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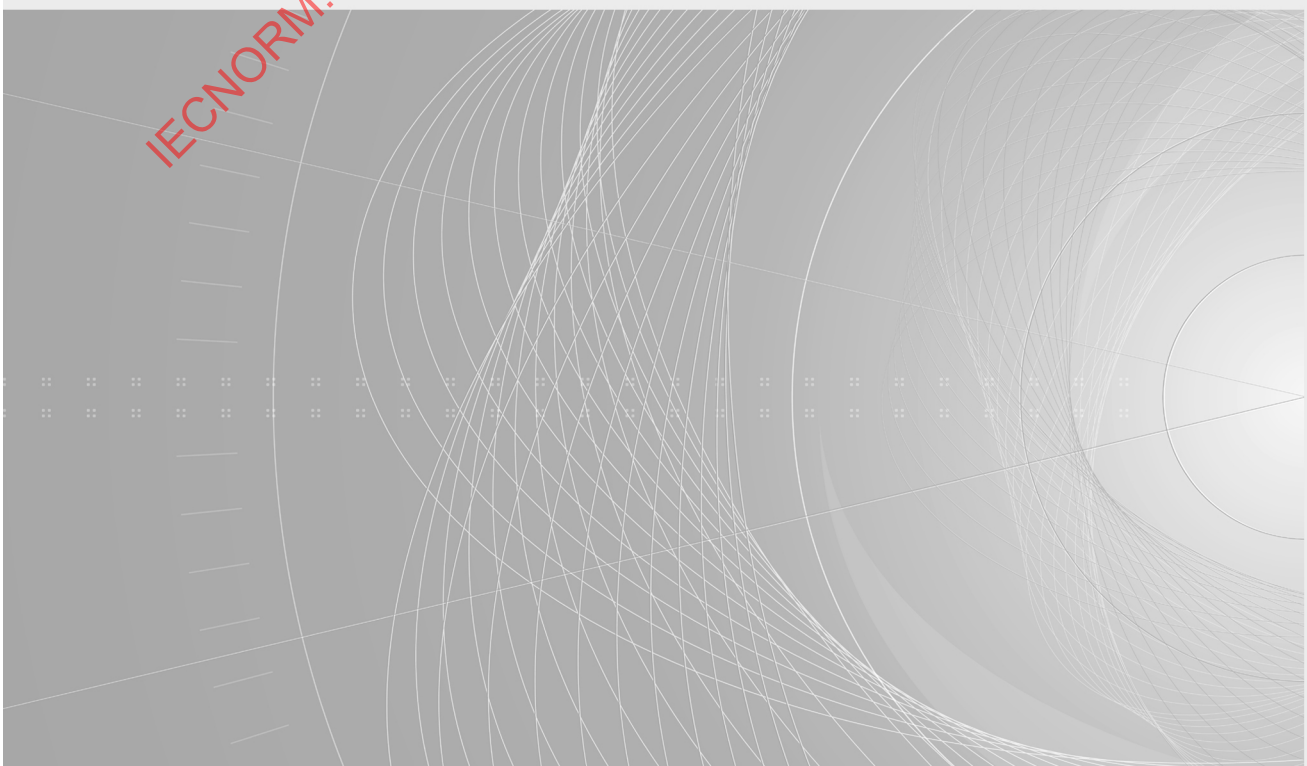
PUBLICLY AVAILABLE SPECIFICATION

PRE-STANDARD

Electrical installations in ships – Primary DC distribution – System design architecture



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ELECTRICAL INSTALLATIONS IN SHIPS –

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IEC PAS 63108 has been processed by IEC technical committee 18: Electrical installations of ships and of mobile and fixed offshore units.

The text of this PAS is based on the following document:	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document
Draft DPAS	Report on voting
18/1560/DPAS	18/1574/RVDPAS

Following publication of this PAS, which is a pre-standard publication, the technical committee or subcommittee concerned may transform it into an International Standard.

This PAS shall remain valid for an initial maximum period of 3 years starting from the publication date. The validity may be extended for a single period up to a maximum of 3 years, at the end of which it shall be published as another type of normative document, or shall be withdrawn.

