

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Electrical installations in ships –
Part 507: Small vessels**

**Installations électriques à bord des navires –
Partie 507: Petits navires**



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INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Electrical installations in ships –
Part 507: Small vessels**

**Installations électriques à bord des navires –
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International Standard IEC 60092-507 has been prepared by IEC technical committee 18: Electrical installations of ships and of mobile and fixed offshore units.

This third edition cancels and replaces the second edition published in 2008 and constitutes a technical revision.

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

- a) The standard now clarifies its application for electrical installations in those recreational craft which require to conform to the Recreational Craft Directive.
- b) The standard specifies requirements for methods of galvanic isolation for small vessels and recreational craft connecting to a low voltage AC shore supply.
- c) The standard includes design guidance for electric propulsion systems suitable for small vessels and associated installation requirements.

The text of this standard is based on the following documents:

FDIS	Report on voting
18/1426/FDIS	18/1443/RVD

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

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

A list of all the 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 publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
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INTRODUCTION

This International Standard incorporates and coordinates, as far as possible, the existing requirements for electrical installations relevant to small vessels as published in other parts of the IEC 60092 series and the IEC 60364 series.

ELECTRICAL INSTALLATIONS IN SHIPS –

Part 507: Small vessels

1 Scope

1.1 General

This part of IEC 60092 specifies requirements for the design, construction and installation of electrical systems in small vessels, which have a length of up to 50 m, or which have a gross tonnage not exceeding 500 Gross Tonnes (GT), designed for use on inland waters or at sea. It is not intended to apply to:

- a) small craft equipped only with a battery supplying circuits for engine starting and navigation lighting recharged from an inboard or outboard engine driven alternator.
- b) recreational craft of less than 24 m hull length requiring to conform to the Recreational Craft Directive 94/25/EC Annex 1 Essential Requirements Part 5.3 Electrical systems, except for three-phase alternating current installations in such recreational craft which operate at a nominal voltage not exceeding AC 500 V.

1.2 Electrical systems

This standard applies to the types of DC and AC electrical systems described below, individually or in combination.

- a) Direct current system which operates at a nominal voltage not exceeding DC 50 V. For many small vessels, this will be the main electrical system supported by batteries for engine starting, navigation lights, navigational aids and communications equipment, lighting and other DC power consumer or converter equipment.
- b) Single-phase alternating current system which operates at a nominal voltage not exceeding AC 250 V. Such a system may be the principal electrical power system of a vessel or a system which may only be energized when connected to a shore supply. AC extra-low voltage, safety extra-low voltage, and other circuits may also comprise part of a single-phase AC system. A vessel may also be equipped with DC system(s) for equipment supplied from batteries as in 1.2 a) above.
- c) Three-phase alternating current system which operates at a nominal voltage not exceeding AC 500 V. The three-phase system is likely to be the principal electrical power system of a vessel's electrical installation. Such a vessel may also be equipped with single-phase AC circuits(s) similar to 1.2 b) above and DC system(s) for equipment supplied from batteries as in 1.2 a) above.

NOTE 1 Concerning recreational craft of less than 24 m hull length referenced in 1.1 b) above, the following standards apply:

- for direct current installations which operate at a nominal voltage not exceeding DC 50 V: ISO 10133;
- for single-phase alternating current installations which operate at a nominal voltage not exceeding AC 250 V single phase: ISO 13297.

NOTE 2 For alternating current systems having voltages exceeding AC 250 V single-phase or AC 500 V three-phase, for direct current systems exceeding DC 50 V, and for vessels larger than 500 GT or with a length greater than 50 m, other standards within the IEC 60092 series apply.

NOTE 3 Attention is drawn to regulations which govern specific requirements for navigation lights for small vessels.

NOTE 4 Attention is drawn to the fact that, in some countries the EC Directives covering EMC (89/336/EEC), low voltage (73/23/EEC) and general product safety (92/59/EEC) may be applied. In addition, Council Directive 97/70 applies to fishing vessels of 24 m in length and over, and Council Directive 98/18/EC applies to passenger ships. For high speed crafts, attention is drawn to the International code of safety for high-speed craft (HSC Code).

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60034 (all parts), *Rotating electrical machines*

IEC 60079 (all parts), *Explosive atmospheres*

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

IEC 60092-202:1994, *Electrical installations in ships – Part 202: System design – Protection*
IEC 60092-202:1994/AMD 1:1996

IEC 60092-301:1980, *Electrical installations in ships – Part 301: Equipment – Generators and motors*

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

IEC 60092-303, *Electrical installations in ships – Part 303: Equipment – Transformers for power and lighting*

IEC 60092-304, *Electrical installations in ships – Part 304: Semiconductor convertors*

IEC 60092-306, *Electrical installations in ships – Part 306: Equipment – Luminaires and accessories*

IEC 60092-307, *Electrical installations in ships – Part 307: Equipment – Heating and cooking appliances*

IEC 60092-350, *Electrical installations in ships – Part 350: General construction and test methods of power, control and instrumentation cables for shipboard and offshore applications*

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

IEC 60092-401:1980, *Electrical installations in ships – Part 401: Installation and test of completed installation*

IEC 60092-501:2013, *Electrical installations in ships – Part 501: Special features – Electric propulsion plant*

IEC 60146 (all parts), *Semiconductor convertors*

IEC 60245-4, *Rubber insulated cables-rated voltages up to and including 450/750 V – Part 4: Cords and flexible cables*

IEC 60309-1, *Plugs, socket-outlets and couplers for industrial purposes – Part 1: General requirements*

IEC 60309-2, *Plugs, socket-outlets and couplers for industrial purposes – Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories*

IEC 60332-1 (all parts), *Tests on electric and optical fibre cables under fire conditions – Part 1: Test for vertical flame propagation for a single insulated wire or cable*

IEC 60332-3-22, *Tests on electric cables under fire conditions – Part 3-22: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category A*

IEC 60364-7-709, *Low-voltage electrical installations – Part 7-709: Requirements for special installations or locations – Marinas and similar locations*

IEC 60445:2010, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60533, *Electrical and electronic installations in ships – Electromagnetic compatibility*

IEC 60898-1, *Electrical accessories – Circuit-breakers for overcurrent protection for household and similar installations – Part 1: Circuit-breakers for a.c. operation*

IEC 60945, *Maritime navigation and radiocommunication equipment and systems – General requirements – Methods of testing and required test results*

IEC 60947-7-1, *Low-voltage switchgear and controlgear – Part 7-1: Ancillary equipment – Terminal blocks for copper conductors*

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

IEC 61140, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61558 (all parts), *Safety of transformers, reactors, power supply units and similar products for supply voltages up to 1 100 V*

IEC 61558-2-4:2009, *Safety of transformers, reactors, power supply units and similar products for supply voltages up to 1 100 V – Part 2-4: Particular requirements and tests for isolating transformers and power supply units incorporating isolating transformers*

ISO 8846, *Small craft – Electrical devices – Protection against ignition of surrounding flammable gases*

ISO 9094-1, *Small craft – Fire protection – Part 1: Craft with a hull length of up to and including 15 m*

ISO 9094-2, *Small craft – Fire protection – Part 2: Craft with a hull length of over 15 m*

ISO 10239, *Small craft – Liquefied petroleum gas (LPG) systems*

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

IMO 904E, *Convention on the International Regulations for Preventing Collisions at Sea, International Maritime Organization (COLREG)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given IEC 60092-101 (some of which are repeated here for convenience), as well as the following, apply.

