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INTERNATIONAL STANDARD

Electrical installations in ships –
Part 201: System design – General

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ELECTRICAL INSTALLATIONS IN SHIPS –

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FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60092-201 has been prepared by IEC technical committee 18: Electrical installations of ships and of mobile and fixed offshore units.

This fifth edition cancels and replaces the fourth edition, published in 1994. It constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) a new subclause regarding studies and calculations has been added;
b) a new subclause regarding documentation has been added;
c) the clause regarding distribution systems has been rewritten;
d) a clause regarding system earthing has been added;
e) the clause regarding sources of electrical power has been rewritten;
f) the clause regarding distribution system requirements has been rewritten;

g) the clause regarding cables has been deleted and transferred to IEC 60092-401;

h) a new subclause regarding electric and electrohydraulic steering gear has been added.

NOTE IEC 60092-204, *Electrical installations in ships – Part 204: System design – Electric and electrohydraulic steering gear*, has been withdrawn.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
18/1673/FDIS	18/1674/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 60092 series, published under the general title *Electrical installations in ships*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

IEC 60092 (all parts) forms a series of international standards for electrical installations in sea-going ships, incorporating good practice and co-ordinating as far as possible existing rules.

These standards form a code of practical interpretation and amplification of the requirements of the International Convention on Safety of Life at Sea, a guide for future regulations which may be prepared and a statement of practice for use by shipowners, shipbuilders and appropriate organizations.

ELECTRICAL INSTALLATIONS IN SHIPS –

Part 201: System design – General

1 Scope

This document is applicable to the main features of system design of electrical installations for use in ships.

2 Normative references

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

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

IEC 60092-202, *Electrical installations in ships – Part 202: System design – Protection*

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

IEC 60364-1, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*

IEC/IEEE 80005 (all parts), *Utility connections in port*

IMO, *International Convention for the Safety of Life at Sea (SOLAS):1974*, *consolidated edition 2009*

3 Terms and definitions

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

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

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

3.1 General

3.1.1
dead ship
condition where the entire machinery installation, including the power supply, is out of operation and where auxiliary services such as compressed air, starting current from batteries etc., for bringing the main propulsion into operation and for the restoration of the main power supply, are not available

3.1.2
arc-flash hazard
dangerous condition associated with the release of energy caused by an electric arc

[SOURCE: IEEE Std 1584™:2002, 3.1.2]

3.1.3
availability
state of an item of being able to perform its required function

[SOURCE: IEC 60050-603:1986, 603-05-04]

3.1.4
function
elementary operation performed by the system which, in conjunction with other elementary operations (system functions), enables the system to perform a task

3.1.5
main steering gear
machinery, rudder actuators, steering gear power units and ancillary equipment and the means of applying torque to the rudder stock (e.g. tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the ship under normal service conditions

3.1.6
auxiliary steering gear
equipment, other than any part of the main steering gear, necessary to steer the ship in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose

3.1.7
electric steering gear
power-operated steering gear where an electric motor applies torque to the rudder stock through mechanical means only

3.1.8
electrohydraulic steering gear
power-operated steering gear where a hydraulic pump, driven by an electric motor, applies torque to the rudder stock through hydraulic and mechanical means

3.1.9
steering gear power unit
a) in the case of electric steering gear, an electric motor and its associated electrical equipment;
b) in the case of electrohydraulic steering gear, an electric motor and its associated electrical equipment and connected pump

3.1.10
steering gear control system
equipment by which orders are transmitted from the navigating bridge to the steering gear power units

Note 1 to entry: Steering gear control systems include transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables, etc.

3.1.11
high voltage
HV
set of voltage levels in excess of low voltage

[SOURCE: IEC 60050-601:1985, 601-01-27, modified – The words "in a general sense" have been deleted, as well as entry 2 of the definition.]

3.1.12
low voltage
LV
set of voltage levels used for the distribution of electricity and whose upper limits are generally accepted to be 1 000 V AC and 1 500 V DC

[SOURCE: IEC 60050-601:1985, 601-01-26, modified – The words "for alternating current" have been replaced by "AC and 1 500 V DC".]

3.1.13
voltage drop
change of the voltage between two given terminals of an electric circuit due to the change of the operating conditions

[SOURCE: IEC 60050-151:2001, 151-15-09]

3.2 Distribution system

3.2.1
branch
electrical line intended for connecting a current-consuming installation to the distribution network

3.2.2
branch system
assembly of branches

3.2.3
meshed network
ring-main
set of conductors that connect feeding points (nodes) and form a closed circuit

3.2.4
diversity factor
demand factor
ratio of the estimated total load of a group of consumers under their normal working conditions to the sum of their nominal ratings

3.2.5
power supply ship high voltage interface
interface between HV shore connection and the ship's primary distribution system

Note 1 to entry: Located at the ship-shore connection switchboard.

3.2.6
essential services
services essential for propulsion and steering, and safety of the ship, which are made up of "primary essential services" and "secondary essential services"

[SOURCE: IACS SC134]

3.2.7
primary essential services
services that need to be in continuous operation to maintain propulsion and steering

[SOURCE: IACS SC134]

3.2.8
secondary essential services
services that need not necessarily be in continuous operation to maintain propulsion and steering but which are necessary for maintaining the vessel's safety

[SOURCE: IACS SC134]

3.2.9
load shedding
automatic disconnection of users

Note 1 to entry: Where the load consists of essential services and non-essential services, consideration shall be given to an arrangement which will automatically exclude non-essential services when any one generator becomes overload by power or current. This load shedding may be carried out in one or more stages, according to the overload ability of the generating sets.

3.2.10
primary distribution system
system having an electrical connection with the main source of electrical power

3.2.11
secondary distribution system
system having no electrical connection with the main source of electrical power, e.g. isolated therefrom by a double-wound transformer, static convertor including galvanic separation or motor-generator

3.2.12
hull return system
system in which insulated conductors are provided for connection to one pole or phase of the supply, the hull of the ship or other permanently earthed structure being used for effecting connections to the other pole or phase

3.3 DC systems of distribution

3.3.1
two-wire DC system
DC system comprising two conductors only, between which the load is connected

3.3.2
three-wire DC system
DC system comprising two conductors and a middle wire, the supply being taken from the two outer conductors or from the middle wire and either outer conductor, the middle wire carrying only the difference-current

3.4 AC systems of distribution

NOTE 1 AC systems are normally designed as an earthed system (TN) or an unearthed system (IT)

NOTE 2 In some countries, "unearthed systems" are also defined as "isolated systems".

3.4.1
single-phase two-wire AC system
single-phase AC system comprising two conductors only, between which the load is connected

3.4.2
single-phase three-wire AC system
single-phase AC system comprising two conductors and a neutral wire, the supply being taken from the two outer conductors or from the neutral wire and either outer conductor, the neutral wire carrying only the difference-current

3.4.3
three-phase three-wire system
system comprising three conductors connected to a three-phase supply

3.4.4
three-phase four-wire system
system comprising four conductors of which three are connected to a three-phase supply and the fourth to a neutral point in the source of supply

3.5 Sources of electrical power

3.5.1
dead-ship condition
condition under which the main propulsion, boilers and ship auxiliaries are not in operation owing to the absence of power and no stored energy for starting the propulsion plant, and the main source of electrical power, is available

3.5.2
main source of electrical power
source intended to supply electrical power for distribution to all services necessary for maintaining the ship in normal operational and habitable condition

3.5.3
emergency source of electrical power
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

4 Safety aspects

4.1 General

Electrical installations in ships shall be such that:

– services essential for safety shall be maintained under emergency conditions;
– the safety of passengers, crew and ship from electrical hazards shall be ensured;
– the requirements with respect to safety in this publication shall be at least in accordance with this publication;
– the IMO resolutions and SOLAS regulations are met as far as is applicable.

