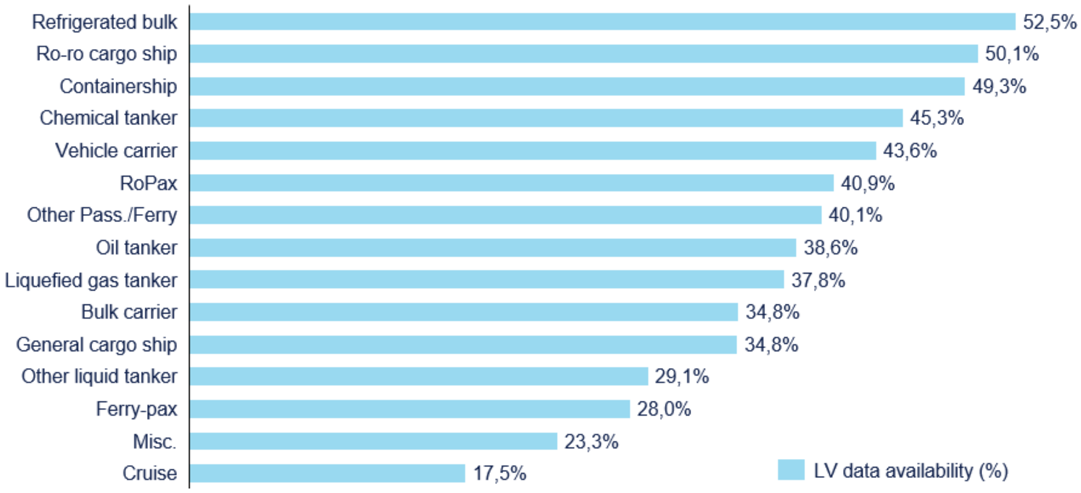


Figure 4: % share of available low voltage data for different vessel segments (Existing fleet)

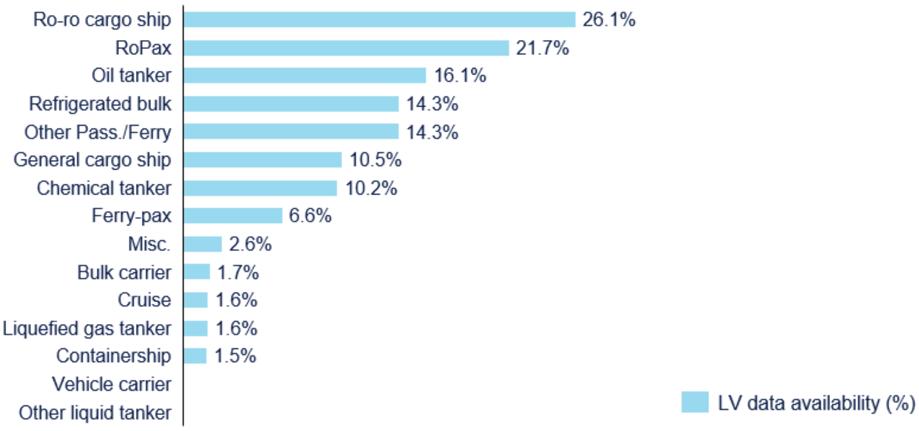


Figure 5: % share of available low voltage data for different vessel segments (Newbuild)

In case of newbuilds, no low voltage data is available for vehicle carriers and other liquid tankers (figure 5).

In order to be able to understand the voltage-frequency combinations used onboard ships, it is important to also have an overview of the available frequency data for the low voltage system installed onboard vessels. For the available low voltage data, the frequency data distribution for different vessel segments is shown in figure 6 for the existing fleet and in figure 7 for the newbuilds.

For the available low voltage data share under existing world fleet, 82.1% of the vessels equipped with low voltage systems have either 50 or 60Hz operating frequency (Figure 6). For the rest 17.9%, the frequency distribution is unknown. For bulk carriers, containerships, liquefied gas tankers and vehicle carriers, more than 85% of the vessels with available low voltage data operate at 60Hz frequency. As for ferry-pax, general cargo ships, misc. vessels, other liquid tankers and ropax vessels, more than 50% of the vessels with available low voltage data operate at 50Hz frequency.

Ferry-pax and other pax/ferry have the lowest share of vessels with 60Hz operating frequency, which is approximately 10%.

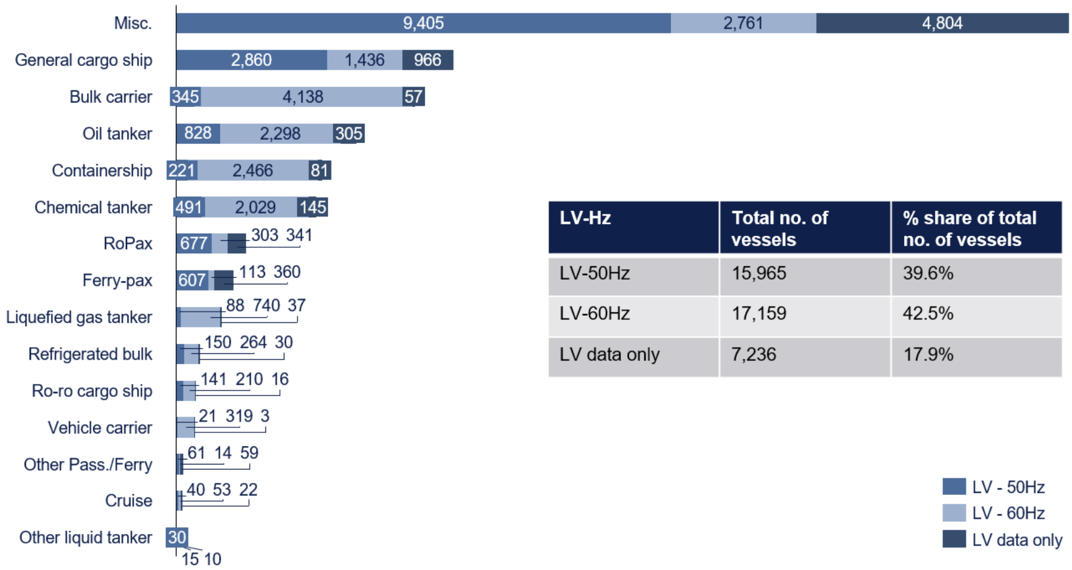


Figure 6: Distribution of no. of vessels with different operating frequency (Existing world fleet)

As for the vessels on orderbook and with available low voltage data, 83.3% of them operate at 50 or 60Hz frequency. For the remaining 16.7% the frequency split is unknown. It can be seen from figure 7, that no voltage and frequency data are available for vehicle carrier and other liquid tankers under newbuilds. Oil tanker segment have a higher share of 60Hz operating frequency for newbuilds in comparison to the oil tankers under the existing fleet (figure 6).