3.1 General terms

3.1.1 safety voltage

<AC> a voltage which does not exceed AC 50 V r.m.s. between conductors, or between any conductor and earth, in a circuit isolated from the supply by means such as a safety isolating transformer, or converter with separate winding

Note 1 to entry: Consideration should be given to the reduction of the limit of 50 V under certain conditions, such as wet surroundings or exposure to heavy seas or where direct contact with live parts is involved.

Note 2 to entry: The voltage limit should not be exceeded either at full load or no load, but it is assumed, for the purpose of this definition, that any transformer or converter is operated at its rated supply voltage.

[SOURCE: IEC 60092-101:1994, 1.3.19]

3.1.2 safety voltage

<DC> a voltage which does not exceed DC 50 V between conductors, or between any conductor and earth, in a circuit which is isolated from higher voltage circuits

Note 1 to entry: Consideration should be given to the reduction of the limit of 50 V under certain conditions, such as wet surroundings or exposure to heavy seas or where direct contact with live parts is involved.

Note 2 to entry: The voltage limit should not be exceeded either at full load or no load, but it is assumed, for the purpose of this definition, that any transformer or converter is operated at its rated supply voltage.

[SOURCE: IEC 60092-101:1994, 1.3.19]

3.1.3 nominal voltage

U

AC r.m.s. voltage between lines or DC voltage between poles

3.1.4 rated voltage

U_0

<TN systems> nominal AC r.m.s. line voltage to earth

<IT systems> nominal AC r.m.s. voltage between line conductor and neutral conductor or mid-point conductor, as appropriate

<DC systems> nominal DC voltage to earth

3.1.5 live part

conductor or conductive part intended to be energised in normal operation including a neutral conductor, but by convention not a PEN conductor (a conductor combining the functions of both a protective conductor and a neutral conductor)

Note 1 to entry: This term does not necessarily imply risk of electric shock.

[SOURCE: IEC 60050-195:1998, 195-02-19, modified as follows: The text “or a PEM conductor or PEL conductor” has been deleted. The text in brackets has been added]

3.1.6

essential services

services essential for the navigation, steering or maneuvering of the ship, or for the safety of human life, or for special characteristics of the ship

EXAMPLE Special services

[SOURCE: IEC 60092-101:1994, 1.3.4]

3.1.7

earthed

grounded (US)

connected to the general mass of the hull of the ship in such a manner as will ensure at all times an immediate discharge of electrical energy without danger

Note 1 to entry: A conductor is said to be “solidly earthed” when it is electrically connected to the hull without a fuse-link, switch, circuit-breaker, resistor, or impedance, in the earth connection.

[SOURCE: IEC 60092-101:1994, 1.3.9]

3.2 Terms and definitions related to DC systems of distribution

3.2.1

two-wire DC system

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

[SOURCE: IEC 60092-201:1994, 2.2.1]

3.3 Terms and definitions related to AC systems of distribution

3.3.1

single-phase two-wire AC system

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

[SOURCE: IEC 60092-201:1994, 2.3.1]

3.3.2

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

[SOURCE: IEC 60092-201:1994, 2.3.2]

3.3.3

three-phase three-wire system

system comprising three conductors connected to a three-phase supply

[SOURCE: IEC 60092-201:1994, 2.3.3]

3.3.4

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

[SOURCE: IEC 60092-201:1994, 2.3.4]

3.4 Terms and definitions related to protection

3.4.1

final circuit

that portion of a wiring system extending beyond the final overcurrent protection device for that circuit

[SOURCE: IEC 60092-101:1994, 1.3.17, modified – The words “overcurrent protective device of a board” have been replaced with “overcurrent protection device for that circuit”]

3.4.2

overcurrent protection device

device provided to interrupt an electric circuit in case the conductor current in the electric circuit exceeds a predetermined value for a specified duration

[SOURCE: IEC 60050-826:2004, 826-14-14]

3.4.3

fuse

device that by the fusing of one or more of its specifically designed and proportioned components, opens the circuit in which it is inserted by breaking the current when this exceeds a given value for a sufficient time

Note 1 to entry. The fuse comprises all the parts that form the complete device

[SOURCE: IEC 60050-441:1984, 441-18-01]

3.4.4

circuit-breaker

mechanical switching device capable of making, carrying and breaking currents under normal circuit conditions, and also making, carrying for a specified time and breaking currents under specified abnormal conditions such as those of a short-circuit

[SOURCE: IEC 60050-441:1984, 441-14-20, modified – The word "circuit" has been deleted from "specified abnormal circuit conditions".]

3.4.5

RCD**residual differential current device****ground-fault circuit interrupter****GFCI**

mechanical switching device designed to make, carry and break currents under normal service conditions and to cause the opening of the contacts when the residual current attains a given value under specified conditions

3.4.6

protective conductor**PE (identification)**

conductor provided for purposes of safety, for example, protection against electric shock by electrically connecting any of the exposed and extraneous conductive-parts of electrical equipment of a vessel with non-metallic hull to the vessel's main earth

Note 1 to entry: In the case of a vessel with metallic hull, exposed and extraneous conductive parts may be bonded to the ship's hull by permanent and reliable metal to metal joints of negligible impedance.

[SOURCE: IEC 60050-195:1998, 195-02-09, modified – The words “by electrically connecting any of the exposed and extraneous conductive-parts of electrical equipment of a vessel with non-metallic hull to the vessel's main earth” as well as the note to entry have been added.]

3.4.7

bond

connection of non-current-carrying parts to ensure continuity of electrical connection, or to equalize the potential between parts comprising, for example, the armour or lead sheath of adjacent length of cable, the bulkhead, etc.

EXAMPLE Bulkhead and cables in a radio-receiving room

[SOURCE: IEC 60092-101:1994, 1.3.7, modified – The last sentence in the source has been converted to an example]

3.4.8

neutral conductor

conductor electrically connected to the neutral point and capable of contributing to the distribution of electrical energy

[SOURCE: IEC 60050-195:1998, 195-02-06]

3.4.9

sheath

jacket, US

uniform and continuous tubular covering of metallic or non-metallic material, generally extruded

[SOURCE: IEC 60050-461: 2008, 461-05-03, modified – The note in the source has been deleted]

3.5 Terms and definitions related to equipment

3.5.1

accessible

object or device that can be inadvertently touched or approached nearer than a safe distance by any person

Note 1 to entry. This term applies to objects not suitably guarded or insulated

[SOURCE: IEC 60092-101:1994, 1.3.5, modified – The last sentence of the source has been made a note.]

