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LASH FIRE

Deliverable D08.6

Guidelines for electrical systems, equipment and routines, providing safe electrical connection of reefers and electrical vehicles in ro-ro spaces

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Abstract

Cargo in refrigerated units called reefers have been transported on ships for several decades. For the operation of these reefers during voyage, they are connected to and powered by the ship's electrical grid. While it seems straightforward, there are often electrical faults such as insulation faults, short circuits, et cetera, of which several have led to fires. While electrical problems in reefer units have persisted for as long as reefers have been used, charging of passengers' electric vehicles and design of a safe infrastructure during the voyage is a new and upcoming requirement. While there is not much data regarding electrical faults in charging EVs, it is not an exaggeration to assume dire consequences if electrical faults led to fires in EVs on board.

Owing to these, this report provides operational guidelines and recommendations mainly to ship operators to help reduce undesired electrical incidents on ro-ro cargo and ro-ro passenger ships. A qualitative approach is suggested based on interactions with ship operators and current practices and procedures on board. Stena Jutlandica and Stena Scandinavica are used as reference vessels, operated by Stena Line. Electrical risks associated with powering of these reefer units and charging of EVs are identified and operation guidelines are presented to mitigate these risks.

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No.	Short name	Full name of Partner	Name and contact info of persons involved
1	RISE	RISE Research Institutes of Sweden	Vasudev Ramachandra, vasudev.ramachandra@ri.se

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2	2023-06-14	Vasudev Ramachandra	Report for review
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Content

1 Executive summary

The guidelines presented in this report focuses on ensuring safe electrical connections for reefer units to prevent electrical fires and other hazards. Identified risks include electrical system malfunctions, overloading or overheating, improper use of extension cords or power sources, lack of grounding or insulation, and human error or negligence. Preventive measures such as regular inspections, professional maintenance, adherence to rated capacities, proper ventilation, use of high-quality cords, correct power connections, grounding, insulation integrity, training, and safety protocols are recommended to mitigate these risks.

In terms of operational aspects, the guidelines emphasize the importance of training and competency for crew members, development of standard operating procedures (SOPs), pre-departure checks, implementation of electrical safety measures, et cetera. By following these measures, regularly reviewing safety protocols, and fostering a safety-conscious environment, the overall safety of handling reefer units on ships can be significantly improved.

The transportation industry is also witnessing a growing trend of charging electric vehicles (EVs) on Ro-Ro/Ro-Pax vessels. These vessels can be equipped with charging infrastructure, such as charging stations and power supply systems, to facilitate the charging of EVs during transit. However, charging EVs on Ro-Ro vessels introduces certain risks such as electrical hazards, fire hazards, compatibility and standards issues, and the risk of overloading the vessel's electrical system. Safety protocols, crew training, regular risk assessments, and updates to safety procedures are crucial for safe and efficient charging operations on Ro-Ro vessels. Monitoring and control systems, including real-time monitoring, load management, and data logging, help oversee the charging process. Regulatory compliance with electrical safety standards, environmental regulations, and charging protocols is also important in supporting sustainable maritime transportation while ensuring the safety and efficiency of the charging process.

1.1 Problem definition

With a large percentage of fires on board being caused by electrical faults, a mere technical solution shall not suffice. This is owed to the fact that human interactions are a major part of the overall process of transporting cargo in reefer units or transporting and charging private EVs onboard vessels. These interactions imply certain orders and procedures are followed which opens an opportunity to refine them and make them safer.

As of today, reefers are driven into ro-ro/ro-pax vessels, connected to electrical outlets, and disconnected and driven out when the destination is reached. Many rules govern specifics, and many operating procedures are in place to ensure a safe way to transport these reefer units and yet reefers happen to be a major cause of fires on board.

1.2 Technical approach

The primary approach opted has been to study current procedures and operational aspects, interact with operators on board and develop an improved system for handling reefers and charging EVs. This report aims to provide a more qualitative approach to the problem statement and is complemented by D08.5 which provides a quantitative technical approach to solve the same problem. Several visits to Stena Danica and Stena Scandinavica and the studies and interaction with crew on board form the crux of this report.

By providing guidelines and recommendations, this report can be a starting point for not only the considered reference vessels but to all ro-ro/ro-pax vessels to improve operational aspects that are relevant and hence reduce risks of electrical accidents and eve fires.

1.3 Results and achievements

The results of this report are qualitative recommendations primarily to ship operators. It addresses electrical risks associated with reefer units that are being powered on board and charging of EVs during transit. The report then presents recommendations and guidelines to best mitigate these identified risks. These are considered based on the different risks and requirements of reefer connections and charging of EVs. Routine inspections of specific components, developing and following specific standard operating procedures, use of correctly rated components, installation and use of more advanced monitoring systems, et cetera are some of the key guidelines that are detailed.

The reported safe operating procedures and guidelines can be valuable as they are changes that have a high impact on safety but do not come necessarily with very high costs. These also apply to all operators that deal with reefer units and EVs on board.