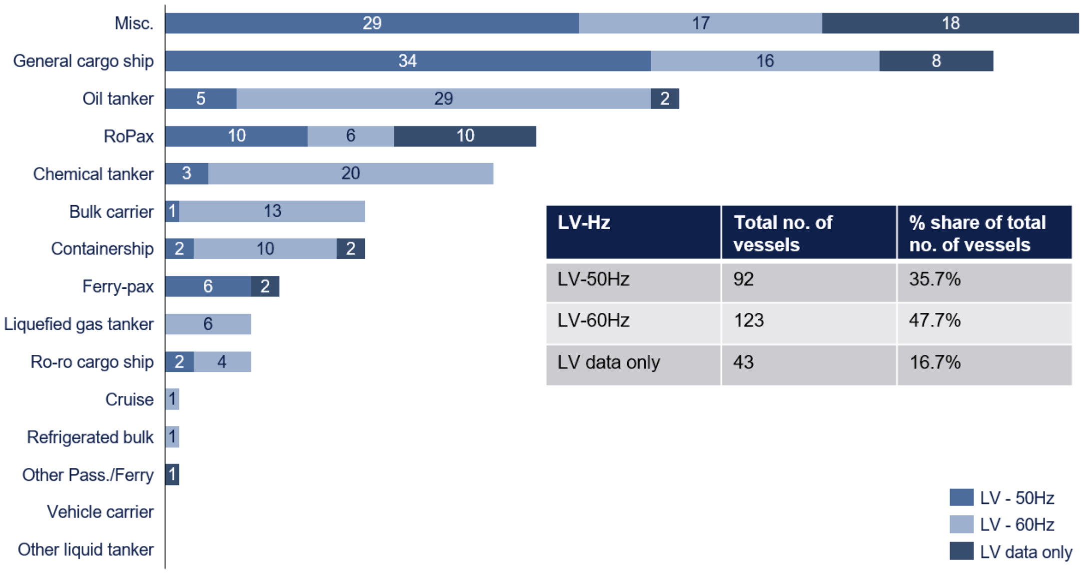
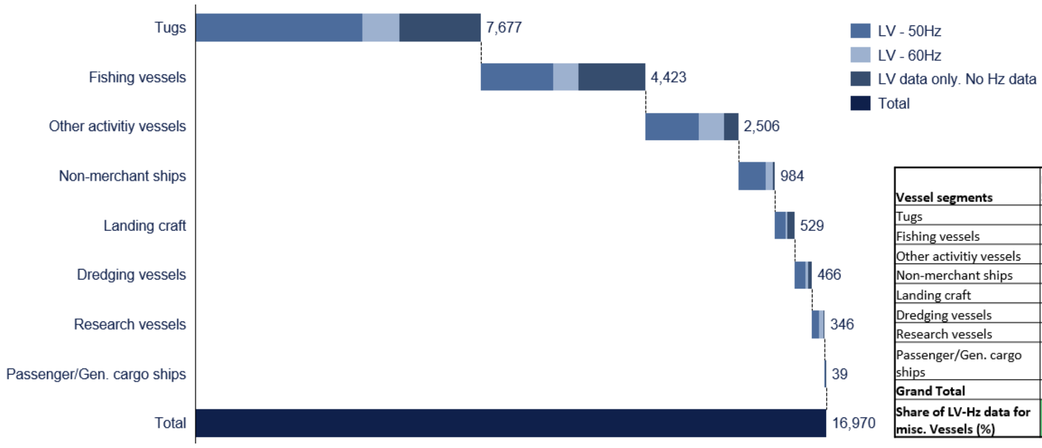


Figure 7: Distribution of no. of vessels with different operating frequency (Newbuild)

The unknown frequency split, both for existing fleet and the newbuild, are most likely 50Hz or 60Hz, but no assumption was made for the unavailable data as mentioned in the scope of the project.

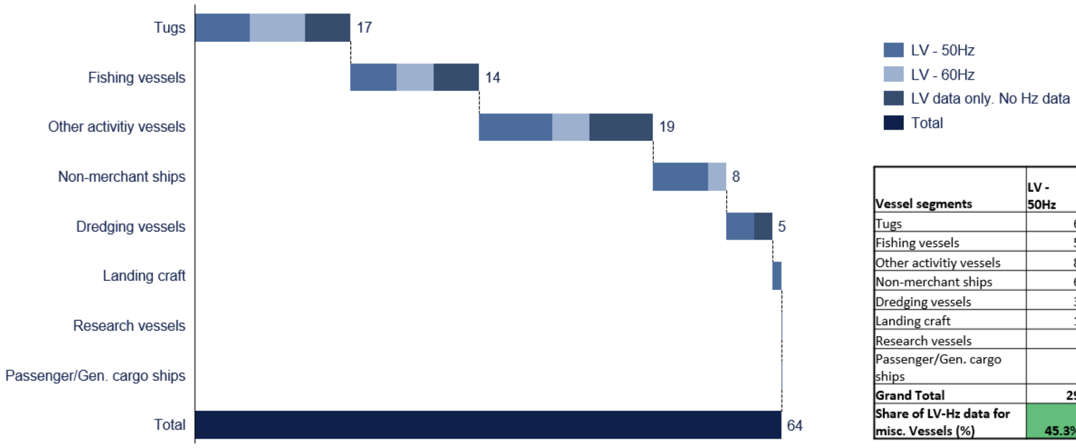
In order to address the vessel segment “misc.”, which constitutes approximately 42% of the existing world fleet, it was further sub-categorized into major vessel types. Tugs and fishing vessels represent more than 70% of the total number of existing misc. vessels with known low voltage system, as seen in figure 8. Furthermore, it has been analysed that 55.4% of the misc. vessels operate at 50Hz frequency, whereas only 16.1% of the misc. vessels operate at 60Hz frequency.



Vessel segments	LV - 50Hz	LV - 60Hz	LV - HZ n.a	Grand Total	Share of no. of vessels (%)
Tugs	4,502	974	2,201	7,677	45.2%
Fishing vessels	1,942	684	1,797	4,423	26.1%
Other activitiy vessels	1,440	670	396	2.506	14.8%
Non-merchant ships	728	201	55	984	5.8%
Landing craft	296	31	202	529	3.1%
Dredging vessels	295	58	113	466	2.7%
Research vessels	190	115	41	346	2.0%
Passenger/Gen. cargo ships	11	7	21	39	0.2%
Grand Total	**9,404**	**2,740**	**4,826**	**16,970**	**100.0%**
Share of LV-Hz data for misc. Vessels (%)	**55.4%**	**16.1%**	**28.4%**	**100.0%**	

Figure 8: Distribution of different sub-categories of misc. vessels (Existing fleet)

In figure 9, the different sub-categories under misc. vessel on orderbook are depicted. For misc. vessels with low voltage data, 48.4% of the vessels constitute of tugs and fishing vessels. Furthermore, 45.3% of the misc. vessels operate at 50Hz frequency, whereas 25% of the misc. vessels operate at 60Hz frequency.



Vessel segments	LV - 50Hz	LV - 60Hz	LV - HZ n.a	Grand Total	Share of total fleet (%)
Tugs	6	6	5	17	26.6%
Fishing vessels	5	4	5	14	21.9%
Other activitiy vessels	8	4	7	19	29.7%
Non-merchant ships	6	2		8	12.5%
Dredging vessels	3		2	5	7.8%
Landing craft	1			1	1.6%
Research vessels					0.0%
Passenger/Gen. cargo ships					0.0%
Grand Total	**29**	**16**	**19**	**64**	**100.0%**
Share of LV-Hz data for misc. Vessels (%)	**45.3%**	**25.0%**	**29.7%**	**100.0%**	

Figure 9: Distribution of different sub-categories of misc. vessels (Newbuild)

As tugs and fishing vessels represent a large share of the segment “misc.” and as these vessel sub-segments require minimum or no power at berth, we suggest excluding the vessel segment “misc.” from consideration under LVSC system. Furthermore, tugs and fishing vessels have lack of space for ship-side shore power installation, which make these sub-segments not relatable to low voltage shore power.

Based on the available voltage data of vessels for the existing fleet, the different categories of vessel segments and their numbers in the existing fleet, an assessment was made to check which vessel segments and their corresponding numbers are technically covered by IEC/IEEE 80005-1 HVSC [2].

Table 1 shows which vessel segments are covered by IEC/IEEE 80005-1 and which are not. In this, the misc. vessels are ruled out.

Table 1: Vessel segments covered and not covered by IEC/IEEE 80005-1

Vessel segment	Covered by IEC 80005-1 (Yes/No)
Bulk carrier, general cargo ship, refrigerated bulk, other liquid tanker, and other pax/ferry	No
Containership, cruise, ro-ro cargo ship. ropax, ferry-pax and vehicle carrier	Yes
Oil tanker, chemical tanker, and liquefied gas tanker	Yes (Currently informative)

Based on the vessel segments covered by IEC/IEEE 80005-1, the number of vessels under different vessel segments are added together and it was found out that 52% of the existing world fleet is covered by IEC/IEEE 80005 -1 (excluding misc. vessels) as seen in figure 10.