The choice of materials and components of construction, as well as the design, location and ship installation, are to be made in accordance with the environmental, maintenance and operating conditions in order to ensure the continued function of the equipment during all normal and reasonably foreseeable abnormal operating and fault conditions and to reduce the risk of:

- injury to crew and passengers;
- damage to the equipment the system is contained within, or adjacent equipment and systems;
- damage to adjacent equipment and systems;
- damage to the ship.

4.2 Degrees of protection

Depending on its location, electrical equipment shall as a minimum have the degree of protection as given in Table 1, which is in accordance with IEC 60529.

Table 1 – Minimum requirements for the degree of protection (in accordance with IEC 60529 coding)

(1) Example of location	(2) Condition in location	(3) Design according to degree of protection	(4) Equipment: Switch-boards Control gear Motor starters	Gene-rators	Motors	Trans-fomers Semi-conduc-tors Conver-tors	Lumi-naires	Heating applian-ces	Cooking appli-ances	Accessories (e.g. switches, branch boxes)
Tankers [a]	Danger of explosion	Certified safe-type[b]								[c]
Ammonia plant rooms			-	-	-	-	X	-	-	X
Battery rooms			-	-	-	-	X	-	-	X
Paint stores			-	-	-	-	X	-	-	X
Stores for welding-gas bottles			-	-	-	-	X	-	-	X
Holds classified as hazardous			-	-	-	-	X	-	-	X
Tunnels for pipes containing oil with a flash-point of 60 °C of below			-	-	-	-	X	-	-	X
Dry accommodation spaces	Danger of touching live	IP20	X	-	X	X	X	X	X	X
Dry control rooms	Parts only		X	-	X	X	X	X	X	X
Control rooms (navigation bridge)	Danger of dripping liquid and/or	IP22	X	-	X	X	X	X	X	X
Engine and boiler rooms above floor	moderate mechanical damage		X	X	X	X	X	X	X	IP44
Steering-gear rooms			X	X	X	X	X	X	-	IP44
Refrigerating machinery rooms (excluding ammonia plants)			X	-	X	X	X	X	-	IP44
Emergency machinery rooms			X	X	X	X	X	X	-	IP44
General store rooms			X	-	X	X	X	X	-	X
Pantries			X	-	X	X	X	X	X	IP44
Provision rooms			X	-	X	X	X	X	-	X

(1) **Example of location**	(2) **Condition in location**	(3) **Design according to degree of protection**	(4) **Equipment** Switch-boards Control gear Motor starters	Gene-rators	Motors	Trans-fomers Semi-conduc-tors Conver-tors	Lumi-naires	Heating applian-ces	Cooking appli-ances	Accessories (e.g. switches, branch boxes)
Bathrooms and showers	Increased danger of liquid and/or mechnanical damage	IP34	-	-	-	-	X	IP44	-	IP55
Engine and boiler rooms below floor			-	-	IP44	-	X	IP44	-	IP55
Closed fuel oil separator rooms			IP44	-	IP44	-	X	IP44	-	IP55
Closed lubricating oil separator rooms			IP44	-	IP44	-	X	IP44	-	IP55
Ballast pump rooms	Increased danger of liquid and mechanical damage	IP44	X	-	X	X	IP34	X	-	IP55
Refrigerated rooms			-	-	X	-	IP34	X	-	IP55
Galleys and laundries			X	-	X	X	IP34	X	X	X
Shaft or pipe tunnels in double bottom	Danger of liquid spraying	IP55	X	-	X	X	X	X	-	IP56
Holds for general cargo	Presence of cargo dust		-	-	-	-	X[d]	-	-	X[d]
	Serious mechanical damage Aggressive fumes		-	-	-	-	X	-	-	X
Open decks	Danger of liquid in massive quantities	IP56	X	-	X	-	IP55	X	-	X

Key

X: complies with column (3)

-: not recommended

Where the protection is not achieved by the equipment itself, other means or the location where it is installed shall ensure the degree of protection required in the table.

[a] For tankers, see IEC 60092-502.

[b] Certified safe-type equipment referred to in IEC 60079-0 may need additional enclosure requirements for spaces on open decks or other spaces where wet conditions are expected. The examples above may be used as guidelines.

[c] Socket-outlets shall not be installed in machinery spaces below the floor, closed fuel and lubricating oil separator rooms or spaces requiring certified safe-type equipment.

[d] For hazardous dust, an appropriate degree of protection is IP 66 or certified safe-type.

5 System design

5.1 General

There shall be one nominated body responsible for the integration of the complete electrical plant. This body shall have the necessary expertise and resources enabling a controlled integration process.

The ship builder is responsible for the system design unless agreed otherwise.

The design of the electrical system shall, wherever possible, consider the efficient use of generated power due to the low energy equipment and application of energy-saving methods.

5.2 System study and calculations

5.2.1 General

Studies and calculations shall reflect the installed power rating and the complexity of the electrical system.

The system studies and calculations shall be in accordance with the designed operating modes of the vessel.

Additions and alterations to the existing electrical system, temporary or permanent, shall be evaluated accordingly. The system studies and calculations are important operational documents. They should be updated as necessary when changes are made to the installation.

As a minimum, the studies listed in IEC 60092-202 shall be carried out.

Additional studies can be considered if it is deemed necessary for the evaluation of the system, or required by appropriate authorities, such as:

– arc-flash hazard risk assessment;

NOTE The objective of the flash hazard assessment is to increase personnel safety by determining the arc-flash.

– load flow and voltage loss calculations: to check voltage profiles, circuit loading under steady-state conditions, transient conditions and power supply interfaces;
– calculation of harmonic currents and harmonic voltages: to analyse the magnitude and location of harmonic distortions within the power system;
– Common mode network studies may be necessary if high-power non-linear loads and filters are applied.

5.2.2 Electrical load study

The electrical load study should be in accordance with IEC 60092-202.

If load flow calculations are performed, these shall be carried out for the operational conditions given.

The electrical load study shall include all electrical services necessary for maintaining the ship in normal operational and habitable condition and preservation of the cargo, as far as possible, over the entire lifetime of the installation.

5.2.3 Short-circuit calculations

See IEC 60092-202.

NOTE: IEC 61363 can be used for fault calculation for AC sources and IEC 61660-1 for DC sources.

5.2.4 Protection and discrimination study

See IEC 60092-202.

The voltage disturbance sustained during the faults and after fault clearance should be ascertained to ensure that transient disturbances do not result in loss of supplies due to low voltages or overstressing of plant insulation due to high voltages.

5.2.5 Load flow calculations

Steady-state load flow calculations shall be carried out for the operational conditions giving maximum peak load and minimum load based on loads determined in 5.2.1.

The following data should be calculated:

– magnitude of the busbar voltages;
– magnitude of voltage at the equipment terminal;
– active and reactive power production and load at the busbars;
– active and reactive power flow in cables and transformers;
– recommended setting of the transformers' tapping;
– voltage transients due to capacitive and inductive loading of the network (transformers, motors, generators, filters, cabling, etc.).

Where specific loads require closer tolerances for voltages in order to maintain functionality or performance, then specific calculations should be made to confirm values of voltage drop, particularly in cables.

5.2.6 Harmonic currents and voltage calculations

The content of currents' harmonics and voltages' harmonics in the electric power system shall be examined for installations with a high presence of power semiconductor systems. For the voltage waveform, the limits indicated in IEC 60092-101 shall be verified.