1.4 Contribution to LASH FIRE objectives

The LASH FIRE project further aims to support the recently adopted IMO Strategic Plan (2018-2023), including the following identified strategic direction:

"Integrate new and advancing technologies in the regulatory framework - balancing the benefits derived from new and advancing technologies against safety and security concerns, the impact on the environment and on international trade facilitation, the potential costs to the industry, and their impact on personnel, both on board and ashore.".

This report contributes to "Objective 1: LASH FIRE will strengthen the independent fire protection of ro-ro ships by developing and validating effective operative and design solutions addressing current and future challenges in all stages of a fire."

WP8 explores and implements State of the Art technology when it comes to monitoring connected Reefers and Electrical Vehicles and gives advice and recommendations to decision makers either in ro-ro spaces, engine room or on the bridge.

1.5 Exploitation

The results of this deliverable, D08.6, is best used along with the outcomes and implementation presented in deliverable D08.5. D08.5 presents a technical approach towards quantitatively monitoring reefer units and EVs and together with the qualitative approach presented in this report, a wholistic solution to safer reefer units and EVs on board can be realized.

The results from both aforementioned deliverables are primarily aimed at ship operators that regularly deal with transporting reefer units and passenger EVs that need charging during voyage. The finding from the visits and the consequent recommendations may also be of interest to classification societies and regulatory bodies to introduce rules that add towards a safer future.

2 List of symbols and abbreviations

EV	Electric Vehicle
IACS	International Association of Classification Societies
IMO	International Maritime Organization
Ro-ro	Roll-on/Roll-off Cargo
SOLAS	International Convention for the Safety of Life at Sea
SOP	Standard Operating Procedure

3 Introduction

Main author of the chapter: Vasudev Ramachandra, RISE

Electrical safety in the maritime industry is of paramount importance, not only for the protection of personnel but also for the preservation of valuable assets and the prevention of environmental incidents. A single electrical fault or malfunction can have far-reaching consequences, ranging from injury and loss of life to severe equipment damage, operational disruptions, and even marine pollution. Annex A shows a table of examples of near miss cases where electrical faults have led to fire risks and in some cases, smoke. Therefore, it is imperative for all stakeholders to have a comprehensive understanding of electrical safety measures, regulations, best practices, and emergency response protocols.

This report aims to serve as a valuable resource for individuals working within the maritime industry, specifically dealing with reefer units, who are responsible for the installation, operation, and maintenance of electrical systems and equipment. It explores the key aspects of electrical safety, providing insights into the relevant international and regional regulations, industry standards, and recommended practices. By familiarizing themselves with these guidelines, maritime professionals can effectively identify electrical hazards, assess risks, implement appropriate control measures, and respond to emergencies in a timely and efficient manner.

The chapters that follow delve into various topics related to electrical safety in the maritime industry. Chapter 4 provides an overview of the regulatory framework governing electrical installations and operations, highlighting the key international conventions, codes, and guidelines that govern this sector. Chapters 5 and 6 focuses on identified risks and developed guidelines related to reefer units and charging EVs respectively. Overall, essential aspects of electrical equipment selection, installation, and maintenance, outlining best practices for ensuring reliability, performance, and compliance are presented.

By adopting the guidelines and recommendations presented in this guide, ship operators can create a safety-conscious culture within their organizations and enhance the overall operational integrity of their electrical systems. The ultimate goal is to prevent accidents, protect human lives, safeguard valuable assets, and contribute to the sustainable development of the maritime industry as a whole.

4 Electrical connection regulations review

Main author of the chapter: Vasudev Ramachandra, RISE

This section aims at presenting a gist of requirements applicable in ro-ro spaces concerning “guidelines for electrical systems, equipment and routines, providing safe electrical connection of reefers and electric vehicles in ro-ro spaces”.

The present review is based on the currently applicable regulations. Therefore, some of the requirements detailed below may not be applicable on old ships.

IMO Documents	SOLAS Convention, as amended
	MSC.1/Circ.1615, Interim Guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships
IACS & Class Rules	IACS Blue book dated January 2019
	BV Rules for Steel Ships (NR467), as amended in January 2020
	DNVGL Rules for the Classification of Ships, December 2019
	LR Rules and Regulations for the Classification of Ships, July 2019
Flag Administration Rules	MMF (French Flag Administration) Division 221 “Passenger ships engaged in international voyages and cargo ships of more than 500 gross tonnage”, 28/12/17 edition

Table 1: List of documents used for the review of regulations.

4.1 Categorization of spaces

As per SOLAS II-2/3 [1], ro-ro spaces, vehicle spaces and special category spaces are distinguished and defined. These aids isolating electrical requirement most relevant to specific spaces. Some additional details regarding space categorization are also available in IACS UI SC 86 [2].

4.2 Regulations and recommendations

In general, electrical equipment, including sockets and shipboard cables, used in ro-ro or vehicle spaces are required to be suitable for use in an explosive petrol and air mixture. SOLAS II-2/20.3.2, SOLAS II-2/19.3.2, IEC 60092-506 talk generally about the specifics of the types of plugs and sockets to be used on specific decks to connect the reefer units to.