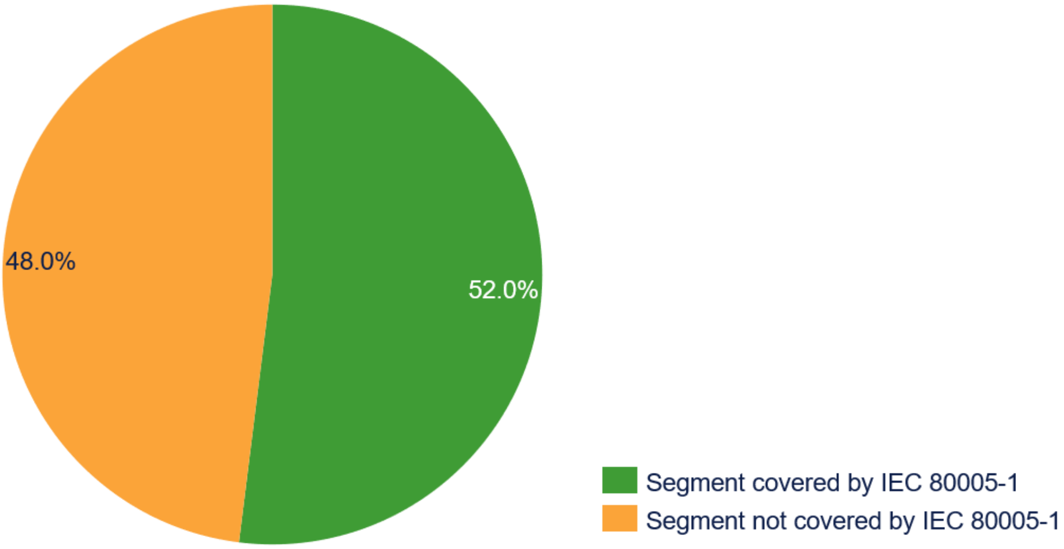


Figure 10: Split of no. of vessel covered and not covered by IEC/IEEE 80005-1 for the current fleet

4.3.2 Different voltage level data analysis

For vessels with available data of its low voltage system onboard, further assessment was conducted to quantify the share of different voltage values for the vessels. The standard voltage values include 115V, 230V, 400V, 440V and 690V. Other voltage levels (below 690V) are designated as "Other voltage data".

According to the assessment, for the existing world fleet (figure 11), 18.4% of all vessels with available low voltage data operate at 400V and 12% at 440V. Only 0.3% of the existing fleet with available low voltage data have 690V onboard vessels.

Approximately 30% of general cargo ships operate at 400V, significantly contributing to the total number of vessels with 400V. As for 440V, vehicle carrier tops the list with 28.3% of its vessels operating at 440V, but the number of existing vehicle carriers is much less than in comparison to deadweight carriers such as bulk carriers, tanker, and containerships.

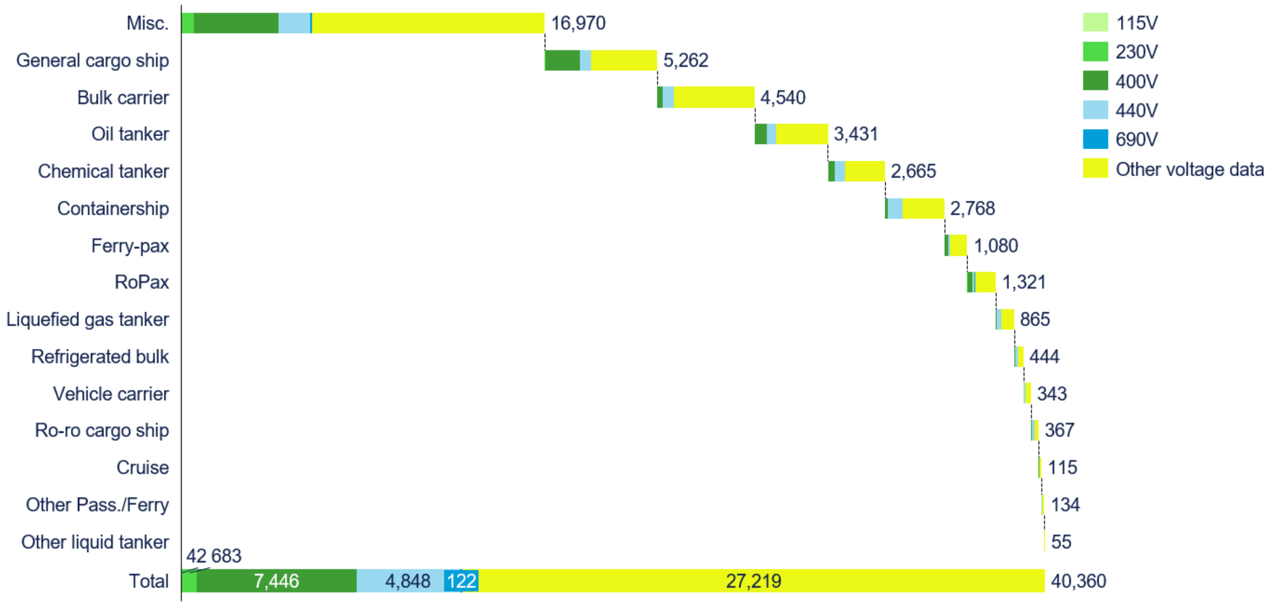


Figure 11: No. of vessels with different low voltage standards under existing fleet with available voltage data

As for the vessels on orderbook and available low voltage data of the system onboard these ships, 18.6% of all vessels operates at 440V and 10.5% operate at 400V (figure 12).

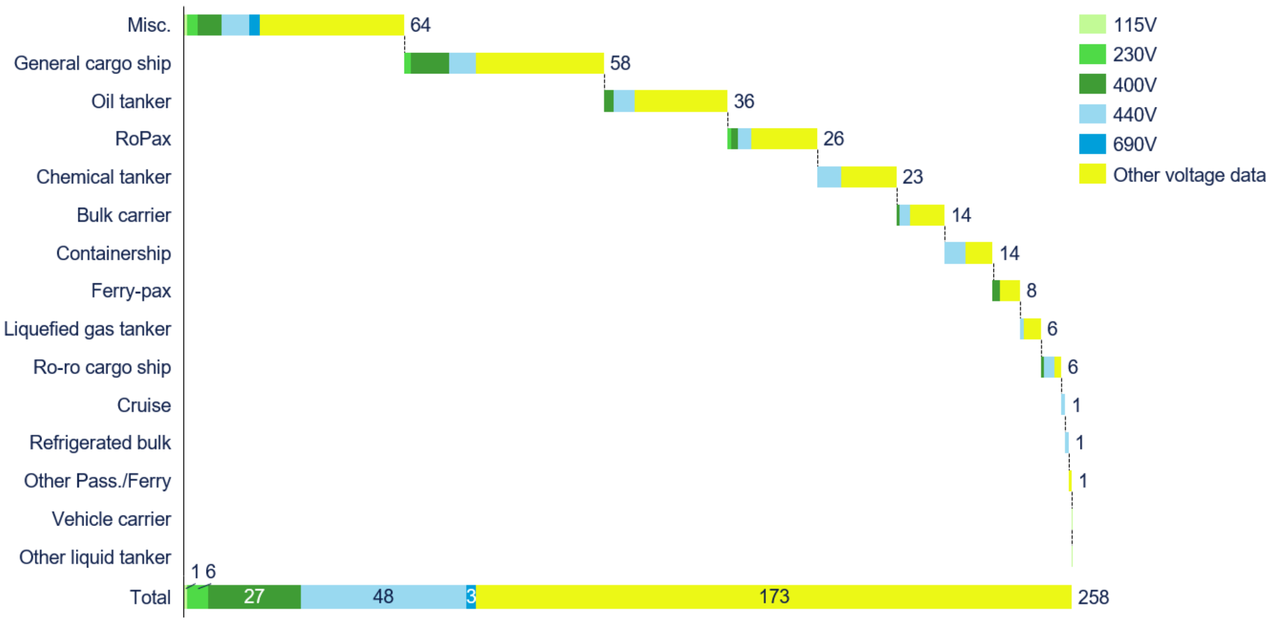


Figure 12: No. of vessels with different low voltage standards under newbuild with available voltage data

4.3.3 Low voltage shore power utilization based on auxiliary power demand

For low voltage shore connection, the power demand for a vessel at port should not exceed 1 MVA apparent power. Therefore, the power demand assessment provides an overview of vessels with low voltage system as well as requiring power less than 1 MVA at port. It also shows vessels which may have low voltage system onboard, but require high power at port, thus making it difficult to receive low voltage shore power. Capping of power at 1 MVA will become essential for vessels with low voltage system but with high power demand at port for LVSC.

In order to properly assess the power demand of vessels under different vessel segments with available voltage and total auxiliary power data, four different clusters are made. According to figure 13, it can be seen that not only the vessels are segregated based on their power demand at port at a threshold of 1 MVA, ships with direct current (DC) power supply as well as vessels which are very small (below 100 kW auxiliary power installation) are also categorized.

