FEASIBILITY ASSESSMENT STUDY

High Voltage Shorepower Connection for Tankers

Port of Rotterdam, Stolt Tankers, Vopak

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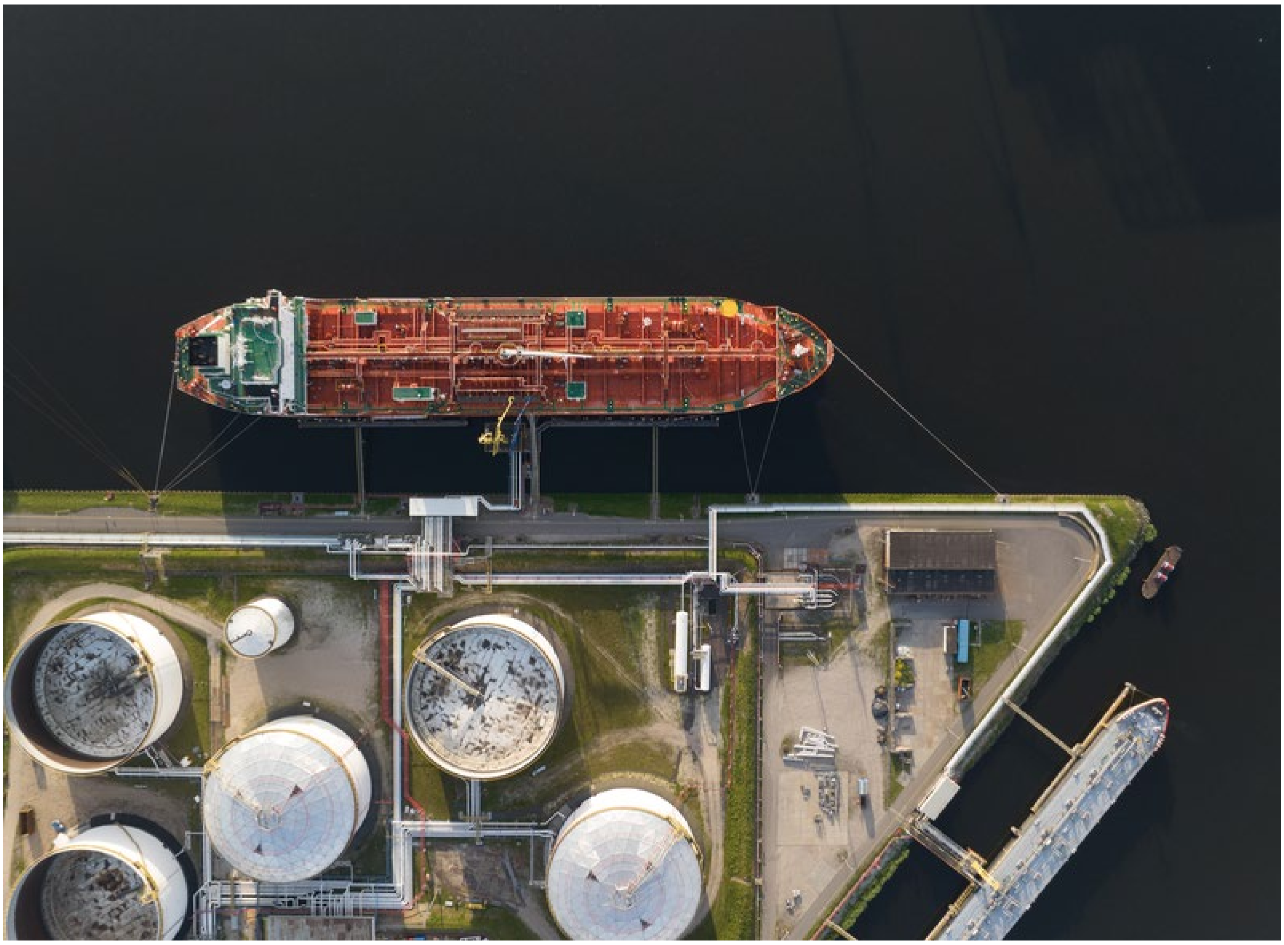

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Customer:	Port of Rotterdam Authority	Safety, Risk and Reliability
	Wilhelminakade 909	Veritasveien 1
	3072 AP Rotterdam	1322 Høvik
	Netherlands	Norway
Customer contact:	N/A	Tel: +47 67 57 99 00
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Applicable contract(s) governing the provision of this Report:

Objective: To carry out a feasibility study for development of a high voltage Onshore Power System (OPS) for tankers, aiming at producing a showcase with the potential for worldwide impact on an international standard on High Voltage OPS for tankers.

Prepared by:	Verified by:	Approved by:
Digitally signed by Jordahl, Magnus Date: 2024.05.24 15:19:40 +02'00'	Digitally signed by Hartmann, Thomas Date: 2024.05.24 15:13:26 +02'00'	Digitally signed by Krugerud, Christine Lagerstedt Date: 2024.05.24 15:16:58 +02'00'
Magnus Jordahl Senior Consultant	Thomas Hartmann Senior Principal Specialist	Christine Lagerstedt Krugerud Head of Section

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Table of contents

1 EXECUTIVE SUMMARY

DNV Maritime Advisory has been requested by a consortium consisting of Port of Rotterdam, Stolt Tankers and Vopak Botlek to support them in a feasibility assessment study for development of a high voltage Onshore Power System (OPS) concept for tankers, aiming at producing a showcase with the potential for worldwide impact on an international standard on High Voltage OPS for tankers.

The following activities were carried out within the project:

- Exploration summary: Current status and challenges addressed in literature.
- Scenario development: Explore potential OPS options for tankers and condensing a long list into a short list
- HAZID: Hazard Identification workshop for the shortlisted scenarios
- Multi Criteria Analysis: Creation of a framework for decision support and evaluation of scenarios.

The initial part of this project investigated literature and articles to shed light on the current status on shore power for tankers and to get an overview of identified challenges and potential showstoppers. The focal point of the study was the interface between ship and shore, thus, some of the identified challenges from the literature were considered out of scope and location specific, such as sufficient available grid power, decision between 50 or 60 Hz, voltage level and load, the associated number of cables, plugs and sockets, and there are ongoing processes already addressing some of the issues where decisions needs to be taken, e.g. at OCIMF.

A long list of potential options for OPS connection was then described and evaluated, condensing into a shortlist of three potential scenarios:

- Scenario 1 - Midship connection with handling of OPS cable with ship's crane, thus no specific CMS
- Scenario 2 - Midship connection with crane-based CMS on jetty
- Scenario 3 - Stern connection with crane-based CMS on shore or constructed platform/monopile in water

A safety assessment for the three scenarios was carried out in the form of a HAZID, leading to identification of several high risk hazards, and a list of 21 recommendations that may assist in improving the safety level. Scenario 1 was associated with four high risk hazards, scenario 2 with three high risk hazards, whereas no high risk hazards were identified for Scenario 3. The high risk hazards identified were mainly associated with connection/disconnection within a hazardous zone.

In the end, a Multi Criteria Analysis (MCA) was carried out across a set of four main criteria identified by the project team.

- Safety
- Operability
- Technical maturity/Equipment availability
- Cost

Each criterion was subject to their own sub-criteria weighted according to their relative importance, and a score between 1-10 (10 being the best score) was set for each criteria based on the showcase Vopak Botlek jetty 5/6 and the vessel Stolt Breland. The final results from the MCA was as follows:

Criteria	Weight	Scenario 1	Scenario 2	Scenario 3
Safety	35 %	0.9	1.1	1.8
Operability	25 %	0.8	1.3	1.6
Technical maturity / Equipment availability	25 %	2.0	1.9	2.1
Cost	15 %	0.8	0.6	0.8
Aggregate score	**100 %**	**4.5**	**5.0**	**6.4**

The result indicates that scenario 3 should be the preferred option according to the MCA, dominating the other scenarios across the range of criteria, with the exception of Cost where Scenario 1 is on par. That indicates scenario 3 would have been the preferred solution regardless of how the weighting of the main criteria was configured, but please note that this relates to the specific showcase assessed.

Through the HAZID and MCA it was evident that the hazardous zones are affecting scenario 1 and 2 scores negatively, specifically in terms of Safety and Operability. However, please note that going through the MCA process with other potential scenarios for a different ship and jetty may very well yield a different result, depending on the configuration. For example, a finger pier with OPS to a VLCC may need a different setup than the Botlek/Breland case discussed in this report, while the possibility the results being the same could be equally valid. The MCA could be used as a framework to assess the relevant scenarios for the case in question, while setting separate scores according to the configuration of those systems.

The main takeaway from the exercises assessed in this project is that although a midship connection may very well be a feasible option, it may not be as practical and flexible as it seems at first glance, in addition to the hazardous zones representing a significant risk involved with the OPS connection. By setting up a stern connection instead, the risk is reduced as far as possible, as there is normally no hazardous zone in the stern area of a tanker.

Please note however, that there is a formal obstacle that needs to be resolved, namely that an ATEX zone is often defined to cover the entire vessel from the terminal point of view, leading to a discrepancy between the hazardous zones definitions that needs solving. This should however not have any practical consequences for safety.

Selection of a stern connection would also allow adaptation to make use of the existing IEC/IEEE 80005-1 standard on high voltage shore connections. The standard does however not allow connection in a hazardous area, thus revision of the existing IEC/IEEE 80005-1 standard addressing a midship connection would be necessary, likely to be a rather time-consuming and complex matter.

2 INTRODUCTION

DNV Maritime Advisory has been requested by a consortium consisting of Port of Rotterdam, Stolt Tankers and Vopak Botlek to support them in a feasibility assessment study for development of an Onshore Power System (OPS) concept for tankers, aiming at producing a showcase with the potential for worldwide impact on an international standard on High Voltage OPS for tankers. .

2.1 Objective

The objective of the project is to support the Consortium in investigating the technical feasibility assessment of a tanker high voltage OPS concept, and potentially the development of a showcase based on Consortium assets. Development of the OPS for tankers is intended to select solutions to enable standardization, aimed to be useful beyond the ship and terminal used to showcase tanker OPS.

2.2 Scope of work

The project is made up by the four activities described below:

- Exploration summary:

  In this activity the consortium partners have looked into available literature to investigate opportunities and challenges that must be addressed in order to realize OPS for tankers. They have also gathered findings from site visits, references and suppliers. Main issues and takeaways are summarised.

- Developing scenarios:

  Following up the first activity summarizing the exploration activities, literature study and looking into existing OPS projects, next step is to develop applicable scenarios to analyse going forward. The objective is to explore different concept solution options that could enable OPS for tankers and be acceptable to achieve a generally applicable solution. To be able to concretise a solution instead of hypothesizing, a case study with the Stolt Breland and jetties 5/6 at Vopak Botlek is considered as a means to achieve that goal.

- HAZID:

  Safety is an essential topic when it comes to OPS for tankers, and likely the single most important factor to why it has not already been implemented. There may be differences to the safety cases for each of the three scenarios developed, thus a HAZID workshop is organized to assess the general safety aspects involved with each of them.

- Multi Criteria Analysis:

  This task aims at providing decision support framework and enable ranking of the most promising solution of the shortlisted scenarios developed in task 2.

The scope of this project is limited to the shipboard implications, as well as the interface between ship and shore.

After each of the four activities was completed, a memo summarizing the work done was created. These memos have been compiled into this final report to provide a comprehensive summary of the entire project.

2.3 Abbreviations

Table 2-1 Abbreviations list

ALARP	As Low As Reasonably Possible
ATEX	Classification directive of equipment for use in Potentially Explosive Atmospheres (originally from French; Appareils destinés à être utilisés en ATmosphères EXplosibles)
CMS	Cable management system (*equipment needed to control, monitor, and handle flexible shore connection cables*, as per DNV Rules Pt. 6, Ch. 7, Sec. 5)
CMS	Cable Management System
DWT	Deadweight tonnage
ESD	Emergency Shutdown
HAZID	Hazard Identification
HVSC	High Voltage Shore Connection
IEC	International Electrotechnical Commission
ISGOTT	International Safety Guide for Oil Tankers and Terminals
LOA	Length overall
MCA	Multi Criteria Analysis
(M)VA	(Mega) Volt-Ampere (Apparent electric power)
OCIMF	Oil Companies International Marine Forum
OPS	Onshore Power Supply
OPS	Onshore Power Supply (shorepower)
SC	Short Circuit
SIMOPS	Simultaneous Operations
SMART	Simple Multi-Attribute Rating Technique
SOLAS	International Convention for the Safety of Lives at Sea
SWB	Switchboard
VLCC	Very Large Crude Carrier

3 EXPLORATION SUMMARY

Researching onshore power supply (OPS) for tankers, the consortium partners have looked into available literature on the subject to investigate opportunities and challenges that must be addressed in order to realize OPS for tankers.

Compared to other ship types OPS for tankers is associated with significant additional challenges tied to them, mainly tied to the hazardous nature of their cargo. The aim of this memo is to summarize the main findings and takeaways from the literature that has been looked at.

3.1 Studies

3.1.1 Ports 2007: Design and development of bid documents for cold ironing of oil tanker vessels at berth T121 at the Port of Long Beach, ASCE article.

- Explains methodology for the development of Long Beach OPS for tankers (with aft ship connection).
- Gives account for estimation of load demand and selection of solutions applied.

3.1.2 Ports 2010: Challenges associated with implementing operations for the first cold ironing of oil tanker vessels, ASCE article.

- Provides overview of the challenges associated with the implementation of shore power at the terminal located at berth T121 in Long Beach, of which there were some practical regulatory issues wrt. construction in an active oil terminal.
- Points to ISGOTT for guideline on equipotential bonding between vessel and shore (connection outside hazardous areas, ground switch on the jetty)
- Some practical interference with mooring operations was experienced, leading to a slight modification of the access trestle.
- Connection process was more complex than anticipated and required extensive development over time to be conducted in a safe and efficient manner.
- Describes commissioning testing of the facility.
- Concludes that the implementation phase of the project was very challenging.

3.1.3 Shore power technology assessment at U.S. ports, EPA report 2017

- General overview of utilization of shore power in the U.S. with focus on onshore infrastructure challenges and grid energy mix, vessel types other than tankers (cruise, container, reefer), and calculation of emissions reduction.

3.1.4 Shore power for liquid bulk vessels – Modelling of terminals and vessels for cost-effectiveness of different shore power systems, Thesis article 2021, Jelle Willeijns)

- Economical KPI-based approach to assessment of shore power

- Points to two main reasons for OPS for tankers being challenging:
  - Lack of internationally accepted standards; uncertainty for ship owners on configuring shore power system on board
  - Negative financial impact of using shore power
- Claims little to no literature concerning shore power for tankers (liquid bulk market is the phrase used).
- Berths/jetties in terminals as well as the cargo manifold area onboard the tanker often has little room for additional equipment.
- Refers to Long Beach as the only current installation of OPS for tankers:
  - Connection outside ATEX zone is an advantage
  - Disadvantages relate to dependency on shipboard crane which may not always be able to reach cable depending on vessels size and/or crane reach.
- Indicates a high utilization rate is necessary to bring down LCOE on the port/terminal side, and explores fleet shorepower readiness in relation to shore power price (€/MWh) and demand (MWh) at different levels of subsidy for the installation.
- Points to aft connection (crane and reel) as having the best performance (in terms of CO2 tax level to make when looking into a case of chemical shortsea- (below 10 000 DWT, 66-120 m in length) and parcel tankers (10-20 000 DWT, 122-148 m in length), which are considered the most viable to make use of OPS due to cargo operations also relying on electrical power, as opposed to larger oil tankers using oil fired boilers for cargo operations which has less potential for emission reduction.
- Collaboration between ports, terminals, ports, shipping and oil companies to create predictability and regularity within a certain group/segment of tankers will enable a more feasible business case for OPS.
- Case studies in paper deals with chemical vessels below 20 000 DWT, meaning the results does not have universal applicability.

3.1.5 California Air Resources Board’s (CARB) ocean-going vessels at berth regulation emissions control technology assessment for tankers, Project report by DNV for Western States Petroleum Association 2021

- Discusses performance expectations to an OPS system, notably:
  - Most tankers will have a 6.6 kV connection, some may have 11 kV. Voltage transformer may be required in some cases.
  - Majority of tankers utilize 60 Hz frequency. May not be compatible with grid frequency in all areas, requiring a frequency converter.
  - Safety for personnel needs to be maintained, and emergency disconnect functionality needs to be in place.
  - Able to compensate for tidal effects.
- Lists standards and regulations relevant to the use of shore power, as well as parameters considered critical for the operation of shore power for tankers (in terms of physical layout):

  - Ship size
  - Height difference from jetty to connection point
  - Crane reach
  - Weather conditions
- Technology assessment categorizes CMS and shipboard installation (connection, plug and socket) to be associated with demanding new technical challenges, and points to lack of electrical equipment acceptable to introduce into an ATEX zone.
- A wide range of ship lengths, two possible vessel orientations, as well as hazardous zones associated with both vessel and terminal makes for huge compatibility challenges in the interface between ship and shore.
- Recommends a solution based on an industry standard, preferably in a non-hazardous area, and recommends the development of a cost effective CMS able to handle the range of ship size calling at the terminal.
- Discusses the opportunities challenges associated with different locations of the connection:
  - At the stern the connection is out of the vessel's hazardous zones, meaning it may use commonly applied shore power connection equipment, enabling an option considered relatively safe. The challenge will then be to managed variations in ship size, ensuring the CMS has sufficient flexibility to reach the connection point.
  - In the bow area the connection will also be outside the hazardous area, however faces the same challenges as the stern. In addition, a great length of cable from connection to the ship's main switchboards may be challenging.
  - A midship connection would be likely to solve the challenge with difference in ship lengths as the connection could be aligned with the manifold to have a fixed location independent of size. It will then however be more likely to end up within a hazardous zone with the safety challenges that involve.
  - Locating the connection inside a pressurized deckhouse could enable the connection to be made within a hazardous zone, as the pressure would displace flammable gas/vapours given the supply is drawn from a non-hazardous area. How to connect the plugs and enable cable penetration without losing the pressure and thus introducing a hazardous zone into the enclosure will be another challenge.
- Terminal jetties may be subject to limited available space, in addition the structural strength necessary to enable the jetty to take the additional load of OPS equipment needs to be taken into account.
- General risks associated with handling of OPS is also discussed, and although applicable also for tankers, they are considered more of a general nature and not tanker specific, thus not summarized in this memo.

3.2 Findings from site visits, references & suppliers

3.2.1 Port of Gothenburg

Port of Gothenburg has an OPS installation under construction for a tanker jetty with 3 berths. Main specifications are:

- Total 3 MVA for 3 berths, each max. 2 MVA. 6.6kV (down to 690/440V onboard). 50Hz supplied (design-ships have frequency converter onboard, as these run on 60Hz). Cavotec PC6 socket/plug

- Midships connection from overpressure (air) container on jetty to overpressure (nitrogen) cabin onboard.

3.2.2 Terntank

The Port of Gothenburg meeting was also attended by representatives from Terntank. They recently had taken delivery of the vessel Tern Fors. It is equipped with a Hybrid solution, a 6.6 kV 50Hz onshore power connection, battery pack and DC-Link system. The system is designed for a mid-ship connection at the manifold area. The cable is connected in a special built pressurised compartment in order to comply with the ATEX requirements Zone 1.

The cable from the shore container to the connection point is not fixed and from the various pictures we have seen is not protected. This we think is one of the weak points of the installation and could be solved with better protection of the cable.

3.2.3 Gävle / Actemium

Port of Gävle has an existing OPS installation at a liquid bulk jetty, which is finished (built by Actemium) but to date has not been in use. Main specifications are:

- Midships connection (in ATEX zone 1, from terminal point of view).
- Installation consists of 1 container in ATEX zone 1 (overpressurised with air), 1 container just outside ATEX zone 1 next to jetty approach trestle to take in clean air for over pressure system, 1 container at distance of jetty for control and steering equipment. Cabin onboard overpressurised with nitrogen.
- 2MVA. Voltage 6.6kV, because of IEC/IEEE 80005, but plug is suitable for 11kV (Client decision).
- 50m power cable on reel. Separate dedicated bonding cable (with ATEX certified circuit breaker).
- When no ship at jetty, all HV is disconnected and grounded, all non-ATEX equipment is de-energised.

Actemium advise to standardize the plug and adopt 11kV to accommodate future higher power demand. Actemium ask attention for the safety hazard of a “loose” cable in the jetty operational area and onboard (ao trip hazard and damage after stepping on cable). Actemium’s Client are terminals, where hazardous area classification usually includes the entire ship; Actemium therefore expect installations aft to be similar to installations midships.

3.2.4 Port of Long Beach

OPS has been in operation for VLCC for many years. Main specs are aft connection on dedicated concrete platform, onshore cable reel & plug, using ships crane. Original choice was based on qualitative evaluation, not quantitative comparison of concrete scenarios. Main factors then were:

- Safety: Stay out of classified areas / ATEX zone 1.
- Costs: Avoid measures (onboard and onshore) to cope with classified areas / ATEX zone 1.
- Simplicity: Use ships crane, as it is available. Place installations onshore as space onboard is limited, but onshore more space is available.
- Weather conditions: Ships encounter more extreme weather and environmental conditions than port facilities. Cable reels etc are more protected onshore than onboard.

This reasoning was applicable for the Long Beach case, which was then considered relatively simple (small variation in vessel sizes). In hindsight:

- The installation performs well in practice.
- The civil/marine scope became expensive, as it is in the berthing/fender line therefore very heavy/robust and designed for ships impact.
- A flexible/movable crane could be better. That would facilitate different ship sizes. It would also place the CMS further from the berthing/fender line, thus avoiding the platform to be very heavy and costly.
- Don’t aim for a system that facilitates 100% of cases. Aim for a staged approach that fits say 90% of ships & jetties.
- Plan for mixed terminals as well, with tankers and e.g. RoRo or containers.

3.2.5 Stenaline Hoek van Holland

Stena have operated 2 OPS for ferries for many years. The connection is aft, with dedicated Cavotec CMS, one telescopic crane and one short fixed arm. Both CMS are very swift in operations.

