Catalogue of measures and recommendations for the transport of alternatively powered vehicles on board of RORO-ferries and for the provision of charging options for electric vehicles during the crossing

Summary of the results of the project ALBERO

"Transport of alternatively operated vehicles on RoRo ferries"

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- Fraunhofer Institut für Kommunikation, Informationsverarbeitung und Ergonomie (FKIE)
- GTE Industrieelektronik GmbH (GTE)
- Hochschule Bonn-Rhein-Sieg (HBRS)
- Institut für Sicherheitstechnik/Schiffssicherheit e.V. (ISV)
- Lloyd's Register (LR)

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Inhalt

1. Background

The number of alternatively operated vehicles is increasing more and more. Accordingly, such vehicles are increasingly being transported on ferries. Passengers with electric vehicles ask about the possibility of charging their cars during the crossing. Shipping companies have to face the new challenges that come up with that and adapt their service and safety concepts.
The aim of the ALBERO research project was to develop concepts and technologies for the safe integration of alternatively powered vehicles (APV) into the RORO ferry transport processes. Both electric vehicles and vehicles with alternative fuels such as natural gas (CNG) and autogas (LPG) should be considered. In the project technical, structural and organizational measures and concepts should be developed that enable the safe transport and (for electric vehicles) safe charging while crossing. In addition, recommendations for effective hazard prevention measures in an emergency situation should be drawn up.

2. Types of alternatively powered vehicles and their special features relevant for the transport on ferries

2.1 Electric vehicles

- Electric vehicles are heavier than identical conventional models. The difference in weight is between 200 and 500 kg.
- The likelihood of fires for EV is not higher than for conventional vehicles with internal combustion engines. In discussions we agreed to report that this comparison is valid for "young" EVs, because there is no experience yet, if this statement will be correct for older electric vehicles, for which a sufficient data base is still missing.
- The combustion temperatures or the heat release rate are not higher than for conventional vehicles with internal combustion engines.
- During a thermal runaway, gases are released which could be used for early detection measures. The main gases to be expected are hydrogen, carbon monoxide and carbon dioxide. The quantities released and the proportions of these gases to one another depend primarily on the specific cell chemistry, the state of charge of the battery and the charging cycles that have already taken place. In addition, electrolyte, which usually consists of compounds containing hydrocarbons, is blown off.
- Once the fire has spread to the battery, the fire becomes difficult to extinguish. Due to the longer duration of the fire and, especially when round cells are used in the battery modules, the risk of burning battery parts flying away, there is a higher risk of the fire spreading.
- During the fire, toxic gases are produced, the composition of which differs from that of conventional vehicle fires, e.g. the release of highly corrosive HF and HCl. However, HF is highly reactive, reacts quickly with substances in the environment and therefore does not last very long in this form in the ambient air or in the extinguishing water. There are also highly toxic gases or aerosols of organometallic compounds, as well as phosphorus and fluorine compounds. Graphite dust can also be released in larger quantities.

- Sprinkler systems can help to contain the spread of fire, but have no cooling effect on the battery, which is usually installed in the underbody of the vehicle.
- Re-ignition has to be expected even hours after apparently put out of the fire.
- The hazard of a dangerous contamination of extinguishing water exists especially if the battery is severely destroyed, so that there can be direct contact with the metallic components of the battery. The extinguishing water then is strongly alkaline and contains various toxic (metal) compounds.
- After the extinguishing work, it must be expected that the soot etc. deposited in the environment and on work clothing contains high proportions of highly toxic (organic) heavy metal compounds. Professional decontamination or disposal is necessary.
- Immersing a damaged battery or an entire damaged electric car in water-filled containers can lead to the development of hydrogen (by electrolysis reactions in cells that are still undamaged or by reactions of water with metallic elements inside damaged cells). In closed rooms there can be a risk of explosion.

2.2 CNG powered cars

- The main component of natural gas is methane. The gas can be used as compressed natural gas (CNG) or as cryogenic liquefied natural gas (LNG) as fuel for vehicles. Currently CNG technology is much more widespread.
- All CNG cars are bivalent vehicles. That means they also have the possibility to drive with petrol. So, beside the gas tank, all CNG cars also have a tank for petrol.
- In the car CNG gas is stored in tanks at 200 bar. On most models the filler neck for the gas is located directly next to the fuel tank inlet behind the same flap. Most CNG car models can be filled up with a natural gas volume between 12 kg and 37 kg.
- The tanks are fitted with the following safety devices:
    - thermally activated pressure relief device (TPRD) opens at 110°C and empties the entire contents of the tank
    - check valve that prevents reverse flow to the fill line
    - automatic shut-off valve that can close to prevent flow from the tank to the fuel cell or internal combustion engine. This valve closes after the car is switched off or in the event of an accident.
- In the event of overheating, safety devices on the tank ensure that all gas in the tank is blown off. CNG is highly flammable and explosive. Ignition sources nearby can cause jet flames or fire.
- CNG gas is much lighter than air and can accumulate in areas under the ceiling. Outside it rises very quickly into the atmosphere.
- At poor ventilation there is the hazard of local displacement of oxygen.
- In closed areas, depending on the ventilation and flow conditions, the gas can accumulate and thus the explosion hazard can occur even far away from the point where the gas exits. Possible initial measures are intensive ventilation and the control of smouldering fires.