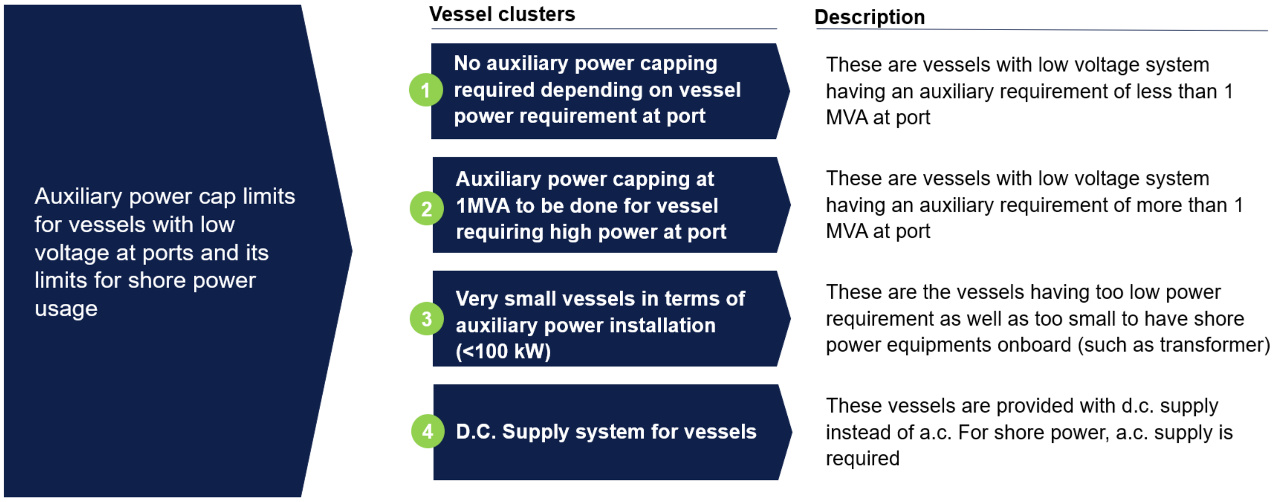


Figure 13: Different clusters defined under power demand analysis

The average power demand of vessel under different vessel segments at port have been analyzed based on MEPC.308(73) [1]. For containerships, reefer load contributes to the total load required at port. Therefore, for containerships the total load (base load + reefer load) was assessed based on the results from the project "Container Vessel Mix for Shore Power Terminal ECT [3]" with Port of Rotterdam. Furthermore, for oil, chemical and liquefied gas tankers, cargo pumps form an essential part of load at port and therefore an assumption of 5% to 20% extra load on top of base load is considered. For oil and chemical tankers, cargo heating also contributes to the auxiliary power demand at port, which is included in the additional load range of 5% to 20% extra load at port. For the rest, average hotel load demand is taken into consideration. In table 2, the auxiliary power average demand at port is shown for different vessel segments.

Table 2: Average power demand in port as % of total auxiliary power installed onboard

Vessel segments	Average power demand (%) at port w.r.t total aux. power installed onboard
Bulk carrier	37%
Containership	31%
Oil tanker	33%
Chemical tanker	35%
Liquefied gas tanker	29%
RoPax	33%
Ferry pax only	33%
Cruise	24%
Ro-Ro cargo ship	34%
Vehicle carrier	31%
General cargo ship	40%
Refrigerated bulk, misc. vessel, other pass./ferry and other liquid tankers	40%

Based on the % share of total auxiliary power required at port with respect to the total power installed onboard a vessel (Table 2), the average auxiliary power demand for different vessel segments is calculated (see figure 14). The data for too small vessels (auxiliary power less than 100 kW) and vessels with DC supply system is taken directly from IHS Fairplay.

The power demand analysis, in general, represents the % share of vessels which require or do not require load reduction at 1MVA (LVSC requirement), even though they have low voltage system onboard. According to the power demand analysis, 21.9% of the vessels of the existing world fleet with available low voltage data requires capping of auxiliary power at 1 MVA, i.e., they are required to reduce their load below 1 MVA at port if they shall be supplied with low voltage shore connection (figure 14). Approximately 60% of the vessels with available low voltage data do not require load reduction at 1MVA, which means these vessels can operate as is in port (figure 14).

81% of vehicle carriers and 70% of containerships require capping at 1 MVA. Subtracting all vessel types already listed in IEC/IEEE 80005-1, which includes vehicle carriers and containerships, the number of vessels which do not require load reduction at 1 MVA, increases to 69.7%. The major vessel types still requiring load reduction are bulk carriers (35.4%) and general cargo ship (6.9%). With a high % of vessels under bulk carriers requiring load above 1 MVA, the bulk carrier segment is considering having a separate Annex in the high voltage standard.

The number of vessels which are too small amounts to 12.2% of the existing world fleet with available voltage data whereas vessel with DC system constitutes only 3.2% of the existing fleet with available voltage data.

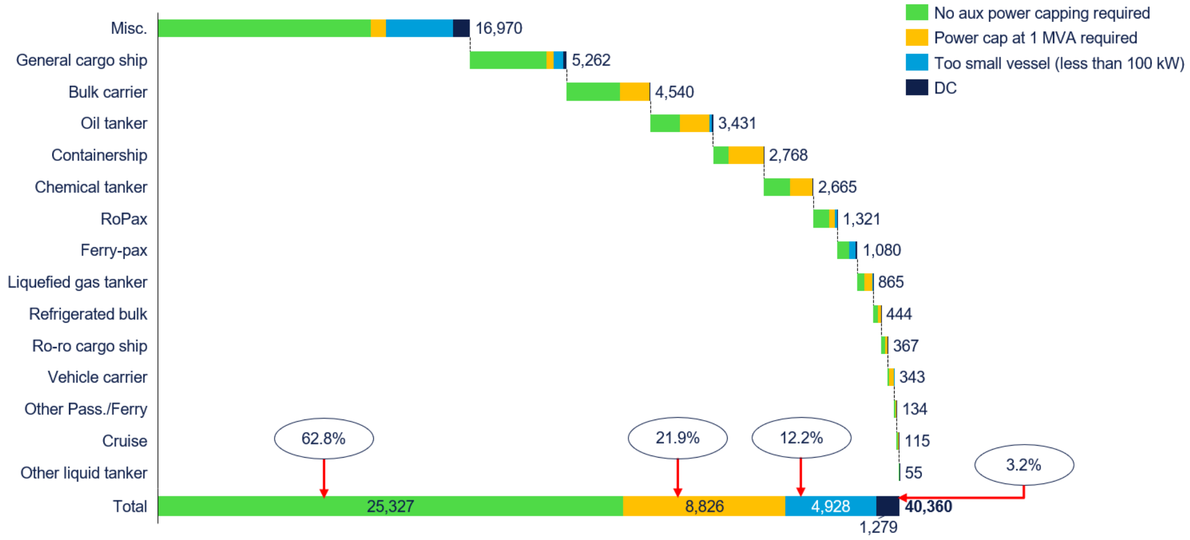


Figure 14: Analysis of power demand at port analysis for the existing world fleet

As for newbuilds (see figure 15), similar to existing fleet with available voltage data, 60% of vessels will not require load reduction at 1MVA at port in order to receive LVSC. 27.1% of vessels with low voltage data require capping at 1 MVA at port, whereas 7.4% of vessels are too small to use shore power. The share of newbuild with available voltage data and d.c. supply system amounts to 5% of the total number of vessels on orderbook with available low voltage data.

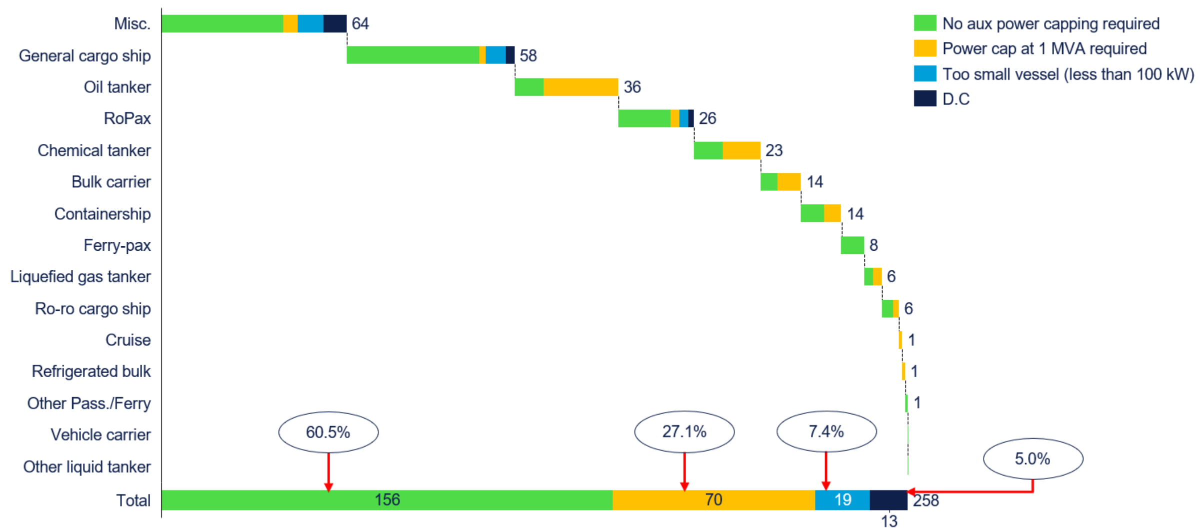


Figure 15: Analysis of power demand at port analysis for the newbuilds

5 QUALITATIVE ANALYSIS

5.1 Overview of shore power supplies standardization

Requirements for low voltage shore power supplies are divided in three application areas.