- Ship connection 11kV 60Hz AC, using power approx. 1.5 MVA and 2.2 MVA, max. approx. 3 MVA
- Grid connection Stedin 25kV 50Hz AC. Covert 25kV 50Hz AC -> 2kV 50Hz DC -> 2kV 60Hz DC -> 11kV 60Hz AC.
- Operational lessons:
    - Data plug is vulnerable. Use large/robust plug or wifi
    - Use sledge/guide to insert power plug into socket to prevent damage to plug (mainly smaller safety pins)
    - Simpler is better

3.2.6 Eemshaven LNG & Energos Igloo

A combination of 2 LNG FSRU’s, moored to a continuous quay wall, connected to shorepower. Main specifications are:

- 16MVA plus 24 MVA connection. Operating on 6.6kV (grid connection 20kV) and 60Hz, which were chosen as the existing FSRU’s already operated on his.
- Total 19 containers (20ft boxes) for onshore OPS system.
- Aft connection, using fixed connection (not plug/socket) & switchgear in 1 container (20ft box).

Advise from the E-expert developing the OPS is to “stay away from attempts to make the system ATEX proof. Even on the FSRU’s this was not necessary”.

3.2.7 Bahrain LNG

Schneider Electric developed a shore power solution for a LNG Floating Storage Unit (FSU) for a new terminal in Bahrain. This is an interesting installation as the FSU is located 4.3 kM from the terminal. The installation includes an flexible cable feed system designed by the company IGUS, that bridges a 30M distance between the jetty and the FSU. Two Medium Voltage cables are enclosed in an Igus heavy duty plastic chain.

Another interesting feature of this installation is that there is a special 3-phase medium voltage connector that can be automatically disconnected in the event of an emergency such as tsunami.

The main electrical characteristics of the system are:

- The shore connection system provides a 7MVA 6,6kV 60Hz output to supply LNG FSU unit
- Incoming Power is 6.6kV, 50Hz, 40kA for from Regas substation

3.3 Main issues

Below the main issues related to developing an OPS for tankers are listed and briefly discussed.

- Difficulty reaching the ship with no direct ship-shore access along the side except midships platform, which is an already congested area onshore and onboard. Issue is not made easier because of the variance in ship types and berth/jetty types.
- Interface of cable management system (CMS) with mooring lines (for a variety of ship sizes and mooring arrangements), with berthing tanker vessel (potentially at an angle to the fender line), and with loading arms / equipment at platform.
- Hazardous area classification. Difference between onboard classification and onshore classification. Large variation in products with effect on classification. Difference in international legislation / regulations on classification. Handling classified/ATEX challenges with midships connection either with ATEX-certified equipment (not identified/available yet) of over-pressure enclosures onboard and onshore (air or nitrogen)
- Power usage differs from ship to ship. Important to design for actual load, not theoretical maximum load in order to keep installation CAPEX manageable. For larger ships, boiler loads may be significant. Important to design futureproof in terms of requirements & legislation.
- Power availability. Due to the global increase in electrification, availability of power from the grid may be an issue impacting the feasibility of OPS. If a grid connection to the terminal is available that has sufficient power available, bringing the power to the jetty may be a costly project in itself.
- Frequency 50/60Hz. USA-type grid operates on 60Hz, but European style grid on 50Hz. Majority of tanker fleet operates on 60Hz frequency. Expected that there are more tankers than jetties worldwide (but data search not conclusive yet) so frequency converter onshore seems cost effective.
- Voltage. Many ships operate on low voltage or on 6.6 kV. Higher voltage would result in a lower number of cables in the CMS, so easier to handle from an OPS perspective. For a High Voltage Shore Connection, step-down transformers may be necessary to accommodate a vessel's low voltage requirements.
- Manner of cable & plug handling with ships crane, jetty crane, dedicated tool/crane. Related is the question of feasibility of a dedicated tool/crane that can reach aft from a location at a distance from the fender line (currently being investigated by Eager. One for PoR).
- Keeping the number of cables limited will help making the OPS system practically manageable. This issue is related to power usage and voltage.

- Swift automatic disconnection of the OPS in case of emergency is an important safety issue. May a/o be handled through a physical disconnection or an automatic de-energising and grounding of the system (without physical disconnect, therefore resulting in damage in case of emergency).
- Procedures to be universally fixed for ships and terminals. Including issue of suitably certified staff to be available 24/7 for connecting and energizing the OPS.
- Speed of operations. At first glance seems crucial, but in practice probably less relevant as 1 hour seems doable from installation & procedures point of view, and allowable based on power usage immediately after berthing.
- Aligning with other trades / existing technology will make OPS technology for tankers more cost effective and make it easier to facilitate innovation, however potentially less specific for this trade / less fit for specific purpose

Summary of main decisions to be made in order to arrive at a standard:

- Location (aft, midships, somewhere in between in ATEX zone 2)
- Manner of cable handling (ships crane, jetty crane, dedicated arm)
- Plug type (including plug from land or from ship)
- Voltage (low voltage, 6.6kV, 11kV)
- Frequency (50Hz, 60Hz)
- Power
- Requirement w.r.t. emergency departure
- Operational procedures

Summary of potential showstoppers identified from studying literature and other OPS-related projects:

1. Feasibility of OPS in a hazardous zone environment. The shore-based installations in Gävle (and Gothenburg) together with the on-board installation of Terntank may provide proof that this has been tackled, but the installations need to be demonstrated and confirmed fit for purpose.
2. Hazardous zone classification (ATEX) and discrepancy in application between the maritime and terminal domain. This issue is further elaborated in section 3.3.1.
3. Feasibility of a dedicated CMS tool/crane that can reach a stern connection on board from a safe location at a distance from the fender line and ATEX zones on the jetty. Such currently being investigated by Eager. One for PoR.
4. Grid power availability.

3.3.1 ATEX classification deviations

An important issue to resolve is the apparent discrepancy in application of gas hazardous zones (often referred to as ATEX zones (European terminals) or EX zones (maritime)).

The maritime application of such zones is governed by international rules and regulations, specifically the International Convention for the Safety of Life at Sea (SOLAS) and the Ship Rules of a vessel's Classification Society. From a general perspective, the cargo area of a tank vessel is considered hazardous area due to cargo vents, cargo piping, cargo treatment, etc that is located within that area. Bow and stern are however usually free of any cargo related equipment unless a vessel is not purpose built to carry out cargo operations via bow or stern. As a result, a stern connection would be considered within a safe area from a maritime point of view.

Terminals on the other hand, have a rather conservative approach to classification of the area around a ship based on guidance from multiple standards (NPR7910(NL)/EI15/ISGOTT) and underlying IEC/EN 60079-10-1 and -2, as well as European ATEX 153 (personal safety for employees) and ATEX 114 (for suppliers/products). From a terminal perspective this makes sense as they do not have any detailed information about the hazardous zone classification of each ship. In addition, there is a considerable size range to cover. Therefore, assigning an ATEX zone surrounding the entire ship assures that the selection of new equipment going on the jetty adjacent to the ship is ATEX certified and will not pose any risk either on jetty or on board regardless of the actual classification.

The general understanding for shore power installations at the moment is, that a stern connection can be created in a safe zone on the ship and therefore the connection can be non-ATEX certified. The hazardous area classification drawings of the terminals however tell us otherwise and do not approve the use of non-ATEX certified equipment. A non-ATEX certified shore power connection is in theory only possible if both hazardous area classification drawings from ship and shore are in line with each other. This is also addressed in IEC/IEEE 80005-1 Edition 2.1 clause F.4.6.4, however, mitigations are described in several other clauses of the standard, for example clause 4.9.

The standards don't give any guidance how to handle any deviations between area classifications. Onshore standards are not necessarily mandatory however, so customization is possible and necessary for each jetty and individual assessments should be performed to modify the hazardous area classification of the terminal. Maritime zones are clearly defined in the regulatory framework.

The biggest problem is that the standards are recommending a hazardous area classification for the surrounding of the ship including the ship as well. Ships are however subject to maritime area classification, and it is very likely that the classification made by the ship owner is not in line with the classification as made by the terminal and could therefore be seen as incorrect from the terminal point of view. Knowing this, the suggestion could be raised to examine the background for a terminal's ATEX classification drawings more closely and see if there may be room to modify them based on actual data from ship owners. This is easier said than done as not all data from every possible ship will be available and therefore it cannot be excluded that there will be no hazardous area on the stern of the ship in all cases. A possible solution for that could be a procedural protective mechanism after arrival of the ship to check whether the stern is actual a safe zone. That would be a step from intrinsic safety towards safety-through-procedures, opening a chance for human error. This needs to be investigated further.

If the above approach is adopted by every terminal, this could lead to the following scenarios:

A) The stern of the ship is within the hazardous area of the terminal and the CMS system is inside the hazardous area of the ship/shore. In this case, an ATEX certified shorepower connection is necessary and the CMS equipment must be ATEX certified.

B) The stern of the ship is within the hazardous area of the terminal and the CMS system is outside the hazardous area of the ship/shore. In this case, an ATEX certified shorepower connection is necessary and the CMS equipment can be non-ATEX.

C) The stern of the ship is outside the hazardous area of the terminal and the CMS system is out of the hazardous area of the ship. In this case, the connection as well as the CMS equipment can be non-ATEX.

D) The stern of the ship is outside the hazardous area of the terminal and the CMS system is within the hazardous area of the ship. In this case, the connection of the shorepower can be non-ATEX, but the CMS equipment must be ATEX certified.

As some of the standards underline themselves, is that classifying jetties is a complicated matter. Both ship and shore installations contribute to final classification which can be different based on which ship is berthed.

The above approach in solving this matter is a practical approach which must be adopted by everybody in order to set the shore power standard right. The question is, if we can convince everybody to adopt this approach, or that it has to be backed-up by updated standards as well.

3.4 Key take-away summary

The lack of a recognized standard that sufficiently covers OPS for tankers is seen as one of the main challenges (IEC/IEEE 80005-1 Edition 2.1 Annex F with informative status only). General standards for shorepower would of course be applicable for the most part, but the final interface between shore and ship is seen as the most challenging part, specifically design of CMS and connection on board.

This challenge to a large extent relates to the wide range of ship sizes a berth may have to accommodate and the flexibility it would have to handle. A midship connection in close to the cargo manifold could potentially help standardize this issue, however, that means the connection will be located within an ATEX zone which poses another challenge as there is currently not readily available electrical equipment rated as safe within such a zone for all types of components needed. In addition, there would in many cases be a very limited area available for the equipment needed both on board and on the jetty as they are already pretty congested areas.

A stern connection is suggested likely to solve the ATEX challenge and is regarded a safer solution, but unless the fleet berthing at the terminal is fairly uniform when it comes to size, a stern connection will require a great deal of flexibility from the CMS. It would have to handle not only ship size differences, but also tidal effects and the difference in draught between fully loaded and an unloaded vessels.

In addition, challenges on electric compatibility are discussed, in terms of different voltage levels, 6.6 kV or 11 kV, or frequencies, where the majority of tankers have 60 Hz but certain areas where the vessels call have 50 Hz grid frequency. Frequency may be handled by frequency conversion, whereas determining between 6.6 kV or 11 kV is a more complex problem.

3.5 Reflections on key take-aways

The lack of standardization of OPS for tankers is likely to relate to the wide array of flexibility it would have to cover and the lack of off-the-shelf equipment, either for ATEX zones or a CMS with sufficient flexibility.

Considering the wide range of ship sizes and arrangement of equipment in the midship section, could a connection close to the manifold pose a false sense of practicality? If for instance the connection would be located near the ship centreline to facilitate connection from either side of the vessel, the routing of the power cable could be rather impractical. The range of ship widths (from <20 m to 40+ m) would also be a challenge in terms of the length of the power cable the CMS would have to handle. If the connection would be on both sides, that would complicate the on board installation. Bringing the connection out to the side of the ship would imply the vessel could only berth towards that side, whereas connection on both sides would further increase the complexity and cost of the installation.

An enclosure for a mid-ship connection would require an airlock if located within an ATEX zone according to maritime regulations, further increasing the footprint such an installation would have in the area.

In terms of frequency, this may be solved with frequency converters in areas with 50 Hz on the grid. On the voltage side, the majority of tankers have LV power generation and distribution systems. Those vessels need to install step-down trasformers. Some vessels have already a HV power generation and distribution system. These vessel could connect directly to a 6.6 kV shore supply system. If the industry descides to utilitze 11 kV as the shore supply voltage also 6.6 kV vessel supply systems would require a step-down transformer. Flexibility between these two voltages is a bit more complex problem, also considering that cargo handling on board is handled by means of oil-fired boilers or diesel-driven hydraulic pumps for a some of vessels. If cargo handling is changed to be handled by means of electrical equipment, this is likely to drastically increase the load demand for such vessels, arguing that a 11 kV connection may be most future proof option but with the caveat that most vessels currently will have 6.6 kV.

Not directly mentioned in the literature, but the number of plugs may also be an issue, which also relates to the applicable load demand and selected voltage level.

The area of responsibility between ship and shore at the interface between them is also a somewhat grey area that may need to be shed some light on and depending on the outcome it could potentially influence the system design and which side may be responsible for what.

Finally, cost is a challenge, and how to distribute the cost between the stakeholders. Vessel flexibility will increase the cost for the shipowner, terminal flexibility will increase the cost on the terminal and/or port side. In addition, there are local authorities, cargo owners etc. that are perhaps not necessarily prepared to take any part of the costs, but may have opinions that may carry weight in the selection of solution.

4 SCENARIO DEVELOPMENT

Following up the memo summarizing the exploration activities, literature study and looking into existing OPS projects, next step is to develop applicable scenarios to analyse going forward. The objective is to explore different concept solution options that could enable OPS for tankers and be acceptable to achieve a generally applicable solution. To be able to concretise a solution instead of hypothesizing, a case study with the Stolt Breland and jetties 5/6 at Vopak Botlek is considered as a means to achieve that goal.

4.1 Description of situation

This subchapter will provide a general overview of relevant information for the reference vessel and jetties that will be used to develop the showcases.

4.1.1 Tanker vessels in general

Tankers come in a whole range of sizes, from small shortsea vessels around 60 m to VLCC's exceeding 300 m in length with a breadth of around 60 m. With a wide range of sizes, there is also a wide range of load demands as well. The larger vessels rely on oil-fired boilers to produce steam to run their cargo pumps, whereas the vessels below 200 m, and specifically chemical tankers are more inclined to have hydraulic cargo pump systems powered by electric motors as aggregates.

With respect to the electrical installation the majority of oil and chemical tankers have low-voltage electrical systems whereas HV-systems are most common in vessels with high load demand and/or electrical propulsion.

4.1.2 Stolt Breland case

4.1.2.1 Technical

Reference vessel is the Stolt Breland, a tanker for oil/chemicals, with the following main particulars:

- LOA 182.72 m
- Breadth: 32.30 m
- Depth: 15:60 m
- Max. draught: 11.90 m
- Gross Tonnage: 25881
- Summer DWT: 43475 t
- Load demand: 2.5 MVA

4.1.2.2 Hazardous area classification

Figure 4-1 shows an illustration of the profile view and main deck top view of the vessel, with its defined hazardous zones. From the figure it can be seen that the cargo deck is scattered with spherical hazardous zones, as well as two cylindrical zones generated by the forward and aft vent stacks. These zones are areas connected to volumes involved with cargo carriage or cargo processing, where presence of flammable gas is likely and potential ignition sources must not be kept or brought inside of these zones.

Assignment of hazardous zones for vessels are regulated in the International Convention for the Safety of Lives at Sea (SOLAS) and categorized depending on whether the opening is dealing with hazardous substances directly or indirectly. Based on SOLAS, the entire cargo deck of a tank vessel is considered hazardous area zone 1 up to 2.4 m above deck, and zone 2 for an additional 1.5 m above deck. Zones depicted in the top view of Figure 4-1. are the extent of hazardous zones extending beyond the 2.4 + 1.5 m above main deck covering the entirety of the cargo deck, as can be seen via the profile view.

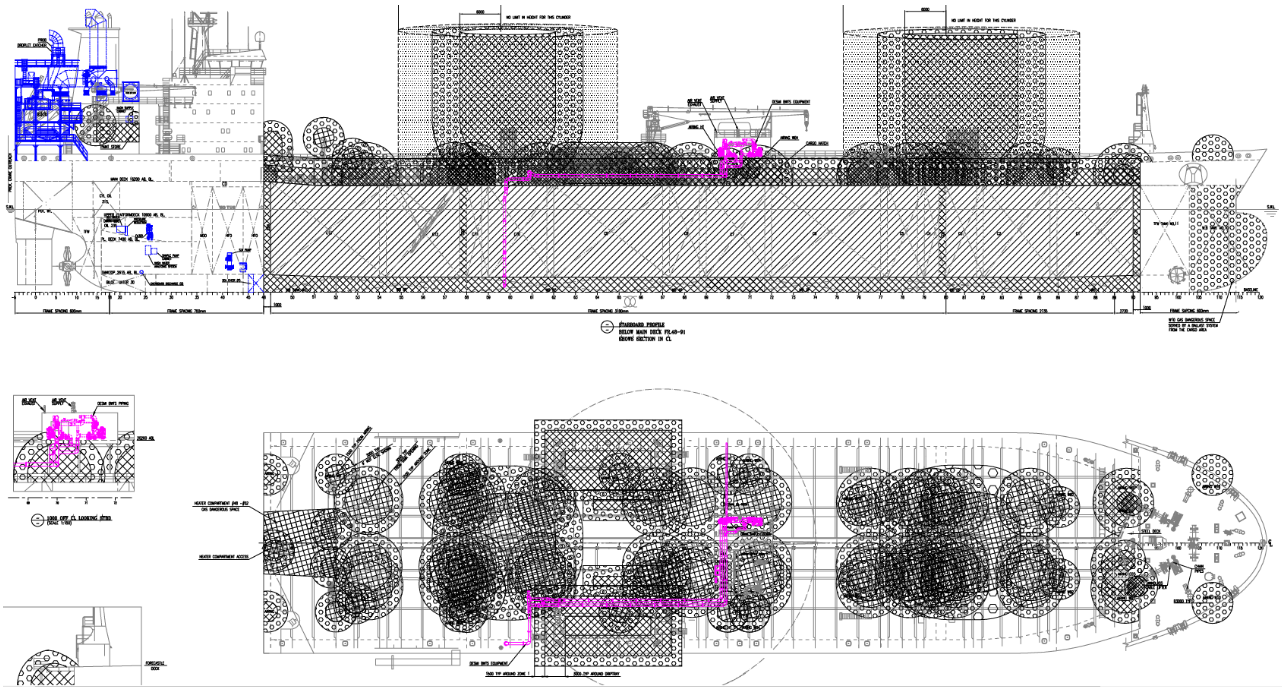

Figure 4-1 Profile- and top view of main deck for Stolt Breland (Source: vessel drawing "Gas hazardous spaces and zones", rev. 0, 12-2019). Please note top view refers to zones more than 3.9 meters above deck.

4.1.3 Tanker terminal jetties in general

Tanker terminal jetties are often designed as either a T-jetty or a finger jetty extending from shore, usually to allow for deeper draughts which often characterizes tankers. An image of a typical finger jetty is shown in Figure 4-2, and an image of typical T-jetties are shown in Figure 4-2.

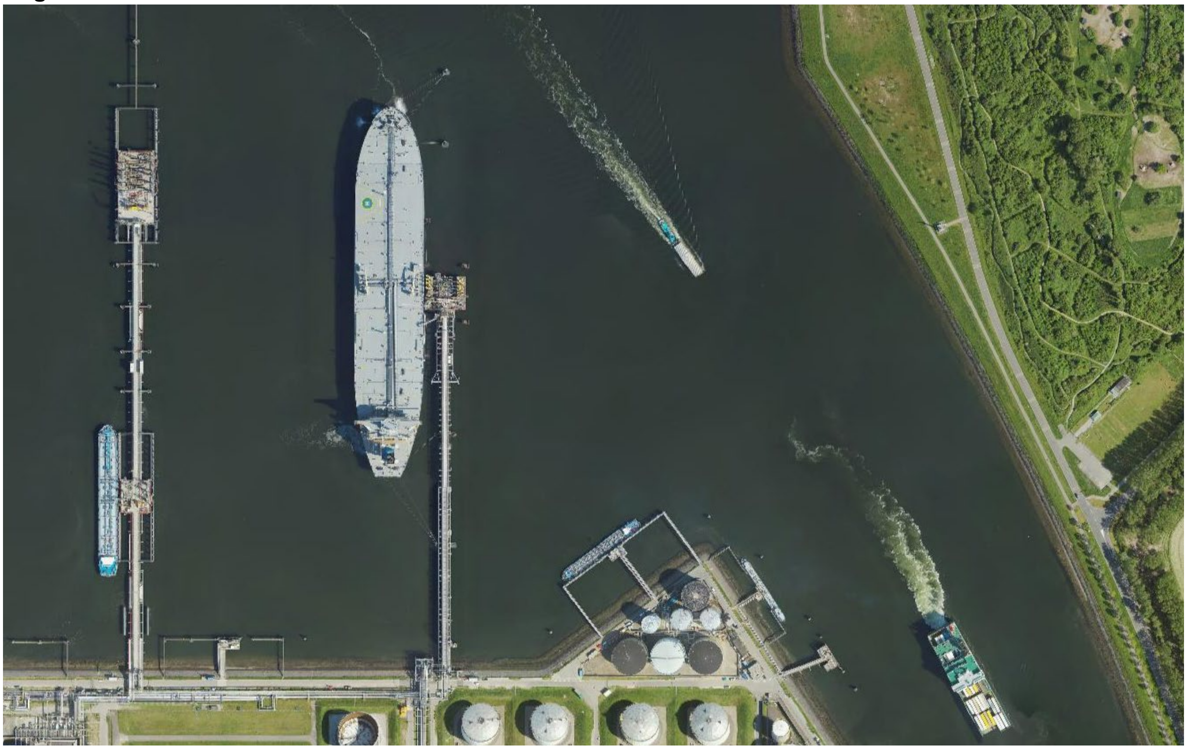

Figure 4-2 Typical finger jetty, Vopak Europoort

Common traits for both types of jetties are that they have the onshore cargo manifold and supporting equipment to facilitate cargo handling on the jetty platforms which leads them to often being rather congested, usually not leaving much room for additional equipment.

In addition, they are often partly or completely covered by a gas hazardous zone as a result of the cargo manifold and associated equipment, meaning all electric utilities need to comply with the ATEX requirements to prevent ignition of any potential gas present.

4.1.4 Vopak Botlek Terminal case

4.1.4.1 Technical

The Vopak terminal for the case is located in the Botlek area of Rotterdam harbour and includes 6 jetties for seagoing vessels, and 3 jetties for inland waterway vessels. Two potential locations have been proposed for the case, seagoing jetty 5 and 6, see Figure 4-3 for an image of what the jetties look like.