NOTE 1 It can be necessary to feed sensitive equipment from a power system with a restricted content of harmonics, for example from a maintained supply or separate secondary distribution system.

NOTE 2 For systems where semiconductors are connected having a total system rating which is a significant portion of the total system rating, it may not be feasible to suppress the harmonics. Consideration should be given to take appropriate measures to attenuate these effects of the distribution system so that safe operation is assured. Care should be taken in selecting consumers supplied from an electric power supply system with a higher harmonic content than specified in IEC 60092-101.

Electrical equipment that requires a higher power quality may need additional provisions to be made locally. Where additional equipment is fitted to this higher power quality supply, it may be required to be duplicated and segregated to the same degree as the electrical equipment it supplies for the same level of continuity of electrical supply.

Special attention should be paid to the installation of electrical equipment that can influence the quality of power supply on local basis or react with any harmonics present on the general distribution system.

NOTE 3 For further information regarding harmonics, see IEC 61000-2-4 and IEC 60533.

5.3 Documentation

5.3.1 General

Documentation required in accordance with 5.3.2 to 5.3.6 is to be available onboard at all times. The documentation is to be updated as required, see 5.2.1.

5.3.2 Apparatus description

For the primary distribution, main secondary distribution, primary essential, essential and emergency loads, the manufacturer shall deliver sufficient information concerning the principles of operation, technical specifications, mounting instructions, required starting up or commissioning procedures, fault-finding procedures, maintenance and repair, as well as lists of the necessary test facilities and replaceable parts.

Sufficient information shall be available to enable a complete system description to be prepared.

5.3.3 Principle single line diagram electrical power system

General single line lay-out of the electric plant, power generation, power storage and power distribution shall be aboard the ship.

5.3.4 Overview diagram

The overview diagram or list of circuits shall be:

– provided for each individual distribution switchboard; and
– permanently displayed in or near the switchboard to which it refers; and
– included in the ship's administrative documents.

Each overview diagram or list of circuits shall present at least the following information:

– circuit number;
– protections and controls;
– cable type;
– connected power and diversity factor for of each circuit, calculated taking into account the diversity factor of the connected load (where applicable).

5.3.5 List of protection and fault discrimination settings

A list of protection and fault discrimination settings shall be available.

5.3.6 Circuit diagrams

Circuit diagrams for at least primary distribution, main secondary distribution, primary essential, essential and emergency loads shall, for each individual control apparatus, be permanently displayed in or near the apparatus to which it refers, or alternatively included in the control system handbook.

5.3.7 FAT, HAT and SAT reports

A document comprising the factory acceptance tests (FAT) reports, harbour acceptance tests (HAT) reports and sea acceptance tests (SAT) reports of the control, safety and power systems, and shall be included in the ship's administrative documents.

6 Distribution systems

6.1 General

The current carrying distribution systems shall be in accordance with IEC 60364-1.

The requirements in 6.2 and 6.3 do not preclude, under conditions approved by the appropriate authority, the use of:

– impressed current cathodic protective systems;
– limited and locally earthed systems, for example engine starting systems;
– insulating monitoring devices in accordance with IEC 61557-8 provided circulation current does not exceed 30 mA under the most unfavourable conditions.

NOTE For tankers, see IEC 60092-502.

Where semiconducting equipment is arranged to distribute electrical power to distribution of a lower voltage of supply, arrangements shall be provided to ensure the lower voltage distribution consumers are not subject to voltages outside their safe rating of operation.

6.2 DC distribution systems

6.2.1 Types of distribution systems

The following types of distribution systems are considered to be standard:

a) two-wire with one pole earthed but without structure or hull return system – TN-S system;

b) three-wire with middle wire earthed but without structure or hull return – TN-S system;

c) two-wire insulated – IT system;

d) three-wire insulated with middle wire not earthed – IT system.

The structure or hull return system of distribution shall not be used.

In earthed DC systems, the effect of electrochemical corrosion shall be considered.

Batteries connected to and charged by the DC bus shall be protected against effects of electrical faults in the system.

Arrangements for the isolation and switching of distribution circuits are to be provided.

Energy storage, such as capacitors shall be provided with arrangements to discharge their stored energy to a safe level after power removal to ensure safety of personnel during maintenance.

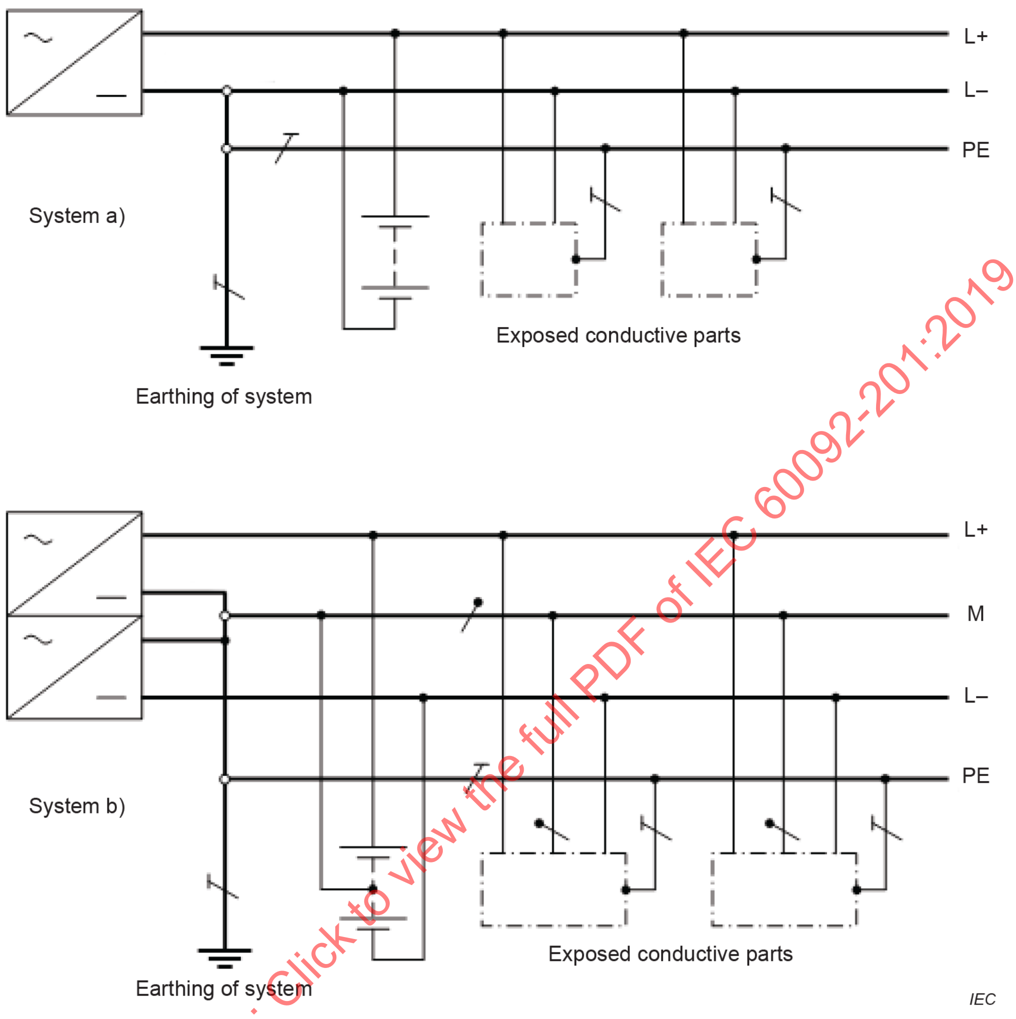
Batteries connected to and charged by the DC bus shall be so located and provided with arrangements allowing for the safe isolation of their terminals and the reduction of voltages to a safe level during maintenance.