- Small crafts
- Inland navigation vessels
- Sea-going vessels

Applicable standards and norms are shown in figure 16. Further discussion and evaluation in this paragraph will focus on inland navigation vessels and sea-going vessels, excluding the shore power applications for small crafts.

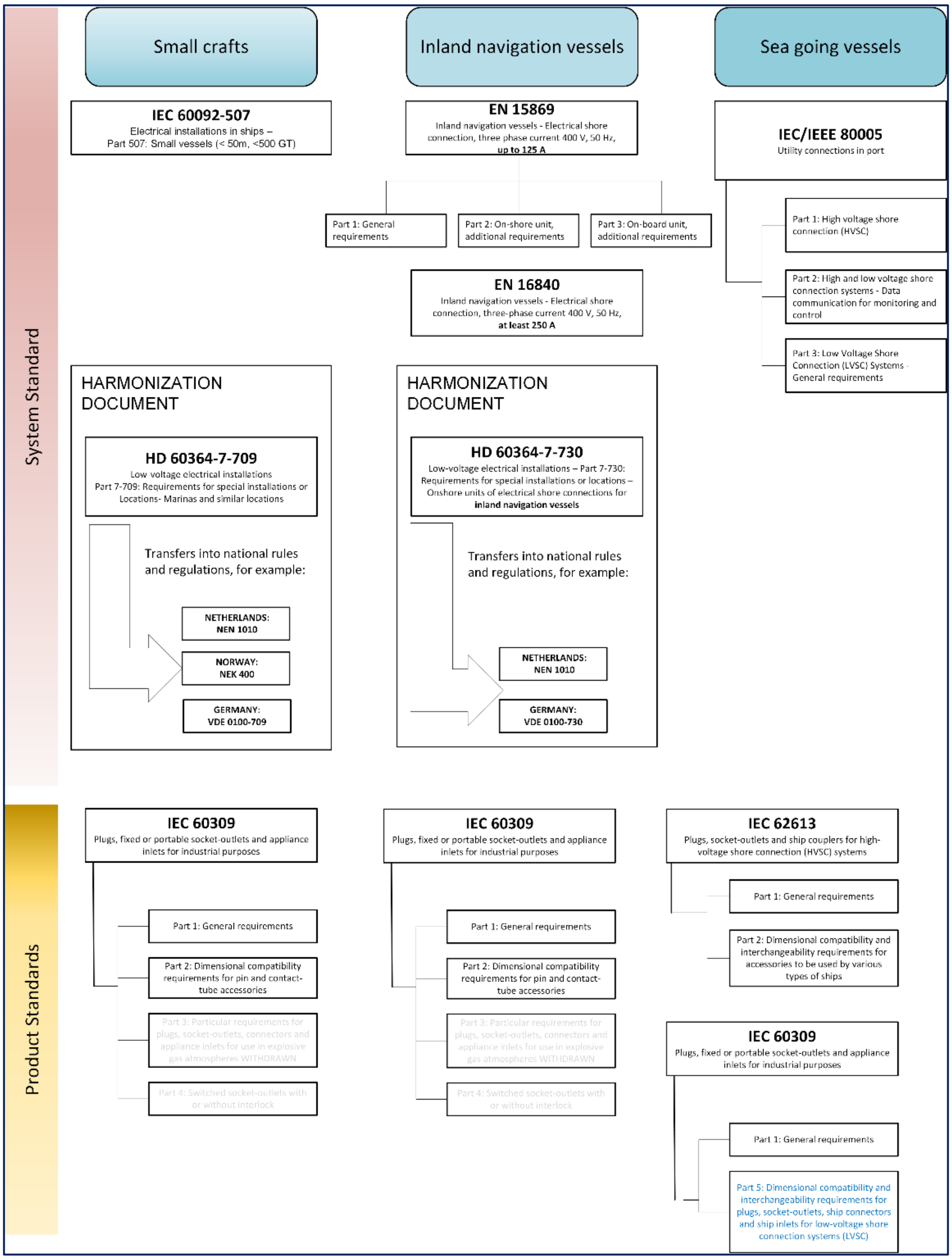


Figure 16: Shore power standards by application area

The system standards describe design and functional requirements for different shore power applications. All system standards refer to compatibility between shore and ship installation to specific sections or parts of the product standard for plugs, fixed or portable socket-outlets and appliance inlets for industrial purposes.

In this context, it needs to be emphasised that the general requirements of the product standard are identical, but not the dimension compatibility requirements. In other words, plugs and sockets between inland navigation and sea-going vessels are **not compatible**.

5.1.1 Inland navigation vessels

Shore power for inland navigation vessels is divided in two sub-categories.

- European Norm EN 15869 for shore power systems up to 125A at 400V 50Hz, and
- European Norm EN 16840 for shore power systems up to 250A at 400V 50Hz.

This electrical specification allows for a maximum transfer of power of approximately 87 kVA respectively, 170 kVA between shore and ship. EN 15869 is generally used for inland navigation cargo vessels, whereas EN 16840 is more seen for inland navigation passenger vessels.

Countries under the CEN-CENELEC Internal Regulations are bound to implement this European Standard.

Moreover, these European Norms are referenced in the harmonized document HD 60364-7-730 (*Low-voltage electrical installations – Part 7-730: Requirements for special installations or locations – Onshore units of electrical shore connections for inland navigation vessels)*.

The harmonized document has been adapted by nation states in Europe into national code regulations, where required respectively necessary (Reference: Harmonization Document (HD) (cenelec.eu)) [4].

5.1.2 Sea-going vessels

Documents and standards in the IEC/IEEE 80005-series are developed by three standardization bodies with the focus on sea-going vessels. The different bodies issuing this document and standards for sea-going vessels are:

IEC- International Electrotechnical Commission

ISO- International Organization for Standardization

IEEE- Institute of Electrical and Electronics Engineers

The working groups of IEC/IEEE 80005 is currently drafting part 3 in the series which will describe the requirements for low-voltage shore connection.

5.2 IEC/IEEE 80005-3 Standard Description

The documents "*Introduction to maritime standardization-Where to participate to influence standards*" [5] and "*Introduction to Maritime Standards – Work being done on IEC/IEEE 80005 series*" [6] provide and excellent introduction in maritime standardization work in general and the work with respect to IEC/IEEE 80005-series.

The documents focus on the administrative and procedural requirements with respect to standardization work and provide a good overview of the work done already.

The estimated timeline for the publication of IEC/IEEE 80005-3 is as follows:

The current document on which this report is based is a draft, subject to changes based on feedback from stakeholders and interest groups. Forming the future standard is still possible by commenting on the CDV through the national committees or participation as a member of JWG-28 (tentatively mid to end of December 2023). The commenting time will be 12 weeks, starting from the publishing date.