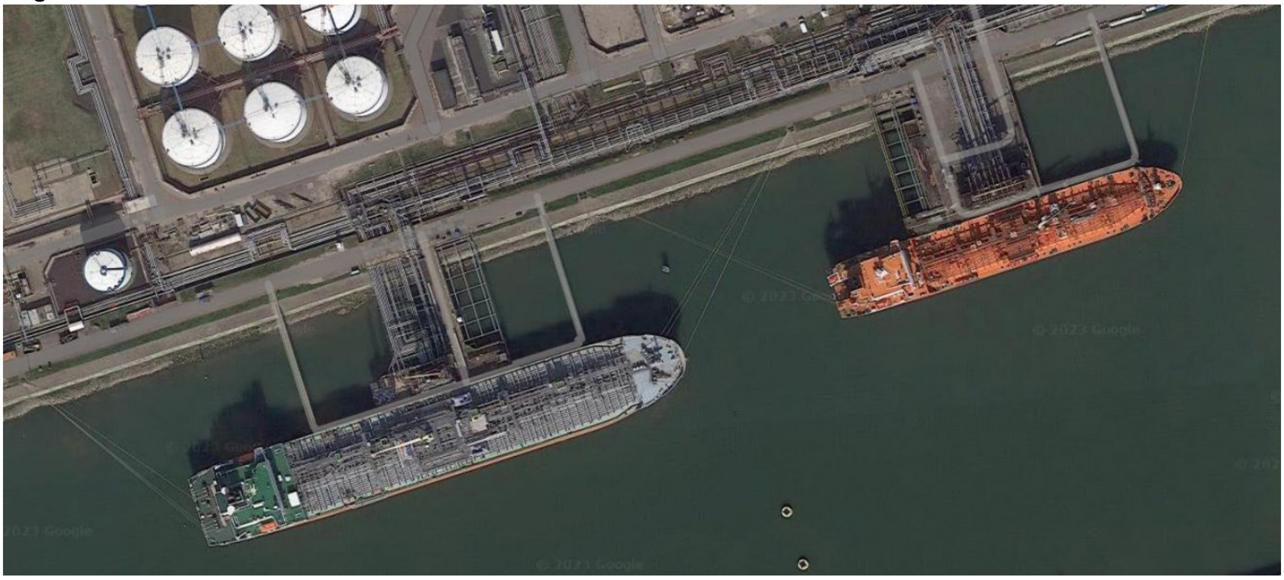

Figure 4-3 Seagoing jetties 5 and 6 at Vopak Botlek terminal

Table 4-1 Specific parameters for the Vopak jetties

Parameter	Seagoing Jetty 5	Seagoing Jetty 6
Berth type	T shape jetty	T shape jetty
Cargo connection type	Hose	Hose / Loading arms
Max. draught [m]	11.89	
Max. LOA [m]	185	205
Max. breadth [m]	32	
Max. DWT [t]	60 000	
Construction	Reinforced Concrete	Reinforced Concrete
Fendering type	Piled steel fendering	Piled steel fendering
Approach speed [m/s]	0.15	0.15
Double banking allowed?	Yes	Yes
Bottom type	Sand/mud	Sand/mud
Hazard area classification	ATEX zone 1 and 2	ATEX zone 1 and 2

Some of the specific parameters for each jetty is listed in Table 4-1, and apart from some difference in the acceptable vessel size parameters they are very similar. Considering the available space for a potential Cable Management System (CMS) both have rather limited space to fit such a system (see Figure 4-3), thus it would be dependent on the area required by a CMS whether it may be fitted or not. Alternatively, a specific CMS could perhaps be omitted, and connection facilitated by the onboard crane.

4.1.4.2 Hazardous area classification

Just like the vessels, terminals are subject to hazardous zones covering areas with a potential for presence of hazardous substances. In the same way as SOLAS is regulating this for ships, ATEX addresses this issue for terminals located in Europe, while different continents may use other but similar directives. The following standards and guidelines provide guidance for the assignment of hazardous zones for terminals:

- IEC/EN 60079-series
- ISGOTT
- EI15 (EI Model code of safe practice Part 15: Area classification code for installations handling flammable fluids)
- ATEX 153 minimum requirements for improving the health and safety protection of workers at risk from an explosive atmosphere

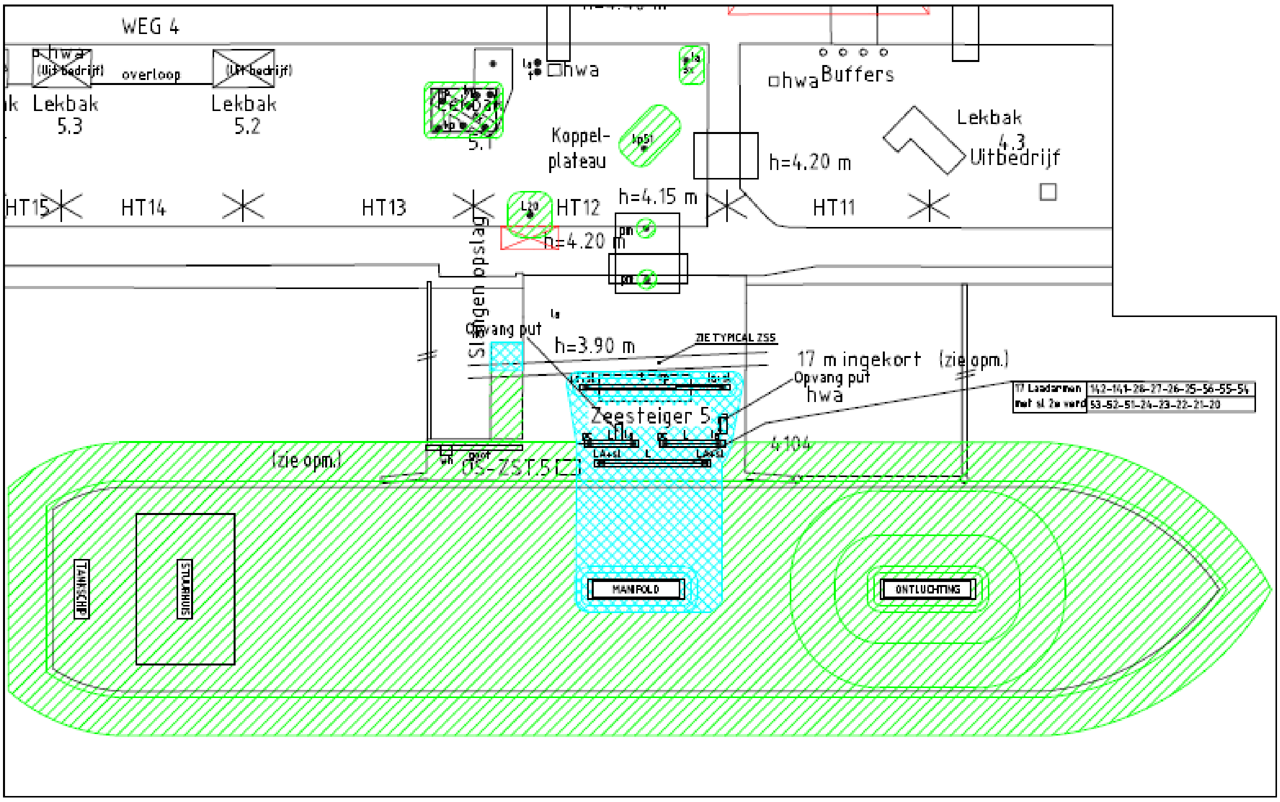

Figure 4-4 Hazardous zones for jetty 5.

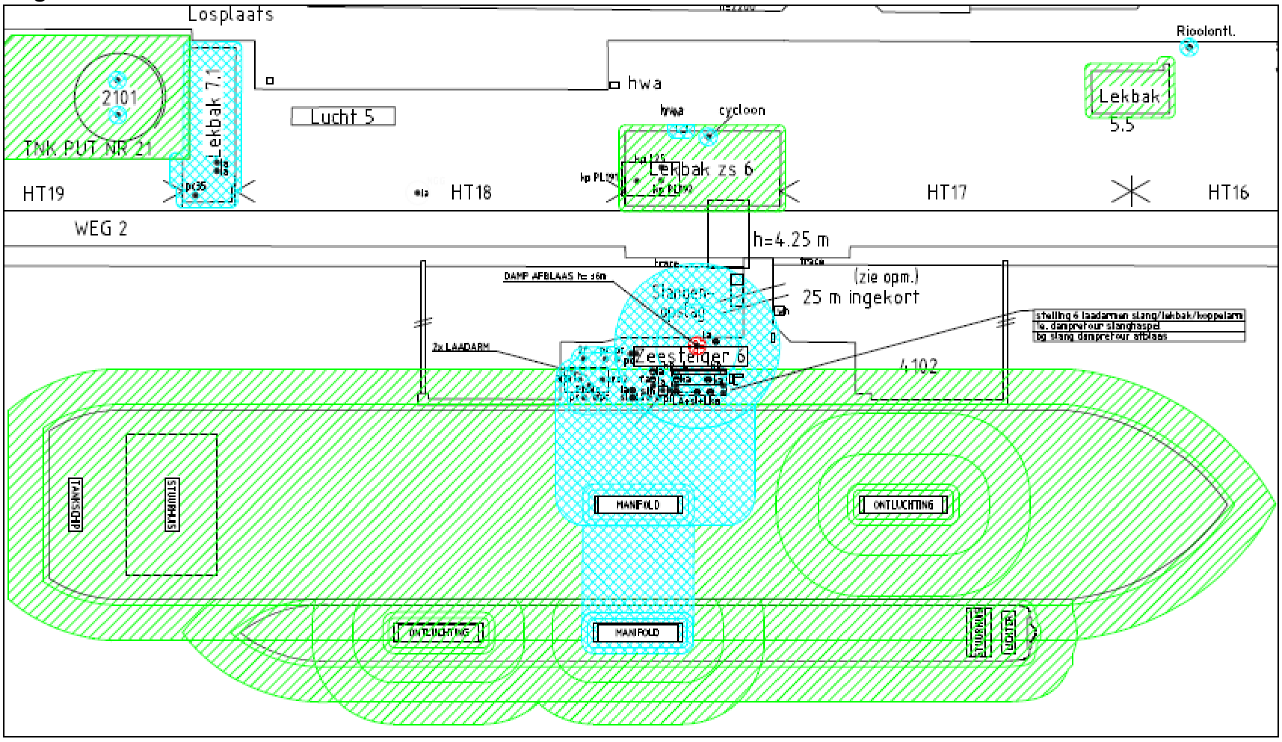

Figure 4-5 Hazardous zones for jetty 6

Hazardous zones according to these guidelines for the jetties in question is illustrated in Figure 4-4 and Figure 4-5 (this illustration also shows an inland waterway vessel laying double banked alongside the tanker).

A huge challenge however is that these standards does not take hazardous zones on board the vessel into account, neither do they refer to SOLAS in this matter.

Thus, when terminals assign hazardous zones, they have to rely on own needs and judgment, and to avoid introducing an ignition source into a potentially hazardous area, terminals usually choose a conservative approach and define a hazardous zone encompassing the entire vessel berthed at the jetty, as shown in the illustrations.

Onshore ATEX zone discrepancy is due to this type of connection not being accounted for in terminal standards or guidelines, and addresses electrical equipment in general rather than specific applications of such equipment. The issue may be considered more of a formal issue rather than an actual safety issue.

4.1.4.3 Mooring arrangements

Depending on the type of OPS connection in question, mooring arrangement may be a factor that could influence and complicate the connection process depending on the configuration of mooring lines.

An example of mooring arrangements depending on size is illustrated in Figure 4-6, which may influence which potential OPS connections that may be applicable for the showcase.

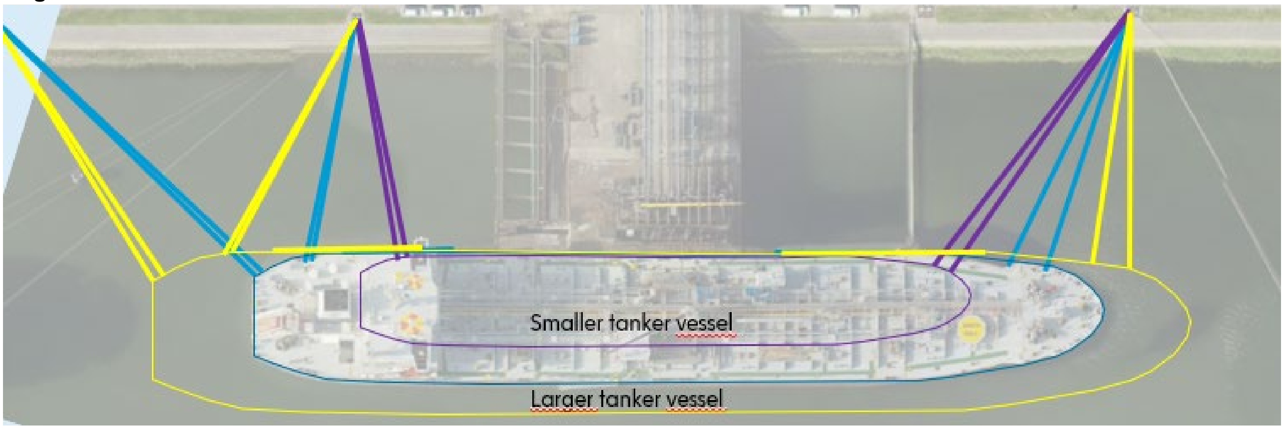

Figure 4-6 Typical mooring arrangements for large (yellow), medium (blue) and small (purple) tanker vessels at Vopak Botlek jetty 5.

4.1.5 Connection between tanker and terminal

Usually, a tanker and a terminal are connected through two main contact points:

1. Moorings, keeping the vessel securely tight to the jetty
2. Cargo handling equipment, hoses or loading arms to enable transfer of cargo

Mooring operation should be completed and the ship secure before any other operations are commencing, this will include potential connection of OPS.

As for the cargo handling, it should obviously be coordinated with in case of a midship connection. If the vessel uses hoses but depend on the ship's crane for connecting OPS as well, these operations can certainly not be carried out simultaneously. Even if the OPS uses a CMS and do not depend on the ship's crane, some interference between connection of cargo handling gear and OPS may occur and should be carefully coordinated.

For a stern OPS connection it will not be expected that there are any interference with cargo gear connection, however, depending on the solution for handling the OPS connection, there may be conflicts with the mooring arrangements which is something that needs to be addressed in selection and design.

4.2 Requirements

A program of requirements for the showcase was produced by Port of Rotterdam, Vopak Botlek and Stolt Tankers. While specific requirements for the showcase were set, potential requirements that could have worldwide applicability was also considered.

The main objective of the OPS is:

> "*Provide electrical power from shore for all power needs of the design vessels in all operational conditions in a safe and efficient manner.*"

In order to do that, it obviously need to have sufficient available power in the grid and supply power to meet the ship's load demand at the applicable frequency, in general this is 60 Hz for the majority of tankers and specified in the requirements. The load demand may vary between ship's, hence a scalable OPS to meet the demand of every ship requesting OPS seems advisable.

Furthermore, the OPS must be able to supply power regardless of size, from coasters up to VLCC in general, but not all jetties would necessarily serve the full range, thus an assessment for specific jetties should be carried out as the range of calling vessels could affect the transfer of the power cable and the transfer application should be designed accordingly and depending on the range there may be a different solution applicable. For the showcase the range would be from 100 m up to 200 m in length, with a max. breadth of up to 32 m.

As vessels normally are moored bow-out at Vopak Botlek, it is specified power that should be supplied at the port side for the showcase, however, in general an OPS system should be designed in a way that enables power supply regardless of the mooring orientation.

It is desirable that the OPS remains functional without restrictions in all foreseeable conditions, specifically weather, waves from passing vessels, tide, draught changes, etc., to the same extent as cargo operations would be expected to continue operating, i.e. at similar requirements as for loading arms/cargo hoses. In any case the master will have discretion as to when OPS shall be disconnected due to external conditions.

The ship should have completed mooring operations prior to connection, other than that OPS should be compatible with foreseeable simultaneous operations, incl. connecting and handling cargo operations.

Lastly, the system should meet applicable safety requirements, allow for emergency departure, comply with applicable standards, allow for sufficient monitoring both on shore and on board, and connection/disconnection within an acceptable timeframe. In addition, the onshore equipment should be readily accessible from shore.

4.3 Scenario Options long list

4.3.1 Introduction

In this section the potential OPS scenario options are presented, with focus on the connection interface between ship and shore. There are aspects on grid power availability and vessel load demand that may be defining for system design on the shore side, however, these are likely to be decisions that to some extent may have to be solved on a case to case basis due to a large difference in frame conditions between terminals, the load demand of calling vessels needs to be accounted for in any case and the infrastructure thus has to be engineered accordingly to cater for the demand of the relevant fleet.

Putting together relevant scenarios involves taking a series of decisions based on the applicable requirements for a specific case, where applicable decisions may have mutual dependencies.

This section aims to highlight such dependencies in the interface between ship and shore, and highlight strengths and weaknesses related to each option. Figure 4-7 attempts to give an indication of the options and how they are tied together, and although perhaps not covering the nuance of every possible option, it still provides an overview of the main options outline and choices that can be made.

Selection may to a large extent also depend on the range of vessels served by the terminal in question and whether the terminal owner aims to serve the full range of tankers with the requirements for flexibility that comes along with it, or if a specific segment of tankers will be targeted which might reduce the need for built-in flexibility in the OPS.

As can be seen from the figure, the decision with the largest implications for the interface infrastructure, is whether to make the connection in the midship area or in the stern of the vessel.

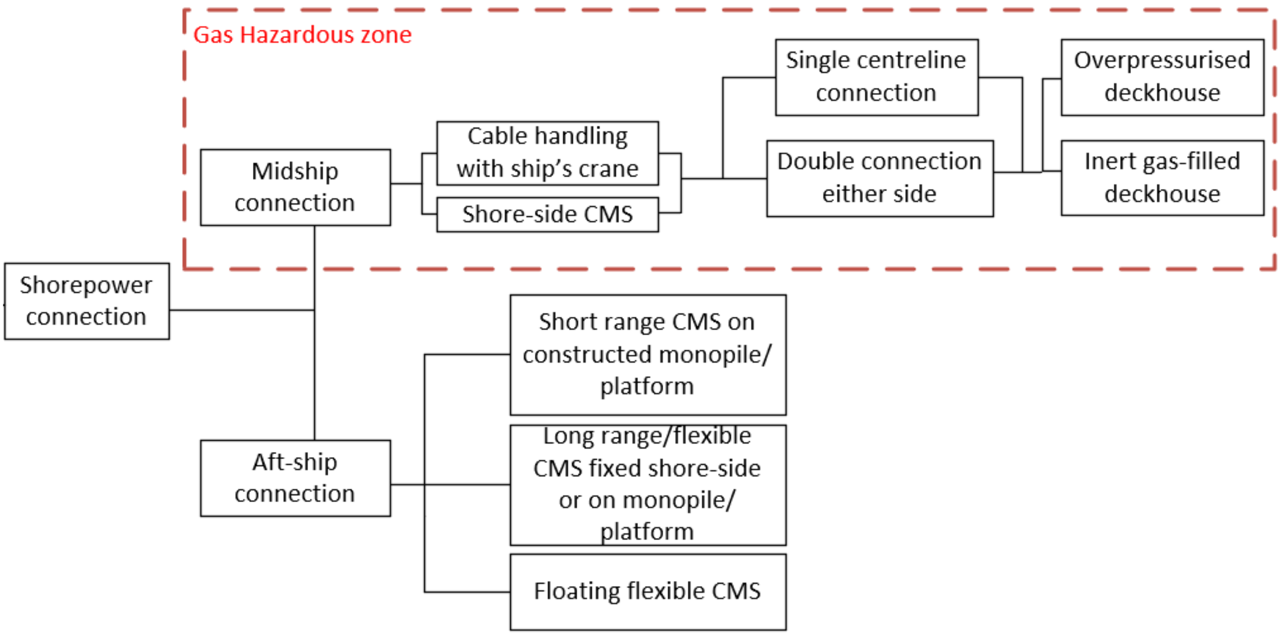

Figure 4-7 Course overview of connection options and interdependencies for OPS ship-shore interface

4.3.2 Long list

The long list of identified scenario options considered includes the following:

1. Midships reel on platform (option A, similar to Gävle & Gothenburg)
2. Midships CMS crane on platform (option B)
3. Midships socket on platform (option C)
4. Stern fender beam (option D)
5. Stern reel platform (option E, similar to Long Beach)
6. Stern socket platform (option F)
7. Stern crane platform (option G)
8. Stern long range CMS crane (option H)
9. Stern crane / reel pontoon (option I)
10. Stern E-buoy (option J)
11. Stern cable bridge (option K)
12. Two CMS cranes connecting in a safe place (option L)

Scenario options are described in the paragraphs following in section 4.3.3.

4.3.3 Description of long list scenario options

4.3.3.1 Midships reel on platform (option A)

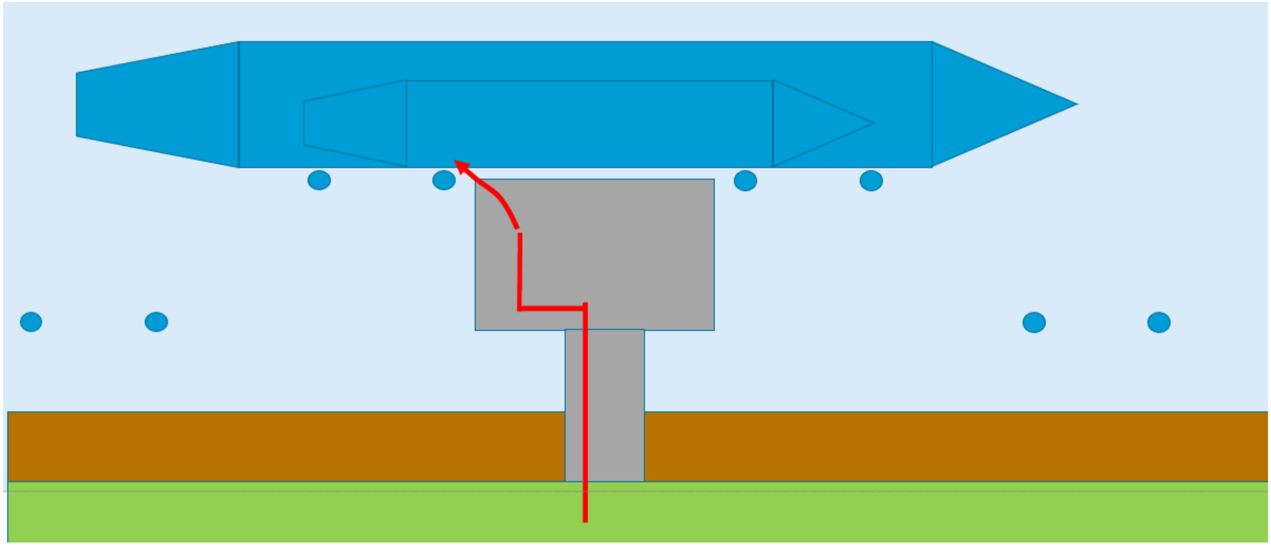

Figure 4-8 Illustration of scenario option A.

