



SAFETY IN HIGH-VOLTAGE MARINE SYSTEMS: CHALLENGES, SOLUTIONS AND MODERNISATION

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Abstract: *The report examines the safety of high-voltage ship systems, focusing on the associated challenges, possible solutions, and modernization. High-voltage systems on ships are crucial for their operation but also pose potential hazards to the crew and equipment. The report analyzes key safety challenges such as high voltage, shocks and electrical hazards, fires, and other emergency situations. It also discusses existing safety standards and recommendations, as well as modernization measures that can be implemented to enhance the safety of high-voltage ship systems. The report is useful for engineers, designers, and maintainers of ship systems who aim to improve the safety of their installations.*

Keywords: *safety; high-voltage ship systems; challenges; standards; International Maritime Organization; high-voltage facilities; electrical power infrastructure*

I. Introduction

High-voltage equipment located in the machinery space of a ship is an important part of the vessel's electrical power infrastructure. These systems are crucial for the operation of the ship and provide electrical power to various systems and electrical devices on board. However, working with high-voltage equipment poses potential risks to personnel and the marine environment, necessitating compliance with international safety standards.

High voltage in ships refers to electrical voltage exceeding 1000 volts. Ships do not have Medium Voltage. Voltages below 1000 volts are considered low, while those above 1000 volts are considered high.

The use of high-voltage voltage in ships is associated with several factors:

Energy transmission efficiency: High-voltage systems allow for more efficient transmission of electrical energy compared to low voltage. High-voltage systems reduce energy losses, leading to more efficient utilization of generated energy and improved electrical efficiency.

Conductor size: Due to the high voltage used in high-voltage systems, the size of conductors (cables or busbars) can be smaller compared to low voltage. This allows for lighter and more compact installations, which is crucial for ships where space is limited.

Energy transmission distance: High-voltage systems can transmit electrical energy over longer distances without significant voltage drop. This is beneficial for ships

where electrical power needs to be delivered to various equipment and systems at different points on the ship.

Safety: High-voltage systems typically employ special protective mechanisms and insulation materials to ensure safety when working with high voltages. This includes insulation of conductors, the use of protective devices such as circuit breakers and protective relays, as well as stringent safety standards and procedures.

High voltage is used in ships to provide electrical power to various systems and equipment, including propulsion systems, electronics, air conditioning, lighting, and others. This enables ships to operate autonomously and provide comfort and safety to passengers and crew.

Cruise ships utilize various types of high-voltage systems that provide electrical power for different functions and facilities on board. Here are some of the main high-voltage systems that can be found on cruise ships:

Main Electrical Power System: This is the primary power delivery system on the ship. It typically consists of generators, transformers, main circuit breakers, and distribution panels that supply power to all other ship systems.

Power Generation: Cruise ships have generators that produce high-voltage electrical power. The generators can operate on different types of fuel, such as diesel, gas, or gas turbines.

Distribution Panels: High-voltage distribution panels are used to distribute electrical power from the generators to various systems and equipment on the ship. They are usually located in the engine room and other strategic areas of the ship.

Electric Motors and Propulsion Systems: Some modern cruise ships use electric propulsion systems for propulsion. These systems consist of high-voltage electric motors that drive the propellers or rotate generators to produce electrical power for propeller rotation.

HVAC Systems: Cruise ships employ high-voltage HVAC systems for air conditioning and heating, ensuring suitable temperature and ventilation in all ship compartments.

Ship Services: High-voltage systems are also used to provide electrical power for various shipboard functions and services, including lighting, kitchen equipment, refrigeration systems, elevators, and others.

These are the most important and fundamental components of high-voltage systems that can be found on cruise ships. All these systems must comply with international standards and safety regulations and be properly maintained and insulated to ensure the safe operation of the ship.

II. International Safety Standards

To ensure the safety of workers and the ship when operating high-voltage equipment in the engine room, a series of international standards and guidelines should be followed. Some of these standards include:

IEC 60092: This is an international standard that defines the basic requirements for electrical installations on ships. It covers various aspects of safety, including the design, testing, operation, and maintenance of ship electrical installations.

IEC 61892: This standard provides guidelines for the safety of electrical installations on offshore oil and gas platforms. Although it pertains to platforms, many of the principles and requirements can be applied in the engine room of ships.