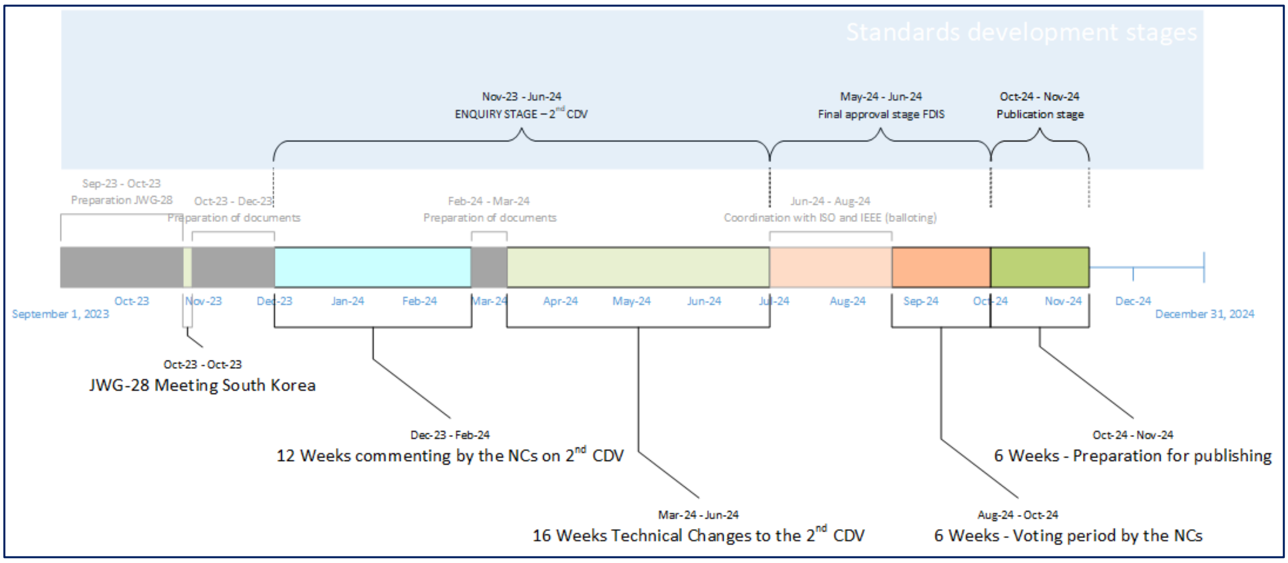


Figure 17: Roadmap and timeline for IEC/IEEE 80005-3 development

5.3 Detailed evaluation of current draft IEC/IEEE 80005-3

This report will focus on the following topics:

1. Shore supply system
2. voltage levels and power ratings
3. cable management system
4. plug in socket connections

5.3.1 Document structure of IEC/IEEE 80005-series

To understand the document structure of IEC/IEEE 80005-3 is helpful to understand the background and environment leading to the current draft document.

Although this document is the third document in the series of IEC/IEEE 80005, it is technically the second document describing the design and construction requirements to enable efficient and safe means of shore power transmission to vessel while at berth. There are many considerations necessary when it comes to power transmission, among other things:

- Distances to be covered between the shore power installation and a vessel
- Amount of power to be transferred (transmission)
- Transmission losses shall be kept to a minimum
- Resources shall be utilized efficiently
- Compatibility between shore and ship grid systems
- Power transmission shall be manageable regarding handling, control, and protection
- Costs
- Space availability at quayside

When applying the above requirements, a further key question is, how much power shall be transferred?

These questions were discussed with the development of Part 1 in IEC/IEEE 80005 and answered by selecting high voltage as the transmission voltage level between the shore and the vessel. High voltage as the transmission voltage reduces transmission losses, reduces the number of cable connection/ respectively conductor cross-section, and keeps the power transmission manageable. Hence IEC/IEEE 80005-1 has stated in the scope of the document as following:

It is expected that HVSC systems will have practicable applications for ships requiring 1 MVA and above or ships with HV main supply.

To achieve the above objectives and requirements, it was necessary to set several design parameters, requirement, pre-conditions, and agreements. Although high voltage was set as a transmission voltage, the fact remains that different type of vessels differs greatly in their power consumption and individual requirements (space restriction, location etc.) while at berth. This has resulted in a document structure with a main body followed by ship specific annexes for different vessel types.

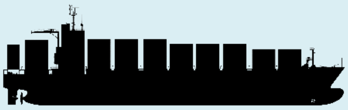
Main Body	
General requirements applicable to all ship types and all shore connection installation (Ship and Shore)	
ANNEX	
Annex A (informative) Ship-to-shore connection cable	
Annex B (normative) Additional requirements for Roll-on Roll-off (Ro-Ro) cargo ships and Ro-Ro passenger ships	
Annex C (normative) Additional requirements for cruise ships	
Annex D (normative) Additional requirements of container ships	
Annex E (informative) Additional requirements of liquefied natural gas carriers (LNGC)	
Annex F (informative) Additional requirements for tankers	
Annex G (normative, will be released end of Aug. 2023) Additional requirements for vehicle carriers	

Figure 18: General shore connection requirements for all ship types and shore connection installation

The main body of IEC/IEEE 80005-1 consists of 12 clauses applicable to HVSC systems in general, regardless of vessel type. The main body addresses basic safety and effectiveness of HVSC systems by setting minimum requirements necessary to achieve standardization.

An essential rule in this context has the compatibility assessment. This formal process shall assess compatibility for each combination of ship and shore supply prior to arriving and connecting to a given shore supply for the first time.

The vessel specific annexes provide further details, modify and address equipment requirements, placement of equipment, power rating and safety measures for specific vessel types. This is to achieve compatibility for compliant ships at different compliant berths world-wide.

The standard may also be used for other vessel types or proprietary connection systems not covered by the ship annexes but following the main body of the document.

5.3.2 Document structure of draft IEC/IEEE 80005-3

The technical requirements and general framework leading to the document structure of part 1 has been adapted also in the drafting and development of part 3.

With one exception, part 3 won't stipulated ***vessel specific annexes***.

Question: Why is that?

One of the biggest advantages of part 1 of being vessel type specific allowing for a customisation and adaptation of different vessel types and their specific needs, which is at the same time the biggest weakness. This is because vessel types not mentioned in vessel specific annexes will not have any guidance on how to establish and set up a shore connection system, except for the basic requirements given in the main body of the document.

International consent and agreements on, power demand, plug and socket connection, cable management system and location of equipment are open and are left to project specific implementations.

Writing vessel specific annexes for all different vessel types covered by LVSC seems impractical and impossible to handle. Hence the future standard will focus on a universal, scalable low voltage supply system applicable to different shore infrastructures and different vessel.

5.3.3 Focus areas with respect to the current draft of IEC/IEEE 80005-3

This report will focus on the following topics:

1. Shore supply system
2. voltage levels and power ratings
3. cable management system
4. plug in socket connections

5.3.3.1 Shore supply system

The description of the shore supply system in the current draft of IEC/IEEE 80005-3 is similar to the requirements and design specification of part 1 in the standard series. The shore supply system for a vessel shall be galvanically isolated from the power grid and between different vessels. Though the shore power supply is galvanically isolated from the power grid, but common supply among vessels is not permissible.

The grid configuration of the shore supply system shall be isolated (IT-isolated terra). Grid configuration is recognized as the type of system earthing in an electrical supply system.

The first letter – Relationship of the power system to earth:

T = direct connection of one point to earth

I = all live parts isolated from earth, or one point connected to earth through a high impedance

Second letter – Relationship of the exposed-conductive-parts of the installation to earth:

T = direct electrical connection of exposed-conductive-parts to earth, independently of the earthing of any point of the power system

N = direct electrical connection of the exposed-conductive-parts to the earthed point of the power system (in a.c. systems, the earthed point of the power system is normally the neutral point or, if a neutral point is not available, a line conductor)

(Reference: IEC 60364-1, clause 312.2 [7])

Identical to the requirements of IEC/IEEE 80005-1, is the frequency conversion tasked to the shore supply system. This may require the use of frequency converters.

5.3.3.2 Voltage level and power ratings

Voltage level and power ratings could be regard as separate entities, respectively design requirements, yet they are interconnected. The following table is illustrating the relationship between voltage level and possible power transmission ratings with different parallel cable connections.

Table 3: Maximum kVA power rating of the LV shore supply system

	Transmission voltage level:		
Number of parallel cable connection with a plug and sockets rated 350 A	400 V	440V	690V
1	242 kVA	267 kVA	418 kVA
2	485 kVA	533 kVA	837 kVA
3	727 kVA	800 kVA	1000 kVA[1)]
4	970 kVA	1000 kVA[1)]	
5	1000 kVA[1)]		
Note:	[1)]The calculated power rating of the connection is higher, but the scope of the standard is limited ≤ 1000 kVA		

The transmission voltage given in Table 3 coincide with the most common onboard system voltage. Matching the transmission voltage of the shore power supply system with the onboard system voltage eliminates the need of addition voltage matching transformers (usually step-down transformers).