Connections and materials used in DC connections shall be especially considered and selected to avoid corrosion at the connection points, which can lead to development of a series arc.

Voltage limiters are to be provided, where required, to limit the damaging effect of overvoltage in the system.

6.2.2 TN-S DC systems

Figure 1 illustrates a TN-S DC system.



NOTE The earthed line conductor (for example L–) in system a) or the earthed middle wire conductor (M) in system b) are separated from the protective conductor throughout the system.

Figure 1 – TN-S DC system

6.2.3 IT DC systems

Figure 2 illustrates an IT DC system.

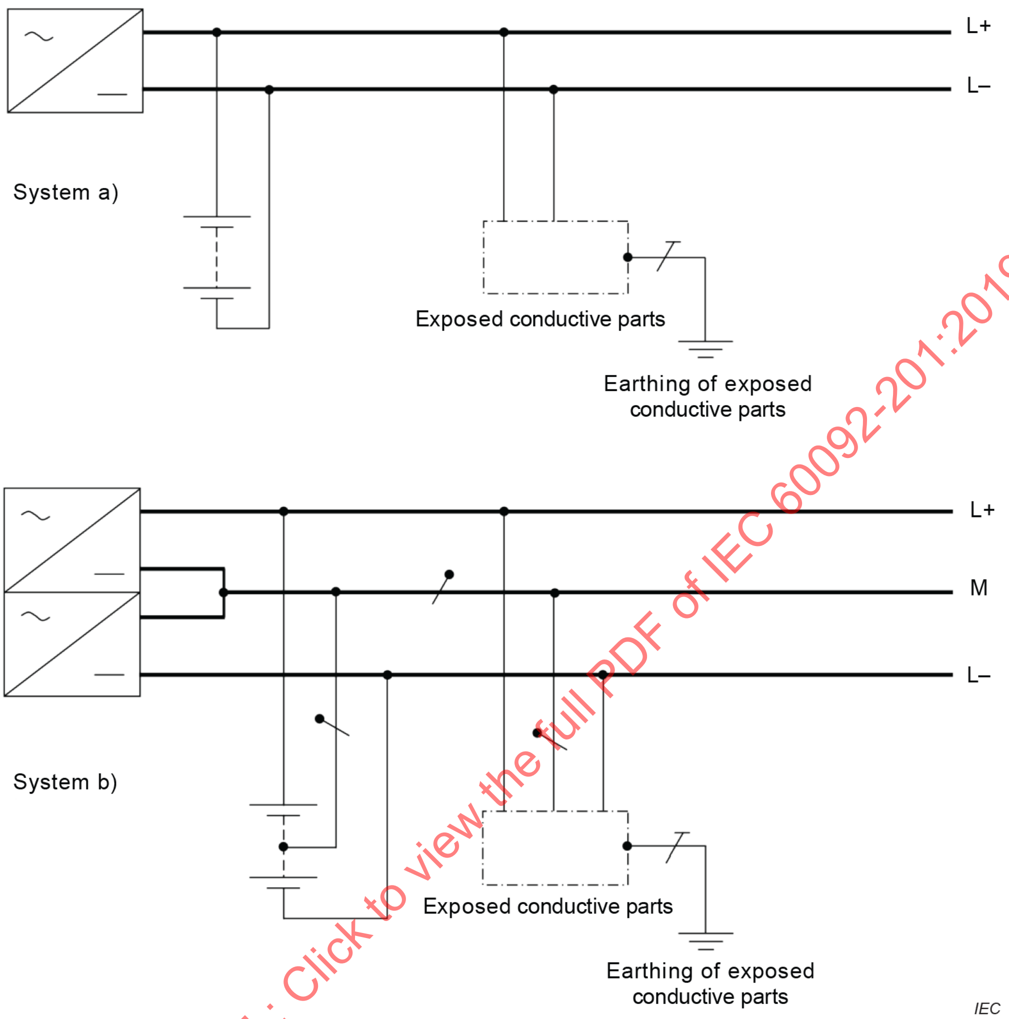


Figure 2 – IT DC system

6.2.4 DC voltages

Table 2 gives recommended values of nominal voltages and maximum voltages allowed for unit service systems of supply:

Table 2 – Voltages for DC systems

Application	Nominal voltages V	Maximum voltages V
Power	110, 220, 600, 750, 1 000	1 500
Cooking, heating	110, 220	500
Lighting and socket outlets	24, 110, 220	500
Communication	6, 12, 24, 48, 110, 220	250
Supplies to lifeboats or similar craft	12, 24, 48	55
Instrumentation	24, 48, 110, 220	250

6.3 AC distribution systems

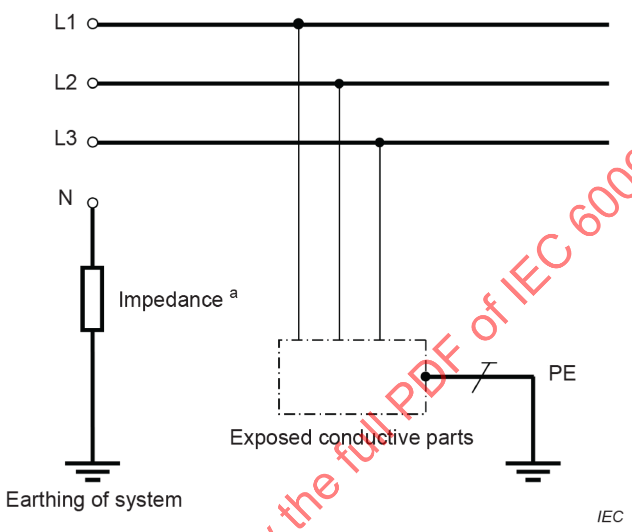
6.3.1 Primary AC distribution systems

The structure or hull return system of distribution shall not be used.

The following systems are recognized as standard for primary distribution:

– three-phase three-wire insulated (IT-system);
– three-phase three-wire with neutral earthed (TN-S-system).

Figure 3 illustrates an IT AC system. Figure 4 illustrates a TN-S system.

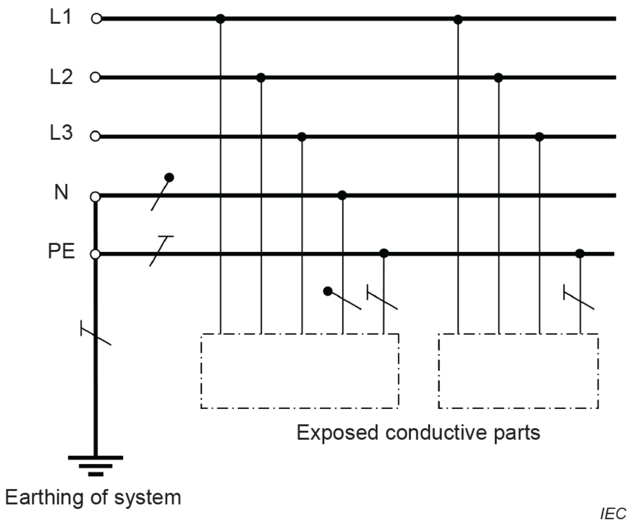


Key

[a] The system may be isolated from earth.

NOTE Typical IT systems are not intentionally earthed "isolated". See 7.2 and Table 4.

Figure 3 – IT AC system



NOTE 1 Separate neutral and protective conductors are used throughout the system.