ISO 13297: This standard is related to the safety of electrical installations in railway vehicles. While it does not directly apply to ships, its guidelines can be useful in determining the safety of high-voltage systems on ships [1,2,3].



The International Maritime Organization (IMO) plays a key role in developing and implementing safety standards and procedures in the maritime sector, including high-voltage equipment in the engine rooms of ships. Here are some of the main standards and procedures proposed by IMO:

SOLAS (International Convention for the Safety of Life at Sea): Chapter II-1: This chapter includes requirements for ship construction, including electrical installations and high-voltage systems. It provides guidelines for safety in the design and construction of installations.

ISM Code (International Safety Management Code): Part A: This part includes general principles and obligations for ship safety, including the safety of electrical systems and equipment. It encourages the development and implementation of procedures for the safe operation and maintenance of high-voltage equipment.

STCW Convention (International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers): Part A-III/1 and A-III/6: These sections define the training and qualification requirements for ship electrical personnel, including working with high-voltage systems. They ensure that personnel have the necessary knowledge and skills for the safe operation of electrical installations.

International Code for Ships Operating in Polar Waters (Polar Code): Chapter 12: This chapter pertains to the safety of electrical systems and equipment on ships operating in polar waters. It provides specific guidelines and requirements that must be followed for safe operation in these conditions.

MSC.1/Circ.1394 - IMO Guidelines for the Safety of High-Voltage Systems on Ships: This guideline provides detailed instructions and recommendations for safety when working with high-voltage equipment on ships. It includes sample procedures for testing, inspections, personnel training, and system maintenance.

It is important to note that compliance with IMO standards and procedures is crucial for the safety of high-voltage equipment in the engine rooms of ships and must be strictly followed by all stakeholders, including ship operators, manufacturers, and personnel.

III. Basic Safety Principles and Potential Incidents in Case of Non-Compliance

Compliance with international safety standards is of vital importance when working with high-voltage equipment in the machinery compartment of a ship. Here are some of the basic safety principles that should be taken into account:

➤ Personnel training: All crew members working with high-voltage equipment should receive specialized training. They should be familiar with the correct procedures, signal colors and labels, as well as safe practices when working near electrical installations.

➤ Proper equipment: Workers should be provided with the necessary protective equipment, such as insulated gloves, safety goggles, and helmets. This equipment should be used when handling high-voltage equipment and maintained in accordance with the manufacturer's recommendations.

➤ Regular maintenance and inspections: All high-voltage equipment should be regularly inspected and maintained. This includes conducting periodic inspections, testing, and replacing worn-out or damaged components.

➤ Isolation and zoning: High-voltage equipment should be properly isolated and separated from the rest of the machinery compartment. This may involve the use

of protective barriers, warning signs, and other means to prevent unauthorized access to hazardous areas.

Safety when working with high-voltage equipment in the ship's machinery compartment is crucial for preventing accidents and preserving the lives and health of the crew. Compliance with international safety standards, such as IEC 60092, IEC 61892, and ISO 13297, helps ensure a secure working environment and reduces the risk of electrical incidents. Safety principles, including personnel training, proper equipment use, regular maintenance and inspections, as well as isolation and zoning, must be strictly followed when working with high-voltage equipment on ships.

Incidents related to high-voltage power can take various forms and have different consequences. Here are a few examples of incidents that have occurred with high-voltage systems:

Electric discharge or sparks: Improper handling or defects in high-voltage equipment can lead to electric discharge or sparks. This can result in fire, electric shock, or even an explosion if there are flammable materials in the vicinity of the incident.

Short circuit: A short circuit in high-voltage systems can cause serious damage to electrical appliances, generators, or circuit breakers, as well as lead to fire or explosion.

Electric current leakage: Malfunctioning or defective insulation materials can lead to electric current leakage. This can cause electric shock to people or damage to other equipment.

Overheating of systems: Overheating of electrical components in high-voltage systems can result in damage or fire. This can occur due to improper operation, overload, or inadequate cooling of the systems.

Insufficient insulation: If insulation materials are damaged or insufficient, problems with protection against electric shock or short circuit may arise.

All of these incidents highlight the importance of strict compliance with international standards and safety procedures when working with high-voltage equipment. Regular inspection, maintenance, and personnel training are essential for preventing incidents and ensuring the safe operation of high-voltage systems.