3.5.2

captive-spade terminal

conductor terminal component which is maintained in connection to the screw or stud even when the threaded terminal fastener is loose

3.5.3

certified safe type equipment

electrical equipment of a type for which a national or other appropriate authority has carried out the type verifications and tests necessary to certify the safety of the equipment with regard to explosion hazard when used in an explosive gas atmosphere

[SOURCE: IEC 60092-502:1999, 3.1]

3.5.4

shore socket-outlet

part intended to be installed with the fixed wiring shore side or incorporated in equipment

Note 1 to entry: A socket-outlet may also be incorporated in the output circuit of an isolating transformer.

Note 2 to entry: See Figure 1.

[SOURCE: IEC 62613-1:2011, 3.2, modified – The word “shore” has been added in the term. The words “shore side” have been added to the definition.]

3.5.5

plug

part intended to be attached directly to one flexible cable

Note 1 to entry: See Figure 1.

[SOURCE: IEC 62613-1:2011, 3.3]

3.5.6

ship coupler

means enabling the connection at will of a flexible cable to the small vessel

Note 1 to entry: It consists of two parts: a ship connector and a ship inlet.

Note 2 to entry: See Figure 1.

[SOURCE: IEC 62613-1:2011, 3.4]

3.5.7

ship connector

part intended to be attached to one flexible cable connected to the supply

Note 1 to entry: See Figure 1.

[SOURCE: IEC 62613-1:2011, 3.5]

3.5.8

ship inlet

the part incorporated in, or fixed to, the ship and intended to receive the ship connector

Note 1 to entry: See Figure 1.

[SOURCE: IEC 62613-1:2011, 3.6 modified – Addition of the words “and intended to receive the ship connector”]

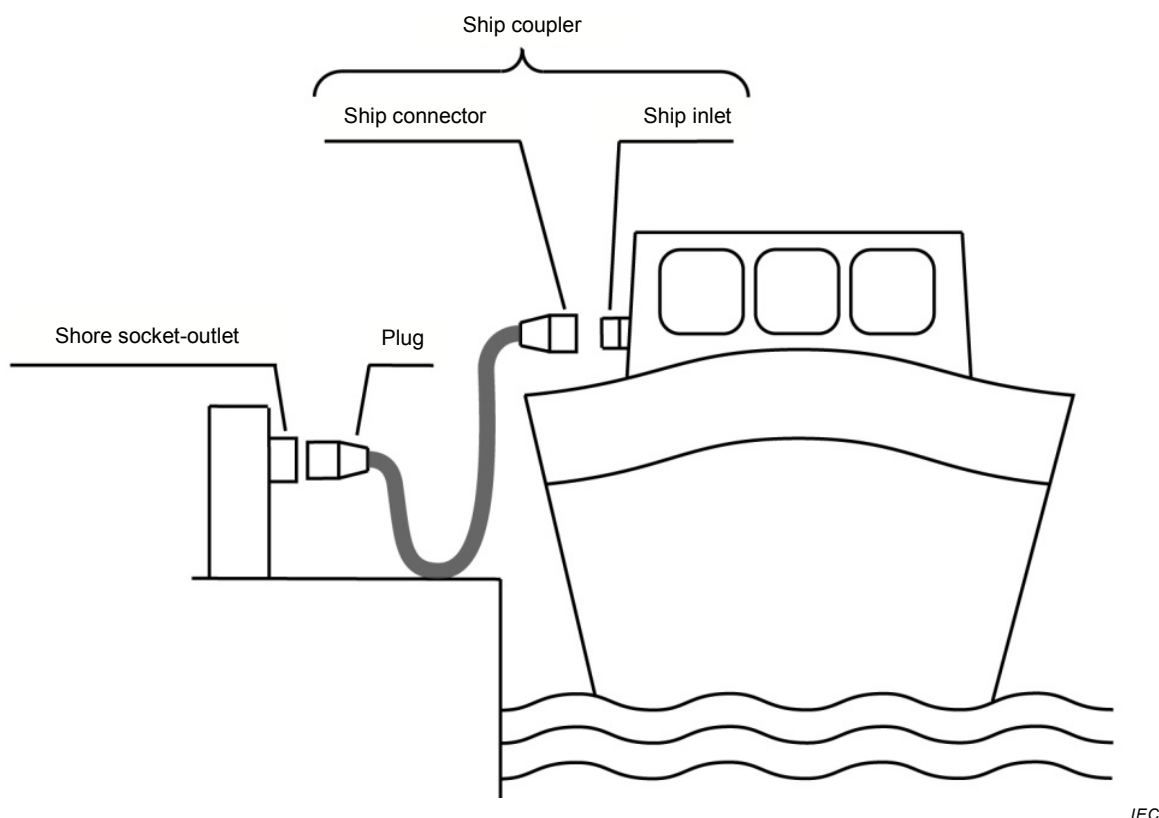


Figure 1 – Diagram showing the use of shore power supply accessories

3.5.9

transformer

energy converter with isolating separation between the input and output windings and the protective conductor

3.5.10

generator

device which creates DC or AC (alternator) power for distribution to the electrical system on board a vessel

Note 1 to entry: In its simplest form a generator may be an engine-driven alternator with integral rectifier for recharging a small vessel's extra-low voltage system. It may also be a solar panel, generator driven by wind, water impellor or propeller shaft, or fuel cell.

3.6 Terms and definitions related to batteries

3.6.1

vented cell

secondary cell having a cover provided with an opening through which products of electrolysis and evaporation are allowed to escape freely from the cell to the atmosphere

[SOURCE: IEC 60050-482:2004, 482-05-14]

3.6.2

sealed cell

cell which remains closed and does not release either gas or liquid when operated within the limits specified by the manufacturer

Note 1 to entry: A sealed cell may be equipped with a safety device to prevent a dangerously high internal pressure and is designed to operate during its life in its original sealed state. Some 6 V and 12 V batteries using sealed cells are also marketed as "low maintenance".

[SOURCE: IEC 60050-482:2004, 482-05-17, modified – Addition of a new last sentence at the end of the note to entry]

3.6.3

VRLA

valve regulated lead acid battery

secondary battery in which cells are closed but have a valve which allows the escape of gas if the internal pressure exceeds a predetermined value

Note 1 to entry: The cell or battery cannot normally receive additions to the electrolyte.

[SOURCE: IEC 60050-482:2004, 482-05-15]

3.7 Terms and definitions related to galvanic isolation from shore supplies

3.7.1

galvanic isolation

means of reducing risks of galvanic corrosion to a metallic hull and/or immersed metallic components of a vessel when connected to a shore supply by seeking to prevent small DC currents created by electrochemical phenomena circulating through the protective conductor to the shore earth (and any adjacent metal structures/components/other vessels also bonded to the shore earth) and then through the water to the hull and/or immersed metal components of the vessel

3.7.2

isolation transformer

<galvanic isolation> device fitted between the ship inlet on board a vessel and the vessel's LV AC distribution system for the purposes of galvanic isolation such that there is no connection between the vessel's protective earth terminal and the protective conductor in the ship coupler

3.7.3

diode type galvanic isolator

<galvanic isolation> electronic device consisting of a suitable rated diode bridge circuit which may be inserted into the protective conductor circuit in a ship inlet such that small DC galvanic currents in the protective conductor of the ship coupler are blocked from circulating between vessel and shore earth but AC fault current is allowed to flow unimpeded to operate the shore protective equipment in the event of a fault on board a vessel when connected to a shore supply

Note 1 to entry: For further explanation and technical details see Annex B.