This scenario assumes a midships connection with a cable from shore. Ship crane is used to handle the cable, which is fed from a cable reel on the jetty. This scenario is similar to the solution adopted in Gävle and Gothenburg. The socket is assumed put in an inerted (or over-pressurized) deckhouse with a penetration for the cable to facilitate pressurization.

Main advantages:

+ Flexibility for all ship sizes and all types of jetties
+ No investment in additional civil/marine structures or in dedicated CMS crane
+ Less space required for infrastructure on jetty
+ Relatively simple onshore implementation

Main disadvantages:

- Connection in classified hazardous area
- High voltage OPS cable in work area
- Safe cable routing across deck may be challenging
- Manual cable handling on jetty (personnel safety hazard with HV)
- Ship - jetty configuration may sometimes leave cable out of reach for the crane
- Potential conflict with cargo handling operations
- May require increased training/competency level of shore crew
- Lack of certified equipment for operation in hazardous zone

4.3.3.2 Midships CMS crane on platform (option B)

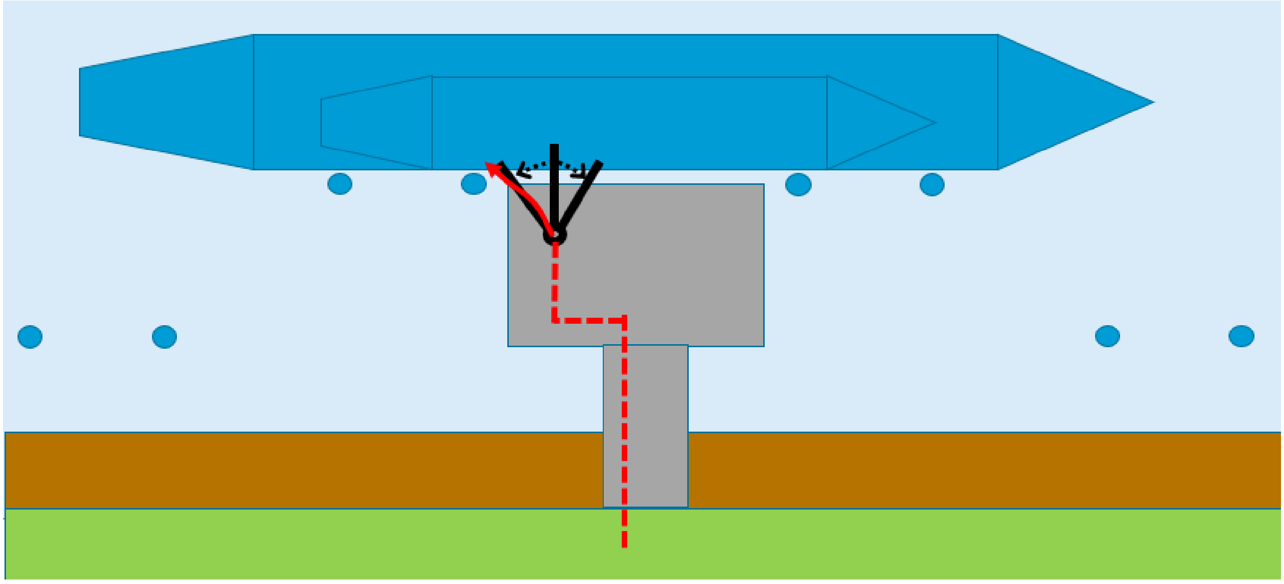

Figure 4-9 Illustration of scenario option B

This scenario is similar to the previous, only instead of the ship's crane, a dedicated CMS crane is put on the jetty for handling of the cable and getting the cable and plug across to the connection point. The socket is assumed put in an inerted (or over-pressurized) deckhouse with a penetration for the cable to facilitate pressurization, while CMS crane is keeping the cable in position.

Main advantages:

- + Flexibility for all ship sizes and all types of jetties
- + Dedicated cable handling which may allow cable to be handled independent of cargo operations
- + No investment in additional civil/marine structures

Main disadvantages:

- Connection in classified hazardous area
- Potentially little available space on jetty to accommodate CMS crane
- Potential reinforcement of jetty structure to handle extra weight of CMS
- Congested midship area, potential interference with onboard equipment when bringing cable across
- Lack of certified equipment for operation in hazardous zone

4.3.3.3 Midships socket on platform (option C)

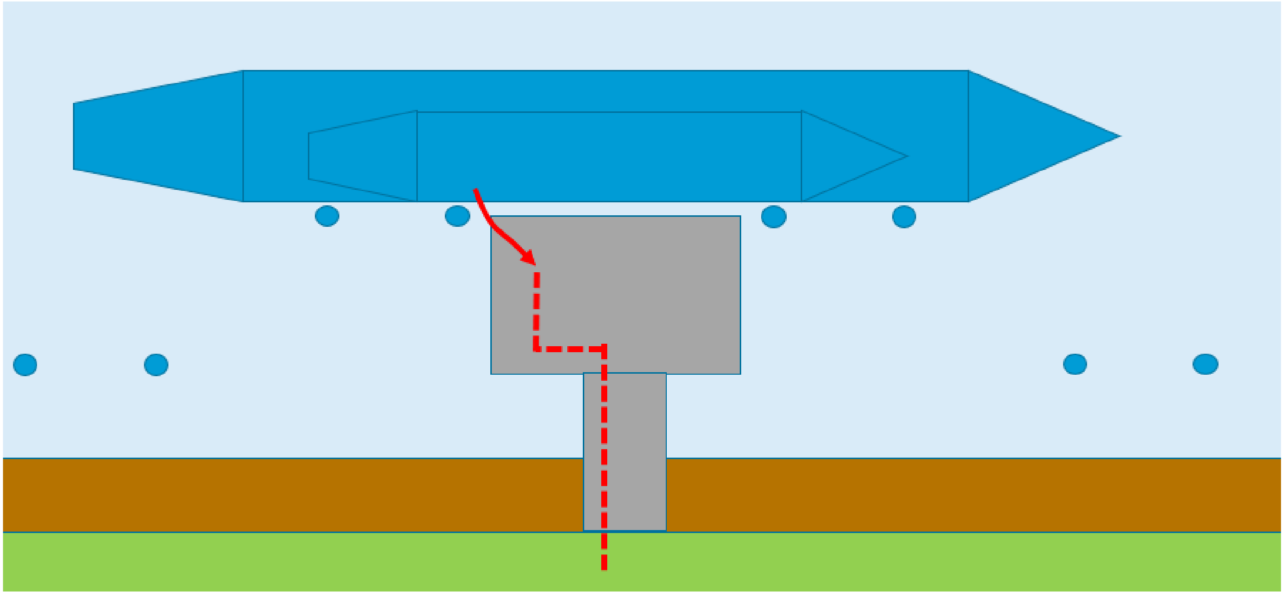

Figure 4-10 Illustration of scenario option C

This scenario is essentially the same as option A, only with the power cable carried on board and transferred from the ship to the jetty for connection. Cable will be handled by the ship's crane.

Main advantages:

- + Flexibility for all ship sizes and all types of jetties
- + No investment in additional civil/marine structures or in dedicated CMS crane
- + Less space required for infrastructure on jetty

Main disadvantages:

- Connection in classified hazardous area
- High voltage OPS cable in work area
- Safe cable routing across deck may be challenging
- Manual cable handling on jetty (personnel safety hazard with HV)
- Potential conflict with cargo handling operations
- Lack of certified equipment for operation in hazardous zone
- Potential lack of qualified onshore personnel (if having to handle HV equipment)

4.3.3.4 Stern fender beam with cable reel (option D)

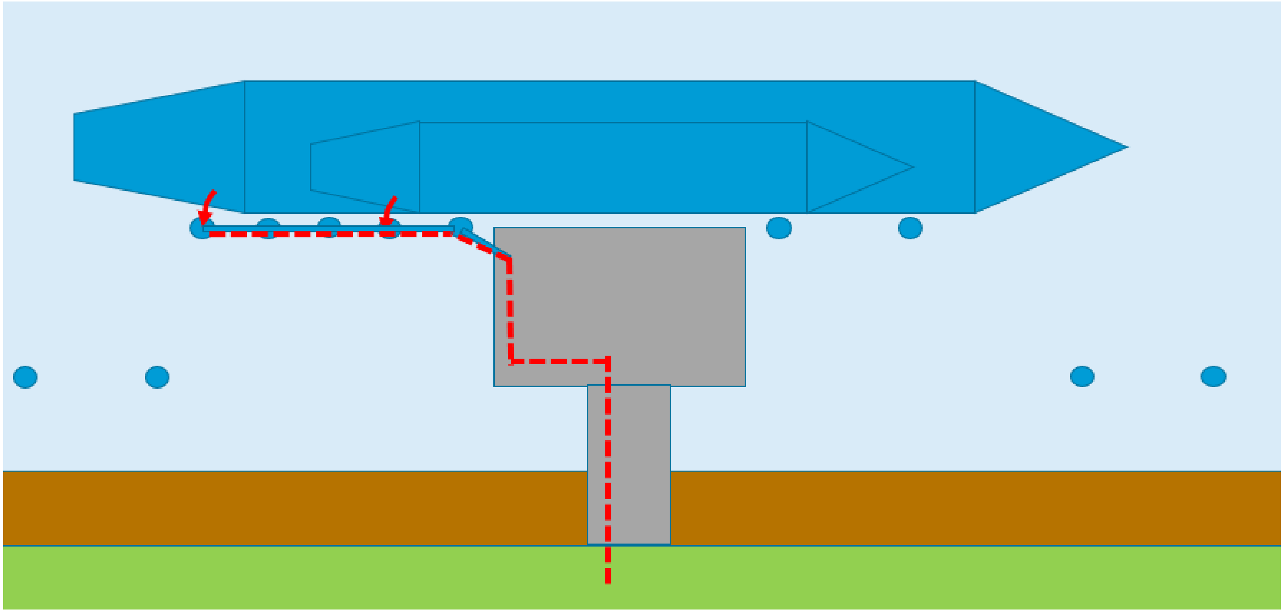

Figure 4-11 Illustration of scenario option D

In this scenario it is envisioned that a dedicated fender structure with walkway is constructed, and potentially several sockets for OPS may be administered to facilitate the range of ship sizes. Cable is carried on board and is being handled using the ship's stern provision crane.

Main advantages:

- + Potentially short power cable connection
- + Likely to be handled outside of the ship's hazardous zone
- + Cable handling independent of cargo operations
- + Shorter power cable for connection
- + May be adapted to comply with existing standard IEC/IEEE 80005-1.

Main disadvantages:

- Exposed socket/connection
- Investment in civil structure required
- Increased investment in OPS technical equipment (switchgear) to avoid daisy chaining
- Complicated manual cable handling on jetty
- Ship - jetty configuration may sometimes leave cable out of reach for the crane (if located on opposite side)
- OPS equipment may be subject to damage during maneuvering and mooring operations.
- Every ship needs to carry own cables

4.3.3.5 Stern reel platform (option E, similar to Long Beach)

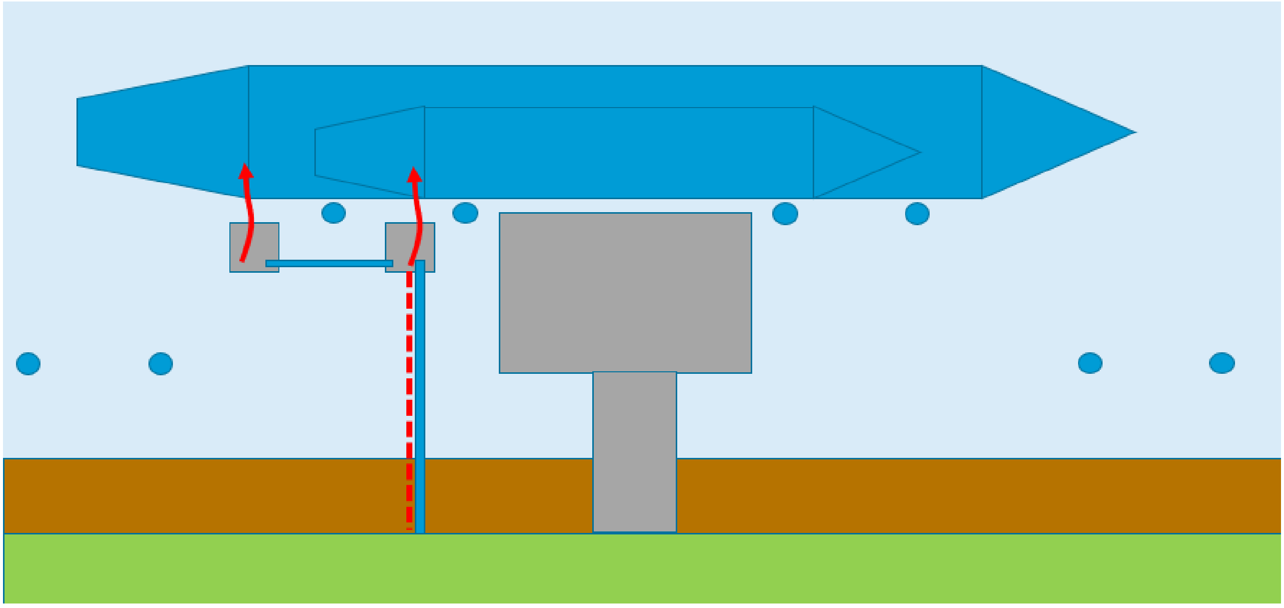

Figure 4-12 Illustration of scenario option C

In this scenario option it is assumed that platforms to enable stern connection from cable reels on the platform will be constructed, with cable handled by the ship's provision crane to be brought from shore for connection on board.

Main advantages:

+ Likely to be handled outside of the hazardous zones
+ Easier retrofit option on board
+ Cable handling independent of cargo operations
+ May be adapted to comply with existing standard IEC/IEEE 80005-1.

Main disadvantages:

- Platforms exposed to impact from ship when maneuvering alongside; substantial construction required
- OPS platform/equipment may be subject to damage during maneuvering and mooring operations
- Investment in civil structure required
- Potential incompatibility with certain ship sizes depending on distance between platforms
- Cannot daisychain onshore cables, larger investment in switchgear required

4.3.3.6 Stern socket platform (option F)

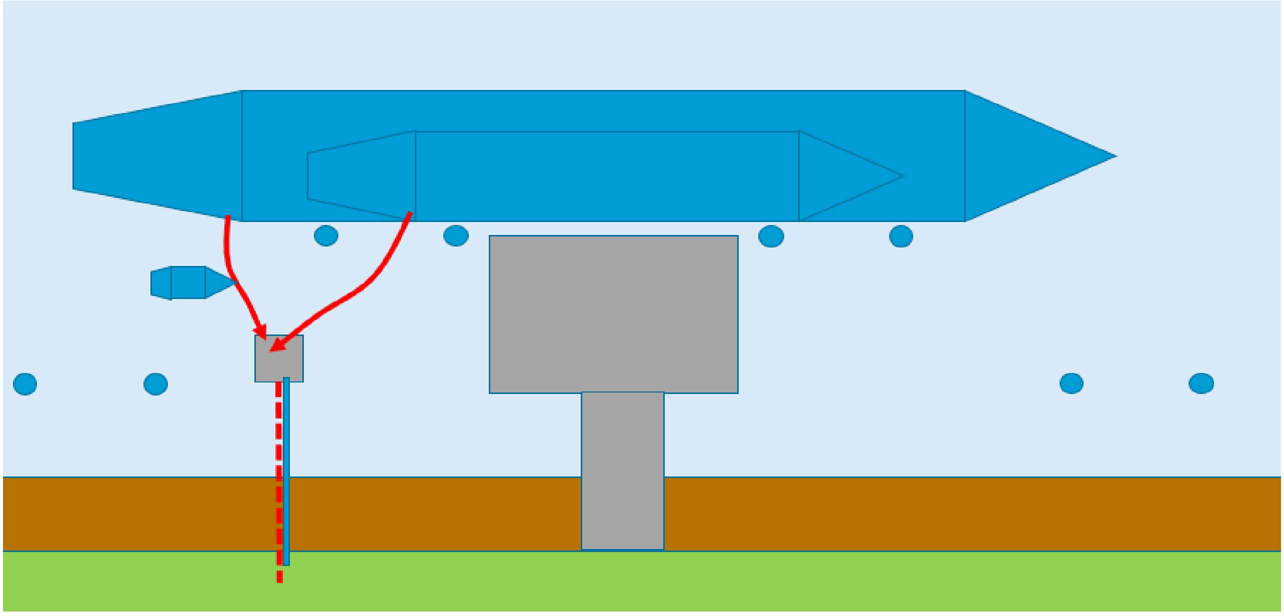

Figure 4-13 Illustration of scenario option F

Scenario option entails power cable being carried on board, with linesmen picking up the power cable and bring it across to the OPS platform.

Main advantages:

- + Likely to be handled outside of the hazardous zones
- + Cable handling independent of cargo operations
- + May be adapted to comply with existing standard IEC/IEEE 80005-1.

Main disadvantages:

- Need to rely on additional personnel for cable handling, likely without HV handling experience
- Every ship needs to carry own cables
- Outdoor socket/ connection
- Investment in civil structure required

4.3.3.7 Stern crane platform (option G)

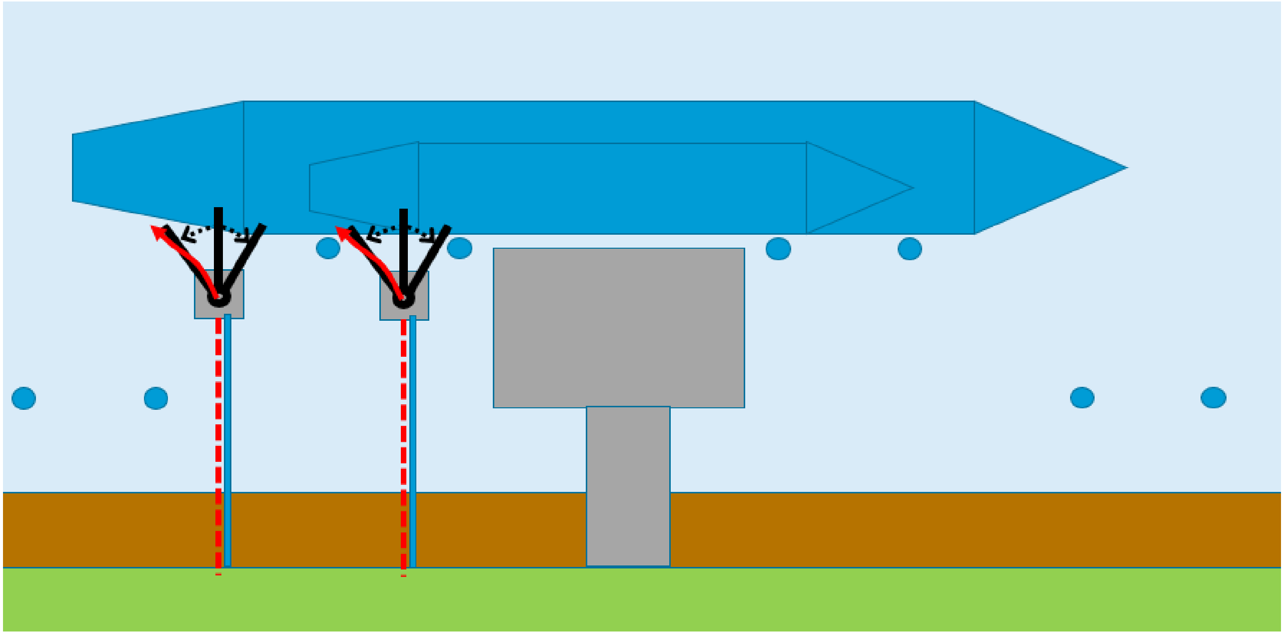

Figure 4-14 Illustration of scenario option G

In this scenario option it is assumed that platforms to enable Stern connection will be constructed (similar to option E), and CMS cranes will be utilized to bring the cable on board for connection.

Main advantages:

- + Likely to be handled outside of the hazardous zones
- + Cable handling independent of cargo operations
- + May be adapted to comply with existing standard IEC/IEEE 80005-1
- + Easier retrofit option on board

Main disadvantages:

- Investment in civil structures and CMS required, at least two platforms may be required
- Potential incompatibility with certain ships/sizes depending on distance between platforms, crane reach, and which side of vessel OPS connection is located
- OPS equipment may be subject to damage during maneuvering and mooring operations
- Cannot daisychain onshore cables, larger investment in switchgear and CMS required

4.3.3.8 Stern long range CMS crane (option H)

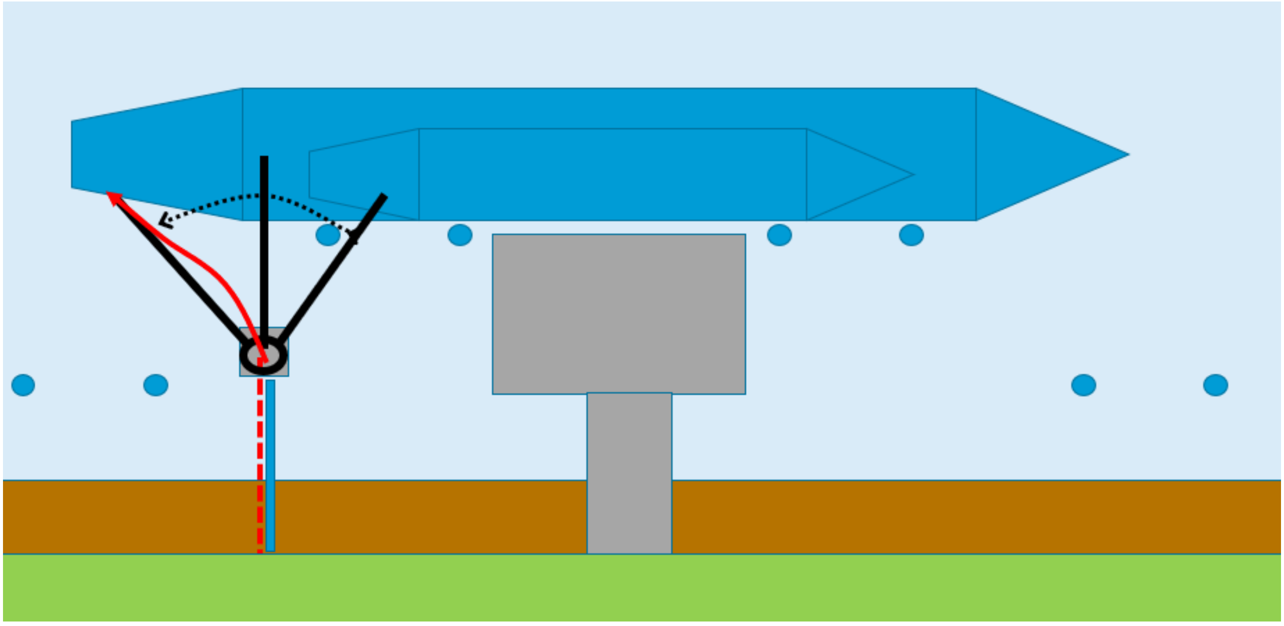

Figure 4-15 Illustration of scenario option H

This scenario is similar to option G, in that a platform, monopile or similar construction is erected, but instead of multiple constructions it only has a single construction with a long range CMS crane on top to get the cable across for a stern connection on the ship.