IV. Practical steps when working with high-voltage systems in the absence of voltage

Isolation of high-voltage equipment is an important procedure to ensure safety when working with them. Here are some general steps followed when isolating high-voltage equipment:

Equipment identification: The first step is to identify the specific high-voltage equipment or facilities that need to be isolated. This may include electrical panels, switches, motors, and other high-voltage equipment.

User disconnects: Make sure that all user disconnects associated with the high-voltage equipment are switched off. This includes turning off the respective breakers or switches.

Lockout and tagging: Lock and tag the high-voltage equipment to prevent accidental energization or operation during isolation. Locking mechanisms should be used to prevent access to key switches or breakers.

Voltage absence verification: Before proceeding with isolation, voltage absence verification must be performed on the high-voltage equipment. This can be done using specialized tools such as voltmeters or voltage indicators.



Isolation devices: Use isolation devices such as insulating materials or protective caps to prevent contact with electrical contacts or conductors. These devices should be properly placed and securely fastened.

Work labeling: Clearly and visibly label the high-voltage equipment and the work areas being isolated with warning signs and labels indicating that the equipment is switched off and isolated.

Energy isolation: Ensure that all energy sources associated with the high-voltage equipment are removed or disconnected. This may involve disconnecting main power lines or using special energy isolation keys.

Insulation testing: Before working in close proximity to isolated high-voltage equipment, insulation testing should be performed to ensure that there are no unintended contacts or possibilities of energy penetration.

These steps are general guidelines, and specific procedures and requirements for isolating high-voltage equipment may vary depending on international standards, IMO guidelines, and specific rules applicable in different countries and ship operators. Official procedures and guidelines provided by relevant organizations and regulators should always be followed. Understanding practical safety examples for high-voltage equipment in the ship's machinery department can help in better implementation of IMO standards and procedures.

Here are some practical measures that can be taken to enhance safety:

- **Proper marking and labeling:** All high-voltage equipment should be clearly marked with signage indicating the voltage and associated hazards. For example, high-voltage equipment should be marked with warning signs and texts indicating the danger of electric shock.
- **Isolation and zone separation:** To prevent unauthorized personnel from accessing hazardous areas, high-voltage equipment should be physically separated and protected with barriers. This may include the use of locking systems controlling access to high-voltage rooms and the placement of visible barriers.
- **Inspections and checks:** Regular inspections and checks are crucial for identifying potential issues and preventing damages or accidents. This may involve insulation testing, measurement of electrical parameters, and visual inspections of components. The results of these checks should be documented, and necessary actions should be taken to rectify any deficiencies.
- **Personnel training:** All crew members who have access to high-voltage equipment should receive appropriate training. This training should include knowledge of safety procedures, recognition of risks, and basic troubleshooting skills.
- **Maintenance and repairs:** Regular maintenance and inspection of high-voltage equipment are essential. Updating software and hardware, insulation testing, checking contacts, and replacing worn or damaged components are just some of the measures that should be undertaken.

V. Modernization

The modernization of safety in high-voltage ship systems is of vital importance for ensuring the safety of ships and the people who use them. By identifying risks, integrating emergency systems and warnings, improving insulation and protection, training the crew, and maintaining the systems, we can reduce the risk of fires, electric shocks, and other hazards. Continuous safety care and regular improvement of high-voltage ship systems are an integral part of modern navigation.

IPS is an acronym that stands for "Integrated Power System." It is a complex system used to manage, control, and optimize the electrical power on ships. IPS

combines various components such as switches, converters, controllers, sensors, and communication systems to provide stable, safe, and efficient power supply to ships.

Figure 1 shows a common IPS scheme, on an electric propulsion type ship, with two DC main propulsion motors. There are two main switchboards, two main busbars separated by a circuit breaker in case of an accident with one of them. Each bus has two generators and rectifiers that work in parallel when more power is needed.