INTRODUCTION

The majority of existing distribution systems of ships are AC systems with electric power generated by fixed speed generator sets and a fixed frequency and voltage for the distribution system. This is also reflected by the current parts of the IEC 60092 series. The ship owners are facing new environmental regulations and are asking for more flexible solutions to meet the new market demands. It is acknowledged that the maritime industry is developing new innovative power and distribution solutions enabling reduced emissions to air, as well as reduced fuel consumption. Next generation of distribution systems involves use of a variety of power sources and DC distribution architecture. Novel concepts for design and operation of electrical systems with energy storage and advanced control of main and emergency power sources, including essential load services such as propulsion systems have evolved. These energy systems combine a wide range of technologies that will improve the fuel and emission profiles and performance of ship operations.

The primary DC distribution system exploit new and radical approaches for system design/configuration, operation and control compared to conventional solutions for power generation and distribution systems.

This PAS intends to describe these solutions. A new IEC International Standard is scheduled to replace this PAS.

The main intention with this PAS is to set design and test criteria to power systems with primary DC distribution. Semiconductor devices used as breaker shall fulfil requirements for breaking current and isolation according to IEC 60947-2 and IEC 60947-3.

ELECTRICAL INSTALLATIONS IN SHIPS –

Primary DC distribution – System design architecture

1 Scope

This PAS specifies the requirements of primary DC distribution systems and interconnected installations.

The requirements of this PAS establish general principles for

- operations, without degrading unit and human safety, capable of a reduced environmental footprint,
- existing and new power generating units, new DC distribution concepts for electrical power, energy storage and advanced control of a total power balance, including semiconductor converters (AC to DC, DC to DC and DC to AC power converters) and dynamic load controllers, and
- relevant system studies and calculations demonstrating a protection philosophy as needed for necessary selectivity, segregation methods and equipment.

This PAS also gives guidelines for integration of energy sources of different nature and suitable ways to identify locations of such installations.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60034 (all parts), Rotating electrical machines

IEC 60092 (all parts), *Electrical installations in ships*

IEC 60092-101:1994, *Electrical installations in ships – Part 101: Definitions and general requirements*
IEC 60092-101:1994/AMD1:1995

IEC 60092-301, *Electrical installations in ships – Part 301: Equipment – Generators and motors*

IEC 60092-302, *Electrical installations in ships – Part 302: Low-voltage switchgear and controlgear assemblies*

IEC 60092-352, *Electrical installations in ships – Part 352: Choice and installation of electrical cables*

IEC 60092-401, *Electrical installations in ships – Part 401: Installation and test of completed installation*

IEC 60364-4-41, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60533, *Electrical and electronic installations in ships – Electromagnetic compatibility (EMC) – Ships with a metallic hull*

IEC 60947-2, *Low-voltage switchgear and controlgear – Part 2: Circuit-breakers*

IEC 60947-3, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*

IEC 61557-8, *Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 8: Insulation monitoring devices for IT systems*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

NOTE Other relevant terms and definitions can be found in IEC 60092-101 and other parts of the IEC 60092 series.

3.1
shore power charging system

Note 1 to entry: Definition under consideration

3.2
DC bus
DC distribution system which interconnects DC loads and power sources

3.3
DC assembly
cabinet with modules interconnected with DC bus for loads and power sources

3.4
energy management system
EMS
system controlling, monitoring and protecting energy sources and loads to ensure safe operation

3.5
battery management system
BMS
system protecting battery, controlling battery charging and/or discharging, and monitoring battery conditions (i.e. state of charge, cell temperature etc.)

Note 1 to entry: The definition is under consideration.

4 General requirements

4.1 General

Attention is drawn to the requirements of the International Convention for the Safety of Life at Sea. Clause 4 contains conditions and requirements which are common to all apparatus and installations within the scope of this PAS.

Semiconductor devices used as breaker shall fulfil requirements for breaking current and isolation according to IEC 60947-2 and IEC 60947-3.

4.2 Acceptance of substitutes or alternatives

Where in this PAS any special type of apparatus, construction or arrangement is specified, the use of any other apparatus, construction or arrangement is admissible, provided it fulfils the requirements of the original apparatus.

4.3 Provisions for maximum load

All components and systems shall be of such size as to be capable of carrying, without their respective ratings being exceeded, the current which can normally flow through them. They shall be capable of carrying anticipated overloads and transient currents, for example the capacitor inrush currents, without operational degradation.

4.4 Additions and alterations

An addition or alteration, temporary or permanent, shall not be made to an existing installation until it has been definitely ascertained that the ratings and the condition of existing accessories, conductors, switchgear, etc. affected are adequate for the new situation.