This benefits the vessel, allowing a smaller footprint of the shore power installation onboard, lower investment costs and better handling. It also has considerable benefits for the shore power supply, particularly those shore supplies utilizing static frequency converter systems for the frequency conversion, since the high in-rush current of onboard matching transformers may trip the shore supply.

The current draft of IEC/IEEE 80005-3 sets the default voltage at 690V, 60Hz IT-Grid, but suggests that ports may offer in additional transmission voltage levels (and frequency) at:

- 440V 60Hz IT
- 400V 50Hz IT or
- 480V 60Hz IT

Offering additional transmission voltage levels gives greater flexibility with a connection of a vessel, which in return will improve general acceptance of the vessel to take shore power. However, this acceptance level will be diminished when a port on the vessel's trade route is offering only the default voltage. Therefore, it might be sensible if European ports would agree jointly to also offer the additional transmission voltages of 400V, 50Hz and 440V 60Hz allowing at least vessel trading between European ports to benefit from the options given within the current draft of the standard.

5.3.3.3 Connection points and cable management system

A further important topic within the current draft is the location and number of connection points, and location of the cable management system. As described earlier, the HV shore connection standard IEC/IEEE 80005-1 has assigned location and number of connection points and location of the cable management in the vessel specific annexes of the document.

The current draft of IEC/IEEE 80005-3 describes on the contrary, that the number of connection points shore side (socket outlet) is flexible. Also, the number of cable connections to the vessel may vary based on the vessel's actual power demand within port.

This is a considerable benefit of LV shore connections in comparison to HV shore connection, where for safety reason, always the full complement of cables is required to be connected.

In other words, a container ship with a power demand of 2 MVA at port, which could be supplied in theory by only one HV connection cable, must connect to two cables for safety reason regardless of its actual power demand.

With LV shore connection, the port has the freedom to decide whether a terminal (berth) shall be furnished with the full complement of five (5) connection points (socket outlets) to allow the supply of a vessel up to 1 MVA or because of its vessel power demand, power restrictions or other circumstances, with a lower number of connection points. This allows for scalable connections, providing more economical coverage with shore power connections.

The cable management system is an arrangement allowing the transmission of power and electrical signals and compensating for vessels movement caused by tidal range and/or cargo operation. The placement of the cable management system shall not interfere with cargo operation nor creating a risk of personal injury.

All vessel specific annexes of IEC/IEEE 80005-1, except for container ships, assigned the cable management system to the shore-side. Determining the location of the cable management system is essential to achieve compatibility between ship to shore installation.

Considering all the benefit of LV shore connection with respect to location and number of connection points and placement of the cable management system, it may be fair to say that, for some applications and ports, the accommodation of a LV and HV shore supply system at the same berth is nearly impossible. The berthing arrangements of container vessels are a good example of such application. Figure 19 illustrates the spatial restrictions of container bridges, flood wall and a movable HV shore connection point. Placing an additional LV- shore connection point in this area is rather challenging.

Figure 19: Moveable HV shore connection Port of Hamburg - Copyright HPA / Schmidt-Wiethoff

5.3.3.4 Plug and Socket Connection

The plug and socket connection plays, for obvious reason, an important role in the development of the standard. The current HV shore connection standard IEC/IEEE 80005-1 describes in the vessel specific annexes several different plug and socket connection, all different in their layout, none of them compatible between different ship types. For example, a containership can't take shore power at a Ro-Ro cargo terminal and vice versa. This incompatibility between different vessel types, however, has only limited impact in day-to-day operation, since most container terminals, and Ro-Ro cargo terminals for that matter, are purpose built depending on vessel types.

This may be different for LV shore connections. Firstly, differentiating between different vessel types in the current draft of the IEC/IEEE 80005-3 standard will create a confusing number of variations. Secondly, some terminals may serve different types of vessels at times. A berth used to unload a general cargo vessel one day, may provide shore power to an offshore supply vessel the next day.

To avoid the above confusion, sub-committee 23H has developed in close cooperation with JWG-28 a plug and socket standard. This new standard is sub-summed in IEC 60309 as part 5 (Figure 16 Shore power standards by application area).

The current draft of IEC/IEEE 80005-3 refers to IEC 60309-5 as the default connection for plugs and sockets with a nominal current rating of 350A per plug connection. Currently, the draft standard also allows connections with a plug and socket connection of less than 250A.

Although this opening bears many restrictions, most importantly incompatibility with the plugs and sockets as per IEC 60309-5, it does allow for design of a lighter shore-to-ship connector.

Using this option permits ports and ship owners in local (national) application, to connect vessels with low power requirements to shore power following the requirements of IEC/IEEE 80005-3 but benefiting from a lighter easier to handle shore power connection. Norway has to that effect, in a national initiative, developed technical documentation in NEK-Landstrømsforum (reference: Landstrømsforum - Norsk Elektroteknisk Komite (NEK) [8]) and published for application within Norway.

As mentioned in item section 6.1.4 there are differences between the plug and socket connections for inland navigation vessels and sea-going vessels according to their power demand. Inland navigation vessels have adopted the compatibility requirements of IEC 60309-2, while sea-going vessels follow IEC 60309-5. The two standards are not compatible and therefore the IEC 60309-2 plug and socket connection is not further considered in this report.

6 SHORE POWER INSTALLATIONS – INLAND NAVIGATION VESSELS AND SEA-GOING VESSELS

6.1 Assessment of different parameters for inland and sea-going vessels

Some European ports, especially those closely located to main European inland waterways and at the same time with sea access, may have berthing and mooring areas which are shared among inland navigation vessels and sea-going vessels.

Figure 20:Section of the European Inland waterway network by UNECE

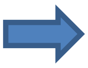
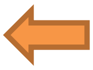
Reference: Where to navigate? The network of inland waterways in Europe and its parameters | UNECE

This circumstance suggests a possible utilization of a common shore power infrastructure for inland navigation vessels and sea-going vessels (also see presentation of EICB- Expertise - en InnovatieCentrum Binnenvaart [9]).

The following analysis is based on the latest draft of IEC/IEEE 80005-3 and established inland navigation standards and norms (EN and HD Documents).

The tables in following subsection utilize the following symbols with respect to implementation:

Table 4: Symbols depicting utilization of shore connection by inland and sea-going vessels

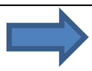
	Implementation/application
	An Inland navigation vessel compliant with shore power supply requirements of EN 15869/ EN 16840 may benefit from the use of an IEC/IEEE 80005-3 compliant shore connection installation. The reverse direction is not beneficial.
	A sea-going vessel compliant with shore power supply requirements of IEC/IEEE 80005-3 may benefit from the use of an EN 15869/ EN 16840 compliant shore connection installation. The reverse direction is not beneficial.
	Incompatible in both directions without adaptation or modification of the shore or/and vessel's installation.

6.1.1 Power demand

The maximum transfer of power of a shore connection supply compliant with the inland navigation standards and norms is limited to 87 kVA respectively 170 kVA.

This limitation in transfer of power may prove to be insufficient for a sea-going vessel.

Table 5: Shore power transfer limitation for inland and sea-going vessels

Inland navigation vessel	Sea-going vessel	Implementation direction
< 170 kVA	< 1,000 kVA	

6.1.2 Voltage level and frequency

Inland navigation standards set the transmission voltage and frequency between shore and ship to 400V at 50Hz. The majority of sea-going vessel have an onboard voltage and frequency of 440V and 60Hz This means that if the plugs are compatible, the sea-going vessels installations (with 50 and 60Hz conversion) will be able to supply the inland navigation vessels (50Hz) but the inland navigation installations (without conversion) will not be able to supply the sea-going vessels (60Hz). Adaption of voltage and frequency is possible but requires modification on the vessel side.

Table 6: Voltage and frequency levels in inland and sea-going vessels

Inland navigation vessel	Sea-going vessel	Implementation direction
400V; 50Hz	440V; 60Hz	

6.1.3 Grid configuration

The inland navigation standard allows IT, TN, and TT grid configurations, whereas IEC/IEEE 80005-3 requires an IT-grid as shore supply.

The inland navigation vessel standards allow IT grid configuration; however, it is likely that most countries in Europe will supply a grid-configuration conforming with the local grid-configuration of the port. This is likely to be a TN or TT grid.