Rules regarding state of on/off switch while being connected or disconnected, maximum temperature of the sockets, prevention of short circuits during connections, et cetera are few of several requirements aimed at limiting the risk of a fire starting on the sockets. These can be found in Classification Society rules such as BV Rules [3] for ro-ro passenger ships as well as in LR Rules [4], usually coming from industrial standards such as the IEC series (see IEC 60092-306 [5] or IEC 60309 [6]). BV Rules [3] also require IP 56 protection level for socket outlets installed in vehicle spaces of ro-ro passenger ships, with a view to ensure that such sockets will be “certified safe” and won’t be affected by possible washing of the car-deck with water. This requirement was implemented in BV Rules [3] further to recommendations from the FIRESAFE I study [7]. It is therefore applicable only to ro-ro passenger ships. There are also regulations and non-mandatory recommendations, such as in MSC.1/Circ.1615 [8], on overcurrent protection, earth fault protection, electrical cables, et cetera.

On the operational side, drills like “fire patrols”, with the aid of thermal imaging devices are recommended to check the conditions and integrity of electrical connections and ship's power supply cables to vehicles.

5 Guidelines for safety - Reefer units

It's crucial to prioritize electrical safety and regularly assess the condition of electrical systems in reefer units to prevent electrical fires. Adhering to manufacturer guidelines, industry standards, and applicable regulations plays a vital role in mitigating the risks associated with electrical fires.

First, identified risks are presented followed by a list of guidelines to address the risks.

5.1 Risks

Unsafe procedures and routines

Handling cables and making connections to reefer units form most of the electrical routine revolving around reefer units onboard and hence statistically contribute more to related faults.

The use of inadequate or damaged extension cords, as well as improper connections to power sources, can introduce fire risks. Vehicles that accidentally run over laid out cables also pose a threat to the integrity of the cables. Stresses like these can cause internal shorts in the cable that are hard to detect, rendering the cables unreliable.

Faults in the electrical systems and equipment

Faulty wiring, damaged electrical components, or poor connections can lead to electrical malfunctions, resulting in sparks, short circuits, or overheating. These issues can ignite nearby flammable materials and cause a fire.

Overloading the electrical system of a reefer unit or continuous operation at maximum capacity can lead to excessive heat generation and potential fire hazards. This, like reefer maintenance, is primarily the owner’s responsibility. However, spreading awareness and educating the reefer owners may be the ship operator’s responsibility.

Inadequate grounding or insulation within the electrical system of a reefer unit can lead to electrical faults and increase the risk of electrical fires. As the electrical network on the load side on a vessel is an ungrounded system, it is required by rules to have an active insulation monitoring system in place. As of today, insulation is monitored for up to 25 reefers units as a group which makes isolating the one with the fault very difficult and impossible without a crew member physically inspecting the 25 units on deck.

5.2 Guidelines

Systems and equipment

Strict electrical safety measures pertaining to systems and equipment concerning reefer units are to be implemented. This includes ensuring appropriate grounding, using high-quality and undamaged power cables and connectors, avoiding overloading electrical circuits, and following safe practices for connecting and disconnecting power sources.

Wiring and Component Integrity: Ensure that wiring and electrical components, such as switches, relays, and connectors, are in good condition and free from damage or corrosion. This is especially important as the environment is humid and salty.

Connection Integrity: Ensure that the power connections between the reefer units and the power source are secure, tight, and properly seated. Verify that the connectors are fully engaged and locked into place to prevent accidental disconnections during the voyage.

Compatibility: Check that the power source matches the requirements of the reefer units. Different reefer units may have specific voltage, frequency, and connector specifications. Verify that the power source meets these requirements to ensure safe and efficient operation.

Cable Condition: Inspect the power cables for any signs of damage, such as frayed or exposed wires, cuts, or abrasions. Damaged cables can pose electrical hazards, including short circuits or electric shocks. If any damage is detected, the cable should be replaced before departure.

Insulation Integrity: Verify that the insulation around the power cables is intact and free from cracks or wear. Damaged insulation increases the risk of electrical faults and potential fires. Ensure that the cables are properly insulated to minimize these risks.

Overcurrent Protection: Ensure that the power connections are equipped with appropriate overcurrent protection devices, such as fuses or circuit breakers. These devices help prevent excessive current flow that can damage the reefer units or pose fire hazards.

Power Source Stability: Verify the stability and reliability of the power source. Unstable or fluctuating power supply can affect the proper functioning of the reefer units and potentially cause damage. If any concerns arise regarding the power source, they should be addressed before departure.

Cable Handling: Ensure that cables are not run over by other refers or vehicles by either managing the stowage plan, or by waiting until all units are loaded to make connections.

Use High-Quality Cords: Employ appropriate extension cords that are rated for the load and conditions, and ensure they are in good condition without frays, cuts, or exposed wiring.