Special attention is taken to those factors affecting the existing system design such as current-carrying capacity, maximum fault current level, harmonic content, power quality and proper discrimination of the protective devices.

4.5 Environmental conditions

Electrical equipment shall operate satisfactorily under various environmental conditions. The environmental conditions of IEC 60092 (all parts) shall apply.

4.6 Power supply system characteristics

4.6.1 General

NOTE The use of primary DC distribution are characterized by

- DC-grids including various sources of power and consumers with power electronic controllers forming operational interfaces, with high dynamics,
- fast response times and small reaction times and inductances in DC-grid systems compared to conventional AC-grid systems, and
- voltage source converters, diode bridges, etc., which will create special fault mitigation scenarios by their ability to block in one direction, and lead in the opposite direction.

4.6.2 DC distribution systems limits

When batteries are used as power supply systems, adequate measures should be taken to keep the voltage within the specified limits during charging, quick charging, gas-charging and discharging of the battery.

4.7 Mechanical protection

Electrical equipment shall be placed so that, as far as practicable, it is not exposed to risk of mechanical damage according to IEC 60092-101 and IEC 60092-352.

Safety barriers shall be established in design and arrangement of energy sources.

4.8 Enclosures

Enclosures shall comply with the degrees of protection in IEC 60092-302.

5 System design

5.1 General

The design of the electrical system shall be in accordance with relevant parts of the IEC 60092 (series) and IEC 60533, with the additional requirements of this PAS.

5.2 Power quality

Harmonic voltage distortion levels in AC parts of ship systems shall be in line with requirements in IEC 60092 (all parts). For DC systems the frequency amplitudes and voltage pulses due to switching of semiconductor devices will vary depending on the load conditions and voltage conditions. All connected devices to the DC bus-bar shall be able to operate normally under any operating conditions with the actual voltage and current amplitudes and frequencies generated by the inverter system according to 2.8.3 of IEC 60092-101:1994/IEC 60092-101:1994/AMD1:1995.

5.3 Combined AC and DC distribution systems

Combinations of AC and DC distribution systems shall be coordinated in such way that safe operation can be documented for all normal and fault conditions. Parallel operation of such systems shall be documented and verified based on testing.

5.4 Black-out start up and start from dead ship condition

Any system configuration can be reconfigured, even under dead ship conditions, to a configuration from which it shall be possible to start from a dead ship or from a black-out situation.

5.5 DC distribution systems

System earth shall be of one of the following alternatives:

- two-wire insulated;
- two-wire with one pole earthed in galvanic separated DC bus sections;
- three-wire with middle wire earthed for special systems.

Battery systems shall be insulated from the ship structure to avoid damaging voltage pulses between chassis and battery cells.

For a DC source of power that requires direct or high impedance earthing, necessary arrangements shall be implemented and accepted by relevant authorities.

5.6 AC distribution systems

AC distribution systems interfacing DC architecture shall comply with IEC 60092-101.

5.7 Shore powered charging systems

If shore interconnection is to be used for charging of batteries, independent control of the shore interconnection current shall be provided in addition to control by the battery management system.

The overall charging system shall be designed and verified for each type of application based on the nature of the power demand and its duration. Charging system connection may be automatic, for example due to limited time available for charging.

A safety analysis shall be made including all phases of the operation of the power transfer system. Automatic connection system shall be tested according to a test procedure accepted

by the relevant authority. Local manual operation shall be possible both on-board and onshore.

The power exchange system shall withstand the dynamic forces in hull heave and sideway movements.

5.8 Short-circuit currents in combined AC and DC systems

5.8.1 General

The short-circuit current contribution of generators and motors shall be calculated on the basis of their characteristics. Contribution from connected DC inverter systems shall be calculated based on the actual technology used.

5.8.2 Short-circuit current in DC systems

The DC distribution system may include passive or active controlled components that limit the contribution of fault currents. Short-circuit current values shall be calculated and when required, verification shall be made by testing in the design phase.

NOTE IEC 61363-1 or IEC 60909 (all parts) can be used as a guidance for fault calculation for AC sources and IEC 61660 (all parts) for DC sources.

5.9 System studies and calculations

Protection and control systems shall include monitoring, fault detection and fault clearance. Comprehensive analyses shall document the actual clearing times and fault current conditions in relevant operation modes.