4 General requirements

4.1 Ratings

Conductors, switchgear and accessories shall be suitable for expected environmental and operational conditions and shall sustain anticipated overloads and transient current induced by motor start-up without damage, tripping or overheating.

4.2 Ambient air and cooling water temperature

Electrical equipment shall be designed to operate satisfactorily under the various temperature parameters indicated in Table 1 (from Table 4 of IEC 60092-101:1994).

Table 1 – Design parameters – Temperature

Type of equipment	Value °C
High air temperature	
Cables	45
Generators and motors	50
Control and instrumentation	55
Certified safe equipment	45
Low air temperature	
General	5
Open deck	-25
High water temperature	
Generators and motors	30

NOTE The values in the table are based on the requirements of IEC 60092-101:1994, except for the requirement to certified safe equipment, which is based on the requirements of IEC 60092-502:1999.

4.3 Inclination of vessel

Electrical equipment shall be designed to continue to operate satisfactorily with the vessel at the inclinations from normal indicated in Table 2 (from Table 6 of IEC 60092-101:1994).

For sailing vessels only, the design shall include for heel angles of up to 45° on either tack.

Table 2 – Angular deviation and motion

Static condition	Angular deviation about fore-and-aft axis (list)	
	General conditions ^{a b}	± 15°
	Emergency conditions	± 22° 30'
	Angular deviation about athwart ship axis (trim)	
	Emergency conditions ^a	± 10°
Dynamic condition	Rotation about fore-and-aft axis (rolling) ^c	± 22° 30'
	Rotation about athwart ship axis (pitching) ^c	± 7° 30'
^a The vessel in any combination of angles within these limits. ^b For ships for the carriage in bulk of liquefied gases and dangerous chemicals, refer to the 1983 Amendment to SOLAS 1974, Volumes II and III. ^c These motions may occur simultaneously.		

4.4 Voltage and frequency variations

4.4.1 General

Equipment shall function under the normal voltage and frequency variations and harmonic distortion which can occur in the distribution system in normal operation.

4.4.2 DC systems

The nominal DC voltage tolerance at the battery terminals over which all DC equipment shall operate is ±10 %.

The essential services of the vessel shall remain functional to the minimum voltage at the battery terminals.

When battery chargers/battery combination are used as DC power systems, adequate measures should be taken to keep the voltage within the specified limits during charging, quick charging and discharging of the battery.

4.4.3 AC systems

The system shall be designed to operate within the following limits:

- a) frequency: ± 5 %;
- b) voltage: $\begin{matrix} + 6 \\ - 10 \end{matrix}$ %;
- c) single harmonic distortion: < 3 %;
- d) total harmonic distortion: < 5 %.

Table 3 gives recommended values of nominal voltage and frequencies as well as the maximum voltages permitted for a vessel's service systems of supply.

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

Application	Recommended nominal voltages V	Recommended nominal frequencies Hz	Maximum voltage V
1 Power, cooking and heating. Equipment securely fixed and permanently connected	Single-phase 120/230 Three-phase 400/440	Single-phase/Three-phase 50 or 60	Single-phase 250 Three-phase 1 000
Socket-outlet supplying equipment which is earthed	Single-phase 120/230	Single-phase 50 or 60	Single-phase 500
2 Fixed lighting and outlets intended 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 a protective conductor	Single-phase 120/230	Single-phase 50 or 60	Single-phase 250
3 Socket-outlets for use where extra precautions against shock are necessary:			
a) supplies with or without the use of isolating transformers	Single-phase 24	Single-phase 50 or 60	Single-phase 55
b) where a safety isolating transformer is used supplying one consuming device only, both conductors shall be insulated from earth	120/230	50 or 60	250

4.5 Electrical power sources

4.5.1 General

A small vessel's electric power may be supplied by generator(s) and/or main battery banks having sufficient capacity to supply the essential services. For each source data given in Table 4 below shall be specified and recorded in the owner's manual.

Table 4 – Required technical data for owner's manual

	Generator	Battery
The rated voltage U_0 or U (V)	X	X
The rated frequency (Hz)	X	-
The rated power (VA)	X	-
The design current I_b (A)	X	X
The maximum prospective short circuit current	X	X
The capacity (Ah) and the type of battery installed in the battery bank(s). e.g. Lead-acid, NiCd, etc.	-	X
The time constant of battery(s), dates of maintenance cycles	-	X
Requirements for installation and ventilation	-	X

For each three-phase AC generator the following data shall be provided by the manufacturer and recorded in the owner's manual to assist in short circuit calculations:

- Sub-transient reactance ($X''d$);
- Transient reactance ($X'd$);
- Synchronous reactance (Xd);
- Sub-transient time constant ($T''d$);
- Transient time constant ($T'd$);
- Time constant (Ta).

The main source of power shall consist of at least two generator sets each of which being provided with an independent starting battery or two battery banks with the associated DC generator(s) capable of charging the batteries and supporting the essential service load, or a combination of these sources of power.

4.5.2 DC systems supplied from batteries

A vessel in which the only means of propulsion is an internal combustion engine with electric starting shall be provided with two batteries or group of batteries, each one of sufficient capacity to start the engine.

One battery or battery group shall be reserved for engine starting service, the other for supplying the vessel's electrical services. It shall be possible to select which battery or group is used for which service and also to connect both battery groups in parallel in an emergency to assist engine starting. Special charge splitting arrangements may also be fitted if required to enable two or more batteries to be re-charged by a single generator.

4.5.3 DC generator

For small vessels these are generally alternators with integral rectifiers and regulators fitted to the propulsion machinery which charge accumulator batteries supplying the vessel's electrical equipment and essential services. Such generator(s) shall be capable of supplying the total load and simultaneously be capable of charging the main battery bank to 80 % charge within 10 h.

Wind-driven DC generators, towed impeller-driven generators and photo-voltaic systems shall be fitted with charge regulators set so that the gassing voltage of the battery to which they are connected is not exceeded.

For separate combustion engine driven DC generators, excitation systems shall be supplied from the generator side and the generator shall be self-excited with an automatic voltage regulator. The combined prime mover, transmission system and generator shall be designed to withstand without damage the effects of the most onerous short-circuit condition at the generator terminals when running at rated voltage and speed.

4.5.4 AC systems

Power may be provided by one or a combination of the following to supply the required design-system load:

- a) one or more shore-power cables per vessel, and associated power inlets, wiring and components with a capacity to supply the required design-system load;
- b) inverter supplying AC power from the vessel's DC system;
- c) on-board AC generator(s) supplying the required system load;
- d) combination of shore-power cable(s) and on-board generator(s) used simultaneously if the vessel's circuitry is arranged in such a way that the load connected to each source is isolated from the other.

