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Deliverable D05.10

Safe electrical system and equipment demonstrator

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Abstract

A demonstrator was established on the ro-pax vessel Stena Scandinavica to serve as a test bed for testing of the developed system for safe electrical connection of reefers and electric vehicles (EVs) .

Full details of test platform and performed activities are given in the LASH FIRE deliverable D08.5 'Development and validation of safe electrical systems, equipment and routines'.

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Content

1 Executive summary

A system for monitoring electrically connected units such as reefers and electric vehicles (EVs) was installed on ro-pax vessel Stena Scandinavica.

The demonstrator enabled validation of the LASH FIRE monitoring concept and provided a platform for function testing.

Full details of test platform and performed activities are given in the deliverable D08.5 'Development and validation of safe electrical systems, equipment and routines', Ref. [1]

1.1 Problem definition

Ro-ro ships are an important component of the global maritime transportation system, but concerns have been raised over the number of significant fire incidents on ro-ro ships in recent years. This has prompted the International Maritime Organization (IMO) and maritime stakeholders to underscore the importance of improving the fire safety in ro-ro spaces. To date, only a limited number of studies focusing on these issues have been conducted. These studies have, to a varying degree, analysed critical aspects in previous ro-ro ship fires, thereby shedding some light on common fire causes in ro-ro shipping.

There is also a need to address the challenges ahead, including the ongoing cargo transformation involving alternative fuel vehicles. Moreover, these fire safety challenges are not limited to ro-ro passenger ships but apply to all types of ro-ro ships, including vehicle carriers and ro-ro cargo ships. Hence, there is a need to update the fire protection of ro-ro ships from a wide and long-term perspective.

Connected reefers and EVs onboard ro-ro cargo and ro-ro passenger ships have been seen as a potential hazard due to the risk of fire. Fire onboard a ro-ro ship is extremely dangerous and fire extinguishing is very hard. With a rise in the number of EVs on board, equipped with lithium-ion batteries, extinguishing these fires are almost impossible. The best solution is to prevent the fire, and this can be done by continuously monitoring the reefers and the EVs onboard.

1.2 Method

In order to design a hardware based quantitative solution to prevent fire situations by proving a safe electrical infrastructure to reefers and EVs, multiple ship visits and interactions with the crew was crucial. With the chief electrical engineer on board and multiple electrical drawings of the ship's electrical infrastructure, the needed connection lines between the distribution transformer and the load units on cargo deck were mapped. The design of the solution considered factors such as effectiveness in identifying faults, cost of components and installation, ease of procurement as there were delays due to Covid-19 and the global silicon shortage. The solution demonstrator was then installed and tested on ro-pax vessel Stena Scandinavica.

1.3 Results and achievements

A qualitative approach to monitor reefer units and charging EVs was developed, implemented as a solution on Stena Scandinavica, and the results from the installation, as a demonstrator, are presented. The point of insulation monitoring and fault location was changed from the output of the distribution transformer to the inputs of the reefer units. In addition, energy meters were added to monitor all crucial parameters of each load unit (reefer or a charging EV). With these, the system allows precise identification of a load unit when there is a deviation from its normal electrical behaviour.

As part of the demonstrator, this solution was tested on five reefer units. All electrical faults, natural or simulated, were automatically identified by the monitoring system. The incorrect parameter, the faulty measurement, the deviation from the expected value and the reefer unit are all raised as flags.

1.4 Contribution to LASH FIRE objectives

One of the main LASH FIRE objectives (Objective 2) is addressed by the ship integration work package (WP05):

> *LASH FIRE will evaluate and demonstrate ship integration feasibility and cost of developed operational and design risk control measures for all types of ro-ro ships and all types of ro-ro spaces.*

This report contributes to the objective through the demonstration of the ship integration of Action 8B solution.

1.5 Exploitation

The report can be used by LASH FIRE and external parties as it provides a description of technical and operational aspects related to innovative solutions. Further, it provides information on the expected or desired implementation, improvements and future developments.