Where DC and AC systems are used in the same installation, a discrimination study shall be performed.

Full downstream selectivity shall be provided.

NOTE The low fault current capability of inverters can introduce a need for special protection arrangements for connected loads.

5.10 Protection

5.10.1 General

In general protective devices for short-circuit, protection shall conform to the requirements of IEC 60092 (all parts). However, other devices may be used for short-circuit protection such as semi-conductor devices. Galvanic isolation and short-circuit protection may be provided by separate devices.

Depending on the type of power source feeding the DC distribution system, the protection function shall be able to protect the power source. Active semiconductor systems shall have built-in protection in the semiconductor software, and separate disconnecting device shall include protection as for AC systems. The special demands for speed regulation shall be taken into account. The semiconductor software shall trip the disconnecting device in case of a fault. The power source shall withstand a short-circuit identified by the protection system.

Passive rectifiers shall be equipped with individual protection.

Where fuses are used as fault protection, a disconnector shall also be installed.

The protection function of DC inverter systems shall be designed according to the relevant IEC standards. The protection functions shall be tested and documented.

NOTE The protection function of DC inverter systems is normally implemented as a part of the inverter control.

Separate protection functions by fuses, semiconductors or circuit breakers shall fulfil requirements for DC or AC ratings documented by suppliers for the relevant fault levels and system voltages.

5.10.2 Fixed and variable speed AC generator protection

For AC generators with fixed or variable speed, circuit protection and ratings shall comply with IEC 60092 (all parts).

For generators, which cannot be de-excited by field winding a stop arrangement for the prime mover shall be considered.

Variable speed AC generators may vary depending on the characteristics of the prime mover. With these variations in speed, the generator need to be protected for fault contribution over the entire speed range; both thermal conditions and short-circuit fault currents as well as voltage regulation.

Where a permanent excited generator is used, there shall be a separate protection for stopping the prime mover in case of short-circuit between the inverter/breaker and the generator.

Protection functions like reverse power may be omitted if the rectifier blocks any back feeding of power.

5.10.3 Battery circuits

Batteries in use as a main source of power are connected with individual cells in series to achieve the required voltage level and with cells in parallel to achieve the required charge/discharge capacity. The short-circuit contribution of battery circuits shall be identified for the actual state of charge, ageing and other factors influencing the capacity of the battery.

Each string of batteries shall have individual protection schemes to isolate a fault occurring in that string, and handle possible short-circuit contribution from paralleled strings.

The complete battery shall have an disconnecting device between the battery and the DC distribution.

Energy storage systems (ESS) shall be insulated from earth (IT).

NOTE Applicable measures depends on the battery technology used.

5.10.4 Safety barriers for energy storage systems

NOTE References to requirements in standards developed by IEC TC 120 are under consideration.

5.10.4.1 General

Energy storage installations shall be designed with a number of safety barriers.

In general, batteries may be of any technology if it can be documented that the batteries are accepted for operation by relevant authorities. Where the battery technology has no proven marine service, a risk assessment shall be carried out to demonstrate the safety of the installation.

5.10.4.2 Power and energy rating

The battery system shall be documented with regards to max C rate that can be used in duty cycles both in discharge and charge conditions.

The temperature conditions for the battery cells shall be monitored and a common alarm shall be given when temperatures are in an area where there is a risk for permanent degradation of the cells or there is a risk for overheating and further thermal escalation.

The battery system shall have sufficient cooling to be able to operate in ambient conditions specified by the manufacturer.

The battery system shall be equipped with a battery management system (BMS) that shall monitor and protect the battery system and also control internal temperatures and voltages and internal cell balancing of the system.

5.10.4.3 Charging facilities

For floating service or for any other conditions where the load is connected to the battery while it is being charged, the maximum battery voltage under any conditions of charging shall not exceed the safe value of any connected apparatus. The voltage characteristics of the generator or generators or semiconductor convertor, which will operate in parallel with the battery, shall be suitable for each individual application. Where apparatus capable of operation at the maximum charging potential is not available, a voltage regulator or other means of voltage control shall be provided.

5.10.5 Protection against electric shock

For protection against electric shock, the requirements of IEC 60364-4-41 shall be met. Where an IT system is designed not to be disconnected in the event of first fault, the occurrence of the first fault shall be indicated by an insulation monitoring device (IMD) according IEC 61557-8, which may be combined with an insulation fault location system (IFLS) according IEC 61557-9.