2.3 LPG powered cars

- LPG (Autogas) is a mixture of propane and butane. LPG is the abbreviation for Liquefied Petrol Gas.
- Vehicles powered by LPG are currently always bivalent vehicles, which means that they can run on both petrol and LPG. The petrol tank and petrol operation remain completely. A second fuel system is installed inside the vehicle for the gas. Either petrol or LPG can be burned in the engine.
- In the car LPG is stored as a liquid in tanks at ca. 6 – 8 bar.
- Often, LPG gas-powered vehicles are retrofits or conversions. Retrofitted gas tanks are often installed in the form of a spare wheel in the spare wheel well. Such a wheel well tank can hold between 30 and 60 litres of liquid gas.
- For safety reasons a tank can only be filled up to 80% to have an expansion reserve.
- At a certain overpressure (ca. 27,5 bar) the gas is blown off in a controlled manner via a safety valve. The blow-off occurs stepwise as the overpressure is for the moment reduced when the valve has opened.
- LPG is highly flammable and explosive. If during gas release ignition sources are nearby, it can lead to jet flames or fire.
- In closed areas, depending on the ventilation and flow conditions, the gas can accumulate and thus the explosion hazard can occur even far away from the point where the gas escapes.
- LPG is heavier than air and can therefore accumulate on the floor or even, if openings are present, in areas and rooms below.
- At poor ventilation there is the hazard of local displacement of oxygen.
- Possible initial measures are intensive ventilation and cooling of the vehicle to prevent further gas release.

2.4 Hydrogen powered cars

- Hydrogen is a pure gas and can be stored compressed (H_2) or cryogenic liquefied (LH_2).
- H_2 can be used for internal combustion engines and fuel cell applications.
- Today hydrogen cars have 2 or 3 tanks with 4 to 7 kg hydrogen with a pressure of up to 700 bar.
- The tanks are fitted with the following closure devices:
  - Thermally activated pressure relief device (TPRD) opens at 110°C and empties the entire contents of the tank.
  - Check valve that prevents reverse flow to the fill line.
  - Automatic shut-off valve that can close to prevent flow from the tank to the fuel cell or internal combustion engine. This valve closes after the car is switched off or in the event of an accident.
- In the event of TPRD activation an ignition is very likely, this can lead to an explosion. After explosion a flash fire will develop until the tank is empty. (CFD simulation has been done in the project further information here:

  https://alberoprojekt.de/index_htm_files/H2-Fahrzeug%20Simulation%20auf%20RoPax%20Faehren.pdf

- Hydrogen has a minimum ignition energy of 0.017mJ for comparison methane 0.274mJ. This makes an autoignition after release very likely (e.g. by electrostatic effects).

- Hydrogen is highly buoyant and diffusive in air, if unconfined these characteristics can assist with reducing the formation of flammable-mixtures, whereas in confined spaces, inadequate ventilation, and, or restricted vertical flow paths, have the potential to create an environment where the formation of flammable mixtures is possible.

3. Organizational Measures

- register the propulsion type of each vehicle and registration plate number during booking process and assess or verify latest upon entry at gate
- establish a labelling system for different alternatively powered vehicles, e. g. by coloured inlay under windshield, to get with ticket, to be placed by customer
- establish a system of dedicated parking positions/areas on board for the distinct types of alternative powered vehicles, possibly offer a charging point
- establish a system of dedicated parking positions/areas on board for the transport of electric bikes, possibly offer a charging point
- pre-sort different alternatively powered vehicles in port area, e. g. with different lanes for sorting to dedicated positions or areas
- assess positions of alternatively powered vehicles retrospectively or with automatic lane detection systems when no dedicated areas or positions are determined
- if no official charging point is provided, ensure that no other sockets are used for “illegal” charging
- use a software system to plan and/or visualize the vehicle distribution at each deck with special concern to alternative powered vehicles
- the ships command should always have an overview about the actual situation on board