Correct Power Connections: Properly connect the reefer unit to the power source, following the manufacturer's instructions and using compatible connectors and outlets.

Regular Inspections: Conduct routine inspections of the electrical system in reefer units to identify and rectify any signs of wear, damage, or loose connections. While in specific this is the responsibility of the reefer owner, a visual inspection of the plug and socket by a crew member during connection is advised.

Adherence to Rated Capacities: Follow the manufacturer's guidelines and recommendations regarding the maximum load capacity and operating duration of the reefer unit to avoid overloading.

Proper Ventilation: Ensure that the reefer unit has sufficient ventilation to dissipate heat effectively and prevent overheating of electrical components.

Monitoring and control system:

Monitoring and Control Systems: The safety infrastructure on ro-ro vessels should include real-time monitoring capabilities to track the electrical behaviour of connected reefer units. In addition, disconnection of any reefer unit remotely should be possible.

Such a system is not traditionally a part of a ro-ro ship’s safety system in current times as no regulation enforces such a requirement and integration on an existing ship can be a significant financial commitment. Regulations demand real time monitoring of the state of the insulation resistance, and this is hence often done at a large cluster level where about 25 reefer units are monitored under one insulation monitoring device. This clustered approach indicates an insulation fault and if the fault is of significance, it is then up to a crew member to physically walk on the cargo deck, trying to identify the reefer, among 25 of them, that is causing the fault. Often this identification is done by carrying a handheld fault locator device and making measurements on the units until the faulty one is found. Then, if the fault has not already advanced to more serious problems such as creating sparks or causing smoke, it is evaluated if the reefer has to be disconnected. If it is to be disconnected, it is done so manually.

To eliminate risk to the crew and to drastically reduce the time between measuring a fault and identifying the faulty unit, a monitoring system is designed to identify the fault and locate the faulty unit automatically. The system also allows remote disconnection of any unit that is to be disconnected.

LASH FIRE deliverable report D08.5 “Development and validation of safe electrical systems, equipment and routines” details this developed solution. All reefer units are treated as “black boxes” and their connections are externally monitored. Their power consumption, individual phase voltages, currents and the insulation resistance levels are constantly measured and compared to preset values based on a reference data set. In case of anomalies, the reefer causing/experiencing electrical faults is identified automatically and a decision can then be taken if the particular unit must be disconnected. If yes, the disconnection can be done remotely or physically on the deck.

The schematic of this solution is as shown in Figure 1.

