



CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

2015

Vol.4/5



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**RULES FOR CLASSIFICATION
OF
SEA-GOING STEEL SHIPS**

2015

Vol.4

**PART FOUR ELECTRICAL INSTALLATIONS
PART SEVEN AUTOMATION SYSTEMS**

Beijing

TABLE OF CONTENTS

Vol.1

PART ONE PROVISIONS OF CLASSIFICATION.....	1-1
--	-----

Vol.2

PART TWO HULL.....	2-1
--------------------	-----

Vol.3

PART THREE MACHINERY INSTALLATIONS.....	3-1
---	-----

PART FIVE REFRIGERATED CARGO INSTALLATIONS.....	5-1
---	-----

Vol.4

PART FOUR ELECTRICAL INSTALLATIONS.....	4-1
---	-----

PART SEVEN AUTOMATION SYSTEMS.....	7-1
------------------------------------	-----

Vol.5

PART SIX FIRE PROTECTION,DETECTION AND EXTINCTION.....	6-1
--	-----

PART EIGHT ADDITIONAL REQUIREMENTS.....	8-1
---	-----

Vol.6

PART NINE COMMON STRUCTURAL RULES FOR BULK CARRIERS AND OIL TANKERS.....	9-1
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CHINA CLASSIFICATION SOCIETY

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OF
SEA-GOING STEEL SHIPS**

2015

PART FOUR ELECTRICAL INSTALLATIONS

Effective from July 1 2015

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CONTENTS

CHAPTER 1	GENERAL.....	4-1
Section 1	GENERAL PROVISIONS.....	4-1
Section 2	OPERATING CONDITIONS.....	4-6
Section 3	DESIGN, CONSTRUCTION AND INSTALLATION.....	4-7
CHAPTER 2	ELECTRICAL INSTALLATIONS IN SHIPS.....	4-15
Section 1	MAIN SOURCE OF ELECTRICAL POWER.....	4-15
Section 2	EMERGENCY SOURCE OF ELECTRICAL POWER.....	4-17
Section 3	EXTERNAL SOURCE OF ELECTRICAL POWER.....	4-21
Section 4	POWER SUPPLY AND DISTRIBUTION.....	4-22
Section 5	PROTECTION.....	4-25
Section 6	AUXILIARY MACHINERIES.....	4-29
Section 7	LIGHTING AND NAVIGATION LIGHTS.....	4-31
Section 8	INTERNAL COMMUNICATION SYSTEMS.....	4-33
Section 9	SAFETY SYSTEMS FOR SHIPS AND PERSONS ONBOARD.....	4-34
Section 10	HEATING AND COOKING EQUIPMENT.....	4-39
Section 11	STORAGE BATTERIES.....	4-39
Section 12	CABLES.....	4-41
Section 13	LIGHTNING PROTECTION.....	4-53
Section 14	SPECIAL REQUIREMENTS FOR HIGH VOLTAGE ELECTRICAL INSTALLATIONS.....	4-54
Section 15	ADDITIONAL REQUIREMENTS FOR ELECTRICAL PROPULSION MACHINERY.....	4-57
Section 16	ADDITIONAL REQUIREMENTS FOR OIL TANKERS.....	4-57
Section 17	ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING VEHICLES WITH FUEL IN THEIR TANKS FOR THEIR OWN PROPULSION.....	4-61
Section 18	ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING DANGEROUS GOODS.....	4-61
Section 19	ADDITIONAL REQUIREMENTS FOR BULK CARRIERS.....	4-65
CHAPTER 3	CONSTRUCTION AND TESTING OF ELECTRICAL EQUIPMENT.....	4-67
Section 1	GENERAL PROVISIONS.....	4-67
Section 2	ROTATING MACHINES.....	4-67
Section 3	SWITCHGEAR ASSEMBLIES.....	4-72
Section 4	CONTROL GEAR.....	4-76
Section 5	CABLES.....	4-77
Section 6	POWER AND LIGHTING TRANSFORMERS.....	4-78
Section 7	STORAGE BATTERIES.....	4-80
Section 8	POWER SEMICONDUCTOR CONVERTORS.....	4-81
Section 9	UNINTERRUPTIBLE POWER SYSTEM.....	4-82
Section 10	OTHER ELECTRICAL EQUIPMENT.....	4-83
CHAPTER 4	SUPPLEMENTARY REQUIREMENTS FOR SMALL SHIPS AND SHIPS IN RESTRICTED SERVICE.....	4-85
Section 1	GENERAL PROVISIONS.....	4-85
Section 2	SHIPS IN CATEGORY 1 SERVICE.....	4-85
Section 3	SHIPS IN CATEGORIES 2 & 3 SERVICES.....	4-85
Section 4	CARGO SHIPS OF LESS THAN 500 GROSS TONNAGE.....	4-86
APPENDIX 1	SHORT-CIRCUIT CURRENTS CALCULATIONS WITH REGARD TO ELECTRICAL INSTALLATIONS.....	4-87
Appendix A	EXAMPLES OF CALCULATION.....	4-99
Appendix B	CONVERSION OF SHORT-CIRCUIT BREAKING CAPACITY OF CIRCUIT BREAKER.....	4-114
APPENDIX 2	TYPE APPROVAL PROCEDURE FOR CABLE TRAYS/PROTECTIVE CASINGS MADE OF PLASTIC MATERIALS.....	4-115

CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 General requirements

1.1.1.1 Unless otherwise specified, the requirements of this PART apply to electrical installations intended for sea-going ships.

1.1.1.2 Electrical propelling machinery and associated equipment together with auxiliary services essential for the safety of the ship are to be constructed and installed in accordance with the relevant requirements of this PART, inspected and tested by the Surveyors. In addition, construction and testing of the electrical equipment are to comply with the relevant acceptable standards.

1.1.1.3 The design and installation of the electrical equipment other than those specified in 1.1.1.2 of this Section is to be such that risk of fire due to its failure is minimized, and it is at least to comply with the acceptable standards to be revised where necessary for ambient conditions.

1.1.1.4 In addition, the electrical installations are to comply with the applicable requirements in PART ONE of the Rules.

1.1.1.5 The electrical installations are to be such that:

- (1) all electrical auxiliary services necessary for maintaining the ship in normal operational and habitable conditions will be ensured without recourse to the emergency source of electrical power;
- (2) electrical services essential for safety will be ensured under various emergency conditions;
- (3) the safety of passengers, crew and ship from electrical hazards will be ensured.

1.1.2 Definitions

1.1.2.1 For the purpose of this PART:

(1) Essential equipment is the equipment necessary for the propulsion, steering and safety of the ship and the special equipment on ships with special class notations, including:

- ① primary essential equipment which need to be in continuous operation for maintaining propulsion and steering:
 - (a) steering gear;
 - (b) controllable pitch propeller installation;
 - (c) scavenging air blowers, fuel oil supply pumps, fuel valve cooling pumps, lubricating oil pumps and cooling water pumps for main and auxiliary engines and turbines required for propulsion;
 - (d) forced draught fans, feed water pumps, water circulating pumps, vacuum pumps, condensate pumps and oil burning installations for auxiliary steam boilers for the operation of primary essential equipment and for steam plants on steam turbine ships;
 - (e) azimuth thrusters which are the sole means for propulsion/steering with lubricating oil pumps, cooling water pumps;
 - (f) electrical equipment for electric propulsion plant with lubricating oil pumps and cooling water pumps;
 - (g) electric generators and associated power sources supplying the equipment mentioned in (a) to (f) above;
 - (h) hydraulic pumps supplying the equipment mentioned in (a) to (f) above;
 - (i) viscosity control equipment for heavy fuel oil;
 - (j) fire pumps and other extinguishing medium pumps;
 - (k) navigation lights, aids and signals;
 - (l) internal safety communication equipment;
 - (m) lighting system;
 - (n) control, monitoring and safety devices/systems for equipment mentioned in (a) to (m) above;
- ② secondary essential equipment which need not necessarily be in continuous operation for maintaining propulsion and steering, but which are necessary for maintaining the ship's safety, e.g.:
 - (a) windlasses;
 - (b) fuel oil transfer pumps and fuel oil treatment equipment;
 - (c) lubricating oil transfer pumps and lubricating oil treatment equipment;
 - (d) pre-heaters for heavy fuel oil;
 - (e) starting air and control air compressors;
 - (f) bilge, ballast and heeling pumps;
 - (g) ventilating fans for engine and boiler rooms;
 - (h) equipment necessary for maintaining dangerous spaces in a safe condition;

- (i) fire detection and alarm system;
 - (j) watertight closing appliances;
 - (k) refrigerating equipment for lowering ambient air temperature (see 1.2.1.2 of this Chapter);
 - (l) electric generators and associated power sources supplying the equipment mentioned in (a) to (k) above;
 - (m) hydraulic pumps supplying the equipment mentioned in (a) to (k) above;
 - (n) control, monitoring and safety systems for cargo containment systems;
 - (o) control, monitoring and safety devices/systems for equipment mentioned in (a) to (m) above;
- ③ special equipment of ships with a special class notation that may be regarded as essential equipment.
- (2) Non-essential equipment is that whose temporary disconnection will not impair propulsion and steer of the ship, nor endanger the safety of passengers, crew, cargo, ship and machinery.
- (3) Emergency consumer is a consumer which, after loss of the main source of electrical power, must be supplied by the emergency source of electrical power.
- (4) Main source of electrical power is a source intended to supply electrical power to the main switchboard for distribution to all services necessary for maintaining the ship in normal operational and habitable condition.
- (5) Emergency source of electrical power is a source of electrical power, intended to supply the emergency switchboard in the event of failure of the supply from the main source of electrical power.
- (6) Dead ship condition is the condition under which the main propulsion plant, boilers and auxiliaries are not in operation and in restoring the propulsion, no stored energy for starting and operating the propulsion plant, the main source of electrical power and other essential auxiliaries is assumed to be available.
- (7) Primary distribution system is a system having electrical connection with the generator.
- (8) Secondary distribution system is a system having no electrical connection with the generator, e.g. isolated therefrom by a double-wound transformer.
- (9) Low-voltage system is an alternating-current system operating with the maximum rated voltage not exceeding 1,000 V inclusive between conductors and with the rated frequency of 50 Hz or 60 Hz, or a direct-current system with the maximum instantaneous voltage under rated operating conditions does not exceed 1,500 V between conductors.
- (10) High-voltage system is an alternating-current system operating with the rated voltage more than 1 kV but not exceeding 15 kV and with the rated frequency of 50 Hz or 60 Hz, or a direct-current system with the maximum instantaneous voltage under rated operating conditions exceed 1,500 V between conductors.
- (11) Switch gear and control gear assembly is a combination of one or more switch gears and means of control, measurement, signal, protection and adjustment etc, assembled by the manufacturer together with all internal electrical and mechanical connectors and components.
- (12) Main switchboard is a switchboard which is directly supplied by the main source of electrical power and is intended to control and distribute electrical energy to switch gear and control gear assemblies of the ship's services.
- (13) Emergency switchboard is a switchboard which, normally supplied by the main switchboard, in the event of failure of the main electrical power supply system is directly supplied by the emergency source of electrical power or the transitional source of emergency power and is intended to control and distribute electrical energy to switch gear and control gear assemblies of the ship's emergency services.
- (14) Distribution board is a switch gear and control gear assembly arranged for the control and distribution of electrical power to final sub-circuits.
- (15) Final sub-circuit is that portion of a wiring system extending beyond the final over-current device of a board.
- (16) Total discrimination (total selectivity) is an over-current discrimination where, in the presence of two or more over-current protection devices in series, the protective device on the load side effects the protection without causing the other protective devices to operate.
- (17) Partial discrimination (partial selectivity) is an over-current discrimination where, in the presence of two or more over-current protective devices in series, the protective device on the load side effects the protection up to a given level of short-circuit current, without causing the other protective devices to operate.
- (18) Back-up protection is the protection equipment or system which is intended to operate when a system fault is not cleared in due time because of failure or inability of the protective device closest to the fault to operate or because of failure of the other protective device.
- (19) Continuity of power supply means that during and after a fault in a circuit, the supply to fault-free circuits is permanently ensured.
- (20) Dangerous zone is a zone where flammable or explosive vapours, gases, dusts, or explosives may be normally expected to accumulate.

(21) Enclosed space is a space enclosed by bulkheads and decks, which may be fitted with doors, windows or other openings capable of being closed.

(22) Semi-enclosed space is a space limited by top plates, wind breaks and bulkheads etc. in such a manner that the natural conditions of ventilation in the space are notably different from those obtained on open deck, and so arranged that the gas will not easily diffuse.

(23) A blackout situation means that the main and auxiliary machinery installations, including the main power supply, are out of operation, but the services for bringing them into operation (e.g. compressed air, starting current from batteries, etc.) are available.

(24) Shelf life of a battery means the duration of storage under specified conditions at the end of which a battery retains the ability to give a specified performance.

(25) An air-lock is to have two gastight steel doors which are self-closing without any hold-back arrangement, and the distance between which is not to be less than 1.5 m and not necessarily more than 2.5 m.

(26) Ripple voltage

The amplitude of the ripple voltage is represented in Figure 1.1.2.1(26) by the difference between $U_{\max}$ and $U_{\min}$.

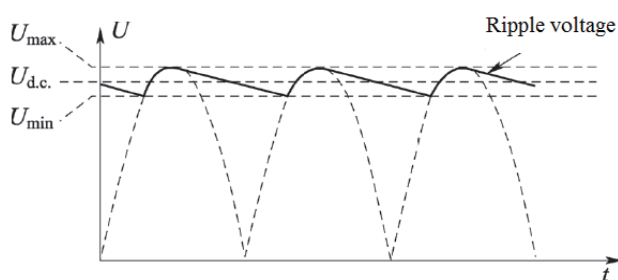


Figure 1.1.2.1(26) Ripple Voltage

(27) Uninterruptible power system (UPS) is a combination of converters, switches and energy storage means, for example batteries, constituting a power system for maintaining continuity of load power in case of input power failure.

(28) Off-line UPS unit is a UPS unit where under normal operation the output load is powered from the bypass line (raw mains) and only transferred to the inverter if the bypass supply fails or goes outside preset limits. This transition will invariably result in a brief (typically 2 to 10 ms) break in the load supply. See Figure 1.1.2.1(28).

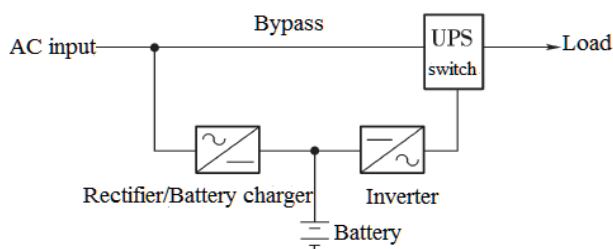


Figure 1.1.2.1(28) Off-Line UPS Unit

(29) Line interactive UPS unit is an off-line UPS unit where under normal operation the output load is powered from the UPS inverter or the power interface and when the input power goes outside the preset voltage and frequency limits, the load is transferred to stored energy power and the input power is disconnected from the power interface. See Figure 1.1.2.1(29).

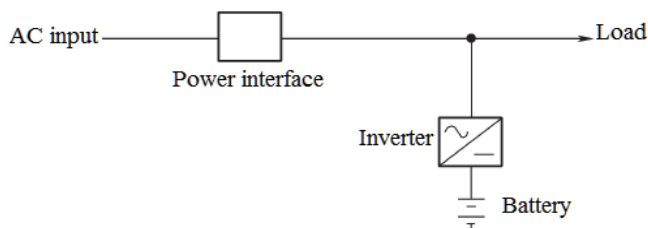


Figure 1.1.2.1(29) Line Interactive UPS Unit

(30) On-line UPS unit is a UPS unit where under normal operation the output load is powered from the inverter, and will therefore continue to operate without break in the event of the supply input failing or going outside preset limits. See Figure 1.1.2.1(30).

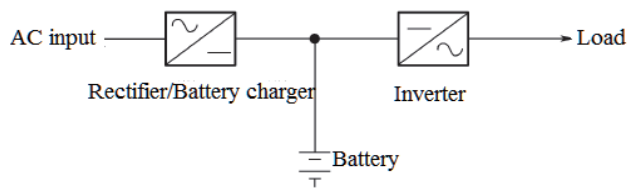


Figure 1.1.2.1(30) On-Line UPS Unit

(31) Zone 0 is an area in which an explosive gas atmosphere is present continuously or for long periods.

(32) Zone 1 is an area in which an explosive gas atmosphere is likely to occur in normal operation.

(33) Zone 2 is an area in which an explosive gas atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only.

1.1.3 Plans and documents

1.1.3.1 The following plans and documents are to be submitted for approval:

- (1) Electrical loading evaluation of main and emergency sources of electrical power.
- (2) Calculations for short-circuit currents (for ships with generators having a total capacity of more than 250 kVA and capable of being connected in parallel).
- (3) Analysis for coordination of protective devices in compliance with the requirements of 2.5.1.1 and 2.5.4.1 of this PART (for ships with generators having a total capacity of more than 250 kVA and capable of being connected in parallel).
- (4) Single line diagram of main switchboard, in which the following are to be indicated:
 - ① type, specifications and setting of protective devices (such as short-circuit, overloading, reverse power and unloading protection);
 - ② instrumentation;
 - ③ synchronizing devices;
 - ④ remote stops;
 - ⑤ earth fault monitoring and alarm;
 - ⑥ interlocks.
- (5) Single line diagram of emergency switchboard (or emergency accumulator battery charging and discharging board), in which the following are to be indicated:
 - ① type, specifications and setting of protective devices (such as short-circuit, overloading protection);
 - ② instrumentation;
 - ③ earth fault monitoring and alarm;
 - ④ interlocks.
- (6) Diagrams of power systems, in which the following are to be indicated:
 - ① main ratings of motors, transformers, batteries, electrical and electronic equipment;
 - ② all feeders connected to main and emergency switchboards;
 - ③ section boards (if fitted) and distribution boards;
 - ④ type, cross-sectional area and current loadings of cables;
 - ⑤ type and main rating of circuit breakers and fuses.
- (7) Arrangement of electrical equipment, in which the positions of the following items are to be indicated:
 - ① main and emergency generators;
 - ② main and emergency switchboards (or emergency accumulator battery charging and discharging boards);
 - ③ emergency accumulator batteries;
 - ④ electrical equipment for essential services (see 1.1.2.1 of this Chapter).
- (8) Schematic diagrams of main lighting.
- (9) Arrangement of main lighting.
- (10) Schematic diagrams of emergency lighting, temporary emergency lighting (if fitted), and additional emergency lighting (if fitted).
- (11) Arrangement of emergency lighting, temporary emergency lighting (if fitted), and additional emergency lighting (if fitted).
- (12) Arrangement and schematic diagrams (if supplied by emergency power) of low location lighting (if fitted).

- (13) Schematic diagrams of internal communication systems, including:
 - ① engine-room telegraph system;
 - ② essential telephone system;
 - ③ communication system for lifesaving;
 - ④ engineers' alarm system.
 - (14) Arrangement of internal communication systems, including:
 - ① engine-room telegraph system;
 - ② essential telephone system;
 - ③ communication system for lifesaving;
 - ④ engineers' alarm system.
 - (15) Schematic diagrams of safety systems for the ship and persons on board, including:
 - ① general emergency alarm system;
 - ② public address system;
 - ③ fire detection and fire alarm systems;
 - ④ alarm system for closing watertight doors;
 - ⑤ other alarm systems, e.g. for the release of fire extinguishing media (see Section 9, Chapter 2 of this PART).
 - (16) Arrangement of safety systems for the ship and persons on board, including:
 - ① general emergency alarm system;
 - ② public address system;
 - ③ fire detection and alarm system;
 - ④ alarm system for closing watertight doors;
 - ⑤ other alarm systems, e.g. for the release of extinguishing media (see Section 9, Chapter 2 of this PART).
 - (17) Arrangement of main cable runs (for passenger ships and high voltage electrical installations).
 - (18) General arrangement of the ship showing dangerous zones and spaces (for oil tankers and other ships carrying dangerous explosive goods).
 - (19) Simplified circuit diagram of electrical propulsion machinery, in which the following are to be indicated:
 - ① main ratings of motors, transformers, batteries, electrical and electronic equipment;
 - ② type, cross-sectional area and current loadings of cables;
 - ③ type and main rating of circuit breakers and fuses;
 - ④ earth fault monitoring.
 - (20) Arrangement of control positions and stations of electrical propulsion machinery, including control panels.
 - (21) List of monitoring and alarm items for electrical propulsion.
 - (22) Arrangement of semiconductor converters, including cooling system, for electrical propulsion system.
 - (23) Calculations of harmonic distortion for all main connectors, including main switchboards and distribution boards, in the electrical system of electrically propelled ships.
 - (24) Electrical system and general arrangement of water level detection systems for cargo holds, ballast tanks and dry spaces of bulk carriers, including arrangement of intrinsically safe circuits (if fitted).
 - (25) All electrical equipment located in hazardous areas together with the following associated information are to be included in their arrangement plan:
 - ① type of protection, explosion group and temperature class;
 - ② degree of protection;
 - ③ hazardous classification of the area where the electrical equipment is installed.
 - (26) Verification information^① of intrinsically safe circuits, including the verification of the voltage, current, inductance and capacitance.
- 1.1.3.2 The specifications for all electrical systems of the ship are to be submitted for information.
- 1.1.3.3 Additional plans and documents may be required as deemed necessary.

1.1.4 Testing

① The maximum inductance and capacitance are the total of the cable out to the hazardous area plus the values of connected equipment. The values of permissible input voltage, input current of each intrinsically safe apparatus is to be greater than or equal to the values respectively of the associated apparatus. Refer to IEC publication 60079-14: "Explosive atmosphere-Part 14: Electrical installations design, selection and erection" or equivalent standards.

1.1.4.1 Electrical equipment specified in 1.1.1.2 and 1.1.2.1(1) of this Section is to be tested in accordance with the requirements of Chapter 3 of this PART at the manufacturer. Tests other than those specified in this PART may be required as deemed necessary.

1.1.4.2 On completion of installation on board, the electrical installations are to be subject to mooring and sea trials in accordance with the test programmes approved by CCS.

Section 2 OPERATING CONDITIONS

1.2.1 Environmental conditions

1.2.1.1 Unless otherwise specified (e.g. in 1.2.1.2 of this Section), all electrical installations are to operate satisfactorily under the following environmental conditions:

(1) The ambient air temperatures and primary cooling water temperatures are as given in Table 1.2.1.1(1), however the upper limit of ambient air temperatures for the electronic equipment is to be 55°C.

Ambient Temperature **Table 1.2.1.1(1)**

Medium	Location	Temperature (°C)	
		Unrestricted service	Restricted service except in tropical zones
Air	In enclosed spaces	0 ~ 45	0 ~ 40
	In spaces subject to temperatures over 45°C (or 40°C) or below 0°C	According to temperatures in such spaces	According to temperatures in such spaces
	On the open deck	-25 ~ 45	-25 ~ 40
Water		32	25

(2) The inclination and roll of the ship is as given in Table 1.2.1.1(2).

Angle of Inclination **Table 1.2.1.1(2)**

Installations, components	Angle (°) ^{①②}			
	Athwartships		fore-and-aft	
	Static	Dynamic	Static	Dynamic
Emergency power installations, switchgear, electrical and electronic appliances	22.5	22.5	10	10
Electrical installations excluding items stated above	15	22.5	5	7.5

Notes: ① Athwartship and fore-and-aft inclinations may occur simultaneously.

② For ships carrying liquefied gases or chemicals, the emergency source of electrical power is also to remain operable with the ship being flooded to a final athwartship inclination up to a maximum of 30°.

(3) The vibration and shock likely to arise in normal service of the ship.

(4) Moisture, sea air, oil vapour and mould.

1.2.1.2 Where electrical equipment is installed within environmentally controlled spaces, the ambient temperature for which the equipment is suitable may be reduced from 45°C to a value not less than 35°C provided:

(1) the equipment is not for use for emergency services;

(2) temperature control is achieved by at least two cooling units so arranged that, in the event of loss of one cooling unit for any reason, the remaining unit(s) is capable of satisfactorily maintaining the design temperature;

(3) the equipment is able to be initially set to work safely within a 45°C ambient temperature until such a time that the lesser ambient temperature may be achieved; the cooling equipment is to be rated for a 45°C ambient temperature;

(4) audible and visual alarms are provided, at a continually manned control station, to indicate any malfunction of the cooling units;

(5) it is to be ensured that electrical cables for their entire length are adequately rated for the maximum ambient temperature to which they are exposed along their length.

1.2.2 Voltage and frequency variations

1.2.2.1 The electrical equipment supplied from the main or emergency systems is to be capable of operating satisfactorily under normally occurring variations in voltage and frequency.

1.2.2.2 Unless otherwise stated in international standards, electrical equipment is to operate satisfactorily with the variations in voltage and frequency from the rated value shown in Table 1.2.2.2 (measured at input terminals of the equipment).

Voltage and Frequency Variations

Table 1.2.2.2

Equipment	Parameters	Permanent (%)	Transient	
			%	Max. recovery time (s)
General AC equipment	Voltage	+6 ~ -10	±20	1.5
	Frequency	±5	±10	5
Direct current equipment supplied by DC generators or rectifiers	Voltage	±10	—	—
	Voltage cyclic variation deviation	5	—	—
	Voltage ripple	10	—	—
Equipment supplied by batteries: Connected to batteries during charging ^① Not connected to the batteries during charging	Voltage	+30 ~ -25	—	—
	Voltage	+20 ~ -25	—	—

Note: ① Different voltage variations as determined by the charging/discharging characteristics, including the ripple voltage from the charging device, are to be considered.

1.2.2.3 Any special system, e.g. electronic circuits, whose function cannot operate satisfactorily within the limits shown in Table 1.2.2.2 is not to be supplied directly from the system but by alternative means, e.g. through a stabilized supply.

1.2.3 Harmonic content

1.2.3.1 AC electrical equipment is to operate satisfactorily with a supply voltage containing a total harmonic content of the voltage waveform not exceeding 5%. If the harmonic content may exceed 5%, attention is to be given in selecting the equipment to ensure its normal function.

Section 3 DESIGN, CONSTRUCTION AND INSTALLATION

1.3.1 General requirements

1.3.1.1 Electrical equipment is to be so designed, constructed and installed as to ensure safe operation and facilitate inspection and repair.

1.3.1.2 The distance between live parts of different potential and between live parts and earthed metal, whether across surfaces or in air, is to be adequate for the working voltage, having regard to the nature of the insulating material and the conditions of service.

1.3.1.3 Equipment is not to remain alive through the control circuits or pilot lamps when switched off by the control switch. This does not apply to synchronizing switches and/or plugs.

1.3.1.4 All nuts and screws used for the connection and fastening of electrical equipment are to be provided with means to ensure that they cannot work loose by vibration and shock.

1.3.1.5 The material used to make electrical equipment is to comply with the following requirements:

(1) It is, in general, to be durable, flame-retardant, moisture resistant unless it is adequately protected against the atmospheric environment and temperatures to which it is likely to be exposed.

(2) Insulating materials and insulated windings are to be resistant to moisture, sea air and oil vapour unless special precautions are taken to protect them.

(3) The current carrying parts of electrical equipment are, in general, to be made of copper or copper alloys.

(4) Metal parts of electrical equipment are to be covered with proper protective coating against corrosion unless they are made of satisfactory corrosion-resistant material.

(5) New installation of materials which contain asbestos is to be prohibited.

1.3.1.6 If electrical fittings, not of aluminium, are connected to aluminium, suitable means is to be taken to prevent electrolytic corrosion.

1.3.1.7 All electrical equipment with internal wiring is to be attached with schematic or wiring diagrams in which wiring codes are indicated. All terminals of electrical equipment are to be provided with durable markings or symbols corresponding to those indicated in the diagrams.

1.3.1.8 The controls for emergency alarms are to be marked in red and provided with durable nameplates indicating their purposes.

1.3.1.9 For the fitting of rheostats, starting and charging resistors, heating appliances and other electrical apparatus likely to cause high temperatures, means are to be provided against overheating or igniting of adjacent objects.

1.3.1.10 All electrical equipment is not to be fitted close to the external surfaces of oil compartments, oil tanks or double bottom tanks intended for carrying oils. If this is necessary, electrical equipment is to be

installed at a minimum distance of 50 mm from these surfaces, provided that the electrical apparatuses mentioned in 1.3.1.9 are strictly prohibited to be installed on such surfaces.

1.3.1.11 Generating sets are to be installed with their shafts in parallel with the fore-and-aft direction of the ship, and horizontal motors are also to be installed, as far as practicable, with their shafts in parallel with the fore-and-aft direction of the ship.

1.3.1.12 For the electrical equipment other than that installed in a dedicated compartment, the live parts having a working voltage or a voltage to earth exceeding 50 V are to be so protected that they cannot be inadvertently touched.

1.3.1.13 Where the temperature of the enclosures of the electrical equipment is in excess of 80°C, suitable means are to be provided or suitable arrangement is to be made so as to protect the operators from injurious heating due to inadvertent touching.

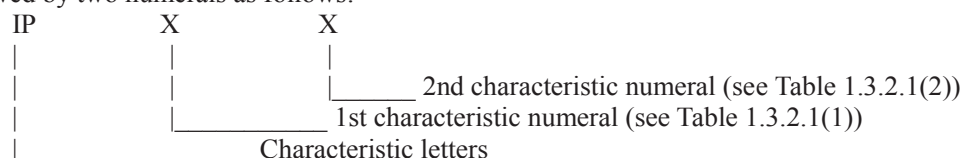
1.3.1.14 Holes are not to be drilled in watertight bulkheads, decks or boundary plating of deckhouses for the purpose of fitting the screws used to securing the electrical equipment and cables.

1.3.1.15 Electrical equipment and cables are not to be fitted on the shell plating.

1.3.1.16 Conductors and equipment are to be placed at a suitable distance from the magnetic compass, or are to be so screened that the interfering external magnetic field is negligible.

1.3.2 Protective enclosures

1.3.2.1 The type of protective enclosures for electrical equipment is to comply with the relevant acceptable standards^①. The designation indicating the degree of protection consists of the characteristic letters IP followed by two numerals as follows:



Degrees of Protection Indicated by the First Characteristic Numeral Table 1.3.2.1(1)

First characteristic numeral	Degree of protection	
	Short description	Definition
0	Non-protected	No special protection
1	Protected against solid objects greater than 50 mm	A large surface of the body, such as a hand (but no protection against deliberate access). Solid objects exceeding 50mm in diameter
2	Protected against solid objects greater than 12 mm	Fingers or similar objects not exceeding 80 mm in length. Solid objects exceeding 12 mm in diameter
3	Protected against solid objects greater than 2.5 mm	Tools, wires, etc. of diameter or thickness greater than 2.5mm. Solid objects exceeding 2.5 mm in diameter
4	Protected against solid objects greater than 1.0 mm	Wires or strips of thickness greater than 1 mm. Solid object exceeding 1 mm in diameter
5	Dust protected	Ingress of dust is not totally prevented, but dust does not enter in sufficient quantity to interfere with satisfactory operation of the equipment
6	Dust tight	No ingress of dust

Degrees of Protection Indicated by the Second Characteristic Numeral Table 1.3.2.1(2)

Second characteristic numeral	Degree of protection	
	Short description	Definition
0	Non-protected	No special protection
1	Protected against dripping water	Dripping water (vertically falling drops) is to have no harmful effect
2	Protected against dripping water when tilted up to 15°	Vertically dripping water is to have no harmful effect when the enclosure is tilted at any angle up to 15° from its normal position
3	Protected against spraying water	Water falling as a spray at an angle up to 60° from the vertical is to have no harmful effect
4	Protected against splashing water	Water splashed against the enclosure from any direction is to have no harmful effect
5	Protected against water jets	Water projected by a nozzle against the enclosure from any direction is to have no harmful effect
6	Protected against heavy seas	Water from heavy seas or water projected in powerful jets is not to

^① Refer to IEC Publication 60529: Classification of Degrees of Protection Provided by Enclosures or equivalent standards.

Second characteristic numeral	Degree of protection	
	Short description	Definition
		enter the enclosure in harmful quantities
7	Protected against the effects of immersion	Ingress of water in a harmful quantity is not to be possible when the enclosure is immersed in water under defined conditions of pressure and time
8	Protected against submersion	The equipment is suitable for continuous submersion in water under conditions specified by the manufacturer Note: Normally, this will mean that the equipment is hermetically sealed. However, with certain types of equipment, it can mean that water can enter but only in such a manner that it produces no harmful effects

1.3.2.2 The type of protective enclosures selected for electrical equipment is to be appropriate to the condition of the location at which such equipment is installed. The lowest degree of protection is to comply with the requirements given in Table 1.3.2.2 unless otherwise specified (e.g. in 1.3.2.3 and 1.3.2.4 of this Section).

Minimum Requirements for the Degree of Protection by Enclosure

Table 1.3.2.2

(1)	(2)	(3)	(4)							
			Equipment							
Location	Condition of location	Degree of protection	Switchboards, control gear, motor starters	Generators	Motors	Transformers, semiconductor converters	Lighting fixtures	Heating appliances	Cooking appliances	Accessories (e.g. switches, connection boxes)
Dry accommodation spaces	Danger of touching live parts only	IP20	×	—	×	×	×	×	×	×
Dry control rooms			×	—	×	×	×	×	×	×
Control rooms	Danger of dripping water and/or moderate mechanical damage	IP22	×	—	×	×	×	×	×	×
Engine and boiler rooms above floor plates			×	×	×	×	×	×	×	IP44
Steering gear rooms			×	×	×	×	×	×	—	IP44
Refrigerating machinery rooms (excluding ammonia plants)			×	—	×	×	×	×	—	IP44
Emergency machinery rooms			×	×	×	×	×	×	—	IP44
General storage rooms			×	—	×	×	×	×	—	×
Pantries			×	—	×	×	×	×	×	IP44
Provision rooms			×	—	×	×	×	×	—	×
Bathrooms and showers	Increased danger of water and/or mechanical damage	IP34	—	—	—	—	×	IP44	—	IP55
Engine and boiler rooms below floor plates			—	—	IP44	—	×	IP44	—	IP55
Closed fuel oil separator rooms			IP44	—	IP44	—	×	IP44	—	IP55
Closed lube oil separator rooms			IP44	—	IP44	—	×	IP44	—	IP55
Ballast pump rooms	Increased danger of water and mechanical damage	IP44	×	—	×	×	IP34	×	—	IP55
Refrigerated rooms			—	—	×	—	IP34	×	—	IP55
Galleys and laundries			×	—	×	×	IP34	×	×	×

(1)	(2)	(3)	(4)							
			Equipment							
Location	Condition of location	Degree of protection	Switchboards, control gear, motor starters	Generators	Motors	Transformers, semiconductor converters	Lighting fixtures	Heating appliances	Cooking appliances	Accessories (e.g. switches, connection boxes)
Shaft or pipe tunnels in double bottom	Danger of water spraying, presence of cargo dust, serious mechanical damage, aggressive fumes	IP55	×	—	×	×	×	×	—	IP56
Holds for dry cargo			—	—	—	—	×	—	—	×
Open decks	Danger of water ingress in massive quantities	IP56	×	—	×	—	IP55	×	—	×

- Notes: ① “×” means that the requirements of column (3) are to be complied with, or if impossible, the requirements of note ② are to be satisfied; “—” means that such equipment is generally not to be installed.
- ② Where the protection is not achieved by the equipment itself, other means are to be taken or the condition of the location for installing the equipment is to be improved to ensure the degree of protection required in the Table.
- ③ Where electrical equipment is installed in areas where explosive dusts may be present, the requirements of 1.3.3.7 of this Section are to be complied with.
- ④ Where the main and emergency switchboards are constructed and installed in accordance with the requirements of Section 3 of Chapter 3 and Sections 1 and 2 of Chapter 2 of this PART respectively, the requirements of this Table may be dispensed with.

1.3.2.3 In the engine room, the electrical and electronic equipment located within areas protected by fixed water-based local fire-fighting systems and those within adjacent areas exposed to direct spray (see Figure 1.3.2.3) are to have a degree of protection not less than IP44, except where evidence of suitability is submitted to and approved by CCS.

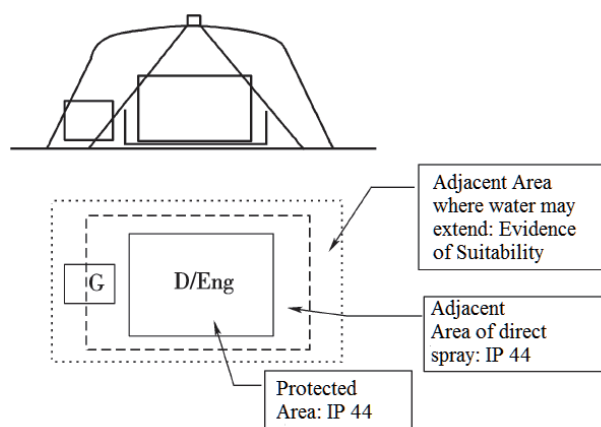


Figure 1.3.2.3 Areas Protected by Fixed Water-Based Local Application Fire-Fighting Systems

G – generator; D/Eng – diesel engine

1.3.2.4 In the engine room, the electrical and electronic equipment within adjacent areas where water may extend and which are not covered by 1.3.2.3 above (see Figure 1.3.2.3) may have a lower degree of protection provided evidence of suitability for use in these areas is submitted taking into account the design and equipment layout, e.g. position of inlet ventilation openings, cooling airflow for the equipment is to be assured.

1.3.3 Explosion protection

1.3.3.1 Where electrical equipment is installed in areas where explosive gas or vapour atmospheres may be present, it is to be of a certified safe type complying with the following requirements:

(1) The construction and type testing of the safe type electrical equipment is to be in accordance with the relevant acceptable standards^①.

(2) The safe type electrical equipment is to be certified by a competent testing authority approved by CCS.

1.3.3.2 The certified safe type equipment normally used on board ships includes the following types of protection:

- | | |
|---------------------------|---------|
| (1) Intrinsically safe | Ex “i”; |
| (2) Flameproof | Ex “d”; |
| (3) Increased safety | Ex “e”; |
| (4) Pressurized enclosure | Ex “p”; |
| (5) Special protection | Ex “s”; |
| (6) Powder filled | Ex “q”; |
| (7) Encapsulated | Ex “m”. |

1.3.3.3 The electrical equipment allowed to be fitted in spaces subject to an explosion hazard, e.g. battery rooms, lamp stores and paint lockers (including ventilation ducts), is to comply with the following requirements:

(1) The electrical equipment is to be installed in paint stores and in ventilation ducts serving such spaces only when it is essential for operational services. Such equipment is to be of a certified safe type listed in 1.3.3.2(1) to (5) of this Section. For other spaces, the electrical equipment of certified safe types listed in 1.3.3.2 of this Section may be fitted, and the explosion groups and temperature classes of such equipment are at least to comply with the requirements in Table 1.3.3.3.

(2) Cables (through runs or terminating cables) of armoured type or installed in metallic conduits are to be used.

(3) The switches, protective devices and motor control gear for the electrical equipment installed in such spaces are to interrupt all poles or phases and preferably are to be located in non-hazardous spaces.

In addition, the relevant requirements for paint locker ventilation openings, battery rooms, oil tankers and ships carrying vehicles with fuel in their tanks for their own propulsion are given in 1.3.3.4, 1.3.3.5 of this Section, and Sections 11, 16 and 17 of Chapter 2.

Explosion Group and Temperature Class

Table 1.3.3.3

Location	Group ^①	Temperature class ^①
Battery rooms	II C ^②	T1
Paint lockers	II B	T3
Lamp stores	II A	T3
Ammonia plant rooms	II A	T1
Acetylene storage rooms	II C	T2
Spaces carrying dangerous goods	According to the category of dangerous goods carried	According to the category of dangerous goods carried
Tunnels for pipes containing oil with a flash point of 60°C or below	II A	T3

Notes: ① The explosion groups and temperature classes of electrical equipment listed in this Table and hereinafter in this PART are according to the relevant requirements of IEC Publication 60079: Electrical Apparatus for Explosive Gas Atmospheres or of GB 3836: Electrical Apparatus for Explosive Atmospheres.

② Explosion groups II A, II B and II C of electrical equipment listed in this PART are applicable only to intrinsically safe apparatus and flame-proof apparatus. For other types of explosion-proof electrical equipment, Group II is to be used.

1.3.3.4 In the areas on open deck within 1 m of inlet and exhaust ventilation openings or within 3 m of exhaust mechanical ventilation outlets of the paint locker, the following electrical equipment may be installed:

① Refer to IEC publication 60079: Electrical Apparatus for Explosive Gas Atmospheres, or an equivalent national standard. e.g., GB 3836: Electrical Apparatus for Explosive Gas Atmospheres.

(1) certified safe type equipment listed in 1.3.3.2(1) to (5) of this Section, while cables and their installation are to comply with the requirements of 1.3.3.3(2);

(2) explosion-proof equipment of non-sparking construction (Ex “n”);

(3) appliances which do not generate arcs in service and whose surface does not reach unacceptably high temperature;

(4) appliances with simplified pressurized enclosures or vapour-proof enclosures (minimum degree of protection IP55) whose surface does not reach unacceptably high temperature.

1.3.3.5 The enclosed spaces giving access to the paint locker may be considered as non-hazardous, provided that:

(1) the door to the paint locker or the door of the paint locker is a gastight door with self-closing devices (a watertight door may be regarded as a gastight door) without holding back arrangements;

(2) the paint locker is provided with an acceptable, independent, natural ventilation system ventilated from a safe area;

(3) warning notices are fitted adjacent to the paint locker entrance stating that the locker contains flammable liquids.

1.3.3.6 Socket outlets are, unless expressly specified otherwise, not to be installed in spaces subject to an explosion hazard.

1.3.3.7 Where electrical equipment is to be installed in areas where explosive dusts may be deposited, it is to comply with the following requirements:

(1) the degree of protection by enclosures is to be at least IP55;

(2) the maximum surface temperature of the equipment in continuous service is to be at least 75 K lower than the glow temperature of a 5 mm thick layer of the dust.

1.3.4 Earthing

1.3.4.1 All accessible metal parts of the electrical equipment, other than current-carrying ones, are to be earthed, except for:

(1) lamp caps;

(2) shades, reflectors and guards supported on lamp holders or lighting fittings constructed of, or shrouded in, non-conducting material;

(3) metal parts on, or screws in or through, non-conducting material, which are separated by such material from current-carrying parts and from earthed non-current-carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;

(4) portable appliances having double and/or reinforced insulation, provided that the appliances conform with recognized safety requirements;

(5) bearing housings which are insulated in order to prevent circulation of current in the bearings;

(6) clips for fluorescent lamps;

(7) apparatus supplied at a working voltage not more than 50 V. For the alternating current, this voltage is a value of root mean square. Autotransformers are not to be used for the purpose of achieving this voltage;

(8) cable clips.

1.3.4.2 When the electrical equipment is directly fixed on the metal hull of the ship or securely fixed on bedplates (or supports) which have a good electrical contact with the metal hull of the ship, a special earthing conductor may not be required.

1.3.4.3 Whether the earthing is achieved through a special conductor or by bedplates (or supports) of the equipment, the surfaces in contact are to be clean, flat and bright so as to ensure an effective contact, and measures are to be taken to prevent the connection from loosening and corrosion.

1.3.4.4 When special earthing conductors are used, they are to be of copper or other corrosion-resistant materials of good conductivity, and are to be protected against mechanical damage and corrosion where necessary. The nominal cross-sectional area of various copper earthing conductors is not to be less than required in Table 1.3.4.4.

1.3.4.5 Bare metal parts of movable or portable appliances, other than current-carrying ones, are to be earthed by means of an earth-continuity conductor in the flexible cable or cord through the associated plug and socket outlet, and the cross-sectional area of the earth conductor is to comply with the requirements of Table 1.3.4.4.

Size of Earthing Conductors

Table 1.3.4.4

Type of earthing conductor	Cross-sectional area of associated current-carrying conductor S (mm ²)	Minimum cross-sectional area of copper earthing conductor Q (mm ²)
Earth-continuity conductor in flexible cable or flexible cord	$S \leq 16$	$Q = S$
	$S > 16$	$Q = S/2$, but at least 16
Earth-continuity conductor incorporated in fixed cable	$S \leq 16$	$Q = S$, but at least 1.5
	$S > 16$	$Q = S/2$, but at least 16
Special fixed earthing conductor	$S \leq 2.5$	$Q = S$, but at least 1.5
	$2.5 < S \leq 120$	$Q = S/2$, but at least 4
	$S > 120$	$Q = 70$

1.3.4.6 Metal sheathings or coverings of cables are to be effectively earthed at both ends of the run, except that final sub-circuits may be earthed at the supply end only. This does not necessarily apply to control and instrumentation cables where single point earthing is permitted for technical reasons.

1.3.4.7 The metal sheathings or coverings of cables may be earthed by one of the means described below:
(1) gripped by metal clamps and connected to the metal hull of the ship by dedicated copper earthing conductors. The relationship between the cross-sectional area Q of the copper earthing conductors and the cross-sectional area S of the current-carrying conductors of the cables is to be as follows:

$$Q \geq 1.5 \text{ mm}^2, \text{ for } S \leq 25 \text{ mm}^2;$$

$$Q \geq 4 \text{ mm}^2, \text{ for } S > 25 \text{ mm}^2;$$

(2) by means of glands intended for this purpose and so designed as to ensure an effective earth connection;
(3) by means of clamps or clips of corrosion-resistant metal, enabling a good contact between the metal sheathings or coverings of cables and the earthed metal.

1.3.4.8 The electrical continuity of metal sheathings or coverings of cables is to be ensured throughout the length of the cables, particularly at joints and tapings.

1.3.4.9 The lead sheath of lead-sheathed cables is not to be used as the sole means of earthing.

1.3.4.10 Every connection of an earth-continuity conductor or a special earthing conductor to the hull structure is to be made in an accessible position, and is to be secured by a screw of brass or other corrosion-resistant material and having a diameter not less than 4 mm, which is to be used for this purpose only.

1.3.4.11 Where aluminium superstructures are secured to the steel hull of a ship with an insulation to prevent electrolytic corrosion between these materials, a separate bonding connection is to be provided between the superstructure and the hull which is to be made in such a manner that electrolytic corrosion is prevented and the connection points may readily be inspected.

1.3.4.12 In order to avoid the hazard of an incentive discharge due to the build-up of static electricity resulting from the flow of liquids/gases/vapours, all cargo tanks, process plants and piping systems that contain flammable liquids, evolve combustible gases and/or develop flammable dusts are to comply with the following requirements:

(1) The resistance between the above cargo tanks, process plants and piping systems and the hull of the ship is not to be greater than 1 MΩ.

(2) The requirements of 1.3.4.12(1) will be readily met without the use of bonding straps where cargo tanks, process plants and piping systems are directly or via their supports, either welded or bolted to the hull of the ship.

(3) Bonding straps are required for cargo tanks, process plants and piping systems which are not permanently connected to the hull of the ship, e.g.:

- ① independent cargo tanks;
- ② cargo tanks and piping systems which are electrically separated from the hull of the ship;
- ③ pipe connections arranged for the removal of spool pieces;
- ④ wafer-style valves with non-conductive (e.g. PTFE) gaskets or seals.

(4) Where bonding straps are required, they are to be:

- ① clearly visible so that any shortcomings can be clearly detected;
- ② designed and sited so that they are protected against mechanical damage and that they are not affected by high resistivity contamination, e.g. corrosive products or paint;
- ③ easy to install and replace.

(5) Bonding straps are to be made of copper or other corrosion-resistant materials of good conductivity, having a cross-sectional area of at least 10 mm².

1.3.5 Electromagnetic compatibility

1.3.5.1 Appropriate measures are to be taken to reduce the interference due to electromagnetic energy so that all electrical and electronic equipment can operate normally in a ship's electromagnetic environment.

1.3.5.2 The allowable value of the voltage (current) of the interference induced by electrical and electronic equipment and the means of interference suppression are to comply with the relevant provisions of acceptable standards^①.

1.3.6 Visual and audible signals

1.3.6.1 Except those required in 1.3.6.2 of this Section, the colour of visual signals is to comply with the requirements of Table 1.3.6.1.