ALBERO result (FKIE): LOMOSS-System

- User studies show a high intent of use and overall good/excellent user experience of a load monitoring support system (LoMoSS) that displays the location and fuel type of vehicles on board the ship (e.g. Image 1).
- LoMoSS supports the crew in the process of applying safety measures locally, i.e. by visualizing the installation of mobile safety equipment on board.
- LoMoSS increases situational awareness of the crew by providing crew with essential information. In case of an incident on a ship, it is essential for the crew, to possess knowledge of the vehicle types involved in the incident and those vehicles at risk, if there is an escalation of events.
- The system provides identification possibilities of the fuel type of a vehicle involved in an incident to enable the crew and first responders to be suitably equipped and take the most effective measures to safely resolve the incident.
- It provides identification possibilities of the fuel type of a vehicle involved in an incident to save valuable time (i.e. crew can enter registration number and is provided with booking information

which contains fuel type and therefore does not have to figure out fuel type by analysing fire behaviour).

- LoMoSS provides users with access to information describing the properties, characteristics and hazards of alternative fuelled vehicles (see Image 2 section 5), and a visualization of the location of available firefighting tools (see Image 3 section 1).
- LoMoSS provides users with the possibility to take notes during their watch (see Image 4 section 3) and pin these to an appropriate location where applicable.
- It enables crew to search for essential driver booking details (i.e. fuel type, cabin number) via the registration plate (see Image 5 section 4).
- LoMoSS connects alerting (i.e. gas or thermal runaway detection systems) to this system to display the respective alerts (see Image 6 section 2) along with information on alert type, location of alert, as well as, if applicable, respective fire-response checklists for the involved vehicles.

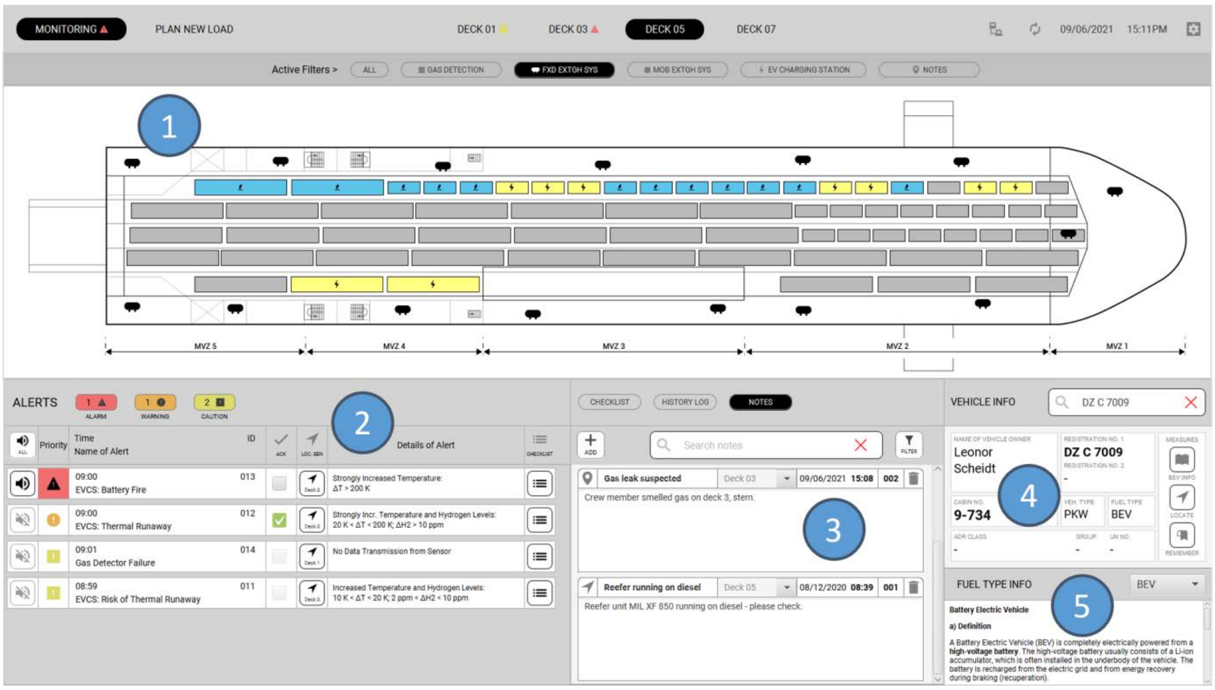

Image 1: Overview of Load Monitoring Support System LOMOSS

4. Technical Measures

4.1 Selected areas for the transport of alternatively operated vehicles

Because of the special features of APV the selection of dedicated areas to position them during transport could be meaningful.