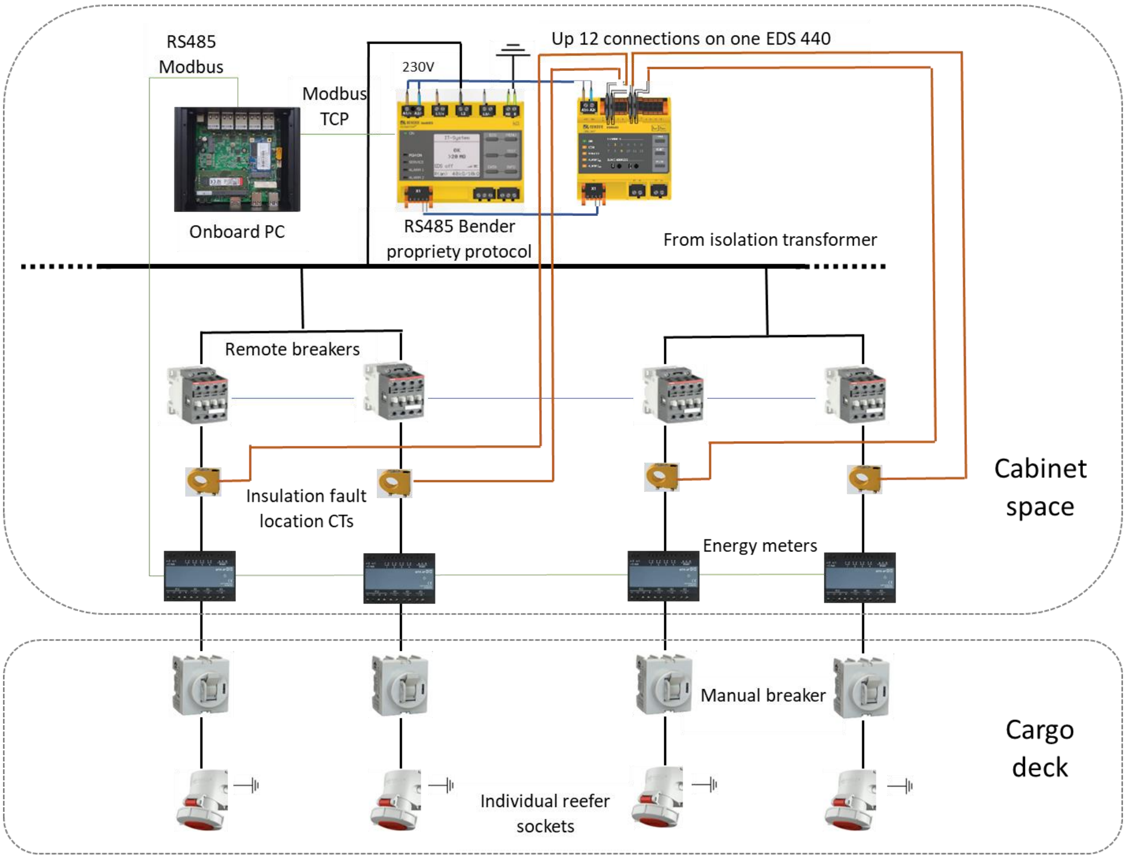

Figure 1 Schematic of a reefer monitoring system

Individual energy meters and breakers with remote tripping capabilities are installed in series with every reefer socket. An insulation monitoring unit is installed along with an insulation fault locator that gets feedback from every reefer socket line via a current transformer. The data from these sensor units are collected by a central computer and the live data is processed to determine if any of them reflect an electrical fault in any of the reefers connected. If there are deviations from the norm, a flag is raised and the nature of fault, its magnitude and the precise reefer unit causing the fault is presented. Based on this information, decision can be taken to remotely and safely disconnect the reefer in contention.

Procedural and routines

Safety Protocols: Develop and enforce safety protocols, including proper shutdown procedures, lockout/tagout practices, and safe working practices around electrical equipment.

Training and Competency: Ensure that the crew members involved in handling reefer units receive proper training and have the necessary competency to identify obvious faults and take necessary action. Training should cover topics such as electrical safety, awareness of common problems with reefer units, emergency procedures, and fire prevention.

Identify Non-Standard Conditions: Provide comprehensive training to personnel responsible for reefer unit handling to identify such quick fixes and deny a connection.

Standard Operating Procedures (SOPs): Develop comprehensive SOPs specifically for the handling of reefer units on the ship. These procedures should include guidelines for connecting and disconnecting power, temperature monitoring, routine inspections, and emergency response protocols. SOPs should be regularly reviewed, updated, and communicated to the crew. It is highly recommended that the connections to reefers are made by crew persons and not reefer drivers. In cases when the traffic is too high for the crew to make all connections themselves, they should hand out the plug end of the cable to the drivers who then make the connections. All connections can then be verified post departure.

Emergency Response Preparedness: Develop and practice emergency response plans specific to reefer unit-related incidents. This should include procedures for fire suppression, evacuation, communication, and coordination with onboard firefighting resources. Conduct regular drills and training exercises to ensure the crew is familiar with emergency response protocols.

6 Guidelines for safety - Charging electric vehicles

Electric vehicles (EVs) being charged on ro-ro cargo and ro-pax ships is an emerging trend in the transportation industry. These vessels can be equipped with charging infrastructure to facilitate the charging of electric cars during transit. This infrastructure typically includes charging stations, power supply systems, and associated electrical components. The charging infrastructure on ro-ro vessels should be designed to ensure safety, efficient operation, and compatibility with a wide range of electric car models. Factors to consider include power capacity, voltage requirements, charging speed, and standardization of charging interfaces.

Risks identified regarding charging of EVs are discussed in the following section and it is essential to address these risks through proper design, installation, and maintenance of charging infrastructure, adherence to safety standards, crew training, and robust emergency response plans. Regular risk assessments and updates to safety procedures should be conducted to ensure the safe and efficient charging of electric cars on board ro-ro or ro-pax ships.

6.1 Risks

Introducing EVs on board brings with it a certain risk but charging them onboard only increases the risks marginally. The charging of electric cars relies on high-capacity batteries that can pose fire hazards if mishandled or if there are defects in the charging infrastructure. Overheating, thermal runaway, or electrical faults within the battery packs can lead to fires. Implementing effective fire detection systems, thermal management measures, and rapid response protocols are essential to minimize the risk of fires and ensure prompt containment in case of an incident.

Malfunction of ship's charging infrastructure

Short circuits and earth faults in the charging stations onboard can cause arcing and heat generation. However, faults like these are relatively easy to tackle as effective solutions such as rightly sized fuses, residual current breakers, et cetera can be used. These faults also are less likely to have an effect on the EVs that are connected to the faulty charging stations. However, loss of control over the charging process, which might stem from an underlying software problem, might result in graver consequences.

Poor feeding power quality of the ship's electrical grid can also be of concern. This might result in abrupt shutting down of the charger, which may have negative consequences on the EV. The electrical grid onboard is also prone to more blackouts than a land-based system is, which also poses a risk.

Other ship side risks can be attributed to the charging cable, which, similar to the reefer cables, are prone to be driven over, stumbled upon, et cetera. These might result in internal shorts which then lead to localized heating, possible arcing and fires.

Malfunction of car's electrical system

These risks are mainly posed by the failure of either the control system and software within the car, or due to the failure of the battery. While such failures leading to fires are less probable than on conventional vehicles, the risk is increased during charging. For instance, an internal fault that fails to communicate the state of charge of the battery to the charger is inevitably subjected to overcharging which eventually leads to a thermal runaway condition. Manufacturing defects in cells can also lead to internal short circuits that result in a thermal runaway condition. However, probabilities of such failures are extremely low.