Mixing of different grid-configurations without modification/adaptations is (mostly) not possible. The majority of sea-going vessels have IT grids.

Table 7: Grid configuration suitable for inland and sea-going vessels

Inland navigation vessel	Sea-going vessel	Implementation direction
TN, TT, IT grid	IT grid	

6.1.4 Connection (plugs and sockets)

Inland navigation vessels have adapted the dimensional compatibility requirements of IEC 60309-2 whereas sea-going vessels are going to follow IEC 60309-5. Part 2 and part 5 are incompatible.

Table 8: Plug and socket connection compatibility requirements for inland and sea-going vessels

Inland navigation vessel	Sea-going vessel	Implementation direction
IEC 60309-2	IEC 60309-5	

6.1.5 Operation and handling

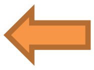
Operation and handling comprise the discussion around the subject, who is allowed to operate and handle (establish) a connection between ship and shore.

The current draft of IEC/IEEE 80005-3 states in scope of the document: *"This document is not intended to cover systems to be operated by ordinary persons as defined in IEV 826-18-03".*

An ordinary person as per IEV 826-18-03 (respectively IEV 195-04-03) is a person who is neither a skilled person nor an instructed person.

The plugs and sockets for inland navigation vessels (IEC 60309-2) are suitable for handling by ordinary persons.

Table 9: Qualification required for shore connection handling for inland and sea-going vessels

Inland navigation vessel	Sea-going vessel	Implementation direction
Ordinary person	Skilled or instructed persons	

6.1.6 FuelEU Maritime and Alternative Fuel Infrastructure Regulation (AFIR)

The publicly available documents on "REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the use of renewable and low-carbon fuels in maritime transport and amending Directive 2009/16/EC (13-July-2023)" and "REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the deployment of alternative fuels infrastructure and repealing Directive 2014/94/EU (13-July-2023)" will regulate, among other things, the use of shore power with EU ports.

The document on "Alternative Fuel infrastructure Regulation (AFIR)" states in Annex II, technical specifications items 5.1 and 5.2. and 5.3 stated for sea-going and inland vessels as follows:

5. Technical specifications for electricity supply for maritime transport and inland navigation

5.1. Shore-side electricity supply for seagoing ships, including the design, installation and testing of the systems, shall comply at least with the technical specifications of standard IEC/IEEE 80005-1:2019/AMD1:2022 for high-voltage shore connections.

5.2. Plugs, socket-outlets and ship couplers for high-voltage shore connection shall comply at least with the technical specification of standard IEC 62613-1:2019.

5.3. Shore-side electricity supply for inland waterway vessels shall comply at least with the standard EN 15869-2:2019 or standard EN 16840:2017 depending on energy requirements.

The EU paper is not citing the IEC/IEEE 80005-3, yet. Since the document is still in draft. But it is reasonable to believe once IEC/IEEE 80005-3 is a standard that the Annex II of the document will be amended.

In any case, 5.1 of the annex states sea-going vessels to follow IEC/IEEE 80005-1, while it directs inland navigation vessels to follow EN 15869 or EN 16840.

Table 10: Standards for inland navigation and sea-going vessels in EU

Inland navigation vessel	Sea-going vessel	Implementation direction
PE-CONS 25/23-annex II 5.3	PE-CONS 25/23-annex II 5.1/5.2 HVSC	

6.1.7 Assessment

The compatibility, scope of application and regulatory compliance suggest keeping shore connection supply for inland navigation vessels and sea-going vessels separate.

Also from a technical perspective, the benefits of having sea-going and inland navigation vessels common supply connection are less in comparison to conflicts that will be faced.

6.2 LVSC system design considerations

6.2.1 Frequency

IEC/IEEE 80005-series states in part 1 (HVSC) and in the current draft of part 3 that frequency shall match.

There are differences between 50Hz and 60Hz grids and not all equipment can be used for either frequency. The frequency of an electrical grid refers to the number of cycles per second (Hertz) at which alternating current (AC) oscillates. The standard frequencies used in power grids worldwide are 50Hz and 60Hz.

Electrical Reasons:

Equipment might not be used interchangeable between 50Hz and 60Hz grids, because of its design or electrical properties, the equipment might over-heat or not function at other than the frequency it is built for.

No synchronizing between 50Hz and 60Hz grid possible. Load transfer only via black-out possible.

Many devices onboard a ship monitor mains frequency. For example, UPS-systems (Uninterruptible Power Supply) may activate, among other things, on low frequency in the supply grid. This will prompt the UPS to activate and to drain the UPS batteries. Other equipment will trigger alarm or possibly trip (shutdown) due to too low or too high frequency.

Mechanical Reasons:

Mechanical reasons are particularly relevant for rotating equipment, such as motors and generators.

<u>Rotational Speed:</u> The rotational speed of motors and generators is directly related to the frequency of the grid. At 60Hz, these devices will rotate faster than at 50Hz, assuming the same number of poles. Using a motor designed for 50Hz on a 60Hz grid would result in an increase in rotational speed, potentially exceeding the design limits and causing mechanical failure.

Conversely, running an asynchronous motor design for 60Hz will result in slower rotational speed. If this motor drives a pump this may result in a lower flow rate possibly causing damage to equipment.

Cooling Requirements: Rotating equipment's cooling systems are often designed to accommodate the specific frequency. Changing the frequency can alter the cooling requirements, leading to overheating or inadequate cooling.

Field of Application - Testing and Certification:

When it comes to testing and certification, equipment must undergo rigorous evaluations to meet safety and performance standards. These certifications are usually frequency-specific due to the electrical and mechanical reasons mentioned earlier.

Safety Concerns: Equipment designed and certified for a specific frequency might not be tested for the other frequency, meaning its safety and performance at the untested frequency are unknown.

Compliance: Regulatory bodies and testing agencies might require equipment manufacturers to certify their products for specific frequencies, ensuring compliance with local safety and efficiency standards.

In summary, the differences between 50Hz and 60Hz grids stem from their electrical and mechanical impacts on various equipment.

Operating a vessel while on shore power with a frequency other than the designed system frequency, may work on a case-by-case bases. However, concluding that a successful in a case-by-case application of 50Hz shore power supply to 60Hz vessel or vice-versa may be difficult or impossible.

7 CONCLUSION

The current draft of IEC/IEEE 80005-3 is a complement to the already established HV-shore connection standard IEC/IEEE 80005-1. The future standard will cover many different vessel types over a wide range of power demands. The draft standard is restricted to maximum power transfer rating of 1 MVA. This restriction is based on practical consideration, i.e., keep the number of parallel cable connection between shore and ship controllable regarding space and handling. The upper limit of 1MVA also keeps a clean separation between LVSC and HVSC installations.

Within the power range of 1 MVA ports and vessels have the freedom to tailor the number of socket connection based on actual load requirements of vessels calling a specific berth. This allows ports and vessel alike to fit only the requirement number of connections. A further advantage is the utilization of one socket and plug layout regardless of vessel type. Allowing different vessel types to connect to the same berth.

The current draft also contains provisions which will allow for lighter version of plug and socket connection <250A. These plugs and sockets are, although similar, not compatible with the plug and socket described in IEC 60309-5.

The system voltage of vessel with HV installation is 6.6 kV respectively 11 kV. These two voltage levels account for the vast majority of vessels. The spectrum of LV installation onboard sea-going vessels has, in contrary to HV vessels a larger distribution of different voltage levels.

The majority of LV sea-going vessel have a system voltage of 440V at 60Hz followed by 400 V at 50Hz, which is more prominent in small vessels. Only 0.3% of the sea-going vessels with available low voltage system data uses 690V at 60Hz.

The main drivers for the selection of a vessels system voltage are vessel's power demand, equipment availability, operation profile and trading regions. Acknowledging the variety in system voltages onboard ships, the standard opens for additional (optional) supply voltages in addition to the default transmission voltage of 690V.

Selecting 690V 60 Hz as the transmission voltage has benefits with respect to the number of parallel connections needed to supply. Weighing these benefits against the fact that many vessels operate on 440V 60Hz would suggest selecting 440V 60Hz as the transmission voltage instead of 690V 60Hz.

Irrespectively of the above, providing different voltage in a (regional) trading area, for example between European ports is worthwhile considering.

Most importantly the current document on which this report is based is a draft, subject to changes based on feedback from stakeholders and interests' groups. Forming the future standard is still possible by commenting on the CDV through the national committees or participation as a member of JWG-28.

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