NOTE 2 The hull of the ship cannot be used as alternative to a PE conductor.

Figure 4 – TN-S AC system

In addition, for all voltages up to and including 500 V:

- three-phase four-wire with neutral earthed but without hull return (TN-S system);
- single-phase two-wire insulated (IT-system);
- single-phase two-wire with one pole earthed (TN-S system).

NOTE 1 For tankers, see IEC 60092-502.

NOTE 2 For high voltage, see IEC 60092-503.

6.3.2 Secondary AC distribution systems

The following systems are recognized as standard for secondary distribution:

- three-phase three-wire insulated (IT-system);
- three-phase three-wire with neutral earthed (TN-S system);

In addition, for all voltages up to and including 500 V:

- three-phase four-wire with neutral earthed but without hull return (TN-S system);
- single-phase two-wire insulated (IT-system);
- single-phase two-wire with one pole earthed (TN-S system);
- single-phase two-wire with mid-wire of system earthed for supplying lighting and socket-outlets;
- single-phase three-wire with mid-wire earthed but without hull return (TN-S system).

6.3.3 AC voltages and frequencies

Table 3 gives the maximum voltages allowed and the recommended values of nominal voltages and frequencies for a ship's service systems of supply.

Table 3 – AC voltages and frequencies for ship's service systems of supply

Application	Nominal voltages V	Nominal frequencies HZ		Maximum voltage V
1 Power, heating and cooking equipment securely fixed and permanently connected. Socket-outlet supplying equipment, which is earthed either permanently by its fixing or by a specific connection which incorporates an earth-continuity conductor of a size in accordance with IEC 60092-401:	Three-phase	Three-phase	Three-phase	Three-phase
	115		60	1 000
	230	50	60	1 000
	400	50	-	1 000
	440	-	60	1 000
	690[a]	50	60	1 000
	3 000[a]/3 300[a]	50	60	15 000
	6 000[a]/6 600[a]	50	60	15 000
	10 000[a]/11 000[a]	50	60	
	24 kV[b]	50	60	
	36 kV[b]	50	60	
	Single-phase	Single-phase	Single-phase	Single-phase
	115	-	60	500
	230	50	60	500
2 Fixed lighting including outlets for purposes not mentioned in items 1 and 3 but intended for apparatus with reinforced or double insulation or connected by a flexible cord or cable incorporating an earth-continuity conductor of a size in accordance with IEC 60092-401	Single-phase	Single-phase	Single-phase	Single-phase
	115	-	60	250
	230	50	60	250
3 Socket-outlets for use where extra precautions against shock are necessary: supplied with or without the use of isolating transformers where a safety isolating-transformer is used supplying one consuming device only Both wires of such systems should be insulated from earth.	Single-phase	Single-phase	Single-phase	Single-phase
	24	50	60	55
	115	-	60	250
	230	50	60	250
4 Instrumentation and control	Single-phase	Single-phase	Single-phase	Single-phase
	24	50	60	55
	48	50	60	55
	115	-	60	250
	230	50	60	250

NOTE 1 For limited distribution in excess of 1 000 V, see IEC 60092-503.

NOTE 2 For tankers, see also IEC 60092-502.

[a] For power only.

[b] Implementing 24 kV and 36 kV in IEC 60092-503 is under consideration.

6.3.4 Control voltage

For distribution systems above 500 V, the control voltage shall be limited to 230 V, except when all control equipment is enclosed in the relevant control gear and the distribution voltage is not higher than 1 000 V.

7 System earthing

7.1 General

This clause gives requirements and recommendations for system earthing, i.e. an intentional connection of the neutral point of the electrical power supply system to hull or structure.

NOTE On occurrence of a fault from line to earth, the steady state and transient voltages to earth and fault currents vary with the impedance between the neutral point and earth. This impedance is dependent on the treatment of the neutral point.

System earthing shall be considered for all electrical power supply systems in order to control and keep the system's voltage to earth within predictable limits. It shall also provide for a flow of current that will allow detection of an unwanted connection between the system conductors and earth, which should instigate automatic disconnection of the power system from conductors with such undesired connections to earth.

System earthing shall be effected by means independent of any earthing arrangements of the non-current-carrying parts.

In IT systems, the insulation resistance shall be continuously monitored by an insulation monitoring device (IMD) complying with IEC 61557-8 and an alarm shall be given at a manned control centre.

In large IT systems, it is recommended to use an insulation fault location system (IFLS) complying with IEC 61557-9 to locate an insulation fault within a shortest practicable delay.

In earthed systems (TN-System), an RCM (residual current monitor) complying with IEC 62020 should indicate the presence of a fault current to prevent an unwanted tripping of an RCD.

Also, the effectiveness of a TN-S system may be enhanced by the use of RCM in cases where significant amounts of information technology equipment are contained or are likely to be contained.

RCDs and RCMs shall be so designed that their function is not decreased by the presence of DC fault currents of more than 6mA, for example by type B devices.

Residual current protective devices (RCD) shall be so selected and erected to limit the risk of unwanted tripping, for example resulting from a high leakage capacitance (line to earth).

Earth indicating devices should be so designed that their function is not decreased by the presence of DC components or capacitance (line to earth) in the distribution system.

For emergency power systems, consideration shall be given to the need for continuous operation of the consumers supplied from the emergency power system when deciding between earthed and isolated systems.

A system with isolated neutral should normally be used for supply to the emergency consumers.

7.2 Neutral earthing methods

The selection of one of the following methods of treating the neutral for a specific electrical power system shall be based on technical and operational factors:

– earthed (TN system/without hull return);
– impedance earthed (IT system);
– isolated (IT system).

NOTE 1 The principal features of these methods are presented in Table 4.

NOTE 2 Although not intentionally connected to earth, the so-called "unearthed" or "isolated" system is in fact capacitively earthed by the distributed capacitance to earth of the conductors throughout the system together with any interference suppression capacitors.

Where phase to neutral loads shall be served, systems shall be directly earthed.

Efficient means shall be provided for detecting defects in the insulation of the system.

For galvanic separated distribution systems where the earth fault current exceeds 5 A, automatic tripping devices should be provided. Where the earth fault current does not exceed 5 A, an indicator (e.g. residual current monitor (RCM) in accordance with IEC 62020) should be provided as an alternative to an automatic tripping device.

Supply to hazardous areas shall be in accordance with IEC 60092-502.

NOTE 3 With an appropriate insulation standard and a design which limits the capacitive currents to less than 5A, unearthed HV systems are possible. This is under consideration for the next edition of IEC 60092-503.

A maximum leakage current of 30 mA is allowed for equipment applied in living quarters, accommodation rooms, control rooms, bathrooms, offices, stores, final circuits for sockets, etc.

Wet spaces or special spaces like pantries, galley and laundry need special attention to prevent an electric hazard due to earth leakage currents.

The aggregate value of earth leakage currents in a distribution system should be limited. If exceeding 30 mA leakage current by individual low voltage loads, the power system designer shall be informed. For exceeding 300 mA leakage current at the power supply interface, isolation by a transformer shall be considered (e.g. load with an electric filter or group of loads like galley, laundry).

7.3 Generators and/or main distribution transformers operated in parallel

The neutral earthing equipment shall, wherever practical, be identically rated for all power sources.

The neutral earth impedance shall reduce the fault current to a level sufficient to operate the distribution system earthing protection and provide suitable discrimination.

Where the normal ratings of the power sources are significantly different, the earth impedance resistor rating selection shall be dictated by the requirement to ensure that the most insensitive earth fault protection on any incoming or outgoing circuit operates positively with the smallest possible source.