Individual circuits shall not be capable of being energized by more than one source of electrical power at a time. Two or more three-phase generators, when properly synchronized, shall be treated as one source. Each shore-power inlet, generator or inverter shall be considered a separate source of AC electrical power. The transfer from one power-source circuit to another shall be made by a means which opens all current-carrying conductors before closing the other source circuit, prevents arc-over between contacts and is interlocked by mechanical or electromechanical means. All current-carrying conductors shall be broken simultaneously when changing power sources.

4.5.5 AC generator

An AC generator may be driven by its own prime mover, be powered from propulsion machinery or be a shaft generator.

Where an AC system is provided as a main source of electric power and consists of a single generator, an alternative means of starting the generator shall be provided. The steady and transient regulation conditions of the excitation system including the automatic regulator shall be in accordance with IEC 60092-301.

Electrical machines, including shaft generators and/or static converters/inverters shall comply with the relevant requirements of IEC 60092-301 and IEC 60092-304.

The power-feeder conductors from a generator shall be adequate for the thermal capacity of the generator and shall be protected at the generator with overcurrent protection devices in accordance with the requirements of IEC 60092-202.

The continuity of supply should not be impaired by load-produced harmonic distortion or high load charges.

The combined prime mover, transmission system and generator shall be designed to withstand without damage the effects of the most onerous short-circuit condition at the generator terminals when running at rated voltage and speed.

Where synchronization and parallel operation of several generators is required, then the relevant sections of other standards within the IEC 60092 series apply.

4.5.6 Measuring instruments

4.5.6.1 General

Normal full load values shall be marked in red on the instrument scale for all indicating instruments and appropriate labels shall be fixed to digital instruments when employed.

4.5.6.2 Instruments for batteries

Main battery banks shall be provided with at least one voltmeter, switchable between each group, and an ammeter. Alternatively, proprietary battery condition monitoring devices may be fitted to the monitor and display the state of the battery(s).

4.5.6.3 Instruments for DC generators

A DC generator with an output of 2 kW or more, which is not operated in parallel, shall be provided with at least one voltmeter and one ammeter.

Generators for parallel operation shall be provided with one voltmeter for each generator (or one voltmeter and a changeover for its connection to each generator), one ammeter for each generator and one voltmeter for each section of busbar.

For compound-wound generators fitted with equalizer connections, the ammeter shall be connected to the pole opposite to that connected to the series winding of the generator.

4.5.6.4 Instruments for AC generators

An AC generator not operated in parallel, except single-phase generators smaller than 2 kVA, shall be provided with at least one voltmeter and an ammeter in each phase (or one ammeter with a selector switch which enables it to measure the current in each phase). Generators greater than 15 kVA shall be provided with a frequency meter.

Generators for parallel operation shall be provided with a wattmeter and an ammeter in each phase conductor (or one ammeter with a selector switch to permit the measurement of current in each phase). Wattmeters shall be capable of indicating reverse power up to 15 % of the rated full load of the generator. Two voltmeters, two frequency meters and a synchronizing device comprising either a synchroscope and lamps, or an equivalent arrangement, shall be provided for paralleling purposes. One voltmeter and one frequency meter shall be connected to the busbars; the other voltmeter and frequency meter shall have a selector switch to permit measurement of the voltage and frequency of any generator.

When generators are run in parallel in installations with the neutral earthed, it shall be ensured that the equalizing current caused by harmonics does not exceed harmful values. Reference should be made to guidance from the generator manufacturer.

4.5.7 Emergency source of electrical power

Small vessels shall be provided with a self-contained emergency source of electrical power.

The emergency source of electrical power shall be capable of simultaneously supplying for the duration of 6 h, if their operation depends upon an electrical source, at least the following services where installed in a small vessel:

- a) emergency lighting;
- b) navigation lighting;
- c) radio and navigational equipment;
- d) internal signalling and communication equipment required in an emergency;
- e) fire detection and fire alarm system;

- f) Intermittent operation of the daylight signalling lamp, the ship's signal horn and all the internal signals required in an emergency.

The emergency source of electrical power and associated equipment shall be located above the uppermost continuous deck and shall be readily accessible from the open deck.

4.6 Equipment

4.6.1 Transformers

Transformers used for power, lighting and as static converters, starting transformers, static balancers, saturable reactors and transducers, including single-phase transformers rated at less than 1 kVA, and three-phase transformers rated at less than 5 kVA, shall comply with IEC 60092-303.

Isolation transformers for general use shall comply with IEC 61558-2-4.

Transformers shall be installed in well-ventilated locations. Their connections shall be protected against such mechanical damage, condensation and corrosion as may be reasonably expected.

Transformers with liquids containing polychlorinated biphenyls (PCBs) shall not be used.

4.6.2 Converters

Semiconductor converters shall conform to IEC 60146.

Converters shall be installed so that the circulation of air around them is not impeded, and so that the air temperature at their cooling inlet does not exceed the ambient temperature.

Natural air-cooling units should be designed with sufficient ventilation openings or with sufficient cooling surface to radiate the heat so that totally enclosed equipment will operate within the design temperature limits.

Converters shall not be mounted near sources of heat such as engine exhaust pipes.

Converter components shall be so constructed that they can be removed without dismantling the complete unit.

4.6.3 Motors

The requirements of the IEC 60034 series and IEC 60092-301 shall apply.

4.7 Electrical equipment and enclosures

4.7.1 General requirements

Ventilation shall be adequate to maintain the ambient temperature at or below the maximum at which the equipment is designed to operate. Enclosures for electrical equipment shall be mechanically strong and rigid, and mounted so that the equipment will not be affected by the distortion, vibration or movement of the vessel's structure that occur during normal operation of the vessel. Switchgear and controlgear assemblies shall be in accordance with IEC 60092-302.

4.7.2 General degree of protection of equipment and enclosures

Energized parts of electrical equipment shall be guarded against accidental contact by the use of enclosures. Access to energized parts of the electrical system shall require the use of

hand tools or have a protection of at least IP2X. Depending on the location, electrical equipment shall, as a minimum, have the degree of protection shown in Table 5.

Table 5 – Degree of protection in accordance with IEC 60529

Example of location	Generators	Motors	Transformers	Switch-board and control-gear	Instruments	Switches	Luminaires	Accessories
Steering gear room (above floor) and control rooms	IP22	IP22	IP22	IP22	IP22	IP22	IP22	IP44
Battery rooms							IP44+(Ex)	
General store; provision room		IP22				IP44	IP44	IP44
Closed navigation bridge; accommodation spaces		IP20	IP20	IP20	IP20	IP20	IP20	IP20
Damp or humid spaces; ventilation pipes and engine room (above floor)	IP44	IP44	IP44	IP44	IP44	IP55	IP44	IP55
Engine room ^a Steering gear (below floor)		IPX8			IPX8	IPX8	IPX8	
Open deck		IP56		IP56	IP56	IP56	IP56	IP56

^a Electrical equipment shall not be installed below floor plates in engine rooms, except as indicated above.

4.7.3 Protection from dripping water

Where necessary, electrical equipment with a degree of protection less than IPX2 shall be provided with a canopy or other suitable means to protect the current-carrying parts and the insulation from dripping water.