1.3.6.2 Except those required above, the visual and audible signals are to comply with the acceptable standards^②.

Colours of Visual signals

Table 1.3.6.1

Colour	Meaning	Explanation	Example
Red	Danger or alarm	Warning of danger or a situation which requires immediate action	Operation failure of essential equipment; Temperature or pressure of water, oil etc. reaching a critical value; Power failure of essential circuits
Yellow	Caution	Change or impending change of conditions	Temperature or pressure is abnormal, but not reaching a critical value
Green	Safety (normal operating or normal working conditions)	Indication of a safe situation	Normal operation of machinery; Normal circulation of liquids; Pressure, temperature and currents within limits
Blue	Instruction/information (specific meaning assigned according to the need in the case considered)	Blue may be given a meaning which is not covered by the three above colours: red, yellow and green	Motor begins to start; Unloading generator begins to switch on; Heating circuit of stopping motor is connected
White	No specific meaning assigned	Any meaning, used if red, yellow or green is considered not applicable	Earthing insulation indication; Synchronizing lamp; Telephone calling; Automated equipment

① Refer to IEC Publication 60533: Electromagnetic Compatibility of Electrical and Electronic Installations in Ships, or corresponding standards.

② Refer to Code on Alerts and Indicators, 2009 adopted by IMO resolution A.1021(26).

CHAPTER 2 ELECTRICAL INSTALLATIONS IN SHIPS

Section 1 MAIN SOURCE OF ELECTRICAL POWER

2.1.1 Generating sets

2.1.1.1 A main source of electrical power having sufficient capacity to supply all services mentioned in 1.1.1.5(1) of this PART is to be provided, and the following requirements are to be complied with.

(1) The main source of electrical power is to consist of at least two generating sets.

(2) The number and ratings of these generating sets are to be such that in the event of any one generating set being stopped it will still be possible to supply those services necessary to provide normal operational conditions of propulsion and safety of the ship and essential for ships with class notation for carrying refrigerated cargoes as specified in PART FIVE of the Rules. Furthermore, minimum comfortable conditions of habitability are also to be ensured, which include at least adequate services for cooking, heating, domestic refrigeration, mechanical ventilation, sanitary and fresh water.

(3) The generating sets are to be such as to ensure that with any one generator or its prime mover out of operation, the remaining generating sets are still capable of providing the electric services necessary to start the main propulsion plant from a dead ship condition.

(4) Where the main source of electrical power is necessary for propulsion and steering of the ship, the continuity of the power supply to the equipment necessary for the propulsion and steering and for ensuring the safety of the ship is to comply with the following requirements:

① Where the electrical power is normally supplied by more than one generating set simultaneously in parallel operation, means of protection, including automatic shedding (see 2.5.7.1 of this Chapter) of non-essential services and if necessary, automatic shedding of the arrangements for habitability and secondary essential services, are to be provided to ensure that in case of loss of any of these generating sets, the remaining ones are kept in operation to supply equipment necessary for propulsion and steering and for ensuring the safety of the ship.

② Where the electrical power is normally supplied by one generator, provision is to be made, upon loss of power, for automatic starting and connecting to the main switchboard of a stand-by generator(s) of sufficient capacity with automatic restarting of the essential auxiliaries, in sequential operation if required. Starting and connection to the main switchboard of the stand-by generator is to be as rapid as possible, preferably within 30 s, but in any case not more than 45 s, after loss of power.

(5) Where the main source of electrical power is necessary for propulsion of the ship, the main bus-bar is to be subdivided into at least two independent sections which are normally be connected by a circuit breaker without tripping mechanism or disconnecting link or switch by which the bus-bar can be split easily. So far as is practicable, the connection of generating sets and other duplicated equipment is to be equally divided between the sections.

(6) A common power plant may be provided as both the main source of electrical power and the electrical power for propulsion, and in this case the requirements of 15.2.1.7 of Chapter 15, PART EIGHT of the Rules are to be complied with.

2.1.1.2 The alternating current system is to be such that with one generating set out of action, the remaining sets have sufficient reserve capacity to permit the starting of the largest motor without causing any motor to stall or any other device to fail due to excessive voltage drop on the system. Motors which have a very large capacity and are not essential to the safe navigation of the ship, such as thruster motors, may be started when all generators are put into operation without causing any essential equipment to stop.

2.1.1.3 The arrangement of the ship's main source of electrical power is to be such that the operation of the services referred to in 1.1.1.5(1) of this PART can be maintained regardless of the speed and direction of the propulsion machinery shafting.

2.1.1.4 For calculation of the capacity of generating sets, where the detailed power of refrigerated containers can not be provided, it is recommended that 11 kW be taken for each socket where the sockets of refrigerated containers are adaptable to power supply for 20 ft or 40 ft containers. It is also recommended that 7.5 kW be taken for each socket suitable only for power supply of 20 ft containers. A diversity factor of 0.6 may be taken for calculation of loading of containers.

2.1.1.5 A main source of electrical power may be provided as necessary for non-self-propelled ships. Where the main source of electrical power is the generator, the provisions of 2.1.1.1 to 2.1.1.3 of this Chapter need not be complied with.

2.1.2 Generators driven by main propulsion machinery (e.g. shaft-driven generators)

2.1.2.1 A generator driven by the ship's main propulsion machinery may be considered part of the ship's main source of electrical power, provided that:

- (1) the generator is capable of operating normally under all weather conditions during sailing or maneuvering, also when the vessel is stopped, within the specified limits for the voltage variation in paragraphs 3.2.7 and 3.2.8 and for the frequency variation in 1.2.2.2;
- (2) the rated capacity of the generator is in compliance with 2.1.1.1(2) upon loss of any other generator in service;
- (3) the short circuit current of the generator is sufficient to trip the generator circuit breaker, taking into account the selectivity of the protective devices for the distribution system. Protection is to be arranged in order to safeguard the generator in case of a short circuit in the main bus-bar. The generator is to be suitable for further use after fault clearance;
- (4) the automatic start of standby sets is in compliance with 2.1.1.1(4)②.

2.1.2.2 A generators and/or generating system driven by the ship's propulsion machinery and not forming part of the ship's main source of electrical power may be used, whilst the ship is at sea, to supply the electrical equipment necessary for normal operational and habitable conditions provided that:

- (1) sufficient and adequately rated additional generators are fitted, which constitute part of the main source of electrical power required by 2.1.1.1 of this Section;
- (2) arrangements are fitted to automatically start at least one of the generators, which constitute part of the main source of electrical power required by 2.1.1.1 of this Section, in compliance with 2.1.1.1(4)②, when frequency variations exceed the limits specified below:

Frequency variations (permanent): $\pm 5.5\%$

Frequency variations (transient): $\pm 11\%$ (5 s);

- (3) voltage variations are within the limits specified in 3.2.7 and 3.2.8 and frequency variations within the limits specified in 1.2.2.2;
- (4) the short circuit current of the generator and/or generating system is sufficient to trip the generator and/or generating system circuit breaker, taking into account the selectivity of the protective devices for the distribution system;
- (5) automatic load shedding arrangements are fitted in accordance with the requirements of 2.5.7 of this Chapter;
- (6) on ships having remote control of the propulsion machinery from the navigation bridge, means are provided or procedures are in place to ensure that the power supply to essential services is maintained during maneuvering conditions in order to avoid a blackout situation.

2.1.3 Transformers

2.1.3.1 The number, capacity and arrangement of transformers are to meet the following requirements if they constitute the necessary parts of lighting system and main electric power source system as required in 2.1.1.1 of this Section.

- (1) The transformers are to be such that, with any one transformer out of operation, the remaining transformers are sufficient to ensure the safe operation of the equipment necessary for normal propulsion and for safety of the ship. Furthermore, minimum comfortable conditions of habitability are also to be ensured, which include at least adequate services for cooking, heating, domestic refrigeration, mechanical ventilation, sanitary and fresh water.
- (2) Each transformer is to be located as a separate unit with separate enclosure or equivalent, and is to be served by separate circuits on the primary and secondary sides.
- (3) Each primary circuit is to be provided with switch gear and protection devices in each phase.
- (4) Each of the secondary circuits is to be provided with a multi-pole isolating switch.

2.1.4 Installation of switchboards

2.1.4.1 The main switchboard is to be so placed relative to the main power plant that, as far as is practicable, the integrity of the normal electrical supply will be affected only by a fire or other casualty in one space. An environmental enclosure for the main switchboard, such as may be provided by a machinery control room situated within the main boundaries of the space, is not to be considered as separating the switchboard from the generators.

2.1.4.2 Water, oil or steam pipes, oil tanks or other liquid containers are not to be installed above or behind the switchboard. If this is unavoidable, suitable protection is to be provided in these positions.

2.1.4.3 Passages of an adequate width are to be left in front of and behind switchboards. The width of the front passage is to be at least 0.8 m. The width of passage behind the switch gear is to be at least 0.6 m, and at least 0.5 m at frames. If the construction of a switchboard is such as to permit maintenance, inspection and replacement of parts from the front or from the ends, the passageway behind the switchboard may be dispensed with.

2.1.4.4 Where the length of the main switchboard is greater than 4 m, passageways are to be, as far as possible, provided at both ends of the switchboard. Except that the main switchboard is installed in the machinery control room, doors with locking devices are to be provided at both ends of the passageway behind the switchboard.

2.1.4.5 The passageways in front of and behind the main switchboard are to be covered by non-slipping and oil-proof insulating mats or insulated wood gratings.

2.1.5 Automatic connecting and disconnecting of main generating set

2.1.5.1 Requirements of paragraph 2.1.5.2 to 2.1.5.6 are to be met where start, stop and load sharing between generators, is controlled by an automation system.

2.1.5.2 The following alarms are to be arranged:

- (1) variations in bus bar voltage from the rated value (high and low);
- (2) variations in bus bar frequency from the rated value (high and low);
- (3) automatic load shedding;
- (4) failure in automatic switch-on of circuit breaker of generator;
- (5) automatic tripping of circuit breaker of generator;
- (6) failure in load distribution (with the necessary time delay, see paragraph 3.2.8.5 of Chapter 3 for the percentage of load distribution).

2.1.5.3 Means are to be provided to avoid two or more than two generating sets being switched on the common bus-bar of main switchboard simultaneously.

2.1.5.4 After a blackout due to short circuit, the generator circuit breaker is permitted to be switched on only once.

2.1.5.5 Where the standby generating set has been started as a result of a prolonged main bus-bar voltage or frequency fluctuation, the running generating set is to be stopped and disconnected from the switchboard prior to connection of the standby generating set.

2.1.5.6 Automatic starting attempts which fail are to be limited to restrict consumption of starting energy.

Section 2 EMERGENCY SOURCE OF ELECTRICAL POWER

2.2.1 General requirements

2.2.1.1 All passenger ships and cargo ships of more than 500 gross tonnage are to be provided with a self-contained emergency source of electrical power.

2.2.1.2 The emergency source of electrical power is to be so arranged as to comply with the following:

(1) The emergency source of electrical power, associated transforming equipment (if any), transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the uppermost continuous deck and are to be readily accessible from the weather deck. They are not to be located forward of the collision bulkhead, except where permitted by CCS for cargo ships in exceptional circumstance.

(2) The location of the emergency source of electrical power, associated transforming equipment (if any), the transitional source of emergency power, the emergency switchboard and the emergency lighting switchboard in relation to the main source of electrical power, associated transforming equipment (if any), and the main switchboard is to be such as to ensure that a fire or other casualty in spaces containing the main source of electrical power, associated transforming equipment (if any), and the main switchboard or in any machinery space of category A will not interfere with the supply, control and distribution of emergency electrical power. As far as practicable, the space containing the emergency source of electrical power, associated transforming equipment (if any), the transitional source of emergency electrical power and the emergency switchboard is not to be continuous to the boundaries of machinery spaces of category A or those spaces containing the main source of electrical power, associated transforming equipment (if any), or the main switchboard.

2.2.1.3 The emergency source of electrical power may be a generator, which is to comply with the following requirements:

(1) driven by a suitable prime mover with independent cooling system and supply of fuel as well as starting arrangements complying with the requirements of 9.5.3 of Chapter 9 of PART THREE of the Rules;

(2) started automatically upon failure of the electrical supply from the main source of electrical power and connected automatically to the emergency switchboard, and those services referred to in 2.2.2.2 (for passenger ships) or 2.2.3.2 (for cargo ships) of this Section then transferred automatically to the emergency generating set, except for cargo ships fitted with a transitional source of emergency electrical power in accordance with 2.2.1.5 of this Section. The automatic starting system and the characteristics of the prime

mover are to be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 s.

2.2.1.4 The emergency source of electrical power may also be an accumulator battery, which is to comply with the following requirements:

- (1) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage;
- (2) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
- (3) supplying those services (except as otherwise stated) referred to in 2.2.2.1 (for passenger ships) or 2.2.3.1 (for cargo ships) of this Section, and immediately supplying those services referred to in 2.2.2.2 (for passenger ships) or 2.2.3.2 (for cargo ships) of this Section.

2.2.1.5 Where the emergency source of electrical power is a generator, a transitional source of emergency electrical power which consists of an accumulator battery is to be provided in compliance with the following requirements, except for cargo ships fitted with an emergency generator capable of automatic starting in accordance with 2.2.1.3(2):

- (1) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage;
- (2) so arranged as to supply immediately and automatically in the event of failure of either the main or emergency source of electrical power those services referred to in 2.2.2.2 (for passenger ships) or 2.2.3.2 (for cargo ships) of this Section.

2.2.1.6 Where the emergency source of electrical power is required to restore propulsion from a dead ship condition, the capacity is to be sufficient to supply the following equipment within 30 min of the blackout (For steam turbine ships, the 30-min time limit is to be taken as the time from blackout/dead ship condition to light-off of the first boiler):

- (1) equipment referred to in 2.2.2.1(1), (2) and (3) or in 2.2.3.1 (1), (2), (3) and (4) of this Section;
- (2) restoring propulsion of the ship and operation of other machineries (as appropriate) from a dead ship condition.

2.2.1.7 The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power and to comply with the following requirements:

- (1) Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired.
- (2) Where the emergency source of electrical power is an accumulator battery, the accumulator battery is not to be installed in the same space as the emergency switchboard.
- (3) The passages in front and behind the emergency switchboard, etc. are to comply with the requirements given in 2.1.4.2 to 2.1.4.5 of this Chapter.

2.2.1.8 An indicator is to be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or transitional source of emergency electrical power are being discharged.

2.2.1.9 The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be protected according to the requirements of 2.5.9.6 and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power.

2.2.1.10 In order to ensure ready availability of the emergency source of electrical power, arrangements are to be made, where necessary, to disconnect automatically non-emergency circuits from the emergency switchboard to ensure that electrical power is to be available to the emergency circuits.

2.2.1.11 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used exceptionally, and for short periods, to supply non-emergency circuits.

2.2.1.12 Where the emergency and/or transient emergency source of electrical power is an accumulator battery which supplies emergency loads via an electronic converter or inverter, the maximum permitted D.C voltage variations (taken as those on the load side of the converter or inverter) are to be within 12% above or below its nominal voltage; where DC is converted into AC the maximum variations are to comply with Table 1.2.2.2.

2.2.1.13 UPS units utilizing valve regulated sealed batteries, as described in 2.2.2.1 and 2.2.3.1 of this Section, may be located in compartments with normal electrical equipment, provided the ventilation arrangements are in accordance with the requirements of IEC 62040 or an acceptable standard.

2.2.2 Scope and period of supply of the emergency source in passenger ships

2.2.2.1 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(1) for a period of 36 h, emergency lighting:

- ① at every muster and embarkation station and over the sides as required in the SOLAS Convention in force;
- ② in alleyways, stairways and exits giving access to the muster and embarkation stations as required in the SOLAS Convention in force;
- ③ in all escape routes with their stairways and exits (including angles and intersections) placed not more than 0.3 m above the deck as required in the SOLAS Convention in force (where an emergency source of electrical power is required for the supply);
- ④ in all service and accommodation alleyways, stairways and exits, personnel lift cars;
- ⑤ in public spaces and in cabins accommodating more than 16 persons;
- ⑥ in the machinery spaces and main generating stations including their control positions;
- ⑦ in all control stations, machinery control rooms, and at each main and emergency switchboard;
- ⑧ at all stowage positions for firemen's outfits;
- ⑨ at the steering gear; and
- ⑩ at the fire pump, the sprinkler pump and the emergency bilge pump referred to in the subparagraph (4) and at the starting position of their motors;

(2) for a period of 36 h:

- ① the navigation lights and other signal lights required in the International Regulations for Preventing Collisions at Sea in force;
- ② VHF radio equipment, MF radio installation (if any), ship earth station (if any) and MF/HF radio equipment (if any) required in the SOLAS Convention in force;

(3) for a period of 36 h:

- ① all internal communication equipment required in an emergency;
- ② the navigational aids as required in the SOLAS Convention in force, where such provision is unreasonable or impracticable, this requirement may be waived for ships of less than 5,000 gross tonnage, subject to agreement of CCS;
- ③ the fire detection and fire alarm system, and the fire door holding and release system; and
- ④ for intermittent operation of the daylight signaling lamp, the ship's whistle, the manually operated call points and all internal signals that are required in an emergency (e.g. general emergency alarm system, alarms for warning of the release of extinguishing media),

unless such services mentioned above in ① to ④ have an independent supply for the period of 36 h from an accumulator battery or have an uninterruptible power system (UPS) complying with the requirements of Section 9, Chapter 3 of this PART suitably located for use in an emergency;

(4) for a period of 36 h:

- ① one of the fire pumps required in the SOLAS Convention in force;
- ② the automatic sprinkler pump, if any;
- ③ the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves;

(5) for the period of time required in 13.1.8 of PART THREE of the Rules, the steering gear if required to be so supplied by that paragraph;

(6) for a period of half an hour:

- ① any watertight doors required in the SOLAS Convention in force to be power operated together with their indicators and warning signals;
- ② the emergency arrangements to bring the lift cars to deck level for the escape of persons. The passenger lift cars may be brought to deck level sequentially in an emergency;

(7) for ships having a class notation of Category 2 Service, engaged regularly in voyages of short duration and proceeding not more than 20 n miles off shore, CCS, if satisfied that the same level of safety would be attained, may accept a lesser period than the 36 h period required in (1) to (4) above, but not less than 12 h.

2.2.2.2 The transitional source of emergency electrical power required in 2.2.1.5 of this Section is to be of sufficient capacity to supply at least the following services, if they depend upon an electrical source for their operation:

(1) for half an hour:

- ① the lighting required in 2.2.2.1(1) and navigation lights and other signal lights required in 2.2.2.1(2)① of this Section;

- ② all services required in 2.2.2.1 (3)①, ③ and ④ unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency;
- (2) power to operate the watertight doors, but not necessarily all of them simultaneously, unless an independent temporary source of stored energy is provided;
- (3) power to the control, indication and alarm circuits for operation of watertight doors for half an hour.

2.2.2.3 In addition to the emergency lighting required above, passenger ships with ro-ro cargo spaces or special category spaces are to be provided with the following:

- (1) all passenger public spaces and alleyways are to be provided with supplementary emergency lighting complying with the following:
 - ① capable of operating for at least three hours when all other sources of electrical power have failed and under any condition of heel;
 - ② the illumination provided is to be such that the approach to the means of escape can be readily seen;
 - ③ the source of power for the supplementary lighting is to consist of accumulator batteries located within the lighting units that are continuously charged, where practicable, from the emergency switchboard. Alternatively, other means of lighting which is at least as effective may be accepted by CCS;
 - ④ the supplementary lighting is to be such that any failure of the lamp will be immediately apparent;
 - ⑤ any accumulator battery provided is to be replaced at intervals having regard to the specified service life in the ambient conditions that they are subject to in service;
- (2) a portable rechargeable battery operated lamp is to be provided in every crew space alleyway, recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required in (1) above, is provided.

2.2.3 Scope and period of supply of the emergency source in cargo ships

2.2.3.1 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously.

The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

- (1) for a period of 3 h, emergency lighting at every muster and embarkation station and over the sides as required in the SOLAS Convention in force;
- (2) for a period of 18 h, emergency lighting:
 - ① in all services and accommodation alleyways, stairways and exits, personnel lift cars and personnel lift trunks;
 - ② in the machinery spaces and main generating stations including their control positions;
 - ③ in all control stations, machinery control rooms, and at each main and emergency switchboard;
 - ④ at all stowage positions for firemen's outfits;
 - ⑤ at the steering gear;
 - ⑥ at the fire pump referred to in (5), at the sprinkler pump (if any), and at the emergency bilge pump (if any), and at the starting positions of their motors;
 - ⑦ in all cargo pump rooms of tankers;
- (3) for a period of 18 h:
 - ① the navigation lights and other signal lights required in the International Regulations for Preventing Collisions at Sea in force;
 - ② VHF radio installation, MF radio installation (if any), ship earth station (if any) and MF/HF radio installation (if any) required in the SOLAS Convention in force;
- (4) for a period of 18 h:
 - ① all internal communication equipment as required in an emergency;
 - ② the navigational aids as required in the SOLAS Convention in force, where such provision is unreasonable or impracticable, this requirement may be waived for ships of less than 5,000 gross tonnage, subject to agreement of CCS;
 - ③ the fire detection and fire alarm system;
 - ④ intermittent operation of the daylight signaling lamp, the ships whistle, the manually operated call points and all internal signals that are required in an emergency (e.g. general emergency alarms system, alarms for warning of the release of extinguishing media, etc.), unless such services mentioned above in ① to ④ have an independent supply for the period of 18 h from an accumulator battery or have an uninterruptible power system (UPS) complying with the requirements of Section 9, Chapter 3 of this PART suitably located for use in an emergency;

(5) for a period of 18 h, one of the fire pumps required in the SOLAS Convention in force if dependent upon the emergency generator for its source of power;

(6) for the period of time required in 13.1.8 of PART THREE of the Rules, the steering gear where it is required to be so supplied by that paragraph;

(7) for ships having a class notation of Category 2 Service, engaged regularly in voyages of short duration and proceeding not more than 20 n miles off shore, CCS, if satisfied that the same level of safety would be attained, may accept a lesser period than the 18 h period required in (2) to (5), but not less than 12 h.

2.2.3.2 The transitional source of emergency electrical power required in 2.2.1.5 of this Section is to be of sufficient capacity to supply at least the following services for half an hour, if they depend upon an electrical source for their operation:

(1) the lighting required in 2.2.3.1(1) and (2), and navigation lights and other signal lights required in 2.2.3.1(3)①. For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps; and

(2) all services required in 2.2.3.1(4)①, ③ and ④, unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

2.2.4 Use of emergency generator in port

2.2.4.1 The emergency generator may be used during lay time in port for the supply of the ship mains, provided the requirements below are complied with:

(1) to prevent the generator or its prime mover from becoming overloaded when used in port, arrangements are to be provided to shed sufficient non-emergency loads to ensure its continued safe operation;

(2) the prime mover is to be fitted with fuel oil filters and lubrication oil filters, monitoring equipment and protection devices as required for the prime mover for main power generation and for unattended operation;

(3) the fuel oil supply tank to the prime mover is to be provided with a low level alarm, arranged at a level ensuring sufficient fuel oil capacity for the emergency services for the period of time as required in 2.2.2 or 2.2.3 of this Section;

(4) the prime mover is to be designed and built for continuous operation and to be subjected to a planned maintenance scheme verified by CCS ensuring that it is always available and capable of fulfilling its role in the event of an emergency at sea;

(5) fire detectors are to be installed in the location where the emergency generator set and emergency switchboard are installed;

(6) means are to be provided to readily change over to emergency operation;

(7) control, monitoring and supply circuits, for the purpose of the use of the emergency generator in port, are to be so arranged and protected that any electrical fault will not influence the operation of the main and emergency services. When necessary for safe operation, the emergency switchboard is to be fitted with switches to isolate the circuits;

(8) instructions, which are to contain information on required fuel oil tank level, position of harbor/sea mode switch, ventilation openings etc., are to be provided on board to ensure that when the vessel is under way all control devices (e.g. valves, switches) are in a correct position for the independent emergency operation of the emergency generator set and emergency switchboard. These instructions are to be posted in the emergency generator room.

Section 3 EXTERNAL SOURCE OF ELECTRICAL POWER

2.3.1 Shore supply

2.3.1.1 Where arrangements are made for the supply of electricity from a source on shore or elsewhere, a connection box complying with the requirements of 3.3.2.12 of this PART is to be installed in a position in the ship suitable for the convenient reception of flexible cables from the external source. Suitable cables having adequate ratings, permanently fixed, are to be provided for connection between the shore connection box and the main switchboard or emergency switchboard.

2.3.1.2 When a three-phase AC system with neutral earthed is adopted for shore and/or ship power, an earth terminal is to be provided for connecting the ship's hull to shore. In the case of DC systems with hull return, the negative terminal of the shore power must be connected to hull.

2.3.1.3 The shore connection is to be provided with an indicator at the main switchboard or emergency switchboard in order to show when the cables are energized.

Section 4 POWER SUPPLY AND DISTRIBUTION

2.4.1 Power supply and distribution systems

2.4.1.1 The following systems of distribution may be used:

(1) DC

two-wire insulated system;

two-wire system with negative pole earthed;

single-wire system with negative to hull return.

(2) AC single phase

two-wire insulated system;

two-wire system with one pole earthed;

single-wire system with hull return.

(3) Three phase AC

three-wire insulated system;

four-wire system with neutral earthed;

three-wire system with neutral earthed and the hull serving as neutral wire.

Other distribution systems than those mentioned above are to be subject to special approval by CCS.

2.4.1.2 For power supply and distribution systems for high-voltage systems, refer to the requirements of 2.14.2.1 of this PART.

2.4.1.3 For the distribution systems of ships intended for the carriage of crude oil and petroleum products in bulk having a flash point (closed-cup test) below 60°C, refer to the requirements of 2.16.2.1 of this PART.

2.4.2 Insulated distribution systems

2.4.2.1 The neutrals of generating sets are not to be connected together in the insulated distribution system.

2.4.2.2 The insulated distribution systems for power, heating and lighting circuits, whether primary or secondary, are to be provided with a device capable of continuously monitoring the insulation level to earth and of giving an audible or visual indication in case of abnormally low insulation values.

2.4.3 Earthed and hull return systems of distribution

2.4.3.1 The hull return system of distribution is not to be used for power, heating or lighting in ships of 1,600 gross tonnage and upwards, but not excluding the following:

(1) impressed current cathodic protective systems;

(2) limited and locally earthed systems, provided that any possible resulting current will not directly flow through any hazardous areas;

(3) insulation level monitoring devices provided the circulation current does not exceed 30 mA under the most unfavourable condition.

2.4.3.2 Where the hull return system is used, all final sub-circuits are to have all poles or phases insulated, the hull return being achieved by connecting to the hull one of the bus-bars of the distribution board from which they originate.

2.4.3.3 The earthed distribution system in a high-voltage system is to be in compliance with the relevant requirements of 2.14.2.1 of this PART.

2.4.3.4 The earthing conductors used in the hull return system are to be of the same cross-sectional area as the conductors in the insulated pole or phase, and bare conductors are not to be used.

2.4.3.5 Enclosures of equipment or their mounting bolts are not to be used as return conductors or connection to the conductors.

2.4.3.6 The cross-sectional area of earthing conductors which do not normally carry current in service is to be 50% of that of the current-carrying conductors, but not less than 1.5 mm².

2.4.3.7 The system earthing of earthed distribution systems is to be effected by means independent of any earthing arrangements of non-current-carrying parts of the electrical equipment.

2.4.4 Voltage and frequency

2.4.4.1 The maximum supply voltages of DC and AC distribution systems are not to exceed the values given in Table 2.4.4.1.

Maximum Supply Voltages of Distribution Systems**Table 2.4.4.1**

No.	Application	Max. voltage (V)
1	For power equipment permanently installed and connected by permanent wiring	15,000
2	(1) For power, heating and cooking equipment permanently installed and connected by permanent wiring, except space heaters. (2) For power and heating equipment (except space heaters) permanently installed where connection by flexible cable is necessary because of the application, e.g. movable cranes. (3) For portable equipment, which is not hand-held during operation, and with connection by socket outlet and flexible cable which incorporates an earth continuity conductor of a size in accordance with 1.3.4.5 of this PART, e.g. welding transformer	1,000
3	(1) For lighting and heaters in accommodation and public spaces (2) For socket outlets supplying the following: ① equipment with double insulation; ② equipment earthed by earth continuity conductors of a size in accordance with 1.3.4.5 of this PART	250
4	For socket outlets used in spaces where particular risks due to exposure and conductivity may exist, e.g. exceptionally damp or confined spaces: (1) supplied with or without the use of isolating transformers; (2) where a safety isolating transformer is used supplying one consuming device only. Both wires of such systems are to be insulated from earth	50 250

Note: For the control voltage of distribution systems operating at a voltage above 500 V, see 2.4.4.2 of this Section.

2.4.4.2 For distribution systems operating at a voltage above 500 V, the control voltage is to be limited to 250 V, except where all control devices of the distribution systems operating at a voltage not exceeding 1000 V are enclosed in appropriate control boxes.

2.4.4.3 The standard frequency for AC distribution systems is to be 50 Hz or 60 Hz.

2.4.5 Balance of loads

2.4.5.1 For AC three-wire or four-wire systems, the electrical consumers are to be so grouped in the final sub-circuits that the load in each phase will, under normal conditions, be balanced as far as possible within 15% of its rated load at the individual distribution and section boards as well as the main switchboard.

2.4.6 Diversity factors

2.4.6.1 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justified, to the application of a diversity factor. Where spare ways are provided on a section or distribution board, an allowance for future increase of load is to be added to the total connected load before application of any diversity factor.

2.4.6.2 The diversity factor may be applied to the calculation of the cross-sectional area of conductors and the rating of switch gear and fuse gear.

2.4.6.3 For cargo winches, a diversity factor may be applied based on the information available from the manufacturer and the information agreed upon between the manufacturer and purchaser. If there is no exact information available, the diversity factors of Table 2.4.6.3 may be applied.

Diversity Factors**Table 2.4.6.3**

Number of motors	Current to be provided for	
	Cases in which motors are of the same size	Cases in which motors are of different sizes
2	100% of combined full load of motors	
3	67% of combined full load of motors	100% of full load of the largest motor + 50% of full load of each one of the other motors
4	62% of combined full load of motors	
5	60% of combined full load of motors	
6 or more	58% of combined full load of motors	

2.4.6.4 For the diversity factors of socket circuits for refrigerated containers, refer to the requirements of Chapter 4 of PART FIVE of the Rules.

2.4.7 Power supply to essential equipment

2.4.7.1 Unless expressly provided otherwise, the primary essential equipment is to be supplied directly from the main or emergency switchboard (if required), except for the total discrimination.

2.4.8 Power supply to radio equipment and navigation equipment

2.4.8.1 The power supply to the radio equipment as required in Chapter IV (hereinafter referred to as the radio equipment) and the electrical/electronic navigation equipment as required in Chapter V (hereinafter referred to as the navigation equipment) of the SOLAS Convention are to comply with the requirements of 2.4.8.2 to 2.4.8.5.

2.4.8.2 The distribution board of supplies to the radio equipment is to be independent of that of supplies to the navigation equipment.

2.4.8.3 The distribution board of the radio equipment and that of the navigation equipment supplied by the emergency source of electrical power are to be supplied by separate feeders from main and emergency switchboards, and each distribution board is to be provided with a device for changing over between main and emergency sources of electrical power, which is in general to be initiated automatically. In the event of any failure of the power supply of the radio distribution board, an audible and visual alarm is to be given in the navigation bridge.

2.4.8.4 Each consumer is to be supplied by an independent final sub-circuit from its distribution board.

2.4.8.5 One or more reserve power sources independent from the ship's propulsion and electric systems are to be provided to supply the radio equipment for the purpose of distress and safety radio communications in the event of failure of the ship's main and emergency sources of electrical power. The capacity of the reserve source or sources is to be sufficient to supply the following equipment simultaneously for 1 h:

- (1) VHF radio installation;
- (2) MF radio installation or ship earth station or MF/HF radio installations;
- (3) Adequate illumination of radio control console for operating the radio equipment.

2.4.9 Power supply to auxiliary machinery motors, etc.

2.4.9.1 In addition to the above-mentioned requirements, the power supply to auxiliary machinery motors, illumination, navigation lights, internal communication systems and safety system for ships and persons on board is to comply with the relevant requirements of this PART.

2.4.10 Sockets

2.4.10.1 The sockets for general portable appliances are to be in compliance with the requirements of No.3 and No.4 in Table 2.4.4.1 of this Section.

2.4.10.2 For the sockets of distribution systems operating at different voltages and/or frequencies, non-interchangeable plugs are to be used for connection.

2.4.10.3 No socket outlets are to be provided below floor plates in machinery spaces, or in enclosed fuel and lubrication oil separator rooms.

2.4.10.4 Where sockets are necessary in cargo holds, they are to be fitted in positions with sufficient protection against mechanical damage.

2.4.10.5 For sockets of refrigerated containers, refer to the relevant requirements of Chapter 4 of PART FIVE of the Rules.

2.4.10.6 Socket outlets for power circuits rated over 16A (AC) or 10A (DC) are to be interlocked in such a way that the plug can be neither inserted nor withdrawn when the socket contacts are live.

2.4.11 Power supply with transformers operating in parallel

2.4.11.1 Transformers arranged for parallel operation are to comply with the following requirements:

- (1) their winding connections are to be compatible;
- (2) their rated voltage ratios are to be equal (with tolerances within permissible limits);
- (3) their short-circuit impedance values are to be equal (if expressed in percentage, a ratio within 0.9 to 1.1 may be allowed);
- (4) when transformers are intended for operation in parallel, the rated output of the smallest transformer in the group is not to be less than 50% of the rated output of the largest transformer in the group.

2.4.12 Power supply to safety, control and alarm systems of prime movers

2.4.12.1 The prime movers referred to in this paragraph mean diesel engines, gas turbines and steam turbines, etc. that drive the electric generators which comprise the main source of electric power.

2.4.12.2 The safety, control and alarm systems of prime movers are to be supplied by two independent power sources, which and associated wiring are to be such that the requirements of 2.1.1.1(2) of this Chapter can be met in case of single failure.

2.4.13 Power supply to electronic control system of diesel engines

2.4.13.1 The power supply to electronic control systems of diesel engines is to comply with the requirements of 2.2.4 of Appendix 2 to Chapter 9 of PART THREE of the Rules.

Section 5 PROTECTION

2.5.1 General requirements

2.5.1.1 Electrical installations are to be suitably protected against overcurrents including short circuits, and other electric faults. The performance and arrangement of the protective devices are to provide complete and coordinated automatic protection to ensure the continuity of supply to available essential services through the discriminative action of the protective devices in the event of a fault elsewhere, and to ensure the elimination of the effects of the fault to reduce damage to the system and hazard of fire.

Coordination is to be provided:

- (1) between main generator protective device, main bus-bar section breakers (if provided with trip), protective devices (if fitted) of feeders connected to the main bus-bar, and protective devices of feeders from the main bus-bar;
- (2) between protective devices of feeders and branch circuits of the distribution board containing essential services, unless otherwise specified in 2.5.3.6 of this Section;
- (3) between protective devices of feeders from the emergency generator and the emergency bus-bar, and between protective devices of feeders interconnecting main and emergency switchboards and feeders from the emergency bus-bar.

2.5.1.2 Short-circuit protection is to be provided in each non-earthed pole or phase of distribution systems.

2.5.1.3 Overload protection is to be provided in:

- (1) insulated two-wire DC or single-phase AC systems: at least one pole or phase;
- (2) insulated three-phase AC systems: at least two phases;
- (3) earthed systems: each non-earthed pole or phase.

2.5.1.4 No fuse or non-linked switch is to be inserted in an earthed conductor of distribution systems.

2.5.2 Calculations of short-circuit current

2.5.2.1 In the calculation of the maximum prospective short-circuit current, consideration is to be given to:

- (1) all generators which are possibly connected in parallel to reach the maximum required power;
- (2) all motors which are normally simultaneously connected in the system.

2.5.2.2 When necessary, the prospective short-circuit power factor of the AC system is to be calculated. If the power factor so obtained is less than the specified one corresponding to the rated short-circuit making or breaking capacity of the selected switch gear, then the breaking capacity of such switch gear is to be reduced accordingly.

2.5.2.3 Short-circuit calculations are to be referred to Appendix 1 of this PART: Short-Circuit Current Calculations with Regard to Electrical Installations, or performed by other methods acceptable to CCS.

2.5.2.4 In general, short-circuit calculations are to be carried out for the following:

- (1) short circuit at the output terminal of generators;
- (2) short circuit at the main bus-bar;
- (3) short circuit at the bus-bars of the emergency switchboard, section switchboards and distribution switchboards;
- (4) short circuit at the secondary side of power and lighting transformers.

For the determination of the discriminative action of protective devices, short-circuit calculations are, if necessary, to be additionally performed for short-circuit at terminals of the protected circuit, when only the smallest generator is in supply.

2.5.3 Choice of protective devices against short-circuit

2.5.3.1 Protection against short-circuit currents is to be provided by fuses or circuit-breakers.

2.5.3.2 Unless otherwise specified in 2.5.3.3 and 2.5.3.5, the breaking capacity of protective devices against short-circuit is to comply with the following requirements:

- (1) The rated short-circuit breaking capacity of fuses and general circuit breakers is not to be less than the maximum prospective fault current at the point of installation. For the AC systems, the rated short-circuit breaking capacity is not to be less than the prospective symmetrical short-circuit current (root mean square value) at the point of installation.

(2) The rated operating short-circuit breaking capacity (I_{cs}) of circuit breakers for relevant circuits of essential equipment is not to be less than the maximum prospective fault current at the point of installation. For the AC systems, the rated operating short-circuit breaking capacity is not to be less than the prospective symmetrical short-circuit current (root mean square value) at the point of installation.

2.5.3.3 The rated short-time withstanding current of category B circuit breakers (with short time-lag) is not to be less than the maximum prospective short-circuit current at the instant of contact separation at the point of installation. For the AC systems, the rated short-time withstanding current is not to be less than the prospective symmetrical short-circuit current (root mean square value) at the instant of contact separation at the point of installation.

2.5.3.4 Unless otherwise stated in 2.5.3.5 of this Section, the rated short-circuit making capacity of every circuit breaker or switch which will possibly be initiated for a short-circuit is not to be less than the maximum peak value of the prospective short-circuit current at the point of installation.

2.5.3.5 The use of a circuit-breaker having a short-circuit breaking and/or making capacity less than the maximum prospective short-circuit current at the point of installation is permitted, provided that it is backed up on the generator side by a fuse or by a circuit-breaker (not the generator circuit-breaker) having the necessary rated short-circuit breaking/making capacity.

The short-circuit performance of the back-up protective arrangement is to be at least as that required for a single circuit-breaker by a standard^① acceptable to CCS. The circuit-breaker is to have the same utilization category as the circuit-breaker on the load side of the back-up arrangement and a rated short-circuit breaking/making capacity for the maximum prospective short-circuit current at the supply terminal of the arrangement.

2.5.3.6 The back-up protection complying with the requirements of 2.5.3.5 may be used for circuits of non-essential services and of duplicated essential services with automatic change-over. The same fuse or circuit-breaker may be used to back up more than one circuit-breaker when essential services are not involved.

2.5.3.7 Circuit-breakers with fuses connected to the load side may be used, provided the back-up fuse and circuit-breaker are designed for coordinated action, so as to ensure that the operation of the fuse takes place in due time to prevent arcing between poles or between poles and metal parts of the circuit breaker when they are subjected to an overcurrent involving the operation of the fuse.

2.5.3.8 When determining the short-circuit performance requirements for the above-mentioned back-up protection arrangement, the impedance of the elements of the arrangement may be taken into account, such as the impedance of a cable connection when the circuit-breaker on the load side is far away from the back-up circuit-breaker or fuse.

2.5.4 Selective protection for short-circuit

2.5.4.1 Unless otherwise stated in 2.5.3.6 of this Section, the short-circuit protection of essential equipment is to be selective and comply with the following:

- (1) to ensure that only the protective device nearest to the fault initiates disconnection of the defective circuit in the case of short-circuit;
- (2) the tripping time of the protective devices connected in series is to be carefully coordinated;
- (3) during the required time of selective protection, the protective device is to be capable of carrying the short-circuit current without breaking at the point of installation.

2.5.5 Choice of protective devices against overload

2.5.5.1 Circuit breakers provided for overload protection are to have a tripping characteristic (overcurrent – trip time) adequate for the overloading ability of protected elements and for any discrimination requirement of the system.

2.5.5.2 The use of fuses for overload protection is permissible up to 320 A, provided they have suitable characteristics, but the use of circuit breakers or similar devices for protection against overload above 200 A is recommended.

2.5.6 Protection of generators

2.5.6.1 Generators are to be protected against short-circuit and overloads by circuit breakers arranged to interrupt simultaneously all insulated poles, and the overload protection is to be adequate for the thermal capacity of the generator. In addition, the following requirements are to be complied with:

^① Refer to IEC Publication 60947-2: Low-Voltage Switch Gear and Control Gear – Part 2: Circuit-Breakers.

(1) for overloads between 10% and 50%, the circuit breaker is to be tripped with a time delay of less than 2 min. It is recommended that the circuit breaker be set within the limits of 125 to 135% of the rated current of the generator and with a time delay of 15 to 30 s;

(2) for overcurrents in excess of 50% but less than the steady short-circuit current of the generator, the circuit breaker is to be tripped after a short-time delay required for the discriminative protection of the system.

It is recommended that the pick-up current for tripping of the circuit-breaker after a short-time delay be set at 200% to 250% of the rated current of the generator and with a maximum time delay of 0.2 s (DC) or 0.6 s (AC);

(3) circuit breakers for three or more generators connected in parallel are also to be provided with instantaneous releases which are to be set slightly greater than the maximum short-circuit current of the generators protected so that the circuit-breaker may break instantaneously.

2.5.6.2 For generators less than 50 kW (or kVA) in unit capacity and not arranged to operate in parallel, a multi-pole linked switch with a fuse in each insulated pole may be fitted for protection.

2.5.6.3 Generators having a capacity of 1,500 kVA or above are to be equipped with a suitable protective device or system which, in the event of a short-circuit in the generator or in the supply cable between the generator and its circuit breaker will de-excite the generator and open the circuit breaker.

2.5.6.4 AC generators arranged to operate in parallel are to be provided with a reverse-power protection, with a time delay set within 3 to 10 s. DC generators arranged for parallel operation are to be provided with instantaneous or short-time delayed (less than one second) reverse current protection. The setting of reverse power (or reverse current) protection of generators arranged for parallel operation, dependent on the type of the prime mover used, is to be as follows:

(1) for diesel engines – 8% to 15% of the rated power (or current) of the generator;

(2) for steam turbines – 2% to 6% of the rated power (or current) of the generator.

A fall of 50% in the applied voltage is not to render the reverse power (or reverse current) protection inoperative, although it may alter the amount of reverse power required to open the breaker.

For the reverse-current protection, due consideration is to be given to the reverse current resulting from the ship's network (e.g. cargo winches).

Where equalizer leads are provided, the reverse current protection is to be connected to the positive pole of DC generators.

2.5.6.5 Generators arranged to operate in parallel are to be provided with undervoltage protection as follows:

(1) the operation of undervoltage release is to be instantaneous, if used to prevent the circuit-breaker from closing when the generator is not generating electrical energy;

(2) when the voltage drops down to 70% ~ 35% of the rated voltage, the undervoltage release is to operate with a time delay for discrimination purpose.

2.5.6.6 Where turbine-driven DC generating sets are arranged to operate in parallel, means are to be provided for the purpose of opening simultaneously all circuit-breakers of the generators when the overspeed tripping device of the driving turbine functions.

2.5.6.7 In the case of substantial reduction of speed of generators, the protective devices associated with generators are to remain effective.

2.5.7 Automatic load shedding

2.5.7.1 Proper load shedding or other equivalent arrangements are to be provided to automatically shed non-essential services, services for habitable conditions and where necessary, secondary essential services to ensure that the connected generator(s) is/are not overloaded. This load shedding may be carried out in one or more stages according to the overloading ability of the generator. In such case, the non-essential services are to be shed firstly.

2.5.8 Protection of power and lighting transformers

2.5.8.1 The primary windings of power and lighting transformers are to be protected against short-circuit and overload by multi-pole circuit-breakers or fuses. Overload protection may also be provided in the secondary windings.

2.5.8.2 When transformers are arranged to operate in parallel, means of isolation are to be provided on the secondary windings. Switches and circuit breakers used for this purpose are to be capable of withstanding surge currents.

2.5.9 Protection of feeder circuits

2.5.9.1 Each feeder circuit is to be protected against overload and short circuits by a multi-pole circuit breaker arranged to interrupt simultaneously all insulated poles, or a multi-pole switch with fuses, but for a transitional emergency lighting feeder circuit it may also be accepted to use fuses only.

2.5.9.2 When a multi-pole switch with fuses is used, the following requirements are to be complied with:

(1) the fuse in the feeder sub-circuit from the main switchboard is to be fitted between the bus-bar and the switch;

(2) where the final sub-circuit from the distribution board has a rated current not exceeding 60 A and the consumers supplied by it can be disconnected at a nearby position, the switch may be omitted.

2.5.9.3 Circuits supplying consuming devices protected individually against overload (e.g. motors) may be provided with short-circuit protection only.

2.5.9.4 The protection of the steering gear circuits is to comply with 13.1.9.2 of PART THREE of the Rules.

2.5.9.5 Permanently fixed cables between the shore connection box and the main switchboard are to be protected by a circuit-breaker or an isolating switch and fuses. Such protection is to be fitted in the shore connection box.

2.5.9.6 In general, the interconnector feeder supplying the emergency switchboard from the main switchboard is to be protected at the main switchboard against overload and short-circuit. Where the system is arranged also for reverse power supply, the interconnector feeder is to be additionally protected at the emergency switchboard at least against short-circuit.

2.5.10 Protection of motors

2.5.10.1 Motors rated at 0.5 kW or above and all motors for essential services are to be protected individually against overload and short-circuit, and against undervoltage as required in 2.5.10.6 of this Section.

The short-circuit protection can be provided by the same protective device for both the motor and its supply cable.

2.5.10.2 Protection of steering gear motors is to comply with 13.1.9.2 of PART THREE of the Rules.

2.5.10.3 The protective devices are to be designed to allow the flow of currents during the normal accelerating period of motors under normal conditions of service. When the time-current characteristics of the overload protective device of a motor are not adequate for the starting period of the motor, the overload protecting device may be rendered inoperative during the accelerating period provided that the protection against short-circuit remains operative and that the suppression of the overload protection is only temporary.

2.5.10.4 For continuous duty motors, protective devices are to have a time delay characteristic which ensures reliable thermal protection of the motors for overload conditions. The maximum continuous current of the protective device is not to exceed 125% of the rated current of the protected motor.

2.5.10.5 For intermittent duty motors, the current setting and the delay characteristics for protective devices are to be chosen after considering the actual service condition.

2.5.10.6 Motors are to be provided with either:

(1) undervoltage protection, operative on the reduction or failure of voltage, to cause and maintain the interruption of power in the circuit until the motor is deliberately restarted; or

(2) undervoltage release, operative on the reduction or failure of voltage, to cause and maintain the interruption of power in the circuit, but so arranged that the motor restarts automatically and without excessive voltage drop or starting current on restoration of voltage.

The protective devices are to allow the motor to start when the voltage is above 85% of the rated voltage, and are without fail to intervene when the voltage is lower than approximately 20% of the rated voltage, at the rated frequency and with time delay when necessary.

2.5.10.7 When fuses are used to protect poly-phase motor circuits, consideration is to be given to protection against single phasing.

2.5.11 Protection of lighting circuits

2.5.11.1 Each lighting circuit is to be protected against overload and short-circuit.

2.5.12 Protection of storage batteries

2.5.12.1 Storage batteries, other than engine starting batteries, are to be protected against short-circuit with devices placed as near as practicable to the batteries.

2.5.12.2 Each battery charger is to be properly protected against discharging of the battery due to the reduction or loss of charging voltage.

2.5.13 Protection of meters, pilot lamps and control circuits

2.5.13.1 Voltmeters, voltage coils of measuring instruments, earthing indicators and pilot lamps together with their connecting leads are to be protected by fuses. A pilot lamp need not be individually protected provided the following conditions are satisfied:

- (1) the pilot lamp is installed with the equipment in the same enclosure;
- (2) the pilot lamp is supplied from the interior circuit of the enclosure of the equipment;
- (3) the protection device in the circuit is rated less than 25 A;
- (4) a fault in the pilot lamp would not jeopardize the supply to essential equipment.

2.5.13.2 The voltage coils of control and protective devices and equipment are to be protected by fuses. The coils themselves need not be protected provided the following conditions are satisfied:

- (1) the coils are installed with the equipment in the same enclosure and protected by a general protective device;
- (2) the coils are supplied from circuits of the equipment and the protective device of such circuits is rated less than 25 A.

2.5.14 Protection of semiconductor equipment

2.5.14.1 Semiconductor equipment is to be protected against overload and short circuit.

Section 6 AUXILIARY MACHINERIES

2.6.1 General requirements

2.6.1.1 Motors rated at 0.5 kW or above and motors required for essential services are to be supplied from distribution boards by separate final sub-circuits.