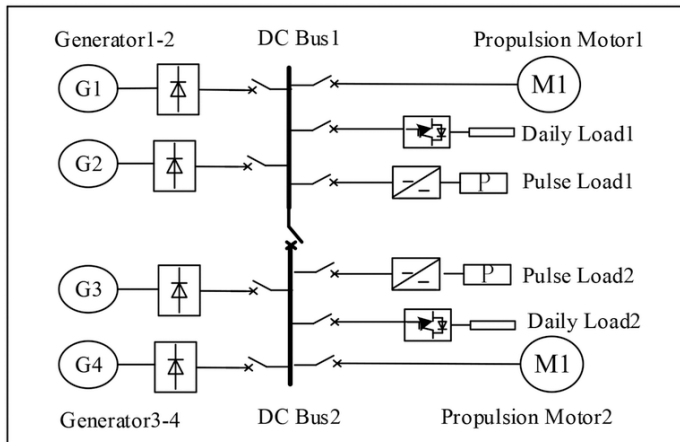


Fig.1 Example diagram of an IPS system on a ship

The goal of IPS is to control and regulate the distribution of electrical power on the ship, balance the load between different sources of energy (such as generators, batteries, and shore power), and ensure continuous and stable power supply to all electrical components and systems on the ship. IPS also includes functionalities for protection and safety, such as detecting electrical problems (short circuits, overload, and others), isolating faulty parts from the network, and preventing the spread of accidents. The system provides real-time monitoring and diagnostics, allowing operators to receive information about the condition of components and take necessary maintenance and repair measures. The implementation of IPS in ship systems aims to improve the safety, efficiency, and reliability of electrical power on ships. This leads to better energy management, fewer accidents, less repair time, and greater flexibility in switching between different power sources [4,5,6,7].

A practical real-life example of modernizing safety in high-voltage ship systems is the implementation of an Integrated Power System (IPS) on the passenger cruise ship "Vision of the Seas" by Royal Caribbean International. "Vision of the Seas" is a popular cruise ship that has been in operation for a long time, offering various services to its passengers. To enhance the safety and efficiency of the ship's electrical systems, Royal Caribbean International decided to modernize its high-voltage ship system by implementing IPS. IPS is a fully integrated system that manages and controls all aspects of the ship's electrical power. It replaces older and unreliable power management systems and provides greater flexibility, reliability, and safety. The system on "Vision of the Seas" includes high-voltage generators, AC motors, and various electrical loads such as pumps, motors, lighting, and others. With IPS, all these components are interconnected and controlled from a central location.

The advantages of IPS include:



- **Safety:** The system provides automatic protection against overload, short circuits, and other electrical problems. This reduces the risk of fires and other power-related accidents.
- **Efficiency:** IPS controls and optimizes the distribution of electrical energy, ensuring more efficient utilization of generators and other electrical systems on the ship. This leads to fuel savings and emission reduction.
- **Flexibility:** IPS allows greater flexibility in switching between different power sources and performing system maintenance without interrupting power supply. This improves operational capability and resilience of the ship.
- **Diagnostics and Maintenance:** IPS provides real-time monitoring and diagnostics of the ship's electrical system. This enables faster detection and resolution of issues, as well as maintenance planning based on the system's condition.

The modernization of "Vision of the Seas" with IPS is a successful example of implementing advanced technologies in ship systems that enhance safety, efficiency, and sustainability of electrical power on ships. This example can be used in a report on the modernization of safety in high-voltage ship systems and represents a real-life demonstration of the possibilities and benefits of such innovations. The modernization of safety in high-voltage ship systems through the implementation of an Integrated Power System (IPS) represents an important step forward in the development of the maritime industry. This technology not only improves the safety

VI. Conclusions and Recommendations

- The safety of high-voltage ship systems is of utmost importance for the normal functioning of modern maritime vessels.
- High-voltage ship systems face numerous challenges, including the risk of electric shocks, fires, and equipment damage.
- One of the main challenges is achieving optimal balance between energy efficiency and safety in the design and operation of high-voltage systems.
- Solutions for improving safety in high-voltage ship systems involve the use of modern monitoring and control technologies, protective schemes, and specialized training for personnel.
- Upgrading high-voltage ship systems is crucial for ensuring the latest safety standards and optimizing the energy processes on board ships.

Safety in high-voltage ship systems is a key factor for the successful operation of maritime vessels. The challenges they face require a comprehensive approach and the integration of various technologies and solutions. The optimal balance between energy efficiency and safety must be a priority in the design and operation of high-voltage systems. The modernization of these systems plays a crucial role in implementing the latest safety standards and improving the energy efficiency of ships. Collaboration between the industry, scientific institutions, and regulatory bodies is essential for continuous development and innovation in the field of safety in high-voltage ship systems.

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