4.7.4 Cable entry

Cable entries shall, wherever possible, be positioned at the bottom of equipment and enclosures and shall have an IP rating equal to that of the equipment enclosure.

If cable entries are located on the sides or top of an enclosure, they shall not alter the IP degree of the equipment enclosure.

4.7.5 Identification

All electrical equipment and enclosures shall be marked with:

- name of manufacturer, and;
- model number or designation, and;
- electrical rating in volts and amperes or volts and watts and;
- phase and frequency, if applicable, and;
- certified safe type, if applicable.

4.7.6 Segregation of DC and AC systems

Vessels equipped with both DC and AC electrical systems shall have the DC and AC distribution from either separate distribution boards, or from a common distribution board with a partition to separate the DC and AC sections from each other.

4.7.7 Electromagnetic compatibility

Electrical and electronic equipment, radio and communications equipment of all commercial and recreational vessels shall conform to IEC 60533 and IEC 60945.

4.7.8 Busbars

Busbars and their connections shall be made of copper and shall be designed to withstand mechanical stresses due to short-circuit. The maximum temperature rise shall be 45 °C.

Bare busbars shall comply with the minimum clearances and creepage distances given in Table 6.

Table 6 – Minimum clearances and creepage distances for bare busbars

Rated insulation voltage	Minimum clearance	Minimum creepage distance
V	mm	mm
≤ 250	15	20
> 250 to < 690	20	25
> 690 to < 1 000	25	35

4.7.9 Switches and controls

Each switch or control shall be marked to indicate its use, unless the purpose of the switch is obvious and its mistaken operation will not cause a hazardous condition. Switching devices shall be so designed and arranged that when in the off position they cannot accidentally move sufficiently to close the circuit.

4.7.10 Final circuits

Final circuits may be supplied from individual distribution boards or panels, or from distribution sections of switchboards.

Protective devices such as circuit-breakers or fuses shall be provided at the origin of each final circuit to interrupt any overload current in the circuit conductors before heat can damage the conductor insulation, connections or wiring-system terminals. The selection, arrangement and performance characteristics should be such that the following is achieved:

- maximum continuity of service to healthy circuits under fault conditions through selective operation of the various protective devices;
- protection of electrical equipment and circuits from damage due to overcurrent by coordination of the electrical characteristics of the circuit or apparatus and the tripping characteristics of the protective devices. For every fuse and circuit-breaker there shall be provided adjacent to it an indication of its intended nominal current appropriate to the circuit it protects. The owner's manual shall include an electrical schematic diagram detailing each fuse and circuit breaker in the vessel's electrical system together with the nominal current of the circuit which each fuse and circuit breaker protects.

4.8 Plugs and socket-outlets

4.8.1 AC system

Where an earthed system is used, plug and socket-outlets of the earthing type shall be arranged with a terminal provided for the protective conductor.

Where socket-outlets are supplied at different voltages, the socket-outlets and plugs shall be designed in such a way that an incorrect connection cannot be made.

4.8.2 DC systems

Socket-outlets and matching plugs used in DC systems shall be different from and not be interchangeable with those used in the AC system on the vessel.

4.8.3 Installation in special locations

Socket-outlets installed in locations subject to rain, spray or splashing (open deck) shall be IP56 or to be enclosed in IP56 enclosures, as a minimum, when not in use. When the appropriate plug is connected the outlet shall maintain IP56.

Socket-outlets installed in areas subject to flooding or momentary submersion shall be in IP67 enclosures, as a minimum, also maintaining IP67 when an appropriate plug is inserted.

Socket-outlets provided for the galley area shall be located so that appliance cords may be plugged in without crossing above a galley stove or sink or across a traffic area.

4.9 Battery installation

4.9.1 General arrangements

Batteries shall be secured against movements and inclinations occurring during small vessel use and shall be protected against falling objects. At inclinations up to 45°, electrolyte from vented cells shall not leak. On sailing vessels, batteries shall be secured sufficiently to prevent them from breaking free in the event of a complete capsize (i.e. inversion). Lead-acid storage batteries and alkaline storage batteries shall not be placed in a common cabinet or container or in close vicinity to each other.

Where batteries, except for valve-regulated types, are fitted in a machinery space, drip trays or containers resistant to the effects of the electrolyte shall be provided. Batteries shall not be installed directly above or below a fuel tank or fuel filter and any other metallic component of the fuel system within 300 mm above the battery top, as installed, shall be electrically insulated.

Battery terminals and any exposed conductor terminations shall be protected against direct contact by persons or tools. Care shall be taken when performing inspection and maintenance work to prevent bodily contact with exposed live battery components and to avoid contact of uninsulated tools between battery terminals/exposed conductors and earth or between poles.

Switches and fuses or other electrical equipment shall not be placed in battery compartments or containers unless the electrical equipment is of certified safe type for the compartment concerned in accordance with IEC 60079.

4.9.2 Isolation of battery banks

Each battery bank shall be capable of being disconnected from the DC system circuits by a readily accessible manually operated isolation switch (on/off) immediately adjacent to the battery bank compartment. The isolation switch function may be combined with the service selection function described in 4.5.2. In fully insulated systems isolation switches shall be two

pole, and in negative earth systems isolation switches shall be single pole in the positive conductor circuit. In negative earth systems a separate isolation switch may be installed for the engine-cranking motor circuit(s).

A remote controlled isolator or remote control circuit breaker may be used as an isolation switch when fitted with a manual on/off mechanism and is installed in a readily accessible location immediately adjacent to the battery compartment.

The minimum interrupting capacity (I_{cn}) of an isolator or circuit breaker performing this function shall be the maximum short circuit current that a fully charged battery can deliver at the location at which the isolating switch or circuit breaker is installed. The minimum continuous current rating of an isolation switch or a circuit breaker used as an isolation switch shall be at least equal to the maximum current for the circuit(s) being supplied from the battery bank plus the intermittent load of any starter motor circuit connected to the battery bank through the isolation switch or circuit breaker.

If a remote controlled isolator, or a remote control contactor or a remote control circuit breaker without a manual operating facility is installed to operationally disconnect a battery bank, then a manually operated isolation switch shall also be provided between the remote control isolator, remote control contactor/fuse arrangement or remote control circuit breaker and the battery bank terminal(s).

4.9.3 Operational switching of battery banks

Operational switching (on/off) may be controlled by remote control contactor/fuse arrangements or remote control circuit breakers which shall be installed in the positive conductor from each battery bank for negative earth systems, and for fully insulated systems such operational switching devices shall be double pole installed in both positive and negative conductors from each battery bank. The continuous current rating of remote control contactor/fuse arrangements or remote control circuit breakers shall be the maximum design current for the circuit(s) being controlled from the battery bank. Operational switching devices shall have as a minimum interrupting capacity (I_{cn}) the design short circuit current at the location at which they are installed.