2.6.1.2 Every electric motor is to be provided with efficient means of starting and stopping which are, in general, placed near the motor, so as to be easily operated by the person controlling the motor.

2.6.1.3 Means are to be provided for the disconnection of the full load from all live poles of supply of every motor rated at 0.5 kW or above and its control gear. Where the control gear is mounted on or adjacent to a main or other distribution switchboard, a disconnecting switch in the switchboard may be used for this purpose. Otherwise, a disconnecting switch within the control gear enclosure or a separate enclosed disconnecting switch is to be provided.

2.6.1.4 When the starter or any other apparatus for disconnecting the motor is remote from the motor, it is required that either:

- (1) provision be made for locking the circuit disconnecting in the OFF position; or
- (2) an additional disconnecting-switch be fitted near the motor; or
- (3) the fuse in each live pole or phase be so arranged that it can be readily removed and retained by an authorized person.

2.6.1.5 Where a single master-starter system (i.e. a starter used for controlling a number of motors successively) is used, undervoltage and over-current protection, means of isolation and a running indicator are to be provided for each motor, not less effective than those required for systems using a separate starter for each motor. Where the starter system is of an automatic type, suitable alternative means are to be provided for manual operation. Where the starter is used for motors for essential services, the starting portion is to be duplicated, and means are to be provided for change-over in the event of failure of one of the starters.

2.6.1.6 All motors with field adjustment for speed control are to be provided with a device which renders the motors to be started only when the field is fully excited.

2.6.1.7 The undervoltage, overload and short-circuit protection for motors are to comply with the requirements of Section 5, Chapter 2 of this PART.

2.6.2 Steering gear

2.6.2.1 Electrical or electrohydraulic steering gears are to comply with the relevant requirements of Chapter 13 of PART THREE of the Rules.

2.6.3 Permanently installed submersible bilge pumps

2.6.3.1 The motors of permanently installed submersible bilge pumps are to be connected to the emergency switchboard. The feeder cables are to be installed in continuous lengths from above the bulkhead to the motor terminals.

The cables are to be impervious-sheathed and armoured. Cables and their connections to such pumps are to be capable of operating under a head of water equal to the height of the bulkhead deck.

2.6.3.2 Under all circumstances it is to be possible to start the motor of a permanently installed submersible bilge pump from a position above the bulkhead deck. If an additional start-stop push button is provided near the motor, the circuits are to be so arranged as to ensure that all control circuits of the start-stop push button may be disconnected from the position above the bulkhead deck.

2.6.3.3 The power source of a permanently installed submersible bilge pump is also to comply with the relevant requirements of Section 5, Chapter 3 of PART THREE of the Rules.

2.6.4 Deck machinery

2.6.4.1 Electromagnetic brakes for electrical deck machinery are to have, in addition, a hand release device.

2.6.4.2 If not otherwise specially required in their specifications, the duty of windlass motors and winch motors is to be rated for not less than 30 min.

2.6.4.3 Boat winch motors are to be provided with limit switches for cutting off the power supply upon returning of the boat to its original position.

2.6.4.4 The control device of boat winch motors is to be interlocked with the manual drive and manual brake.

2.6.5 Fire safety equipment

2.6.5.1 The electrical power supply to fire pump motors and fixed emergency fire pump motors is to comply with the relevant requirements of this PART.

2.6.5.2 The electrical power supply to automatic sprinkler systems and water-spraying systems is to comply with the relevant requirements of the International Code for Fire Safety Systems.

2.6.6 Stopping of ventilating fans and oil pumps

2.6.6.1 Power ventilation of accommodation spaces, service spaces, cargo spaces and control stations is to be capable of being stopped from an easily accessible position outside the space being served. This position is not to be readily cut off in the event of a fire in the space served.

The exhaust fans in the exhaust ducts from galley ranges are to be capable of being shut off within the galley.

2.6.6.2 Stopping of the ventilation fans and oil pumps in machinery spaces

(1) The means provided for stopping the power ventilation serving the machinery spaces are to be grouped so as to be operable from two positions outside the space served, one of which is to be easily accessible and close to such space, and is not to be readily cut off in the event of a fire in the space served.

The means provided for stopping the power ventilation of the machinery spaces are to be entirely separate from the means provided for stopping ventilation of other spaces.

(2) Means of control are to be provided for stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps, lubricating oil service pumps, thermal oil circulating pumps and oil separators (purifiers). Except oil separators, such means of control are to be situated outside each related space so that it will not to be cut off in the event of a fire in the space served.

2.6.6.3 Additional requirements for passenger ships

(1) In passenger ships, the controls required in 2.6.6.2 of this Section are to be situated at one control position or grouped in as few positions as possible. Such positions are to have safe access from the open deck.

(2) In passenger ships carrying more than 36 passengers, power ventilation, except machinery space and cargo space ventilation and unless otherwise specified in PART SIX of the Rules, is to be fitted with controls so grouped that all fans may be stopped from either of two separate positions which are to be situated as far apart as practicable.

Fans serving power ventilation systems to cargo spaces are to be capable of being stopped from a safe position outside such spaces.

2.6.7 Integrated cargo and ballast systems on tankers

2.6.7.1 The following requirements are applicable to integrated cargo and ballast systems on tankers.

2.6.7.2 An integrated cargo and ballast system means any integrated hydraulic and/or electric system used to simultaneously drive both cargo and ballast pumps (including active control and safety systems and excluding passive components, e.g. piping).

2.6.7.3 The operation of the cargo and/or ballast systems may be necessary, in certain emergencies or during navigation, to enhance the safety of the tanker, and measures are to be taken to prevent cargo and ballast pumps becoming inoperative simultaneously due to a single failure in the integrated cargo and ballast system (including its control and safety systems).

2.6.7.4 The following design features are, inter alia, to be fitted:

- (1) the emergency stop circuits of the cargo and ballast systems are to be independent from the circuits of the control systems. A single failure in the control system circuits or the emergency stop circuits is not to render the integrated cargo and ballast system inoperative;
- (2) manual emergency stops of the cargo pumps are to be arranged in a way that they will not cause the stop of the power pack, rendering ballast pumps inoperable;
- (3) the control systems are to be provided with backup power supply, which may be achieved by duplicated power supply from the main switch board. The failure of any power supply is to activate an audible and visual alarm at each location where the control panel is fitted;
- (4) in the event of failure of an automatic or remote control system, a secondary means of control is to be available for the operation of the integrated cargo and ballast system. This may be achieved by manual overriding and/or redundancy control arrangements within the control system.

2.6.8 Vehicle ramp control system for ferries

2.6.8.1 The vehicle ramp control station is to be so arranged that the movement of the ramp can be observed by the operator.

2.6.8.2 An audible and visual alarm is to be given for power failure of the control system. At the same time, the ramp is to be kept at its position automatically. When the power supply is recovered, operation of the control mechanism is not to be continued until it is reset.

2.6.8.3 The indicator of ramp conditions is to be provided in the control station.

2.6.8.4 Devices for preventing control and driving circuits from action are to be provided under the following conditions:

- (1) any of the covers is not taken off;
- (2) enclosures of vehicles are not closed.

2.6.8.5 Audible and visual indications are to be given continuously at a conspicuous position by the ramp when the ramp is running.

2.6.8.6 Where the ramp is fixed by a retractable locking device, means are to be provided to ensure that the power will not be interrupted when the locking device is clutched and that no launching of the ramp is possible before the locking device is disengaged.

2.6.8.7 Where a ramp, in addition to that for the stern door, is provided for access from the wharf, its angle to the horizontal is to be less than 10° before the stern door is opened or closed.

2.6.8.8 The maximum inclination of the access ramp in operation to the horizontal is not to be more than the predetermined angle. An audible and visual alarm is to be given if the inclination exceeds the allowable angle.

2.6.8.9 Where a remote locking device is fitted, alternative means is to be provided for locking the ramp in case of failure of the locking control or locking mechanism.

Section 7 LIGHTING AND NAVIGATION LIGHTS

2.7.1 General requirements

2.7.1.1 The lighting fittings fitted in cargo holds, exterior passageways, or other spaces where they are liable to mechanical damage, are to be provided with robust protective grids.

The lighting fittings located in such spaces where they are liable to considerable vibration are to be provided with means for damping the vibration.

Where lighting fittings are directly fixed on wooden panelling or other inflammable materials, precautions are to be taken against overheating and fire.

2.7.1.2 The switches of lighting fittings of baggage rooms, mail rooms, provisions rooms, refrigerated spaces and other similar spaces are not to be fitted inside such spaces.

Switches for the lighting used in wet spaces and in spaces where the risk of explosion might arise are to be capable of isolating all insulated poles.

The lighting fittings used in baggage rooms, mail rooms, provisions rooms and refrigerated spaces are to be provided with a pilot lamp at the switch.

2.7.1.3 The warning signs showing "DANGER! HIGH VOLTAGE!" are to be provided in the spaces adjacent to discharge lamps operating at a voltage over 250 V and elsewhere as necessary.

2.7.2 Supply and control

2.7.2.1 The lighting point supplied by each final sub-circuit of rating of more than 16 A at the lighting distribution board is not to exceed one. The number of lighting points supplied by each final sub-circuit of rating 16 A or less at the lighting distribution board is not to exceed:

10 for circuits of rating 55 V or less;

14 for circuits of rating 56 ~ 120 V circuits;

24 for circuits of rating 121 ~ 250 V circuits.

In final sub-circuits for cornice lighting, panel lighting and electrical signs where lampholders are closely grouped, the number of points supplied is unrestricted provided that maximum operating current in the sub-circuit does not exceed 10 A.

Final sub-circuits for lighting are not to supply heating and power appliances, except for small galley equipment (e.g. toasters, mixers, coffee makers), small motors (e.g. of desk and cabin fans, refrigerators), wardrobe heaters and similar items.

2.7.2.2 The lighting for main engine rooms, large machinery spaces other than main engine rooms, large galleys, passageways (including accesses), stairways leading to boat decks, public spaces and berthing compartments accommodating more than 16 passengers is to be supplied by at least two final sub-circuits, and one of which may be the final sub-circuit for emergency lighting so that in the event of failure of any one of the sub-circuits the other one could still maintain the necessary lighting for such spaces. The lighting points for main engine and boiler rooms are to be distributed alternately.

In machinery spaces, the oil fuel system containing heated oil under pressure exceeding 0.18 MPa are to be adequately illuminated so that defects and leakage will readily be observed. In machinery spaces of category A and whenever practicable in other machinery spaces, the arrangements for storage, distribution and utilization of oil used in pressure lubrication systems are also to be adequately illuminated.

2.7.2.3 Each main vertical fire zone is to be provided with at least two separate lighting feeders, one of which may be an emergency light feeder.

2.7.2.4 The permanently fixed lighting in cargo holds is to be controlled by switches located in a suitable position outside the cargo holds, capable of isolating all insulated poles and provided with a pilot lamp to indicate the power supply.

2.7.2.5 The degree of protection of lighting fittings located in various spaces in ships is to comply with the requirements of Table 1.3.2.2 of this PART. Lighting switches for spaces with special requirements are to be installed in accordance with the requirements of 2.7.1.2 of this Section.

2.7.2.6 Lighting circuits are to be provided with protection in accordance with the requirements of 2.5.11.1 of this Chapter.

2.7.2.7 A main electrical lighting system is to provide illumination throughout those parts of the ship normally accessible to and used by passengers or crew, and is to be supplied from the main source of electrical power.

2.7.3 Emergency lighting

2.7.3.1 The arrangement of emergency lighting and the supplementary emergency lighting for ro-ro passenger ships are to comply with the relevant requirements of Section 2 of this Chapter.

2.7.3.2 In passenger ships, the means of escape, including stairways and exits, are to be marked by lighting or photo-luminescent strip indicators complying with acceptable standards^① and placed not more than 0.3 m above the deck at all points of the escape route including angles and intersections. The marking must enable passengers to identify the routes of escape and readily identify the escape exits.

If electric illumination is used, it is to be supplied by the emergency source of power (see 2.2.2.1(1)③ of this Chapter).

2.7.3.3 All emergency lighting fittings are to be provided with a prominent mark or structurally different from other luminaries.

2.7.3.4 No local switch is to be installed in the transitional emergency lighting feeders.

2.7.3.5 No local switch is to be installed in the emergency lighting circuits in the spaces so specified in 2.2.2.1(1) and 2.2.3.1(2) of this Chapter except for the emergency lights in the navigation bridge, at the stowage positions of lifeboats and life rafts.

2.7.3.6 Respective power sources of main and emergency switchboards, associated transforming equipment (if any), the main or emergency switchboard and lighting switchboard (excluding section board and distribution board) are not to be provided in the same space so that the two systems would not fail simultaneously in the event of a fire or other casualty in any space containing these appliances.

① Refer to the Guidelines for the Evaluation, Testing and Application of Low-Location Lighting on Passenger Ships adopted by IMO resolution A.752(18).

2.7.3.7 In passenger ships, supplementary lighting shall be provided in all cabins to clearly indicate the exit so that occupants will be able to find their way to the door. Such lighting, which may be connected to an emergency source of power or have a self-contained source of electrical power in each cabin, shall automatically illuminate when power to the normal cabin lighting is lost and remain on for a minimum of 30 min.

2.7.4 Navigation lights

2.7.4.1 Each navigation light is to be supplied by a sub-circuit connected separately to the control box fitted at an easily accessible position on the navigation bridge and is to be controlled and protected in each insulated pole by a switch and a fuse or by a circuit breaker fitted in the control box.

2.7.4.2 The control box for navigation lights is to be supplied directly from the main switchboard and emergency switchboard. Where the transitional source of emergency power is provided according to Section 2 of this Chapter, the control box is to be supplied directly from the emergency switchboard and transitional emergency charging and discharging switchboard.

2.7.4.3 The change-over switch for the supply circuits required in 2.7.4.2 of this Section is to be installed on the control box or at a suitable position on the navigation bridge.

2.7.4.4 Each navigation light is to be provided with an automatic indicator giving an audible and visual indication of failure of the light. If a visual signal is used and connected in series with the navigation light, means are to be provided to prevent extinction of the navigation light due to failure of the signal, and the audible and visual alarms for failure of the power source of the control box are to be provided.

2.7.4.5 The power supply from the control box of navigation lights may be extended to the signal lights required in the International Regulations for Preventing Collisions at Sea, and other consumers are not to be connected to the box.

Section 8 INTERNAL COMMUNICATION SYSTEMS

2.8.1 Main engine telegraph system

2.8.1.1 At least two independent means are to be provided for communicating orders from the navigating bridge to the position in the machinery space or in the control room from which the speed and direction of thrust of the propeller (hereinafter referred to as the normal control position of the propeller) are normally controlled. One of the means is to be the main engine telegraph system complying with the requirements of 2.8.1.2 of this Section.

2.8.1.2 The main engine telegraph system is to be in compliance with the following requirements:

(1) The controls of the transmitters and receivers are to be safeguarded by suitable means against being inadvertently moved.

(2) The engine telegraph is to be a two-way system in which the signal given by the receiver is also immediately discernible at the transmitter.

(3) In the case of installations with several control positions the acknowledged command must be indicated at all control positions. Where a control position is selected by switching, an additional indication is to be provided to show which one is in use.

(4) Both the transmitter and the receiver are to be equipped with a call-up device which remains in operation from the start of the command transmission till it is correctly acknowledged. The audible signal is to be audible at any position in the engine room. If necessary, a visual signal is to be provided in addition to the audible signal.

(5) An audible alarm is to be provided for wrong direction of rotation of the main engine in the normal control position of the propeller.

(6) Power is to be supplied by the independent final sub-circuit and audible and visual alarms are to be provided on the navigation bridge for the purpose of indicating the failure of power supply.

2.8.1.3 The other means for communicating orders required in 2.8.1.1 may be an emergency engine telegraph system, the functions of which are to be in compliance with the requirements of 2.8.1.2(1) and (2), and which is to be supplied by the emergency power source.

2.8.1.4 A telephone system required in 2.8.2.2(4) may be fitted instead of the emergency engine telephone system.

2.8.2 Important telephone systems

2.8.2.1 The important telephone systems are to be such as to ensure clear vocal intercommunication in all conditions of the ship.

2.8.2.2 The telephone system is to be provided in the following spaces:

- (1) Bridge – Engine control room;
- (2) Bridge – Steering gear control position in steering gear compartment;
- (3) Bridge – Radio room, not required if communication can be made without telephone;
- (4) Bridge – Normal control position of the propeller, not required if an emergency main engine telegraph system is provided;
- (5) Bridge – Other control positions of the propeller, not required if a repeater of the main engine telegraph is provided in these positions;
- (6) Engine control room – Other control positions of the propeller, not required if a repeater of the main engine telegraph is provided in these positions.

2.8.2.3 The telephone systems required in 2.8.2.2 are to be individual links, although a common telephone system may be used if it is ensured that the bridge can cut into existing conversations at all times.

2.8.2.4 The common telephone system described in 2.8.2.3 is to be an independent one and is allowed to provide voice communications, in addition to the spaces described in 2.8.2.2, only for those that are relevant to ship safety, such as the fire control station, CO₂ room and emergency generator room, etc.

2.8.2.5 Two-way calling equipment is to be provided for the telephone systems fitted in the engine room (except engine control room) and designed as being audible at any position in the engine room under full-power operation of the main propelling plant, and visual signals are to be provided in addition to the audible signals.

2.8.2.6 The important telephone system is to remain operable in case of failure of the main power supply.

2.8.3 Communication in an emergency

2.8.3.1 An intercommunication system is to be provided which enables commands to be transmitted between strategic positions, i.e. the emergency control station, the muster and embarkation station of survival craft and navigation bridge etc.

2.8.3.2 The communication system may comprise portable or permanently installed equipment, and is to remain operable in case of failure of the main power supply.

2.8.4 Engineers' alarms

2.8.4.1 An engineers' alarm is to be provided to be operated from the engine room or engine control room and is to be clearly audible in the engineers' accommodation.

2.8.4.2 The audible alarm may be mounted centrally in the passageway of the engineers' accommodation, or individually in the cabins and the mess.

Where a decentralized arrangement is used, it is to be possible to transmit the alarm to the engineers both individually and collectively.

Section 9 SAFETY SYSTEMS FOR SHIPS AND PERSONS ONBOARD

2.9.1 General emergency alarms

2.9.1.1 In order to sound general emergency signals, a general emergency alarm system comprised of the ship's whistle or siren and additionally an electrically operated bell or klaxon or other equivalent apparatus, is to be provided on all passenger ships and cargo ships of 500 gross tonnage and above. In passenger ships, the alarm is to be capable of being given separately or simultaneously to crew and passengers.

2.9.1.2 The system is to be capable of operation from the navigation bridge and, except for the ship's whistle or siren, also from at least one other strategic points^①. The alarm is to continue to function after it has been triggered until it is manually turned off or is temporarily interrupted by a message from the public address system. For passenger ships there is also to be an additional activation point in the safety centre.

2.9.1.3 Where the general emergency alarm system is in operation, the acoustic system for entertainment is to be interrupted automatically.

2.9.1.4 The general alarm system is to be supplied from special feeders, being capable of automatically converting to the emergency source of electrical power in the event of failure of the main source of electrical power. In passenger ships, the system is also to be capable of being supplied by a temporary emergency source of electrical power.

2.9.1.5 The system is to be audible throughout all the accommodation and normal crew working spaces, including open decks in passenger ships.

① Other strategic points are taken to mean those locations, other than the navigation bridge, from where emergency situations are intended to be controlled and the general alarm system can be activated. A fire control station or a cargo control station should normally be regarded as strategic points.

The minimum sound pressure level for the emergency alarm tone in interior and exterior spaces is to be 80 dB(A) and at least 10 dB(A) above ambient noise levels existing during normal equipment operation with the ship underway in moderate weather. The sound pressure levels at the sleeping position in cabins and in cabin bathrooms are to be at least 75 dB(A) and at least 10 dB(A) above ambient noise levels.

2.9.1.6 Each electrically operated bell or klaxon or other equivalent warning system is to be separately protected against short circuit.

2.9.2 Public address system

2.9.2.1 Cargo ships of 500 gross tonnage and above are to be provided with a public address system in compliance with the following requirements:

- (1) capable of broadcasting messages from the navigation bridge and fire control station etc. to all spaces where crew are normally present and muster stations;
- (2) no operation required of receivers to accept the broadcast message;
- (3) protected against unauthorized use;
- (4) amplifiers have sufficient output power so that all loudspeakers for the purpose of emergency announcement can be operated at the same time;
- (5) arranged to prevent feedback or any other interference;
- (6) with the ship underway in normal conditions, the minimum sound pressure level for broadcasting emergency announcements is to be:
 - ① in interior spaces 75 dB(A) and at least 20 dB(A) above the speech interference level;
 - ② in exterior spaces 80 dB(A) and at least 15 dB(A) above the speech interference level;
- (7) capable of being supplied by both main and emergency power sources;
- (8) if the public address system is used to give the general alarm, the general emergency alarms as required by 2.9.1 of this Section may not be fitted, provided that the following requirements are fulfilled:
 - ① the performance requirements of 2.9.1 of this Section are to be complied with;
 - ② at least two amplifiers are to be provided, each of them separately supplied;
 - ③ the loudspeaker circuits are to be so arranged that an announcement at a reduced acoustic irradiation is maintained in the event of a failure of an amplifier or loudspeaker circuit;
 - ④ where loudspeakers with built-in volume controls are used, the volume controls are to be disabled by the release of the alarm signal;
 - ⑤ it is to be possible to transmit the clearly audible alarm signal at all times and other simultaneous signal transmissions are to be automatically interrupted;
 - ⑥ an independent short-circuit protection is to be provided for each loudspeaker.

2.9.2.2 All passenger ships are to be provided with a public address system in compliance with the following requirements:

- (1) capable of simultaneously broadcasting messages from bridge and central control station, etc. to all spaces where crew and passengers or both are normally present and muster stations, and capable of broadcasting messages to crew and passengers separately;
- (2) complying with the requirements of 2.9.2.1(2) to (6);
- (3) capable of interrupting at the control position on the navigation bridge any broadcast of the system from any other position onboard;
- (4) the spaces where control units of the system are located are the control stations as defined in Chapter II-2 of the SOLAS Convention, and each of the control stations is to be provided with the following emergency function controls:
 - ① clearly indicating any emergency function;
 - ② automatically overriding any other input system or programme;
 - ③ automatically overriding all volume controls and on/off controls so that the required volume for the emergency mode is achieved in all spaces;
- (5) at least two independent and separate amplifiers are to be provided, each of them separately supplied;
- (6) at least two loudspeaker circuits connected to their respective amplifiers are to be installed in each fire zone, and their cables are to be laid as widely apart as practicable for their entire length;
- (7) independent short-circuit protection is to be provided for each loudspeaker;
- (8) capable of being supplied by main, emergency and temporary emergency sources of electrical power;
- (9) if the public address system is used to give the general emergency alarm, the requirements of 2.9.1 of this Section are also to be complied with.

2.9.3 Pre-discharge alarms of fire extinguishing medium

2.9.3.1 In any ro-ro spaces, container holds equipped with integral reefer containers, spaces accessible by doors or hatches (except general cargo holds), and other spaces in which personnel normally work or to

which they have access, which are protected by fixed gas fire-extinguishing systems, means are to be provided for automatically activating audible and visual alarms for the release of fire-extinguishing medium. The alarms are to operate for the time required to evacuate the space, but in no case less than 20 s before the medium is released.

2.9.3.2 Machinery spaces, cargo pump-rooms, vehicle spaces, ro-ro spaces and special category spaces which are protected by fixed high-expansion foam fire-extinguishing systems are to be provided with audible and visual alarms for the release of fire-extinguishing medium in order to give warning of the release of the system. The alarms are to operate for the time required to evacuate the space, but in no case less than 20 s before the medium is released.

2.9.3.3 The above-mentioned alarm system is to be supplied by the emergency source of electrical power.

2.9.4 Elevator alarms

2.9.4.1 Elevators having an internal control are to be fitted with an emergency audible call-up device capable of being operated in the car and the alarm signal is to be transmitted to the positions where persons are normally present.

2.9.4.2 The emergency audible call-up device is to be independent from the power and control circuits of the elevator and supplied by the emergency source of electrical power.

2.9.5 Alarms for closing refrigerated spaces

2.9.5.1 Where the doors to refrigerated spaces such as refrigerated holds and refrigerating food chambers cannot be opened from the inside, an alarm capable of being activated within the spaces upon inadvertent closing of such doors is to be fitted and the alarm transmitted to normally manned positions.

2.9.6 Fire detection and fire alarm systems

2.9.6.1 The fire detection and fire alarm systems are to comply with the relevant requirements of Chapter II-2 of the SOLAS Convention in force and Chapter 9 of the International Code for Fire Safety Systems.

2.9.6.2 There are to be not less than two sources of power supply for the fixed fire detection and fire alarm system, one of which is to be an emergency source. The supply is to be provided by separate feeders reserved solely for that purpose. Such feeders are to run to an automatic change-over switch situated in or adjacent to the control panel for the fire detection system. The main (respective emergency) feeder shall run from the main (respective emergency) switchboard to the change-over switch without passing through any other distributing switchboard.

2.9.6.3 Operation of the automatic changeover switch or a failure of one of the power supplies is not to result in permanent or temporary degradation of the fixed fire detection and fire alarm system.

2.9.6.4 Where the fixed fire detection and fire alarm system would be degraded by the momentary loss of power, a source of stored energy having adequate capacity is to be provided to ensure the continuous operation during changeover between power supplies.

2.9.6.5 Connection of electrical power supplies to an automatic changeover switch is to be arranged such that a fault will not result in the loss of all supplies to the automatic changeover switch.

2.9.6.6 The fixed fire detection and fire alarm system emergency power may be supplied by an accumulator battery. Where the system is supplied from an accumulator battery, the arrangements are to comply with the following requirements:

(1) The accumulator battery is to have the capacity to operate the fire detection system under normal and alarm conditions during the period required by 2.2.2 or 2.2.3 of this Chapter for the emergency source of power supply.

(2) The rating of the charge unit, on restoration of the input power, is to be sufficient to recharge the batteries while maintaining the output supply to the fire detection system.

(3) The accumulator batteries are to be suitably located for use in an emergency.

(4) The feeders are to run from the accumulator battery or the accumulator battery charging and discharging board to the automatic changeover switch without passing through any other distributor.

2.9.7 Fire doors

2.9.7.1 The power, control, indication and alarm systems of fire doors as required in Chapter II-2 of the SOLAS Convention in force are to be supplied by the emergency source of electrical power.

2.9.7.2 For passenger ships, an indicator to show whether each door operated by remote control is opened or closed is to be provided in the normally manned control station.

2.9.7.3 For passenger ships, the control and indication systems for the fire doors are to be designed on the fail-safe principle, provided with a release system having manual reset capable of being operated from either side of the door.

2.9.8 Watertight doors in passenger ships

2.9.8.1 The power circuit and its associated control, indication and alarm circuits for power-operated sliding watertight doors are to be supplied either directly by the emergency switchboard or by a dedicated distribution board connected with the emergency switchboard above the bulkhead deck.

2.9.8.2 Where a motor is provided for the opening and closing of the watertight doors, unless an independent reserve energy is provided, the power source is to be capable of being automatically changed over to the transitional source of emergency electrical power in the event of failure of either the main or the emergency source of electrical power. The capacity of the motor is to be sufficient to operate the watertight door at least three times, i.e. closed – open – closed.

2.9.8.3 A single electrical failure in the operating or control system of a power-operated sliding watertight door is not result in a closed door opening or interrupt any manual operation of the watertight door.

2.9.8.4 Availability of the power supply is to be continuously monitored at a point in the electrical circuit as near as practicable to the door operating equipment. Loss of any such power supply is to activate an audible and visual alarm at the central operating console on the navigation bridge.

2.9.8.5 Electrical power, control, indication and alarm circuits are to be protected against fault in such a way that a failure in one door circuit will not cause a failure in any other door circuit. Short circuits or other faults in the alarm or indicator circuits of a watertight door are not result in a loss of power operation of that door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck will not cause the door to open.

2.9.8.6 The enclosures of electrical components necessarily situated below the bulkhead deck are to provide suitable protection against the ingress of water as follows:

(1) electric motors, associated circuits and control components: IPX7;

(2) door position indicators and associated circuit components: IPX8.

Where the water pressure testing is to be based on the pressure that may occur at the location of the component during flooding for a period of 36 h;

(3) door movement warning signals: IPX6.

2.9.8.7 Electrical controls of watertight doors, including their cables, are to be kept as close as practicable to the bulkhead in which the doors are fitted and so arranged as to minimize the likelihood of them being involved in any damage which the ship may sustain.

2.9.8.8 An audible alarm, distinct from any other alarm in the area, is to sound whenever the door is closed remotely by power and sound for at least 5 s but not more than 10 s before the door begins to move and is to continue sounding until the door is completely closed. In passenger areas and areas where ambient noise level exceeds 85 dB(A), the audible alarm is to be supplemented by an intermittent visual signal.

2.9.8.9 The central operating console is to be fitted on the navigation bridge, having a “master mode” switch with the following two modes of control:

(1) “Local control” mode for normal use, which is to allow any door to be locally opened and locally closed after use without automatic closure; and

(2) “Door closed” mode for emergency use, which is to automatically close any door that is opened while still permitting any door to be opened locally but with automatic reclosure upon release of the local control mechanism.

2.9.8.10 The central operating console at the navigation bridge is to be provided with a diagram showing the location of each door. Visual indicators showing whether the doors are open or closed are to be provided both on the central operating console and at hand operation positions above the bulkhead deck for watertight doors. A red light is to indicate a door is fully open and a green light is to indicate a door is fully closed. When the door is closed remotely, a red light is to indicate the intermediate position by flashing. The indicating circuit is to be independent of the control circuit for each door.

2.9.8.11 It is not to be possible to remotely open any watertight door from the central operating console.

2.9.9 Watertight access doors and hatch covers, etc. in cargo ships

2.9.9.1 For sliding watertight doors provided to ensure the watertight integrity of internal openings which are used while at sea, their operation, control and indicators are to comply with the following requirements:

(1) capable of being closed remotely at the navigation bridge and operated at either side of the bulkhead;

(2) an indicator to show whether the door is open or closed is to be provided in the control position;

(3) audible and visual alarms are to be given as the door is closed;

(4) each power-operated door is to be provided with an individual hand-operated mechanism, and it is to be possible to open and close the door by hand from each side.

2.9.9.2 Access doors and hatch covers normally closed at sea to ensure the watertight integrity of internal openings are to be provided with means of indication showing locally and on the navigation bridge whether these doors or hatch covers are open or closed.

2.9.9.3 All external openings leading to compartments assumed intact in the damage analysis, which are below the final damage waterline, except for cargo hatch covers, are to be fitted with indicators on the navigation bridge to show whether the openings are open or closed.

2.9.9.4 The electrical power, control, indication and audible and visual alarms required in 2.9.9.1 are to remain operable in the event of the failure of the main source of electrical power.

2.9.10 Boundary doors of special category spaces and ro-ro spaces

2.9.10.1 The requirements below are applicable to boundary doors of special category spaces or ro-ro spaces as defined in Chapter 9, PART TWO of the Rules. These spaces may be flooded through the doors. In cargo ships, where no part of a side shell door or stern door is under the highest waterline and the open area of the door is not greater than 6 m², the requirements from 2.9.10.2 to 2.9.10.5 of this Section are not applicable.

2.9.10.2 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to show that the doors are closed and that their securing and locking devices are properly positioned.

The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator lights.

2.9.10.3 The indicator system is to be designed^① on the fail-safe principle and is to show by a visual alarm if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be provided with a back-up power supply from the emergency source of electrical power or other secure power supply (e.g. UPS).

The sensors of the indicator system are to be protected from water, icing and mechanical damage.

2.9.10.4 The indication panel on the navigation bridge is to be equipped with a mode selection function "harbor/sea voyage", so arranged that an audible alarm is given on the navigation bridge if the vessel leaves harbor with the bow door or inner door not closed or with any of the securing devices not in the correct position.

2.9.10.5 For side shell doors or stern doors, a water leakage detection system^② with audible alarm and television surveillance is to be arranged on passenger ships to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors. A water leakage detection system^② with audible alarm is to be arranged on cargo ships to provide an indication to the navigation bridge.

2.9.10.6 For inner doors, a water leakage detection system^② with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the doors.

2.9.10.7 Between the bow door and the inner door a television surveillance system^② is to be fitted with a monitor on the navigation bridge and in the engine control room. The system is to monitor the position of the doors and a sufficient number of their securing devices. Special consideration is to be given for the lighting and contrasting colour of objects under surveillance.

2.9.10.8 A drainage system^② is to be arranged in the area between the bow door and ramp, or where no ramp is fitted, between the bow door and inner door. The system^② is to be equipped with an audible alarm on the navigation bridge being set off when the water levels in these areas exceed 0.5 m or the high water level alarm threshold, whichever is lesser.

① The indicator system is considered designed on the fail-safe principal when the following are provided:

- a. The indication panel is provided with:
 - a power failure alarm;
 - an earth failure alarm;
 - a lamp test;
 - separate indication for door closed, door locked, door not closed and door not locked.
- b. Limit switch electrically closed when the door is closed (when more limit switches are provided, they may be connected in series).
- c. Limit switch electrically closed when securing arrangements are in place (when more limit switches are provided, they may be connected in series).
- d. Two electrical circuits (also in one multicore cable), one for the indication of door closed/not closed and the other for door locked/not locked.
- e. In the case of dislocation of limit switches, indication to show : not closed/not locked/securing arrangement not in place, as appropriate.

② The system is to be designed on the fail-safe principle, see footnote of 2.9.10.3 of this Section.

2.9.10.9 For ro-ro passenger ships, the special category spaces and ro-ro spaces are to be continuously patrolled or monitored by effective means (e.g. television surveillance) so that any movement of vehicles in adverse weather conditions, or unauthorized access by passengers thereto, will be detected whilst the ship is underway.

2.9.11 Emergency dumping system of dredgers and barges

2.9.11.1 For dredgers and hopper barges of which the operation draft is marked according to Section 13, Chapter 1 of PART TWO of the Rules, emergency devices, controlled from the navigating bridge, are to be fitted so that the discharge of spoil is possible in case of failure of the main electric power supply or the main hydraulic unit and/or a single failure of the normal control systems.

Section 10 HEATING AND COOKING EQUIPMENT

2.10.1 General requirements

2.10.1.1 All electric space heaters are to be installed permanently.

2.10.1.2 Heating appliances are not to be installed in positions where combustible gases and dusts are likely to accumulate.

2.10.1.3 Heating appliances are to be so mounted that there will be no risk of excessive heating of adjacent decks, bulkheads or other surroundings.

2.10.2 Control and installation of heating and cooking equipment

2.10.2.1 Each item of heating or cooking equipment is to be controlled as a complete unit by a multi-pole linked switch mounted in the vicinity of the equipment. In the case of cabin heaters, a single-pole switch will be acceptable.

2.10.3 Supply of heating equipment

2.10.3.1 Each heater is to be connected to a separate final sub-circuit for heating except that up to ten small heaters of total connected current rating not exceeding 16 A may be connected to a single final sub-circuit for heating.

Section 11 STORAGE BATTERIES

2.11.1 Arrangement and installation

2.11.1.1 Storage batteries are not to be installed in spaces where they are exposed to excessively high or low temperatures, water splattering, steam or other factors which will impair their serviceability or shorten their service life. They are to be installed in such a way that persons will not be endangered and equipment will not be damaged by escaping gases or electrolytic leakage.

2.11.1.2 Storage batteries are to be so installed as to ensure accessibility for replacing cells, inspection, testing, topping-up and cleaning.

2.11.1.3 Storage batteries are not to be installed in the accommodation area. An exception may be granted for gastight cells, where charging does not result in the development of harmful gases.

2.11.1.4 Suitable protection measures are to be provided where the storage batteries are exposed to the risk of mechanical damage or falling objects.

2.11.1.5 Storage batteries connected to a charging device with a power output^① of more than 2 kW are to be housed in a room assigned to the batteries only, or in a box or a locker on open deck.

2.11.1.6 Storage batteries connected to a charging device with a power output of 0.2 kW to 2 kW are to be installed in accordance with 2.11.1.5. They also may be installed in a box or a locker within a suitable space, or may be installed in an open position in a well ventilated machinery space.

2.11.1.7 Storage batteries connected to a charging device with a power output of less than 0.2 kW may be installed in an open position or in a battery box in any suitable space.

2.11.1.8 A gap of more than 20 mm is to be provided around each battery, and non-hygroscopic and electrolyte-resistant insulating material is to be used for the separation, dunnage and fixing of the battery. Measures are to be taken to prevent any leaking electrolyte from entering in contact with the ship's structure.

① Power output of the charging device is to be calculated from the maximum charging current multiplied by the rated voltage of batteries.

2.11.1.9 Any surface of dedicated battery rooms, boxes, lockers and associated ventilation ducts, etc., liable to corrosion, by the electrolyte or by the gas escaped from the electrolyte, are to be protected against corrosion.

2.11.1.10 Prime mover starter batteries are to be installed as close as practicable to the primer mover served.

2.11.1.11 Storage batteries used as emergency and temporary emergency source of electrical power are to be installed in accordance with the requirements of 2.2.1.2 of this PART.

2.11.1.12 A warning notice of "NO SMOKING OR NAKED LIGHTS" is to be displayed adjacent to doors of battery rooms and covers of battery boxes or lockers.

2.11.2 Ventilation

2.11.2.1 Battery rooms, boxes and lockers are to be ventilated to prevent the accumulation of flammable gases.

2.11.2.2 Natural ventilation may be employed if the required number of air changes is small and the duct can be run directly from the top of the battery room, box or locker to the open air above, with no part of the duct more than 45° from the vertical.

2.11.2.3 For natural ventilation of the battery room, the cross-sectional area A of the inlet is to be equal to that of the outlet, not less than:

(1) for vented type batteries

$$A = \frac{50 \times U_n \times Q \times n}{1000} \quad \text{cm}^2$$

(2) for valve-regulated sealed batteries

$$A = \frac{20 \times U_n \times Q \times n}{1000} \quad \text{cm}^2$$

where: U_n — nominal voltage of the battery, in V;

Q — battery capacity, in Ah;

n — number of cells in series.

2.11.2.4 Mechanical ventilation is to be provided for the battery room, box or locker containing vented type batteries with a total charging power higher than 2 kW.

2.11.2.5 Except those boxes and lockers on open deck or within the spaces required in 2.11.1.6 and 2.11.1.7 of this Section, the ventilation system for battery rooms, boxes or lockers is to be separate from other ventilating systems. The exhaust ducting is to be led to a location where any flammable gas can be safely diluted, away from any source of ignition, and the inlet ducting is to be led into spaces where flammable gases may accumulate. The outlet is to be situated at the top and the inlet at the bottom with the means to prevent the ingress of water and flame.

2.11.2.6 Mechanical ventilators for battery rooms, boxes or lockers are to be provided with means to prevent sparking in case of the impeller touching the casing. Non-metal impellers are to be of an antistatic material.

2.11.2.7 All openings of battery rooms, other than ventilation openings, are to be effectively sealed to prevent the explosive gas from entering adjacent compartments.

2.11.2.8 The quantity Q of air expelled from the rooms, boxes or lockers containing vented type batteries is not to be less than:

$$Q = 0.11 I n \quad \text{m}^3/\text{h}$$

where: I — the maximum charging current during the development of gas, but not less than 25% of the maximum charging current output by the charging device, in A;

n — number of battery cells.

2.11.2.9 The quantity of air expelled from the rooms, boxes or lockers containing valve-regulated sealed batteries may be reduced to 25% of that required in 2.11.2.8.

2.11.3 Charging facilities

2.11.3.1 Charging facilities are to be provided for all storage batteries such that the completely discharged battery can be recharged to the rated capacity in not more than 10 h, having regard to the service requirements.

2.11.3.2 Suitable means are to be provided for controlling and monitoring charging of storage batteries, and to protect them in accordance with the requirements of 2.5.12.2 of this PART.

2.11.3.3 For floating circuits or any other conditions where the load is connected to the storage battery whilst it is on charge, the maximum battery voltage is not to exceed the safe value for any connected apparatus.

2.11.4 Electrical equipment

2.11.4.1 The installation of electrical equipment is to be avoided in battery rooms. Where this is necessary, the explosion-proof electrical equipment required in 1.3.3.3 of this PART is to be selected.

2.11.5 Recording of the type, location and maintenance cycle of batteries

2.11.5.1 A schedule of batteries used for essential and emergency services is to be compiled and maintained. The schedule, which is to be reviewed by the CCS attending Surveyor, is to include at least the following information regarding the batteries:

- type and manufacturer's type designation;
- voltage and ampere-hour rating;
- location;
- equipment and/or system(s) served;
- maintenance/replacement cycle dates;
- date(s) of last maintenance and/or replacement;
- for replacement batteries in storage, the date of manufacture and shelf life.

2.11.5.2 Procedures are to be put in place to ensure that, where batteries are replaced, they are of an equivalent performance type.

2.11.5.3 Where valve-regulated sealed batteries are replaced by vented type batteries, it is to be ensured that there is adequate ventilation as so required in 2.11.2.4 and 2.11.2.8 of this Section, and that the requirements in 2.11.1 of this Section relevant to the location and installation of vented type batteries are complied with.

2.11.5.4 Details of the schedule reviewed by the Surveyor and of the procedures, as mentioned above, are to be included in the ship's safety management system.

Section 12 CABLES**2.12.1 General requirements**

2.12.1.1 Cables are to be selected according to the environmental conditions of the space where the cables will be installed, methods of installation, rated current, duty, diversity factor, permissible voltage drop, etc.

2.12.1.2 The rated voltage of any cable is not to be lower than the nominal voltage of the circuit for which it is used.

2.12.1.3 Portable electrical equipment is to be provided with movable flexible cables.

2.12.1.4 Cables used in the non-earthing system are to be provided with suitable rating so as to sustain the additional stress of the cable insulation in the event of failure.

2.12.2 Choice of insulating material and voltage rating

2.12.2.1 The rated maximum operating temperature of the insulating material is to be at least 10°C higher than the maximum ambient temperature liable to be produced in the space where the cable is installed.

2.12.2.2 The insulating material of cables is generally to be selected in accordance with Table 2.12.2.2. The selection of other insulating materials is to comply with IEC publication 60092.

Maximum Rated Conductor Temperature of Insulating Material**Table 2.12.2.2**

Insulating material		Abbrev.	Max. rated conductor temp. (°C)	
			Normal operation	Short circuit
Thermoplastic compounds ^①	Polyvinyl chloride	PVC	70	150
	Copolymer of vinyl chloride and vinyl acetate			
Elastomeric or thermoset compounds	Ethylene propylene rubber	EPR	90	250
	High modulus or hard grade ethylene propylene rubber	HEPR	90	250
	Cross-linked polyethylene	XLPE	90	250
	Silicone rubber ^③	S95	95	350 ^③
	Halogen-free ethylene propylene rubber	HF EPR	90	250
	High modulus or hard grade halogen-free ethylene propylene rubber	HF HEPR	90	250
	Halogen-free cross-linked polyethylene	HF XLPE	90	250
	Halogen-free silicone rubber	HF S95	95	350 ^③
	Cross-linked polyolefin material for halogen-free cables	HF90	90	250
Other materials	Mineral ^③	—	95	—

Notes: ① Not applicable to power cables.

② Applicable only to power cables and not appropriate for tinned copper conductors.

③ Silicone rubber and mineral insulation may be used for higher temperatures (up to 150°C for silicone rubber, unlimited for mineral insulation) where they are not liable to be touched by crew, subject to agreement of CCS.

2.12.2.3 The rated voltage of a cable is expressed in U_0/U , where U_0 is the voltage between conductor and “earth” (metallic screen or surrounding medium of cables) and U is the voltage between any two conductors. In AC insulation systems, or in AC systems with high-resistance earthed neutral without automatic disconnection of circuits having insulation faults, the rated voltage of the cables is not to be lower than that given in Table 2.12.2.3.

Choice of Cables for AC Systems

Table 2.12.2.3

Rated (between phases) voltage (kV) of Systems	Rated voltage U_0/U (kV) of cables
≤ 0.25	0.15/0.25
≤ 1.0	0.6/1.0
≤ 3.0	3.6/6.0
≤ 6.0	6.0/10.0
≤ 10.0	8.7/15.0

2.12.3 Choice of protective covering

2.12.3.1 Cables permanently fitted on decks exposed to the weather, in bathrooms, cargo holds, refrigerated spaces, machinery spaces or in any other location where water condensation or harmful vapour (e.g. oil vapour) may be present are to have a metallic impervious sheath (of copper or lead alloy) or a nonmetallic impervious sheath (of polyvinyl chloride, polychloroprene, chlorosulphonated-polyethylene, etc.). The nature of the impervious sheath is to satisfy the requirements for environmental conditions.

2.12.3.2 In permanently wet spaces, metallic sheaths are to be used for cables with hygroscopic insulation.

2.12.3.3 All cables and wiring external to electrical equipment are to be at least of a flame-retardant type. In general, cables which have passed the test of bunched flame-retardant cables in accordance with acceptable standards^① are to be used. Where cables which have individually passed the test of a single flame-retardant cable in accordance with acceptable standards^② are to be bunched, means are to be provided to limit the propagation of fire along the bunched cables (see 2.12.10).

2.12.3.4 Where cables for services, required to be operable under fire conditions, including their supply cables, pass through high fire risk areas^③, and in addition for passenger ships, main vertical fire zones, other than those which they serve, they are to be so arranged that a fire in any of these areas or zones does not affect the operation of the service in any other area or zone. This may be achieved by either of the following:

(1) Cables being of a fire resistant type^④ complying with the requirements of 3.5.1.1 of this PART are installed and run continuously to keep the fire integrity within the high fire risk area, as shown in Figure 2.12.3.4.

(2) At least two-loops/radial distributions run as widely apart as is practicable and so arranged that in the event of damage by fire at least one of the loops/radial distributions remains operational.

① Refer to IEC Publication 60332-3-22: Tests on electric and optical fibre cables under fire conditions – Part 3-22: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category A, or the equivalent standards.

② Refer to IEC Publication 60332-1-2: Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame and IEC 60332-2-2: Tests on electric and optical fibre cables under fire conditions – Part 2-2: Test for vertical flame propagation for a single small insulated wire or cable – Procedure for diffusion flame, or the equivalent standards.

③ The “high fire risk areas” are defined as follows:

- (1) machinery spaces as defined in Reg. II-2/3.30 of SOLAS, excluding spaces having little or no fire risk as defined in Reg. II-2/9.2.2.3.2.2 (10) of SOLAS;
- (2) spaces containing fuel treatment equipment or other highly flammable substances;
- (3) galley and pantries containing cooking appliances;
- (4) laundry containing drying equipment;
- (5) spaces as defined in Reg. II-2/9.2.2.3.2.2(8), (12), and (14) of SOLAS for ships carrying more than 36 passengers.

④ Fire resistant type cables are to be easily distinguishable.

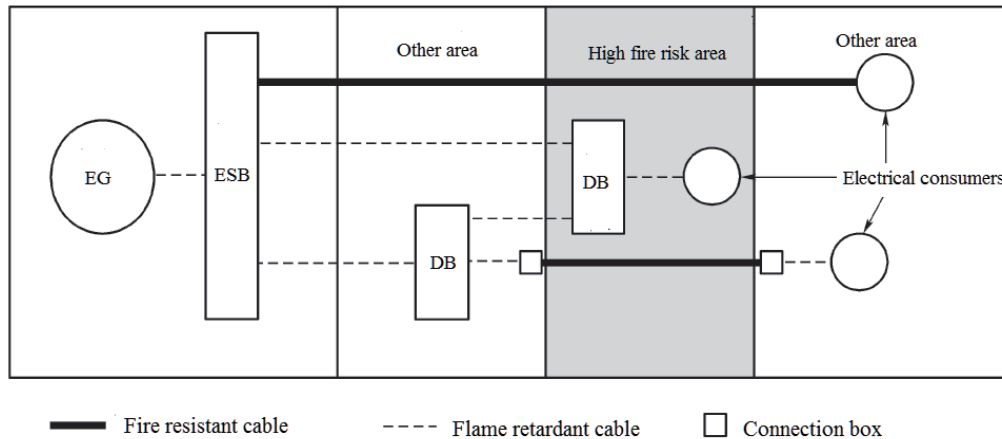


Figure 2.12.3.4 Cables for Services under Fire Conditions

2.12.3.5 Services required to be operable under fire conditions include:

- (1) general emergency alarm system;
- (2) fire detection and fire alarm system;
- (3) fire extinguishing system and fire extinguishing medium release alarm;
- (4) public address system;
- (5) control and power systems of power operated fire doors and status indication systems for all fire doors;
- (6) control and power systems of power operated watertight doors and their status indication systems;
- (7) emergency lighting;
- (8) low location lighting;
- (9) remote emergency stop/shutdown arrangements for systems which may support the propagation of fire and/or explosion;
- (10) emergency fire pump.