This information can be useful for any stakeholder in the maritime industry.

2 List of symbols and abbreviations

EV	Electric vehicle
CPU	Central processing unit
GB	Giga bytes
GHz	Giga hertz
IMO	International Maritime Organization
LAN	Local Area Network
RAM	Random Access Memory
TCP/IP	Transmission Control Protocol/Internet Protocol
USB	Universal Serial Bus

3 Introduction

Main author of the chapter: Vasudev Ramachandra, RISE

To significantly minimize the risk of accidents due to electrical faults, it is crucial to monitor relevant electrical parameters real time and facilitate better recognition of faults. In lieu of this, a central monitoring system is developed that gathers relevant data from various sensors connected to different loads and processes the data to determine if there is an anomaly in the system, Ref. D08.5, [1]. The system is designed to identify the specific kind of electrical fault and also to identify the particular load unit in which the fault occurs. The solution also allows for remote disconnection of the identified load unit if need be.

The relevant electrical parameters that need real time measurements and monitoring, common to reefer units and EVs, are instantaneous power consumed, individual phase voltages and currents, and system frequency. In addition to these, reefer units need constant insulation monitoring as they are on an ungrounded system and hence insulation measurement units with fault locators are used.

4 Electric connection monitoring solution

Main author of the chapter: Vasudev Ramachandra, RISE

From the output of the isolation transformers, multiple lines feed reefer units on the cargo deck. These lines first enter a cabinet space where they go through individual breaker units which are capable of being tripped remotely. The line is then drawn out of the cabinet space and pulled into the cargo deck where it feeds individual reefer sockets via a manual breaker that is accessible to personnel on deck. Within the cabinet space, all three phases of each line, after passing through the breaker, passes through an insulation fault location current transformer. For the current and voltage sensing, the individual phases then pass through three separate current transformers that are connected to the energy metres. The schematics of the monitoring system is illustrated on Figure 1.

The above description implies that the energy meters that measure instantaneous power, voltage and currents are placed in series with every load connection. These meters measure parameters specific to individual loads and transmit them to the computer via RS485 serial communication protocol. The on-board computer used is a TLSense J4125v3 router. With 4GB of RAM and Intel Celeron J4125 quad core 2.7 GHz CPU, this router has adequate computing capacity to handle data from these sensors. The router also has five 2.5Gbit LAN ports, and four USB 3.0 ports and hence supports all communication protocols needed to communicate with the selected sensors.

Full details of solution including specifics of the energy metres and insulation monitoring unit, along with the insulation fault locator, are given in D08.5, Ref. [1].