- deck above the waterline – especially for electric vehicles- to get out big amounts of water in case of a fire
- sufficiently dimensioned drainage openings
- continuous and sufficient ventilation (if neccessary installation of extra ventilation systems)

- camera surveillance

4.2 Safety technique to ensure early detection of hazardous situations

ALBERO result (GTE): combined sensor system H_2-Gas sensor and IR-Sensor

Real tests were carried out to evaluate the detection characteristics. Additional classification work has been done - The fire hazard of a battery electric vehicle ("bev" or "plug in hybrid") has to be structured:
A – thermal runaway, with mechanical integrity
B – thermal runaway, cells cracked and electrolyte released
C – battery fire, the electrolyte burns with a flame
D – battery and car fire, the electrolyte and plastics of the car interior is burning
For fire phases C and D the existing detection methods by use of smoke detection and / or flame detection is sufficient – and additionally manual fire fighting is not recommended during this phase, to avoid high personal risks. One experimental result is, that the duration of phase A is several minutes up to hours, while phase B is significantly shorter, even only some seconds. Therefore in ALBERO we focus on detection of phase A.

During thermal runaway we found mainly the release of H_2 gas in combination with a slight increase of surface temperature of the battery housing.
Detection of just H_2 will give false alarms, as other sources of H_2 are present on the ferry, like corrosion process or hot metals, e. g. conventional engines.

The thermal runaway detector (ALBERO detection demonstrator of GTE) combines H_2 increase detection with detection of surface-temperature increase – and performing correlation evaluation.
The alarming interface consists of at least 2 alarm switches and one failure switch (relay contacts). Optional IP access via ethernet for alarm information and sensors signals can be provided.
Installation requirements:
-Aside each single car that has to be monitored; e. g. near to a "wall box" if installed.
-Suitable only in closed, lower decks, at positions with low air flow
The environmental properties at different installation positions will interfere with optimal detection threshold settings – engineering will be required.

4.3 Adapted fire-fighting measures and equipment at dedicated areas

- ensure a parking distance of min 60 cm (according to sprinkler test procedure for car decks) between electric cars and conventional cars to prevent spreading of fire and to ease firefighting measures
- ensure regular fire patrols
- provision of mobile devices to prevent fire spread (e.g. fire blankets, mobile walls), to be applied to the accidental car manually by firefighting team or semi-automatically, use in combination with water deluge system

ALBERO result: Tests regarding the suitability of fire blankets for fighting fires in electric vehicles

Real tests were carried out to evaluate the behaviour of fire blankets and / or sprinkler systems when fighting Li-ion battery fires. The following observations and findings resulted:

- Fire blankets cannot stop the thermal runaway in the battery module from continuing. However, the combustion of other vehicle construction materials can be stopped by the blanket and the flying away of particles is reduced. So the blanket clearly helps to prevent the fire from spreading.
- A fire blanket does not hold tight. Without warning there occurred violent outbreaks of gas from under the blanket, often with these gases igniting. Emergency services in the vicinity need to know this - there is no such thing as a “safe stay” in the vicinity of a covered electric vehicle!
- Despite the use of a fire blanket, there is a strong accumulation of smoke gas outside the blanket, even if a sprinkler system is used at the same time – resulting in low visibility and toxic environment. A breathing apparatus must be worn!
- Depending on the type, the material of the fire blanket can be destroyed if a jet flame from a battery module directly hits the blanket. Holes can arise.
- After removing the fire blanket, the reaction in the battery module can continue. This mainly depends on whether there are any unreacted cells.
- A re-use of the blanket is not recommended because of toxic organometallic contaminations.

- use of mobile water spraying system which can be placed only in case of emergency under the car or on the bottom near the car to cool the cars bottom

ALBERO result (LR, FKFS): mobile boundary cooling system

- The suggested boundary cooling device (see image 2) is a device that is positioned next to the vehicle and sprays water on to the underbody of the vehicle as well as creates a water wall next to it.
- The cooling performance of the mobile boundary cooling device and a deluge system on a traction battery or gas tank was tested. For these tests a heated battery/gas tank dummy was used. The following observations were made:
  - No significant cooling effect of the deluge system on to the battery/gas tank, due to the mounting position underneath the vehicle.
  - The boundary cooling device sprays water on to the underbody of the vehicle where the battery or gas tank is typically mounted. Thereby the cooling effect on to the surfaces of a battery or gas tank is high.
- In the case of an external heat source heating up the battery or gas tank, the boundary cooling device helps to protect them, in order to avoid a thermal runaway or the release of gas.
- In the case of a battery malfunction, which lead to an increasing temperature of the cells, the cooling effect of the boundary cooling device mainly depends on the thermal conductivity between the battery housing and the cells. Due to the influence of low temperatures on to the battery performance, the cells are typically isolated from the housing, which leads to low cooling capabilities during these scenarios.
- The water wall, created next to the vehicle, helps to avoid the spread of fire to adjacent vehicles.