2.12.3.6 The electrical cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source(s) of power and/or prime mover(s). When cables pass through high fire risk areas, the cables are to be of a fire resistant type.

2.12.3.7 Where necessary for particular applications, CCS may permit the use of special types of cables which do not comply with the requirements of 2.13.3.3 of this Section, such as radio frequency cables or digital computer information transmission system cables.

2.12.3.8 In choosing different types of protective coverings, due consideration is to be given to the mechanical actions to which each cable may be subjected during installation and in service. If the mechanical strength of the protective covering is considered insufficient, the cable is to be fitted in pipes or conduits or trunking or otherwise protected.

2.12.3.9 In passenger spaces and in service areas only halogen-free cables are to be used.

2.12.4 Determination of the cross-sectional area of conductors

2.12.4.1 The maximum continuous load carried by a cable is not to exceed its current rating corrected by correction factors. The diversity factor of the individual loads and the duration of the maximum load may be taken into account in estimating the maximum continuous load.

2.12.4.2 The voltage drop from the main switchboard or emergency switchboard bus-bars to any point in the installation, when the cable is carrying the maximum current under normal conditions of service, is not to exceed 6% of the nominal voltage. Where the supply is from batteries with a voltage not exceeding 50 V, this voltage drop may be increased to 10%.

For circuits of navigation lights it is necessary to limit voltage drops to lower values in order to maintain required lighting and colour.

2.12.4.3 In assessing the current rating of lighting circuits, every lampholder is to be assessed at the maximum load likely to be connected to it, with a minimum of 60 W, unless the fitting is so connected as to take only a lamp rated at less than 60 W.

Two lampholders are to be counted for each lighting socket.

2.12.4.4 Cables supplying cargo winches, revolving cranes, windlasses and capstans are to be suitably rated for their duty.

2.12.4.5 The cross-sectional area of the conductors of equalizer leads for DC generators is not to be less than 50% of that of the main circuit cables. The cross-sectional area of neutral conductors in three-phase four-wire distribution systems is to be equal to at least 50% of that of phase conductors. If the cross-sectional area of phase conductors is 16 mm² or less, the cross-sectional area of the neutral conductors is to be the same.

2.12.5 Continuous service current rating

2.12.5.1 The maximum continuous load carried by a cable is not to exceed the values as given in Table 2.12.5.1.

The current ratings given in the Table are based on maximum operating temperatures of insulating material given in Table 2.12.2.2. Where a more precise evaluation of current rating has been carried out based on empirical or calculated data, details may be submitted to CCS for approval.

**Current Ratings for Cables during Continuous Working Time
(Based on Ambient Temperature of 45°C) (A)**

Table 2.12.5.1

Insulation	Thermoplastic compounds			Thermoset compounds			Silicone rubber and mineral insulation		
Maximum rated conductor temp.	70°C			90°C			95°C		
mm ²	Single core	2 cores	3 or 4 cores	Single core	2 cores	3 or 4 cores	Single core	2 cores	3 or 4 cores
1	12	10	8	16	14	11	20	17	14
1.5	15	13	11	23	20	16	26	22	18
2.5	21	18	15	40	26	21	32	27	22
4	29	25	20	51	34	28	43	37	30
6	37	31	26	52	44	36	55	47	39
10	51	43	36	72	61	50	76	65	53
16	68	58	48	96	82	67	102	87	71
25	90	77	63	127	108	89	135	115	95
35	111	94	78	157	133	110	166	141	116
50	138	117	97	196	167	137	208	177	146
70	171	145	120	242	206	169	256	218	179
95	207	176	145	293	249	205	310	264	217
120	239	203	167	339	288	237	359	305	251
150	275	234	193	389	331	272	412	350	288
185	313	266	219	444	377	311	470	400	329
240	369	314	258	522	444	365	553	470	387
300	424	360	297	601	511	421	636	541	445

2.12.5.2 The continuous service of cables required in this Section is the service that the continuous service period of current with constant loading are three times longer than the time constant of cables, i.e. more than the critical duration (see Figure 2.12.5.2).

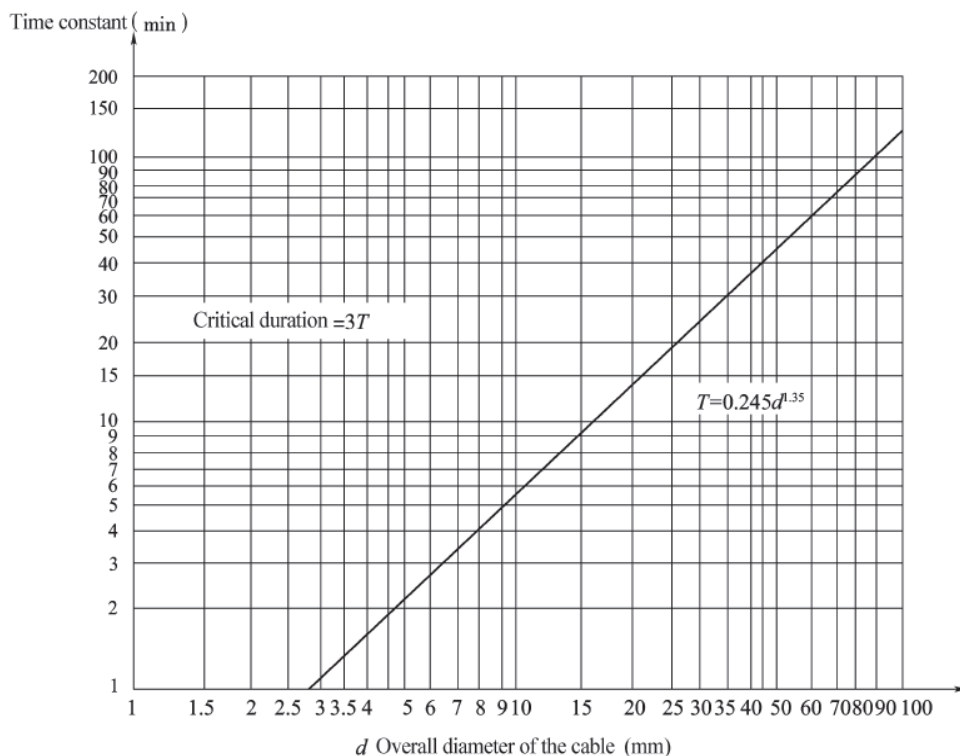


Figure 2.12.5.2 Time Constant of Cables

2.12.6 Correction factors for current rating**2.12.6.1 Correction factors for different ambient temperatures.**

When it is known that the ambient temperature is different from 45°C, correction factors given in Table 2.12.6.1 are to be applied.

Correction Factor for Ambient Temperature**Table 2.12.6.1**

Ambient temp. (°C) Max. operating conductor temp. (°C)	35	40	45	50	55	60	65	70	75	80	85
60	1.29	1.15	1.00	0.82	—	—	—	—	—	—	—
65	1.22	1.12	1.00	0.87	0.71	—	—	—	—	—	—
70	1.18	1.10	1.00	0.89	0.77	0.63	—	—	—	—	—
75	1.15	1.08	1.00	0.91	0.82	0.71	0.58	—	—	—	—
80	1.13	1.07	1.00	0.93	0.85	0.76	0.65	0.53	—	—	—
85	1.12	1.06	1.00	0.94	0.87	0.79	0.71	0.61	0.50	—	—
90	1.10	1.05	1.00	0.94	0.88	0.82	0.74	0.67	0.58	0.47	—
95	1.10	1.05	1.00	0.95	0.89	0.84	0.77	0.71	0.63	0.55	0.45

2.12.6.2 Correction factors for bunched cables

(1) For cables laid in one of the following manners and so arranged as to ensure free circulation of cooling air around each bunch, the current ratings in Table 2.12.5.1 may be directly applied:

- ① not more than six cables bunched together on cable trays, in cable conduits, pipes or trunking;
- ② more than six cables arranged in the following manners:

distance between any two sextuplets is at least equal to the diameter of the thickest cable

○○○○○○ ○○○○○○ ○○○○○○

or distance between any two triplets both horizontally and vertically is at least equal to the diameter of the thickest cable

○○○ ○○○ ○○○
○○○ ○○○ ○○○

(2) Where more than six cables, which may be expected to operate simultaneously at their rated capacity, are laid close together in a cable bunch^① in such a way that there is an absence of free air circulation

① Cables are said to be bunched when two or more are contained within a single conduit, trunking or duct, or if not enclosed, are not separated from each other.

around them, a correction factor of 0.85 is to be applied. When a correction factor of 0.85 is used, care is to be taken that there are in general not more than two layers in each cable bunch.

2.12.6.3 Correction factors for non-continuous service

(1) For half-hour and one-hour services, the corresponding correction factors given by Figure 2.12.6.3(1) may be applied. These correction factors are applicable only if the periods of no load are longer than the critical duration given in Figure 2.12.5.2.

(2) For repetitive short-time services, the corresponding correction factors given in Figure 2.12.6.3(2) may be applied.

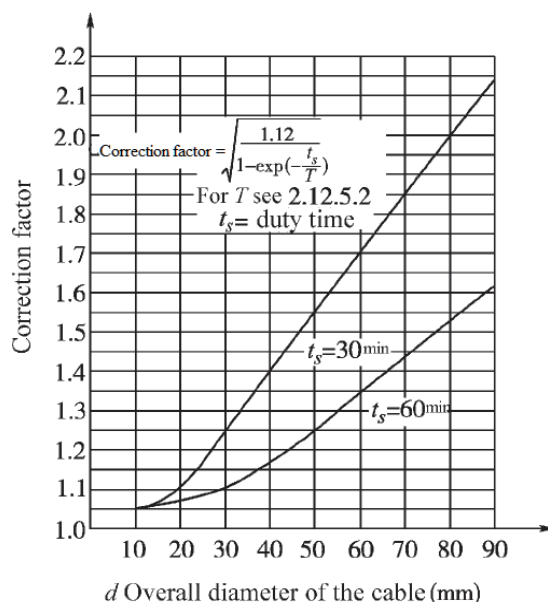
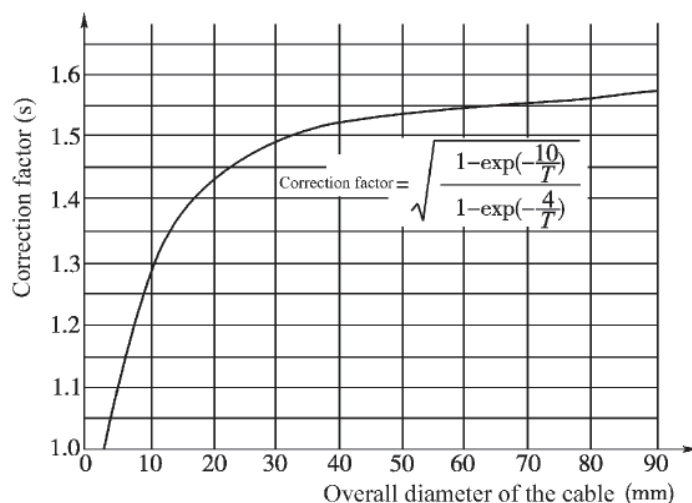


Figure 2.12.6.3(1) Correction Factors for Half-Hour and One-Hour Services



Note: The correction factors given in the Figure are roughly calculated for periods of 10 min, with a constant load for 4 min and without load for 6 min.

Figure 2.12.6.3(2) Correction Factors for Repetitive Short-Time Services

2.12.7 Parallel connection of cables

2.12.7.1 Parallel connection of cables will be permitted only for cables having a cross section of 10 mm² or more. The current rating of cables connected in parallel is the sum of the current ratings of all parallel conductors provided the cables have equal impedance, cross section and rated maximum operating conductor temperature.

2.12.8 Short-circuit capacity

2.12.8.1 Cables and their insulated conductors are to be capable of withstanding the mechanical and thermal effects of the maximum short-circuit.

2.12.9 Cable runs

2.12.9.1 Cable runs are to be, as far as possible, straight and accessible for inspection.

2.12.9.2 Cable runs are to be so arranged as to avoid the harmful effects from moisture or condensed water.

2.12.9.3 Cable runs are to be, as far as possible, away from the sources of heat such as boilers, hot pipes, resistors, etc., and are to be protected against mechanical damage.

2.12.9.4 Cables are not to be installed across expansion joints in any structure. Where this is unavoidable, a loop of cable having a length sufficient to accommodate the expansion of the joint is to be provided. The internal radius of the loop is to be at least 12 times the external diameter of the cable.

2.12.9.5 Cables having insulating materials with different maximum rated conductor temperatures are not to be bunched together. Where this is unavoidable, the cables are to be so installed that no cable reaches a temperature higher than that permitted for the cable with the lowest temperature rating in the bunch.

2.12.9.6 Cables having a protective covering or sheathing which may damage the covering or sheathing of other cables are not to be bunched together.

2.12.9.7 Where a duplicate supply is required for essential electrical equipment, such as the two cables for the supply of the control box of navigation lights, the two cables are to follow different routes which are to be as far apart as practicable, both vertically and horizontally.

2.12.9.8 In the case of duplicated essential equipment, or systems which could operate as each other's stand-by for an essential function (such as duplicated power equipment of steering gears), the supply and any associated control cables are to follow different routes which are to be as far apart as practicable, both vertically and horizontally.

2.12.9.9 In passenger ships, distribution systems are to be so arranged that fire in any main vertical zone as defined in PART SIX of the Rules will not interfere with supply to services essential for safety in any other such zone. The requirement is considered satisfied if main and emergency feeders passing through any such zone are separated both vertically and horizontally as widely as is practicable.

2.12.9.10 Cables serving essential equipment or emergency power equipment, emergency lighting and internal communications or signals used in an emergency are to be as far as practicable routed clear of galleys, laundries, machinery spaces and their casings and other high fire risk areas, except for supplying equipment in these spaces.

Where possible, these cables are to be run in such a manner as to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

2.12.9.11 Main cable runs and cables for the supply and control of essential services are to be kept away from the machinery and machinery parts^① having an increased fire risk unless:

(1) the cables serve such installations;

(2) the cables are separated by a steel bulkhead or deck from such installations;

(3) the cables are of a fire-resisting type.

2.12.9.12 Where trunk cables are laid in concealed manner, the panelling in way of which is to be arranged for easy removal.

2.12.9.13 Cables are not to be directly embedded in the thermal or sound insulation made of combustible material. Where cables are separated by non-combustible covering, they may be laid in the insulation, but the load carried is to be reduced accordingly.

2.12.9.14 The arrangement and run of fire resistant cables are to be in compliance with the following:

(1) Cables are to be so arranged that the loss of these services due to a localized fire at any one area or zone specified in 2.12.3.4 of this Section is minimized.

(2) Cables are to be run as straight as is practicable.

2.12.9.15 Each intrinsically safe circuit is to have its own separate cable. Such cables are to be laid apart from those for non-intrinsically safe circuits, e.g. neither bundled together or placed in the same casing or pipe, nor fixed by common clamps. The outer sheath of the cable is to be coloured blue or alternatively black with clearly visible blue stripes.

2.12.10 Means to limit the propagation of fire along bunched cables

2.12.10.1 Where cables which have individually passed the test of a single flame-retardant cable in accordance with acceptable standards (see 2.12.3.3) are to be bunched, means are to be provided to limit the propagation of fire along the bunched cables^②, as required in 2.12.10.2 to 2.12.10.4.

① Machinery, machinery parts or equipment containing combustibles are considered to have an increased fire risk.

② The bunched cables mentioned here are 5 or more cables from machinery spaces and high fire hazard spaces and more than 10 cables from other spaces are laid close together in the cable trunking.

2.12.10.2 Fire dampers are to be provided (see Figure 2.12.10.2).

(1) Cables laid vertically in enclosed or semi-enclosed spaces are to be provided with fire dampers in the following locations:

- ① at every second deck or approximately 6 m, except cables installed within the fully-closed trunking;
- ② at cable entrances of main switchboard and emergency switchboard;
- ③ at cable entrances of engine control room;
- ④ at cable entrances of centralized control panels for propulsion machinery and essential auxiliary machinery;
- ⑤ at each end of the fully-closed cable duct.

(2) Cables laid horizontally in closed or semi-enclosed spaces are to be provided with fire dampers in the same locations required in (1), but the maximum spacing of fire dampers may be increased to 14 m.

(3) In the passageways having a height lower than the neck of a standing person within cargo holds and cargo areas, fire dampers can only be fitted on the boundaries of compartments.

2.12.10.3 The fire dampers are to be designed to meet the following requirements:

(1) The fire resistance of cables passing through fire stops must meet the requirements for class B-0 divisions.

(2) Fire dampers are to be made of steel plate with the thickness of at least 3 mm.

(3) Where cables are laid vertically in the non-fully-closed trunking, the fire damper is to cover the sectional area of the trunking.

(4) Where cables are laid open, the fire damper is to extend around to twice the maximum laying size of cables, but not to penetrate ceilings, decks, bulkheads or the rigid sidewall of trunking.

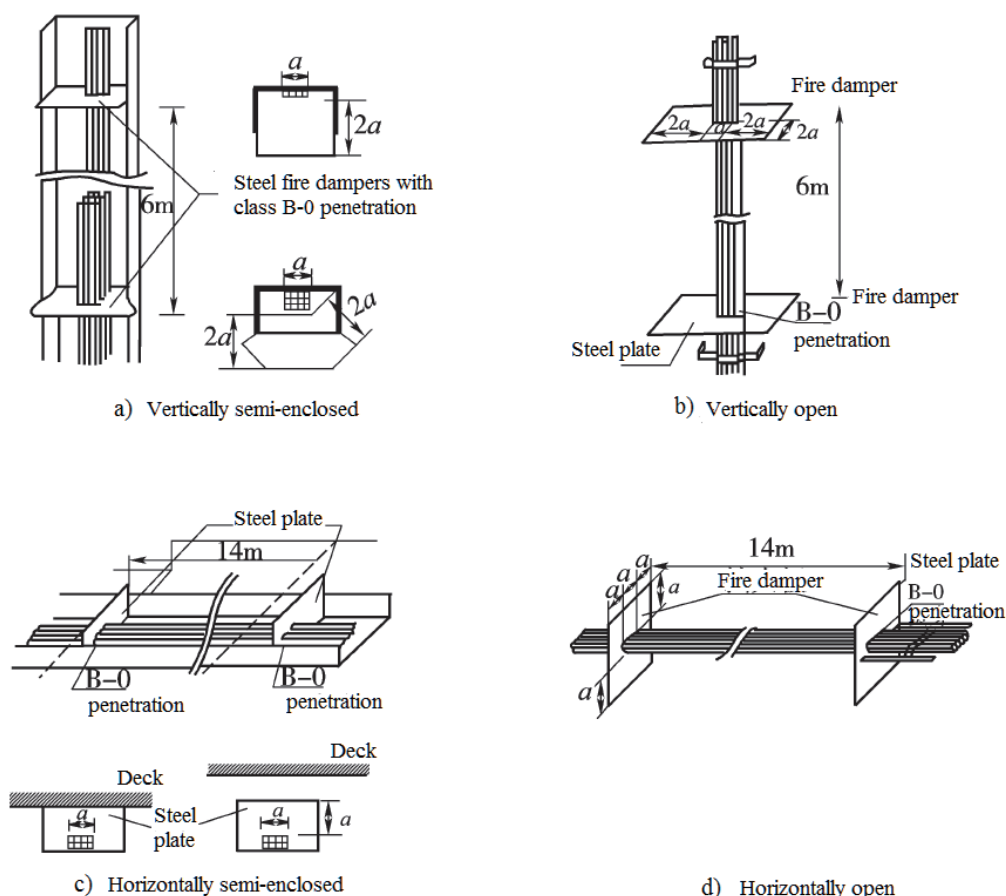


Figure 2.12.10.2 Locations of Fire Dampers

2.12.10.4 Instead of the fire dampers required above, installed cable bunches may be provided with flameproof coating:

- (1) over a length of 1 m in every 14 m for horizontal cable runs (see Figure 2.12.10.4a);
- (2) over the entire length of vertical cable runs (see Figure 2.12.10.4b).

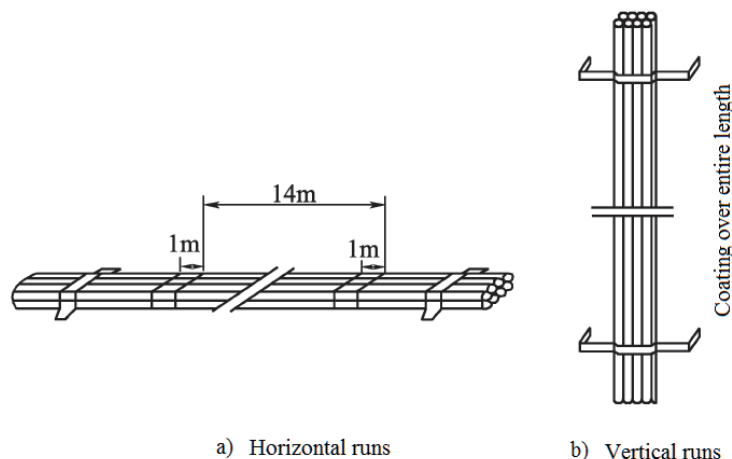


Figure 2.12.10.4 Location of Flameproof Coating

2.12.11 Mechanical protection of cables

2.12.11.1 Cables exposed to risk of mechanical damage are to be protected by metal channels or casings or enclosed in steel conduits, unless the protective sheathing of cables is sufficient to withstand the possible damage.

2.12.11.2 Cables in cargo holds and other spaces where there is exceptional risk of mechanical damage are to be suitably protected, even if armoured.

2.12.11.3 Metal casings for mechanical protection of cables are to be efficiently protected against corrosion.

2.12.11.4 Where cables are placed underneath the floor plates in machinery spaces, reliable precautions are to be taken to prevent such cables from being soaked in oil or water, or being exposed to mechanical damage.

2.12.12 Radius of bend

2.12.12.1 The minimum internal radius of bend of installed cables is to be generally in accordance with Table 2.12.12.1.

Minimum Internal Radius of Bends in Cables for Fixed Wiring **Table 2.12.12.1**

Cable construction		Overall diameter of cable D (mm)	Minimum internal radius of bend F
Insulation	Outer covering		
Thermoplastic or thermoset material (circular copper conductor)	Not armoured or not braided	≤ 25	$4D$
		> 25	$6D$
	Metal sheathed, braided or armoured	Any	$6D$
	Metal thread armoured, metal strip armoured or metal sheathed	Any	$6D$
	Synthetic polyester/metal sheathed slice or combined sheathed	Any	$8D$
Thermoplastic or thermoset material (circular copper conductor)	Any	Any	$8D$
Mineral	Hard metal sheathed	Any	$6D$

2.12.13 Securing of cables

2.12.13.1 Cables are to be effectively supported and secured with the exception of cables for portable appliances and of those installed in pipes, conduits, trunking or special casings.

2.12.13.2 Clips or straps are to be robust and are to have a sufficient surface area and a certain shape so that the cables may remain tight without their covering or sheathing being damaged.

2.12.13.3 Clips, supports and accessories are to be made of corrosion-resistant material or suitably corrosion inhibited before erection.

2.12.13.4 The distance between supports is to be suitably chosen according to the type of cables and the possible vibration, and is generally to be in accordance with Table 2.12.13.4.

External Diameter of Cable and Distance between Supports**Table 2.12.13.4**

External diameter of cable (mm)		Distance between supports (mm)	
Exceeding	Not exceeding	Non-armoured cables	Armoured cables
—	8	200	250
8	13	250	300
13	20	300	350
20	30	350	400
30	—	400	450

2.12.13.5 When cables are fixed by means of non-metallic clips or straps, and are not laid on top of horizontal cable trays or supports, suitable metal cable clips or straps are to be added at regular distances not greater than 1 m in order that in the event of a fire, cables are prevented from falling and causing an injury to personnel or an obstruction to any escape route.

2.12.14 Penetration of bulkheads and decks by cables

2.12.14.1 Penetration of watertight bulkheads or decks may be carried out with either individual watertight glands or with packed watertight boxes carrying several cables, provided that the watertight integrity of the bulkheads or decks is to be maintained.

2.12.14.2 Where cables pass through non-watertight bulkheads or structural steel, the holes are to be bushed with lead or other approved material.

If the steel is 6 mm or more in thickness, adequately rounded edges may be accepted as the equivalent of bushing.

2.12.14.3 Penetration of bulkheads and decks requiring a certain fire integrity is to be so effected as to ensure that the required fire integrity is not impaired.

2.12.14.4 Cables passing through decks are to be protected by deck tubes or ducts having a suitable height.

2.12.14.5 Materials used for glands and bushings are to be such that there is no risk of corrosion to cables or hull structures.

2.12.14.6 Where rectangular holes are cut in bulkheads or structural steel, the corners of the holes are to be radiused.

2.12.15 Installation of cables in pipes, conduits or trunking

2.12.15.1 When cables are installed in metal pipes, conduits or trunking, the following requirements are to be complied with:

- (1) The internal surfaces of the pipes, conduits or trunking are to be smooth and protected against corrosion.
- (2) Provision is to be made at the ends of pipes, conduits or trunking so as to protect the sheathing or covering of cables from being damaged.
- (3) The internal sectional area and radius of bend of pipes or conduits are to be such as to permit easy drawing in and out the cables contained therein; the internal radius of bend of pipes or conduits is not to be less than that allowed for cables, provided that for pipes equal to or above 63 mm in external diameter, the internal radius of bend is not less than twice the external diameter of the pipe.
- (4) The drawing-in factor (ratio of the sum of the cross-sectional areas of the cables to the internal cross-sectional area of the pipe) is not to exceed 0.4.
- (5) Pipes, conduits or trunking are to be effectively earthed and are to be mechanically and electrically continuous across joints.
- (6) Pipes, conduits or trunking are to be so arranged that water will not accumulate inside them (consideration being given to possible condensation).
- (7) If necessary, ventilation openings are to be provided, preferably at the highest and lowest points, so as to permit air circulation and to prevent possible accumulation of water at any part of the pipes, conduits or trunking. This may be done only if the fire risk will not be increased thereby.
- (8) Expansion joints are to be provided where necessary for long pipe run.
- (9) Lead-sheathed cables without any outer covering are not to be laid in pipes, conduits or trunking.

2.12.15.2 Where cables are laid in trunks, the trunks are to be so constructed as not to afford passage for fire from one 'tween deck or compartment to another.

2.12.15.3 Cables used for cold cathode luminous discharge lamps are not to be installed in metal conduits unless protected by metal sheathing or screen.

2.12.16 Installation of cables in refrigerated spaces

2.12.16.1 Cables not serving refrigerated spaces are not to pass through such spaces. Cables installed in refrigerated spaces are to have a watertight or impervious sheath and are to be protected against mechanical damage. If an armoured cable is used, the armour is to be protected against corrosion by a further moisture-resisting covering.

2.12.16.2 Cables are to be run in the open in refrigerated spaces.

2.12.16.3 Where it is necessary for the cables to pass through the thermal insulation of refrigerated spaces, they are to do so at right angles in metal tubes sealed watertight at both ends.

2.12.16.4 Metal supports used for securing the cables are to be galvanized or otherwise protected against corrosion.

2.12.16.5 Precautions are to be taken to prevent the placing of hooks along the cables as a casual means of suspension.

2.12.16.6 PVC insulated or covered cables are generally not to be used in refrigerated spaces unless the PVC compounds are appropriate to low temperature service.

2.12.17 Relief of tension

2.12.17.1 Cables are to be so installed that the tension stress applied to them either by their own weight or for any other reason is minimized. This is particularly important for cables of small cross-sections and for cables laid vertically or in vertical pipes.

2.12.18 Electrodynamic forces

2.12.18.1 In order to guard against the effects of electrodynamic forces in the event of short-circuit, single-core cables are to be firmly fixed and the strength of supports is to be sufficient to withstand the electrodynamic forces corresponding to the prospective short-circuit currents.

2.12.19 Installation of single-core cables for alternating current

2.12.19.1 For AC power systems, two-core or multi-core cables are to be used as far as practicable. Where it is necessary to use single-core cables for circuits rated in excess of 20 A, the following requirements are to be complied with:

- (1) Cables are to be either non-armoured or armoured and covered with non-magnetic material.
- (2) Cables belonging to the same circuit are to be contained in the same pipe, conduit or trunking. Cable clips are to include cables of all phases of a circuit, unless the clips are of non-magnetic material.
- (3) In the installation of two, three or four single-core cables forming respectively single-phase, three-phase, or three-phase four-wire circuits, the cables are to be as far as possible in contact with one another. In any event, the distance between adjacent cables is not to be greater than one cable diameter.
- (4) When it is necessary to install single-core cables of current rating greater than 250 A near a steel bulkhead, the clearance between the cables and the bulkhead is to be at least 50 mm, unless the single-core cables belonging to different phases are installed in trefoil formation.
- (5) Magnetic material is not to be placed between single-core cables of a group for the same circuit. Where cables pass through steel plates, all conductors of the same circuit are to pass through a plate or gland so constructed that there is no magnetic material between the cables, and the clearance between the cables and the magnetic material is not to be less than 75 mm, unless single-core cables belonging to different phases are installed in trefoil formation.
- (6) In order to equalize to some degree the impedance of three-phase circuits of considerable length consisting of single-core cables having a cross sectional area of 185 mm^2 or over, the phases are to be transposed at regular intervals of not exceeding 15 m. Alternatively, the three single-core cables of different phases may be installed in a trefoil formation. The above precautions are, however, not necessary when the length of the run is less than 30 m.
- (7) In circuits with several single-core cables in parallel for each phase, all cables are to follow the same route and have the same cross-sectional area.

In addition, cables belonging to the same phase are, as far as practicable, to be alternated with those of other phases so that an unequal division of current is avoided. For instance, in the case of six cables for each phase, the correct dispositions are as shown in Table 2.12.19.1.

Disposition of Cables

Table 2.12.19.1

Cables in parallel for each phase	1-layer disposition	2-layer disposition
2	ABC CBA	ABC CBA
3		ABCA BCABC
4		ABCABC

Cables in parallel for each phase	1-layer disposition	2-layer disposition
		CBACBA
5		ABCABCA BCABCABC
6		ABCABCABC CBACBACBA

(8) The metal sheaths or coverings of single-core cables are to be earthed at one point only.

2.12.20 Installation of cables with respect to prevention of electromagnetic interference

2.12.20.1 In order to minimize the effects of unwanted electromagnetic interference, cables are to be installed in accordance with the relevant standards^① accepted by CCS.

2.12.21 Earthing of metal sheathings or coverings of cables

2.12.21.1 The earthing of metal sheathings or coverings of cables is to be in accordance with the relevant requirements of Section 3, Chapter 1 of this PART.

2.12.22 Cable ends

2.12.22.1 The ends of all conductors of a cross-sectional area greater than 4 mm² are to be fitted with soldered sockets, compression type sockets or mechanical clamps. Corrosive fluxes are not to be used.

2.12.22.2 The temperature of cable sockets and terminals is, in general, not to exceed the maximum operating temperature of insulated cables.

2.12.22.3 Cables with a supplementary insulating tape beneath the protective sheath are to have additional insulation for each core having or possibly having contact with earthed metal where the insulating tape is stripped at cable ends.

2.12.22.4 The fixing of conductors in terminals at joints and at tappings is to be capable of withstanding the thermal and dynamic effects of short-circuit currents.

2.12.22.5 The ends of mineral insulated cables are to be prepared in accordance with the instructions by the manufacturer of cables.

2.12.22.6 Cables having hygroscopic insulation (e.g. mineral insulated) are to have their ends sealed against ingress of moisture.

2.12.23 Joints and tappings

2.12.23.1 Cable runs are normally not to include joints. If a joint is necessary in the case of repair or sectional construction of the ship, the joint is to be such that the electrical continuity, insulation, mechanical strength and protection, earthing and fire-resisting or flame-retardant characteristics are not inferior to those required for the cables.

2.12.23.2 Tappings are to be made in suitable boxes of such a design that the conductors remain suitably insulated, protected from atmospheric action and fitted with terminals or bus-bars of dimensions appropriate to the current rating.

2.12.23.3 Joints and tappings are to be clearly marked.

2.12.24 Connection boxes

2.12.24.1 Connection boxes are to be made of flame-retardant material. Mountings of live parts are to be robust, durable, flame-retardant and moisture-resistant, having permanently insulation resistance with high dielectric strength.

2.12.24.2 Live parts within the box are to be suitably spaced or provided with shielding by flame-retardant insulating material so that a short-circuit will not occur between conductors of different polarity or between conductors and earthed metal.

2.12.24.3 Each connection box is to be provided with a nameplate indicating its purpose or a durable no. mark corresponding to the wiring diagram. Where the connection boxes are installed in a concealed manner, the panelling in way of the boxes is to be arranged for easy removal.

2.12.25 Cable trays/protective casings made of plastic materials

2.12.25.1 Cable trays/protective casings^② made of plastic^③ materials are to be type tested in accordance with Appendix 2 of this PART – “Type Approval Procedure for Cable Trays/Protective Casings Made of Plastic Materials”.

① Refer to IEC Publication 60533: Electrical and Electronic Installations in Ships – Electromagnetic Compatibility, or the relevant requirements in relevant standards.

② “Protective casing” means a closed cover in the form of a pipe or other closed ducts of non-circular shape.

③ “Plastic” means both thermoplastic and thermosetting plastic materials with or without reinforcement, such as PVC and fibre reinforced plastics - FRP.

2.12.25.2 Cable trays/protective casings made of plastic materials are to be supplemented by metallic fixing and straps such that in the event of a fire they, and the cables affixed, are prevented from falling and causing an injury to personnel and/or an obstruction to any escape route. When plastic cable trays/protective casings are used on open deck, they are additionally to be protected against UV light.

2.12.25.3 The load on the cable trays/protective casings is to be within the Safe Working Load (SWL). The support spacing is not to be greater than the manufacturer's recommendation nor in excess of spacing at the SWL test. In general the spacing is not to exceed 2 m. The selection and spacing of cable tray/protective casing supports are to take the following into account:

- (1) cable trays/protective casings' dimensions;
- (2) mechanical and physical properties of their material;
- (3) mass of cable trays/protective casings;
- (4) loads due to weight of cables, external forces, thrust forces and vibrations;
- (5) maximum accelerations to which the system may be subjected;
- (6) combination of loads.

2.12.25.4 The sum of the cables' total cross-sectional area, based on the cables' external diameter, is not to exceed 40% of the protective casing's internal cross-sectional area. This does not apply to a single cable in a protective casing.

Section 13 LIGHTNING PROTECTION

2.13.1 Protection against primary structural damage

2.13.1.1 A protective system need not be fitted to a ship of metallic construction where a low resistance path to earth will be inherently provided by masts, structural members and the hull.

2.13.1.2 A protective system is to be fitted to any ship having a substantial number of non-metallic structural members.

2.13.1.3 The protective system is to be comprised of air terminal, down conductor and earth termination.

2.13.1.4 Metallic masts and metallic structural members may form part or all of any protective system.

2.13.1.5 The metal rigging, such as stays, shrouds, etc., are to be bonded to the protective system.

2.13.1.6 Joints in down conductors are to be accessible and be located or protected so as to minimize accidental damage. They are to be made by means of copper rivets or clamps. Clamps may be of copper or of copper alloy and are to preferably be of the serrated contact type and effectively locked. No connection is to be dependent on a soldered joint.

2.13.1.7 The resistance between air terminals and earth terminations is not to exceed 0.02Ω .

2.13.1.8 Suitable means are to be provided to enable ships when in dry dock, or on a slipway, to have their protective systems or metal hull connected to an efficient earth on shore. Connecting cables to the shore earth is to be external to the earth throughout their length.

2.13.1.9 Air terminals of the protective system are to comply with the following requirements:

- (1) An air terminal is to be fitted to each non-metallic mast.
- (2) Air terminals are to be made of copper or copper alloy conducting bar of not less than 12 mm diameter, and are to project at least 300 mm beyond the top of the mast. Other materials may be used, for example stainless steel or aluminium alloys, or steel bar effectively protected against corrosion, subject to the requirement of 2.13.1.7. The material is to be resistant to sea water.
- (3) Vent outlets for flammable gases located at or near the top of masts on tankships are to be protected by air terminals which extend at least 2 m above the vent outlet. A steel mast may serve as the air terminal if it extends 2 m above the outlet.

2.13.1.10 Down conductors of the protective system are to comply with the following requirements:

- (1) Down conductors are to be made of copper, or copper alloy tape or cable. Cable is preferred as both the insulation and the circuit shape inhibit surface discharge. Other materials may be used, for example stainless steel or aluminium alloys, subject to the requirement of 2.13.1.7. The material is to be resistant to sea water.
- (2) Down conductors of copper are to have a minimum cross-section of 70 mm^2 , be firmly secured to the structure and be run as straight as possible between the air terminal and the earth termination. Bends, where necessary, are to have a minimum radius of at least 10 times the equivalent diameter of the conductor.

2.13.1.11 The ends of down conductors are to be reliably bonded to the earth terminations of the metallic construction of the ship nearby. Where necessary, measures are to be taken for preventing electrochemical corrosion.

2.13.2 Protection against secondary damage

- 2.13.2.1 On all ships, equipment is to be so installed as to minimize the effect of secondary damage caused by lightning to the electrical system.
- 2.13.2.2 Metallic enclosures are to be reliably earthed. Particular attention is to be paid to navigation lights and other equipment at the top of masts and on other elevated structures.
- 2.13.2.3 Cable screens or armour, though normally earthed for signal interference suppression, are not to provide the sole lightning path to earth for equipment. Separate earthing, as required in 2.13.2.2, is to be provided.
- 2.13.2.4 The formation of cable loops, or metallic loops such as pipework, in proximity to down conductors of the protective system required in 2.13.1.2 is to be avoided. Cables in close proximity to down conductors are to be installed in metal pipes.
- 2.13.2.5 Cables along decks are to be installed close to the deck and advantage is to be taken of the screening effect of earthed metallic structures near to or above the cable runs, for examples handrails, pipes, etc.
- 2.13.2.6 Means are to be provided for the discharging to earth of any lightning energy that may be induced in for example radio and navigational equipment antennas. Consideration is to be given to installing devices such as spark gaps or surge diverters to provide protection from voltage transients.

Section 14 SPECIAL REQUIREMENTS FOR HIGH VOLTAGE ELECTRICAL INSTALLATIONS

2.14.1 General requirements

- 2.14.1.1 This Section applies to AC three-phase systems with nominal voltage (voltage between phases) exceeding 1 kV. If not otherwise stated herein, construction and installation applicable to low voltage equipment generally apply to high voltage equipment.
- 2.14.1.2 The nominal system voltage is not to exceed 15 kV. Where necessary for special application, higher voltages may be accepted by CCS.
- 2.14.1.3 Equipment with voltage above about 1 kV is not to be installed in the same enclosure as low voltage equipment, unless segregation or other suitable measures are taken to ensure that access to low voltage equipment is obtained without danger.

2.14.2 System design

- 2.14.2.1 The distribution of high-voltage electrical installations is to comply with the following:

(1) It is to be possible to split the main switchboard into at least two independent sections, by means of at least one circuit breaker or other suitable disconnecting devices, each supplied by at least one generator. If two separate switchboards are provided and interconnected with cables, a circuit breaker is to be provided at each end of the cable.

Services which are duplicated are to be divided between the sections.

(2) For earthed neutral systems in case of earth fault, the current is not to be greater than full load current of the largest generator on the switchboard or relevant switchboard section and not less than three times the minimum current required to operate any device against earth fault.

It is to be assured that at least one source neutral to ground connection is available whenever the system is in the energized mode. Electrical equipment in directly earthed neutral or other neutral earthed systems is to withstand the current due to a single phase fault against earth for the time necessary to trip the protection device.

(3) Means of disconnection are to be fitted in the neutral earthing connection of each generator so that the generator may be disconnected for maintenance and for insulation resistance measurement.

(4) All earthing impedances are to be connected to the hull. The connection to the hull is to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.

(5) In the systems with neutral earthed, connection of the neutral to the hull is to be provided for each separate section of the main switchboard.

2.14.2.2 The degrees of protection provided by enclosures for the high-voltage electrical equipment is to be appropriate to the location of installation, as a minimum in compliance with the requirements of Table 1.3.2.2 of this PART and in addition the following:

(1) The degree of protection by enclosures for rotating electrical machines is to be at least IP23. The degree of protection of terminals is to be at least IP44. For motors installed in spaces accessible to unqualified personnel, a degree of protection against approaching or contact with live or moving parts of at least IP4X is required.

(2) The degree of protection by enclosures for transformers is to be at least IP23. For transformers installed in spaces accessible to unqualified personnel, a degree of protection of at least IP4X is required.

For transformers not contained in enclosures, 2.14.7.1 of this Section is to be complied with.

(3) The degree of protection of metal enclosed switchgear, control gear assemblies and static convertors is to be at least IP32. For switchgear, control gear assemblies and static converters installed in spaces accessible to unqualified personnel, a degree of protection of at least IP4X is required.

2.14.2.3 The air clearances and creepage distances are to comply with the following:

(1) In general, for non-type-tested equipment phase-to-phase air clearances and phase-to-earth air clearances between non-insulated parts are not to be less than those specified in Table 2.14.2.3.

Where intermediate values of nominal voltages are accepted, the next higher air clearance is to be observed.

In the case of smaller clearances, appropriate voltage impulse test is to be applied.

Minimum Air Clearances

Table 2.14.2.3

Nominal voltage (kV)	Minimum air clearance (mm)
3 (3.3)	55
6 (6.6)	90
10 (11)	120
15	160

(2) Creepage distances between live parts and between live parts and earthed metal parts for standard components are to be in accordance with IEC publication 60092-503 for the nominal voltage of the system, the nature of the insulation material and the transient overvoltage developed by switch and fault conditions. For non-standardized parts within the bus-bar section of a switchgear assembly, the minimum creepage distance is to be at least 25 mm/kV and behind current limiting devices, 16 mm/kV.

2.14.2.4 For protection of the high-voltage electrical system, the following special requirements are to be complied with:

(1) Protective devices are to be provided against phase-to-phase faults in the cables connecting the generators to the main switchboard and against interwinding faults within the generators. The protective devices are to trip the generator circuit breaker and automatically de-excite the generator.

In distribution systems with a neutral earthed, phase to earth faults are also to be treated as above.

(2) Any earth fault in the system is to be indicated by means of a visual and audible alarm. In low impedance or direct earthed systems (a system is defined effectively earthed when the earthing factor^① is lower than 0.8), provision is to be made to automatically disconnect the faulty circuits. In high impedance earthed systems (a system is defined non-effectively earthed when the earthing factor is higher than 0.8), where outgoing feeders will not be isolated in case of an earth fault, the insulation of the equipment is to be designed for the phase to phase voltage.

(3) Power transformers are to be provided with overload and short circuit protection. When transformers are connected in parallel, tripping of the protective devices at the primary side has to automatically trip the switch connected at the secondary side.

(4) Voltage transformers are to be provided with overload and short circuit protection on the secondary side.

(5) Fuses are not to be used for overload protection.

(6) Lower voltage systems supplied through transformers from high voltage systems are to be protected against overvoltages. This may be achieved by:

- ① direct earthing of the lower voltage system;
- ② appropriate neutral voltage limiters;
- ③ earthed screen between the primary and secondary windings of transformers.

2.14.3 Rotating machinery

2.14.3.1 Generator stator windings are to have all phase ends brought out for the installation of the differential protection.

2.14.3.2 Rotating machinery is to be provided with temperature detectors in their stator windings to actuate a visual and audible alarm in a normally attended position whenever the temperature exceeds the permissible limit.

If embedded temperature detectors are used, means are to be provided to protect the circuit against overvoltage.

① Earthing factor is defined as the ratio between the phase to earth voltage of the health phase and the phase to phase voltage. This factor may vary between $1/\sqrt{3}$ and 1.

2.14.3.3 In addition to the tests normally required for rotating machinery, a high frequency high voltage test in accordance with acceptable standard(s)^① is to be carried out on the individual coils in order to demonstrate a satisfactory withstand level of the inter-turn insulation to steep fronted switching surges.

2.14.4 Power transformers

2.14.4.1 Dry type transformers are to comply with acceptable standard(s)^②, and liquid cooled transformers are also to comply with acceptable standard(s)^③.

2.14.4.2 Oil immersed transformers are to be provided with the following alarms and protections:

- (1) liquid level (Low) – alarm;
- (2) liquid temperature (High) – alarm;
- (3) liquid level (Low) – trip or load reduction;
- (4) liquid temperature (High) – trip or load reduction;
- (5) gas pressure relay (High) – trip.

2.14.5 Cables

2.14.5.1 Cables are to be constructed in accordance with acceptable standards^④.

2.14.6 Switchgear and control gear assemblies

2.14.6.1 Switchgear and control gear assemblies are to be constructed according to acceptable standards^⑤.

2.14.6.2 Switchgear and control gear assemblies are to be constructed in accordance with the following requirements:

(1) Switchgear is to be of metal-enclosed type or of the insulation-enclosed type in accordance with acceptable standard(s)^⑥.

(2) Withdrawable circuit breakers and switches are to be provided with mechanical locking facilities in both service and disconnected positions. For maintenance purposes, key locking of withdrawable circuit breakers and switches and fixed disconnectors is to be possible.

Withdrawable circuit breakers are to be located in the service position so that there is no relative motion between fixed and moving portions.

(3) The fixed contacts of withdrawable circuit breakers and switches are to be so arranged that in the withdrawable position the live contacts are automatically covered.

(4) For maintenance purposes an adequate number of earthing and short-circuiting devices is to be provided to enable circuits to be worked upon with safety.

2.14.6.3 Requirements for auxiliary systems

(1) If electrical energy and/or physical energy is required for the operation of circuit breakers and switches, a store supply of such energy is to be provided for at least two consecutive operations of all the components.

However, the tripping due to overload or short-circuit, and under-voltage is to be independent of any stored electrical energy sources. This does not preclude shunt tripping provided that alarms are activated upon lack of continuity in the release circuits and power supply failures.

(2) When external source of supply is necessary for auxiliary circuits, at least two external sources of supply are to be provided and so arranged that a failure or loss of one source will not cause the loss of more than one generator set and/or set of essential services. Where necessary, one source of supply is to be from the emergency source of electrical power for the start-up from dead ship condition.

2.14.6.4 A power-frequency voltage test is to be carried out on any switchgear and control gear assemblies. The test procedure and voltages are to be according to acceptable standard(s)^⑦.

① Refer to IEC Publication 60034-15 Rotating electrical machines – Part 15: Impulse voltage withstand levels of rotating AC machines with form-wound stator coils, or other equivalent standards.

② Refer to IEC Publication 60076-11 Dry-type power transformers, or other equivalent standards.

③ Refer to IEC Publication 60076 Power transformers, or other equivalent standards.

④ Refer to IEC Publication 60092-353 Electrical installations in ships – Part 353: Power cables for rated voltages 1 kV and 3 kV and IEC Publication 60092-354 Electrical installations in ships – Part 354: Single- and three-core power cables with extruded solid insulation for rated voltages 6 kV ($U_m = 7.2$ kV) up to 30 kV ($U_m = 36$ kV).

⑤ Refer to IEC Publication 62271-200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV, or other equivalent standards.

⑥ Refer to IEC Publication 62271-200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV, and compliance with IEC Publication 62271-201: AC insulation-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV.

⑦ Refer to IEC Publication 62271-200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV, or other equivalent standards.

2.14.7 Installation

2.14.7.1 Where equipment is not contained in an enclosure but a room forms the enclosure of the equipment, the access doors are to be so interlocked that they cannot be opened until the supply is isolated and the equipment earthed down.

At the entrance of the spaces where high-voltage electrical equipment is installed, a suitable marking is to be placed which indicates danger of high-voltage. As regards the high-voltage electrical equipment installed outside a.m. spaces, the similar marking is to be provided.

2.14.7.2 Run of high-voltage cables is to comply with the following:

(1) In accommodation spaces, high voltage cables are to be run in enclosed cable transit systems.
(2) High voltage cables are to be segregated from cables operating at different voltage ratings each other; in particular, they are not to be run in the same cable bunch, nor in the same duct or pipe, or, in the same box. Where high voltage cables of different voltage ratings are installed on the same cable tray, the air clearance between cables is not to be less than the minimum air clearance for the higher voltage side in 2.14.2.3(1) of this Section. However, high voltage cables are not to be installed on the same cable tray for the cables operating at the nominal system voltage of 1 kV and less.