Other risks

It can be argued that a fully charged EV poses more risk than a less charged EV as it holds more energy. However, there might be other more trivial problems that prove to be of higher risk. For instance, home fixes or modifications done without professional consultation can be a much larger risk. It is also the case that in a large percentage of EV fires, the fire originates elsewhere and eventually reaches the battery, making it harder to contain or fight.

6.2 Guidelines

Safety is a critical aspect of charging electric cars on Ro-Ro vessels. Proper electrical insulation, grounding, and protection against short circuits and over currents should be implemented. Safety protocols and guidelines for handling charging equipment, such as proper storage of charging cables and connectors, should be established and communicated to the crew.

It is important to have monitoring and control systems in place to oversee the charging process. This includes real-time monitoring of charging status, power usage, and temperature to ensure safe and efficient operation. Automated control systems can help manage charging loads and prevent overloading of electrical systems.

Charging electric cars on Ro-Ro vessels may require adherence to relevant regulations and standards. These can include electrical safety standards, environmental regulations, and compliance with specific charging protocols or standards established by regulatory bodies.

Charging electric cars on Ro-Ro vessels offers an opportunity to support sustainable transportation and reduce emissions in the maritime sector. As this technology continues to develop, it is important to address the unique challenges and requirements associated with charging infrastructure onboard Ro-Ro vessels while ensuring the safety and efficiency of the charging process.

Electrical Safety

Electrical Insulation: Adequate electrical insulation should be implemented throughout the charging infrastructure to prevent electrical faults and ensure the safety of personnel and vehicles onboard.

Grounding: Proper grounding of the charging system is essential to provide a safe path for electrical currents and minimize the risk of electric shocks. It helps dissipate any stray currents and protect against potential electrical hazards.

Protection Systems: Overcurrent protection devices, such as fuses and circuit breakers, should be integrated into the charging infrastructure. These devices help prevent excessive current flow and protect the charging system from damage.

Thermal Management: Charging systems should incorporate effective thermal management measures to prevent overheating. This can include temperature sensors, cooling mechanisms, and thermal shutdown features to ensure safe operation and protect against fire risks.

Crew Training: Crew members responsible for operating and maintaining the charging infrastructure should receive proper training on electrical safety procedures, including handling charging cables, connectors, and emergency shutdown protocols.

Monitoring and Control Systems

Real-Time Monitoring: The charging infrastructure on ro-ro vessels should include real-time monitoring capabilities to track the charging status, power consumption, and temperature of the charging process. This allows for early detection of any anomalies or potential issues.

Similar to the monitoring of reefer units, it is important to track electrical parameters of the EV being charged in real-time. While all charging units do monitor certain parameters as they are required to, an external and generic solution adds a layer of redundancy and allows otherwise not monitored parameters to be measured. Unlike reefer units, it is mandatory for EVs and chargers to be connected to a grounded system and hence monitoring of insulations faults is no longer necessary. As an alternative in grounded networks, residual current breakers and appropriate fuses are used to disconnect the load (an EV in this case) if an earth fault were to occur. Nonetheless, it is crucial to measure other electrical parameters such as the instantaneous power consumed, phase voltages and phase currents. These facilitate better recognition of possible faults and help disconnect an EV from the charger before the fault becomes significant.

The solution to monitor EVs being charged onboard is developed with some components of the reefer monitoring system as common infrastructure. The schematic of the solution is as shown in Figure 2.