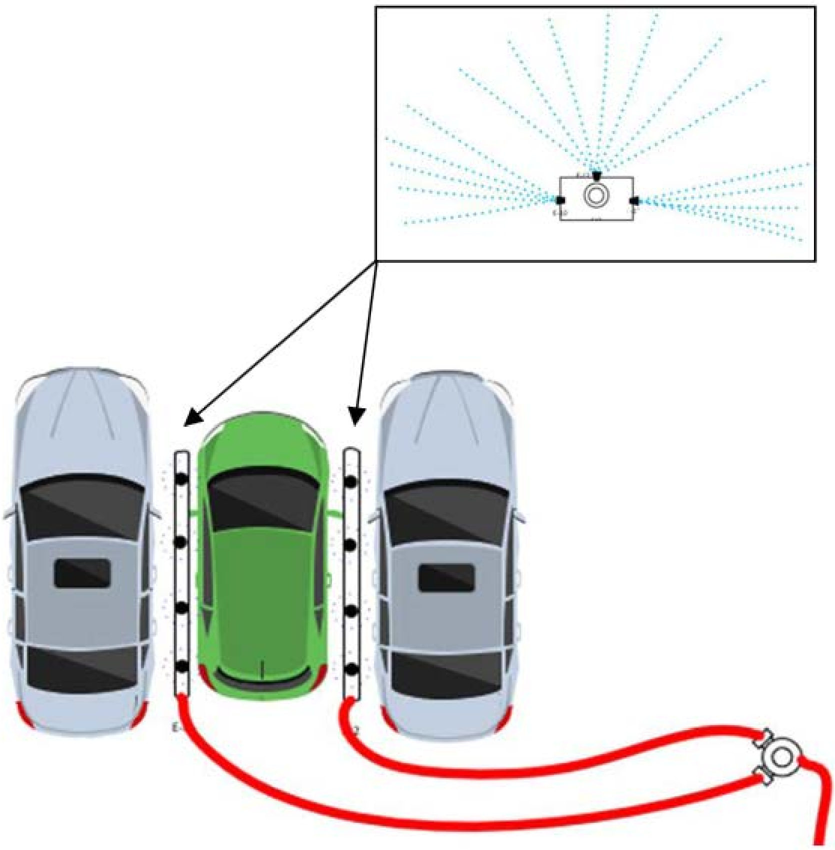

Image 2: principle illustration of a boundary cooling device

4.4 Towing devices

- be aware that electric cars possibly could be unable to drive after passage because of complete discharge of battery (especially at very low temperatures outside)
- provide suitable towing devices to move the car to a safe place, follow the manufacturer’s recommendations

5. Measures in an Emergency

5.1 General characteristics and measures

- Alternatively powered vehicles can show specific behaviour in case of an emergency.
- Emergency services should know whether the damaged vehicle is an electric car or a gas-powered vehicle!
- All alternatively powered vehicles can release gases that are explosive or flammable on the one hand and harmful to health on the other. An approach may therefore only be made with self-contained breathing apparatus and suitable personal protective equipment. Intensive ventilation can be useful. Avoid sources of ignition!

- All alternatively powered vehicles can suddenly release gases which can cause spontaneously long jet flames. Emergency services should keep sufficient distance to the damaged vehicle!
- Independently from the type of car it is advisable to use a lot of water as extinguishing and / or cooling agent. Make sure that there is sufficient drainage to avoid endangering the stability of the ship!

5.2 Electric car fire

Possible measures (depending on the specific situation):

- Fast and massive cooling of the vehicle with water. Use of sprinkler system in the affected section.
- If possible, direct water supply also to the underbody of the affected vehicle.
- If possible, try to apply separating aids, like fire blankets ore mobile separating walls.
- Continue cooling with water even if the fire appears to be extinguished - re-ignition is possible even after hours!
- Monitoring of the vehicle / battery e.g. with a handheld thermal camera.
- Parts of the battery can be thrown away for meters from burning electric vehicles. Keep distance whenever possible.

5.3 LPG car fire

Inside the tank of a LPG vehicle no fire can occur because there is not enough oxygen in it. Usually, a fire spreads to the tank from the outside which causes an increase in pressure inside the tank. At a certain overpressure the gas is blown off in a controlled manner step by step via a safety valve. If there is already a fire nearby or another source of ignition the gas release can be expected to result in sudden, long jet flames. When all gas has been blown out of the tank and burned further firefighting can be carried out like for a conventional vehicle.

5.4 CNG car fire

Inside the tank of a CNG vehicle no fire can occur because there is not enough oxygen in it. Usually, a fire spreads to the tank from the outside which causes an increase in pressure inside the tank. In case of overheating safety devices on the tank ensure that all gas in the tank is blown off. If there is already a fire in the vicinity or another source of ignition the gas release can be expected to result in sudden, long jet flames. Because a CNG vehicle has several gas tanks, it can never be guaranteed that all tanks are empty. Firefighters must be aware of this.