(3) High-voltage cables, in general, are to be installed on carrier plating when they are provided with a continuous metallic sheath or armour which is effectively bonded to earth; otherwise they are to be installed for their entire length in metallic casings effectively bonded to earth.

(4) Terminations in all conductors of high voltage cables are to be, as far as practicable, effectively covered with suitable insulating material. In terminal boxes, if conductors are not insulated, phases are to be separated from earth and from each other by substantial barriers of suitable insulating materials. High voltage cables of the radial field type, i.e. having a conductive layer to control the electric field within the insulation, are to have terminations which provide electric stress control.

Terminations are to be of a type compatible with the insulation and jacket material of the cable and are to be provided with means to ground all metallic shielding components (i.e. tapes, wires etc.).

(5) High-voltage cables are to be readily identifiable by suitable marking.

(6) Before a new high voltage cable installation, or an addition to an existing installation, is put into service, a voltage withstand test is to be satisfactorily carried out on each completed cable and its accessories. The test is to be carried out after an insulation resistance test and in accordance with standard(s) acceptable to CCS^① or the following:

① When a DC voltage withstand test is carried out, the voltage is not to be less than:

1.6 (2.5 U_0 + 2 kV) for cables of rated voltage (U_0) up to and including 3.6 kV, or
4.2 U_0 for higher rated voltages

where U_0 is the rated power frequency voltage between conductor and earth or metallic screen, for which the cable is designed. The test voltage is to be maintained for a minimum of 15 min. After completion of the test the conductors are to be connected to earth for a sufficient period in order to remove any trapped electric charge. An insulation resistance test is then repeated.

② When an AC voltage withstand test is carried out, the voltage is not to be less than normal operating voltage of the cable and it is to be maintained for a minimum of 24 h.

Section 15

ADDITIONAL REQUIREMENTS FOR ELECTRICAL PROPULSION MACHINERY

Electrical propulsion machinery is to comply with the applicable requirements of this PART and the requirements of Chapter 15 of PART EIGHT of the Rules.

Section 16 ADDITIONAL REQUIREMENTS FOR OIL TANKERS

2.16.1 General requirements

2.16.1.1 Electrical installations on tankers carrying crude oil and oil products are to comply with the provisions of this Section and other provisions of this PART as appropriate.

2.16.1.2 The classification of typical hazardous areas of oil tankers is carried out in accordance with zone 0, zone 1 and zone 2 based on the provisions of IEC60092-502 in this Section. For areas or spaces not mentioned in this Section, the classification of hazardous areas may be carried out in accordance with the principles given in IEC60079-10-1.

① Refer to IEC Publication 60502 Power cables with extruded insulation and their accessories for rated voltages from 1 kV up to 30 kV, or other equivalent standards.

2.16.1.3 Electrical equipment and cables are, in principle, not to be installed in any hazardous areas. If it is impracticable to avoid doing so, the relevant provisions of this Section are to be complied with.

2.16.2 Distribution systems

2.16.2.1 The following distribution systems may be used:

- (1) DC, two-wire, insulated;
- (2) AC, single-phase, two-wire, insulated;
- (3) AC, three-phase, three-wire, insulated.

2.16.2.2 No direct electrical connection is allowed between power networks operating at different voltages.

2.16.2.3 All circuits of generation, supply and distribution systems are not to be earthed, and hull return system is not permitted with the following exceptions:

- (1) intrinsically safe circuits;
- (2) power supplied control circuits and instrumentation circuits where technical or safety reasons preclude the use of a system with no connection to earth, provided the current in the hull is limited to not more than 5 A in both normal and fault conditions;
- (3) limited and locally earthed systems, provided that any possible resulting current does not flow directly through any of the hazardous spaces;
- (4) AC distribution systems with 1,000 V (root mean square) and over between phases, provided that any possible resulting current does not flow directly through any of the hazardous spaces.

2.16.3 Cables and their installation

2.16.3.1 All cables, other than those of intrinsically safe circuits, installed in zone 0 and zone 1, are to be provided with at least one of the following:

- (1) a non-metallic impervious sheath in combination with braiding or other metallic covering;
- (2) copper or stainless steel sheath (for mineral insulated cables only). Aluminium sheathed cables may be considered for special applications.

2.16.3.2 Cables of intrinsically safe circuits are to have a metallic shielding with at least a non-metallic external impervious sheath.

2.16.3.3 Where cables are subject to lengthy immersion in the cargo, the construction of the cables is to be such as to withstand the substances to which they can be exposed, or the cables are to be enclosed in casings (such as metallic pipes) capable of withstanding such substances.

2.16.3.4 Where corrosion may be expected, a non-metallic impervious sheath is to be applied over the metal meshwork, metallic sheath or steel armour of the cable.

2.16.3.5 Where cables pass through gastight bulkheads or decks separating hazardous areas from non-hazardous areas, arrangements are to be such that the gastight integrity of the bulkhead or deck is not impaired.

2.16.3.6 Cables installed on deck or on fore and aft gangways are to be protected against mechanical damage. Cables are to be so installed as to avoid strain or chafing and due allowance is to be made for expansion or working of the structure. Where ring-type expansion bends are fitted, they are to be accessible for maintenance.

2.16.3.7 Cables installed in pump rooms are to be suitably protected against mechanical damage.

2.16.3.8 Flexible cables or wires for portable electrical appliances are not to pass through hazardous areas or spaces, with the exception of flexible cables or wires of intrinsically safe type.

2.16.4 Electrical equipment in hazardous areas

2.16.4.1 For electrical equipment installed in hazardous areas, the appropriate certified explosion-proof equipment is to be selected in accordance with the category of hazardous areas, and the explosion group and temperature class are not to be lower than II A T3.

2.16.4.2 The following equipment is allowed to be installed in zone 0:

- (1) certified intrinsically-safe apparatus of category "ia";
- (2) simple electrical apparatus and components (for example thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically safe circuits of category "ia", not capable of storing or generating electrical power or energy in excess of the limits given in IEC 60079-14;
- (3) submersible pumps, having at least two independent methods of shutting down automatically in the event of low liquid level.

2.16.4.3 The following equipment is allowed to be installed in zone 1:

- (1) electrical equipment specified in 2.16.4.2 of this Section;
- (2) certified intrinsically-safe apparatus of category "ib";

- (3) simple electrical apparatus and components (for example thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically safe circuits of category “ib”, not capable of storing or generating electrical power or energy in excess of the limits given in IEC 60079-14;
- (4) certified flameproof (type “d”);
- (5) certified pressurized (type “p”);
- (6) certified increased safety (type “e”);
- (7) certified encapsulated (type “m”);
- (8) certified sand filled (type “q”);
- (9) certified specially (type “s”)^①;
- (10) anodes or electrodes of an impressed current cathodic protection system, or transducers such as those for depth-sounding or log systems, provided that such fittings are housed within a gastight enclosure, and are not located adjacent to a cargo tank bulkhead;
- (11) through runs of cable.

2.16.4.4 The following equipment is allowed to be installed in zone 2:

- (1) electrical equipment specified in 2.16.4.3 of this Section;
- (2) non-sparking electrical equipment “n”;
- (3) the type which ensures the absence of sparks and arcs and of “hot spots” during its normal operation.

2.16.4.5 Transmitting aerials and any associated riggings are to be sited well clear of gas and vapour outlets.

2.16.4.6 For the electrical equipment permitted in hazardous areas or spaces, all switches and protective devices are to be capable of interrupting all poles or phases and are to be located in a non-hazardous area or space. Such equipment, switches and protective devices are to be clearly and durably labelled for identification purposes.

2.16.5 Earth connection and static electricity protection

2.16.5.1 The metal casings of all electrical equipment in any hazardous areas or spaces, regardless of the working voltage, are to be reliably earthed.

2.16.5.2 Cargo tanks, process plants and piping systems are to be earthed in accordance with 1.3.4.12 of this PART for the control of static electricity.

2.16.5.3 All rigging is to be effectively bonded to ship’s hull.

2.16.6 Classification of hazardous areas of oil tankers carrying cargo oils having a flash point (closed cup) not exceeding 60°C

2.16.6.1 Zone 0 is to include the following areas or spaces:

- (1) cargo tanks, slop tanks, any pipework of pressure-relief or other venting systems for cargo and slop tanks;
- (2) interior spaces containing the pipes and equipment containing cargo oil.

2.16.6.2 Zone 1 is to include the following areas or spaces:

- (1) cofferdams and ballast tanks adjoining cargo tanks;
- (2) cargo pump rooms and the mechanical ventilation is to comply with the following requirements:
 - ① audible and visual alarms are to be given at a manned location in case of failure of the mechanical ventilation in the cargo pump room;
 - ② actions are to be taken to restore ventilation immediately after failure of the mechanical ventilation;
 - ③ where the mechanical ventilation can not be restored for an extended period, the remaining electrical equipment other than those mentioned below is to be capable of being disconnected outside of hazardous areas and provided with means against unauthorized re-connections:
 - (a) intrinsically safe equipment;
 - (b) flameproof lighting;
 - (c) general emergency alarm sounder of flameproof type, without internal sparking contacts;
 - ④ where the mechanical ventilation has been stopped for an extended period or it is initially used, the cargo pump room is to be purged for at least five air changes before connecting the electrical equipment (except the intrinsically safe equipment, flameproof lighting and general emergency alarm sounder of flameproof type);
- (3) enclosed or semi-enclosed spaces immediately above cargo tanks (e.g. ’tween-deck spaces) or having bulkheads above and in line with cargo tank bulkheads;

① Where explosion-proof types (flameproof, increased safety, intrinsically-safe, pressurized, oil filled, sand filled, encapsulated and non-sparking) not included in the special standards are used for electrical equipment, they may be treated as electrical equipment certified specially (type “s”).

- (4) spaces other than cofferdams adjoining to and below the top of a cargo oil tank (e.g. trunks, passageways and general cargo holds), and double bottom and pipe tunnels below cargo tanks;
- (5) areas on open deck, or semi-enclosed spaces on open deck, within 3 m of any cargo tank outlet, gas or vapour outlet^①, cargo manifold valve, cargo valve, cargo pipe flange, cargo pump-room ventilation outlets and cargo tank pressure/vacuum relief valve provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;
- (6) areas on open deck, or semi-enclosed spaces on open deck above and in the vicinity of any cargo gas outlet intended for the passage of large volumes of gas or vapour mixture during cargo loading and ballasting or during discharging, within a vertical cylinder of unlimited height and 6 m radius centred upon the centre of the outlet, and within a hemisphere of 6 m radius below the outlet;
- (7) areas on open deck, or semi-enclosed spaces on open deck, within 1.5 m of cargo pump room entrances, cargo pump room ventilation inlet, openings into cofferdams or other zone 1 spaces;
- (8) areas on open deck over all cargo tanks (including all ballast tanks within the cargo tank area) where structures are restricting the natural ventilation and to the full breadth of the ship plus 3 m fore and aft of the forward-most and aft-most cargo tank bulkhead, up to a height of 2.4 m above the deck;
- (9) areas on open deck within spillage coamings surrounding cargo manifold valves and 3 m beyond these, up to a height of 2.4 m above the deck;
- (10) compartments for cargo hoses;
- (11) enclosed or semi-enclosed spaces in which pipes containing cargoes are located;
- (12) fore peak tank and vent pipe openings as defined in 3.4.14.1, Chapter 3, PART SIX of the Rules.

2.16.6.3 Zone 2 is to include the following areas or spaces:

- (1) areas of 1.5 m surrounding the open spaces or semi-enclosed spaces in zone 1 as specified in 2.16.6.2, if not otherwise specified in this standard;
- (2) spaces 4 m beyond the area defined in 2.16.6.2(6);
- (3) areas within 2 m beyond areas on open deck, or semi-enclosed spaces on open deck, within 3 m of any cargo tank outlet, cargo tank pressure/vacuum relief valve provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;
- (4) the spaces forming an air-lock leading to zone 1;
- (5) areas on open deck extending to the coamings fitted to keep any spills on deck and away from the accommodation and service areas and 3 m beyond these up to a height of 2.4 m above the deck;
- (6) areas on open deck over all cargo tanks (including all ballast tanks within the cargo tank area) where unrestricted natural ventilation is guaranteed and to the full breadth of the ship plus 3 m fore and aft of the forward-most and aft-most cargo tank bulkhead, up to a height of 2.4 m above the deck surrounding open or semi-enclosed spaces of zone 1;
- (7) spaces forward of the open deck areas to which reference is made in 2.16.6.2(8) and 2.16.6.3(6) of this Section, below the level of the main deck, and having an opening on to the main deck or at a level less than 0.5 m above the main deck, unless:
 - ① the entrances to such spaces do not face the cargo tank area and, together with all other openings to the spaces, including ventilating system inlets and exhausts, are situated at least 5 m from the foremost cargo tank and at least 10 m measured horizontally from any cargo tank outlet or gas or vapour outlet; and
 - ② the spaces are mechanically ventilated.

2.16.6.4 The hazards in some hazardous areas or spaces, e.g. those having direct openings into hazardous areas or spaces, may be reduced or these zones or spaces may be regarded as non-hazardous areas or spaces, provided that the arrangements of ventilation, pressurization, doors at openings, and other safety precautions are in compliance with relevant acceptable standards^②.

2.16.7 Classification of hazardous areas of oil tankers carrying cargo oils having a flash point (closed cup) exceeding 60°C and not heated or heated to a temperature more than 15°C below their flash point

2.16.7.1 The interiors of cargo tanks, slop tanks, any pipework of pressure/vacuum relief valve or other venting systems for cargo and slop tanks, pipes and equipment containing the cargo or handling flammable gas or vapour belong to zone 2.

2.16.8 Classification of hazardous areas of oil tankers carrying cargo oils having a flash point (closed cup) exceeding 60°C and heated to a temperature above their flash point or heated to a temperature within 15°C of their flash point

① Such areas are sight ports, tank cleaning openings, ullage openings, sounding pipes, cargo vapour outlets.

② See IEC publication 60092-502: Electrical installations in ships –Part 502: Tankers – Special Features.

2.16.8.1 Such tankers are to comply with the requirements for oil tankers carrying cargo oils having a flash point (closed cup) not exceeding 60°C, as specified in 2.16.6 of this Section.

Section 17 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING VEHICLES WITH FUEL IN THEIR TANKS FOR THEIR OWN PROPULSION

2.17.1 General requirements

2.17.1.1 This Section applies to the electrical installations of ships with spaces for carrying vehicles with fuel in their tanks for their own propulsion.

2.17.1.2 The certified explosion-proof equipment required by this Section is to comply with the provisions of 1.3.3 of this PART, and the explosion group and temperature class are not to be lower than II A, T3.

2.17.2 Carriage of vehicles in special category spaces, closed ro-ro spaces^① above the bulkhead deck of passenger ships and in closed ro-ro cargo spaces (with not less than 10 air changes per hour) of cargo ships

2.17.2.1 The electrical equipment fitted within a height of 450 mm above the vehicle deck or any platform on which vehicles are carried and within the exhaust ventilation trunking for the spaces is to be of certified safe type.

2.17.2.2 In spaces other than those specified in 2.17.2.1, where electrical equipment other than that of certified safe type is fitted, the enclosure of which is to be of at least IP55 type and the temperature rise on the surface is not to exceed 200°C.

2.17.3 Carriage of vehicles in special category spaces, closed ro-ro spaces below the bulkhead deck of passenger ships and in closed ro-ro cargo spaces (with less than 10 air changes per hour) of cargo ships

2.17.3.1 The electrical equipment fitted within such spaces and their exhaust ventilation trunking are to be of certified safe type.

2.17.4 Carriage of vehicles in cargo spaces of passenger ships and cargo ships

2.17.4.1 The electrical equipment fitted within such spaces and their exhaust ventilation trunking are to be of certified safe type.

2.17.4.2 All electrical circuits terminating in such spaces are to be provided with multi-pole linked isolating switches located outside such spaces. Provision is to be made for locking in the off position. This does not apply to circuits such as those for fire, smoke or gas detectors.

2.17.4.3 For spaces with not less than 10 air changes per hour and other than those within a height of 450 mm above the vehicle deck or vehicle platform, where electrical equipment other than that of certified safe type is fitted, the enclosure of which is to be of at least IP55 type and the temperature rise on the surface is not to exceed 200°C.

2.17.5 Carriage of vehicles in an area on weather deck of passenger ships and cargo ships

2.17.5.1 For the electrical equipment fitted in the area, the degrees of protection by enclosures are to comply with the relevant requirements of Table 1.3.2.2 of this PART and in addition, the temperature rise on the surface is not to exceed 200°C.

Section 18 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING DANGEROUS GOODS

2.18.1 General requirements

2.18.1.1 The electrical installations onboard ships fitted with cargo spaces intended for carrying dangerous goods specified in 2.18.1.2 are to comply with the requirements of this Section and other applicable requirements of this PART.

2.18.1.2 Dangerous goods, for which safety measures are required with respect to the electrical equipment, are grouped into the following classes in accordance with IMO International Maritime Dangerous Goods Code (IMDG Code) and International Maritime Solid Bulk Cargoes (IMSBC) Code:

(1) Dangerous goods in packaged form

① With not less than 10 air changes per hour.

Class 1	Explosives, except goods in division 1.4, compatibility group S of IMDG Code;
Class 2.1	All flammable gases, compressed, liquefied or dissolved under pressure;
Class 3.1, 3.2	All flammable liquids having a flashpoint below 23°C (closed-cup test);
Class 6.1	All toxic substances having a flashpoint below 23°C (closed-cup test);
Class 8	All corrosive liquids having a flashpoint below 23°C (closed-cup test).
(2) Solid dangerous goods in bulk	
Class 4.1	Flammable solids;
Class 4.2	Substances liable to spontaneous combustion;
Class 4.3	Substances, which in contact with water, emit flammable gases;
Class 5.1	Oxidizing substances;
Class 9	Miscellaneous dangerous substances, that is, any other substance which experience has shown, or may show, to be of such a dangerous character that the provisions of this Section apply to it;
MHB	Materials which, when carried in bulk, present sufficient hazards to require specific precautions.

2.18.1.3 Possible hazardous areas for carrying the dangerous goods specified in this Section comprise the following:

(1) Zones and spaces, in which an explosive atmosphere^① is likely to occur in normal operation, are defined as hazardous areas.

(2) Zones and spaces, in which an explosive atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only, are defined as extended hazardous areas.

2.18.1.4 Electrical equipment is to be installed in hazardous areas only when it is essential for the safety and operation of the ship. The explosion protection of the installed and operated electrical equipment is to be suitable for the characteristics of the dangerous goods.

2.18.1.5 When carrying flammable liquids having flashpoints less than 23°C as Class 3.1, 3.2, 6.1 or 8 in cargo spaces, aluminium smelting by-products or aluminium remelting by-products (UN 3170), aluminium smelting or remelting by-products processed (MHB), ferrosilicon (MHB) and ferrosilicon (UN 1408), the bilge pipes with flanges, valves, pumps, etc., constitute a source of release and the enclosing spaces (e.g. pipe tunnels, bilge pump rooms, etc.) are to be classified as an extended hazardous area (comparable with Zone 2).

2.18.2 Carriage of explosives class 1 in packaged form as specified in 2.18.1.2 (1) (except goods in division 1.4, compatibility group S)

2.18.2.1 The following zones or spaces are hazardous areas:

(1) closed cargo spaces, and closed or open ro-ro cargo spaces;

(2) permanently fixed containers (e.g. magazines).

2.18.2.2 Cables required in 2.18.8.2 and the electrical equipment not inferior to that required in Table 2.18.2.2 are permitted in the hazardous areas specified in 2.18.2.1 of this Section.

Permitted Electrical Equipment

Table 2.18.2.2

Environment	Electrical equipment			
	Type	Explosion group	Temperature class or maximum surface temperature	Degree of protection
Explosive dust	General electrical equipment		100°C	IP65
Explosive gas	Intrinsically safe Ex “i”	IIA	T5	
	Flameproof Ex “d”	IIA		
	Increased safety Ex “e” (only for lighting)	II		
Explosive gas and dust	Intrinsically safe Ex “i”	IIA	T5	IP65
	Flameproof enclosure Ex “d”	IIA		
	Increased safety Ex “e” (only for lighting)	II		

2.18.3 Carriage of solid dangerous goods in bulk and capable of creating explosive dust atmosphere only

2.18.3.1 The following zones or spaces are hazardous areas:

(1) closed cargo spaces;

(2) ventilation ducts (if any) for hazardous areas;

① An explosive atmosphere may exist due to gas and/or dust.

(3) enclosed or semi-enclosed spaces having a direct opening into any of the spaces listed in (1) or (2) above, without appropriate measures to prevent flammable dust from entering.

2.18.3.2 Cables required in 2.18.8.2 and the electrical equipment not inferior to that required as follows are permitted in the hazardous areas specified in 2.18.3.1 of this Section:

- (1) general electrical equipment
 - degree of protection IP55;
 - maximum surface temperature 200°C; or
- (2) certified explosion-proof electrical equipment
 - degree of protection IP55;
 - temperature class T3.

2.18.3.3 Where dangerous goods are to be carried which require a lower surface temperature than that given in 2.18.3.2 of this Section, the relevant requirements are to be complied with (see also 2.18.7).

2.18.4 Carriage of flammable liquids having a flashpoint below 23°C in packaged form (classes 3.1, 3.2) and flammable gas (class 2.1)

2.18.4.1 The following zones or spaces are hazardous areas:

- (1) closed cargo spaces and closed ro-ro cargo spaces;
- (2) ventilation ducts (if any) for hazardous areas;
- (3) areas on weather deck, or semi-enclosed spaces on weather deck, within 1.5 m of any exhaust ventilation outlet of a hazardous area;
- (4) enclosed or semi-enclosed spaces having a direct opening into any of the spaces listed in (1) and (2) above, and without appropriate measures to prevent flammable gas from entering.

2.18.4.2 The following zones or spaces are extended hazardous areas:

- (1) spaces which are separated by self-closing gastight doors (watertight doors may be regarded as gastight) from the hazardous areas as mentioned in 2.18.4.1(1) and (2), and have natural ventilation;
- (2) inside the air lock (if any) adjoining the hazardous areas as mentioned in 2.18.4.1;
- (3) open or semi-enclosed spaces within 1.5 m of the hazardous areas as specified in 2.18.4.1(3).

2.18.4.3 Cables required in 2.18.8.2 and the electrical equipment not inferior to that required in Table 2.18.4.3 are permitted in the hazardous areas specified in 2.18.4.1 and 2.18.4.2 of this Section.

Permitted Electrical Equipment			Table 2.18.4.3
Type of hazardous areas	Electrical equipment		
	Type	Explosion group	Temperature class or maximum surface temperature
Hazardous areas	Intrinsically safe Ex “i”	IIC	T4
	Flameproof Ex “d”	IIC	
	Pressurized enclosure Ex “p”	II	
	Encapsulated Ex “m”	II	
Extended hazardous areas	Electrical equipment permitted in the above hazardous areas	IIC or II	T4
	Non-sparking Ex “n”	II	
	Appliances which do not generate sparks or arcs during normal operation		135°C

2.18.4.4 If cargoes to be carried do not include hydrogen gases, hydrogen mixtures or bulk cargo which may produce hydrogen under certain conditions, the explosion group required above may be IIB.

2.18.5 Carriage of solid dangerous goods in bulk and MHB only

2.18.5.1 Where solid dangerous goods in bulk (solid dangerous goods capable of creating explosive gas atmosphere) and MHB only are to be carried:

- (1) zones or spaces mentioned in 2.18.4.1 are hazardous areas;
- (2) zones or spaces mentioned in 2.18.4.2 are extended hazardous areas.

2.18.5.2 The types of cables and electrical equipment permitted in hazardous areas defined in 2.18.5.1 are to be in compliance with the requirements of 2.18.3.2 and 2.18.4.3 and the minimum requirements given in Table 2.18.5.2.

2.18.5.3 For some of dangerous goods class 5.1 and class 9, all electrical circuits terminating in cargo spaces are to be disconnected in accordance with the requirements of 2.18.8.1 (see Table 2.18.5.2 of this Section).

Characteristics of Electrical Equipment for Use in Hazardous Areas (Example)**Table 2.18.5.2**

Dangerous goods	IMO class	Dominant risk ^①	Protection against explosive dust atmosphere	Protection against explosive gas atmosphere	
			Degree of protection	Explosion group	Temperature class
Aluminium dross	MHB	H ₂	—	IIC	T2
aluminium ferrosilicon powder	4.3	H ₂	—	IIC	T2
Aluminium silicon powder uncoated	4.3	H ₂	—	IIC	T2
Ammonium nitrate fertilizer — Type A — Type B	5.1 9	② ②	— —	— —	— —
Coal	MHB	Dust, methane	IP55	IIA	T4
Direct reduced iron	MHB	H ₂	—	IIC	T2
Ferrophosphorus (no briquettes)	MHB	H ₂	—	IIC	T1
Ferrosilicon	4.3	H ₂	—	IIC	T1
Iron oxide, spent Sponge iron, spent	4.2	Dust	IP55	IIA	T2
Dust (e.g. from grain)		Dust	IP55	—	—
Seed cake, expellers	4.2	Hexane	—	IIA	T3
Silicomanganese	MHB	H ₂	—	IIC	T1
Sulphur	4.1	Combustible	IP55	—	T4
Zinc ashes Zinc dross Zinc residues Zinc skimmings	4.3	H ₂	—	IIC	T2

Notes: ① The term “risk” relates only to the risk of explosion due to dangerous goods and electrical appliances.

② All electrical circuits terminating in cargo spaces are to be disconnected in accordance with 2.18.5.3.

2.18.6 Pressurized protection and air locks

2.18.6.1 Spaces having openings into adjacent hazardous spaces or areas (such as the hazardous areas specified in 2.18.4.1(4) of this Section) may be regarded as non-hazardous spaces provided they are pressurized as indicated in the acceptable standards^①.

2.18.6.2 Where air locks are fitted adjacent to a hazardous area specified in 2.18.4.1, the external spaces adjacent to the air locks and fitted with natural ventilation may be regarded as non-hazardous spaces.

2.18.7 Special requirements

2.18.7.1 If no details of the characteristics of the prospected cargo are available, or if a ship is intended for the carriage of all the materials defined in 2.18.1.2, the electrical equipment permitted in hazardous areas are to be in compliance with the following requirements:

- degree of protection provided by enclosure IP65;
- maximum surface temperature 85°C;
- explosion group IIC;
- temperature class T6.

2.18.8 Installation of electrical system in hazardous areas

2.18.8.1 If the electrical equipment installed is not suitable for use in areas where a risk of explosion exists, the equipment is to be capable of being disconnected and protected against unauthorized re-connection. Disconnection is to be made outside the hazardous areas and be effected with isolating links or lockable switches.

2.18.8.2 Cables are to be armoured or braided, or to be laid in metallic conduits, with the exception of extended hazardous areas.

2.18.8.3 Cable joints in cargo spaces are to be avoided where possible. Where joints are unavoidable, they are to be enclosed in explosion-proof metallic or high strength plastic junction boxes, or encapsulated crimp sleeve cable joints.

2.18.8.4 Except in extended hazardous areas, cable penetrations of decks and bulkheads are to be sealed against the passage of inflammable gas or vapour.

① See IEC publication 60092-506: Special features – Ships carrying specific dangerous goods and materials hazardous only in bulk.

2.18.9 Portable electrical appliances in hazardous areas

2.18.9.1 Portable electrical appliances, which must be used in hazardous areas for operation of the ship, are to be of a certified safe type suitable for such areas and except for intrinsically safe circuits, generally provided with their own power source.

Section 19 ADDITIONAL REQUIREMENTS FOR BULK CARRIERS

2.19.1 Application

2.19.1.1 This Section applies to all bulk carriers and single hold cargo ships other than bulk carriers of 500 gross tonnage and upwards engaged on international voyages.

2.19.2 Water level detector system

2.19.2.1 Water level detectors installed in cargo holds, ballast tanks and dry spaces are to comply with the relevant requirements of acceptable standards^① in addition to the provisions of this Section, and are to be subject to type approval.

2.19.2.2 Audible and visual alarms are to be given in each cargo hold, one when the water level above the inner bottom in any hold reaches a height of 0.5 m and another at a height not less than 15% of the depth of the cargo hold but not more than 2.0 m. On bulk carriers to which regulation XII/9.2 of SOLAS applies, detectors with only the latter alarm need be installed. The water level detectors are to be fitted in compliance with the provisions of 2.19.2.11 of this section. For cargo holds which are used for water ballast, an alarm overriding device may be installed. The audible and visual alarms are to clearly discriminate between the two different water levels detected in each hold.

2.19.2.3 In any ballast tank forward of the collision bulkhead required by regulation II-1/11 of SOLAS, an audible and visual alarm is to be given when the liquid in the tank reaches a level not exceeding 10% of the tank capacity. An alarm overriding device may be installed to be activated when the tank is in use.

2.19.2.4 In any dry or void space other than a chain cable locker, any part of which extends forward of the foremost cargo hold, an audible and visual alarm is to be given at a water level of 0.1 m above the deck. Such alarms need not be provided in enclosed spaces the volume of which does not exceed 0.1% of the ship's maximum displacement volume.

2.19.2.5 The audible and visual alarms specified in 2.19.2.2 to 2.19.2.4 are to be located on the navigation bridge.

2.19.2.6 Detection equipment is to be suitably corrosion resistant for all intended cargoes. Detection equipment includes the sensor and any filter and protection arrangements for the detector installed in cargo holds and other spaces.

2.19.2.7 The part of the water level detector system which has circuitry in the cargo area is to be of an intrinsically safe type complying with ib class as specified in acceptable standards^②. Where a ship is designed only for the carriage of cargoes that cannot create a combustible or explosive atmosphere, then the requirement for intrinsically safe circuitry may not be mandatory provided that this is specified in the operation manual of the water level detector system, the ship's cargo book and the certificate relating to the carriage of specially identified cargoes.

2.19.2.8 Where intrinsically safe equipment is installed in cargo spaces, it is to be of a certified safe type complying with 1.3.3.1 of this PART. The explosion group and the maximum surface temperature of the equipment are to be appropriate for the combustible dust and/or explosive gas likely to be encountered. Where the characteristics of the dust and gas are unknown, the explosion group is not to be lower than IIC and the temperature class is to be T6 or the maximum surface temperature is not to exceed 85°C.

2.19.2.9 The electrical power supply for the water level detector system is to comply with the following:

(1) It is to be supplied from two independent sources of electrical power:

- ① the main source of electrical power and the emergency source of electrical power; or
- ② the main source of electrical power, and a continuously charged dedicated accumulator battery of which the arrangement, location and endurance for power supply (18 h) are equivalent to those of the emergency source of electrical power. The battery may be an internal battery of the water level detector system;

(2) The changeover of supply from one source of electrical power to another need not be integrated into the water level detector system;

① See resolution MSC.188(79) adopted by IMO – Performance Standards for Water Level Detectors on Bulk Carriers and Single Hold Cargo Ships Other than Bulk Carriers.

② See IEC publication 60079.

(3) Failure of the primary electrical power supply is to be indicated by an alarm. Where batteries are used for the secondary power supply, failure alarms for both power supplies are to be provided.

2.19.2.10 The degree of protection provided by enclosures for electrical components installed in cargo holds, ballast tanks and dry spaces are to satisfy the requirements of IP 68.

2.19.2.11 Installation requirements for water level detectors

(1) The sensors are to be located in a protected position that is in communication with the specified part of the cargo hold (usually the aft part) such that the position of the sensor detects the level that is representative of the levels in the actual hold space. These sensors are to be located either as close to the centerline as practicable, or at both the port and starboard sides of the cargo hold.

For ships the keels of which are laid on or after 1 July 2004, the sensors are to be placed at a distance not exceeding 1 corrugation spacing or 1 bulkhead vertical stiffener spacing from the centerline, otherwise sensors are to be located at both the port and starboard sides of the cargo hold.

For ships the keels of which are laid before 1 July 2004, the sensors are to be placed at a distance not exceeding or equal to $B/6$ (B being breadth of the ship) from the centerline, otherwise sensors are to be located at both the port and starboard sides of the cargo hold.

(2) The detector installation is not to inhibit the use of any sounding pipe or other water level gauging device for cargo holds or other spaces.

(3) Detectors and equipment are to be installed where they are accessible for survey, maintenance and repair.

(4) Any filter element fitted to detectors is to be capable of being cleaned before loading.

(5) Electrical cables and any associated equipment installed in cargo holds are to be protected from damage by cargoes or mechanical handling equipment associated with bulk carrier operations, such as in tubes of robust construction or in similar protected locations.

(6) Any change/modification to the ship's structure, electrical systems or piping systems that involves cutting and/or welding are to be approved by CCS prior to commencement of work.

CHAPTER 3 CONSTRUCTION AND TESTING OF ELECTRICAL EQUIPMENT

Section 1 GENERAL PROVISIONS

3.1.1 General requirements

3.1.1.1 This Chapter applies to class-related electrical equipment. The additional requirements for high voltage electrical installations are given in Section 14, Chapter 2 of this PART, and additional requirements for electrical propulsion machinery are given in Chapter 15 of PART EIGHT of the Rules.

3.1.1.2 Class-related electrical equipment is to be provided with certificates corresponding to its type. The specific requirements for certificates are given in Chapter 3 of PART ONE of the Rules.

Section 2 ROTATING MACHINES

3.2.1 General requirements

3.2.1.1 The characteristics of the prime movers of generators and their governors are to comply with the relevant requirements of Chapters 7, 8 and 9 of PART THREE of the Rules.

3.2.1.2 For generating sets operating in parallel, the governing characteristics of the prime mover are to be such as to ensure the load sharing specified in 3.2.7.5 and 3.2.8.5 of this Section. Facilities are to be provided to adjust the governor sufficiently fine to permit an adjustment of load not exceeding 5% of the rated load at normal frequency.

3.2.1.3 Shaft material for electrical propulsion motors and for main engine driven generators where the shaft is part of the propulsion shafting is to be certified by CCS.

3.2.1.4 Electrical machines are to be protected against ill effects of shaft current.

3.2.1.5 For non-closed-type bearings of electrical machines, consideration is to be to the fitting of grease cups or oil holes and corresponding oil drainage so as to ensure efficient lubrication.

3.2.2 Plans and documents

3.2.2.1 The following plans and documents are to be submitted for approval:

- (1) General plan;
- (2) Detailed drawings of main parts including assembly of stators, assembly of rotors, drawing of rotating shaft, assembly of slip rings or commutators, drawing of bedplate, and structural drawing of connection boxes;
- (3) Technical specifications of the products;
- (4) Front panel arrangement and system control flow diagram (applicable to electrical propulsion motors and their controls);
- (5) Electrical schematic diagram (applicable to electrical generators and their excitation systems, electrical propulsion motors and their controls);
- (6) External wiring diagram (applicable to electrical generators and their excitation systems, electrical propulsion motors and their controls).

3.2.2.2 The following plans and documents are to be submitted for information:

- (1) Specifications of associated electrical appliances (applicable to electrical generators and their excitation systems, electrical propulsion motors and their controls).

3.2.3 Temperature rise

3.2.3.1 The limits of temperature rise of air-cooled machines based on an ambient air temperature of 45°C are given in Table 3.2.3.1.

3.2.3.2 Where the ambient air temperature for motor operation is more than 45°C, the permissible temperature rise is to be reduced by an amount equal to the difference between the actual air ambient temperature and 45°C, based on the specified value given in Table 3.2.3.1.

Where the ambient air temperature for motor operation is less than 45°C, the permissible temperature rise is to be increased by a value equal to the difference between the actual ambient air temperature and 45°C, based on the specified value given in Table 3.2.3.1, and the increased value is not to be more than 15 K.

Limits of Temperature Rise (K) of Air-Cooled Machines

Table 3.2.3.1

Thermal classification		A			E			B			F			H		
Method of measurement ^③		Th	R	ETD	Th	R	ETD	Th	R	ETD	Th	R	ETD	Th	R	ETD
Item	Part of machine															
1a)	AC windings of machines having output of 5,000 kW (or kVA) or more	–	55	60	–	–	–	–	75	80	–	95	100	–	120	125
1b)	AC windings of machines having output above 200 kW (or kVA), but less than 5,000 kW (or kVA)	–	55	60	–	70	–	–	75	85	–	100	105	–	120	125
1c)	AC windings of machines having output of 200 kW (or kVA) or less, other than those of items 1d) or 1e) ^①	–	55	–	–	70	–	–	75	–	–	100	–	–	120	–
1d)	AC windings of machines having rated output of less than 600 W (or VA) ^①	–	60	–	–	70	–	–	80	–	–	105	–	–	125	–
1e)	AC windings and/or encapsulated windings of self-cooled machines without a fan (IC410) ^①		60	–	–	70	–	–	80	–	–	105	–	–	125	–
2	Windings of armatures having commutators	45	55	–	60	70	–	65	75	–	80	100	–	100	120	–
3	Field windings of AC and DC machines other than those of item 4	45	55	–	60	70	–	65	75	–	80	100	–	100	120	–
4a)	Field windings of synchronous machines with cylindrical rotors having DC excitation windings embedded in slots, excluding synchronous induction motors	–	–	–	–	–	–	–	85	–	–	105	–	–	130	–
4b)	Stationary field windings of DC machines having more than one layer	45	55	–	60	70	–	65	75	85	80	100	105	100	120	130
4c)	Single-layer low-resistance field windings of AC and DC machines and compensating windings of DC machines having more than one layer	55	55	–	70	70	–	75	75	–	95	95	–	120	120	–
4d)	Single-layer	60	60	–	75	75	–	85	85	–	105	105	–	130	130	–

Thermal classification		A			E			B			F			H		
Method of measurement ^③		Th	R	ETD	Th	R	ETD	Th	R	ETD	Th	R	ETD	Th	R	ETD
Item	Part of machine															
	windings of AC and DC machines with exposed bare or varnished metal surfaces and single-layer compensating windings of DC machines ^②															
5	Permanently short-circuited windings	The temperature rise or the temperature of any part is not to be detrimental to the insulation of that part or to any other part adjacent to it														
6	Commutators and slip rings and their brushes and brush gears	The temperature rise or the temperature of any part is not to be detrimental to the insulation of that part or any other part adjacent to it. In addition, the temperature rise or the temperature of a commutator or slip ring is not to exceed that at which the combination of brush grade and commutator or slip ring material can handle the current over the full operating range														
7	Structural components (other than bearings) and magnetic cores regardless of contact with insulation	The temperature rise or the temperature of any part is not to be detrimental to the insulation of that part or to any other part adjacent to it														

Notes:

- ① With application of the superposition test method to windings of machines rated 200 kW (or kVA) or less with insulation classes A, B, E and F, the limits of temperature rise given for the resistance method may be exceeded by 5 K.
- ② Multi-layer windings are also to be included where the under layers are all in contact with the circulating primary coolant.
- ③ Th – thermometer, R – resistance, and ETD – embedded temperature detector.

3.2.3.3 Main and emergency generators, including their exciters, and continuously rated motors are to be suitable for continuous duty at their full rated output at maximum cooling air temperature for an unlimited period, without the limits of temperature rise in Table 3.2.3.1 being exceeded.

Other generators and motors are to be rated in accordance with the duty which they have to perform and when tested under rated load conditions, the temperature rise is not to exceed the values given in Table 3.2.3.1. For intermittent service S2 machines, the limits of temperature rise of windings may be 10 K above the values given in Table 3.2.3.1.

3.2.4 Sparking

3.2.4.1 Direct current motors and generators are to work with fixed brush setting from no load to the momentary overload specified without injurious sparking.

3.2.4.2 Alternating current commutator motors are to work over the specified range of load and speed without injurious sparking.

3.2.5 Overloads

3.2.5.1 Machines are to withstand, on test, the following overcurrents or excess torques without injury:

DC generators: 50% overcurrent for 15 s;

AC generators: 50% overcurrent for 2 min;

DC motors: 50% excess torque for 15 s;

Polyphase asynchronous motors: 60% excess torque for 15 s;

Polyphase salient synchronous motors: 50% excess torque for 15 s;

Polyphase non-salient synchronous motors: 35% excess torque for 15 s;

Polyphase synchronous motors of asynchronous construction (wound rotor): 35% excess torque for 15 s.

3.2.6 Short-circuits

3.2.6.1 Ship's service generators are to be capable of withstanding the mechanical and thermal effects of a short-circuit current for the duration of any time delay for discrimination purposes when tripping a protective device. AC generators and their excitation systems are to be capable of maintaining, under steady-state short-circuit conditions, a current of at least 3 times the full load rated current for a duration of 2 s or where precise data are available, for the duration of any time delay which may be provided by a tripping device.

3.2.7 DC generators

3.2.7.1 All DC generators other than charging generators are, in general, to be of compound-wound or shunt-wound with automatic voltage regulator, or stabilized shunt-wound (shunt-wound with few turns of series windings).

3.2.7.2 Manual voltage regulators are to be provided at the control panel to enable the voltage of each DC generator to be adjusted separately. For each DC generator, at any temperature within the working range and at any load between no load and full load, and when the voltage varies from 80% to 105% of the rated value, the accuracy of voltage adjustment is to be as follows:

- (1) 0.5% of rated voltage for generators of rating exceeding 100 kW;
- (2) 1.0% of rated voltage for generators of rating not exceeding 100 kW.

The circuit of manual voltage regulators is in general to be capable of being opened and means are to be provided to protect against over-voltage when the circuit is opened. Non-opened circuit is permitted only in such a case where the manual voltage regulator could adjust the no-load voltage to a value approaching to the remanence voltage.

The handwheel of manual voltage regulators is to be so arranged that when it is turned clockwise, the generator voltage will rise and vice versa.

3.2.7.3 Equalizer leads are to have a cross-sectional area appropriate to the system but in no case less than 50% of that of the negative lead from the generator to the switchboard.

3.2.7.4 For compound-wound generators rated at 50 kW and over, at full load operating temperature and with due regard being paid to governing characteristics of the prime mover, the voltage regulation characteristics are to be such that voltage variations are within 1% of the rated voltage for 20% of the rated load, that voltage variations are within 2.5% of the rated voltage for the full rated load and that the average of the ascending and descending curves of voltage regulation characteristics between 20% load and full load does not vary more than 3% from the rated voltage.

3.2.7.5 All DC generating sets arranged to run in parallel are to be stable in operation. When the combined load on the sets is varied between 20% and 100% of the combined ratings, the individual load on each machine is not to differ from the theoretical load (proportional to rating) by an amount greater than:

- (1) $\pm 12\%$ of the rated full load of the largest machine; or
- (2) $\pm 25\%$ of the rating of the smallest machine when the rating of the smallest machine is less than 50% of that of the largest one.

Such a load sharing is not to result in overloading the smaller set.

3.2.8 AC generators

3.2.8.1 Each AC generator, unless of the self-regulated type, is to be provided with separate automatic and manual voltage regulators at the generator control panel.

3.2.8.2 Each AC generator driven by the prime mover having governing characteristics complying with Chapter 7, 8 or 9 of PART THREE of the Rules together with its excitation system is to be capable of maintaining the voltage under steady conditions within $\pm 2.5\%$ of the rated voltage from zero to full load at rated power factor. These limits may be increased to $\pm 3.5\%$ for emergency generators.

3.2.8.3 When the generator is driven at rated speed and a voltage close to its rated voltage on no-load, and is subjected to a sudden change of symmetrical load within the limits of 60% of the rated current with a power factor not exceeding 0.4 (lagging), the transient voltage is not to fall below 85% nor exceed 120% of the rated voltage. The voltage of the generator is then to be restored to within plus or minus 3% of the rated voltage in not more than 1.5 s. For emergency generators, these values may be increased to plus or minus 4% in not more than 5 s, respectively.

3.2.8.4 For AC generators, the sinusoidal distortion of the voltage waveform under no-load conditions is not to exceed 5%, except for small (e.g. less than 24 kW) generators.

3.2.8.5 All AC generating sets arranged to run in parallel are to be stable in operation. In the range between 20% and 100% of the combined rated load of all generators, the load sharing is to be as follows:

(1) The active load on any individual generator is not to differ from the proportionate share of the total active load by more than the lesser of the following:

- ① $\pm 15\%$ of the rated active output of the largest generator; or
- ② $\pm 25\%$ of the rated active output of the individual generator.

(2) The reactive load on any individual generator is not to differ from the proportionate share of the total reactive load by more than the lesser of the following:

- ① $\pm 10\%$ of the rated reactive output of the largest generator;
- ② $\pm 25\%$ of the rated reactive output of the smallest generator.

3.2.9 Testing

3.2.9.1 All electrical machines are to be tested by the manufacturer according to IEC Publication 60092-301. Manufacturer's test records are to be provided for machines for essential services.

3.2.9.2 All machines of 50 kW and over, intended for essential services, are to be surveyed by CCS Surveyors during test and, if appropriate, during manufacturing.

3.2.9.3 Items for type and routine tests of the electrical machines are to be in compliance with Table 3.2.9.3. Test requirements may differ for shaft generators, special purpose machines and machines of novel construction.

Items for Type and Routine Tests of Electric Machines

Table 3.2.9.3

No	Tests	AC Generators		Motors	
		Type test ^①	Routine test ^②	Type test ^①	Routine test ^②
1	Examination of the technical documentation, as appropriate and visual inspection	×	×	×	×
2	Insulation resistance measurement	×	×	×	×
3	Winding resistance measurement	×	×	×	×
4	Verification of the voltage regulation system	×	× ^③		
5	Rated load test and temperature rise measurements	×		×	
6	Overload/overcurrent test	×	× ^④	×	× ^④
7	Verification of steady short circuit conditions ^⑤	×			
8	Overspeed test	×	×	× ^⑥	× ^⑥
9	Dielectric strength test	×	×	×	×
10	No-load test	×	×	×	×
11	Verification of degree of protection	×		×	
12	Verification of bearings	×	×	×	×

Notes: ① Type tests on prototype machine or tests on at least the first batch of machines.

② The report of machines routine tested is to contain the manufacturer's serial number of the machine which has been type tested and the test result.

③ Only functional test of voltage regulator system.

④ Only applicable for machines of essential services rated above 100 kW.

⑤ Verification of steady short circuit condition applies to synchronous generators only.

⑥ Not applicable for squirrel cage motors.

3.2.9.4 The tests required in Table 3.2.9.3 are to be in accordance with the requirements in 3.2.9.5 to 3.2.9.15, in addition to complying with the relevant requirements of acceptable standards^①.

3.2.9.5 Visual inspection

A visual examination is to be made of the machine to ensure, as far as is practicable, that it complies with submitted technical documentation.

3.2.9.6 Insulation resistance measurement

Immediately after the high voltage tests the insulation resistances are to be measured using a direct current insulation tester (DC megameter) between:

(1) all current carrying parts connected together and earth;

(2) all current carrying parts of different polarity or phase, where both ends of each polarity or phase are individually accessible.

The minimum values of test voltages and corresponding insulation resistances are given in Table 3.2.9.6. The insulation resistance is to be measured close to the operating temperature, or an appropriate method of calculation is to be used.

Minimum Test Voltage and Minimum Insulation Resistance Value

Table 3.2.9.6

Related voltage U_n (V)	Minimum test voltage (V)	Minimum insulation resistance (MΩ)
$U_n \leq 250$	$2 \times U_n$	1
$250 < U_n \leq 1,000$	500	1
$1,000 < U_n \leq 7,200$	1,000	$(U_n / 1,000) + 1$
$7,200 < U_n \leq 15,000$	5,000	$(U_n / 1,000) + 1$

3.2.9.7 Winding resistance measurement

The resistances of the machine windings are to be measured and recorded using an appropriate bridge method or voltage and current method.

① Refer to IEC Publication 60092-301: Electrical installations in ships – Part 301: Equipment – Generators and motors and IEC Publication 60034-1: Rotating electrical machines – Part 1: Rating and performance, or other equivalent standards.

3.2.9.8 Verification of voltage regulation system

Verification results are to meet the requirements in 3.2.8.2 and 3.2.8.3 of the Section.

3.2.9.9 Rated load test and temperature rise measurements

The temperature rises are to be measured at the rated output, voltage, frequency and the duty for which the machine is rated and marked in accordance with the testing methods specified in IEC Publication 60034-1, or by means of a combination of other tests. Temperature rise is to be measured after the test and the limits of temperature rise are those specified in Table 3.2.3.1.

3.2.9.10 Overload/over-current tests

Electrical machines are to be able to withstand the overload/over-current tests as required in 3.2.5.1 of this Section after the rated load test. The overload test can be replaced at routine test by the over-current test.