The value should not risk damage to the winding or magnetic steel parts of the generator or transformer in accordance with the manufacturer's recommendations of earth fault current connected to the system.

An insulation fault inside the metal casing of a TN-connected generating set may severely damage the generator of this set. The fault shall be quickly detected and eliminated. Furthermore, if other generators are parallel connected, they will generate energy in the fault and may cause overload tripping. Continuity of supply is no longer ensured.

7.4 Earthing resistors, connection to hull/structure

Earthing resistors shall be provided with insulation suitable for the phase-to-phase voltage of the systems to which they are connected. They shall be designed to carry their rated fault current for at least 10 s and for the maximum time this fault could occur in addition to any continuous loading, without any destructive effect to their component parts.

Earthing resistors shall be connected to the unit's structure or hull. In addition, earthing resistors shall be connected together on the structure/hull side of the resistor, whereto also the protective earthing (PE) conductor (if applicable) of the distribution system shall be connected. Suitable disconnecting links, which allow for measuring or maintenance purposes, shall be provided.

The means of connection shall be separate from that provided at the unit's structure or hull for radio, radar and communications circuits in or to avoid interference.

Table 4 – Summary of principal features of the neutral earthing methods

Means of earthing	Not intentionally earthed "isolated"	Impedance earthed	Directly earthed
System voltage	All methods are potentially applicable (but note higher voltage systems are likely to have higher VA earth fault levels, which may make directly earthed connections, or low impedance methods, unattractive)		
Overvoltages	The most significant overvoltages are due to causes not influenced by the method of neutral earthing		
Electric shock risk	All major installations are potentially lethal whatever method of neutral earthing is used		
Use of residual current device for electrical safety	Will normally not function	Use of residual current device with 30 mA operating current should be considered	Acceptable
Use of 3-phase 4-wire supply	Not acceptable	Acceptable	Acceptable
Earth fault current magnitude	Depends on system capacitance but usually very low, e.g. 1 A	Depends on impedance value, typically 5 A to 20 A	May be up to 50 % greater than symmetrical 3-phase value
Sustained operation with earth fault	Normally possible	May be possible but not advisable, depending on impedance value	Not possible
Minimum earth fault protection required	Alarm or indication	Alarm/indication, earth fault relay, over-current protection, depending on impedance	Over-current protection
Switchgear fault rating	May be rated on normal phase to phase or 3-phase symmetrical fault value		May have to be rated on single-phase-to earth or phase-to-phase-to-earth value
Earth fault location	Faults not self-revealing. Shall normally be located manually unless core balance current transformers are fitted	If relays fitted, faults self-revealing. Otherwise, shall be located manually	Faults are self-revealing on over-current

Means of earthing	Not intentionally earthed "isolated"	Impedance earthed	Directly earthed
Fire risk	Very low, provided that earth fault current does not exceed 1 A. Prolonged fault may present a hazard.	Risk of igniting flammable gases. High-impedance faults can lead to burning at fault location.	
Flash hazard (phase-to-earth)	Low -------------------------Increasing ---High		
Availability of suitable equipment	Similar generation and distribution equipment is applicable on all systems		Allows use of land-based equipment designed for TN-S systems

Means of disconnecting shall be fitted in the neutral earthing connection of each generator so that the generator may be disconnected for maintenance.

In distribution systems with neutral earthed and generators intended to run with neutrals interconnected, manufacturers shall be informed so that the machines can be suitably designed to avoid excessive circulating currents. This is particularly important if they are of different size and make.

Transformer neutrals should not be earthed unless all corresponding generator neutrals are disconnected from the system (e.g. during shore supply). To prevent hull currents during shore supply, the neutral of the power supply grid shall be connected to the hull at one point only (see 9.8).

Earthing of isolated (IT) HV networks supplied by several generators in parallel may be achieved by connection of earthing transformers.

8 Sources of electrical power

8.1 Sources of electrical power for auxiliary services

8.1.1 General

All vessels shall have a main electric power generation and distribution system in accordance with the following:

NOTE All considerations are based upon electrical systems in conformity with IMO documents such as SOLAS consolidated edition 2014.

The main electric power generation and distribution system shall ensure power to all electrical services necessary for maintaining the ship in normal operational and habitable condition and preservation of the cargo without the use of the emergency source of electrical power and/or the emergency distribution system.

Electrical services required by appropriate authority to be powered from an emergency source of power are not considered as "necessary for maintaining the ship in normal operational and habitable conditions" used in the previous paragraph.

For location and capacity of the emergency source of electrical power, and separation between the main and emergency power source, see SOLAS consolidated edition 2014, Regulation 42, 42-1 and 43, or other relevant documents from IMO or flag state.

The emergency services shall comply with SOLAS 74/78, Chapter II-2 Regulation 21 (Safe return to port).

There shall be redundancy for main sources of electrical power so that normal operational conditions for safety, and comfortable conditions of habitability shall have necessary power supply with any main source of power, transformer, or power converter out of operation.

Figure 5 illustrates a typical ship generation and distribution system

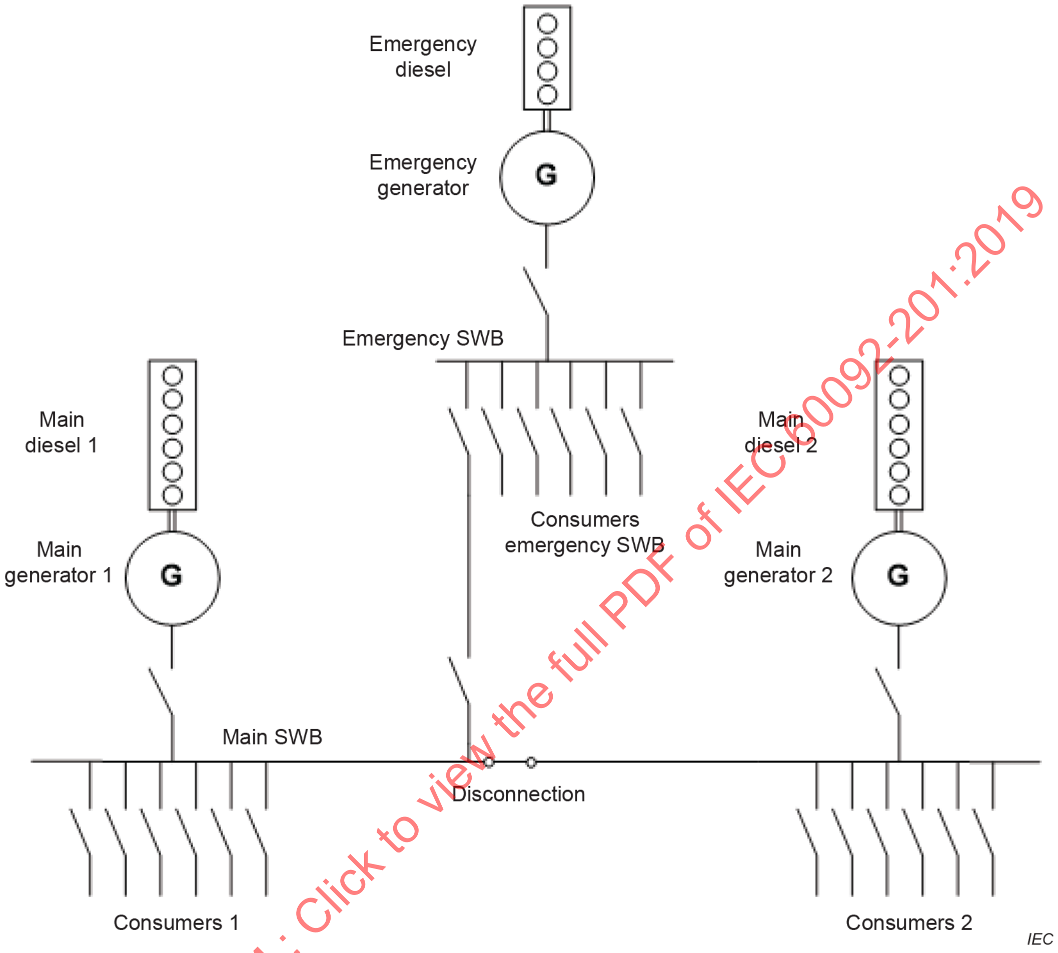


Figure 5 – Typical ship generation and distribution system

Table 5 illustrates a typical distribution of loads.