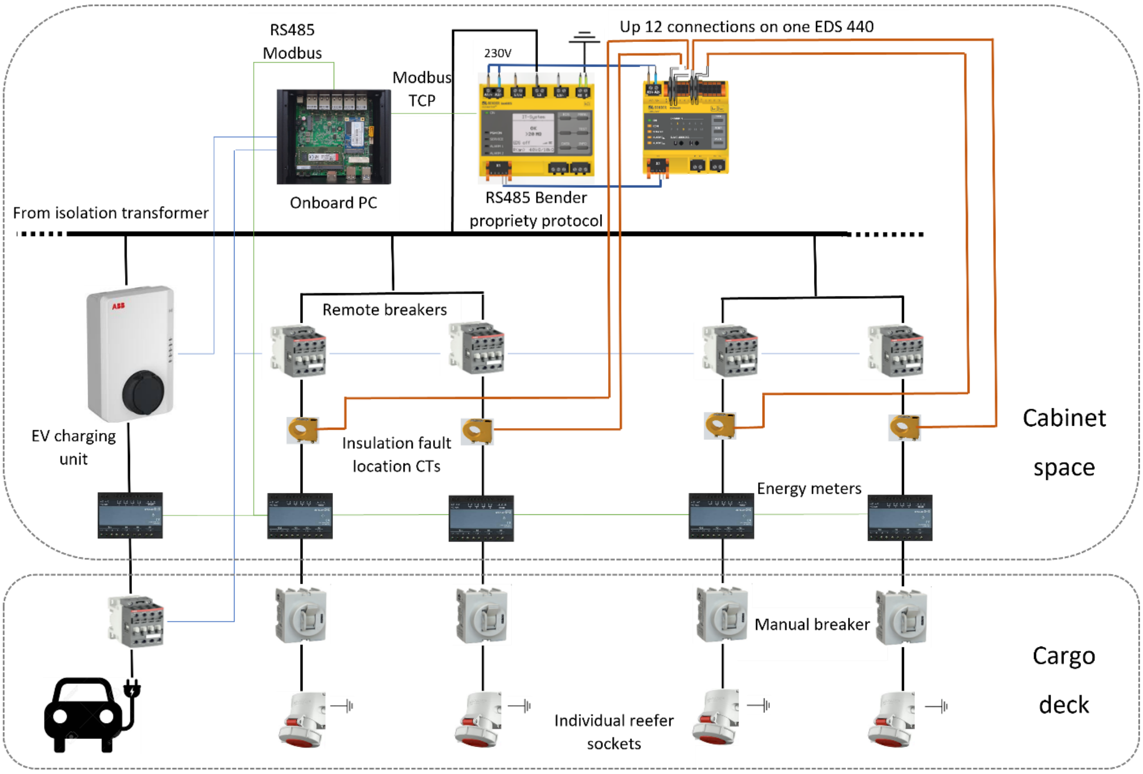

Figure 1. Schematics of the monitoring system.

5 Demonstrator

Main author of the chapter: Vasudev Ramachandra, RISE

To demonstrate the solution, a test bed was set up on a ro-pax vessel Stena Scandinavica, Figure 2. This test bed involved monitoring of five individual reefer sockets out of the 90 available on board. The set up included all aspects of the solution and all mentioned parameters.

Figure 2. Stena Scandinavica

The cabinet with the installed solution is shown on **Error! Reference source not found.**. While the reefers are parked on deck 3, the monitoring system and the breaker cabinet is situated on deck 4.

First, individual socket lines from deck 3 that connect to their respective breakers were traced to this cabinet. Energy metres, the insulation measurement unit and fault locators were then installed for the five specific connections. The central computer to acquire and process data from these sensors was also installed in the same cabinet.

Initially, all the physical electrical connections were made, and the sensors were rightly configured. It was ensured that relevant data is measured and stored conveniently. For the energy metre, the individual phase voltages of each socket, the individual frequencies, currents through individual phases, overall power consumption and the face differences were primary parameters that were checked for and configured. Proper communication between the energy metres and with the on-board computer was ensured via serial communication protocol RS485. For the insulation monitoring part of the solution, firstly proper communication between the insulation fault locator and the insulation monitoring unit was ensured. Then, communication via TCP/IP was configured with the onboard computer.

The algorithm that collects and processes the data from the sensors was then tested. This was done by first collecting live data from connected reefer units on multiple voyages. With this data, trends and expected values for the measured parameters were obtained. This gave the acceptable values and limits off the electrical parameters during normal operation of these reefer units. Based on this, the algorithm was tuned to recognise an anomaly when any of these parameters were measured to be out of bounds.