3.2.9.11 Verification of steady short-circuit conditions

Verification of AC synchronous generators and their excitation systems is to be in accordance with the requirements in 3.2.6.1 of this Section.

3.2.9.12 Overspeed test

Machines are to withstand the overspeed test as specified in IEC Publication 60034-1. This test is not applicable for squirrel cage motors.

3.2.9.13 Dielectric strength test

Machines are to withstand a dielectric test as specified in IEC Publication 60034-1. For high voltage machines an impulse test is to be carried out on the coils according to 2.14.3.3 of this PART.

3.2.9.14 No load test

Machines are to be operated at no load and rated speed whilst being supplied at rated voltage and frequency as a motor or if a generator it is to be driven by a suitable means and excited to give rated terminal voltage. During the running test, the vibration of the machine and operation of the bearing lubrication system, if appropriate, are to be checked.

3.2.9.15 Verification of degree of protection

As specified in the standards acceptable to CCS^①.

3.2.9.16 Verification of bearings

Upon completion of the above tests, machines which have sleeve bearings are to be opened to establish that the shaft is correctly seated in the bearing shells.

Section 3 SWITCHGEAR ASSEMBLIES**3.3.1 Plans and documents**

3.3.1.1 The following plans and documents are to be submitted for approval:

- (1) General plan;
- (2) Front panel arrangement;
- (3) Technical specifications of the products;
- (4) Electrical schematic diagram.

3.3.1.2 The following plans and documents are to be submitted for information:

- (1) Specifications of associated electrical appliances;
- (2) Operation instructions for the products (which may be omitted if they are covered in other plans and documents for switchgear assemblies);
- (3) External wiring diagram.

3.3.2 Design and construction of switchgear assemblies

3.3.2.1 The construction of main and emergency switchboards is to satisfy the following requirements:

- (1) The top of switchboards is to have a degree of protection of IP22, and where the switchboard is installed in the control room complying with the requirements of 2.1.4.2 of this PART, a protection of IP21 at the top may be accepted. The sides of switchboards are to have at least a degree of protection of IP2X. For switchboards having a rated voltage in excess of 500 V, a protection of at least IP2X at the rear is to be provided.
- (2) For switchboards having a voltage to earth or a working voltage above 50 V, exposed live parts are not to be installed on the front.

① Refer to IEC Publication 60034-5 Rotating electrical machines – Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) – Classification, or other equivalent standards.

(3) Insulated handrails are to be provided at the front of all main and emergency switchboards. Where access to the rear of above-mentioned switchboards is necessary for operational or maintenance purposes, an insulated handrail is to be fitted on the rear. And horizontal insulated handrails are to be fitted on a fixed part of the switchboard.

(4) Provision is to be made at the cable entry to switchboards so that there is no water leakage into the switchboard along the cables.

(5) The main bus-bar is to be subdivided in accordance with the requirements in 2.1.1.1(5) of this PART.

(6) Where the total capacity of the main generating sets exceeds 100 kVA, a separate cubicle is to be provided for each generator, and the cubicles are to be separated from each other by partitions of steel or flame-retardant material.

(7) Terminals for systems having a rated voltage above 500 V are to be separated from terminals for lower voltages and are to be clearly marked.

3.3.2.2 Section and distribution boards are to be enclosed according to Table 1.3.2.2 of this PART. All enclosures are to be constructed of flame-retardant and non-hygroscopic material, and are to be of robust construction.

3.3.2.3 The arrangement of protection of electrical installations and the choice of protective devices are to comply with the relevant requirements of Section 5 of Chapter 2 of this PART.

3.3.2.4 All instruments, switchgear, pilot lamps, push buttons, operating handles or handwheels fitted on switchboards are to be provided with durable labels indicating their purposes and operating positions.

3.3.2.5 A durable label indicating the purpose of each circuit and the rating or appropriate setting of its overload protective device is to be provided at the location of the protective device. For fuses above 500 V where the fuse holders permit the insertion of fuses for lower rated voltages, special warning labels are to be placed, for example, "CAUTION: 660 V FUSES ONLY!"

3.3.2.6 Devices for monitoring the insulation level to earth, which are in compliance with the requirements of 2.4.2.2 of this PART, are to be provided on the main and emergency switchboards.

3.3.2.7 Pilot lamps are to be provided at the generator control panels to indicate whether the generator circuit breakers are at the on or off position. Where a space heater is provided for the generator, a pilot lamp indicating the operation of the space heater is to be provided at the control panel.

3.3.2.8 Means are to be provided at the control panel of DC generators to enable the voltage to be regulated in accordance with the requirements of 3.2.7.2 of this PART.

3.3.2.9 For each AC generator arranged to operate in parallel, a remote control device is to be provided at the control panel to enable the speed of the prime mover to be adjusted within 10% of its rated value.

3.3.2.10 Means are to be provided at the control panel for magnetization of the DC generator.

3.3.2.11 Unless requirements of paragraphs 19.2.5.3, 19.2.5.4 and 19.2.6 of PART EIGHT of the Rules are met, the main and emergency generators are to be interlocked with the shore connection so as to prevent simultaneous supply.

3.3.2.12 Shore connection boxes of shore supply or other external sources are to be provided with the following:

- (1) suitable terminals for connecting the flexible cables;
- (2) an earth terminal for connecting the hull to the shore;
- (3) switches with necessary protection complying with the requirements of 2.5.9.5 of this PART;
- (4) a lamp or voltmeter to indicate the terminal voltage;
- (5) means for checking the polarity (for direct current) or the phase sequence (for three-phase AC) of the incoming supply in relation to the ship's system;
- (6) means to prevent the imposing of excessive mechanical forces on cable terminals;
- (7) a nameplate giving full information on the system of supply, the rated voltage and frequency (for AC) of the ship's system.

3.3.2.13 The charging facilities of battery charging and discharging boards for the emergency or transitional source of electrical power are to comply with the requirements of 2.11.3 of this PART.

3.3.2.14 A disconnect switch and a indicator light for power supply are to be provided on battery charging and discharging boards for the emergency or transitional source of electrical power.

3.3.3 Bus-bars

3.3.3.1 Bus-bars are to be made of conducting cathode copper or copper-sheeted aluminium alloy. The maximum permissible temperature rise for bus-bars is 45 K.

3.3.3.2 Bus-bars and their supports are to be designed to withstand the mechanical stresses which will arise during short-circuits.

3.3.3.3 Bare main bus-bars in main and emergency switchboards (excluding the conductors between the main bus-bar and the supply side of outgoing units) are to have the minimum clearances and creepage distances as given in Table 3.3.3.3.

Minimum Clearances and Creepage Distances **Table 3.3.3.3**

Rated voltage (V)	Minimum clearance (mm)	Minimum creepage distance (mm)
$U_n \leq 250$	15	20
$250 < U_n \leq 690$	20	25
$U_n > 690$	25	35

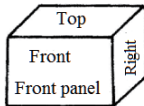
Note: Values given in the Table apply to clearances and creepage distances between live parts as well as between live parts and exposed conductive parts.

3.3.3.4 The current rating of equalizer bus-bars is not to be less than 50% of the rated full load current of the largest generator in the generating plant.

3.3.3.5 The cross sectional area of neutral bus-bar in AC three-phase four-wire systems are not to be less than 50% of that of the bus-bar in the corresponding phase.

3.3.3.6 The arrangement of bus-bars in the switchboard as per the phase sequence (DC) or the polarity (AC) is to be arranged in accordance with Table 3.3.3.6 (as viewed from the front of the assembly).

Arrangement per Phase Sequence or Polarity **Table 3.3.3.6**

Bus bar	Phase sequence or polarity	Position of bus bars			Sketch
		Vertically	Horizontally	Outgoing	
AC	1st phase	Top	Front	Left	As viewed from the front of switchboard assembly 
	2nd phase	Middle	Middle	Middle	
	3rd phase	Bottom	Back	Right	
DC	Positive pole	Top	Front	Left	
	Equalizer pole	Middle	Middle	Middle	
	Negative pole	Bottom	Back	Right	

Note: AC neutral bus-bars may be located at suitable positions.

3.3.4 Measuring instruments

3.3.4.1 The precision grade of instruments is to be selected according to the service of the instruments, but in no case is the precision grade to be inferior to 1.5.

3.3.4.2 The range and scale of the measuring instruments are to comply with the following requirements:

(1) The upper limit of the scale of every voltmeter is to be approximately 120% of the normal voltage of the circuit.

(2) The upper limit of the scale of every ammeter is to be approximately 130% of the normal rating of the circuit in which it is installed.

(3) The upper limit of the scale of every wattmeter is to be approximately 120% of the normal rating of the circuit in which it is installed. Ammeters for use with direct current generators operating in parallel and wattmeters for use with alternating current generators operating in parallel are to be capable of indicating 15% reverse current or power respectively.

(4) The frequency meter is to have a scale range of $\pm 10\%$ of the rated frequency.

(5) Ammeters, voltmeters and wattmeters are to be clearly marked on the scale to indicate their rated values.

3.3.4.3 Generator control panels are to be provided at least with the measuring instruments as required in Table 3.3.4.3.

3.3.4.4 The secondary windings of potential and current transformers are to be effectively earthed.

3.3.4.5 At least the following meters are to be provided for battery charging and discharging boards for emergency or transitional sources of power:

(1) voltmeter to measure the charging voltage;

(2) ammeter to measure the charging current.

Measuring Instruments of Generator Control Panel **Table 3.3.4.3**

Generator	Operating condition	Type of instrument	Quantity
DC	Not in parallel	Ammeter	1 for each generator (connected to positive pole)
		Voltmeter	1 for each generator
	In parallel	Ammeter	1 for each generator (connected to positive pole)

Generator	Operating condition	Type of instrument	Quantity
		Voltmeter	2 (1 for measuring the bus-bar voltage, 1 for measuring the voltage of each generator)
AC	Not in parallel	Ammeter	1 for each generator (to be capable of measuring the current in each phase or each line separately)
		Voltmeter	1 for each generator (to be capable of measuring the voltage in each phase or each line separately)
		Wattmeter	1 for each generator (excluding generators rated less than 50 kW (kVA))
		Frequency meter	1 for each generator
		Excitation ammeter	1 for each generator (to be fitted only when necessary)
	In parallel	Ammeter	1 for each generator (to be capable of measuring the current in each phase or each line separately)
		Voltmeter	2 (1 for measuring the voltage in each phase or each line of the generator separately, 1 for measuring the bus-bar voltage)
		Wattmeter	1 for each generator
		Frequency meter	2 (1 for measuring the bus-bar voltage, 1 for measuring the frequency of each generator)
		Synchronous meter	1 for all generators
		Excitation ammeter	1 for each generator (to be fitted only when necessary)

3.3.5 Circuit breakers and switches

3.3.5.1 Circuit breakers are to be designed, manufactured and tested in accordance with IEC Publication 60947-2 or other recognized standards. Circuit breakers are to be of the trip-free type.

3.3.5.2 Circuit breakers and switches are to be so arranged that when in the OFF position, they cannot accidentally move to close the circuit.

3.3.5.3 The protective performance of circuit breakers for generators is to comply with the requirements of 2.5.6 of this PART. The overcurrent trip setting of these circuit breakers is to be adjustable, or if not adjustable, the set values are to be readily replaceable by different ones.

3.3.5.4 Where circuit breakers are operated by a power operating device, a hand operated mechanism is to be provided to operate the circuit breaker in case of failure of the electrical driven gear and is to be operated at the front of panels.

3.3.5.5 The fused circuit breakers are to be so constructed that single phasing does not occur in the event of blowing of fuses and that the fuses can be replaced easily without the risk of accidental touch to their live parts.

3.3.5.6 Durable labels are to be fitted on circuit breakers to indicate their rated voltage, and the rated current and setting of their overcurrent trip devices, etc.

3.3.6 Fuses

3.3.6.1 Fuses are to be designed, manufactured and tested in accordance with IEC Publication 60269 or other recognized standards.

3.3.6.2 Fuses are to be of enclosed type and the construction is to be such that the enclosure is not broken or burnt and the adjacent insulation is not deteriorated by melted metal or emitted gases, when the fuse element has blown out.

3.3.6.3 Fuses are to be easily replaceable for their spare parts without the risk of getting electrical shock or burn on removing and replacing of fuses.

3.3.6.4 When fuses are operating for long periods at rated current, the temperature rise at the terminals is to be such that the maximum permissible operating temperature of the connected cable is not exceeded.

3.3.6.5 Fuses are to be durably marked to indicate their rated voltage, rated current and rated breaking capacity.

3.3.7 Testing

3.3.7.1 Switchboards are to be tested at the manufacturer in accordance with the provisions of 3.3.7.2 to 3.3.7.5 of this Section. However, the test required in 3.3.7.2 may be omitted for batch products of the same type.

3.3.7.2 Switchboards are to be subjected to temperature rise test at the specified load current.

3.3.7.3 Switchboards are to be subjected to functional testing for verifying the function of instruments and switchgear.

3.3.7.4 Switchboards are to be subject to high voltage test as required in Table 3.3.7.4. The test voltage may be applied at any frequency between 25 and 100 Hz and is to be maintained for one minute without breakdown. Instruments and ancillary apparatus may be disconnected during the test.

Test Voltage		Table 3.3.7.4
Rated voltage (V)		Test voltage (V)
$U_n \leq 60$		1,000
$60 < U_n \leq 300$		2,000
$300 < U_n \leq 690$		2,500
$690 < U_n \leq 800$		3,000
$800 < U_n \leq 1,000$		3,500
$1,000 < U_n \leq 1,500^{①}$		3,500

Notes: ① For DC only.

② During testing all semi-conductor component parts are to be disconnected from the circuits to be tested and in the meantime, the measuring instruments, condensers, pilot lamps and other ancillary apparatus may also be disconnected.

③ The test voltage is to be applied between all current carrying parts and earthed enclosure, and between current carrying parts of different polarity or phase.

3.3.7.5 Insulation resistance measurement: Immediately after the high-voltage test, the insulation resistance between all current-carrying parts connected together and earth and between all current-carrying parts of different polarity or phase is not to be less than 1 MΩ, tested at least with a DC 500 V megameter.

Section 4 CONTROL GEAR

3.4.1 General requirements

3.4.1.1 The operating wheels or handles of the control gear are to comply with the following requirements:

- (1) The temperature is not to exceed 55°C for those made of metal, and not to exceed 65°C for those made of insulating material.
- (2) They are to be provided with mechanically locking devices so that their operating positions will not be changed due to shock or vibration.
- (3) They are to be provided with durable labels to indicate their purposes, positions and effect of movement.

3.4.1.2 The hand wheels of the control gear are to be arranged to rotate clockwise to “raise”, “heave anchor”, “haul in rope”, and counterclockwise to “lower”, “drop anchor”, “pay out rope”, if position “0” is the starting point.

The handles of control gear are to be arranged to move forward to “lower”, “drop anchor”, “pay out rope”, and counterclockwise to “raise”, “heave anchor”, “haul in rope”, if position “0” is the starting point.

3.4.1.3 The control gear is to be provided with protective devices complying with the relevant requirements of Section 5, Chapter 2 of this PART.

3.4.1.4 Suitable means are to be provided for the control push buttons against wrong action due to inadvertent touching.

3.4.1.5 Parallel field windings which allow an open circuit are to be provided with discharge circuits to protect against induced overvoltage.

3.4.2 Plans and documents

3.4.2.1 The following plans and documents are to be submitted for approval:

- (1) General plan;
- (2) Detailed drawings of main parts;
- (3) Technical specifications of the products;
- (4) Electrical schematic diagram.

3.4.2.2 The Operation Instructions for the Products is to be submitted for information.

3.4.3 Motor control gear

3.4.3.1 The motor control gear is to be provided with an indicating device to show that the motor is running.

3.4.3.2 The control gear of motors used for various services is also to comply with the relevant requirements of Section 6, Chapter 2 of this PART. The control gear of the steering gear is also to comply with the relevant requirements of Chapter 13, PART THREE of the Rules.

3.4.3.3 The control gear of windlasses, warping winches, and cargo winches is to be provided with a device for emergency disconnection of the circuits.

3.4.3.4 Where windlass motors and warping winch motors have rating equal to or more than 10 kW, their control gears are to be provided with an ammeter to monitor the operating current of the motors, and this ammeter is to be properly illuminated or to be of fluorescent type.

3.4.4 Testing

3.4.4.1 Temperature rise test: Control gear is to be subjected to temperature rise test under normal working conditions. However, for the products of the same type and the same specification, only the first product is required to be tested.

3.4.4.2 Functional test: All control gears are to be subjected to functional testing.

3.4.4.3 High voltage test: The test is to be carried out according to Table 3.3.7.4. The test voltage may be applied at any frequency between 25 and 100 Hz and is to be maintained for one minute without breakdown. Instruments and ancillary apparatus may be disconnected during the test.

3.4.4.4 Insulation resistance test: Immediately after the high voltage test, the insulation resistance is not to be less than 1 MΩ, tested at least with a DC 500 V megameter.

Section 5 CABLES

3.5.1 General requirements

3.5.1.1 Cables are to comply with the requirements of this Section. Those not covered in this Section are to comply with the relevant requirements of acceptable standards^①. Fire-resisting cables are to additionally comply with the relevant requirements for fire-resisting cables of acceptable standards^②.

3.5.1.2 In addition to the standards referred to in 3.5.1.1, cables may be manufactured and tested to other acceptable and relevant international or national standards.

3.5.1.3 Structural drawings and technical specifications of cables are to be submitted for approval.

3.5.2 Conductors

3.5.2.1 Conductors are to be of annealed copper with or without metal coating. The component copper wires are to be metal-coated and the wire surface is to appear smooth, uniform and bright when used for conductors having a thermosetting insulation, unless a separator between the conductor and the insulation is provided. For conductors having thermoplastic insulation, the metal coating may be omitted. The same applies to thermosetting insulation provided suitable type tests demonstrate that no harmful effects occur.

3.5.2.2 Conductor composition and stranding is to be so selected that adequate flexibility of the finished cable is assured. Cores of multi-core cables are to be readily identifiable.

3.5.3 Insulating materials

3.5.3.1 Permitted insulating materials and maximum rated conductor temperatures are to comply with the requirements of 2.12.2.2 of this PART.

3.5.3.2 Cables with different maximum rated conductor temperatures are to be readily identifiable.

3.5.4 Insulation

3.5.4.1 For elastomeric or thermoplastic compound insulation, the use of a single layer of compounds is permitted only when applied by the extrusion process. With other processes the insulation is to consist of at least two layers of compounds equal in quality, and the layers are to be bonded together. The insulating wall is to be close fitting but not adherent to the conductor.

3.5.4.2 Mineral insulation is to consist of powdered mineral material, i.e. magnesium oxide, highly compressed between conductors and copper sheath. It is to be temperature-stable and non-corrosive to copper.

3.5.5 Construction

① Refer to IEC publications 60092-350, 60092-351, 60092-352, 60092-353, 60092-354, 60092-359, 60092-373, 60092-374, 60092-375 and 60092-376.

② Refer to:

IEC publication 60331-1 for testing electric cables of greater than 20 mm overall diameter;

IEC publication 60331-21 or 60331-2 for testing electric cable of up to 20 mm overall diameter;

IEC publication 60331-23 for testing electric data cables;

IEC publication 60331-25 for testing optical fibre cables.

3.5.5.1 Regardless of the insulating material used, the belted or non-belted construction may be used for cables having two, three and more cores.

3.5.5.2 For non-belted cables, the clearances between cores are to be filled with fibrous or rubber-like fillers and the cylindrical assembly is to be sheathed with an appropriate protective covering. Fillers may be omitted in multi-core cables having conductor sections of 4.5 mm² or less. Alternatively, elastomeric or thermoplastic insulated cables may have a compatible compound extruded over the cable cores so as to form, in one body, the fillers and a continuous covering similar to a sheath.

3.5.5.3 Belted cables are to be constructed as non-belted cables, except that an insulating wall is to be applied to the cable cores before applying the protective covering. For elastomeric or thermoplastic insulated cables, the common belt is to be elastomeric or thermoplastic respectively, which may or may not form one body with the fillers.

3.5.5.4 When fibrous fillers are used they are to consist of jute or similar rovings (including glass filament, etc.) and are to be resistant to moisture.

3.5.5.5 When rubber-like fillers are used they are to consist of rubber (including regenerated and/or unvulcanized rubber) compounds or plastic compounds.

3.5.6 Sheaths and protective coverings

3.5.6.1 Cables are to be protected by one or more of the following, and the sheath or protective covering is to be compatible with the insulation:

(1) Sheath:

- Lead alloy sheath;
- Copper sheath;
- Non-metallic sheath.

(2) Protective covering:

- Steel wire armour
- Steel tape armour;
- Metal braid armour;
- Impregnated fibrous braid.

3.5.6.2 Copper sheath is permitted only for mineral-insulated cables.

3.5.6.3 Metal braid armour is to be made of galvanized steel, copper or copper alloy, or aluminium alloy wires. Aluminium alloy is to be corrosion resistant. The coverage density of the braid is to be such that the weight of the braid is at least 90% of the weight of a tube of the same metal, having an internal diameter equal to the internal diameter under the braid and a thickness equal to the nominal diameter of the wires forming the braid.

3.5.6.4 Steel wire armour is to consist of galvanized annealed steel wires having an elongation at break of at least 12%. The wires are to be applied over the bedding to form a uniform and cylindrical layer and to ensure a sufficient flexibility for the finished cable.

3.5.6.5 Steel tape armour is to be made of annealed steel tapes. In general, the armour is to be formed of two tapes wound over the bedding in the same direction so that the gap in the first layer is not more than half the tape width and the second layer covers this gap with an overlap.

3.5.6.6 Armour is to be protected against corrosion where necessary. A protective bedding is to be inserted beneath armour (of any type). This may be textile tape or braid, chloroprene rubber tape or other suitable material. Textile materials are to be treated against moisture.

3.5.6.7 Polychloroprene, polyvinyl chloride compound and chlorosulphonated polyethylene may be used for non-metallic impervious sheath. Other compounds will be considered.

3.5.6.8 Textile braid is to be of cotton, hemp, glass filament, or other equivalent fibre, and is to be of a strength suitable for the size of the cable. It is to be effectively impregnated with a compound which is resistant to moisture, and flame retardant.

3.5.7 Testing

3.5.7.1 Tests in accordance with the relevant acceptable standards^① are to be made at the manufacturer prior to delivery.

Section 6 POWER AND LIGHTING TRANSFORMERS

3.6.1 General requirements

^① Refer to IEC Publication 60092 or relevant standards.

3.6.1.1 The requirements of this Section apply to single phase transformers rated at 1 kVA or more and 3-phase transformers rated at 5 kVA or more.

3.6.1.2 All transformers, except those used for motor starting, are to be double wound or multi wound, with no electrical connection between primary and secondary windings.

3.6.1.3 In general, transformers are to be of dry air-cooled type. The use of liquid-filled transformers is to comply with the following requirements:

(1) Liquid fillings for transformers are to be non-toxic and of a type which does not readily support combustion. Such transformers are to have a pressure release device with an alarm and there is to be a suitable means provided to contain any liquid which may leak from the transformer due to the operation of the release device or damage to the tank.

(2) Where forced liquid cooling is used, there is to be temperature monitoring of the cooling medium and transformer windings with an alarm being given when the temperature exceeds a preset limit, and provision is to be made for reducing the load to a level commensurate with the cooling available.

3.6.1.4 Transformers rated at 50 kVA and over are to be inspected by CCS Surveyors during testing and where necessary, during manufacturing.

3.6.2 Plans and documents

3.6.2.1 The following plans and documents are to be submitted for approval:

- (1) General plan;
- (2) Detailed drawings of main parts including coils, magnetic cores and connection boxes;
- (3) Technical specifications of the products.

3.6.2.2 The following plans and documents are to be submitted for information:

- (1) Operation instructions for the products;
- (2) External wiring diagram.

3.6.3 Voltage regulation

3.6.3.1 The voltage drop of transformers supplying secondary distribution systems from no load to rated load at resistive load is not to exceed the following:

- (1) 2.5% for single phase transformers rated more than 5 kVA or 3-phase transformers rated more than 15 kVA;
- (2) 5% for single phase transformers rated up to 5 kVA or 3-phase transformers rated up to 15 kVA.

3.6.4 Temperature rise

3.6.4.1 The temperature rise of transformers at any part is not to exceed the values given in Table 3.6.4.1 during continuous operation at rated output, where the ambient air temperature is based on 45°C.

Part of transformer		Limit of temperature rise (K)	Method of measurement
Windings	Class A insulation	55	Resistance method
	Class E insulation	70	
	Class B insulation	75	
	Class F insulation	95	
	Class H insulation	120	
External surface of the magnetic core and structural components		Not to exceed the permissible temperature rise of the insulating material in contact	Thermometer or thermocouple

3.6.5 Short-circuits

3.6.5.1 All transformers are to be capable of withstanding, without damage, the thermal and mechanical effects of a short-circuit at the terminals of any winding for 2 s.

3.6.6 Tests

3.6.6.1 The tests in 3.6.6.2 to 3.6.6.6 of this Section are at least to be carried out to all transformers at the manufacturer. However, the test required in 3.6.6.2 may only be carried out to the first product for batch products of the same type and specification.

3.6.6.2 Temperature rise test: Transformers are to be tested for temperature rise at rated output. The limits of temperature rise are not to exceed the values given in Table 3.6.4.1.

3.6.6.3 High voltage test^{①②}: Transformers are to be subjected to high voltage test according to Table 3.6.6.3, applying a test voltage between primary and secondary windings and between windings and the earthed enclosure for 1 min without breakdown and flashover.

Voltage of High Voltage Test**Table 3.6.6.3**

Highest voltage (root-mean-square value) kV	Rated short duration power frequency withstand voltage (root-mean-square value) kV
≤ 1.1	3
3.6	10
7.2	20
12.0	28
17.5	38
24.0	50
36.0	70

3.6.6.4 Induced high voltage test: Transformers are to withstand an induced high voltage test with a voltage twice the rated voltage. The duration of the test is to be 1 min with a frequency less than or equal to twice the rated frequency. If the frequency is greater than twice the rated frequency, the duration of the test is to be obtained from the following formula with a minimum of 15 s:

$$t = \frac{60 \times 2 \times \text{rated frequency}}{\text{test frequency}} \text{ s}$$

For transformers subject to temperature rise test, the induced high voltage test is to be carried out immediately after the temperature rise test.

3.6.6.5 Insulation resistance test: The insulation resistance of each winding to earth is to be measured, with all other windings, magnetic core, frame and casing or enclosure connected together to earth, and recorded together with the temperature of the transformer at the test.

3.6.6.6 Voltage regulation test: Transformers are to be subjected to voltage regulation test and the requirements of 3.6.3.1 of this Section are to be complied with. If the test is impracticable at the manufacturer, it may be waived, subject to agreement of CCS.

3.6.6.7 Short-circuit test: Short-circuit test is to be carried out as necessary and in accordance with the requirements of 3.6.5.1 of this Section.

Section 7 STORAGE BATTERIES

3.7.1 General requirements

3.7.1.1 This Section is applicable to the permanently installed batteries.

3.7.2 Plans and documents

3.7.2.1 The following plans and documents are to be submitted for approval:

- (1) General plan;
- (2) Detailed drawings of main parts including enclosures and pole plates;
- (3) Technical specifications of the products.

3.7.2.2 The Operation Instructions for the Products is to be submitted for information.

3.7.3 Type

3.7.3.1 Storage batteries used on board ships may be of lead-acid or nickel-alkaline type. Other types of batteries are not to be put on board ships without agreement of CCS.

3.7.4 Construction

3.7.4.1 All pole plates are to be of rigid construction, and are to be designed to reduce the shedding of active material to a minimum. The cells are to be so constructed as to prevent spilling of electrolyte due to an inclination of 40° from the normal, and to prevent emission of acid or alkaline spray.

3.7.4.2 The cells are to be grouped in crates or trays of rigid construction and suitable material and equipped with means to facilitate handling. The weight of the assembled batteries is preferably not to exceed 100 kg.

① For transformers subject to temperature rise test, the high voltage test is to be carried out immediately after the temperature rise test.

② The high voltage test is in general not to be repeated, but if it is necessary, one additional test is permitted to be carried out with a test voltage equal to 75% of the voltage at the first test.

This requirement does not apply to the cells the assembly of which in the above-mentioned crates or trays is impossible due to their weight.

3.7.4.3 Emergency accumulator batteries are to be so designed and arranged as to ensure that they will function at full rated power when the ship is upright or when inclined at any angle of list up to 22.5° or when inclined up to 10° either way in the fore or aft direction, or is in any combination of angles within those limits.

3.7.5 Nameplate

3.7.5.1 Each crate or tray is to be provided with a durable nameplate securely attached, indicating the manufacturer's name, type designation and date of delivery, the ampere-hour rating at a specific rate of discharge (preferably that corresponding to the duty for the specific application 5 h, 10 h or 20 h rating) and the relative density of the electrolyte (when the battery is fully charged in the case of a lead-acid battery).

Section 8 POWER SEMICONDUCTOR CONVERTORS

3.8.1 General requirements

3.8.1.1 This Section is applicable to power semiconductor convertors using semiconductor rectifying elements such as diodes, reverse blocking triode thyristors etc., and does not apply to convertors for communication and the ancillary apparatus for instrumentation. The conversion may be from AC to DC, from DC to AC, from DC to DC and from AC to AC.

3.8.1.2 Unless otherwise specified by the manufacturer, the maximum permissible junction temperature of the rectifier cells is not to exceed the following values:

Selenium diodes:	70°C;
Silicon diodes:	150°C;
Silicon thyristor:	100°C (up to 50 A); 125°C (more than 50 A).

3.8.1.3 Semiconductor convertors are preferably to be of the dry air-cooled type.

3.8.1.4 Liquid-filled semiconductor convertors are preferably to be hermetically sealed. If provision is made for breathing, suitable desiccants are to be provided.

3.8.1.5 Transformers used in combination with semiconductor convertors are to be of two-winding transformers and are to comply with the relevant requirements of Section 6 of this Chapter.

3.8.1.6 Semiconductor convertors or semiconductor components are to be mounted in such a manner that they may be removed from a unit without dismantling the complete unit.

3.8.1.7 Mercury-based fungicides are not to be used in the vicinity of the selenium rectifiers.

3.8.2 Plans and documents

3.8.2.1 The following plans and documents are to be submitted for approval:

- (1) General plan;
- (2) Electrical schematic diagram;
- (3) Technical specifications of the products.

3.8.2.2 The following plans and documents are to be submitted for information:

- (1) External wiring diagram;
- (2) Specification list of associated electrical appliances;
- (3) Operation instructions for the products.

3.8.3 Protection

3.8.3.1 Where forced cooling is provided, the circuit is to be so designed that the convertor cannot remain in operation unless effective cooling is maintained.

3.8.3.2 Semiconductor convertors are to be capable of withstanding the effects of transient over-voltage from the ship's network and the effects of DC voltage rise due to regenerated power.

3.8.3.3 Semiconductor convertors are to be protected against overload and short-circuit in accordance with the requirements of 2.5.14.1 of this PART.

3.8.3.4 For liquid-filled semiconductor convertors, consideration is to be given to the provision of an alarm for excessive liquid temperature and of pneumatic protection devices.

3.8.4 Testing

3.8.4.1 Semiconductor convertors are to be tested at the manufacturer in accordance with the requirements of 3.8.4.2 to 3.8.4.5 of this Section. However, the test required in 3.8.4.2 may be omitted for the products produced in series.

3.8.4.2 Semiconductor convertors are to be subjected to temperature rise test under normal working conditions.

3.8.4.3 Semiconductor convertors are to be subjected to functional test.

3.8.4.4 Semiconductor convertors are to withstand a high voltage test at the following testing voltage (with a minimum of 2,000 V):

$$U_p = 2 \times \frac{U_m}{\sqrt{2}} + 1000 \quad \text{V}$$

where: U_p — the effective value of testing voltage, in V;

U_m — the maximum no-load peak value between any pair of terminals of semiconductor convertors. If the voltage to earth is higher than the voltage between two terminals (e.g. the convertors are connected in series), the higher voltage, in V, is to be taken.

If $U_m/\sqrt{2}$ is less than 90 V, U_p is to be taken as 1,000 V.

This testing voltage is to be alternating at any frequency between 25 and 100 Hz and is to be applied between the live parts and any non-current carrying metal part which may be earthed for a period of 1 min without breakdown or flashover.

3.8.4.5 The insulation resistance between live parts of convertors or their accessories and earth is not to be less than 1 MΩ when tested with a DC 500 V megameter.

Section 9 UNINTERRUPTIBLE POWER SYSTEM

3.9.1 Application

3.9.1.1 The UPS^① units, to which this Section applies, may provide an alternative power supply or transitional power supply, in lieu of independent accumulator batteries, to services as defined in 2.2.2.1(3) and 2.2.3.1(4) of Chapter 2 of this PART.

3.9.2 Plans and documents

3.9.2.1 The following plans and documents are to be submitted for approval:

- (1) General plan;
- (2) Electrical schematic diagram;
- (3) Technical specifications of the products.

3.9.2.2 The following plans and documents are to be submitted for information:

- (1) External wiring diagram;
- (2) Specifications of associated electrical appliances;
- (3) Operation instructions for the products.

3.9.3 Design and construction

3.9.3.1 UPS units are to be constructed in accordance with IEC 62040, or an acceptable a standard.

3.9.3.2 The operation of the UPS is not to depend upon external services.

3.9.3.3 The type of UPS unit employed, whether off-line, line interactive or on-line, is to be appropriate to the power supply requirements of the connected load equipment.

3.9.3.4 An external bypass is to be provided.

3.9.3.5 The UPS unit is to be monitored and audible and visual alarm is to be given in a normally attended location for:

- (1) power supply failure (voltage and frequency) to the connected load;
- (2) earth fault;
- (3) operation of battery protective device;
- (4) when the battery is being discharged; and
- (5) when the bypass is in operation for on-line UPS units.

3.9.4 Performance

3.9.4.1 The output power is to be maintained for the duration required for the connected equipment as stated in 2.2.2.1(3) and 2.2.3.1(4) of Chapter 2 of this PART.

3.9.4.2 No additional circuits are to be connected to the UPS unit without verification that the UPS unit has adequate capacity. The UPS battery capacity is, at all times, to be capable of supplying the designated loads for the time specified in Chapter 2 of this PART.

① Refer to IEC publication 62040.

3.9.4.3 On restoration of the input power, the rating of the charge unit is to be sufficient to recharge the batteries while maintaining the output supply to the load equipment.

3.9.5 Testing and survey

3.9.5.1 UPS units of 50 kVA and over are to be surveyed by CCS Surveyors during manufacturing and testing.

3.9.5.2 Appropriate testing is to be carried out to demonstrate that the UPS unit is suitable for its intended environment. This is expected to include as a minimum the following tests:

- (1) Functionality, including operation of alarms;
- (2) Temperature rise;
- (3) Ventilation rate;
- (4) Battery capacity.

3.9.5.3 Where the supply is to be maintained without a break following a power input failure, this is to be verified after installation by practical test.

Section 10 OTHER ELECTRICAL EQUIPMENT

3.10.1 Incandescent lighting

3.10.1.1 The voltage and load of tungsten filament lamps and lampholders are not to exceed the values specified in Table 3.10.1.1.

Voltage and Load of Tungsten Filament Lamps

Table 3.10.1.1

Type of lampholders		Voltage (V)	Load
Bayonet cap	B22	250	200W/4A
	B15d	250	15W/2A
	B15s	55	15W/2A
Screw cap	E40	250	3,000W/16A
	E27	250	200W/4A
	E14	250	15W/2A

3.10.1.2 Lampholders are to be constructed of flame-retarding and non-hygroscopic material. All metal parts are to be of robust construction. E40 lampholders are to be provided with means for locking the lamp in the holder.

3.10.1.3 The lighting fittings are to be so constructed that the temperature of the incoming cables will not exceed the maximum rated conductor temperature given in Table 2.12.2.2 of this PART.

3.10.2 Discharge lamps operating at voltages below 250 V

3.10.2.1 All independent ballasts, capacitors and other auxiliaries mounted separately are to be enclosed in an earthed metal casing.

3.10.2.2 Capacitors of 0.5μF and above are to be provided with a means of prompt discharge on disconnection of the supply.

3.10.2.3 The voltage and load of the fluorescent lamps and lampholders are not to exceed the values specified in Table 3.10.2.3.

Voltage and Load of Fluorescent Lamps

Table 3.10.2.3

Type of lampholders	Voltage (V)	Load (W)
G13	250	80
G5	250	13

3.10.2.4 The construction of fluorescent lamp holders is to comply with the requirements of 3.10.1.2 of this Section.

3.10.3 Discharge lamps operating at voltages above 250 V

3.10.3.1 Discharge lamps are to be of robust construction.

3.10.3.2 All live parts are to be so designed, placed and installed that they cannot be touched accidentally or inadvertently, and the creepage distance along the discharge tube is to be taken into consideration.

3.10.3.3 Transformers for discharge lamps are to have their primary and secondary windings electrically separated and are not to contain flammable liquid.

3.10.3.4 The transformers is to be placed within the discharge lamp or located as closely as possible to the lamp.

3.10.3.5 Warning notices calling attention to “DANGER! HIGH VOLTAGE!” are to be provided in accordance with 2.7.1.3 of this PART.

3.10.4 Heating and cooking appliances

3.10.4.1 Heating elements are to be substantially guarded. The holes of the protective guard are to be sufficiently narrow to prevent foreign bodies from falling in.

3.10.4.2 Heating and cooking appliances are to be so constructed that the temperature of supply cable terminals will not exceed the maximum rated conductor temperature given in Table 2.12.2.2 of this PART.

3.10.4.3 Internal connection wires of heating and cooking appliances are to be continuously insulated with incombustible material. Connections between heating elements are not to be effected by soldering.

3.10.4.4 The insulation resistance of heating and cooking appliances in hot condition is not to be less than 0.5 MΩ.

3.10.4.5 Heating and cooking appliances are to be so constructed that the parts which must be hand-held in use cannot be heated to a temperature exceeding the values given in Table 3.10.4.5.

Maximum Temperature of Hand-Held Parts **Table 3.10.4.5**

Material of handles, grips and the like	Maximum temperature for normal hand-held operation (°C)	
	Long period	Short period
Metal	55	60
Porcelain, vitreous material, moulded material, rubber or wood	65	70

3.10.4.6 Heating and cooking appliances and their control gear fitted in galley spaces are to have a degree of protection of at least IP44. Their enclosures are to be corrosion-resistant and provided with one or more drainage holes.

3.10.4.7 Cooking appliances are to be so constructed that spilling or overflowing of liquid or food will not cause insulation failures or short-circuits.

3.10.4.8 Space heaters are to be so constructed, protected and installed that clothing, bedding or other combustible materials cannot come in contact with them in such a manner as to cause risk of fire. Furthermore, they are to be so constructed that combustible materials cannot be placed on the top of their enclosures.

3.10.4.9 Space heaters are to be equipped with means to interrupt the current when the temperature exceeds the permissible limit.

3.10.5 Accessories

3.10.5.1 Accessories are to be so designed and constructed that the passages for the insulated conductors are of ample size and free from rough projections, sharp angles, and abrupt bends. All outlets for cables are to have well-rounded edges or be suitably bushed.

3.10.5.2 Accessories are to be so designed and insulated conductors so installed that stress cannot be applied by the conductors to any terminal to which the conductors may be connected.

3.10.5.3 Accessories are to be so designed and fixed that dust and moisture will not readily accumulate on live parts and their insulation.

3.10.5.4 Enclosures are to be made of metal or flame-retardant insulating material.

3.10.5.5 The construction of plugs and socket outlets is to comply with the following requirements:

(1) The temperature rise of the live parts of plugs and socket outlets is not to exceed 30°C.

(2) They are to be so constructed that the live parts cannot be touched by the operator when the plug is being inserted in, and that it is impossible to insert only one pin of the plug into the socket outlet.

(3) They cannot be readily short-circuited whether the plug is in or out, and a pin of the plug cannot be made to earth either pole of the socket outlet.

(4) Plugs and socket outlets operating at a voltage exceeding 50 V are to be provided with a pin and jack for earthing connection. The cross section and length of the earthing pin of the plug are to be greater than those of other pins.

(5) Plugs and sockets operating at different voltages and/or frequencies are to be of different types.

3.10.5.6 Socket outlets of current rating in excess of 16 A are to be interlocked with a switch such that the plug cannot be inserted or withdrawn when the switch is in the “on” position.

3.10.5.7 Socket outlets and plugs with protection degree of IP56 are to be provided with means to maintain the same degree of protection whether the plug is inserted or withdrawn.

CHAPTER 4 SUPPLEMENTARY REQUIREMENTS FOR SMALL SHIPS AND SHIPS IN RESTRICTED SERVICE

Section 1 GENERAL PROVISIONS

4.1.1 General requirements

4.1.1.1 The requirements of this Chapter apply to electrical installations on the following ships, and may substitute for the related aforesaid requirements in this PART:

- (1) ships with the class notation of Category 1 service or engaged in an equivalent service;
- (2) ships with the class notation of Category 2 service or engaged in an equivalent service;
- (3) ships with the class notation of Category 3 service or engaged in an equivalent service;
- (4) cargo ships of less than 500 gross tonnage.

Section 2 SHIPS IN CATEGORY 1 SERVICE

4.2.1 Earth indicator

4.2.1.1 For ships of less than 1,600 gross tonnage other than those carrying dangerous goods such as tankers carrying dangerous liquid cargoes, an earth indicator may be used instead of an alarm device for monitoring the insulation level to earth as required in 2.4.2.2 of this PART.

Section 3 SHIPS IN CATEGORIES 2 & 3 SERVICES

4.3.1 General requirements

4.3.1.1 Paragraph 4.2.1.1 of this Chapter is applicable.

4.3.2 Main source of electrical power

4.3.2.1 At least one generating set is to be provided in domestic cargo ships in category 3 service.

4.3.2.2 At least one generating set is to be provided in domestic passenger ships in category 3 service where the auxiliary machineries serving the main engine, steering gear oil pumps, fire pumps and bilge pumps are driven by the main engine.

4.3.3 Emergency source of electrical power

4.3.3.1 For domestic ships in categories 2 & 3 services, the period of power supply of the emergency source of electrical power as required in 2.2.2.1 and 2.2.3.1(2) to 2.2.3.1(5) of this PART may be reduced to:

- (1) category 2 service: 6 h for passenger ships and 3 h for cargo ships;
- (2) category 3 service: 3 h for passenger ships and 3 h for cargo ships.

4.3.3.2 For domestic ships in category 3 service, the emergency source of electrical power as required in Section 2, Chapter 2 of this PART may not be fitted provided that an independent reserve power source in compliance with the following requirements is fitted.

(1) The reserve power source is to be the accumulator battery in compliance with the following requirements:

- ① located not in the same space as the main source of electrical power and located above the uppermost continuous deck as far as practicable;
- ② complying with the requirements of 2.2.1.4(1), (2) and 1.2.1.1(2) of this PART;
- ③ capable of providing immediately power supply for any equipment as required in 4.3.3.3(2) of this Section.

(2) The capacity of the reserve power source is to be sufficient to supply the following equipment for at least 3 h:

- ① lighting at muster and embarkation stations, over the sides, in all alleyways, stairways and exits, in cabins accommodating more than 16 persons, and at the main switchboard, reserve power source and control stations;
- ② navigation lights and other signal lights as required in the International Regulations for Preventing Collisions at Sea;
- ③ internal communication equipment required in emergency;
- ④ fire detection and fire alarm system (if any);

- ⑤ daylight signalling lamp, the ship's whistle, the manually operated call points (if any) in intermittent operation and all internal signals that are required in an emergency (e.g. general emergency alarm system, etc.);
- ⑥ radio communications on board.

4.3.4 Transformer

4.3.4.1 Requirements of 2.1.3.1(1) and (2) of this PART may not be met for domestic cargo ships in category 3 service.

Section 4 CARGO SHIPS OF LESS THAN 500 GROSS TONNAGE

4.4.1 General requirements

4.4.1.1 Paragraphs 4.2.1.1 and 4.3.3 of this Chapter are applicable.

4.4.2 Distribution systems

4.4.2.1 In addition to the distribution systems as referred to in 2.4.1.1 of this PART, an AC three-phase four-wire insulated system may be used.

4.4.3 Main source of electrical power

4.4.3.1 The minimum comfortable conditions of habitability as required in 2.1.1.1(2) of this PART may not be complied with.

4.4.3.2 The requirements in 2.1.1.1(4) and (5) of this PART may not be complied with.

4.4.3.3 Distribution boards are not required to be positioned in accordance with 2.1.4.1 of this PART.

4.4.4 Reserve sources of electrical power

4.4.4.1 The emergency source of electrical power as required in Section 2, Chapter 2 of this PART may not be fitted provided that an independent reserve power source in compliance with the following requirements is fitted.

(1) The reserve power source is to be the accumulator battery in compliance with the following requirements:

- ① located not in the same space as the main source of electrical power and located above the uppermost continuous deck as far as practicable;
- ② complying with the requirements of 2.2.1.4(1), (2) and 1.2.1.1(2) of this PART;
- ③ capable of providing immediately power supply for any equipment as required in 4.4.4.1(2) of this Section.

(2) The capacity of the reserve power source is to be sufficient to supply the following equipment for at least 3 h:

- ① lighting at muster and embarkation stations, over the sides, in all alleyways, stairways and exits, in cabins accommodating more than 16 persons, and at the main switchboard, reserve power source and control stations;
- ② navigation lights and other signal lights as required in the International Regulations for Preventing Collisions at Sea;
- ③ internal communication equipment required in emergency;
- ④ fire detection and fire alarm system (if any);
- ⑤ daylight signalling lamp in intermittent operation, the ship's whistle, the manually operated call points (if any) and all internal signals that are required in an emergency (e.g. general emergency alarm system, etc.);
- ⑥ radio communications on board.

4.4.5 Supply of control box for navigation lights

4.4.5.1 The control box of navigation lights may be supplied by the main switchboard and the reserve power source.

APPENDIX 1 SHORT-CIRCUIT CURRENTS CALCULATIONS WITH REGARD TO ELECTRICAL INSTALLATIONS

1.1 General Provisions

1.1.1 General requirements

1.1.1.1 This Appendix applies to the calculation of three-phase short-circuit currents that occur on a marine AC electrical installation and short-circuit power factors. The value of a two-phase short-circuit current may be taken as 0.866 times the corresponding value of a three-phase short-circuit current.

1.1.1.2 The calculation methods are for use on unmeshed low and high voltage three-phase alternating current systems operating at 50 Hz or 60 Hz, and having their neutral point connected to the ship's hull through an impedance, or having their neutral point isolated from the ship's hull.

1.1.1.3 The calculating methods described produce sufficiently accurate results to calculate the short-circuit current during the first 100 ms of a fault condition. The results of calculation may be used for:

- (1) checking short-circuit making and breaking capacity of the protection devices selected;
- (2) checking electrodynamic stability and thermal equilibrium of bus-bars etc.;
- (3) providing the basis for design and setting of electrical system protection;
- (4) providing the basis for the selection, if necessary, of suitable devices capable of limiting short-circuit currents within the capacity of protective devices.

1.1.1.4 When calculating the maximum short-circuit current, the following are to be considered in the most severe condition, i.e. the condition corresponding to the fully loaded generating plant of ships or offshore installations:

- (1) All short-circuit currents fed through generators which may be connected in parallel to the main bus-bar (including the generators transferring load in short time).
- (2) All short-circuit currents fed through motors which may be put into service.

1.1.1.5 In general, the short-circuit current is to be calculated at:

- (1) output of generators;
- (2) main bus-bars;
- (3) bus-bars of emergency switchboards, sub-switchboards and distribution boards;
- (4) secondary side of power and lighting transformers.

Sometimes, feeder terminal short-circuit currents are additionally to be calculated for design and setting of electrical system protection.

1.1.1.6 The manufacturers are to provide the characteristic parameters of generators, motors, transformers and cables as needed by the calculations and ensure that the parameters are within sufficiently accurate.

1.1.2 Definitions

1.1.2.1 Short-circuit

The accidental or intentional connection, by a relatively low resistance or impedance, of two or more points in a circuit, which are normally at different voltages.

1.1.2.2 Short-circuit current

An over-current resulting from a short circuit due to a fault or an incorrect connection in an electric circuit without any change of the supply.

1.1.2.3 Prospective short-circuit current (with respect to a switching device)

The short-circuit current that would flow in the circuit if each pole of the device were replaced by a conductor of negligible impedance.

1.1.2.4 Symmetrical short-circuit current

The r.m.s. value of the AC symmetrical component of a prospective (available) short-circuit current, the DC component, if any, being neglected.