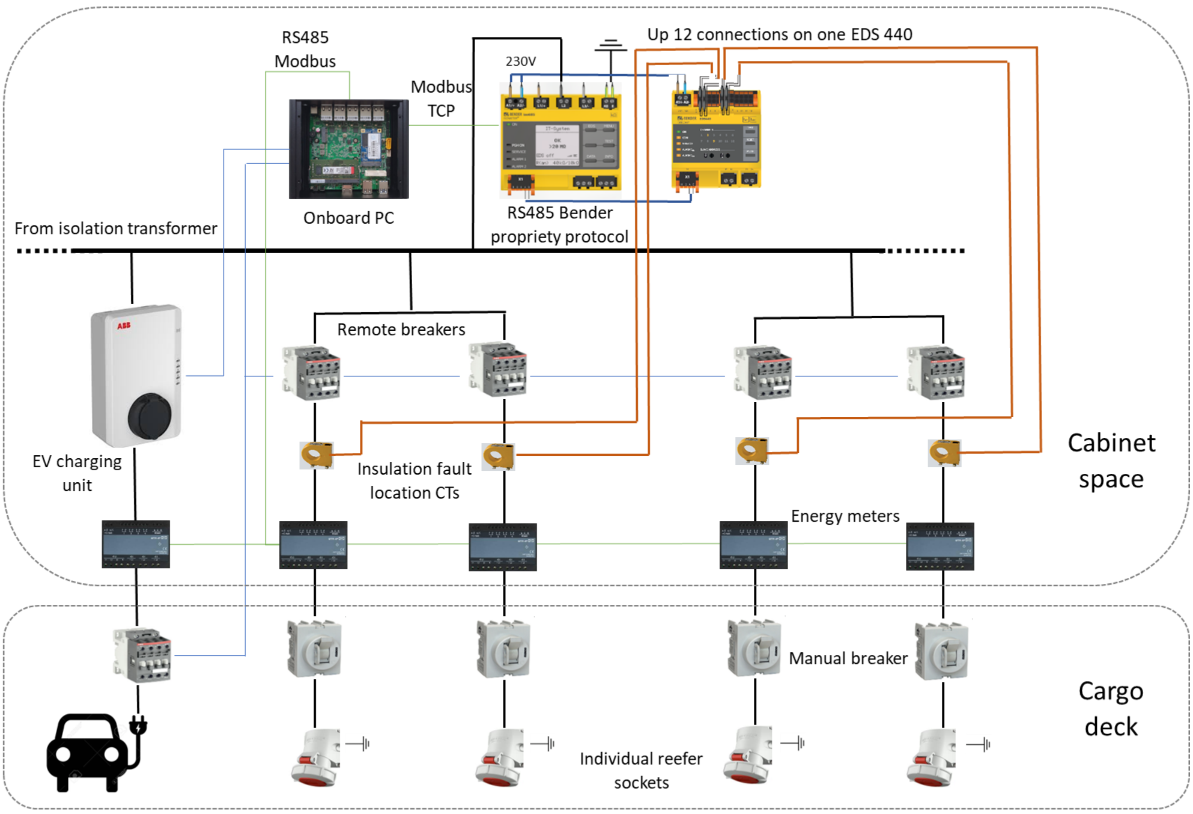

Figure 2 Schematic of solution monitoring charging EVs in addition to reefer units

The energy meter, which is in series with the socket that connects to an EV, measures and transmits data to the common computer. The data is processed in real-time to recognize anomalies in the measured values. If any are found, an appropriate flag is raised, and the EV can be remotely and safely disconnected. LASH FIRE deliverable report D08.5 “Development and validation of safe electrical systems, equipment and routines” details this developed solution further.

Load Management: Automated control systems can be implemented to manage the charging loads onboard. These systems can distribute the available power supply efficiently among the charging stations, preventing overloading of the electrical systems and ensuring optimal charging performance for each vehicle.

Data Logging: Logging and storing charging data can provide valuable insights into energy consumption, charging patterns, and system performance. This data can be utilized for analysis, optimization, and maintenance planning.

Regulatory Compliance

Electrical Safety Standards: Charging infrastructure onboard Ro-Ro vessels must comply with relevant electrical safety standards and regulations. These standards typically cover aspects such as insulation, grounding, overcurrent protection, and electrical equipment certifications to ensure the safe operation of the charging system.

Environmental Regulations: The charging infrastructure should also adhere to environmental regulations, including the proper handling and disposal of hazardous materials, such as batteries and associated components.

Charging Protocols and Standards: Compliance with charging protocols and standards established by regulatory bodies or industry organizations may be required. These protocols ensure interoperability and compatibility between the charging infrastructure and electric car models, promoting a standardized and efficient charging experience.

It's important to note that the specific safety considerations, monitoring and control systems, and regulatory compliance requirements may vary depending on the jurisdiction, applicable standards, and technological advancements. Adhering to these aspects will help ensure a safe and efficient charging infrastructure for EVs on ro-ro ships.

7 Conclusion

Main author of the chapter: Vasudev Ramachandra, RISE

From discussions with ship operators and observations from ship visits during operation, it is evident that safety on board with respect to electrical connections to vehicles of various kinds is evolving and is given importance. While this is true, there is also room for implementation of certain operational aspects, such as ones discussed in this report, that improve safety on board. Some of these aspects are already being observed on some scale while others are new. The specific objective of implementing these operational aspects and guidelines is to reduce electrical related faults onboard that might lead to not just negative consequences to the cargo or vehicles but more importantly to persons on board. Electrical faults, almost irrespective of magnitude, can lead to large fires if not dealt with adequately in early stages and this is a motivation to implement operational changes and additions, along with technical upgrades to safety systems onboard.

The contents of this report can be best exploited by modifying and implementing onboard different but relevant vessels. With more operators and different routes, the operational procedures can be finetuned and tailored as required, and hence serve the purpose of having a safer voyage.

8 References

[1] IMO, 2014, *SOLAS Convention, Consolidated Edition*, as amended.

[2] IACS, 2019, *Blue Book*.

[3] BV, 2020, *Rules for the Classification of Steel Ships, PART D – Service Notations*, NR 467.D1 DT R12 E.

[4] LR, 2019, *Rules and Regulations for the Classification of Ships*.

[5] IEC, 2020, *Electrical installations in ships*, IEC 60092.