5.5 Hydrogen car fire

Inside the tank of a H_2 vehicle no fire can occur because there is not enough oxygen in it. Usually, a fire spreads to the tank from the outside which causes the activation of the TPRD opens at 110°C. In case of overheating safety devices on the tank ensure that all gas in the tank is blown off. If there is already a fire in the vicinity or another source of ignition the gas release can be expected to result in sudden, long jet flames. Because a H_2 vehicle has several gas tanks, it can never be guaranteed that all tanks are empty. Firefighters must be aware of this.

6. Charging points on Board

The conditions on board differ from those on land. Charging stations have to be adapted to this special surrounding.

ALBERO-Result (LR, ISV): Requirements catalogue for charging stations on board

Selection of a suitable charging station (DC or AC)

The selection should be done according to the following aspects, among others:

- Number of electric cars to be transported. What capacity utilization can be expected?
- Time of passage
- Available power: The number and capacity of the charging station(s) must be calculated according to the "surplus" power available on board. The safety of ship's operation takes priority in any case and must always primarily guaranteed.
- maximum possible length of the charging cable: Depending on the power the maximum possible length of the charging cable is limited. A longer charging cable allows greater flexibility in terms of positioning the vehicles and also allows to charge several vehicles in the vicinity of the charging station. On the other hand a longer cable may increase the risk of tripping and falling over or the damage of the cable when driving over it. If necessary, the cable routing e.g. from top down to the car should be considered.
- Type of charging plug: There are several types of charging plugs available for electric cars. In any case, the charging station should offer the type 2 plug, which has been defined as the European standard. Some charging stations also offer (two) cable outlets with different plug types.
- Current issue of today is still that there is no possibility for conventional AC charging to get sufficient information via the charger station out of the car (BMS). For DC-charging such information exchange can be ensured by the requirements of the IEC 61851-23 and -24.

Electrical protection class:

Charging stations ashore offer an IP 54 protection class in accordance to the industry standard. For onboard operation a protection class of IP 55 (closed decks) or IP 56 (weather decks) is required for electrical installations. In addition, resistance to salty atmosphere should be provided, proven by a separate standardized test.

Explosion protection:

Charging stations ashore are not designed to be ex-protected. On board this is different:

Below the bulkhead deck all electrical equipment must be approved to be used in ex-protection area zone 1, above the bulkhead deck in ex-protection area zone 2 but at least IP 55 at all decks. Many decks or deck areas are designated as explosion protected zones up to a height of 45 cm or fully protected (if dangerous goods are to be transported or below the bulkhead deck). All electrical installations in these areas must have an appropriate explosion protection. Since the implementation of this requirement is very cost-intensive an alternative location on board should be defined that is not subject to these requirements. It should be noted that the charging cable can also pose an explosion hazard, but could be covered with a metallic cable sheath. As the cable will be maintained like this within the responsibility of the ship’s operator (only ship’s cable can be used), there should not be a point of a bigger hazard, in relation to the zones.

Vibrations:
Onboard charging stations should have at least the same vibration resistance as required for all other electrical installations on board. Electrical machinery and equipment used on board ships must be designed to withstand a vibration load of at least 0.7 g according to most classification regulations. This is based on vibrations in a defined frequency range (e.g. from 2 - 100 Hz according to the classification regulations of Lloyds Register).

Inclined positions:
No unintentional switching operations or functional changes may occur at electrical or electronic devices on board up to an angle of inclination of 22.5° to each side.

Electromagnetic compatibility:
Corresponding regulations apply to electrical equipment that have to be complied on board. When charging electric cars the plug connection between the charging station and the car is a challenge. In this context the focus should also be placed on the rectifier (converter) at DC-charging stations as this is clocked and works with power electronics.
Electrical equipment installed on board, which is not defined as being essential, safety and/or habitable related, needs as the minimum comply with the EMC requirements for radiated and conducted emissions (refer to IEC 60092-504, IACS E10 or LR Type Approval Test Specification No. 1)

Voltage and frequency deviations:
All electrical equipment on board must be designed to operate without interference coming from voltage and frequency deviations during normal operation. These deviations are defined for onboard equipment as follows:
voltage: +6/-10% (permanently) +20/-20% (temporarily)
frequency: +5/-5% (permanently) +10/-10% (temporarily)
The industrial standard ashore usually requires a tolerance of +10/-10% for voltage or frequency.

Network parameters:
While the transmission voltage ashore is usually at 400 V and 50 Hz most vessels are operating at 440 V and 60 Hz. A charging station must be able to function accordingly to these input values, this especially applies if the conversion of voltage and frequency is done within the charging station and not by the car.