1.1.2.5 DC component of the short-circuit current

The component of current in the circuit immediately after it has been suddenly short-circuited, all components of fundamentals and harmonics being excluded.

1.1.2.6 Peak short-circuit current

The maximum possible instantaneous value of the prospective (available) short-circuit current.

1.1.2.7 Equivalent generator

In order to calculate short-circuit currents, individual generators and motors in service are combined to form an equivalent generator, the short-circuit current fed through which is equivalent to the sum of the short-circuit currents fed through such generators and motors.

1.1.2.8 Equivalent motor

In order to simplify the calculation of short-circuit currents, individual motors in service, other than large motors, are combined to form an equivalent motor, the short-circuit current fed through which is equivalent to the sum of the short-circuit currents fed through such motors.

1.1.2.9 Large motor

Any motor rated more than 100 kW or 25% of the rated power of the maximum generator in the system.

1.1.3 Symbols, Subscripts and superscripts

1.1.3.1 General requirements

(1) The symbols, subscripts and superscripts specified in 1.1.3.2 and 1.1.3.3 below are used and uniform units provided in this Appendix.

(2) In case of impedance, reactance, resistance and voltage drops, capital letters denote absolute values and lowercase letters denote relative values (per unit or per cent).

(3) For time-dependent values (current, voltage), capital letters denote r.m.s. values and lowercase letters denote momentary (instantaneous) values.

1.1.3.2 Symbols

(1) Voltage symbols are given in Table 1.1.3.2(1).

Voltage Symbols

Table 1.1.3.2(1)

Symbol	Name	Unit
E''_{q0}	Subtransient q-axis voltage of a generator	V
E'_{q0}	Transient q-axis voltage of a generator	V
E''_M	Subtransient voltage of a motor	V
U_r	Rated voltage (line to line)	V
U_{rM}	Rated voltage of a motor	V
U_{rT2}	Rated line voltage at the secondary side of a transformer	V
u_K	Rated short circuit voltage of a transformer in %.	%
u_R	Rated ohmic voltage of a transformer in %	%
u_x	Rated ohmic voltage of a transformer in %	%

(2) Current symbols are given in Table 1.1.3.2(2).

Current Symbols

Table 1.1.3.2(2)

Symbol	Name	Unit
I''_{kd}, I'_{kd}	Subtransient and transient short-circuit current of a synchronous generator (r.m.s.)	kA
I''_*, I'_*	Subtransient and transient short-circuit current of an equivalent generator (r.m.s.)	kA
I_*	Current of an equivalent generator (r.m.s.)	kA
I''_M, I''_{M*}	Subtransient short-circuit current of a asynchronous motor and an equivalent motor (r.m.s.)	kA
I_{ac}	Symmetrical short-circuit current at the fault point (r.m.s.)	kA
I_{acG}	Symmetrical short-circuit current of a synchronous generator (r.m.s.)	kA
I_{acM}	Symmetrical short-circuit current of a asynchronous motor (r.m.s.)	kA
i_{dc}	DC component of the short-circuit current at the fault point	kA
i_{dcG}	DC component of the short-circuit current of a synchronous generator	kA
i_{dcM}	DC component of the short-circuit current of an asynchronous motor	kA
i_K	Upper envelope of the short-circuit current	kA
I_{K*}	Steady state short-circuit current of an equivalent generator (r.m.s.)	kA
I_{kd}	Steady state short-circuit current of a synchronous machine (r.m.s.)	kA
i_M	Upper envelope of the short-circuit current of a asynchronous motor	kA
i_{pG}	Peak value of the short-circuit current of a synchronous machine	kA
i_{pM}	Peak value of the short-circuit current of an asynchronous motor	kA
i_p	Peak value of the short-circuit current at the fault point	kA
I_r	Rated current (r.m.s.)	kA
I_{ac2}	Symmetrical short-circuit current at the secondary side of a transformer (r.m.s.)	kA
i_{K2}	Upper envelope of the short-circuit current at the secondary side of a transformer	kA
i_{p2}	Peak value of the short-circuit current at the secondary side of a transformer	kA
I_{CR}	Rated short-circuit breaking capacity of a circuit breaker, as given	kA
I_{Cr}	Rated short-circuit breaking capacity of a circuit breaker, as converted	kA

(3) Symbols of reactance, resistance and impedance are given in Table 1.1.3.2(3).

Symbols of Reactance, Resistance and Impedance		Table 1.1.3.2(3)
Symbol	Name	Unit
R	Resistance	mΩ
r	Cable resistance per unit length	mΩ/m
R_*	Stator resistance of an equivalent generator	mΩ
R_g	Stator resistance of a synchronous generator	mΩ
R_M	Resistance of an asynchronous motor	mΩ
R_R	Rotor resistance of an asynchronous motor as converted to the stator side	mΩ
R_{R*}	Rotor resistance of an equivalent asynchronous motor as converted to the stator side	mΩ
R_S	Stator resistance of an asynchronous motor	mΩ
R_{S*}	Stator resistance of an equivalent asynchronous motor	mΩ
R_T	Resistance of a transformer	mΩ
X	Reactance	mΩ
x	Cable reactance per unit length	mΩ/m
X''_*, X'_*	Subtransient and transient reactance of an equivalent generator	mΩ
X''_d, X'_d	Subtransient and transient reactance of a synchronous generator in the d-axis	mΩ
X''_M	Subtransient reactance of an asynchronous motor	mΩ
X''_{M*}	Subtransient reactance of an equivalent asynchronous motor	mΩ
X_R	Rotor reactance of an asynchronous motor as converted to the stator side	mΩ
X_S	Stator reactance of an asynchronous motor	mΩ
X_d	Reactance of a synchronous generator in the d-axis	mΩ
X_T	Reactance of a transformer	mΩ
Z	Impedance	mΩ
Z_*	Equivalent impedance	mΩ
Z''_d, Z'_d	Subtransient and transient impedance of a synchronous generator	mΩ
Z''_*, Z'_*	Subtransient and transient impedance of an equivalent generator (including circuit impedance)	mΩ
Z''_M	Subtransient impedance of an asynchronous motor	mΩ
Z''_{M*}	Subtransient impedance of an equivalent asynchronous motor	mΩ
Z_T	Impedance of a transformer	mΩ
R_{e1}	Primary cable resistance of a transformer	mΩ
R_{e2}	Cable resistance at the secondary side of a transformer as converted to the primary side	mΩ
X_{e1}	Primary cable reactance of a transformer	mΩ
X_{e2}	Cable reactance at the secondary side of a transformer as converted to the primary side	mΩ

(4) Symbols of time and time constants are given in Table 1.1.3.2(4).

Symbols of time and time constants		Table 1.1.3.2(4)
Symbol	Name	Unit
t	Time duration from the beginning of a short circuit	ms
t_x	Defined time duration from the beginning of a short circuit	ms
T''_d, T'_d	Subtransient and transient time constant of a synchronous generator in the d-axis	ms
T''_{d*}, T'_{d*}	Subtransient and transient time constant of an equivalent generator in the d-axis	ms
T''_e, T'_e	Subtransient and transient time constant of a synchronous generator including non-active components	ms
T''_M, T'_{M*}	Subtransient time constant of an asynchronous motor and an equivalent asynchronous motor	ms
T''_{Me}	Subtransient time constant of an asynchronous motor including the connecting cables	ms
T_{dc}, T_{dc*}	DC time constant of a synchronous generator and an equivalent generator	ms
T_{dce}	DC time constant of a synchronous generator including non-active components	ms
T_{dcM}, T_{dcM*}	DC time constant of an asynchronous motor and an equivalent asynchronous motor	ms
T_{dcMe}	DC time constant of an asynchronous motor including the connecting cables	ms

(5) Power symbols are given in Table 1.1.3.2(5).

Power Symbols		Table 1.1.3.2(5)
Symbol	Name	Unit
S_{rG}	Rated apparent power of a synchronous generator	kVA
P_{rG}	Rated power of a synchronous generator	kW
P_{rM}	Rated output power of an asynchronous motor	kW
P_{rM*}	Rated output power of an equivalent asynchronous motor	kW
S_{rT}	Rated apparent power of a transformer	kVA
P_K	Short circuit losses of a transformer	kW

(6) Other symbols are given in Table 1.1.3.2(6).

Other Symbols		Table 1.1.3.2(6)
Symbol	Name	Unit
$\cos \varphi_K$	Power factor of a short circuit	
$\cos \varphi_r$	Rated power factor of a generator	
$\cos \varphi_M$	Rated power factor of an asynchronous motor	
η_M	Efficiency of an asynchronous motor	
a	Number of parallel cables	
A_i	Fault point at the power end of a generator breaker	
B_i	Fault point adjacent to the main bus-bar	
C_i	Fault point in the feeder circuit of primary distribution system outside the main bus-bar	
D_i	Fault point at the secondary side of a transformer	
e	Radix of exponential	
f	Frequency	Hz
l	Cable length	m
n	Coefficient of peak value	
S	Sectional area of cable	mm ²
T	Period	ms
CB	Circuit breaker	
FU	Fuse	

1.1.3.3 Subscripts and superscripts

(1) Symbols of subscripts are given in Table 1.1.3.3(1).

Symbols of Subscripts		Table 1.1.3.3(1)
Symbol	Meaning	
*	Equivalent generator and equivalent asynchronous motor	
0	Prefault condition	
a	Armature	
ac	Alternating current	
d	Direct axis	
dc	Direct current	
e	Value including non-active components (external)	
$\underline{E}, \underline{I}, \underline{U}$	phasor of E, I and U	
G	Synchronous generator	
i	Number of generators	
j	Number of motors	
K	Short circuit	
M	Asynchronous motor or group of asynchronous motors	
q	Quadrature-axis	
R	Rotor of an asynchronous motor	
S	Stator of an asynchronous motor	
T	Transformer	
$\underline{Z}$	Complex impedance	

(2) Symbols of superscripts are given in Table 1.1.3.3(2).

Symbols of Superscripts		Table 1.1.3.3(2)
Symbol	Meaning	
"	Subtransient value	
,	Transient value	

1.2 Calculation of Short-circuit Currents

1.2.1 Basic assumptions

1.2.1.1 The formulae described herein, calculate the upper envelope of the maximum value of the time dependent short-circuit current (see Figure 1.2.2.2). The envelope is calculated using particular machine characteristic parameters obtainable from equipment manufacturers using recognized testing methods, and applying the following assumptions:

- (1) all system capacitances are neglected;
- (2) at the start of the short circuit, the instantaneous value of voltage in one phase at the fault point is zero;
- (3) during the short circuit, there is no change in the short-circuit current path;
- (4) the short-circuit arc impedance is neglected. The impedance of the bus-bar, potential transformer (PT) and the contact resistance of the connecting points between the conductors are also neglected;
- (5) transformers are set at the main tap position;
- (6) the short circuit occurs simultaneously in all three phases;
- (7) in the prefault condition, the generator is operated at its rated values of load;
- (8) for generators connected in parallel, all generators share their active and reactive load proportionally at the start of and during the short circuit;
- (9) during each discrete time interval, all circuit components react linearly.

With the above assumptions, the calculation results are considered to be acceptable for the engineering objectives.

1.2.2 Calculation of the short-circuit current fed through a synchronous machine

1.2.2.1 General

(1) The synchronous machines used on marine/offshore electrical installations comprise synchronous generators, motors and condensers. The short-circuit currents produced by these machines are fundamental to the calculation of the short-circuit current of an electrical system.

During the first few cycles of a short circuit, all synchronous machines respond in a similar way and accordingly the short-circuit current produced has the same basic characteristics.

(2) Equivalent electrical circuit

When the three-phase terminal short-circuit current of a synchronous generator occurs, the equivalent electrical circuit under subtransient and transient conditions are as shown in Figure 1.2.2.1.

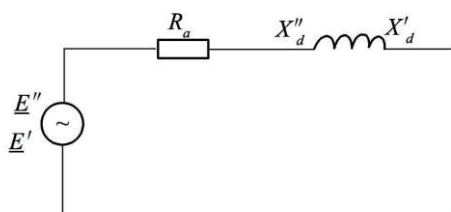
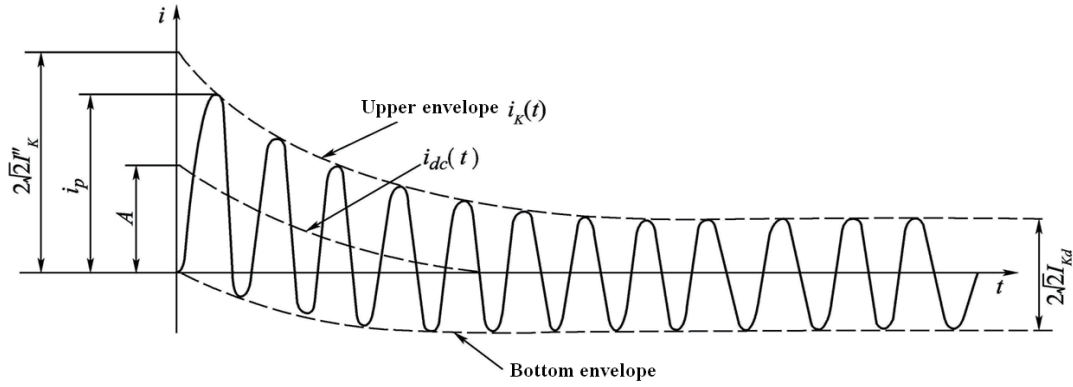


Figure 1.2.2.1 Equivalent Electrical Circuit of the Three-Phase Terminal Short-Circuit Current of a Synchronous Generator

1.2.2.2 Three-phase short-circuit current

(1) The three-phase short-circuit current condition occurs when all three phase are simultaneously shorted together. The resulting current is a complex time-dependent function occurring in each phase. The time-dependent oscillogram of the typical three-phase terminal short-circuit current of a synchronous generator is shown in Figure 1.2.2.2. The current consists of a synchronous short-circuit current (AC components) and DC components.



I_K'' – Initial symmetrical short-circuit current; i_p – Peak short-circuit current; I_{Kd} – Steady-state short-circuit current;

i_{dc} – Decaying (aperiodic) component of short-circuit current; A – Initial value of the aperiodic component

Figure 1.2.2.2 Terminal Short-Circuit Current Time Function of a Typical Synchronous Generator on No-Load

1.2.2.3 Calculation of the short-circuit current

(1) When calculating the short-circuit current, it is usual to consider only the highest values of the current, Figure 1.2.2.2 shows that the highest values vary as a function of time along the upper envelope of the complex time-dependent function. The current $i_K(t)$ defined by this upper envelope is calculated from formula (1):

$$i_K(t) = \sqrt{2}I_{ac}(t) + i_{dc}(t) \quad (1)$$

(2) The calculation of symmetrical short-circuit current $I_{ac}(t)$

$I_{ac}(t)$ may be calculated using the following formulae:

$$I_{ac}(t) = (I_{Kd}'' - I_{Kd}') \cdot e^{-t/T_d''} + (I_{Kd}' - I_{Kd}) \cdot e^{-t/T_d'} + I_{Kd} \quad (2)$$

$$I_{Kd}'' = \frac{E_{q0}''}{Z_d''} = \frac{E_{q0}''}{\sqrt{R_a^2 + X_d''^2}} \quad (3)$$

$$I_{Kd}' = \frac{E_{q0}'}{Z_d'} = \frac{E_{q0}'}{\sqrt{R_a^2 + X_d'^2}} \quad (4)$$

$$E_{q0}'' = \sqrt{\left(\frac{U_r}{\sqrt{3}} \cos \varphi_r + R_a \cdot I_r\right)^2 + \left(\frac{U_r}{\sqrt{3}} \sin \varphi_r + X_d'' \cdot I_r\right)^2} \quad (5)$$

$$E_{q0}' = \sqrt{\left(\frac{U_r}{\sqrt{3}} \cos \varphi_r + R_a \cdot I_r\right)^2 + \left(\frac{U_r}{\sqrt{3}} \sin \varphi_r + X_d' \cdot I_r\right)^2} \quad (6)$$

(3) I_{Kd} is the steady-state short-circuit current and to be obtained from the manufacturer.

(4) The calculation of the DC component $i_{dc}(t)$

$i_{dc}(t)$ may be calculated from the following formula (7):

$$i_{dc}(t) = \sqrt{2}(I_{Kd}'' - I_r \cdot \sin \varphi_r) \cdot e^{-t/T_{dc}} \quad (7)$$

(5) The calculation of the peak value i_p of the short-circuit current

The peak value of the short-circuit current occurs between time $t = 0$ and $t = T/2$ of the short-circuit condition. The exact time depends on the preload conditions, the generator impedance and time constants. In general, it is acceptable to calculate i_p at time $T/2$, i.e. at the first half cycle of the short-circuit condition, using formula (8):

$$i_p = \sqrt{2}I_{ac}\left(\frac{T}{2}\right) + i_{dc}\left(\frac{T}{2}\right) \quad (8)$$

1.2.3 Calculation of the short-circuit current fed through a asynchronous motor

1.2.3.1 General

(1) Quite a number of asynchronous motors are fitted on ships and offshore installations, which can be considered in two broad groups, i.e. large motors and small motors. The grouping depends upon both the system generator capacity and the actual motor rating.

(2) When a short circuit occurs on a system, all motors connected at instant of short circuit, contribute to the short-circuit current. In general large motors must be evaluated individually. Small motors may be grouped together and treated as an equivalent single source.

1.2.3.2 Equivalent electrical circuit

(1) Where the three-phase terminal short-circuit current of an asynchronous motor occurs, the equivalent electrical circuit is as shown in Figure 1.2.3.2.

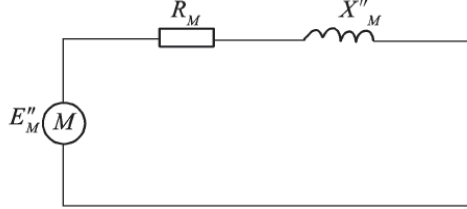


Figure 1.2.3.2 Equivalent Electrical Circuit of the Three-Phase Terminal Short-Circuit Current of an Asynchronous Motor

1.2.3.3 Basic calculation of three-phase short-circuit currents

(1) The upper envelope $i_M(t)$ of the maximum values of the three-phase short-circuit current of an asynchronous motor may be obtained from the following formula:

$$i_M(t) = \sqrt{2}I_{acM}(t) + i_{dcM}(t) \quad (9)$$

(2) The calculation of the symmetrical short-circuit current $I_{acM}(t)$

$I_{acM}(t)$ may be obtained from formula (10):

$$I_{acM}(t) = I_M'' \cdot e^{-t/T_M''} \quad (10)$$

If the preload condition is ignored, I_M'' may be obtained from the formula (11):

$$I_M'' = \frac{U_{rM}}{\sqrt{3} \cdot \sqrt{(R_R + R_S)^2 + (X_R + X_S)^2}} = \frac{U_{rM}}{\sqrt{3} \cdot \sqrt{R_M'^2 + X_M''^2}} \quad (11)$$

(3) Where the of preload condition is ignored, the DC component $i_{dcM}(t)$ and the peak value i_{pM} of the short-circuit may be obtained from formulae (12) and (13) respectively:

$$i_{dcM}(t) = \sqrt{2}I_M'' \cdot e^{-t/T_{dcM}} \quad (12)$$

$$i_{pM} = \sqrt{2}I_{acM}\left(\frac{T}{2}\right) + i_{dcM}\left(\frac{T}{2}\right) \quad (13)$$

1.2.3.4 Calculation of the short-circuit current of large motors

(1) For large motors defined in 1.1.2.9, the terminal short-circuit current is to be calculated using respectively the calculation methods given in 1.2.3.3.

(2) If insufficient motor data are available, the following approximate values for the motor characteristic parameters may be used:

① Motor impedance (for both 50 Hz and 60 Hz installations)

$$z_M'' = 0.16$$

$$x_M'' = 0.15$$

$$r_s = 0.034$$

$$r_R = 0.021$$

② Time constants

$$\text{At 50 Hz, } T_M'' = 22.4 \text{ ms, } T_{dcM} = 14.08 \text{ ms}$$

$$\text{At 60 Hz, } T_M'' = 18.67 \text{ ms, } T_{dcM} = 11.73 \text{ ms}$$

1.2.3.5 Calculation of the short-circuit current of small motors

(1) Comparatively speaking, except large motors involved in 1.2.3.4(1), all other motors fitted on ships or offshore installations belong to small motors. The total motor group including their connecting cables may be considered as a single equivalent motor and if insufficient motor data are available, the following approximate values for the motor characteristic parameters may be used:

① Motor impedance (for both 50 Hz and 60 Hz installations)

$$z_M'' = 0.2$$

$$x_M'' = 0.188$$

$$r_S = 0.043$$

$$r_R = 0.027$$

② Time constants

$$\text{At 50 Hz, } T_M'' = 22.4 \text{ ms, } T_{dcM} = 14.08 \text{ ms}$$

$$\text{At 60 Hz, } T_M'' = 18.67 \text{ ms, } T_{dcM} = 11.73 \text{ ms}$$

(2) The rated output of the equivalent motor may be calculated in accordance with the Electrical Load Calculations or may be taken as 60% of the total rated active output of actually running generators (excluding those transferring loads in short time) minus the sum of the rated outputs of individual large motors.

1.2.4 Effects of non-active component impedances on short-circuit currents

1.2.4.1 General

(1) In actual electrical systems, the cables, transformers and reactors connected in series with synchronous motors and asynchronous motors are to be also taken into account. Although these components do not feed the short-circuit current, they have a significant impact on the value of the short-circuit current. In general, the net effect is a lower value of short-circuit current which decays more slowly.

1.2.4.2 Effects on short-circuit current of generators

(1) Non-active component impedances R_e and X_e are taken into account by increasing the impedance of the active components, and in formulae (3) and (4) Z_d'' and Z_d' are to be replaced by Z_e'' and Z_e' where

$$Z_e'' = \sqrt{(R_a + R_e)^2 + (X_d'' + X_e)^2} \quad (14)$$

$$Z_e' = \sqrt{(R_a + R_e)^2 + (X_d' + X_e)^2} \quad (15)$$

For steady-state short-circuit currents accordingly:

$$Z_e = \sqrt{(R_a + R_e)^2 + (X_d + X_e)^2} \quad (16)$$

However, the effects of the cable impedance on steady-state short-circuit currents between the generator and the main switchboard near the main bus-bar may be ignored.

(2) Time constants T_d'', T_d' and T_{dc} are also changed and become T_e'', T_e' and T_{dce}

$$T_e'' = \frac{[(R_a + R_e)^2 + (X_d'' + X_e)^2] \cdot X_d' \cdot T_d''}{[(R_a + R_e)^2 + (X_d'' + X_e)(X_d' + X_e)] \cdot X_d''} \quad (17)$$

$$T_e' = \frac{[(R_a + R_e)^2 + (X_d' + X_e)^2] \cdot X_d \cdot T_d'}{[(R_a + R_e)^2 + (X_d' + X_e)(X_d + X_e)] \cdot X_d'} \quad (18)$$

$$T_{dce} = \frac{T_{dc} + 1000X_e / (2\pi f R_a)}{1 + R_e / R_a} \quad (19)$$

1.2.4.3 Effects on short-circuit current of motors

(1) The impedance is increased and in formula (11) R_M and X_M'' are to be replaced by R_{Me} and X_{Me}'' where

$$R_{Me} = R_R + R_S + R_e \quad (20)$$

$$X_{Me}'' = X_R + X_S + X_e \quad (21)$$

(2) Time constant changes

The subtransient time constant:

$$T_{Me}'' = \frac{1000X_{Me}''}{2\pi f R_R} \quad (22)$$

The DC time constant:

$$T_{dcMe}'' = \frac{1000X_{Me}''}{2\pi f (R_S + R_e)} \quad (23)$$

1.2.5 Calculation of short-circuit currents at the main bus-bar

1.2.5.1 General

(1) Owing to neglecting the contact resistance between bus-bars, mutual inductors and conductors, the short circuits within the main bus-bar in the main switchboard are regarded as the short circuit at the main bus-bar.

1.2.5.2 Calculation of the short-circuit current

(1) With the assumption that a ship's electrical system is provided with i generators and j motors connected in parallel to the main bus-bar, the maximum short-circuit current at the main bus-bar is to be calculated as follows:

- ① First, the short-circuit current fed through each individual generator and motor is to be calculated in accordance with the requirements of 1.2.2, 1.2.3 and 1.2.4 of this Appendix.
- ② The maximum short-circuit current at the main bus-bar is to be the algebraic sum of short-circuit currents of individual generators and motors, i.e.:

$$I_{ac}(t) = \sum_i I_{acG}(t)_i + \sum_j I_{acM}(t)_j \quad (24)$$

$$i_{dc}(t) = \sum_i i_{dcG}(t)_i + \sum_j i_{dcM}(t)_j \quad (25)$$

$$i_K(t) = \sum_i i_{KG}(t)_i + \sum_j i_{KM}(t)_j \quad (26)$$

1.2.6 Calculation of the short-circuit current at the feeder circuit outside the main bus-bar

1.2.6.1 Application of the equivalent generator

(1) In order to calculate the short-circuit current at the feeder outside the main bus-bar, all generators and motors, which feed the short-circuit current to fault points, are to be combined to form an equivalent generator at the point of common connection (at the main bus-bar). The short-circuit current fed through the equivalent generator is equal to the sum of the short-circuit currents fed through individual generators and motors.

1.2.6.2 Determination of the characteristic parameters of an equivalent generator

(1) As mentioned above, the short-circuit current fed through the equivalent generator at the main bus-bar is correspondingly equal to the sum of the short-circuit currents fed through individual generators and motors, i.e.:

$$I_{ac}(t)_* = \sum_i I_{acG}(t)_i + \sum_j I_{acM}(t)_j \quad (27)$$

$$i_{dc}(t)_* = \sum_i i_{dcG}(t)_i + \sum_j i_{dcM}(t)_j \quad (28)$$

$$I''_* = \sum_i I''_{Kdei} + \sum_j I''_{Mej} \quad (29)$$

$$I'_* = \sum_i I'_{Kdei} \quad (30)$$

$$I_{K*} = \sum_i I_{Kdei} \quad (31)$$

(2) As in the case of a single generator, the time function $I_{ac}(t)_*$ of the symmetric short-circuit current of the equivalent generator is corresponding to formula (2) as follows:

$$I_{ac}(t)_* = (I''_* - I'_*) \cdot e^{-t/T''_{d*}} + (I'_* - I_{K*}) \cdot e^{-t/T'_{d*}} + I_{K*} \quad (32)$$

Assuming

$$M_* = I''_* - I'_*$$

$$N_* = I'_* - I_{K*}$$

formula (32) may be rewritten as:

$$I_{ac}(t)_* = M_* \cdot e^{-t/T''_{d*}} + N_* \cdot e^{-t/T'_{d*}} + I_{K*} \quad (33)$$

(3) Determination of equivalent generator subtransient time constant T''_{d*}

Ignoring the transient decay of the short circuit of the generator, the time-dependent function $K''(t)$ of the symmetric short-circuit current for each generator may be expressed as follows:

$$K''(t) = (I''_{Kd} - I'_{Kd}) \cdot e^{-t/T''_d} + I'_{Kd} \quad (34)$$

For the equivalent generator accordingly:

$$K''(t)_* = M_* \cdot e^{-t/T''_{d*}} + I'_{K*} \quad (35)$$

The following is obtained from formulae (27) and (10):

$$K''(t)_* = \sum_i K''(t)_i + \sum_j I''_{Mj} \cdot e^{-t/T''_M} \quad (36)$$

$K''(t_x)_*$ may be obtained using formula (36) where $t = t_x$, then:

$$T''_{d*} = \frac{-t_x}{\ln[(K''(t_x)_* - I'_{K*}) / M_*]} \quad (37)$$

(4) Determination of equivalent generator transient time constant T'_{d*}

The symmetric short-circuit current fed through the equivalent generator may be calculated using formula (33) where $t = t_x$:

$$I_{ac}(t_x)_* = M_* \cdot e^{-t_x/T'_{d*}} + N_* \cdot e^{-t_x/T_{d*}} + I_{K*} \quad (38)$$

Similarly, $I_{ac}(t_x)_*$ may be obtained as follows:

$$I_{ac}(t_x)_* = \sum_i I_{acG}(t_x)_i + \sum_j I_{acM}(t_x)_j \quad (39)$$

Accordingly T'_{d*} may be obtained from:

$$T'_{d*} = \frac{-t_x}{\ln\{[I_{ac}(t_x)_* - (M_* \cdot e^{-t_x/T_{d*}} + I_{K*})]/N_*\}} \quad (40)$$

(5) Determination of DC time constant T_{dc*}

The DC component of the short-circuit current fed through the equivalent generator for $t = t_x$ may be calculated as follows:

$$i_{dc}(t_x)_* = \sqrt{2}I''_* \cdot e^{-t_x/T_{dc*}} \quad (41)$$

and $i_{dc}(t_x)_*$ may be calculated also as follows:

$$i_{dc}(t_x)_* = \sum_i i_{dcG}(t_x)_i + \sum_j i_{dcM}(t_x)_j \quad (42)$$

Accordingly T_{dc*} may be calculated from:

$$T_{dc*} = \frac{-t_x}{\ln[i_{dc}(t_x)_*/(\sqrt{2}I''_*)]} \quad (43)$$

(6) Determination of impedances

Where the preload condition is ignored, the equivalent generator impedance may be obtained as follows:

$$R_* = \frac{1000X''_*}{2\pi f T_{dc*}} \quad (44)$$

Assuming $C = \frac{1000}{2\pi f T_{dc*}},$

Hence

$$R_* = CX''_*$$

$$Z''_* = U_r / (\sqrt{3}I''_*) \quad (45)$$

$$Z'_* = U_r / (\sqrt{3}I'_*) \quad (46)$$

$$Z_* = U_r / (\sqrt{3}I_*) \quad (47)$$

Hence:

$$X''_* = \frac{Z''_*}{\sqrt{1+C^2}} \quad (48)$$

$$X'_* = \sqrt{Z'^2_* - R_*^2} \quad (49)$$

$$X_* = \sqrt{Z_*^2 - R_*^2} \quad (50)$$

1.2.6.3 Calculation of the short-circuit current at the feeder outside the main bus-bar

(1) First, characteristic parameters of an equivalent generator at the main bus-bar are to be obtained in accordance with the above-mentioned requirements of 1.2.6.2. Then the short-circuit current at any point on the feeder outside the main bus-bar may be calculated in accordance with the requirements of 1.2.2 and 1.2.4.

(2) When the short-circuit current at the feeder of a large motor is calculated, the impact of the motor may not be taken into account.

1.2.6.4 Calculation of the short-circuit current at secondary side of transformers

(1) This belongs to one of the cases of the short circuit at the feeder outside the main bus-bar, only the transformer impedance is considered as one part of the circuit impedance (for impedance calculation see 1.4.2), and the changes of the transformer impedance are to be also considered.

1.2.7 Simplified calculation of short-circuit currents

1.2.7.1 Synchronous machines

(1) If the stator resistance is unavailable it may be ignored in formulae (3), (4), (5) and (6). For a short-circuit current calculated at the terminals of a machine, the result will be higher but well within acceptable tolerances. For system calculations, the error is negligible.

(2) If the preload condition, I_0 , is ignored, i.e. assuming a generator on no load in formulae (5), (6), (7) and (8), the values of E''_{q0} and E'_{q0} may be assumed to be equal to $U_r / \sqrt{3}$, and results in lower calculated value (generally less than 10%).

(3) If the transient AC component decay is ignored, formula (2) becomes:

$$I_{ac}(t) = (I''_{kd} - I'_{kd}) \cdot e^{-t/T_d'} + I'_{kd} \quad (51)$$

Excessive inaccuracies occur in the peak short-circuit current for formula (51). Such inaccuracies will invalidate any results calculated beyond the first half-cycle of the fault condition, and accordingly this approximation is not recommended when time-dependent calculations are required.

(4) If the short-circuit current decay is ignored and stator resistance and preload current are ignored for the terminal short-circuit, the AC component of the short-circuit current may be assumed to be a ratio of a constant voltage divided by constant subtransient reactance and the DC component as a proportional constant, i.e.:

$$I_{ac} = U_r / \sqrt{3} X_d'' \quad (52)$$

$$i_p = \sqrt{2} I_{ac} + i_{dc} = 1.8(\sqrt{2} I_{ac}) \quad (53)$$

These assumptions are only to be made when estimating approximate values, as the results will produce excessive positive errors for calculations required beyond the first 0.5 cycles.

1.2.7.2 Asynchronous motors

(1) As a first approximation, it may be assumed that all asynchronous motors connected at the time of the short-circuit, contribute an AC short-circuit current equal to their starting current (usually 4 to 7 times the machine's normal full load current).

It may also be assumed that the motor contribution is constant throughout the complete short-circuit fault period.

Such assumptions will give higher values of short-circuit currents than will occur on the actual installation. The error will depend upon the number and size of motors connected.

(2) As above mentioned in 1.2.3.3(2) of this Appendix, if the preload condition is ignored when the short-circuit current of motors is calculated, the preload motor condition can be neglected with negligible errors.

(3) On the basis of asynchronous motor characteristic parameters given in 1.2.3.4(2) and 1.2.3.5(1) of this Appendix, the short-circuit current fed through the motor, with a short circuit occurring near the main bus-bar, may be calculated as follows:

① Large motors:

$$I_M'' = 6.25 I_{rM}$$

$$I_{acM} = 4.00 I_{rM} \text{ (for } t = T/2 \text{)}$$

$$i_{pM} = 10 I_{rM}$$

② Small motors:

$$I_M'' = 5 I_{rM}$$

$$I_{acM} = 3.2 I_{rM} \text{ (for } t = T/2 \text{)}$$

$$i_{pM} = 8 I_{rM}$$

(4) If insufficient data is available, the motor rated current may be evaluated using the following formula:

$$I_{rM} = \frac{P_{rM}}{\sqrt{3} \cdot U_{rM} \cdot \eta_M \cdot \cos \varphi_M} \quad (54)$$

where $\eta_M \cdot \cos \varphi_M$ may be calculated from the following formula:

$$\eta_M \cdot \cos \varphi_M = 0.76$$

(5) The short-circuit current of asynchronous motor designed to work in limited service, whose parameters are not completely known, may be calculated assuming the motor is in continuous service and operating at reduced power.

1.3 Calculation of Circuit Power Factor

1.3.1 General

1.3.1.1 The rated short-circuit breaking capacity of the circuit breaker is related to the short-circuit power factor for the interruption of power in the circuit, and the power factor of a short circuit near the main bus-bar on marine and offshore AC electrical installations is generally less than those used for circuit breaker short-circuit tests. Therefore, the short-circuit power factor is to be calculated and if necessary, the short-circuit breaking capacity of the selected breaker is to be converted in accordance with the conversion coefficient provided by the manufacturer. If insufficient data are available, the method given in Appendix B of this Appendix can be used for conversion (not applicable to the circuit breaker with time delay).

1.3.2 Calculation of short-circuit power factor

1.3.2.1 For the short-circuit at a certain point in way of the feeder outside the main bus-bar, the short-circuit power factor during subtransient periods may be calculated using formula (55):

$$\cos \varphi_K = \frac{R_* + R_e}{\sqrt{(R_* + R_e)^2 + (X_* + X_e)^2}} \quad (55)$$

1.3.2.2 For the short-circuit near the main bus-bar, the short-circuit power factor during subtransient periods may be calculated in accordance with formula (55), but $R_e = 0$ and $X_e = 0$ are to be taken.

1.4 Calculation and Conversion for Reactance, Resistance and Impedance

1.4.1 Conversion for generator/motor reactance and resistance

1.4.1.1 Conversion for generator reactance and resistance

(1) Conversion for subtransient reactance acting in the direct axis is as follows:

$$X_d'' = x_d'' \frac{U_r}{\sqrt{3}I_{rG}} = x_d'' \frac{U_r^2}{S_{rG}} \quad (56)$$

(2) Transient reactance acting in the direct axis:

$$X_d' = x_d' \frac{U_r}{\sqrt{3}I_{rG}} = x_d' \frac{U_r^2}{S_{rG}} \quad (57)$$

(3) Conversion for stator resistance:

$$R_a = r_a \frac{U_r}{\sqrt{3}I_{rG}} = r_a \frac{U_r^2}{S_{rG}} \quad (58)$$

1.4.1.2 Conversion for motor resistance and reactance

(1) Conversion for motor subtransient resistance and reactance:

$$X_M'' = x_M'' \frac{U_{rM}}{\sqrt{3}I_{rM}} = x_M'' \frac{U_{rM}^2 \cdot \eta_M \cdot \cos \varphi_M}{P_{rM}} \quad (59)$$

$$R_s = r_s \frac{U_{rM}}{\sqrt{3}I_{rM}} = r_s \frac{U_{rM}^2 \cdot \eta_M \cdot \cos \varphi_M}{P_{rM}} \quad (60)$$

$$R_R = r_R \frac{U_{rM}}{\sqrt{3}I_{rM}} = r_R \frac{U_{rM}^2 \cdot \eta_M \cdot \cos \varphi_M}{P_{rM}} \quad (61)$$

1.4.2 Calculation and conversion for transformer reactance, resistance and impedance

1.4.2.1 Calculation and conversion for transformer reactance and resistance may be carried out using the following formulae:

$$Z_T = u_K \frac{U_r^2}{S_{rT}} \quad (62)$$

$$R_T = P_K \frac{U_r^2}{S_{rT}^2} \quad (63)$$

$$X_T = \sqrt{Z_T^2 - R_T^2} \quad (64)$$

$$R_T = r_T \frac{U_r^2}{S_{rT}} = u_R \frac{U_r^2}{S_{rT}} \quad (65)$$

$$X_T = x_T \frac{U_r^2}{S_{rT}} = u_X \frac{U_r^2}{S_{rT}} \quad (66)$$

1.4.3 Calculation for cable resistance and reactance

1.4.3.1 Cable reactance and resistance can be calculated using the following formulae:

$$R = rl / a \quad (67)$$

$$X = xl / a \quad (68)$$

Appendix A Examples of Calculation

A.1 The diagrammatic sketch of an electrical system

A.1.1 The diagrammatic sketch of an electrical system indicating the position of each fault point is as shown in Figure A.1.1

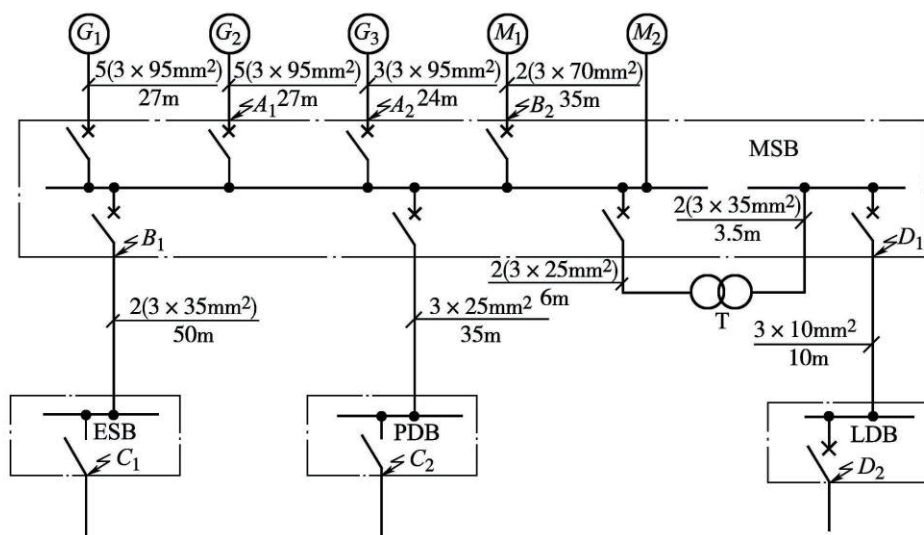


Figure A.1.1 Diagrammatic Sketch of Electrical System

A.2 Parameters for calculation

A.2.1 Generator parameters for calculation are given in Table A.2.1.

Generator Parameters			Table A.2.1
Code	G_1, G_2	G_3	
Type	IFC5502-8TA42	IFC5354-4	
S_{rG} (kVA)	550	312.5	
U_r (V)	400	400	
I_{rG} (kA)	0.79	0.451	
f (Hz)	50	50	
x''_d	0.112	0.099	
x'_d	0.193	0.17	
x_d	2.19	3.16	
r_a	0.0178	0.0174	
T''_d (ms)	3	3	
T'_d (ms)	80	49	
T_{dc} (ms)	22	20	
I_{Kd} (kA)	2.4	1.40	

A.2.2 Transformer parameters for calculation are given in Table A.2.2.

Transformer Parameters		Table A.2.2
Code	T	
Type	CSGD-100	
S_{rT} (kVA)	100	
U_{rT2} (V)	230	
u_K (%)	3.5	
P_K (kW)	2.0	

A.2.3 Motor parameters for calculation are given in Table A.2.3.

Motor Parameters

Table A.2.3

Code	M ₁	M ₂ (Equivalent motor)
P_{rM} (kW)	120	408
U_{rM} (V)	380	380
r_R	0.021	0.027
r_S	0.034	0.043
x''_M	0.15	0.188
T''_M (ms)	22.4	22.4
T_{dcM} (ms)	14.076	14.076

A.3 Calculation of the short-circuit current fed through the generator where the short-circuit occurs at the main bus-bar

A.3.1 Calculation of the impedance of cables connecting the generator to the main bus-bar

G_1, G_2 :

$$\begin{aligned} R_e &= rl / a = 0.215 \times 27 \div 5 = 1.161 & \text{m}\Omega \\ X_e &= xl / a = 0.0809 \times 27 \div 5 = 0.437 & \text{m}\Omega \end{aligned}$$

G_3 :

$$\begin{aligned} R_e &= rl / a = 0.215 \times 24 \div 3 = 1.72 & \text{m}\Omega \\ X_e &= xl / a = 0.0809 \times 24 \div 3 = 0.647 & \text{m}\Omega \end{aligned}$$

A.3.2 Calculation of generator reactance and resistance

G_1, G_2 :

$$\begin{aligned} X''_d &= x''_d \cdot \frac{U_{rG}^2}{S_{rG}} = \frac{0.112 \times 160000}{550} = 32.582 & \text{m}\Omega \\ X'_d &= x'_d \cdot \frac{U_{rG}^2}{S_{rG}} = \frac{0.193 \times 160000}{550} = 56.145 & \text{m}\Omega \\ X_d &= x_d \cdot \frac{U_{rG}^2}{S_{rG}} = \frac{2.19 \times 160000}{550} = 637.09 & \text{m}\Omega \\ R_e &= r_a \cdot \frac{U_{rG}^2}{S_{rG}} = \frac{0.0178 \times 160000}{550} = 5.18 & \text{m}\Omega \end{aligned}$$

G_3 :

$$\begin{aligned} X''_d &= x''_d \cdot \frac{U_{rG}^2}{S_{rG}} = \frac{0.099 \times 160000}{312.5} = 50.688 & \text{m}\Omega \\ X'_d &= x'_d \cdot \frac{U_{rG}^2}{S_{rG}} = \frac{0.17 \times 160000}{312.5} = 87.04 & \text{m}\Omega \\ X_d &= x_d \cdot \frac{U_{rG}^2}{S_{rG}} = \frac{3.16 \times 160000}{312.5} = 1617.92 & \text{m}\Omega \\ R_a &= r_a \cdot \frac{U_{rG}^2}{S_{rG}} = \frac{0.0174 \times 160000}{312.5} = 8.909 & \text{m}\Omega \end{aligned}$$

A.3.3 Calculation of generator phase electromotive forces E''_{q0} and E'_{q0}

G_1, G_2 :

$$\begin{aligned} E''_{q0} &= \sqrt{\left(\frac{U_r}{\sqrt{3}} \cos \varphi_r + R_a I_r\right)^2 + \left(\frac{U_r}{\sqrt{3}} \sin \varphi_r + X''_d I_r\right)^2} \\ &= \sqrt{\left(\frac{400 \times 0.8}{\sqrt{3}} + 5.18 \times 0.79\right)^2 + \left(\frac{400 \times 0.6}{\sqrt{3}} + 32.582 \times 0.79\right)^2} \\ &= 250.314 \text{ V} \\ E'_{q0} &= \sqrt{\left(\frac{U_r}{\sqrt{3}} \cos \varphi_r + R_a I_r\right)^2 + \left(\frac{U_r}{\sqrt{3}} \sin \varphi_r + X'_d I_r\right)^2} \\ &= \sqrt{\left(\frac{400 \times 0.8}{\sqrt{3}} + 5.18 \times 0.79\right)^2 + \left(\frac{400 \times 0.6}{\sqrt{3}} + 56.145 \times 0.79\right)^2} \\ &= 262.908 \text{ V} \end{aligned}$$

G_3 :

$$\begin{aligned}
 E_{q0}'' &= \sqrt{\left(\frac{U_r}{\sqrt{3}} \cos \varphi_r + R_a I_r\right)^2 + \left(\frac{U_r}{\sqrt{3}} \sin \varphi_r + X_d'' I_r\right)^2} \\
 &= \sqrt{\left(\frac{400 \times 0.8}{\sqrt{3}} + 8.909 \times 0.451\right)^2 + \left(\frac{400 \times 0.6}{\sqrt{3}} + 50.688 \times 0.451\right)^2} \\
 &= 248.377 \text{ V} \\
 E_{q0}' &= \sqrt{\left(\frac{U_r}{\sqrt{3}} \cos \varphi_r + R_a I_r\right)^2 + \left(\frac{U_r}{\sqrt{3}} \sin \varphi_r + X_d' I_r\right)^2} \\
 &= \sqrt{\left(\frac{400 \times 0.8}{\sqrt{3}} + 8.909 \times 0.451\right)^2 + \left(\frac{400 \times 0.6}{\sqrt{3}} + 87.04 \times 0.451\right)^2} \\
 &= 259.332 \text{ V}
 \end{aligned}$$

A.3.4 Calculation of generator short-circuit currents

1 Calculations of $I_{Kde}'', I_{Kde}', T_e'', T_e'$ and T_{dce}

(1) I_{Kde}'' and I_{Kde}'

G_1, G_2 :

$$\begin{aligned}
 I_{Kde}'' &= \frac{E_{q0}''}{\sqrt{(R_a + R_e)^2 + (X_d'' + X_e)^2}} \\
 &= \frac{250.314}{\sqrt{(5.18 + 1.161)^2 + (32.582 + 0.437)^2}} \\
 &= 7.445 \text{ kA} \\
 I_{Kde}' &= \frac{E_{q0}'}{\sqrt{(R_a + R_e)^2 + (X_d' + X_e)^2}} \\
 &= \frac{262.908}{\sqrt{(5.18 + 1.161)^2 + (56.145 + 0.437)^2}} \\
 &= 4.618 \text{ kA}
 \end{aligned}$$

G_3 :

$$\begin{aligned}
 I_{Kde}'' &= \frac{E_{q0}''}{\sqrt{(R_a + R_e)^2 + (X_d'' + X_e)^2}} \\
 &= \frac{248.377}{\sqrt{(8.909 + 1.72)^2 + (50.688 + 0.647)^2}} \\
 &= 4.738 \text{ kA} \\
 I_{Kde}' &= \frac{E_{q0}'}{\sqrt{(R_a + R_e)^2 + (X_d' + X_e)^2}} \\
 &= \frac{259.332}{\sqrt{(8.909 + 1.72)^2 + (87.04 + 0.647)^2}} \\
 &= 2.936 \text{ kA}
 \end{aligned}$$

(2) T_e'', T_e' and T_{dce}

G_1, G_2 :

$$\begin{aligned}
 T_e'' &= \frac{[(R_a + R_e)^2 + (X_d'' + X_e)^2] \cdot X_d' \cdot T_d''}{[(R_a + R_e)^2 + (X_d'' + X_e)(X_d' + X_e)] \cdot X_d''} \\
 &= \frac{(40.208 + 1090.254) \times 56.145 \times 3}{(40.208 + 33.019 \times 56.582) \times 32.582} \\
 &= 3.062 \text{ ms} \\
 T_e' &= \frac{[(R_a + R_e)^2 + (X_d' + X_e)^2] \cdot X_d \cdot T_d'}{[(R_a + R_e)^2 + (X_d' + X_e)(X_d + X_e)] \cdot X_d'}
 \end{aligned}$$

$$\begin{aligned}
 &= \frac{(40.208 + 3201.523) \times 637.09 \times 80}{(40.208 + 56.582 \times 637.527) \times 56.145} \\
 &= 81.49 \text{ ms} \\
 T_{dce} &= \frac{T_{dc} + 1000 X_e / (2\pi f R_a)}{1 + R_e / R_a} \\
 &= \frac{22 + 1000 \times 0.437 / (100\pi \times 5.18)}{1 + 1.161 / 5.18} \\
 &= 18.191 \text{ ms}
 \end{aligned}$$