5.11 Protection of interconnection to shore

The DC distribution system or shore connection box on a vessel shall be equipped with a passive or controllable feature that inhibit any reverse currents to shore in case of a fault in the shore system.

Cascading faults in the interconnection of shore and vessel system shall be prevented.

6 Sources of electrical power

NOTE Identification of main, essential, emergency sources of power are under consideration.

6.1 General

Power generation may include both traditional fixed and variable speed generating sets, fuel cells, batteries and other type of energy sources.

Rotating machines shall comply with IEC 60034 (all parts) including any relevant requirements of this PAS in addition to best practice.

The ship shall be provided with a main source of electrical power of sufficient capacity to supply all the services mentioned in IEC 60092 (all parts).

6.2 AC power generation with variable speed

For AC primary distribution, the requirements of IEC 60092 (all parts) shall apply.

6.3 DC power generation with variable speed

DC power generation with variable speed allows for a wide speed range for the prime mover, which holds limitation for the actual speed range. The configuration of the power management system shall take into account the variances in available power at different prime mover speeds within the operating range.

The fuel consumption, emission, speed, power and torque capability of the prime mover shall be documented over the selected speed range. The prime mover shall be protected by its own safety system.

The generator shall be designed to operate at any speed within the selected speed range area. The power and fault current capabilities for this speed range shall be documented.

6.4 Various DC power sources

DC power sources may consist of electrochemical systems like fuel cells or battery technologies. These types of power sources may be controlled by a DC converter.

Batteries may be installed as a main power source either as a stand-alone unit or in combinations with other power generation units.

6.5 Load sharing

Load sharing of different power sources may be performed by a separate control system or by the power management system. The available power for each power source may be a static or a dynamic value depending on the speed, state of charge or other characteristics of the power source.

6.6 Transient operation

Combination of power sources shall be able to supply all relevant ship loads; start currents, inrush currents and fault currents to such levels that effectiveness of safety devices is guaranteed, within the limits of voltage and frequency drop as stated in IEC 60092 (all parts) and maintain active protection functions.

7 Power distribution systems

7.1 General

Power distribution systems may include both traditional AC systems with fixed frequency and voltage, AC systems with variable frequency and DC inverter systems. The different systems may be present in the same installation or one of the systems may be the only alternative.

7.2 AC distribution systems

These systems shall comply with IEC 60092 (all parts).

7.3 DC distribution systems

Special attention should be drawn to DC bus systems where two or more DC distribution systems are connected. The DC bus shall be equipped with a disconnector or a combination of semiconductor device and isolator. Connection of several DC distribution systems shall not degrade the operational conditions in any of the DC distribution systems. Necessary technical arrangements shall be installed to compensate for any oscillations between units connected by cables or other arrangement. Any fault in the DC bus arrangement or in one of the DC distribution systems shall not cause tripping of the other consumers connected to the other DC distribution systems.

Each active controlled unit shall have monitoring and protection to protect the connected device and also to protect the semiconductor devices in the unit for external faults and for internal thermal faults.

The tie connection shall provide short-circuit protection, separation and shall ensure discrimination.

7.4 DC distribution systems feeding AC distribution systems

DC distribution systems with connection to AC systems shall be connected to the AC system with an inverter control unit. The inverter may feed power in both directions.

Galvanic isolation shall be considered to prevent any circulating currents.

All normal closing and tripping including synchronizing and dead-bus connection shall be controlled by the inverter software and distribution breaker.

With black-out start function, the inverter systems shall automatically connect to the AC network and maintain AC operation from the DC side if necessary. The inverter system shall be able to deliver a steady voltage and frequency to the AC network without any power generating units on the AC side.

During fault conditions in the AC network, the AC bus-bar breaker shall isolate the faulty part of the system and the remaining system shall be steady and maintain normal operation after the fault is cleared.

Parallel operation of AC distribution inverters and other AC power sources operated individually or in parallel shall be designed to allow utilization of any power source.

8 Equipment

8.1 General

Equipment used in distribution systems shall be in accordance with relevant IEC product standards. For new equipment or new use of equipment where standards are not available, functional requirements shall be outlined according to this PAS, and equivalence to existing conventional products shall be demonstrated.

8.2 Generators

Generators shall be designed and built according to IEC 60092-301 with regards to variable speed generators.

8.3 DC assemblies

8.3.1 General

The construction shall include adequate inside segregation and necessary protection to avoid damages on neighbouring units.