Power grid, grounding, distribution:
Charging stations ashore are designed for TT or TN networks which both guarantee grounding of the connected consumers via the distributing network. Onboard ships, however, an IT network is often used, where the neutral point of the network is not connected to earth. The devices are individually and separately connected directly to earth instead. For safety reasons and to ensure that the charging electronics detects a protective conductor an earthed network must be created by using an isolating transformer. The transformer must be adapted to the performance parameters of the charging station.

Cable: The cable should be firmly connected to the charging station in a way that no driver can use his own cables.

For the risk of ship’s movement, the cars should be fixed and secured. So far, an emergency disconnection of the cable is not possible. If heavy weather is expected, no charging should be allowed.

Integration into the onboard Power Management System: The charging station should be integrated into the ship's Power Management System. In the future for applications where the communication between ship-charger-car can be established and sensitive data can be transferred (e.g. SOH-state of health, battery temperature, cell voltage, etc.), an automatic / remote stop of the energy flow from charger to car should be possible, while ensuring that the communication will still be working. So, the battery behaviour can further be monitored. Same will be also applicable for other scenarios, where fires might endanger the EV resp. its battery. The disconnection will only be required, if the car already burns or if the situation is so critical that even the sensitive data from the battery does not have any benefit anymore.

Manual switch-off in special situations:
It should be possible to disconnect the entire charging station easily from the grid to stop further use, e.g. by a manual switch-off (access only for crew). This may become necessary, for example, if dangerous goods are transported at nearby parking spaces or if heavy weather is expected. The switch-off device (to disconnect charging station from power supply) should always be located in a non-explosive area/room. This can also be realized by integration into the Power Management System, if necessary.

Integrated safety features:
The charging station must include all safety measures that are also required ashore. Among other things the functionality of communication between the charging station and the battery management system of the vehicle is required, e.g.

- short circuit protection
- overcharging protection – shut down if an overcharging of the battery occurs
- internal cooling of the charging station or the charging cable, if necessary (depending on power)
- temperature monitoring of the charging station, the cable and the plug - switch-off in case of damage and overheating
- shutdown at a hazard alert of vehicle's battery management system Additionally certain ship-specific protection functions seem to be useful, e.g:
- shutdown at severe angles of inclination
- shutdown at strong external forces

Integration into ship´s Alarm and Monitoring System:
The charging station should give an alert in case of internal as well as external malfunctions. The alert should be transferred to the bridge or to a permanently manned control center (e.g. engine control room).

Remote emergency shutdown:
In case of an accident, e.g., a fire nearby, it should be possible to remotely switch off the charging station.

Alarm:
If necessary, it may be useful for the charging station to trigger a noticeable alert in case of dangerous situations (e.g. problem within the charging station, with the connection or with the car battery). This alert must be audible and visually perceptible.

Early detection Measures:
In the vicinity of the charging station various systems are useful for early detection of hazards, e.g.
- camera surveillance
- fixed installation of a combination of H_2-Senssor and IR-Sensor at charging points
- thermography, thermal imaging camera

The choice and design of monitoring depends on the specific location of the charging station onboard (open or closed deck, solar radiation, air circulation, ...). If certain hazardous limits are exceeded an alert should be triggered (bridge, acoustic, optical).

Fire prevention:
Locations of charging stations should be equipped with suitable, possibly additional, fire detectors. Water connection possibilities nearby are useful to extinguish a burning electric car. Before starting to fight the fire the charging process should be stopped and the charging station should be disconnected from the power supply! Good point is of course that the drencher system will be released by the operator / manually and therefore the operator has to ensure that water release will be safe and does not create additional hazards for the fire fighters.

Also keep in mind charging possibilities for E-bikes. The charging of portable bike-accumulators somewhere on board (e.g. at cabins) should not be allowed.

7. Training of the people involved

- Have rescue cards from the car manufacturers on board which describe the basic construction of different alternative powered car types and recommend suitable measures for each type.
- All responsible personnel on board and in port should be qualified in a special course according to the topic, especially how to recognize alternative powered vehicles, which hazards are connected with alternative powered cars and what to do in case of an emergency.