G_3 :

$$\begin{aligned}
 T_e'' &= \frac{[(R_a + R_e)^2 + (X_d'' + X_e)^2] \cdot X_d' \cdot T_d''}{[(R_a + R_e)^2 + (X_d'' + X_e)(X_d' + X_e)] \cdot X_d''} \\
 &= \frac{(112.9756 + 2635.282) \times 87.04 \times 3}{(112.9756 + 4501.412) \times 50.688} \\
 &= 3.068 \text{ ms} \\
 T_e' &= \frac{[(R_a + R_e)^2 + (X_d' + X_e)^2] \cdot X_d \cdot T_d'}{[(R_a + R_e)^2 + (X_d' + X_e)(X_d + X_e)] \cdot X_d'} \\
 &= \frac{(112.9756 + 7689.01) \times 1617.92 \times 49}{(112.9756 + 87.687 \times 1618.567) \times 87.04} \\
 &= 50.03 \text{ ms} \\
 T_{dce} &= \frac{T_{dc} + 1000 X_e / (2\pi f R_a)}{1 + R_e / R_a} \\
 &= \frac{20 + 1000 \times 0.647 / (100\pi \times 8.909)}{1 + 1.72 / 8.909} \\
 &= 16.957 \text{ ms}
 \end{aligned}$$

2 Where $t = 10$ ms, the short-circuit current is to be calculated as follows:

G_1, G_2 :

$$\begin{aligned}
 I_{acG} &= (I_{Kde}'' - I_{Kde}') \cdot e^{-t/T_e''} + (I_{Kd}' - I_{Kd}) \cdot e^{-t/T_e'} + I_{Kd} \\
 &= (7.445 - 4.618) \cdot e^{-10/3.062} + (4.618 - 2.4) \cdot e^{-10/81.49} + 2.4 \\
 &= 4.47 \text{ kA} \\
 i_{dcG} &= \sqrt{2} (I_{Kde}'' - I_r \cdot \sin \varphi_r) \cdot e^{-t/T_{dce}} \\
 &= \sqrt{2} (7.445 - 0.79 \times 0.6) \cdot e^{-10/18.191} \\
 &= 5.689 \text{ kA} \\
 i_{pG} &= \sqrt{2} I_{acG} + i_{dcG} \\
 &= \sqrt{2} \times 4.47 + 5.689 \\
 &= 12.01 \text{ kA}
 \end{aligned}$$

G_3 :

$$\begin{aligned}
 I_{acG} &= (I_{Kde}'' - I_{Kde}') \cdot e^{-t/T_e''} + (I_{Kd}' - I_{Kd}) \cdot e^{-t/T_e'} + I_{Kd} \\
 &= (4.738 - 2.936) \cdot e^{-10/3.068} + (2.936 - 1.4) \cdot e^{-10/50.03} + 1.4 \\
 &= 2.727 \text{ kA} \\
 i_{dcG} &= \sqrt{2} (I_{Kde}'' - I_r \cdot \sin \varphi_r) \cdot e^{-t/T_{dce}} \\
 &= \sqrt{2} (4.738 - 0.451 \times 0.6) \cdot e^{-10/16.957} \\
 &= 3.503 \text{ kA} \\
 i_{pG} &= \sqrt{2} I_{acG} + i_{dcG} \\
 &= \sqrt{2} \times 2.727 + 3.503 \\
 &= 7.36 \text{ kA}
 \end{aligned}$$

A.4 Calculation of the short-circuit current fed through the motor where the short-circuit occurs at the main bus-bar

A.4.1 Calculation of impedance

A.4.1.1 The impedance of large motor M_1

1 Calculation of X_M'' , R_S and R_R

$$\begin{aligned} X_M'' &= x_M'' \frac{U_{rM}^2 \cdot \eta_M \cdot \cos \varphi_M}{P_{rM}} \\ &= \frac{0.15 \times 380^2 \times 0.76}{120} \\ &= 137.18 \text{ m}\Omega \\ R_S &= r_S \frac{U_{rM}^2 \cdot \eta_M \cdot \cos \varphi_M}{P_{rM}} \\ &= 0.034 \times 914.533 \\ &= 31.094 \text{ m}\Omega \\ R_R &= r_R \frac{U_{rM}^2 \cdot \eta_M \cdot \cos \varphi_M}{P_{rM}} \\ &= 0.021 \times 914.533 \\ &= 19.205 \text{ m}\Omega \end{aligned}$$

2 Cable impedance from the motor to the main bus-bar

$$\begin{aligned} R_e &= rl / a \\ &= 0.279 \times 35 \div 2 \\ &= 5.198 \text{ m}\Omega \\ X_e &= xl / a \\ &= 0.0821 \times 35 \div 2 \\ &= 1.437 \text{ m}\Omega \end{aligned}$$

A.4.1.2 The impedance of equivalent motor M_2

$$\begin{aligned} X_M'' &= x_M'' \frac{U_{rM}^2 \cdot \eta_M \cdot \cos \varphi_M}{P_{rM}} \\ &= 0.188 \times \frac{380^2 \times 0.76}{408} \\ &= 50.568 \text{ m}\Omega \\ R_S &= r_S \frac{U_{rM}^2 \cdot \eta_M \cdot \cos \varphi_M}{P_{rM}} \\ &= 0.043 \times 268.98 \\ &= 11.566 \text{ m}\Omega \\ R_R &= r_R \frac{U_{rM}^2 \cdot \eta_M \cdot \cos \varphi_M}{P_{rM}} \\ &= 0.027 \times 268.98 \\ &= 7.262 \text{ m}\Omega \end{aligned}$$

A.4.2 Calculation of time constants for large motor M_1

$$\begin{aligned} T_{Me}'' &= \frac{1000 X_{Me}''}{2\pi f R_R} \\ &= \frac{1000 (X_M'' + X_e)}{2\pi f R_R} \\ &= \frac{1000 \times (137.18 + 1.437)}{100\pi \times 19.205} \\ &= 22.975 \text{ ms} \\ T_{dcMe} &= \frac{1000 (X_M'' + X_e)}{2\pi f (R_S + R_e)} \\ &= \frac{10 \times 138.617}{\pi \times (31.094 + 5.198)} \\ &= 12.158 \text{ ms} \end{aligned}$$

A.4.3 Calculation of short-circuit currents

A.4.3.1 Where $t = 10$ ms, the short-circuit current of large motor M_1 is to be calculated as follows:

$$\begin{aligned}
 I''_{Me} &= \frac{U_{rM}}{\sqrt{3}\sqrt{(R_R + R_S + R_e)^2 + (X''_M + X_e)^2}} \\
 &= \frac{380}{\sqrt{3} \times \sqrt{(19.205 + 31.094 + 5.198)^2 + (137.18 + 1.437)^2}} \\
 &= 1.469 \text{ kA} \\
 I_{acM} &= I''_{Me} \cdot e^{-t/T''_{Me}} \\
 &= 1.469 \times e^{-10/22.975} \\
 &= 0.951 \text{ kA} \\
 i_{dcM} &= \sqrt{2}I''_{Me} \cdot e^{-t/T'_{dcMe}} \\
 &= \sqrt{2} \times 1.469 \times e^{-10/12.158} \\
 &= 0.913 \text{ kA} \\
 i_{pM} &= \sqrt{2}I_{acM} + i_{dcM} \\
 &= \sqrt{2} \times 0.951 + 0.913 \\
 &= 2.258 \text{ kA}
 \end{aligned}$$

A.4.3.2 Where $t = 10$ ms, the short-circuit current of the equivalent motor (small motor group) M_2 is to be calculated as follows:

$$\begin{aligned}
 I''_{Me} &= \frac{U_{rM}}{\sqrt{3}\sqrt{(R_S + R_R)^2 + X''_M{}^2}} \\
 &= \frac{380}{\sqrt{3} \times \sqrt{(11.566 + 7.262)^2 + 50.568^2}} \\
 &= 4.066 \text{ kA} \\
 I_{acM} &= I''_{Me} \cdot e^{-t/T''_{Me}} \\
 &= 4.066 \times e^{-10/22.4} \\
 &= 2.602 \text{ kA} \\
 i_{dcM} &= \sqrt{2}I''_{Me} \cdot e^{-t/T'_{dcMe}} \\
 &= \sqrt{2} \times 4.066 \times e^{-10/14.076} \\
 &= 2.826 \text{ kA} \\
 i_{pM} &= \sqrt{2}I_{acM} + i_{dcM} \\
 &= \sqrt{2} \times 2.602 + 2.826 \\
 &= 6.506 \text{ kA}
 \end{aligned}$$

A.5 Calculation of short-circuit currents at points A_1 , A_2 , B_1 and B_2

A.5.1 Calculation of the short-circuit current at point A_1

A.5.1.1 Where $t = 10$ ms, the short-circuit current is to be calculated as follows:

$$\begin{aligned}
 I_{ac} &= I_{acG1} + I_{acG3} + I_{acM1} + I_{acM2} \\
 &= 4.47 + 2.727 + 0.951 + 2.602 \\
 &= 10.75 \text{ kA} \\
 i_p &= i_{pG1} + i_{pG3} + i_{pM1} + i_{pM2} \\
 &= 12.01 + 7.36 + 2.258 + 6.506 \\
 &= 28.134 \text{ kA}
 \end{aligned}$$

A.5.2 Calculation of the short-circuit current at point A_2

A.5.2.1 Where $t = 10$ ms, the short-circuit current is to be calculated as follows:

$$\begin{aligned}
 I_{ac} &= I_{acG1} + I_{acG2} + I_{acM1} + I_{acM2} \\
 &= 2 \times 4.47 + 0.951 + 2.602 \\
 &= 12.493 \text{ kA} \\
 i_p &= i_{pG1} + i_{pG2} + i_{pM1} + i_{pM2}
 \end{aligned}$$

$$= 2 \times 12.01 + 2.258 + 6.506$$

$$= 32.784 \text{ kA}$$

A.5.3 Calculation of the short-circuit current at point B_1

A.5.3.1 Where $t = 10 \text{ ms}$, the short-circuit current is to be calculated as follows:

$$I_{ac} = I_{acG1} + I_{acG2} + I_{acG3} + I_{acM1} + I_{acM2}$$

$$= 2 \times 4.47 + 2.727 + 0.951 + 2.602$$

$$= 15.22 \text{ kA}$$

$$i_p = i_{pG1} + i_{pG2} + i_{pG3} + i_{pM1} + i_{pM2}$$

$$= 2 \times 12.01 + 7.36 + 2.258 + 6.506$$

$$= 40.144 \text{ kA}$$

A.5.4 Calculation of the short-circuit current at point B_2

A.5.4.1 Where $t = 10 \text{ ms}$, the short-circuit current is to be calculated as follows:

$$I_{ac} = I_{acG1} + I_{acG2} + I_{acG3} + I_{acM2}$$

$$= 2 \times 4.47 + 2.727 + 2.602$$

$$= 14.269 \text{ kA}$$

$$i_p = i_{pG1} + i_{pG2} + i_{pG3} + i_{pM2}$$

$$= 2 \times 12.01 + 7.36 + 6.506$$

$$= 37.886 \text{ kA}$$

A.6 Calculation of short-circuit currents at points C_1 , C_2 , D_1 and D_2

A.6.1 Determination of parameters of the equivalent generator where $t = 10 \text{ ms}$

A.6.1.1 The determination of subtransient time constant T''_{d*}

1 It may be calculated from formulae (29), (30) and (31):

$$I''_* = \sum_i I''_{Kdei} + \sum_j I''_{Mej}$$

$$= 2 \times 7.445 + 4.738 + 1.469 + 4.066$$

$$= 25.163 \text{ kA}$$

$$I'_* = \sum_i I'_{Kdei}$$

$$= 2 \times 4.618 + 2.936$$

$$= 12.172 \text{ kA}$$

$$I_{K*} = \sum_i I_{Kdi}$$

$$= 2 \times 2.4 + 1.4$$

$$= 6.2 \text{ kA}$$

Hence:

$$M_* = I''_* - I'_*$$

$$= 25.163 - 12.172$$

$$= 12.991 \text{ kA}$$

$$N_* = I'_* - I_{K*}$$

$$= 12.172 - 6.2$$

$$= 5.972 \text{ kA}$$

2 Where $t_x = 10 \text{ ms}$, $K''(t)$ and $K''(t)_*$ of G_1 , G_2 and G_3 are to be calculated from formulae (34) and (36)

G_1 , G_2 :

$$K''(t_x) = (I''_{Kde} - I'_{Kde}) \cdot e^{-t/T''_e} + I'_{Kde}$$

$$= (7.445 - 4.618) \cdot e^{-10/3.062} + 4.618$$

$$= 4.726 \text{ kA}$$

G_3 :

$$K''(t_x) = (I''_{Kde} - I'_{Kde}) \cdot e^{-t/T''_e} + I'_{Kde}$$

$$= (4.738 - 2.936) \cdot e^{-10/3.068} + 2.936$$

$$= 3.005 \text{ kA}$$

Hence:

$$K''(t_x)_* = \sum_i K''(t_x)_i + \sum_j I''_{Mj} \cdot e^{-t/T''_{Me}}$$

$$= 2 \times 4.726 + 3.005 + 0.951 + 2.602$$

$$= 16.01 \text{ kA}$$

3 Hence:

$$T_{d*}'' = \frac{-t_x}{\ln[(K''(t_x) * -I'_*) / M_*]}$$

$$= \frac{-10}{\ln[(16.01 - 12.172) / 12.991]}$$

$$= 8.20 \text{ ms}$$

A.6.1.2 The determination of transient time constant T_{d*}'

Where $t_x = 10 \text{ ms}$, it is to be calculated from formula (39):

$$I_{ac*} = \sum_i I_{acGi} + \sum_j I_{acMj}$$

$$= 15.22 \text{ kA (i.e. the value of } I_{ac} \text{ at point } B_1)$$

Hence:

$$T_{d*}' = \frac{-t_x}{\ln \left[\frac{I_{ac}(t_x)_* - (M_* \cdot e^{-t_x/T_{d*}''} + I_{k*})}{N_*} \right]}$$

$$= \frac{-10}{\ln \left[\frac{15.22 - (12.991 \times e^{-10/8.20} + 6.2)}{5.972} \right]}$$

$$= 70.553 \text{ ms}$$

A.6.1.3 The determination of DC time constant T_{dc*}

Where $t_x = 10 \text{ ms}$, it is to be calculated from formula (42):

$$i_{dc}(t_x)_* = \sum_i i_{dcGi} + \sum_j i_{dcMj}$$

$$= 2 \times 5.689 + 3.503 + 0.913 + 2.826$$

$$= 18.62 \text{ kA}$$

Hence:

$$T_{dc*} = \frac{-t_x}{\ln \left[\frac{i_{dc}(t_x)_*}{\sqrt{2} I_*''} \right]}$$

$$= \frac{-10}{\ln \left[\frac{18.62}{\sqrt{2} \times 25.163} \right]}$$

$$= 15.439 \text{ ms}$$

A.6.1.4 The determination of impedance

It may be calculated from formulae (45), (46) and (47):

$$Z_*'' = \frac{U_r}{\sqrt{3} I_*''} = \frac{400}{\sqrt{3} \times 25.163} = 9.178 \text{ m}\Omega$$

$$Z_*' = \frac{U_r}{\sqrt{3} I_*'} = \frac{400}{\sqrt{3} \times 12.172} = 18.973 \text{ m}\Omega$$

$$Z_* = \frac{U_r}{\sqrt{3} I_{K*}} = \frac{400}{\sqrt{3} \times 6.2} = 37.248 \text{ m}\Omega$$

and

$$C = \frac{1000}{2\pi f T_{dc*}} = \frac{10}{\pi \times 15.439} = 0.2062 \text{ m}\Omega$$

Hence:

$$X_*'' = \frac{Z_*''}{\sqrt{1 + C^2}} = \frac{9.178}{\sqrt{1 + 0.2062^2}} = 8.99 \text{ m}\Omega$$

$$R_* = C X_*'' = 0.2062 \times 8.99 = 1.854 \text{ m}\Omega$$

$$X_*' = \sqrt{Z_*'^2 - R_*^2} = \sqrt{18.973^2 - 1.854^2} = 18.88 \text{ m}\Omega$$

$$X_* = \sqrt{Z_*^2 - R_*^2} = \sqrt{37.248^2 - 1.854^2} = 37.202 \text{ m}\Omega$$

A.6.2 Calculation of the short-circuit current at point C_1

A.6.2.1 The calculation of the circuit impedance from the main bus-bar to fault points

$$R_e = rl / a = 0.582 \times 50 / 2 = 14.55 \quad \text{m}\Omega$$

$$X_e = xl / a = 0.0871 \times 50 / 2 = 2.178 \quad \text{m}\Omega$$

A.6.2.2 The calculation of T_e'' , T_e' and T_{dce}

$$\begin{aligned} T_e'' &= \frac{[(R_* + R_e)^2 + (X_*'' + X_e)^2] \cdot X_*' \cdot T_{d*}''}{[(R_* + R_e)^2 + (X_*'' + X_e)(X_*' + X_e)] \cdot X_*''} \\ &= \frac{[(1.854 + 14.55)^2 + (8.99 + 2.178)^2] \times 18.88 \times 8.20}{[(1.854 + 14.55)^2 + (8.99 + 2.178)(18.88 + 2.178)] \times 8.99} \\ &= 13.449 \quad \text{ms} \\ T_e' &= \frac{[(R_* + R_e)^2 + (X_*' + X_e)^2] \cdot X_* \cdot T_{d*}'}{[(R_* + R_e)^2 + (X_*' + X_e)(X_* + X_e)] \cdot X_*'} \\ &= \frac{[(1.854 + 14.55)^2 + (18.88 + 2.178)^2] \times 37.202 \times 70.553}{[(1.854 + 14.55)^2 + (18.88 + 2.178)(37.202 + 2.178)] \times 18.88} \\ &= 90.186 \quad \text{ms} \\ T_{dce} &= \frac{T_{dc*} + 1000 X_e / (2\pi f R_*)}{1 + R_e / R_*} \\ &= \frac{15.439 + 1000 \times 2.178 / (100\pi \times 1.854)}{1 + 14.55 / 1.854} \\ &= 2.168 \quad \text{ms} \end{aligned}$$

A.6.2.3 The calculation of I_{Kde}'' , I_{Kde}' and I_{Kde}

$$\begin{aligned} I_{Kde}'' &= \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_*'' + X_e)^2}} \\ &= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 14.55)^2 + (8.99 + 2.178)^2}} \\ &= 11.637 \quad \text{kA} \\ I_{Kde}' &= \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_*' + X_e)^2}} \\ &= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 14.55)^2 + (18.88 + 2.178)^2}} \\ &= 8.652 \quad \text{kA} \\ I_{Kde} &= \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_* + X_e)^2}} \\ &= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 14.55)^2 + (37.202 + 2.178)^2}} \\ &= 5.413 \quad \text{kA} \end{aligned}$$

A.6.2.4 Where $t = 10$ ms, the short-circuit current is to be calculated as follows:

$$\begin{aligned} I_{ac} &= (I_{Kde}'' - I_{Kde}') \cdot e^{-t/T_e''} + (I_{Kde}' - I_{Kde}) \cdot e^{-t/T_e'} + I_{Kde} \\ &= (11.637 - 8.652) \cdot e^{-10/13.449} + (8.652 - 5.413) \cdot e^{-10/90.186} + 5.413 \\ &= 9.731 \quad \text{kA} \\ i_{dc} &= \sqrt{2} I_{Kde}'' \cdot e^{-t/T_{dce}} \\ &= \sqrt{2} \times 11.637 \times e^{-10/2.168} \\ &= 0.163 \quad \text{kA} \\ i_p &= \sqrt{2} I_{ac} + i_{dc} \\ &= \sqrt{2} \times 9.731 + 0.163 \\ &= 13.925 \quad \text{kA} \end{aligned}$$

A.6.3 Calculation of the short-circuit current and power factor at point C_2

A.6.3.1 The calculation of the circuit impedance from the main bus-bar to fault points

$$R_e = rl / a = 0.807 \times 35 = 28.245 \quad \text{m}\Omega$$

$$X_e = xl / a = 0.0855 \times 35 = 3.098 \quad \text{m}\Omega$$

A.6.3.2 The calculation of T_e'' , T_e' and T_{dce}

$$\begin{aligned} T_e'' &= \frac{[(R_* + R_e)^2 + (X_*'' + X_e)^2] \cdot X_*' \cdot T_{d*}''}{[(R_* + R_e)^2 + (X_*'' + X_e)(X_*' + X_e)] \cdot X_*''} \\ &= \frac{[(1.854 + 28.245)^2 + (8.99 + 3.098)^2] \times 18.88 \times 8.20}{[(1.854 + 28.245)^2 + (8.99 + 3.098)(18.88 + 3.098)] \times 8.99} \\ &= 15.464 \quad \text{ms} \\ T_e' &= \frac{[(R_* + R_e)^2 + (X_*' + X_e)^2] \cdot X_* \cdot T_{d*}'}{[(R_* + R_e)^2 + (X_*' + X_e)(X_* + X_e)] \cdot X_*'} \\ &= \frac{[(1.854 + 28.245)^2 + (18.88 + 3.098)^2] \times 37.202 \times 70.553}{[(1.854 + 28.245)^2 + (18.88 + 3.098)(37.202 + 3.098)] \times 18.88} \\ &= 107.775 \quad \text{ms} \\ T_{dce} &= \frac{T_{d*} + 1000X_e / (2\pi f R_*)}{1 + R_e / R_*} \\ &= \frac{15.439 + 1000 \times 3.098 / (100\pi \times 1.854)}{1 + 28.245 / 1.854} \\ &= 1.28 \quad \text{ms} \end{aligned}$$

A.6.3.3 The calculation of I_{Kde}'' , I_{Kde}' and I_{Kde}

$$\begin{aligned} I_{Kde}'' &= \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_*'' + X_e)^2}} \\ &= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 28.245)^2 + (8.99 + 3.098)^2}} \\ &= 7.12 \quad \text{kA} \\ I_{Kde}' &= \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_*' + X_e)^2}} \\ &= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 28.245)^2 + (18.88 + 3.098)^2}} \\ &= 6.197 \quad \text{kA} \\ I_{Kde} &= \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_* + X_e)^2}} \\ &= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 28.245)^2 + (37.202 + 3.098)^2}} \\ &= 4.591 \quad \text{kA} \end{aligned}$$

A.6.3.4 Where: $t = 10$ ms, the short-circuit current is to be calculated as follows:

$$\begin{aligned} I_{ac} &= (I_{Kde}'' - I_{Kde}') \cdot e^{-t/T_e''} + (I_{Kde}' - I_{Kde}) \cdot e^{-t/T_e'} + I_{Kde} \\ &= (7.12 - 6.197) \cdot e^{-10/15.464} + (6.197 - 4.591) \cdot e^{-10/107.775} + 4.591 \\ &= 6.538 \quad \text{kA} \\ i_{dc} &= \sqrt{2} I_{Kde}'' \cdot e^{-t/T_{dce}} \\ &= \sqrt{2} \times 7.12 \times e^{-10/1.28} \\ &= 0.0041 \quad \text{kA} \\ i_p &= \sqrt{2} I_{ac} + i_{dc} \\ &= \sqrt{2} \times 6.538 + 0.0041 \\ &= 9.25 \quad \text{kA} \end{aligned}$$

A.6.4 Calculation of the short-circuit current at point D_1

A.6.4.1 The calculation of the circuit impedance from the main bus-bar to fault points

1. The primary circuit impedance of a transformer

$$R_{e1} = r_l / a = 0.807 \times 6 / 2 = 2.421 \quad \text{m}\Omega$$

$$X_{e1} = x_l / a = 0.0885 \times 6 / 2 = 0.2655 \quad \text{m}\Omega$$

2. The calculation of the transformer impedance

$$\begin{aligned} Z_T &= u_K \cdot \frac{U_r^2}{S_{rT}} \\ &= 3.5\% \times \frac{400^2}{100} \\ &= 56 \quad \text{m}\Omega \end{aligned}$$

$$\begin{aligned} R_T &= P_K \cdot \frac{U_r^2}{S_{rT}^2} \\ &= 2.0 \times \frac{400^2}{100^2} \\ &= 32 \quad \text{m}\Omega \end{aligned}$$

$$\begin{aligned} X_T &= \sqrt{Z_T^2 - R_T^2} \\ &= \sqrt{56^2 - 32^2} \\ &= 45.9565 \quad \text{m}\Omega \end{aligned}$$

3. The circuit impedance at the secondary side of the transformer as converted to the primary side

$$\begin{aligned} R_{e2} &= (r_l / a) \cdot (U_r / U_{rT2})^2 \\ &= (0.582 \times 3.5 / 2) \times (400 / 230)^2 \\ &= 3.0805 \quad \text{m}\Omega \end{aligned}$$

$$\begin{aligned} X_{e2} &= (x_l / a) \cdot (U_r / U_{rT2})^2 \\ &= (0.0871 \times 3.5 / 2) \times (400 / 230)^2 \\ &= 0.461 \quad \text{m}\Omega \end{aligned}$$

4. The circuit impedance from the main bus-bar to fault points

$$\begin{aligned} R_e &= R_{e1} + R_T + R_{e2} \\ &= 2.421 + 32 + 3.0805 \\ &= 37.5015 \quad \text{m}\Omega \\ X_e &= X_{e1} + X_T + X_{e2} \\ &= 0.2655 + 45.9565 + 0.461 \\ &= 46.683 \quad \text{m}\Omega \end{aligned}$$

A.6.4.2 The calculation of T_e'' , T_e' and T_{dce}

$$\begin{aligned} T_e'' &= \frac{[(R_* + R_e)^2 + (X_*'' + X_e)^2] \cdot X_*' \cdot T_{d*}''}{[(R_* + R_e)^2 + (X_*'' + X_e)(X_*' + X_e)] \cdot X_*''} \\ &= \frac{[(1.854 + 37.5015)^2 + (8.99 + 46.683)^2] \times 18.88 \times 8.20}{[(1.854 + 37.5015)^2 + (8.99 + 46.683)(18.88 + 46.683)] \times 8.99} \\ &= 15.397 \quad \text{ms} \\ T_e' &= \frac{[(R_* + R_e)^2 + (X_*' + X_e)^2] \cdot X_* \cdot T_{d*}'}{[(R_* + R_e)^2 + (X_*' + X_e)(X_* + X_e)] \cdot X_*'} \\ &= \frac{[(1.854 + 37.5015)^2 + (18.88 + 46.683)^2] \times 37.202 \times 70.553}{[(1.854 + 37.5015)^2 + (18.88 + 46.683)(37.202 + 46.683)] \times 18.88} \\ &= 115.328 \quad \text{ms} \\ T_{dce} &= \frac{T_{dc*} + 1000 X_e / (2\pi f R_*)}{1 + R_e / R_*} \\ &= \frac{15.439 + 1000 \times 46.683 / (100\pi \times 1.854)}{1 + 37.5015 / 1.854} \\ &= 4.503 \quad \text{ms} \end{aligned}$$

A.6.4.3 The calculation of I''_{Kde} , I'_{Kde} and I_{Kde}

$$\begin{aligned} I''_{Kde} &= \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_* + X_e)^2}} \\ &= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 37.5015)^2 + (8.99 + 46.683)^2}} \\ &= 3.387 \text{ kA} \\ I'_{Kde} &= \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X'_* + X_e)^2}} \\ &= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 37.5015)^2 + (18.88 + 46.683)^2}} \\ &= 3.02 \text{ kA} \\ I_{Kde} &= \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_* + X_e)^2}} \\ &= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 37.5015)^2 + (37.202 + 46.683)^2}} \\ &= 2.492 \text{ kA} \end{aligned}$$

A.6.4.4 Where $t = 10$ ms, the short-circuit current is to be calculated as follows:

$$\begin{aligned} I_{ac} &= (I''_{Kde} - I'_{Kde}) \cdot e^{-t/T''_e} + (I'_{Kde} - I_{Kde}) \cdot e^{-t/T'_e} + I_{Kde} \\ &= (3.387 - 3.02) \cdot e^{-10/15.397} + (3.02 - 2.492) \cdot e^{-10/11.5328} + 2.492 \\ &= 3.168 \text{ kA} \\ i_{dc} &= \sqrt{2} I''_{Kde} \cdot e^{-t/T_{dec}} \\ &= \sqrt{2} \times 3.387 \times e^{-10/4.503} \\ &= 0.52 \text{ kA} \\ i_p &= \sqrt{2} I_{ac} + i_{dc} \\ &= \sqrt{2} \times 3.168 + 0.52 \\ &= 5.0 \text{ kA} \end{aligned}$$

The short-circuit current at the secondary side of a transformer

$$\begin{aligned} I_{ac2} &= I_{ac} (U_r / U_{rT2}) \\ &= 3.168 \times 400 / 230 \\ &= 5.51 \text{ kA} \\ i_{p2} &= i_p (U_r / U_{rT2}) \\ &= 5.0 \times 400 / 230 \\ &= 8.696 \text{ kA} \end{aligned}$$

A.6.5 Calculation of the short-circuit current at point D_2

A.6.5.1 The calculation of the circuit impedance from the main bus-bar to fault points

1 The circuit impedance from the main bus-bar to the lighting bus-bar (i.e. the impedance at point D_1)

$$\begin{aligned} R_e &= 37.5015 \text{ m}\Omega \\ X_e &= 46.683 \text{ m}\Omega \end{aligned}$$

2 The circuit impedance from the lighting bus-bar to fault points as converted to the primary side of the transformer

$$\begin{aligned} R_{e2} &= (rl/a) \cdot (U_r / U_{rT2})^2 \\ &= (2.02 \times 10 / 1) \times (400 / 230)^2 \\ &= 61.096 \text{ m}\Omega \\ X_{e2} &= (xl/a) \cdot (U_r / U_{rT2})^2 \\ &= (0.0957 \times 10 / 1) \times (400 / 230)^2 \\ &= 2.895 \text{ m}\Omega \end{aligned}$$

3 The circuit impedance from the main bus-bar to fault points

$$\begin{aligned} R_e &= R_{e(D1)} + R_{e2} \\ &= 37.5015 + 61.096 \\ &= 98.598 \quad \text{m}\Omega \\ X_e &= X_{e(D1)} + X_{e2} \\ &= 46.683 + 2.895 \\ &= 49.578 \quad \text{m}\Omega \end{aligned}$$

A.6.5.2 The calculation of T_e'' , T_e' and T_{dce}

$$\begin{aligned} T_e'' &= \frac{[(R_* + R_e)^2 + (X_*'' + X_e)^2] \cdot X_*' \cdot T_{d*}''}{[(R_* + R_e)^2 + (X_*'' + X_e)(X_*' + X_e)] \cdot X_*''} \\ &= \frac{[(1.854 + 98.598)^2 + (8.99 + 49.578)^2] \times 18.88 \times 8.20}{[(1.854 + 98.598)^2 + (8.99 + 49.578)(18.88 + 49.578)] \times 8.99} \\ &= 16.513 \quad \text{ms} \\ T_e' &= \frac{[(R_* + R_e)^2 + (X_*' + X_e)^2] \cdot X_* \cdot T_{d*}' }{[(R_* + R_e)^2 + (X_*' + X_e)(X_* + X_e)] \cdot X_*'} \\ &= \frac{[(1.854 + 98.598)^2 + (18.88 + 49.578)^2] \times 37.202 \times 70.553}{[(1.854 + 98.598)^2 + (18.88 + 49.578)(37.202 + 49.578)] \times 18.88} \\ &= 128.144 \quad \text{ms} \\ T_{dce} &= \frac{T_{dce*} + 1000X_e / (2\pi f R_*)}{1 + R_e / R_*} \\ &= \frac{15.439 + 1000 \times 49.578 / (100\pi \times 1.854)}{1 + 98.598 / 1.854} \\ &= 1.89 \quad \text{ms} \end{aligned}$$

A.6.5.3 The calculation of I_{Kde}'' , I_{Kde}' and I_{Kde}

$$\begin{aligned} I_{Kde}'' &= \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_*'' + X_e)^2}} \\ &= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 98.598)^2 + (8.99 + 49.578)^2}} \\ &= 1.986 \quad \text{kA} \\ I_{Kde}' &= \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_*' + X_e)^2}} \\ &= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 98.598)^2 + (18.88 + 49.578)^2}} \\ &= 1.899 \quad \text{kA} \\ I_{Kde} &= \frac{U_r / \sqrt{3}}{\sqrt{(R_* + R_e)^2 + (X_* + X_e)^2}} \\ &= \frac{400 / \sqrt{3}}{\sqrt{(1.854 + 98.598)^2 + (37.202 + 49.578)^2}} \\ &= 1.74 \quad \text{kA} \end{aligned}$$

A.6.5.4 Where $t=10$ ms, the short-circuit current is to be calculated as follows:

$$\begin{aligned} I_{ac} &= (I_{Kde}'' - I_{Kde}') \cdot e^{-t/T_e''} + (I_{Kde}' - I_{Kde}) \cdot e^{-t/T_e'} + I_{Kde} \\ &= (1.986 - 1.899) \cdot e^{-10/16.513} + (1.899 - 1.74) \cdot e^{-10/128.144} + 1.74 \\ &= 1.931 \quad \text{kA} \\ i_{dc} &= \sqrt{2} I_{Kde}'' \cdot e^{-t/T_{dce}} \\ &= \sqrt{2} \times 1.986 \times e^{-10/1.89} \\ &= 0.0141 \quad \text{kA} \end{aligned}$$

$$\begin{aligned} i_p &= \sqrt{2}I_{ac} + i_{dc} \\ &= \sqrt{2} \times 1.931 + 0.0141 \\ &= 2.745 \text{ kA} \end{aligned}$$

The short-circuit current at the secondary side of a transformer

$$\begin{aligned} I_{ac2} &= I_{ac}(U_r / U_{rT2}) \\ &= 1.931 \times 400 / 230 \\ &= 3.358 \text{ kA} \\ i_{p2} &= i_p(U_r / U_{rT2}) \\ &= 2.745 \times 400 / 230 \\ &= 4.774 \text{ kA} \end{aligned}$$

A.7 Calculation of short-circuit power factors

A.7.1 Calculation of short-circuit power factors at points A_1 , A_2 , B_1 and B_2 .

$$\begin{aligned} \cos \varphi_K &= \frac{R_*}{\sqrt{R_*^2 + X_*'^2}} \\ &= \frac{1.854}{\sqrt{1.854^2 + 8.99^2}} \\ &= 0.202 \end{aligned}$$

A.7.2 Calculation of short-circuit power factors at points C_1 , C_2 , D_1 and D_2

1 At point C_1 :

$$\begin{aligned} \cos \varphi_K &= \frac{R_* + R_e}{\sqrt{(R_* + R_e)^2 + (X_*'' + X_e)^2}} \\ &= \frac{1.854 + 14.55}{\sqrt{(1.854 + 14.55)^2 + (8.99 + 2.178)^2}} \\ &= 0.827 \end{aligned}$$

2 At point C_2 :

$$\begin{aligned} \cos \varphi_K &= \frac{R_* + R_e}{\sqrt{(R_* + R_e)^2 + (X_*'' + X_e)^2}} \\ &= \frac{1.854 + 28.245}{\sqrt{(1.854 + 28.245)^2 + (8.99 + 3.098)^2}} \\ &= 0.928 \end{aligned}$$

3 At point D_1 :

$$\begin{aligned} \cos \varphi_K &= \frac{R_* + R_e}{\sqrt{(R_* + R_e)^2 + (X_*'' + X_e)^2}} \\ &= \frac{1.854 + 37.5015}{\sqrt{(1.854 + 37.5015)^2 + (8.99 + 46.683)^2}} \\ &= 0.577 \end{aligned}$$

4 At point D_2 :

$$\begin{aligned} \cos \varphi_K &= \frac{R_* + R_e}{\sqrt{(R_* + R_e)^2 + (X_*'' + X_e)^2}} \\ &= \frac{1.854 + 98.598}{\sqrt{(1.854 + 98.598)^2 + (8.99 + 49.578)^2}} \\ &= 0.864 \end{aligned}$$

A.8 A complete summary of results of short-circuit current calculation and data of selected protective devices

A.8.1 A complete summary of the results of the short-circuit current calculation and the data of the selected protective devices is given in Table A.8.1.

A Complete Summary of Results of Short-Circuit Current Calculation and Data of Selected Protective Devices
Table A.8.1

Results of short-circuit current calculation					Selected protective devices								
Code of fault points	Time after occurrence of short-circuit	Symmetrical short-circuit current (kA)	Upper envelope of short-circuit current (kA)	Power factor of short-circuit current	Type	Rated current (A)	Rated voltage (V)	Rated short-circuit breaking capacity (kA)	Rated short-circuit making capacity (kA)	Rated short-time withstanding current (kA)	Power factor of short-circuit	$\cos \phi_k$ conversion	
												Conversion coefficient	Short-circuit breaking capacity (kA)
A_1	T/2 Steady state	10.75 3.80	28.134	0.202	AH-10B	790	500	40	104	30 (1 s)			
A_2	T/2 Steady state	12.493 4.80	32.784	0.202	AH-6B	451	500	35	98.5	22 (1 s)			
B_1	T/2	15.22	40.144	0.202	TG-100B	50	500	42	95.5				
	T/2 Steady state	15.22 6.20	40.144	0.202	XH225NE ^①	150	415	25	50	5.0 (300 ms)			
	Steady state	6.20			XH600NE ^②	200	415			10.0 (300 ms)			
B_2	T/2	14.269	37.886	0.202	TO-225BA	225	500	22	44				
C_1	T/2	9.731	13.925	0.827	TO-100BA	15	500	18	38				
C_2	T/2	6.538	9.25	0.928	TO-100BA	15	500	18	38				
D_1 ^③	T/2	5.51	8.696	0.577	TO-100BA	15	250	22	35				
D_2	T/2	3.358	4.774	0.864	TH-50B	10	250	5	8.6				

Notes:

- ① High-efficiency instantaneous trip breaker for the primary side of transformer T, with the transient current being 4 kA.
- ② Circuit breaker for feeders connecting main switchboard and emergency switch board.
- ③ Points D_1 and D_2 are short-circuit currents at the secondary side of the transformer.

Appendix B Conversion of Short-Circuit Breaking Capacity of Circuit Breaker

B.1 Foreword

The rated short-circuit breaking capacity of a circuit breaker is values provided by the manufacturer for the short-circuit breaking capacity corresponding to different rated operational voltages at the rated frequency and specified short-circuit power factor.

Because the sources of the short-circuit current in marine AC electrical systems are AC synchronous and asynchronous motors and the short-circuit power factor is small, the short-circuit power factors specified in standards for industrial circuit breakers cannot in general meet marine requirements.

This Appendix provides a method for conversion of the short-circuit breaking capacity where the given value of the test power factor of the selected breaker is not in compliance with the actual short-circuit power factor required for a marine electrical system.

B.2 Conversion method

The conversion is to be in accordance with the following steps:

a. The peak coefficient n corresponding to the given value of the test short-circuit power factor $\cos \varphi_{Kr}$ of the breaker may be obtained from Figure B.2.

Note: Where only the rated short-circuit making capacity and rated short-circuit breaking capacity of the breaker is given, the ratio of the rated short-circuit making capacity to the rated short-circuit breaking capacity is peak coefficient n .

b. The peak coefficient n' corresponding to the actually required short-circuit power factor $\cos \varphi_K$ may be obtained from Figure B.2.

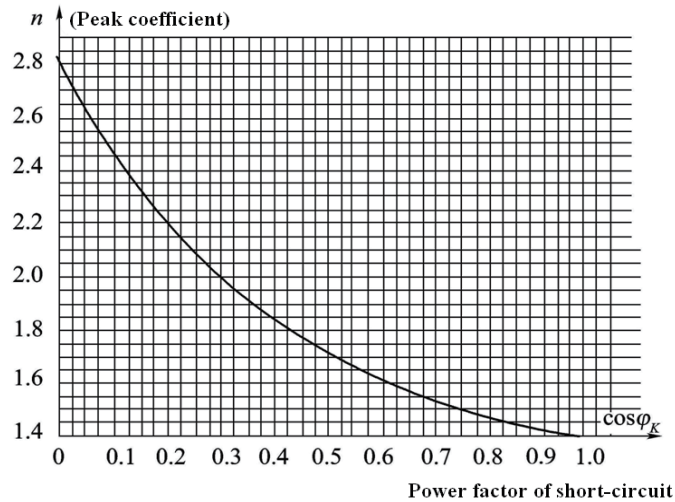


Figure B.2 Curve where Peak Value Coefficient $n = f(\cos \varphi_K)$

c. With the short-circuit power factor $\cos \varphi_K$, the short-circuit breaking capacity I_{Cr} of the breaker conversion is as follows:

$$I_{Cr} = \frac{n}{n'} I_{CR} = C I_{CR}$$

B.3 Example

It is assumed that the considered short-circuit power factor $\cos \varphi_K$ at the main bus-bar of a ship equals 0.16, and the known parameters of the selected TO-100BA circuit breaker are as follows:

Rated voltage: 500 V

Rated short-circuit breaking capacity: 18 kA

Rated short-circuit making capacity: 38 kA

Evaluation: The value of the short-circuit breaking capacity where the short-circuit power factor $\cos \varphi_K = 0.16$.

Solution:

(a) $n = \frac{38}{18} = 2.111$;

(b) $n' = 2.30$ where $\cos \varphi_K = 0.16$, as shown in Figure B.2;

(c) $I_{Cr} = \frac{n}{n'} I_{CR} = \frac{2.111}{2.30} \times 18 = 16.52 \text{ kA}.$

APPENDIX 2 TYPE APPROVAL PROCEDURE FOR CABLE TRAYS/PROTECTIVE CASINGS MADE OF PLASTIC MATERIALS

2.1 General design requirements

2.1.1 Ambient temperatures

Cable trays/protective casings are to be designed to the following ambient temperatures:

–25°C to 90°C for outdoor use;

+ 5°C to 90°C for indoor use.

Consideration will be given to the use of plastic cable trays/protective casings in the cold environment where the ambient temperature is below –25°C provided the mechanical properties of the plastics can be maintained for the intended purpose and the installation location. In this particular instance, the cold bend and cold impact properties of the material are also to be considered.

2.1.2 Safe Working Load

Cable trays/protective casings are to be assigned a Safe Working Load in accordance with 2.2.2 of this Appendix.

2.2 Mechanical requirements

2.2.1 Impact resistance test

The test is to be performed according to IEC 60068-2-75 using the pendulum hammer.

2.2.1.1 The test is to be carried out on samples of cable tray lengths or cable ladder lengths, of 250 mm $\pm$ 5 mm long. Samples of ladder are to consist of two side-members with one rung positioned centrally. Samples of mesh trays are to be prepared in such a way that there will be a wire in the centre.

2.2.1.2 Before the test, plastic components are to be aged at a temperature of 90°C $\pm$ 2°C for 240 h continuously.

2.2.1.3 The samples are to be mounted on wooden fibreboard of thickness 20 mm $\pm$ 2 mm.

2.2.1.4 The samples to be tested are to be placed in a refrigerator, the temperature within which is maintained at the declared temperature according to 1.1 above with a tolerance of $\pm$ 2°C.

2.2.1.5 After 2 h, the samples are, in turn, to be removed from the refrigerator and immediately placed in the test apparatus.

2.2.1.6 At 10 s $\pm$ 1 s after removal of each sample from the refrigerator, the hammer complying with Table 2.2.1.6 is to be allowed to fall with impact energy.

Hammer Specification

Table 2.2.1.6

Approximate energy (J)	Mass of hammer (kg)	Fall height (mm)
10	5.0	200 $\pm$ 2

2.2.1.7 The impact is to be applied to the base, or the rung, in the first sample, to one of the side members in the second sample, and to the other side member in the third sample. In each case, the impact is to be applied to the centre of the face being tested.

2.2.1.8 After the test, the samples are to show no signs of disintegration and/or deformation that will impair the safety.

2.2.2 Safe Working Load (SWL) test

2.2.2.1 Cable trays/protective casings and joints are to be assigned a Safe Working Load (SWL) satisfying the following criteria, tested at the declared temperatures according to 2.1.1 above (see note):

- the maximum deflection is not to exceed $L/100$, where L is the distance between the supports,
- no mechanical defects or failure are observed when tested to $1.7 \times \text{SWL}$.

2.2.2.2 All loads are to be uniformly distributed (UDL) over the length and width of the samples as shown in Figure 2.2.2.2.

The loads are to be applied in such a way that a UDL is ensured even in the case of extreme deformation of the samples.

To allow for settlement of the samples, a preload of 10% of the test load unless otherwise specified, is to be applied and held for at least 5 min, after which the measurement apparatus is to be calibrated to zero.

2.2.2.3 The load is then to be gradually increased evenly longitudinally and transversely up to the test load continuously or when a continuous increase is impractical, the load may be increased by increments. These increments are not to exceed about a quarter of the safe working load. The load increments are to be distributed through the load plates longitudinally and transversely as evenly as is practical.

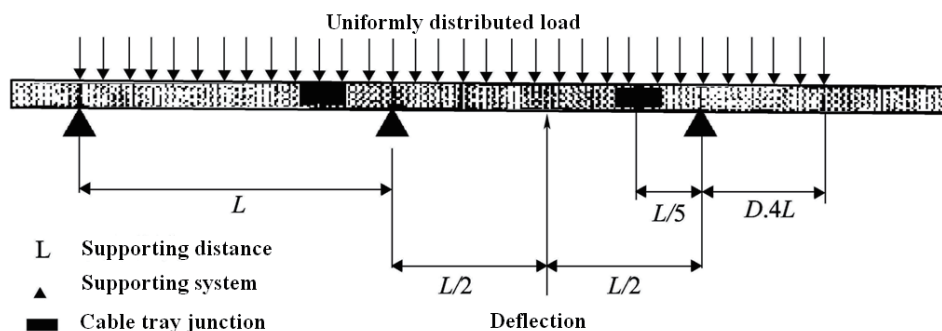


Figure 2.2.2.2 IEC 61537 Loading Test Procedure Summary

2.2.2.4 After loading, the deflection is to be measured at the points specified to give a practical mid-span deflection.

2.2.2.5 The samples are to be left and the deflections measured every 5 min until the difference between two consecutive sets of readings is less than 2 % with regard to the first set of the two consecutive sets of readings. The first set of readings measured at this point is the set of deflections measured at the test load.

2.2.2.6 When subject to the test load the samples, their joints and internal fixing devices, are to show no damage or crack visible to normal view or corrected vision without magnification.

2.2.2.7 The load is then to be increased to 1.7 times the test load.

The samples are to be left and the deflections measured every 5 min until the difference between two consecutive sets of readings is less than 2% with regard to the first set of the two consecutive sets of readings. The samples are to sustain the increased loading without collapsing. Buckling and deformation of the samples is permissible at this loading.

Note: Alternatively, tests can be carried out:

- at any temperature within the declared range if documentation is available which states that the relevant structural properties of the materials as used within the system do not differ by more than 5% of the average between the maximum and minimum property values, or
- only at maximum temperature within the range, if documentation is available which states that the relevant structural properties of the materials as used within the system decrease when the temperature is increasing, or
- at maximum and minimum temperature only.

Tests are to be carried out for the smallest and largest sizes of cable tray lengths or cable ladder lengths, having the same material, joint and topological shape.

2.3 Fire properties

2.3.1 Flame retardant test

The cable trays/protective casings are to be at least flame retardant. They are to be tested in accordance with Table 2.3.1.

Flame Retardant Test

Table 2.3.1

Procedure according to	Test parameters	Other information
IEC 60092-101, or	– Flame application: 5 times 15 s each – Interval between each application: 15 s or 1 time 30 s	– The burnt out or damaged part of the specimen by not more than 60 mm long – Equipment design and the choice of materials is to reduce the likelihood of fire ensuring where surfaces of the specimen can be exposed to external fire they do not contribute to the fire growth
IEC 60695-2-2	Test criteria based upon application	

2.3.2 Smoke and toxicity test

The cable trays/protective casings are to be tested in accordance with the IMO Fire Test Procedures Code (FTPC), resolution MSC.61(67), Part 2 – Smoke and Toxicity Test, or any international or national standard.

2.4 Special requirements

2.4.1 Resistivity test

Cable trays/protective casings passing through a hazardous area are to be electrically conductive.

The volume resistivity level of the cable trays/protective casings and fittings is to be below $10^5 \Omega$ and the surface resistivity is to be below $10^6 \Omega$. The cable trays/protective casings are to be tested in accordance with IEC 60093.

The resistance to earth from any point in these appliances is not to exceed $10^6 \Omega$.