Main advantages:

- + Flexibility for all ship sizes
- + Likely to be handled outside of the ship's hazardous zone
- + Cable handling independent of cargo operations
- + May be adapted to comply with existing standard IEC/IEEE 80005-1
- + Easier retrofit option on board

Main disadvantages:

- Potential incompatibility with certain ships depending on which side of vessel OPS connection is located
- Investment in civil structure and CMS required

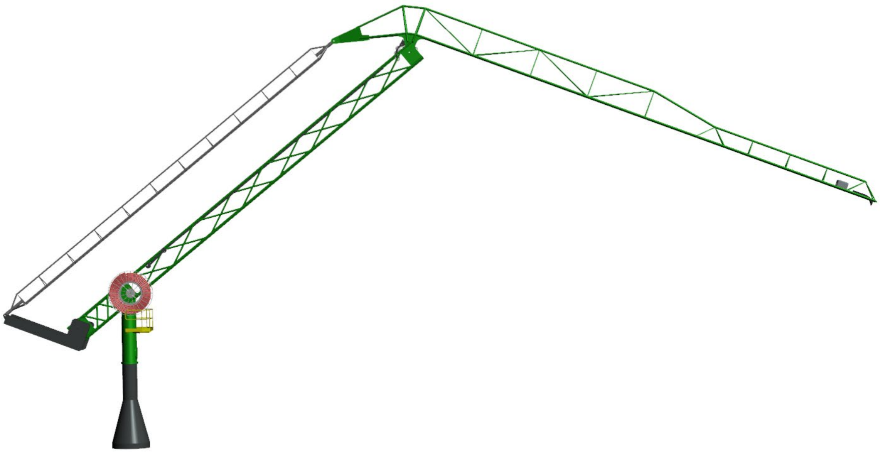

Figure 4-16 Potential solution for long-reach CMS crane (Credit: Eager.One)

4.3.3.9 Stern crane / reel pontoon (option I)

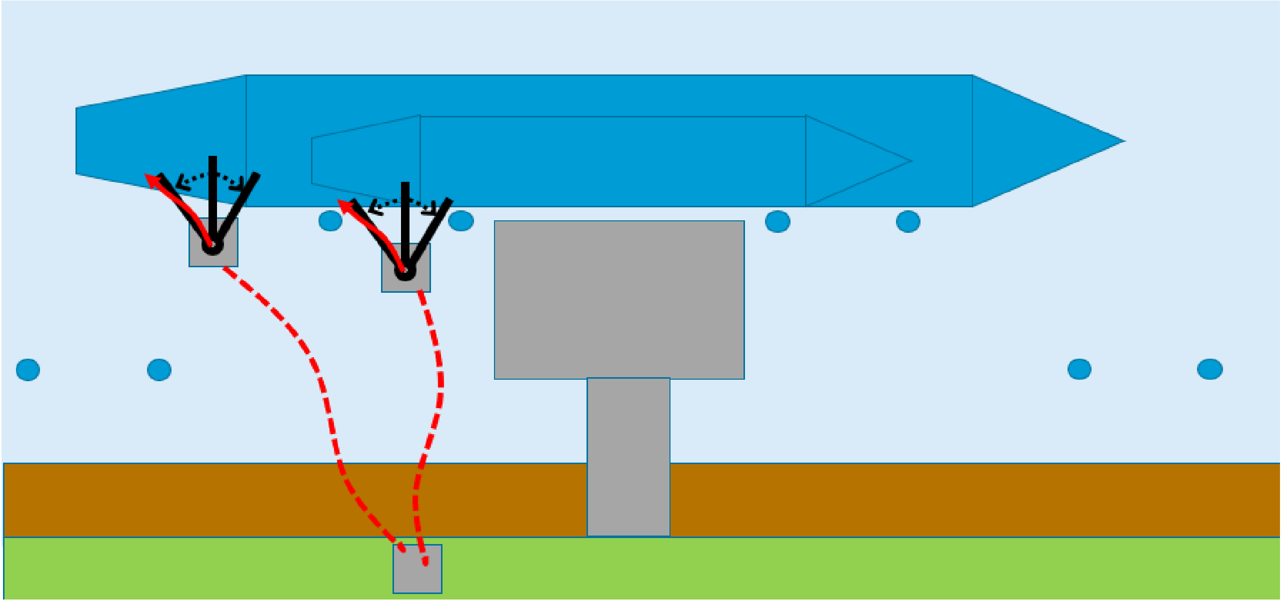

Figure 4-17 Illustration of scenario option I. (Please note there are not two pontoons, just an attempt to illustrate the flexibility to serve a range of ship sizes)

This scenario assumes a floating solution where a pontoon with either a reel or CMS crane is floated out to the ship, bringing a shoreside cable across to make a stern connection onboard. In a reel scenario the cable will be handled by the ship's provision crane.

Main advantages:

- + Flexibility for all ship sizes
- + Likely to be handled outside of the ship's hazardous zone
- + Cable handling independent of cargo operations
- + May be adapted to comply with existing standard IEC/IEEE 80005-1
- + Easier retrofit option on board

Main disadvantages:

- High maintenance solution
- Potentially unavailable during maintenance
- Potential conflict with mooring arrangement
- Investment in civil structure required
- Cumbersome handling; unclear how to maneuver pontoon, may require external assistance to enable connection of different ship sizes
- Pontoon may require additional means of securing to prevent relative movement once connected.

4.3.3.10 Stern E-buoy (option J)

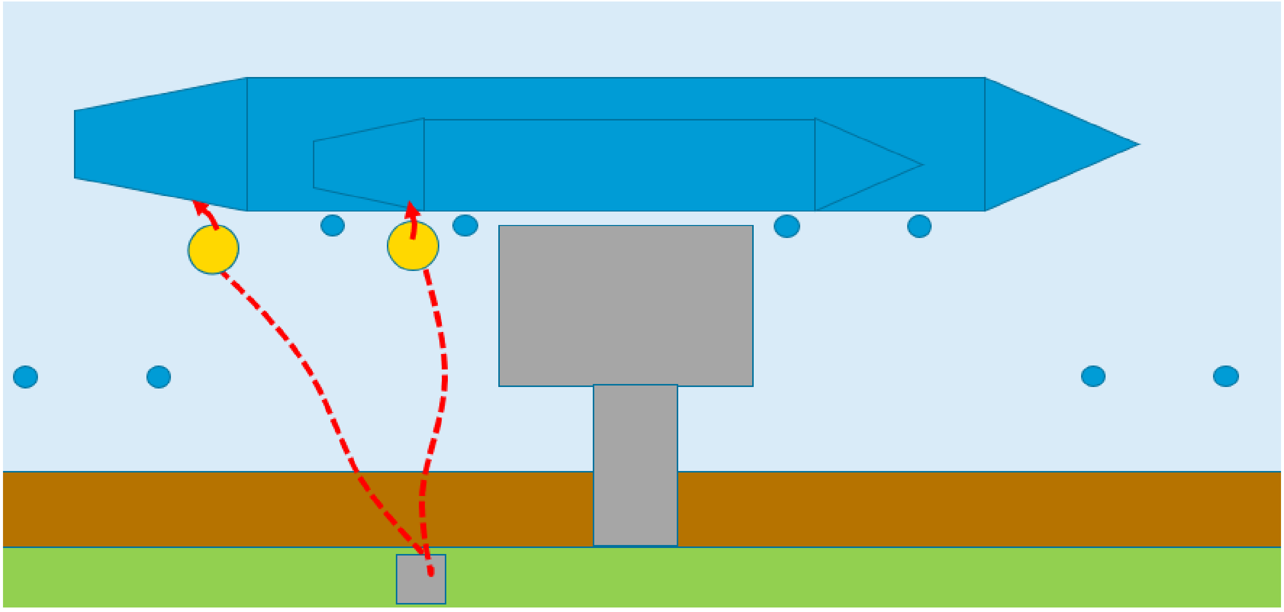

Figure 4-18 Illustration of scenario option J. (Please note there are not two buoys, just an attempt to illustrate the flexibility to serve a range of ship sizes)

This scenario is similar to option I, only it utilizes a specific product, the e-buoy, instead of a generic pontoon solution having to be developed and produced.

Main advantages:

+ Flexibility for all ship sizes
+ Likely to be handled outside of the ship's hazardous zone
+ Cable handling independent of cargo operations
+ May be adapted to comply with existing standard IEC/IEEE 80005-1
+ Easier retrofit option on board

Main disadvantages:

- High maintenance solution
- Potentially unavailable during maintenance
- Potential conflict with mooring arrangement
- Investment in civil structure required
- Potentially more exposed to a corrosive environment
- Cumbersome handling; E-buoys are normally stationary, may require external assistance to enable connection of different ship sizes, either by moving e-buoy or by fetching and transferring the cable
- E-buoy will require means of securing to prevent relative movement once connected

4.3.3.11 Stern cable bridge (option K)

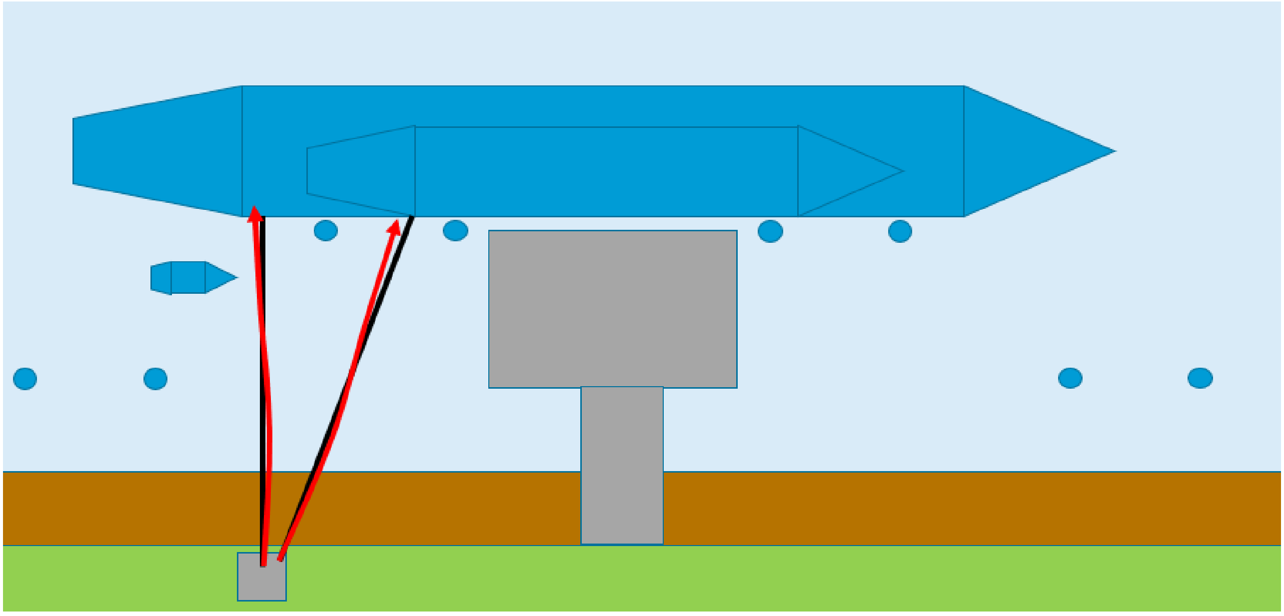

Figure 4-19 Illustration of scenario option K.

This scenario assumes that a steel cable is brought ashore from the ship by linesmen. The power cable is then brought to the ship suspended on the steel cable by a "crawler".

Figure 4-20 Cable suspension

Main advantages:

- + Flexibility for all ship sizes
- + Likely to be handled outside of the ship's hazardous zone
- + Cable handling independent of cargo operations
- + May be adapted to comply with existing standard IEC/IEEE 80005-1

Main disadvantages:

- Power cable directly exposed to external influence between ship and shore (tugs/barges, etc.)
- Potential conflict with mooring arrangement
- Will require additional equipment on board (cable reel for steel cable)
- Complicated mechanical construction with movable
- Cable more exposed to damage and elemental wear in stored position
- Many degrees of freedom to enable solution (steel cable, hanger booms, power cable) may render it vulnerable to complications.
- Applicable cable may not be available

4.3.3.12 Onshore and onboard CMS cranes connecting in a safe place (option L)

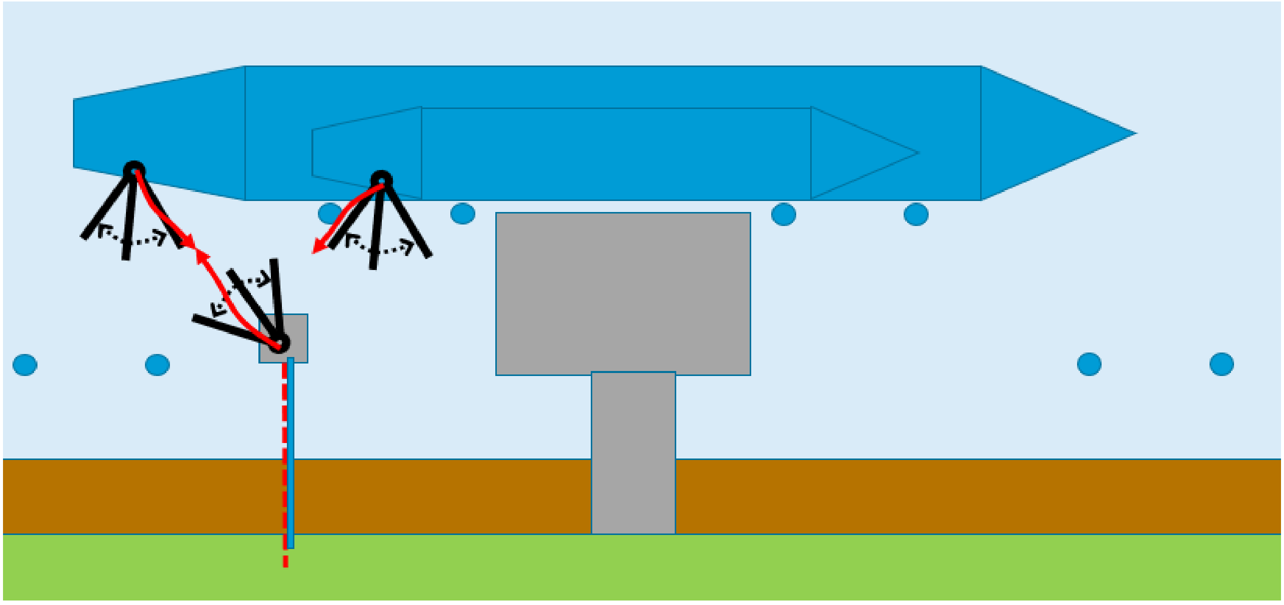

Figure 4-21 Illustration of scenario option L.

This scenario assumes having the socket in a safe place either onshore or over water. Intention is to solve some of the safety issues related to the hazardous area. The idea is to have an arm (being conduit with cable and socket within) from the ship, swivelling out to a safe place above water or a safe part of the jetty. Then an arm from the jetty would meet that socket in the designated safe place to make the connection.

Main advantages:

- + Likely to be handled outside of the hazardous zones
- + Cable handling independent of cargo operations
- + May be adapted to comply with existing standard IEC/IEEE 80005-1
- + Easier retrofit option on board

Main disadvantages:

- Investment in civil structure required
- Potential incompatibility with certain ships/sizes depending on distance between platforms, crane reach, and which side of vessel OPS connection is located
- OPS equipment may be subject to damage during maneuvering and mooring operations

4.4 Considerations

4.4.1 Midship OPS connection options

It may seem there is an industry push to investigate the midship connection option as a result of the general jetty layout for tanker terminal jetties having a limited piece of length interfacing with the ship when alongside, as creating new constructions to enable new infrastructure potentially represents a sizable investment compared to utilizing existing area. Thus, a midship connection is also the option that has the highest attention due to its apparent advantage in flexibility.

The general idea with a midship connection is that the connection would be in the same area for all vessels regardless of its size, thus less flexibility is required for handling of the shore-power cable. In theory this would enable easier standardization of a shore power system through enabling a common reference point across all vessel sizes in an area that usually will be alongside irrespective of the type and shape of jetty.

As pointed out in the Exploration Summary, there are however still a few challenges involved.

- Alignment of location:
  - Common reference point for standardization would be the cargo manifold
    - Not all jetties will be able to facilitate shore-side OPS infrastructure in the same location with reference to the manifold, i.e. it could potentially be located on both sides of the shoreside cargo manifold
    - Not all vessels will be able to facilitate shipboard infrastructure in the same location with reference to the manifold, i.e. it could potentially be located either forward or aft of the onboard cargo manifold

As a result, a midship connection may require more adaptations and flexibility from infrastructure than initially thought, and a compatibility issue between vessels and terminals could easily be experienced depending on the compatibility between the onboard and jetty layout. Considering the width of a VLCC could be up to 60 m with a connection located approximately along centreline of vessel, a CMS crane which should be able to extend to the connection point could potentially need to have a horizontal range of 40-50 m with maximal fore-aft misalignment between ship and shore. Height of the CMS crane should be able to accommodate a sufficient height above deck for an unloaded vessel which could be up to 15-20 m measured from the jetty for the largest vessels. The compatibility challenge may also lead to potential interference with cargo operations, or the other way around, in case a problem with either of the systems arises and both are in close vicinity to each other or if they have crossing piping or cabling.

Standardization should ideally help prevent such compatibility issues from occurring, but for OPS to have an impact on reduction of at berth-emissions which does not only apply to new constructions (of both vessels and terminals/jetties), a large amount of retrofits will be a requirement for success. With the manifold area already being a congested area both on board and on the jetty, retrofits are not necessarily an easy task when in addition the hazardous nature of these areas are also taken into account.

Both on the jetty and on board the applicable area to locate the OPS connection equipment is an already congested area, thus a lot of vessels and jetties will not be able to facilitate retrofitting of OPS infrastructure in a standardized position with reference to the manifold.

Furthermore, a midship solution will be reliant on a several external support systems:

- Overpressure or inert gas system to supply connection deckhouse
- Monitoring and control systems
  - Overpressure/inert gas parameters
  - CMS systems (cable tension, draught and/or tidal corrections)

An increasing number of support systems means increasing the number of things that may go wrong, and an error in the support system is likely leading to OPS downtime given strict safety requirements in hazardous zones. Support system error does not automatically lead to a hazardous event in itself, but it may very well increase the likelihood to an unacceptable level if not rectified considering the potential consequences that may happen within a hazardous area.

4.4.2 Stern OPS connection options

A stern OPS connection will in theory set higher demands to the flexibility of the CMS in terms of accommodating the range of ship sizes that may be experienced by tanker terminal jetties. Still, a stern connection has a great advantage in the fact that it will be located outside of a ship's hazardous area which enables a much simpler implementation of onboard connection and significantly reduces the risk for further escalation beyond the OPS system in case anything goes wrong.

Another benefit compared to a midship connection is that a stern connection enables use of the existing IEC/IEEE 80005-1 standard on high voltage shore power connections (HVSC), which potentially may simplify and accelerate the process to implement and adopt OPS for tankers.

There is however a challenge on compatibility similar to the one for a midship connection, which relates to the onshore CMS being located on the opposite side of the ship's connection point. This is an issue that can not be easily standardized, as which side of the ship is alongside may differ between jetties and depend on available space on board as well in case of retrofits. Ideally the onboard connection point will be located such that it ensures the best possible accessibility for the CMS regardless of which side is alongside.

4.4.3 Considerations on selection of shortlist options

This section discusses implications of the different options and makes a comparison between them. Selection is done partly by process of elimination of options that are considered less viable, and partly from a general judgement. Furthermore, it has been attempted to keep a balance between both case specific and general perspectives when evaluating the options.

4.4.3.1 Midship connection options

Only three options are included when it comes to a midship scenario for OPS, which basically constitutes part of the reason for exploring a midship OPS connection as discussed in section 4.4.1. There is a lot of similarities with option A and option B, the main differentiator being that option B includes a CMS.

Option C is basically the same as option A, but "in reverse", meaning that the cable reel is carried on board and the cable is lifted onto the jetty by the ship's crane and connected to a socket. Carrying the cable reel onboard however, would further complicate potential retrofit of OPS to existing tankers, as it would require space in the midship area for a cable reel that needs to include tenfold of meters of cable, protective housing (e.g. overpressurized deckhouse), switchgear, thus it will likely require even more space than an option where the deckhouse only protects a connection (plug & socket) and switchgear, thus option C is considered a less viable alternative than option A. This aspect also makes it impractical for newbuilds as well.

Given that a vessel has already been built according to the option A scenario strongly suggests this scenario should be covered as a reference case to explore its performance also in the Botlek-Breland case.

As a counterweight to the extensive manual handling involved in option A, option B should also be assessed for benchmarking of the midship option, as an option with CMS crane in general should be preferred to one without for several reasons:

- Safety (HSE, amount of manual handling, etc.)
- Ease of operation (onshore manpower needed, competency level, cable routing onboard, etc
- Potential interference with other operations (typically cargo ops).

4.4.3.2 Stern connection options

A stern connection allows for quite a few more alternatives, and the list provided in chapter 4.3 is not necessarily exhaustive, there may be countless variations of potential solutions for a stern connection. However, the main options should be represented in that list. There may of course be location specific conditions which means the considerations made in this section may apply to a lesser extent than for the Botlek-Breland case and is probably best dealt with on a case-by-case basis, however, for a majority of cases it is likely that the considerations will apply.