ALBERO-Result (ISV): Definition of competencies involved staff should have with regard to the transport of alternatively powered vehicles on RORO-ferries

- Knowledge of the different types of alternative drives in vehicles
- Possibilities of recognizing the different drive types by external characteristics
- Understanding of the fuels used in the various alternatively powered vehicles (CNG, LPG, H_2) and their special features when released (density, toxicity, risk of explosion)
- Understanding of causes of a thermal runaway in vehicle batteries
- Knowledge of the possible consequences of a thermal runaway in vehicle batteries (gas release, fire, flashbacks)
- Evaluation of suitable parking spaces for alternatively operated vehicles on car decks
- Assessment of situations where charging of vehicles on deck should be permitted or not

- Knowledge of the first measures to be taken when gas is released from an alternatively powered vehicle
- Knowledge of initial measures in the event of a fire in an alternatively powered vehicle
- Use of personal protective equipment in accidents with alternatively powered vehicles
- Dealing with contaminated surfaces after a fire in an electric vehicle

ALBERO-Result (ISV): web-based training system "Handling of alternatively powered vehicles on RORO-Ferries"

- Online training system, structured according to the single steps in the transport process
- Language switching German / English
- Interactive 360 ° representation of the individual scenes in the port, during loading, on deck, during unloading
- structured presentation of the special features of the various alternatively powered vehicles (construction, identifying features)
- Recommendations for a safe location on board
- Recommendations for the safe installation of a charging point on board
- Instructions on how to behave in emergency situations
- Test questions to query the knowledge you have learned

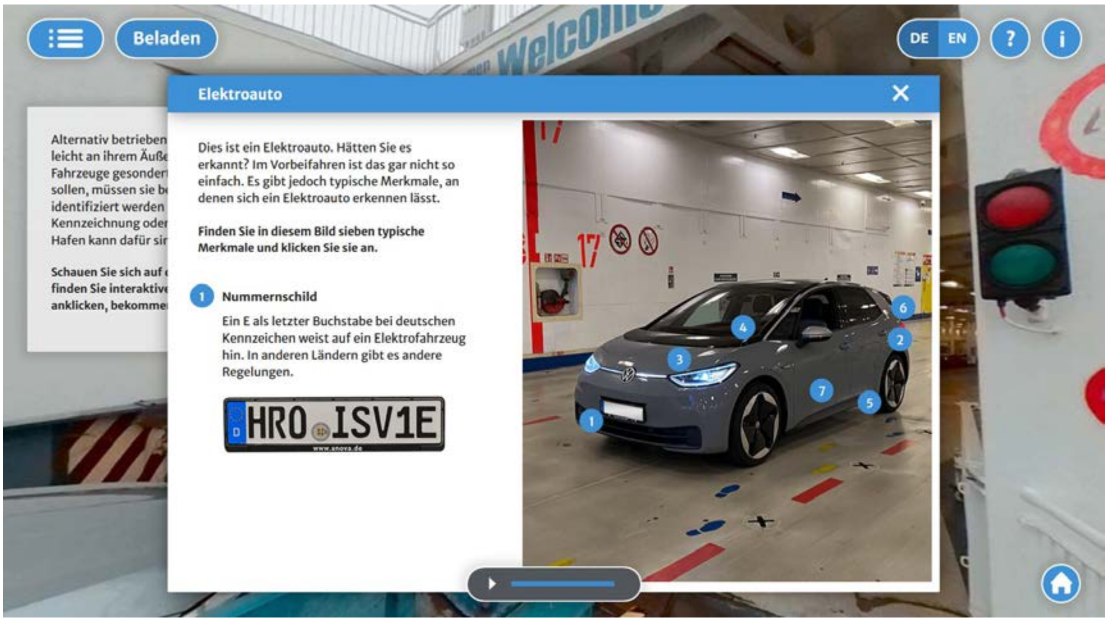

Image 3: Screenshot from the web based training system

- handling accidents with alternative powered cars should be regularly trained in practical drills on board

8. General recommendations for (political) measures

- There should be a general European regulation to enable the easy recognition of the kind of propulsion quickly from outside, e.g. by colour of license plate (has to be agreed by European authorities).
- We recommend the output of an optical and / or acoustical alarm signal, if the battery management system of an electric car detects a severe failure (Has to be realized by manufacturers of electric cars, has to be required from them by European authorities). A “silent” radio signal to the ship’s bridge or the operator of a parking garage could also be meaningful.
- For effective cooling in case of a thermal runaway of an EV-battery a kind of access leading to the inside of the battery pack for direct (water) cooling of the battery could be meaningful. (Has to be realized by manufacturers of electric cars, has to be required from them by European authorities.)
- Demand of general European regulation to declare RoPax crew (acting fire squads/first responders) same rights as firefighters i.e. to permit access to car-registry information.
- A technical possibility should be developed to enable the disconnection of a vehicle from a charging station in an accident situation without destroying (the cable).
- Re-ignition can occur if there are remaining intact cells in a damaged battery module. For improved safety after a fire in an electric vehicle, a procedure/technical system should be developed that ensures a safe discharge of unaffected residual cells in partially damaged vehicle battery modules.
- Regular training of responsible persons (ship crews, firefighters on shore,...) should be mandatory.

For detailed result presentation see

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