Table 5 – Typical distribution of loads

Consumers 1	Consumers 2	Emergency consumers
Primary essential	***Primary essential***	
Propulsion auxiliary 1	Propulsion auxiliary 2	Propulsion auxiliary
Steering pump 1	Steering pump 2	Steering pump
etc.	etc.	etc.
Secondary Essential	***Secondary Essential***	***Secondary Essential***
Cooling water pump 1	Cooling water pump 1	
Fire detection 1	Fire detection 2	Fire detection
Fire fighting 1	Fire fighting 2	Fire fighting
Bilge pump 1	Bilge pump 2	Bilge pump
Navigation 1	Naviation 2	

Consumers 1	Consumers 2	Emergency consumers
etc.	etc.	
Non-essential	***Non-essential***	
Ligthing 1	Ligthing 2	Emergency lighting
Laundry	Galley	
etc.	etc.	

Where transformers or power convertors constitute an essential part of the electrical distribution system, the system shall be arranged to ensure the same continuity of the supply.

The capacity of these sources shall be such that in the event of any one being stopped, it shall still be possible to supply those services necessary to provide:

a) normal operational safety;
b) minimum comfortable conditions of habitability, including at least adequate services for lighting, cooking, heating, domestic refrigeration, mechanical ventilation, sanitary and fresh water;
c) preservation of the cargo.

The main electrical generation shall consist of at least two independent power sources, such as diesel generators and fuel cells.

A generator or generator system, having the ship's main propulsion machinery as its prime mover, may be accepted as main sources of electrical power, provided that it can be used in all operating modes for the propulsion plant, including standstill of the vessel (with the propeller stopped). When there are several main propulsion engines, each of these could be the driver of a main source of power. One propulsion engine can only be the driver of one main source of electric power.

8.1.2 Arrangement

The main principle for arrangement of machinery for propulsion and power generation on a normal seagoing vessel is that the installation shall be located within the boundaries of the engine room (i.e. within the extreme main transverse watertight bulkheads forming the engine room), and that the engine room has an A60 boundary towards other parts of the vessel. For smaller vessels like fishing vessels and yachts, this requirement may be modified (see IEC 60092-507).

Sources of electric power located outside the engine room are regarded as additional sources of power.

For ships with specific redundancy and vulnerability requirements, the arrangement shall be in accordance to the applicable regulations and appropriate authority requirements.

NOTE Ships with more stringent redundancy requirements are for example DP vessels and cruise vessels with electric propulsion.

8.1.3 Operability

It shall be possible to start the required main sources of power by an operator in the engine room. Starting shall be based on stored energy located within the engine room, and with control systems located within the boundaries of the engine room. Manual starting of all main sources of power is a functional requirement and shall not be dependent on any other main source of power running (i.e. all main sources of power shall have individual capability to be started in a blackout situation).

It is accepted that only one main source of power can be started by stored energy, as long as this generator is not used in any other operating mode of the vessel (i.e. a dedicated standby generator). The stored energy used for this purpose shall be duplicated.

There shall be a manual mode of operation for the generator sets (start, stop, and operation) enabling individually control of the different sources of power, without dependency of common control systems.

Automatic actions, such as standby start, load shedding, or automatic start and stop, may depend on a common automation system located within the engine room. Automatic actions are not required to be operable in the manual mode.

8.1.4 Load shedding and automatic restoration of power

The design of the main power generation system shall include automatic response (e.g. load shedding) in case one main source of power suddenly becomes unavailable, i.e. the engine stops or the generator circuit breaker trips.

A seaworthy vessel shall be able to continue normal operation after a failure of any one of the main sources of electric power.

Any main source of power that is not in use when a blackout occurs shall be able to start and connect to the main busbars automatically when the blackout happens (unless it is locked out by its protection or made unavailable due to maintenance activities). This requirement applies unless the system is designed with a dedicated standby generator.

The control, monitoring and protection of essential loads shall be supplied by a limited break supply or maintained supply.

The continuity of electrical power supply of control, monitoring and protection of essential systems shall be in accordance to the applicable regulations and appropriate authority requirements.

If a generator is tripped by its short-circuit protection or differential protection, it will not be available for any restarting before the fault is manually acknowledged. Any requirements for automatic actions will therefore not be applicable.

Generators that are tripped by less-critical protective functions, for example their undervoltage relays or overcurrent protection, may be restarted and connected without manual acknowledgement of the protective action. However, it is accepted that an activated protection function prevents the generator set from being reconnected.

8.2 Bus-tie breakers

In installations where the main source of electrical power is necessary for propulsion of the ship, the main busbar shall be subdivided into at least two parts which shall normally be connected by circuit breakers or other approved means; so far as is practicable, the connection of generating sets and other duplicated equipment shall be equally divided between the parts.

NOTE See also IEC 60092-501.

The location of the subdivided main busbar parts shall be located in separate rooms if required owing to applicable regulations or appropriate authority requirements. Typically, only one main switchboard is installed in one room.

In addition to the required automatic system for load shedding and/or standby start in case of a failing main source of power, it is required that it is possible to split the main busbar in installations where the total installed of the main power sources is in excess of 3 MW. Duplicated sources of power, consumers and feeders shall be distributed on each side of the bus-tie, so that it is possible to restore necessary power supply to propulsion, safety, and habitability in case there is a failure in one of the main busbar sections.

The bus-tie breaker/s shall be equipped with a protection relay and or tripping interlocking, to ensure operation of at least one part of the subdivided main busbars.

In a scenario where a main busbar section has been damaged, its related standby generator may no longer be available due to the failure. In this case, successful automatic restoration of electric power is not required. Manual operation in order to re-establish the power supply is accepted, but without the need to use the emergency source of power or the emergency power distribution system.

8.3 Starting from a dead ship condition

It is required that the installation be designed and installed so that it is possible to bring the ship into operation from a "dead ship" condition. Starting from a dead ship condition shall be possible with any main source of power out of operation.

Since a system with a dedicated standby generator may be accepted, it can also be accepted that this dedicated standby generator is necessary in order to start the machinery from a dead ship condition.

Where the means for starting from a dead-ship condition is solely electrical and the emergency source of electrical power cannot be used for this purpose, the means for starting the generator set to be used for start-up from the dead-ship condition shall be provided with starting arrangements at least equivalent to those required for starting the emergency generator set.

The emergency source of electrical power may be used for the purpose of starting from a dead-ship condition if its capability either alone or combined with that of any other source of electrical power is sufficient to provide at the same time the emergency services required by the appropriate authority.

NOTE It is acceptable that the procedure for starting in a dead ship condition requires power feedback from the emergency switchboard. If the receiving busbar for this emergency power is damaged, restart may be impossible. A failing busbar will by itself not result in a dead ship condition since all forms of stored energy still shall be available in the engine room after such a failure. It is therefore acceptable that restart in a dead ship condition with a damaged part of the main busbar is impossible without repair.