[6] IEC, 2017, *Plugs, socket-outlets and couplers for industrial purposes*, IEC 60309.

[7] Wilkman J. and al., 2016, *Study investigating cost effective measures for reducing the risk from fires on ro-ro passenger ships (FIRESAFE)*, EMSA/OP/01/2016, EMSA.

[8] IMO, 2019, *Interim guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships*, MSC.1/Circ.1615.

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10 Annexure

10.1 Annex A: Examples of near miss cases of fires due to electrical faults

Incident Date Year	Size	Event	Incident Description/Fault	Investigation Report/ Firefighting Equipment Used
2015-01-09	3800	**Fire Risk**	**electrical cable heated**	AB discovered during his fire round patrol, one of the heated tank containers with a working temperature round 200 C had its electrical cable connection coiled and was heated and smell burnt. The electrical cable coil from the ship was unrolled but the tank unit coil wasn't.
2014-07-06	5600	**Smoke**	**Fire Incident main deck**	Customer did an investigation; the reefer was not on fire but producing a lot of smoke. The coupling of the reefer was getting stuck, so the V belts were getting hot and produced the smoke.
	1900	**Smoke**	**- Fridge Drop - Sparks and Smoke**	Seaman plugged in refrigerated trailer once it was parked on deck 5. When ships power was turned on the bosun noticed that the fridge started to spark and smoke. The power was immediately turned off and the cable unplugged. A fire extinguisher was quickly collected in case it was required. Smoking reduced. The patch was called to remove the trailer. Email sent to port to inform them of the situation.
2019-09-01	3400	**Fire Risk**	**Near Miss with unsafe 220v/440v plug adaptor**	A rigid unit was presented which requested a plug in, it informed shore staff that it required a 440v, but as it was a rigid the loading officer wisely decided to get it on early and check it with the motorman. The attached photo shows the cable they had, the van itself required a standard 3 pin 220v cable (which we can supply) but in this socket was a length of cable leading to a 440v socket. This "adaptor" allowed 440v to run right into the 220v system with no step down in the voltage whatsoever. If we had plugged the ships connection into this adaptor it would have no doubt caused substantial damage to the driver fridge unit but also put it at a high risk of fire. The driver was informed to get rid of the cable and we were able to plug it in without any issues. The shore staff done an excellent job highlighting that the rigid required 440v which was unusual, and the ship staff done the right thing by checking it before bringing it onboard.

2019-08-09	**3400**	**Smoke**	**Potential Fire Risk by Van Reefer Unit**	A driver of a box van requested a 5 Pin 440 V plug in off the Shore loader, and the Bosun was told this on deck 5. The box van was sent to deck 5 where he in fact needed a 3 pin 230 V plug in. The Bosun gave the Driver the ships cable for this, and the driver plugged the unit in himself to ships supply. The Bosun advised him to remain at his vehicle for at least 10 mins to ensure his reefer was working correctly. The driver did this, told the Bosun he was satisfied and then went into the accommodation. A few mins later one of the loading crew noticed the vans reefer unit smoking and alerted the Bosun and bridge. The unit was immediately switched off and disconnected from the ships supply. The driver was also located and returned to the car deck. The unit continued to smoke, and as the loading was completed the box van could not be discharged ashore. Still smoking and the unit hot, 2 x fire Ext were discharged into the reefer. The smoking then stopped and there was a marked reduction in the reefer's temperature. With the unit cooled and not smoking, car deck fans were started to clear the small amount of smoke and fumes. A fire watch was the maintained on the unit for the rest of the passage, which passed without incident.
2019-01-27	**5600**	**Smoke**	**Near Miss - Running Fridge set off fire alarms**	Running fridge stowed on deck 5 not plugged in by driver. Fire alarm investigated deck 5 found smoke filled. Working party called and crew mustered at emergency stations. Thermal imaging camera revealed no fire but found running fridge. Fridge switched off and driver informed. Emergency stations stood down. Fans set to clear smoke.
2018-12-18	**3400**	**Smoke**	**Plug In Malfunction / Artic BH22ESB/1QEV-981**	The unit was loaded into B9 on deck 3 and plugged in to the ships power via the rear plug-in point on a trailer by the duty Motorman. The deck officer then proceeded to load the port wing and the lower hold. After about 15 minutes the deck officer noticed a strange smell on the car deck and went to investigate the source. On proceeding to the starboard side of the vessel she noticed smoke and arcing coming from the unit and immediately informed the bridge and the rest of the deck crew. The unit was immediately isolated from ships power and the deck officer proceeded to obtain a dry powder extinguisher. On returning to the unit with an extinguisher it was found that the smoking had stopped as the unit had been isolated. The rest of the deck crew immediately attended. Upon investigation the plug-in point on the trailer was found to be melted and blackened and plastic from the unit had dripped down onto the trailers bumper. See attached photographs. The plug-in cable was removed, the unit switched off, the driver called and informed and upon discussion with the Master it was decided that it would be safe to carry the unit with the fridge switched off.