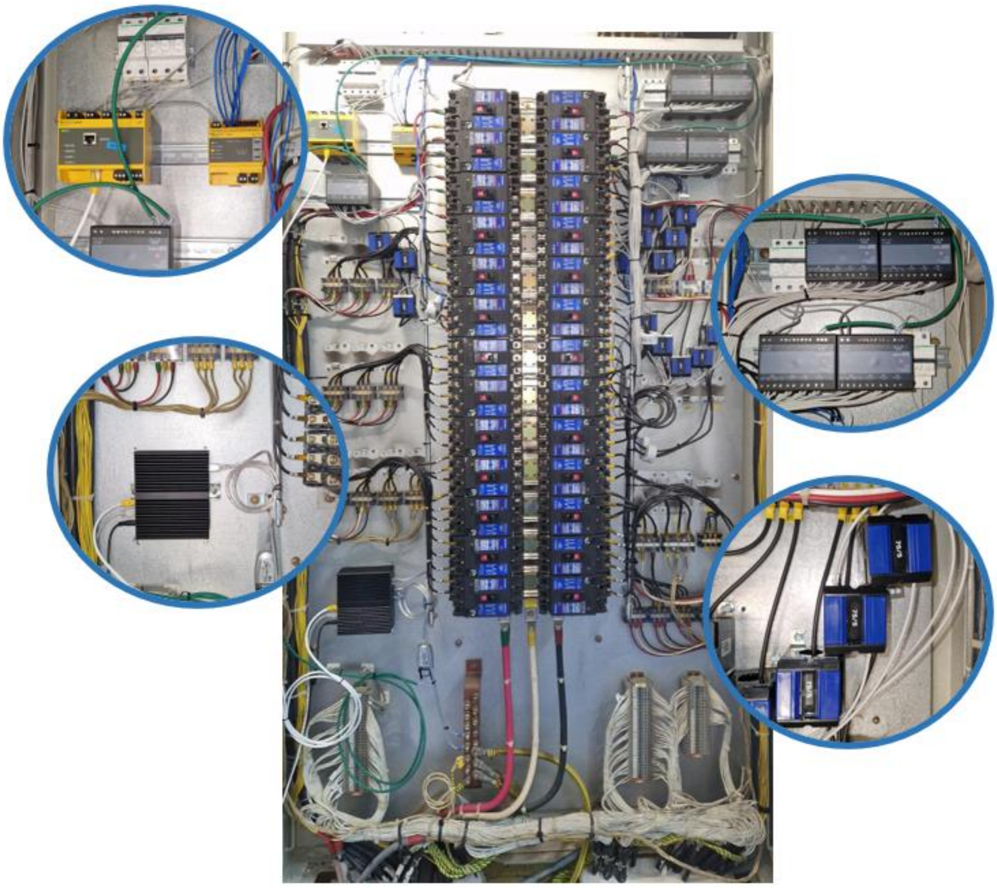

Figure 3. Demo monitoring system as installed in reefer cabinet

A key challenge was to safely test the overall solution. Destructive testing on board was certainly not possible. This ruled out deliberately creating short circuits or insulation faults in the reefer units during voyage. Since the solution had also not been benched onshore, even mild stress tests were deemed unsafe to test on board. With these restrictions, two methods were found to test abnormal conditions.

The first was to reduce the window of acceptable deviation in the measured parameters. This meant that the solution would be tuned to be extremely conservative and hence consider the slightest of deviations to be a fault. For instance, practically under normal operating conditions, a phase voltage between 240V and 245V was found to be acceptable. However, to test with this method of reducing the window of acceptable deviation, the limits in the algorithm for normal operation was set as any voltage between 243V and 243.5V. Every time the measured value was out of bounds of this defined window, the system recognised it as a phase voltage fault.

The second was to induce faults via software. The actual measured values were masked by made-up values which were synonymous to an electrical fault in the system. This method was particularly useful in testing the system against parameters like frequencies which usually do not fluctuate much during normal operation. The same is also valid for insulation faults.

Once both methods had been used to verify detection of deviation among all measured parameters, the algorithm was tested against a simulation with random faults in random reefers among the five connections.

Full details of test platform and performed activities are given in the deliverable D08.5, Ref. [1].

6 Conclusion

Main author of the chapter: Martin, Carlsson, STL

The installed demonstration system validated the newly developed LASH FIRE monitoring concept in an existing ro-pax vessel.

The demonstrator allowed for function validation in terms of collection and display of normal operational data for connected reefer units. Further, detecting anomalies and creating artificial parameter values resembling an elevated risk situation and testing of alarm functions for deviations was performed.

7 Indexes

7.1 Index of figures

8 References

[1] LASH FIRE, *Development and validation of safe electrical systems, equipment and routines (D08.5), 2023.*