8.4 Consequences of a busbar failure or a control system failure

The requirement to automatic load shedding or starting of main sources of power in a blackout situation is a functional requirement which does consider a faulty generator set. There is no requirement that the bus-tie is automatically opened in a blackout situation. Therefore, if the blackout is caused by a failure of the main busbar, automatic starting and connection of a standby generator may not be successful and the bus-tie shall be opened and interlocked.

NOTE 1 For additional class notations, or on vessels without dedicated emergency system, it might be a requirement that the bus-ties shall open on black-out and that there shall be black-out recovery arrangements on both (all) sections.

However, after manual opening of the bus-tie, it shall be possible to manually start and connect a generator on each side of the main busbar (except on the faulty busbar). Such starting and connection shall comply with the requirements given above.

The above also applies to a situation where a common control system fails (e.g. a centralized IAS or PMS system). As long as most common control system failures are alarmed in a centralized alarm system, a failure in the control system may result in loss of automatic starting in a blackout situation. However, after setting the diesel control system and the generator/generator cubicle in local mode, the possibility to perform starting and connection shall comply with the requirements above.

NOTE 2 It is acceptable that the procedure for starting in a dead ship condition requires power feedback from the emergency switchboard. If the receiving busbar for this emergency power is damaged, restart may be impossible. A failing busbar will by itself not result in a dead ship conditions since all forms of stored energy still shall be available in the engine room after such a failure. It is therefore acceptable that restart in a dead ship condition with a damaged part of the main busbar is impossible without repair.

8.5 Additional source of electrical power

Generators driven from the propulsion plant that do not comply with Clause 8 may be used as additional source(s) of electrical power with respect to the power balance, but attention should be given to a quick restoration of electrical power to all auxiliaries necessary for maintaining the ship in operational and safe condition. The time involved for restoring the above-mentioned services should be no longer than 45 s.

Source(s) of power that do not comply with the requirements given in 8.1 to 8.5 may be used as additional source(s) of electrical power.

8.6 Emergency source of electrical power

When an emergency source of power is required by the appropriate authority this shall be a self-contained and independent source of electrical power. Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency source of electrical power may, in exceptional cases and for periods of short duration, be used to supply non-emergency circuits. These non-emergency circuits shall be disconnected in the event of an overcurrent.

The physical arrangement (location), electrical system design, power available, duration of supply and services provided for safety in an emergency shall be as required by the appropriate authority.

It shall not be possible to overload the emergency source of power when used in an emergency situation. The emergency source of power shall therefore only be protected by short circuit protection and undervoltage tripping. Overload protection may, instead of disconnecting the generator automatically, give a visual and audible alarms.

Provision shall be made for the testing at regular intervals of the complete emergency power system and shall include the testing of the automatic starting arrangements.

9 Distribution system requirements

9.1 General

Requirements for installation of equipment are given in IEC 60092-401.

Requirements for tankers are given in IEC 60092-502.

9.2 Distribution systems for electrically powered containers or temporary loads

Where the ship is intended to carry containers or temporary loads, provisions shall be installed for preventing earth faults affecting the main distribution system.

9.3 Methods of distribution

The output of the ship's service generators can be supplied to the consumers of current by the way of either:

a) branch system, or

b) meshed network or ring-main.

The cables of a ring-main or other looped circuit (e.g. interconnecting section boards in a continuous circuit) shall be formed of conductors having sufficient current-carrying and short-circuit capacity for any possible load and supply configuration.

9.4 Balance of loads

9.4.1 Balance of load on three-wire DC systems

Current-consuming units connected between line and middle wire (M in System b) in Figure 1 and Figure 2) shall be grouped in such a way that, under normal conditions, the load on the two halves of the system is balanced as far as possible within 15 % of their respective load at the individual distribution and section boards as well as the main switchboard.

9.4.2 Balance of loads in three- or four-wire AC systems

For AC three- or four-wire systems, the current-consuming units shall be so grouped in the final sub-circuits that the load on each phase is, under normal conditions, balanced as far as possible within 15 % of their load at the individual distribution and section boards as well as the main switchboard.

9.5 Final sub-circuits

9.5.1 General

A separate final sub-circuit shall be provided for every motor required for an essential service and for every motor rated at 1 kW or more.

When not dedicated to socket outlets up to 32 A, final sub-circuits rated above 16 A shall supply not more than one appliance.

9.5.2 Final sub-circuits for lighting

Final sub-circuits for lighting shall not supply appliances for heating and power except that small galley equipment (e.g. toasters, mixers, coffee makers) and small miscellaneous motors (e.g. desk and cabin fans, refrigerators) and wardrobe heaters and similar items may be supplied.

NOTE Final sub-circuits for lighting should preferably be dedicated to lighting only.

In a final sub-circuit having a current rating not exceeding 16 A, the total connected load shall not exceed 80 % of the set current of the final sub-circuit protective device.

The number of lighting points supplied by a final sub-circuit having a current rating not exceeding 16 A shall not exceed the following maxima in Table 6.

Table 6 – Maximum number of lighting points

Voltage	Max number of points
Up to 55 V	10
From 56 V to 120 V	14
From 121 V to 250 V	24

Cornice-lighting, panel-lighting and electric signs, where lampholders are grouped in close proximity to each other and are connected to the circuit with fixed wires, may be connected to a final sub-circuit, provided that the maximum operating current in the final sub-circuit does not exceed 10 A.

In the absence of precise information regarding lighting loads of final sub-circuits it may be assumed that every lamp holder requires a current equivalent to the maximum load likely to be connected to it, which is assumed to be at least 60 W; except that, where the lampholder is so constructed as to take only a lamp rated at less than 60 W, the current rating may be assessed accordingly.

Final sub-circuits for lighting in accommodation spaces may, as far as practicable, include socket-outlets. In that case, each socket-outlet counts for 200 VA.

9.5.3 Final sub-circuits for heating

Each heater shall be connected to a separate final sub-circuit 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.

Separate transformers should be used for supply to trace heating systems.

9.5.4 Control circuits

9.5.4.1 General

Requirements for control circuits are given in IEC 60092-504 and IEC 60204-1.

9.5.4.2 Supply systems and nominal voltages

As the extension and complexity of control circuits may vary, it is not possible to lay down detailed recommendations for type of supply and voltage, but consideration should be given to choosing DC or AC systems with nominal voltages as indicated in Tables 2 and 3.

Where external control systems are grouped in a console, unless individually protected against accidental contact and properly marked, the control voltage shall not exceed 230 V.

9.5.4.3 Circuit design

Control circuits shall be designed in such a manner that, as far as practicable, faults in these circuits do not impair the safety of the system.

In particular, control circuits shall be designed, arranged and protected to limit dangers resulting from a fault between the control circuit and other conductive parts liable to cause malfunction (e.g. inadvertent operation) of the controlled apparatus.

Electrical faults and low insulation of control or safety circuits for propulsion, manoeuvring and power systems shall generate audible and/or visual alarms clearly identified by the operator.

NOTE 1 For tankers, locally earthed control circuits in safe areas are exceptions as per IEC 60092-502.

NOTE 2 Attention is drawn to the separation of control circuits to maintain the availability of essential services in the case of a fault in a control circuit exterior to the equipment.

9.5.4.4 Motor control

Unless automatic restarting is required, motor control circuits shall be designed so as to prevent any motor from unintentional automatic restarting after a stoppage due to a fall in or loss of voltage, if such starting is liable to cause danger.