8.3.2 Cooling

In general, power electronics will produce additional heat due to switching and conducting losses.

At least one independent cooling system for each DC distribution system is required.

8.3.3 Individual circuits

8.3.3.1 General

Each connected circuit shall be connected to the DC distribution with a suitable breaker or fuses and disconnector to control outgoing faults and isolating capacity in case of faults in the circuits, or during maintenance work on a circuit. This does not preclude the use of additional semiconductor switching for high speed protection against over currents.

Each inverter shall have necessary built-in protection to control safely any faults outside the assembly. In case of fault in the inverter, there shall be a separate protection that safely isolate the faulty circuit and maintain the operation of the DC distribution without tripping other circuits connected to the DC distribution. The protection may be fuses, DC breakers or semiconducting breakers. Semiconducting breakers are to be provided with disconnectors or other means to provide physical isolation of circuits.

The function shall be tested and documented for fault clearance in case of worst fault in the inverter circuit and still maintaining operation of other circuits.

The different inverter, breaker or fuse units may be fixed mounted or withdrawable.

8.3.3.2 Generator circuits

Each generator supplying a DC primary distribution shall have a rectifier as a part of the DC distribution assembly or a DC connection to the generator. The rectifier may be an active or passive semiconductor unit.

In case of a passive rectifier, the DC voltage shall be controlled by the generator excitation control system.

The rating of the units shall be documented for all operational conditions of the generators.

In case of internal failure, the prime mover shall be stopped and the energy source shall be disconnected from the busbar.

8.3.3.3 Energy storage circuits

Each energy storage circuit is normally a DC source (e.g. batteries) and should be connected to the DC distribution with a controlled DC/DC converter or directly uncontrolled if this meet functional requirements for the other circuits. An outgoing circuit breaker or semiconductor coordinated with a disconnector shall be a part of the DC distribution to be able to isolate the energy storage sources in case of a fault.

The rating of the units shall be documented for all operational conditions of the energy storage system.

NOTE In case of other types of energy storage systems like flywheel systems, the control is normally an inverter controlling an AC motor equal to a traditional motor control.

8.3.3.4 Shore charging circuits

The feeding from shore may be connected to the DC distribution system with an AC/DC or DC/DC converter or as defined by vessel design if it meets all functional requirements. A disconnector shall be a part of the DC distribution system to be able to isolate the incoming supply in a safe way.

8.3.3.5 Energizing DC distribution systems in series

DC distribution systems may connect to other DC distribution systems in case of faults or repowering by available power sources. Such connections to other DC distribution systems

may be energized, for example by combination of precharge circuits, fuses and disconnectors, or an isolator in combination with an electronic switch based on semiconducting devices.

The rating of the bus-bar connection with auxiliary circuits shall be documented for all operational conditions. The interconnection shall have necessary built-in protection to control safely any faults and safely isolate the faulty DC distribution systems and maintain the operation of the healthy DC distribution systems without tripping other circuits connected to the distribution systems. The function shall be tested and documented for fault clearance in case of worst fault and still maintain operation of other circuits.

9 Control systems

9.1 General

Ship energy control systems shall follow the principles for computer based control systems and automatic control installation in IEC 60092 (all parts) where relevant.

9.2 Control architecture

Distribution systems shall have a dedicated control system, which does not reduce the integrity or reliability of any part of a redundant power system.

The energy control system consists of several levels of controls and alarm functions, such as:

- monitoring of all power sources and inverters and disconnectors for the distribution system;
- alarm functions for all power sources and inverters and disconnectors for the distribution system;
- active control of power sources and distribution system
- voltage and power control for DC distribution system;
- available power control depending on state of charge;
- charge and discharge control;
- power management system (PMS) functions for a DC distribution system;
- interface with energy storage management systems, if used;
- interface with PMS for combinations of AC and DC distribution systems;
- inverter control for the overall system stability;
- interconnection to alert system or integrated automation system. The alert functions will be classified and presented according to the instructions given in MSC.302(87).

9.3 Automatic control of vessel energy systems

9.3.1 General

Automatic control systems for power production and distribution may include

- automatic starting of a power source,
- automatic connecting onto a dead bus bar,
- automatic paralleling and load sharing,
- automatic shut-down of power source,
- automatic disconnecting of non-essential loads, and
- automatic analysis of power reserve.