Similar to the considerations mentioned in section 4.4.3.1, an option with cables stored onboard is undesirable due to the share bulk of it and the fact it will be exposed to a far harsher environment than on shore, and an option with CMS crane is generally preferred over an option without, and that is no difference between the midship and the stern connection. Applying these considerations means that options D, E and F should be eliminated as less attractive options for a stern OPS connection.

Although likely to be less bulky than a cable reel, option K still involves some sort of winch for the steel cable to be installed on board, most likely the option would require a steel cable winch be installed on both sides of the vessel to accommodate berthing on either side on different terminals. The steel cable would have to be sturdy enough to take some level of tension not to drop into the water, as it is extended to shore across water like a mooring rope and in addition must bear the weight of the power cable as well. The crawler then brings the cable across to the ship with an envisioned solution similar to an overhead gantry crane. However, such cranes normally use flat power cables, not readily available to high voltage applications, and are usually suspended from a fixed boom that the crane travels back and forth on which may not work as easily with a steel cable. A system with a series of rigid booms where the power cable is suspended beneath, hinged together in some way and pulled out by the crawler allowing the OPS cable to slide below the rigid booms and extend out to the ship, however, then it starts being a complicated system with several mechanical systems relying on each other while allowing independent movement, thus increasing the likelihood of jamming. The option will be reliant on external assistance to bring the steel cable to shore, and there is also a possibility it may interfere with the moorings. Overall, this option is assessed not to fulfil criteria in a satisfactory manner.

A couple of options involve floating solution for CMS, with the intention that it will allow for almost infinite flexibility in terms of ship size. However, it is not fully clear how these will be handled. If we consider option J, this is an already existing product used in offshore applications as a permanently moored installation where the offshore supply vessels pick up and connect the cable. This would however be cumbersome for a much less manoeuvrable tanker in what often are narrow channels, meaning the vessel will need outside assistance on the water, either to connect the vessel crane to pick up the cable or bring the cable into range for the crane to pick it up, or to manoeuvre the buoy into range for the crane to pick up the cable. If the connection operation requires any kind of manoeuvring this also runs the risk of interfering with the moorings. A similar consideration is also valid for option I. If the buoy or pontoon is envisioned to be a self-propelled unit to enable manoeuvring to the ship's side for connection, that initiates a much more rigid regulatory regime when it comes to construction and regular inspection of the unit, which may influence the availability. In addition option J being a proprietary solution is likely to require external assistance when it comes to maintenance and troubleshooting. On a case specific note the area and depth for manoeuvring such a unit renders it an impractical option. An overall assessment thus indicates that options I and J are less feasible options.

Option L is an appealing idea from a safety point of view to enable connection in a safe area above water without any manual handling of the cable whatsoever. There are however some less appealing implications with the option as well. There would be some potential challenges in coordinating compensation systems, e.g. cable tension, between the onshore and onboard CMS. The connection procedure will also be a challenge in terms of alignment between the CMS cranes to connect, possibly doubling the potential for connection problems, notwithstanding coordinating connection protocols across the industry for such a solution. Having a CMS both on board and onshore also indicates this may be an expensive solution, worst case it will also require a CMS on both sides of the vessel to enable connection at all terminal independent of which side is alongside the jetty. Hence, option L is not assessed to be an attractive solution neither for the showcase or on a global level.

The options left to consider are then options G and H, which bear some similarities to each other in that they both are based on a platform to be constructed in the water between the vessel and the shore and have a CMS crane on top to facilitate the cable to be brought onboard for connection. There is however a difference in that option G will likely require two or more sets of everything; platforms, CMS', switchgear, cables, etc., which calls for a more expensive solution. In addition the shorter reach of the CMS' in option G may expose the platforms and OPS equipment to impact and damage during manoeuvring and mooring operations, increasing the necessary robustness of the platforms and equipment. The long reach necessary for option H also means that the platform in this option is likely to need reinforcement to support the CMS crane, as well as the long reach increasing cost. Still, option H appears somewhat more attractive than option G in that it allows a greater distance to the hazardous zones, hence increasing safety margin, and allowing for certain scalability and tailoring to the needs of individual jetties and the range of ship sizes in the fleet calling there.

Option H is therefore selected to proceed for further assessment and an alternative to the midship options selected for further assessment in section 4.4.3.1.

4.5 Scenario short list

This subchapter gives a bit more detail on how the configuration of each of the shortlisted options are envisioned, and attempt to explore the scenarios they represent in the Breland-Botlek case.

There are some preconditions that are assumed for the ship-shore interface options discussed in chapters 4.3 and 4.4:

- Onshore infrastructure up to the ship-shore interface (grid connections, substations, cable routings etc.) will be the same regardless of the three scenario options.
- Voltage and frequency is a parameter independent of ship-shore interface that needs to be facilitated prior to the interface connection.
- Interface is assumed to be designed to enable whatever is decided to be the appropriate voltage level of either 6.6 kV or 11 kV
- CMS is designed in a way that enables handling whatever is decided to become determined between one or two power cables to meet vessels current and future load demand

4.5.1 Scenario 1 - Midships reel on platform (option A)

This scenario may be considered as a reference case, as discussed in section 4.4.3.1, considering there is already a vessel with this option that have been constructed, as well as supporting jetty infrastructure at selected jetties to serve this option, that are currently being under construction.

Configuration:

- Cable reel on jetty, with cable length sufficient to allow for some margin in draught increase, safe cable routing on board, ship-shore alignment
- Manual handling by shore personnel to make cable from cable reel available (if necessary) to be picked up by ship's crane. On shore side cable is permanently connected.
- Cable lifted on board and connected by ship's personnel prior to commencing cargo connections
- Cable permanently connected to shore side, as extension cables are not allowed according to existing standard, but with the ability to de-energize cable from a safe location on shore.
- Connection point on board inside a simple one-compartment deckhouse within hazardous area, enabled to be inerted or over-pressurized with air, and containing necessary switchgear (similar to what appears constructed for existing vessel with this solution).
- Currently no EX/ATEX-proof plug and socket are available on the market according to the team's investigations
- Uncertainty whether flexible power cables that fit the requirements for hazardous areas will become readily available according to specifications in standards

4.5.2 Scenario 2 - Midships CMS crane on platform (option B)

This scenario is similar to scenario 1, with some differences in configuration compared to scenario 1 when it comes to cable handling:

- Power cable fully handled by CMS with cable reel and crane from shore side, i.e. no manual handling from shore side personnel.
- CMS operated by shore personnel
- Crane reach able to bring cable across next to onboard connection point to facilitate easy handling and connection on board.

- Crane may possibly be constructed either with telescopic boom or something similar to a loading arm. Other designs fit for purpose may also be considered.

4.5.3 Scenario 3 - Stern long range CMS crane (option H)

The main difference between scenario 2 and scenario 3 is that both onshore and onboard the equipment is moved outside the hazardous area, leading to the CMS crane needing a larger reach than what is necessary in scenario 2.

- Long range CMS with reel and crane, likely in a loading arm-like design
- Crane able to bring cable across to the most suitable area of the vessel, as close as possible to the connection point on board.
- CMS able to pay out sufficient length of cable to reach socket, even if it is located on the opposite side of the ship
- Cable brought from crane to connection point and connected by ship’s crew.

Care should also be taken when designing onboard solution to enable connectivity from either side even if the socket is located on the opposite side of the jetty.

5 HAZID

Safety is an essential topic when it comes to Onshore Power Supply (OPS) for tankers, and likely the single most important factor to why it has not already been implemented. There may be differences to the safety cases for each of the three scenarios developed, thus a HAZID workshop is organized to assess the general safety aspects involved with each of them, which will be discussed in the following.

5.1 Scope of work

5.1.1 Objective

The objective of the hazard identification is to ensure the feasibility of an OPS, and to:

- Identify hazards and hazardous events; what can go wrong?
- Review the effectiveness of existing safety measures
- Expand existing measures if deemed necessary for the safe operation of the OPS
- Increase understanding among involved parties about risks and main challenges.
- Identify potential differences in safety performance between alternative concept scenarios.

The existing safety measures primarily relates to what is required by applicable regulations or guidelines adhered to.

5.1.2 Assumptions and Limitations

- Hazard identification is limited to normal operation of the OPS.
- The analysis does not include manufacturing, installation, commissioning and decommissioning phases.
- Simultaneous events or failures (i.e., double jeopardy) are not considered when they do not have a common failure.
- All personnel who will be involved in operation of the OPS, shall be well trained and qualified, and familiar with the system. They should also be able to address any potential accidents with proper course of action.
- The study is based on documentation and information available and discussed prior to workshop.

5.2 HAZID Methodology

The HAZID study is a structured review technique to identify all hazards associated with a specific concept, design, operation, or activity, including the likely initiating causes, possible consequences, and safeguards so that the hazards can be assessed, eliminated at source, if possible, controlled and/or mitigated otherwise.

The HAZID aimed to:

- Identify hazards & hazardous events that may give rise to risks;
- Identify potential causes and consequences of the hazardous events identified;
- Identify preventive measures (e.g. measures to prevent the hazardous events from occurring);
- Identify mitigating measures (e.g. measures to help prevent escalation);

- Assess risks semi-quantitatively by using a risk matrix (i.e. risk ranking); and
- Recommend additional measures to ensure required safety level is met and in line with internationally recognized standard requirements such as IGC code, SOLAS, OCIMF, and SIGTTO.

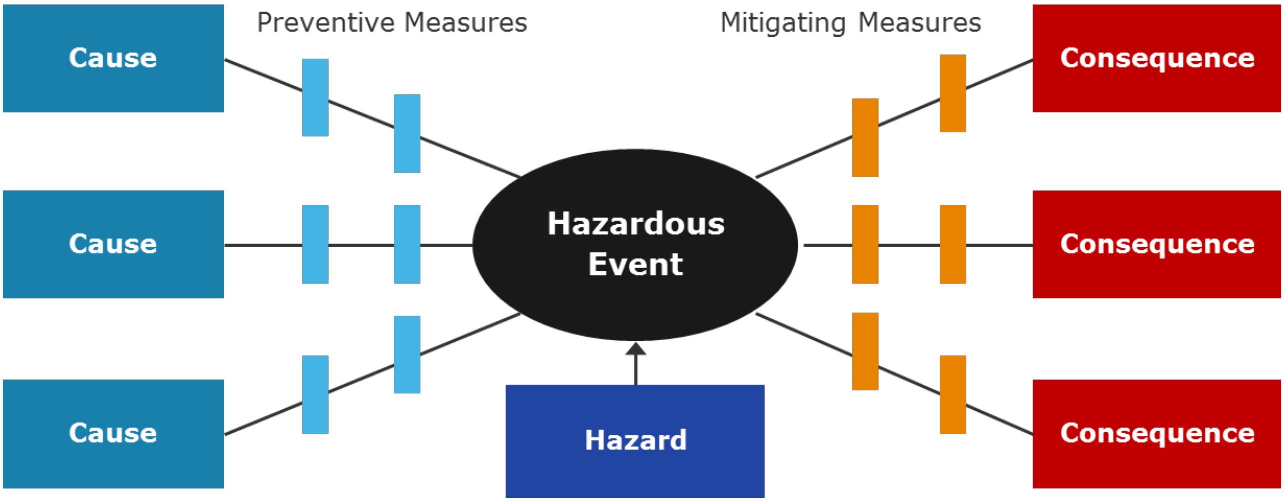

Figure 5-1 Bow-tie Diagram

5.2.1 Procedure

The HAZID study for the feasibility of an ammonia fuel supply system was carried out as a brainstorming exercise in the HAZID workshop attended by a multidisciplinary team (i.e., HAZID team) as specified in Table 5-2. The detailed procedure applied in the HAZID workshop followed the steps outlined below, and schematically presented in Figure 5-2.

1. *Identification of HAZID Nodes:* To assess the specifics of each individual area or operation, the areas and operations were broken down into the series of nodes listed in Table 5-1. For each node, the following steps were performed.
2. *Node Briefing:* For all HAZID team members to obtain a common understanding of the intended operation of the node, a brief introduction of the node in question has been given.
3. *Identification of Hazards and Hazardous Events:* Hazard and hazardous events were identified by the HAZID team. The HAZID team considered each node in turn based on the documents and drawings provided and previous experience.
4. *Identification of Causes:* For each hazardous event identified, all potential causes of the hazard being realized were identified and discussed if relevant. However, double jeopardy which is a combination of multiple independent events occurring at the same time was not considered during the HAZID workshop.
5. *Identification of Consequences:* For each hazardous event and cause identified, all potential consequences were identified without taking credit for preventive or mitigating measures in place. Consequences were not limited by the HAZID node definitions or scope boundaries in evaluating the consequences of a given event.
6. *Identification of Preventive and Mitigating Measures (Safeguards):* For each identified accident scenario, existing measures expected to prevent a hazardous event from occurring (i.e. preventive measures) as well as those intended to control its development or mitigate its consequences (i.e. mitigating measures) were identified.

7. *Risk Ranking:* Risk ranking is the categorization of the identified accident scenarios. Risk ranking for each identified accident scenario was performed using a risk matrix agreed by the HAZID team. For provision of the likelihood rating existing preventive measures in place were considered. Hazards where insufficient provision of required measures was identified were ranked with higher probability rating.

8. *Identification of Recommendations:* In case that the current provision of preventive or mitigating measures was considered insufficient to manage risks, or that further assessments are required to obtain a better understanding of hazard/hazardous event, recommendations were raised during the HAZID workshop. These recommendations were assigned to responsible parties.

The procedure is represented in Figure 5-2.

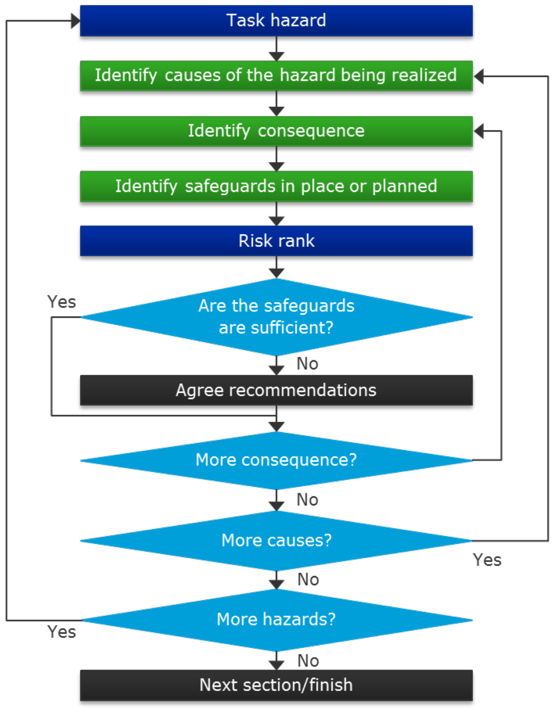

Figure 5-2 HAZID Procedure

5.2.2 HAZID Nodes

The nodes used in the HAZID workshop is based on the operational steps involved with operation on OPS. The nodes considered are listed in Table 5-1.

Table 5-1 HAZID Nodes

No.	Description
Node 1	Cable Handling, pre-connection
Node 2	Connection of OPS
Node 3	Operation on OPS
Node 4	Disconnection of OPS
Node 5	Retraction of cable

In addition to the nodes, the three concept scenarios (ref. memo on scenario development) were assessed separately where applicable according to the following denotations

A. Midship connection with handling of OPS cable with ship's crane, thus no specific CMS

B. Midship connection with crane-based CMS on jetty

C. Aft-ship connection with crane-based CMS on shore or constructed platform/monopile in water

The denotations are added to the hazard ID's in the log sheet where differentiation is applicable between the three concept scenarios.

5.2.3 Risk Ranking

Risk ranking was carried out for every applicable risk scenario according to the below risk matrix which was agreed up front of the workshop. Please note that not all risk scenarios were risk ranked

				Frequency					
				0	1	2	3	4	5
				Extremely unlikely	Very Unlikely	Unlikely	Possible	Probable	Regular
				Never heard of in industry	Heard of in industry	Happened within company	Happened at the location	Happened multiple times at location	Happens regularly
				≤ 10^{-5} /yr	>10^{-5} /yr ≤ 10^{-4} /yr	>10^{-4} /yr ≤ 10^{-3} /yr	>10^{-3} /yr ≤ 10^{-2} /yr	>10^{-2} /yr ≤ 10^{-1} /yr	>10^{-1} /yr
MINOR	• FAC • Exposure ≥ limit value • Minor fire without escalation	Severity	1						
SIGNIFICANT	• LTI , MTC, RWC • Exposure to hazardous substances above limit value		2						
SERIOUS	• Severe LTI • Exposure ≥ STEL (Short Term Exposure Limit)		3						
MAJOR	• Permanent disablement • Single fatality • Exposure ≥ IDLH (Immediate Dangerous for Life and Health)		4						
CATASTROPHIC	• Multiple fatalities		5						

Figure 5-3 Risk matrix

Based on the risk matrix, all the scenarios by their frequency and severity were categorized as follows:

- **Acceptable Risk** (green region): Risk is considered broadly acceptable. No additional preventive or mitigating measure are required unless they can be implemented at a very low cost (in terms of time, money and effort); nevertheless, risk to be continuously monitored to ensure acceptable risk level.
- **Tolerable Risk** (yellow region): Risk reducing measures must be implemented to reduce the risk to As Low As Reasonably Practicable (ALARP), i.e. ALARP to be demonstrated; and
- **Unacceptable Risk** (red region): Risk is unacceptable/intolerable. Risk reducing measures must be implemented to reduce the risk to tolerable level or below.

5.2.4 HAZID Team

The workshop was held the 6th of March 2023 at the Vopak Terminal in Botlek, Rotterdam, the Netherlands. The session was attended by a multi-disciplined team of specialists from Port of Rotterdam, Vopak, Stolt Tankers, and DNV. The workshop was facilitated and scribed by DNV Maritime Safety Advisory. The list of participants is documented in Table 5-2.

Table 5-2 HAZID team

Name	Company	Role
Joost Bos	Port of Rotterdam	Sr. Project Engineer
Peter Voets	Port of Rotterdam	Port Development Engineer
Paul Vogelzang	Vopak	Team lead, Technical expert E&I
Jaco van der Leeden	Vopak	Process Safety Leader
Joris Nuijten	Vopak	Technical Expert Civil
Sean Crowley	Stolt Tankers	Sr. Electrical Project Manager
Giorgio Guadagna	Stolt Tankers	Business Partner Sustainability & Decarbonization
Thomas Hartmann	DNV	Electrical Shorepower Expert
Erik Istad	DNV	Ship Type Expert – Tankers
Magnus Jordahl	DNV	Workshop facilitator

5.3 HAZID Results

5.3.1 Risk ranking

Hazards associated with the OPS for tanker scenarios were identified and reviewed by a multi-disciplinary team at the HAZID workshop based on the scope and methodology described in previous chapters.

The workshop was conducted based on the concept scenarios shortlisted in chapter 4, scenario development;

A. Midship connection with handling of OPS cable with ship's crane, thus no specific CMS
B. Midship connection with crane-based CMS on jetty
C. Stern connection with crane-based CMS on shore or constructed platform/monopile in water

All the results of the HAZID study (i.e., hazards, hazardous events, causes, consequences, safety measures, recommendations, and comments) were documented in the HAZID Log presented in Appendix B. One of the objectives was also to identify whether the concept scenarios had differences in safety performance, thus the hazards IDs were signified with A, B and C if any identified hazards were assessed to have difference in safety performance.

In total, 12 hazards were identified, out of which 7 were risk ranked. Concept scenario A was identified with 4 high risk hazards and 3 medium risk hazards, concept scenario B was identified with 3 high risk hazards and 4 medium risk hazards, whereas concept scenario C was identified with 1 high risk hazard, 5 medium risk hazards and 3 low risk hazards. Five risks were not ranked due to similarity to other hazardous scenarios, or due insufficient information to confidently risk rank the applicable hazards.

The distribution of risks for the three concept scenarios is illustrated in Figure 5-4, Figure 5-5, and Figure 5-6. Table 5-3 lists the hazardous events associated with the Hazard ID used in the risk matrices, with a corresponding list of hazards in Table 5-3.

As could be expected due to the fact that the connection takes place away from the hazardous zones leading to a lower severity ranking for the identified hazards, concept scenario C appears to be safer option of the three scenarios based on the HAZID assessment, mainly due to the reduced severity of the identified hazards. However, considering the assessment is based on general outlines of the concept scenarios, sound engineering solutions could potentially contribute to lowering the risk for concept scenarios A and B to an acceptable level according to the ALARP principle. The risk reduction would on the other hand primarily be based on frequency reduction by way of safety measures aimed to prevent the occurrence of the event, but the severity of the identified consequences of the event remains unchanged.