4.9.4 Permanently energised circuits

The following systems may be connected between the isolation switch or remote controlled device performing an isolation switch function and the battery bank terminal(s):

- a) electronic devices with protected memory and protective devices such as bilge-pumps and alarms, which shall be individually protected by a circuit-breaker or fuse as close as practical to the battery bank terminal(s);
- b) ventilation exhaust blower of engine/fuel-tank compartment which shall be protected by a fuse(s) or circuit-breaker as close as practical to the battery bank terminals;
- c) charging devices intended to be used when the vessel is unattended (for example, solar panels, wind generators) which shall be individually protected by a fuse(s) or circuit-breaker as close as practical to the battery bank terminal(s);
- d) for an electric propulsion system battery bank, a circuit maintaining a remote control switch coil or remote control contactor coil via a control switch at the steering/control position shall be individually protected by a fuse or circuit breaker as close as practical to the battery bank terminal(s).

4.9.5 Ventilation

The machinery space in which lead-acid storage or alkaline storage batteries are placed shall be well ventilated to free air so that hydrogen and oxygen cannot accumulate.

Where batteries are installed in a closed compartment or container(s) reserved for batteries, a vent system or other means shall be provided to permit the discharge from the battery compartment or container of gasses released by battery during charge to the open air.

The air inlet to battery compartments or containers shall be below the level of the battery, and the outlet shall be at the highest point of the compartment or container and shall lead directly to the open air with bends of no more than 45°.

The minimum rate of ventilation (q) in litres per hour (l/h) shall be as given by the following formula:

$$q = 110 \times I \times n$$

where

n is the number of cells in series;

I is the current in amperes, selected from Table 7.

Table 7 – Reference currents for calculation of minimum ventilation

Battery type	Vented lead-acid		Valve-regulated lead-acid (VRLA)		Vented NiCd	
Nominal charging voltage per cell, Volts per cell (VPC)	2,23	2,4	2,27	2,4	1,4	1,55
Current I at nominal charging voltage per cell per 100 Ah nominal capacity, Amperes (A)	0,5	2,0	0,1	0,8	0,5	5
Further reference shall be made to appropriate national or international standards regarding protection against hazards generated from electricity, gas emission and electrolyte from lead-acid and NiCd batteries.						

If natural ventilation is impractical or insufficient, mechanical ventilation shall be provided.

Where mechanical ventilation is employed, the charging system(s) shall be interlocked so as to switch off if the ventilation fails. A warning device shall be provided and operate if failure occurs.

Cable entries to battery compartments shall be gastight.

4.10 Electrical apparatus for explosive gas atmospheres

Electrical equipment which is intended for use in explosive gas atmospheres or which is installed where flammable gases, vapours or explosive dusts are liable to accumulate, such as in spaces containing petrol-powered machinery, petrol fuel tank(s), or joint fitting(s) or other connections(s) between components of a petrol system, and in compartments or lockers containing LPG cylinders and/or pressure regulators, shall conform to the IEC 60079 series and/or ISO 8846, ISO 10239 and ISO 9094-1 and ISO 9094-2.

It shall be noted that open compartments having 0,34 m² of open area per cubic metre of compartment volume exposed to the open atmosphere outside the vessel constitute an exception to this requirement.

4.11 Battery chargers

4.11.1 Protection against overcharging and reversal of charging current

Chargers shall incorporate protection against overcharging and overvoltage and shall have a charge indicator. Protection against reversal of the charging current shall be provided.

4.11.2 Wind generator and photovoltaic devices

Charge regulators used with a wind generator or photovoltaic cells shall be specially designed for use in such systems. They may be used to charge battery installations with an output voltage limit set to the gassing voltage appropriate for the battery.

4.12 Electric propulsion systems

4.12.1 General

Electric propulsion systems for small vessels are generally designed and constructed from a number of component parts many of which can be of proprietary origin and all of the electrical and control items are interconnected by cables and operated as a system.

It is essential that the propulsion system designer/installer shall be competent with all aspects of the equipment included in the design of a particular system such that the component parts of the propulsion system are integrated in a coherent and safe manner.

The rated power output of each electric propulsion system at the motor shaft shall be designed to match the propeller characteristics and the required rotational speed range.

The electric propulsion system may be electrically separate from other electrical systems on board a small vessel. Types of AC electrical system include four-wire with neutral earthed, but without hull return (TN-C), five-wire with neutral earthed, but without hull return (TN-S), and IT with particular requirements for earth leakage current monitoring, alarm and tripping systems. DC systems may be either earthed, or be fully insulated with particular requirements for insulation resistance monitoring, alarm and tripping systems. For DC propulsion systems operating at voltages greater than safety voltage a three wire system (e.g. DC +110 V/0/ -110 V) may be considered with or without the middle wire earthed.

For DC electric propulsion systems for small vessels with rated nominal voltages in excess of safety voltage the precautions against the risk of electric shock given in Clause 6 shall be observed.

DC electric propulsion systems may have large capacity battery bank(s) as the main power source and reference shall be made to 4.9 for:

- a) ventilation requirements necessary for battery bank compartments, and;
- b) requirements for an isolation switch for each propulsion battery bank, and;
- c) circuit protection requirements for permanently energised circuits supplied from a battery.

Particular attention shall be given to the electromagnetic compatibility (EMC) of the electric propulsion system including choice of cables for power and control, cable routes and installation methods to minimise interference with other electrical and electronic equipment on board a small vessel.

IEC 60092-501 shall be used to provide guidance for the design and installation of electric propulsion systems suitable for small vessels.

4.12.2 Component parts of electric propulsion systems suitable for small vessels.

Component parts may include:

- a) DC and AC generators which may be dedicated for propulsion purposes or be part of the overall small vessels electrical system of which the electrical propulsion circuit(s) is a part.
- b) battery banks (including charging arrangements, ventilation, management/monitoring, operational control and isolation).

- c) semiconductor converters (including DC motor controllers, AC inverters, AC variable frequency drives, and their enclosures).
- d) DC and AC propulsion motors (which may be de-rated depending on harmonic output currents from converter/variable frequency inverters).
- e) switchboards/control panels.
- f) transformers (including isolation transformers).
- g) harmonic filters.
- h) cables and cable support/enclosure systems.
- i) controls, monitoring, alarm and fault tripping equipment.

Many of the above component parts suitable for inclusion in an electric propulsion system for small vessels are addressed or referenced in this standard as indicated in the Table 8 below.

Table 8 – Table of main component parts of an electric propulsion system and associated clauses and sections in this standard

Component Part	Clause reference
General Requirements:-	
Ratings	4.1
Ambient temperatures	4.2
Inclination of vessel	4.3
Voltage ratings	4.4 and Table 3
Environment protection for electrical equipment	4.7.2 and Table 5, 4.7.3, 4.7.4.
Transformers	4.6.1, 7.6
Converters	4.6.2
Motors	4.6.3
Battery installation, isolation and ventilation requirements	4.9
Battery chargers	4.11
Shore power supply for recharging batteries	5.5
Generators	4.5.3, 4.5.5 and 7.5
Electromagnetic compatibility	4.7.7
Types of DC system:- Two wire fully insulated or two wire with negative earth	5.1
Types of AC system:- IT, TN-C, TN-S	5.2
Treatment of neutral conductor in TN AC system	5.2.2
Protection against electric shock, AC and DC systems with rated voltage greater than 50 V	6
Protection against over-current and fault-current, AC and DC	7
Cable selection/current ratings up to voltage rating 500 V	9
Cable installation and conductor termination and identification	10
Earthing and earth bonding	11

4.12.3 Operator controls, instruments, system and trip alarms

4.12.3.1 General

Each electric propulsion system for a small vessel shall be provided with controls, monitoring, and system and trip alarms at the steering/control position(s).