Table 5-3 - List of Hazard ID and associated Hazardous event

Hazard ID	Hazardous event
1.1A, 1.1C	Bringing live cable across jetty and/or deck
1.1B	Bringing live cable across deck
1.2A, 1.2B, 1.2C	Failure of plug (leading to SC)
2.2A, 2.2B, 2,2C	Connection of damaged cable (internal/external?)
2.3A, 2.3B, 2.3C	Connecting earthed cable to live socket (powered by ship's generators)
2.4A, 2.4B, 2.4C	Sparking when connecting cable to socket
3.1A, 3.1B, 3.1C	Uncontrolled disconnection of OPS
3.6A, 3.6B, 3.6C	3rd party risk

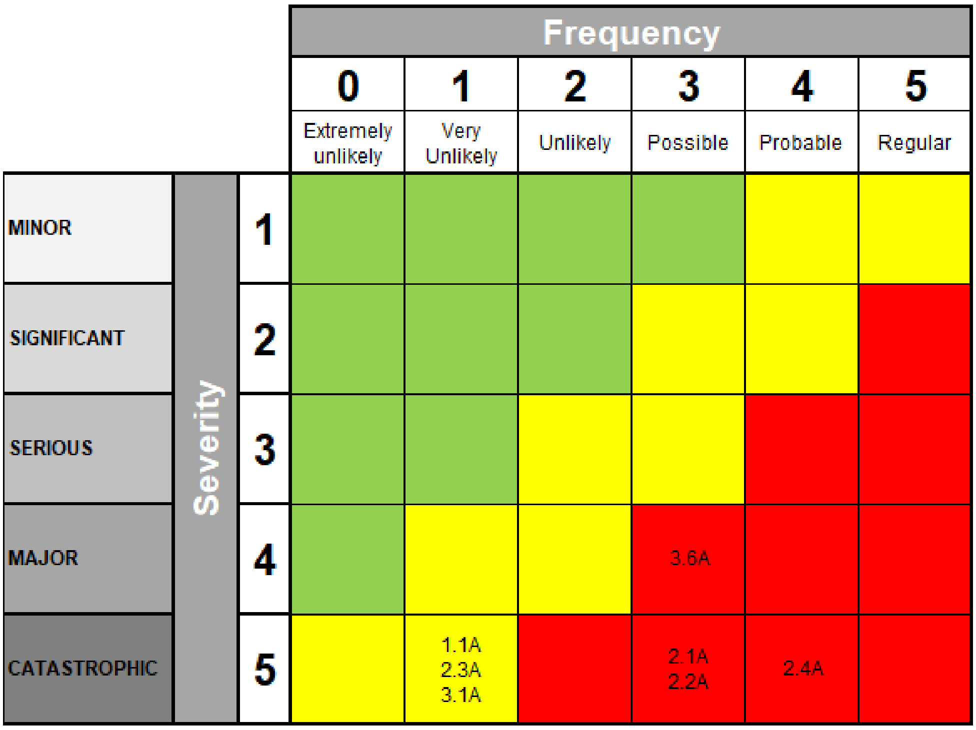

Figure 5-4 Risk distribution for concept scenario A

			Frequency					
			0	1	2	3	4	5
			Extremely unlikely	Very Unlikely	Unlikely	Possible	Probable	Regular
MINOR	Severity	1						
SIGNIFICANT		2						
SERIOUS		3						
MAJOR		4			3.6B			
CATASTROPHIC		5		1.1B 2.3B 3.1B	2.1B 2.2B		2.4B	

Figure 5-5 Risk distribution for concept scenario B

			Frequency					
			0	1	2	3	4	5
			Extremely unlikely	Very Unlikely	Unlikely	Possible	Probable	Regular
MINOR	Severity	1						
SIGNIFICANT		2		3.1C			2.4C	
SERIOUS		3		1.1C 2.3C	2.1C 2.2C			
MAJOR		4		3.6C				
CATASTROPHIC		5						

Figure 5-6 Risk distribution for concept scenario C

5.3.2 Recommendations

Where Hazard ID is referred to without A, B, or C for the different scenarios, the recommendation is assessed to be applicable to all three scenarios. The colour on the hazard ID represent the risk distribution and is equal to in Figure 5-4, Figure 5-5, and Figure 5-6.

Rec. no.	Recommendation	Hazard ID
1	Determine procedures for connection and if the responsibility for plugging in lies with the shore or the ship, to lower the likelihood for misunderstandings between the involved operators.	1.1A, 1.1B
2	Establish protocols for communication between ship and shore to prevent live cables from being handled across deck or jetty.	1.1A, 1.1B
3	Consider some kind of watertight cover for plug or storage of plug/cable in a dry space when not in use to prevent connection of a wet plug into a ship's socket	2.1A, 2.1B 2.1C
4	Ensure that connection procedures addresses that a wet plug is not connected to the ship's socket to prevent arc flash explosions.	2.1A, 2.1B 2.1C
5	Ensure the connection is not energized until the connection enclosure is closed and there is no personnel present, to prevent injury to personnel.	2.1A, 2.1B 2.1C
6	Consider means of handling an arc flash explosion in a way that an explosion does not affect the deck structure or interact with potential hazardous areas to prevent escalation of a potential arc flash inside the connection enclosure	2.1A, 2.1B 2.1C
7	Consider implementation of arc flash protection relays to lower the risk of escalation	2.1A, 2.1B 2.1C
8	Ensure mechanical protection of the cable between shore and connection deckhouse along the cable route, to reduce the likelihood of damage to the cable when making the connection and in use.	2.2A, 2.2B 2.2C
9	Ensure an adequate inspection scheme is put in place to detect any damage to the cable in the semi-automated CMS that is not regularly in close eyesight to operators making the connection.	2.2B 2.2C
10	Consider adequate replacement intervals for cables to reduce the likelihood for degradation errors of the connection.	2.2A, 2.2B 2.2C
11	Consider the procedures for connection of EP bonding cable, to ensure the connection is sufficient to equalize the potential difference and prevent potential sparks when connecting the cable, and the potential escalation a spark could represent inside a hazardous area.	2.4A 2.4C

12	Consider enabling connection to be made in a safe atmosphere, i.e. within an enclosure made safe e.g. by pressurization of the enclosure prior to plugging in the connection, airlock, gas tight penetrations etc.	2.4A 2.4C
13	Investigate the weakest link in the OPS connection, what would break first; ship or onshore plug, cable, or other equipment, and consider what would be the least hazardous place where the connection will break and consider to design the system accordingly.	3.1A, 3.1B 3.1C
14	Consider integrating OPS emergency disconnection with the ESD procedures for shutdown of cargo operations.	3.1A, 3.1B 3.1C
15	Investigate what cause of action would be relevant to reduce any blackout period leaving the vessel without power to fire pumps, leaving it unable to fight the fire until power is restored by the vessel's generators.	3.5
16	Investigate OPS disconnect time in case of an emergency, and assess whether it may impede any specific evacuation times for relevant terminals.	3.1A, 3.1B 3.1C
17	Investigate on a case-by-case basis if the reliability/availability of grid/OPS power is at least equal or better to that of a vessel's gensets, and consider means of backup power to maintain essential functions for a smooth transition until a ship's gensets are brought online in case of loss of power from grid.	General rec.
18	Ensure that OPS is always disconnected prior to release of moorings to prevent cable damage and potentially hazardous situations resulting from vessel movement checks.	4.1
19	Consider an OPS compatibility assessment to be carried out between ship and terminal for every first visit a ship has to a specific terminal, to align and ensure there are no compatibility issues, neither wrt. system compatibility nor hazardous zones, that could lead to hazardous situations.	3.3
20	Enforce access restriction and ensure that all visitors (and non-technical personnel) coming in the vicinity of high voltage equipment are informed of the risks of high voltage to prevent them from getting in contact with it.	3.4, 3.5 3.6A 3.6B, 3.6C
21	Ensure all cables and equipment are sufficiently marked and have appropriate warning signs in relevant locations	3.4, 3.5 3.6A 3.6B, 3.6C

6 MULTI CRITERIA ANALYSIS

6.1 Introduction

Although the scenarios have been discussed and indirectly compared in the scenario development phase, there has not yet been carried out a direct comparison between the scenarios across a comparable set of criteria. The Multi Criteria Analysis (MCA) aims to enable that comparison by establishing relevant criteria and applicable sub-criteria for direct comparison of the scenarios and apply weighting indicating the relative importance between them.

6.1.1 Objective

The objective of the MCA is to:

- Establish the main criteria for evaluation, along with applicable sub-criteria
- Apply weighting to each criterion and sub-criterion
- Indicate a score for the sub-criteria
- Aggregate the sub-criteria score to a final score for the main criteria
- Establish which scenario is the best option according to the MCA

6.2 Approach

The multi criteria analysis in this has been based on a form of analytic hierarchy process sometimes referred to as the weighted sum method, alternatively the simple multi-attribute rating technique (SMART). Weighting to the applicable main criteria and sub-criteria was applied by expert judgement in the project group.

When the weighting was established, scores on a scale from 1 (worst) to 10 (best) was assigned to each applicable level of criteria based on the three scenarios developed in chapter 4 with reference to Vopak Botlek Jetty 5/6 and the Stolt Breland. The criteria framework could also be used for other locations and/or vessels, but obviously the scores assigned would then be project specific for those other locations/vessels.

6.3 Criteria

The main criteria and their sub-criteria were determined in discussion between the involved parties and will be described in the following section.

6.3.1 Safety

The first and perhaps most obvious criterion was safety, which is an integral part of the operation of both tankers and terminals. By considering the option to put an OPS connection within a hazardous area also calls for a meticulous focus on safety.

Having already carried out a HAZID previously, the parties also had some tangible reference to the hazards involved with the applicable scenarios.

Safety is a multi-faceted criterion and was thus split up into several sub-criteria that may have different relative importance between themselves.

6.3.1.1 Connect / Disconnection safety

Safe connection and disconnection of a cable is essential in managing risk in an OPS system and was identified as a hazard in the HAZID. Although the exposure time in this phase of the operation is relatively short, the operation will consist of several steps and repeated frequently, with several things having the potential to go wrong.

6.3.1.2 Emergency disconnection

This sub-criterion was also identified during the HAZID and assessed to have high enough importance to be included as a sub-criterion in the safety category. Emergency disconnection should ideally be handled be the CMS by monitoring of relevant parameters such as cable tension, relative movement, etc., which first should trigger alarms and subsequently de-energize and disconnect the system at pre-set levels.

6.3.1.3 Cable exposure

The cable exposure to external influence or potential impact when connected and active is an important factor for safety, considering this will be the mode of operation with the highest exposure time.

6.3.1.4 3rd party risk

There may be 3rd parties coming close to the cable and connections at some point, and the level they may be exposed to potential errors with the OPS was deemed relevant to the assessment of the safety category.

6.3.2 Operability

Operability is essential for a successful OPS system, which in a way also reflects back on the overall safety. A system that is hard to operate and maintain, will potentially also give a higher likelihood for errors.

Like safety, operability was assessed to have several sub-criterion.

6.3.2.1 Required manpower

The amount of manpower needed to handle to OPS, primarily the connection/disconnection operation, was assessed to have significant importance for the operability. Depending on the terminal, there may be a limited amount of personnel available on the on the shore side, and on board the crew may also have other pressing tasks to handle, limiting the number of persons able to be freed up for handling the OPS connection. In addition, an increased number of people involved may also increase the potential for misunderstandings that could lead to hazardous situations.

6.3.2.2 Maintainability and accessibility

A system without an adequate level of maintainability and/or accessibility may be subject to incomplete servicing, increasing the likelihood for the system to have unscheduled downtime and potentially increased wear and tear which may shorten the lifespan of the system or parts of the system. For instance, maintenance work that e.g. would involve hot work within a hazardous area might require gas freeing of the area, something not easily facilitated in normal operation.

6.3.2.3 Ease of operation

Apart from the title, this sub-criterion covers the time to connect as well as competency requirements and training of personnel involved in the connection; for example it requires a higher level of competence to be directly involved with handling and operation of electrical equipment, compared to indirectly handling it e.g. by operating a CMS crane with an integrated cable solution.

6.3.3 Technical maturity and equipment availability

The technical maturity of the scenarios and equipment being readily available for the selected option is an important factor in realizing an OPS for tankers. It is evaluated both in terms of available components for the system, but also the overall constructability of the system, i.e. feasibility and complexity of the system as well as available space and potential modifications necessary to enable OPS.

Both components and constructability has been evaluated for the jetty side and the vessel side of the system separately in the MCA model.

6.3.4 Cost

The final main criterion evaluated is cost, in terms of CapEx. It may be argued that this is an irrelevant criterion given that regulatory requirements for an OPS installation may be introduced, however, in terms of comparing different scenarios cost may still be a differentiator between them. Cost has been separately evaluated for onshore and onboard installation, as this may differ somewhat between vessel and terminal side depending on the applicable scenarios.

6.4 Weighting and Results

In the following section the results from the project team's weighting discussions and scoring of the criteria and relevant sub-criteria.

6.4.1 Weighting of Main Criteria

The main criteria were discussed and weighted by the team according to the relative importance listed in Table 6-1.

Table 6-1 Overview of main criteria and assigned weighting of relative importance

Criteria	Weight	Reasoning
Safety	35 %	Consensus on being the most important criterion, given that safety constitutes an effective showstopper for OPS for tankers if it cannot be carried out within an acceptable safety level. As per the HAZID, showstoppers were not specifically identified, but will likely depend on specific engineering solutions.
Operability	25 %	An OPS system that cannot be operated and maintained effectively is likely to become redundant in the form that it may not or cannot be used as intended due to unscheduled downtime or prolonged maintenance.
Technical maturity / Equipment availability	25 %	The availability of technical equipment and the maturity of the technical solutions represented is essential to the success of a functional OPS system, considered equally important to the operability criterion.
Cost	15 %	Although cost plays a role in differentiating between different options, it is considered less important than the other criteria, given the fact the OPS is likely to become a future requirement in most ports.

6.4.2 Criteria Scores

In the following section the scores within each criteria, as well as the weighting of the sub-criteria is indicated. Please note that the scores are assigned conservatively based on concept scenarios and outlined solutions and may improve pending specific engineering solutions justifying it. In addition, scoring is preferably applied based on a specific case, as the Vopak Botlek jetty 5/6 and Stolt Breland as stated earlier in section 6.2.

6.4.2.1 Safety

The safety scores were determined based on related hazards identified in the HAZID workshop described in chapter 5 by deducting the risk ranking from the maximal score, i.e. if the risk had a low risk ranking of 3, the corresponding score for the safety sub-criteria would be 7. If several hazards were identified related to the relevant sub-criterion, then the average was used to determine the score. This approach was discussed in the team and found acceptable.

Table 6-2 Assigned scores for Safety criterion

SAFETY				
		Score		
Sub-Criteria	**Weight**	**Scenario 1**	**Scenario2**	**Scenario 3**
Connect/disconnect safety	25 %	2.6	3.2	5.2
Emergency disconnection	10 %	4	4	7
Cable Exposure	55 %	2	3	5
3rd party risk	10 %	3	4	5
Criteria score	**100 %**	**2.4**	**3.3**	**5.3**

The scores indicate that scenarios associated with a midship connection are tied to a higher risk level, which is also reflected by the HAZID. Lower score on connection/disconnection, including emergency disconnection, is attributed to the hazardous area and the potential for arcing or sparks escalating in the presence of gas. Emergency disconnection is an event rarely experienced, nevertheless it should be accounted for by monitoring applicable parameters and facilitate de-energizing and grounding if operating outside boundary limits and allow for emergency departure. Any connection/disconnection issues are significantly reduced with a stern connection located outside the hazardous zone.

Cable exposure to external influence is considered greater in the midship area simply because it is a more congested area where other operations may be taking place simultaneously, whereas the stern connections is separated from other operations and provides an easier overview.

As the gangway is located in the midship area, this also gives a higher risk for any 3rd parties coming on board or disembarking the vessel.

6.4.2.2 Operability

Scores for operability were set based on expert judgement within the team and the outlined scenarios. Required manpower is determined by the number of personnel required to carry out the connection, and for scenario 1 it requires more manual labour both onshore and onboard. Scenario 2 is assumed to need more people for the onboatd part of the connection, whereas scenario 3 ideally only needs two persons to connect, one on shore and one on board.

Differentiating factors between the scenarios were thus to a large extent related to whether the operation was within the hazardous zone, and the amount of manual labour required.

For maintainability and accessibility the hazardous zone is also a drawback in case of e.g. necessary unplanned maintenance is needed, but also with regards to the ease of operation within a hazardous zone.

Table 6-3 Assigned scores for Operability criterion

OPERABILITY				
		Score		
Sub-Criteria	**Weight**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Required Manpower	40 %	2	6	7
Maintainability and Accessibility	20 %	3	4	4
Ease of operation	40 %	4	5	7
Criteria score	**100 %**	**3**	**5.2**	**6.4**

6.4.2.3 Technical maturity and Equipment availability

An even distribution was determined in the relative importance between jetty and vessel, with a 30/70 distribution respectively between components and constructability for both. In this case the scoring was relatively even between the scenarios, as most of the necessary equipment can be made available, and the properties of the jetty and vessel likely allows for a not too complex construction of the OPS.

Main drawback for scenario 2 was that the team was not familiar with the existence of an ATEX proof CMS crane, which if available would likely bring the jetty equipment component score on par with scenario 3. As for the relatively high score on onboard constructability for scenario 1 and 2, this relates to Stolt Breland being a relatively large vessel which may facilitate the retrofit of a deckhouse protecting the connection and related onboard equipment. For smaller vessels such a retrofit is likely to be more complex and less feasible, whereas for newbuilds this could be planned for.

Table 6-4 Assigned scores for Technical maturity and Equipment availability criterion

Technical maturity / Equipment availability					
			Score		
Sub-Criteria	***Sub-Sub-criteria***	**Weight**	**Scenario 1**	**Scenario2**	**Scenario 3**
Jetty equipment		**50 %**			
	Components	30 %	8	5	7
	Constructability	70 %	8	7	7
	Sub-total	*100 %*			
Onboard equipment		**50 %**			
	Components	30 %	9	9	10
	Constructability	70 %	8	9	10
	Sub-total	*100 %*			
Criteria score		**100 %**	**8.2**	**7.7**	**8.5**

6.4.2.4 Cost

Cost was set to have equal importance between terminal and vessel. Sub-division into different types of equipment and construction work within the two sub-criteria, but it was determined that in the end it is the final cost that matter. On the terminal side scenario 1 would be the simplest and least costly solution, whereas for the onboard side that would be the case for scenario 3. Scenario 2 would be similar to scenario 3 on the terminal side, but similar to scenario 1 on the ship side, i.e. scenario 2 would be the most costly option for both sides.

Table 6-5 Assigned scores for Cost criterion

COST				
		Score		
Sub-Criteria	**Weight**	**Scenario 1**	**Scenario2**	**Scenario 3**
Terminal	50 %	7	4	4
Vessel	50 %	4	4	7
Criteria score	**100 %**	**5.5**	**4**	**5.5**

6.5 Results

When the scores of section 6.4.2 are aggregated, the total score becomes as indicated in Table 6-6 below. According to the MCA model it appears scenario 3 presents the overall best option considering the Vopak Botlek jetties and Stolt Breland. From the table it is evident that scenario 3 best option across the range of criteria, apart from Cost where it is level with scenario 1. It is primarily Safety and Operability that puts scenario 3 ahead of the other scenarios.

Table 6-6 Aggregated scores for main criteria of MCA

Criteria	Weight	Scenario 1	Scenario 2	Scenario 3
Safety	35 %	0.9	1.1	1.8
Operability	25 %	0.8	1.3	1.6
Technical maturity / Equipment availability	25 %	2.0	1.9	2.1
Cost	15 %	0.8	0.6	0.8
Aggregate score	**100 %**	**4.5**	**5.0**	**6.4**

Given scenario 3 scores better across the range, this option would still retain an advantage on the other scenarios, however, with a reduced weight on Safety and Operability and increased relative importance of Tech. maturity / Equipment availability the advantage of scenario 3 would still be retained, although the comparative advantage would be slightly less. In addition, scenario 1 would improve its score relative to scenario 2 with such changes in weighting.

As previously mentioned, these scores are based on the outlined scenarios 1-3 for a T-jetty and a mid-size tanker, and different cases, e.g. a VLCC at a finger pier, may yield both different scenarios and different scores, whereas the MCA model itself may still be applied as a framework for assessing the relative differences between a set of scenarios. Still, the results from the present case indicates a stern connection may be a preferred solution considering the advantage it is likely to gain through the advantages gained for Safety and Operability by not being subject to the hazardous zones requirements.

7 SUMMARY AND CONCLUSIONS

The initial part of this project investigated literature and articles to shed light on the current status on shore power for tankers and to get an overview of identified challenges and potential showstoppers. The focal point of the study was the interface between ship and shore, thus, some of the identified challenges from the literature were considered out of scope and location specific, such as sufficient available grid power, decision between 50 or 60 Hz, voltage level and load, the associated number of cables, plugs and sockets, and there are ongoing processes already addressing some of the issues where decisions needs to be taken, e.g. at OCIMF.

A long list of potential options for OPS connection was then described and evaluated, condensing into a shortlist of three potential scenarios:

- Scenario 1 - Midship connection with handling of OPS cable with ship's crane, thus no specific CMS
- Scenario 2 - Midship connection with crane-based CMS on jetty
- Scenario 3 - Stern connection with crane-based CMS on shore or constructed platform/monopile in water

A safety assessment for the three scenarios was carried out in the form of a HAZID, leading to identification of several high risk hazards, and a list of 21 recommendations that may assist in improving the safety level. Scenario 1 was associated with four high risk hazards, scenario 2 with three high risk hazards, whereas no high risk hazards were identified for Scenario 3.

In the end, a Multi Criteria Analysis (MCA) was carried out across a set of four main criteria identified by the project team.

- Safety
- Operability
- Technical maturity/Equipment availability
- Cost

Each criterion was subject to their own sub-criteria weighted according to their relative importance, and a score between 1-10 (10 being the best score) was set for each criteria based on the showcase Vopak Botlek jetty 5/6 and the vessel Stolt Breland. The final results from the MCA were as follows:

Criteria	Weight	Scenario 1	Scenario 2	Scenario 3
Safety	35 %	0.9	1.1	1.8
Operability	25 %	0.8	1.3	1.6
Technical maturity / Equipment availability	25 %	2.0	1.9	2.1
Cost	15 %	0.8	0.6	0.8
Aggregate score	**100 %**	**4.5**	**5.0**	**6.4**

The result indicates that scenario 3 should be the preferred option according to the MCA, dominating the other scenarios across the range of criteria, with the exception of Cost where Scenario 1 is on par. That indicates scenario 3 would have been the preferred solution regardless of how the weighting of the main criteria was configured, but please note that this relates to the specific showcase assessed.

Through the HAZID and MCA it was evident that the hazardous zones are affecting scenario 1 and 2 scores negatively, specifically in terms of Safety and Operability. However, please note that going through the MCA process with other potential scenarios for a different ship and jetty may very well yield a different result, depending on the configuration. For example, a finger pier with OPS to a VLCC may need a different setup than the Botlek/Breland case discussed in this report, while the possibility the results being the same could be equally valid. The MCA could be used as a framework to assess the relevant scenarios for the case in question, while setting separate scores according to the configuration of those systems.

The main takeaway from the exercises assessed in this project is that although a midship connection may very well be a feasible option, it may not be as practical and flexible as it seems at first glance, in addition to the hazardous zones representing a significant risk involved with the OPS connection. By setting up a stern connection instead, the risk is reduced as far as possible, as there is normally no hazardous zone in the stern area of a tanker.

Please note however, that there is a formal obstacle that needs to be resolved, namely that an ATEX zone is often defined to cover the entire vessel from the terminal point of view, leading to a discrepancy between the hazardous zones definitions that needs solving. This should however not have any practical consequences for safety.

Selection of a stern connection would also allow adaptation to make use of the existing IEC/IEEE 80005-1 standard on high voltage shore connections. The standard does however not allow connection in a hazardous area, thus revision of the existing IEC/IEEE 80005-1 standard addressing a midship connection would be necessary, likely to be a rather time-consuming and complex matter.

APPENDIX A

OPS for Tankers - Programme of requirements

Port of Rotterdam

Memo

Intern

Aan DNV

Van Sean Crowley (Stolt Tankers), Paul Vogelzang (Vopak Botlek), Joost Bos (Port of Rotterdam)

Kopie aan Stolt Tankers, Vopak Botlek, Port of Rotterdam project team members

Onderwerp **OPS Tankers Programme of Requirements**

Actie Ter informatie

Havenbedrijf Rotterdam N.V.
Datum 2 December 2022
Telefoon +31 6 5335 9407
E-mail jw.bos@portofrotterdam.com

This document is part of the joint project by Stolt Tankers, Vopak Botlek and Port of Rotterdam on developing a showcase for Onshore Power Supply for tankers. The show case aims to help establish a worldwide standard; therefore for all requirements, generic applicability is considered, where relevant. This Programme of Requirements applies to the shorepower connection only, excluding purely onboard installations, and excluding grid connection. Scope split to be further detailed in a later design/development stage. This document consists of 2 parts: the Requirements ("need to have") and the Design Philosophy ("nice to have").

Requirements

Nr.	Requirement for show case (Vopak Botlek j5 & j6, and Stolt Breland)	Requirement for generic applicability (all vessels, all jetties), if different	Clarification / notes
1	**Provide electrical power from shore for all power needs of the design vessels in all operational conditions in a safe and efficient manner.**		
1.1	**The system should work based on the available grid connection.**		Verhulst-design of grid connection available.
1.2	**The system should provide sufficient power for all foreseen operations.**		
1.2.1	The system should provide 2.5 MVA	The system should provide 15 MVA	2,5 MVA based on Stolt Breland, 15 MVA based on VLCC. Needs to be revisited in later development stage

Nr.	Requirement for show case (Vopak Botlek j5 & j6, and Stolt Breland)	Requirement for generic applicability (all vessels, all jetties), if different	Clarification / notes
1.2.2	The system should provide power at 60Hz frequency.		Frequency conversion (if any) from grid (NL 50Hz) to required 60Hz onboard is part of system, either onshore or onboard.
1.3	**The system should facilitate all design vessels.**		
1.3.1	For jetty 5, ship dimensions Length (LOA) x Beam (B) x Draught (D) & Moulded Depth (MD) & tonnage (dwt) vary from/to • LOA 100m x B 16m x D 6m & MD …m & … dwt (smallest) • LOA 185m x B 32m x D 11,89m x MD …m & 60,000dwt (largest)	The system should be able to facilitate the entire range of tanker vessels from coasters up to VLCC, but excluding barges.	System will be developed at either jetty 5 or jetty 6. For generic applicability, specs of smallest and largest vessels shall later be determined more precisely.
1.3.2	For jetty 6, ship dimensions Length (LOA) x Breadth (B) x Moulded Depth (MD) & tonnage (dwt) vary from/to • LOA 100m x B 16m x D 6m & MD …m & … dwt (smallest) • LOA 200m x B 32m x D 11,89m x MD …m & 60,000dwt (largest)	The system should be able to facilitate the entire range of tanker vessels from coasters up to VLCC, but excluding barges.	System will be developed at either jetty 5 or jetty 6.
1.3.3	The system should supply shorepower to the vessel moored directly to the berth. In case of board-board transfer or bunkering, no shorepower is required for the 2nd vessel.		Starting point for OCIMF at this stage, to simplify the design challenge.
1.3.4	The system should provide shorepower to the vessels when	The system should provide power to the	Bow out is not mandatory in

Nr.	Requirement for show case (Vopak Botlek j5 & j6, and Stolt Breland)	Requirement for generic applicability (all vessels, all jetties), if different	Clarification / notes
	moored bow-out, thus at the portside of the tanker vessel.	tanker vessels regardless of mooring orientation.	Rotterdam, but is the most frequent orientation at berths 5 & 6. This has an impact on connection points onboard (fore and aft? port and starboard?) and onshore (both sides of the jetty platform?).
1.4	**The system should be operational in all foreseen operational conditions.**		
1.4.1	The OPS system should be operational in all weather conditions, including wind, waves, tide etc.		May be alleviated later, as from a certain point the captain may want to be ready for emergency departure in case storm breaks vessel loose, and will start the main engine. Requirements should be in same magnitude as loading arms / hoses. Will be design-input at later design / engineering stage.
1.4.2	The OPS system should be operational while allowing all ship movements such as those following from (un)loading operations, weather conditions and passing vessels.		Should be in same magnitude as loading arms / hoses. Will be design-input at later design / engineering stage.
1.4.3	The system should be operational simultaneously with all foreseen ship and jetty operations while the ship is at berth. This includes loading arm / -hose handling, cargo (un)loading, board-board transfer and bunkering.		

Nr.	Requirement for show case (Vopak Botlek j5 & j6, and Stolt Breland)	Requirement for generic applicability (all vessels, all jetties), if different	Clarification / notes
	This excludes mooring lines handling during (de)berthing, however intermediate mooring lines adjustment should be possible.		
1.5	**The system should facilitate safe and efficient operations.**		
1.5.1	The system should meet ATEX requirements onboard.		ATEX zone determined a/o by location of connection
1.5.2	The system should meet ATEX requirements onshore.		ATEX zone determined a/o by location of connection
1.5.3	The system should allow emergency departure of the vessel through a failsafe measure.		Whether ESD disconnection (note physical locks) or de-energise or other, may be determined in HAZID
1.6	**Deployment of the system should be safe and efficient.**		
1.6.1	The system should be electrically safe and should comply with all applicable E-standards.		tbd
1.6.2	The system should facilitate continuous monitoring of the system, with feedback onboard & onshore.		
1.6.3	The system/installation should be accessible from shore on foot.		Some manual work is foreseen (dummy connector plug? etc.), but also inspection before use, maintenance etc.
1.6.4	The physical connection of the system shall be made by ships staff that is presently available.		Not at all terminals E-staff is available 24/7. Training of ships staff is acceptable. Procedure for turning on power to be determined later.

Nr.	Requirement for show case (Vopak Botlek j5 & j6, and Stolt Breland)	Requirement for generic applicability (all vessels, all jetties), if different	Clarification / notes
1.6.5	The maximum duration of mobilization of the system is approx. 60 minutes.		To be later determined based on power usage profile
1.6.6	The maximum duration of demobilization of the system is approx.. 60 minutes.		To be later determined based on power usage profile

Design philosophy

Following important aspects are starting points for the design, that should be treated as wishes, not strict requirements.

Nr.	Requirement for show case (Vopak Botlek j5 & j6, and Stolt Breland)	Requirement for generic applicability (all vessels, all jetties), if different	Clarification / notes
2.1	KISS		
2.1.1	Use easily available parts		Parts should be already available or relatively easily amended from parts that are available already in the market, to facilitate swift, easy, low-cost implementation. Shorepower installations for RoRo, cruise, containers etc should be used as inspiration
2.1.2	Minimum number of moving parts.		Minimize wear and tear in the marine environment.
2.1.3	Connection points onboard should be static.		Lower maintenance.
2.2	The system must be integrated in existing facilities, including w.r.t. size and weight		When midships, integrating into busy jetty deck might be challenging. Weight of CMS onto existing jetty deck.

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APPENDIX B
HAZID Log Sheet

ID	Hazardous event	Potential causes	Potential consequences	Existing or planned safety measures	F1	Ss1	R1	Proposed additional safety measures (recommendations)	Comments and notes
Node 1: Cable handling pre-connection									
1.1A	Bringing live cable across jetty and/or deck	- Human error - Equipment failure	~~*- Electrocution of personnel*~~ - Potential for sparking - Potential ignition of flammable gases - Potential explosion - Potential fatalities - Potential spill of hazardous cargo	- Interlock between earthing switch and isolation SWB - Safety loop to prevent energizing a cable not connected	1	5	6	1. Determine procedures for connection and if the responsibility for plugging in lies with the shore or the ship, to lower the likelihood for misunderstandings between the involved operators 2. Establish protocols for communication betw. ship and shore to prevent live cables from being handled across deck or jetty.	- Safety loop to be connected after the connected after the cable. - Electric connection is assumed done prior to commencing cargo operation, including any sampling, gas freeing, tank cleaning, or other cargo related actions.
1.1B	Bringing live cable across deck	- Human error - Equipment failure	~~*- Electrocution of personnel*~~ - Potential for sparking - Potential ignition of flammable gases - Potential explosion - Potential fatalities - Potential spill of hazardous cargo	- Interlock between earthing switch and isolation SWB - Safety loop to prevent energizing a cable not connected - Semi automated CMS involves less manual handling of cable	1	5	6	1. Determine procedures for connection; if the responsibility for plugging in lies with the shore or the ship, to lower the likelihood for misunderstandings between. 2. Establish protocols for communication betw. ship and shore to	

ID	Hazardous event	Potential causes	Potential consequences	Existing or planned safety measures	F1	Ss1	R1	Proposed additional safety measures (recommendations)	Comments and notes
								prevent live cables from being handled across deck or jetty.	
1.1C	Bringing live cable across jetty and/or deck	- Human error - Equipment failure	~~- *Electrocution of personnel*~~ - Potential for sparking	- Interlock between earthing switch and isolation SWB - Safety loop to prevent energizing a cable not connected - Semi automated CMS involves less manual handling of cable	1	3	4		
Node 2: Connection of OPS									
2.1A	Failure of plug (leading to SC)	- Plug getting wet due to e.g. Weather or accidentally dipping cable into the sea - Insulation failure - Human error	- Short circuit - Arc flash explosion when energizing - Potential escalation to flammable vapour/gases	- Personnel training - Pre-connection inspection of plug and socket - Maintenance and inspection procedures	3	5	8	3. Consider some kind of watertight cover for plug or storage of plug/cable in a dry space when not in use to prevent connection of a wet plug into a ship's socket 4. Ensure that connection procedures addresses that a wet plug is not connected to the ship's socket to prevent arc flash explosions. 5. Ensure the connection is not energized until the connection enclosure is	

ID	Hazardous event	Potential causes	Potential consequences	Existing or planned safety measures	F1	Ss1	R1	Proposed additional safety measures (recommendations)	Comments and notes
								closed and there is no personnel present, to prevent injury to personnel. 6. Consider means of handling an arc flash explosion in a way that an explosion does not affect the deck structure or interact with potential hazardous areas to prevent escalation of a potential arc flash inside the connection enclosure 7. Consider implementation of arc flash protection relays to lower the risk of escalation	
2.1B	Failure of plug (leading to SC)	- Plug getting wet due to e.g. Weather or accidentally dipping cable into the sea - Insulation failure - Human error	- Short circuit - Arc flash explosion when energizing - Potential escalation to flammable vapour/gases	- Personnel training - Pre-connection inspection of plug and socket - Maintenance and inspection procedures - Semi automated CMS involves less manual handling of cable, and less chance of getting plug wet	2	5	7	See rec. 3, 4, 5, 6, and 7	

ID	Hazardous event	Potential causes	Potential consequences	Existing or planned safety measures	F1	Ss1	R1	Proposed additional safety measures (recommendations)	Comments and notes
2.1C	Failure of plug (leading to SC)	- Plug getting wet due to e.g. Weather or accidentally dipping cable into the sea - Insulation failure - Human error	- Short circuit - Arc flash explosion	- Personnel training - Pre-connection inspection of plug and socket - Maintenance and inspection procedures	2	3	5	See rec. 3, 4, 5, 6, and 7	- Stern connection would not be subject to the same level of sealing as a midship connection, and would more easily allow arc flash explosion to be ventilated to a safe area.
2.2A	Connection of damaged cable (internal/external ?)	- Wear and tear - Rough handling - Exceeding allowable bending radius - Dropped object (SIMOPS)	- Earth fault - Internal short circuit when energizing the cable - Heat development in cable (potential ignition source) when energized - Potential and ignition of flammable vapour/gas in hazardous area	- Inspection and maintenance procedures of cable - Manual handling of cable enables regular visible inspection every time the cable is connected - Electrical protection against SC and EF on both shore and ship according to IEC std - Personnel training	3	5	8	8. Ensure mechanical protection of the cable between shore and connection deckhouse along the cable route, to reduce the likelihood of damage to the cable when making the connection and in use. 10. Consider adequate replacement intervals for cables to reduce the likelihood for degradation errors of the connection.	- DNV Ship rules requires dedicated cable routing with mechanical protection of the cable from ship side to connection point

ID	Hazardous event	Potential causes	Potential consequences	Existing or planned safety measures	F1	Ss1	R1	Proposed additional safety measures (recommendations)	Comments and notes
2.2B	Connection of damaged cable (internal/external ?)	- Wear and tear - Rough handling - Exceeding allowable bending radius - Dropped object (SIMOPS)	- Earth fault - Internal short circuit when energizing the cable - Heat development in cable (potential ignition source) when energized - Potential and ignition of flammable vapour/gas in hazardous area	- Inspection and maintenance procedures of cable - Less wear and strain on cable due to semi auto CMS - Electrical protection against SC and EF on both shore and ship according to IEC std - Personnel training	2	5	7	- See rec. 8 and 10 9. Ensure an adequate inspection scheme is put in place to detect any damage to the cable in the semi-automated CMS that is not regularly in close eyesight to operators making the connection.	
2.2C	Connection of damaged cable (internal/external ?)	- Wear and tear - Rough handling - Exceeding allowable bending radius - Dropped object (SIMOPS)	- Internal short circuit when energizing the cable - Earth fault	- Inspection and maintenance procedures of cable - Stern connection usually less congested with equipment and structure than midships - Less wear and strain on cable due to semi auto CMS - Electrical protection against SC and EF on both shore and ship according to IEC std - Personnel training	2	3	5	- See rec. 8, 9, and 10	- Considered easier to make mechanical protection of the cable in a stern connection.

ID	Hazardous event	Potential causes	Potential consequences	Existing or planned safety measures	F1	Ss1	R1	Proposed additional safety measures (recommendations)	Comments and notes
2.3A	Connecting earthed cable to live socket (powered by ship's generators)	- Human error - Equipment failure -	- Potential for sparking - Potential ignition of flammable gases - Potential explosion - Potential fatalities - Potential spill of hazardous cargo	- Interlock between earthing switch and isolation SWB - Safety loop to prevent energizing a cable not connected -	1	5	6		- Considered similar hazardous scenario as hazard ID 1.1
2.3B	Connecting earthed cable to live socket (powered by ship's generators)	- Human error - Equipment failure -	~~*- Electrocution of personnel*~~ - Potential for sparking - Potential ignition of flammable gases - Potential explosion - Potential fatalities - Potential spill of hazardous cargo	- Interlock between earthing switch and isolation SWB - Safety loop to prevent energizing a cable not connected - Semi automated CMS involves less manual handling of cable	1	5	6		
2.3C	Connecting earthed cable to live socket (powered by ship's generators)	- Human error - Equipment failure	- Potential for sparking	- Interlock between earthing switch and isolation SWB - Safety loop to prevent energizing a cable not connected - Semi automated CMS involves less manual handling of cable	1	3	4		

ID	Hazardous event	Potential causes	Potential consequences	Existing or planned safety measures	F1	Ss1	R1	Proposed additional safety measures (recommendations)	Comments and notes
2.4A	Sparking when connecting cable to socket	- Residual or static voltage in the cable - Voltage potential difference between ship and shore	- Potential ignition of flammable vapour/gases at connection point - Potential explosion - Potential fatalities - Potential spill of hazardous cargo	- Equipotential bonding cable?	4	5	9	11. Consider the procedures for connection of EP bonding cable, to ensure the connection is sufficient to equilize the potential difference and prevent potential sparks when connecting the cable, and the potential escalation a spark could represent inside a hazardous area. 12. Consider enabling connection to be made in a safe atmosphere, i.e. within an enclosure made safe e.g. by pressurization of the enclosure prior to plugging in the connection, airlock, gas tight penetrations etc.	
2.4B	Sparking when connecting cable to socket	- Residual or static voltage in the cable - Voltage potential difference between ship and shore	- Potential ignition of flammable vapour/gases at connection point - Potential explosion - Potential fatalities - Potential spill of hazardous cargo	- Equipotential bonding cable?	4	5	9	See rec. 11 and 12	

ID	Hazardous event	Potential causes	Potential consequences	Existing or planned safety measures	F1	Ss1	R1	Proposed additional safety measures (recommendations)	Comments and notes
2.4C	Sparking when connecting cable to socket	- Residual or static voltage in the cable - Voltage potential difference between ship and shore	- Personnel injury	- Equipotential bonding cable?	4	2	6		- Could involve minor shock to operator, considered similar to slips trips and falls
Node 3: Operation on OPS									
	Sudden loss of power	*Hazard considered similar to present situation*		*Is there any actual difference to how this would be currently handled with loss of power from gensets?*				17. Investigate on a case-by-case basis if the reliability/availability of grid/OPS power is at least equal or better to that of a vessel's gensets, and consider means of backup power to maintain essential functions for a smooth transition until a ship's gensets are brought online in case of loss of power from grid.	

ID	Hazardous event	Potential causes	Potential consequences	Existing or planned safety measures	F1	Ss1	R1	Proposed additional safety measures (recommendations)	Comments and notes
3.1A	Uncontrolled disconnection of OPS	- Loss of vessel position; - Mooring failure - Wind/Waves/Ship traffic - Collision	- Equipment damage - Forced disconnection of live cable - Potential ignition of flammable vapour/gases at connection point - Potential explosion - Potential fatalities - Potential spill of hazardous cargo	- Weather protocols; disconnection of OPS and cargo connections at relevant weather conditions - Maintenance and inspection of mooring equipment	1	5	6	13. Investigate the weakest link in the OPS connection, what would break first; ship or onshore plug, cable, or other equipment, and consider what would be the least hazardous place where the connection will break and consider to design the system accordingly. 14. Consider integrating OPS emergency disconnection with the ESD procedures for shutdown of cargo operations. 16. Investigate OPS disconnect time in case of an emergency, and assess whether it may impede any specific evacuation times for relevant terminals.	

ID	Hazardous event	Potential causes	Potential consequences	Existing or planned safety measures	F1	Ss1	R1	Proposed additional safety measures (recommendations)	Comments and notes
3.1B	Uncontrolled disconnection of OPS	- Loss of vessel position; - Mooring failure - Wind/Waves/Ship traffic - Collision	- Equipment damage - Forced disconnection of live cable - Potential ignition of flammable vapour/gases at connection point - Potential explosion - Potential fatalities - Potential spill of hazardous cargo	- Weather protocols; disconnection of OPS and cargo connections at relevant weather conditions - Maintenance and inspection of mooring equipment - Tension and length (cable payout) monitoring in OPS CMS	1	5	6	See rec. 13, 14 and 16.	
3.1C	Uncontrolled disconnection of OPS	- Loss of vessel position; - Mooring failure - Wind/Waves/Ship traffic - Collision	- Equipment damage - Forced disconnection of live cable -		1	2	3	See rec. 13, 14 and 16.	
	~~Excessive relative movement between CMS and vessel~~	- Heavy waves - Ship traffic							- Considered covered by hazard ID 3.1
3.2	Mechanical cable impact	- Dropped object - Equipment handling - SIMOPS (crane operations)							- Damage to energized cable is considered similar to energizing a damaged cable, and thus covered by hazard ID 2.2

ID	Hazardous event	Potential causes	Potential consequences	Existing or planned safety measures	F1	Ss1	R1	Proposed additional safety measures (recommendations)	Comments and notes
	Mechanical cable impact	- Dropped object - Equipment handling - SIMOPS (crane operations)							
	Mechanical cable impact	- Dropped object - Equipment handling - SIMOPS (crane operations)							
3.3	Overheating of plug and socket	- Poor connections - Connection corrosion -	- Overcurrent - Potential fire	- Protection relays against overcurrent (for single connection) - Smoke detection in connection enclosure -				19. Consider an OPS compatibility assessment to be carried out between ship and terminal for every first visit a ship has to a specific terminal, to align and ensure there are no compatibility issues, neither wrt. system compatibility nor hazardous zones, that could lead to hazardous situations.	

ID	Hazardous event	Potential causes	Potential consequences	Existing or planned safety measures	F1	Ss1	R1	Proposed additional safety measures (recommendations)	Comments and notes
3.4	Magnetic/induced current effects in CMS cable reel			- Three core cable, partially cancelling out each other in terms of induced effects					
3.5	Fire on board	Various causes		- Deck fire fighting equipment - Onshore fire fighting equipment				15. Investigate what cause of action would be relevant to reduce any blackout period leaving the vessel without power to fire pumps, leaving it unable to fight the fire until power is restored by the vessel's generators.	- Fire on deck is already serious, and at a higher level of detail it could be considered to carry out a specific assessment to see effects of and effects on the OPS
3.6A	3rd party risk	- Ship/terminal visitors not familiar with high voltage	- Electric shock/electrocution		3	4	7	20. Enforce access restriction and ensure that all visitors (and non-technical personnel) coming in the vicinity of high voltage equipment are informed of the risks of high voltage to prevent them from getting in contact with it. 21. Ensure all cables and equipment are sufficiently marked and have appropriate warning signs in relevant locations	- Gangway usually located in midship area

ID	Hazardous event	Potential causes	Potential consequences	Existing or planned safety measures	F1	Ss1	R1	Proposed additional safety measures (recommendations)	Comments and notes
3.6B	3rd party risk	- Ship/terminal visitors not familiar with high voltage	- Electric shock/electrocution		2	4	6	See rec. 20 and 21	- Likelihood considered lower as the cable is handled by CMS, potentially out of reach of 3rd parties.
3.6C	3rd party risk	- Ship/terminal visitors not familiar with high voltage	- Electric shock/electrocution		1	4	5	See rec. 20 and 22	- Likelihood considered lower as the cable is handled by CMS, and stern connection is located away from gangway, further lowering the likelihood of 3rd parties getting in contact with cable or any equipment
Node 4: Disconnection of OPS									
	Spark when disconnecting, considered covered by 2.4								
4.1	Ahead and astern check while connected to OPS	- Engine and manoeuvring test	- Damaging OPS equipment - Potential spark generation - Potential ignition of flammable vapour/gases - Potential explosion - Potential fatalities - Potential spill of hazardous cargo					18. Ensure that OPS is always disconnected prior to release of moorings to prevent cable damage and potentially hazardous situations resulting from vessel movement checks.	

ID	Hazardous event	Potential causes	Potential consequences	Existing or planned safety measures	F1	Ss1	R1	Proposed additional safety measures (recommendations)	Comments and notes
Node 5: Retraction of cable									
	No new hazardous scenarios identified (considered similar to node 1).								

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About DNV

DNV is the independent expert in risk management and assurance, operating in more than 100 countries. Through its broad experience and deep expertise DNV advances safety and sustainable performance, sets industry benchmarks, and inspires and invents solutions.

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