4.12.3.2 Controls

Propulsion control(s) shall include, as a minimum, the following controls and switches for each propulsion motor/propeller system:

- a) electric propulsion On/Off control for each propulsion system (E.g. start/stop propulsion generator, close/open propulsion battery circuit breaker or contactor, close/open propulsion system circuit breaker in main electrical system). Consideration shall be given to making the on/off control capable of being lockable in the “off” position;
- b) Ahead/Neutral/Astern control;
- c) propeller speed control;

The controls b) and c) may be combined into a common control device for each propulsion motor/propeller system.

It shall be noted that the propeller(s) may continue to rotate when a small vessel is under way when neutral is selected or an emergency stop/battery disconnect switch is operated, caused by inertia of the rotating equipment and/or movement of the small vessel through the water. Special precautions shall be taken in the case of permanently excited propulsion motors to prevent the generation of hazardous system voltages under these circumstances.

NOTE ISO 25197 provides general guidance on these systems and provides detailed type testing criteria for mechanical, environmental and EMC for such electrical /electronic steering, shift and throttle systems intended for use in small craft/recreational craft requiring to conform to essential requirements of EU Directive 94/25/EC as amended by Directive 2003/44/EC.

- d) propulsion system(s) fault trip reset.

A propulsion system fault trip reset shall only be allowed when the following conditions are satisfied:-

- No propulsion system trip is present (first warning alarms are allowable)
 - Ahead/Neutral/Astern control is set at Neutral position,
 - Propeller speed control set at minimum speed,
 - The “emergency stop” or “battery disconnect” control is not operated.
- e) “Emergency stop” pushbutton switch or equivalent device for each propulsion system. The “emergency stop” switch or equivalent device shall “lock-off” when operated and be capable of being manually reset at the steering/control position only. The emergency stop circuit shall be hard-wired to immediately power off the associated propulsion system when the “emergency stop” is operated.
 - f) A “Battery Disconnect” control switch shall be provided for each battery sourced propulsion system, the switch controlling a circuit breaker or a contactor installed in the output circuit from each propulsion battery bank. For battery sourced propulsion systems the “Battery Disconnect” control switch may be used instead of the “Emergency Stop” switch described in e) and in this case the control switch shall also be of the lock off/manually reset type as described in e). It shall be noted that a manually operated battery bank isolation facility shall also be provided adjacent and accessible to each battery bank.
 - g) In case of a propulsion control failure a manual emergency control mode shall be provided for a safe return.

4.12.3.3 Instruments and alarm indications

For small vessels under 24 m length the steering/control station shall be provided with the following instruments and alarm/trip indications for each electric propulsion system.

- a) Propeller speed,
- b) Approximate battery charge (0 % to 100 %) remaining (for each system powered from a battery power source),
- c) Power meter(s) up to rated power (0 % to 100 % or KW) or DC battery current(s) (A). Consideration shall be given to extending the range display of these instrument to indicate the safe maximum power or current allowed under temporary overload conditions,
- d) System alarms
E.g.:
 - high propulsion motor temperature,
 - high battery compartment temperature (for battery sourced electric propulsion systems),
 - low state of charge (for battery source systems),
 - low insulation resistance (IR) (for fully insulated DC systems),
 - single earth fault (for AC IT systems).
- e) Fault trip alarms.
E.g.:
 - propulsion motor system overload trip,
 - motor and /or converter high temperature trip,
 - very low IR trip (for fully insulated DC systems),
 - second earth fault trip (for AC IT systems).

Where a separate propulsion control panel is installed which provides for system alarm and trip indications a common system alarm and fault trip alarm indicator may be provided at the steering/control station.

For small vessels 24 m to 50 m length reference shall be made to Annex A of IEC 60092-501:2013 regarding protection and alarms which may be more applicable to small vessel electric propulsion systems of these length criteria.

4.13 Electrical fittings and cables attached to structures of another metal

If electrical fittings are attached to structures of another metal, for instance aluminium, suitable precautions shall be taken to prevent galvanic corrosion.

4.14 Internal communication circuits

Where a communication circuit takes its supply direct from the power or lighting circuits and its voltage exceeds the safety voltage, all equipment shall be in accordance with the requirements for final circuits.

4.15 Navigation lights supply

All sea-going vessels of every type are required to comply with the IMO COLREG requirements International Regulations for Preventing of Collisions at Sea 1972 (COLREG). The construction and installation of navigation lights shall be to the satisfaction of the appropriate authority.

Navigation lights, if required, shall each be separately connected to a dedicated distribution board, placed in an accessible position on the vessel. Provision shall be made at this position for the navigation lights to be transferred to an alternative supply source.

4.16 Luminaires

Luminaires shall comply with the relevant requirements of IEC 60092-306.

Luminaires likely to be exposed to a risk of mechanical damage shall either be protected against such damage or be of suitable robust construction. The construction and installation of luminaires should be appropriate to their location and environment.

4.17 Electrical heating and cooking appliances

Electrical heating and cooking appliances shall comply with the relevant requirements of IEC 60092-307.

4.18 Magnetic compasses

Conductors and equipment shall be placed at such a distance from the compass, or shall be so screened, that the interfering external magnetic field is negligible, causing a compass deviation of no more than 30' when the circuits are switched on or off under maximum load.

5 Distribution systems

5.1 DC distribution systems

The DC distribution systems shall be:

- a) either fully insulated two wire DC system, or
- b) a two-wire DC system with negative earth.

5.2 Standard AC distribution systems

5.2.1 Types of AC distribution system

The systems shall be either, or a combination of:

- a) single-phase systems or final circuits
 - single-phase two-wire insulated;
 - single-phase two-wire with neutral earthed;
 - single-phase two-wire with mid-point earthed for lighting and socket-outlets;
 - single-phase three-wire with mid-point earthed, but without hull return;
- b) three-phase systems
 - three-wire insulated three-phase (IT);
 - four-wire with neutral earthed (TN-C type) but without hull return;
 - five-wire with neutral earthed (TN-S) but without hull return.

5.2.2 Earthing the neutral conductor in type TN AC systems

The neutral conductor of an AC system shall be grounded (earthed) only at the source of power, for example, at the on-board generator. When a vessel is connected to shore-power, the neutral shall be grounded only at the shore-power source through the shore-power cable unless an isolating transformer is fitted to the vessel when the neutral shall be grounded at the secondary of the isolating transformer.

Earthed neutral systems shall be designed so that the potential earth fault current will not exceed the design capacity of any part of the system and such current is of sufficient magnitude to operate any protection. Where the neutral point is connected directly to earth, the earth loop impedance should be low enough to permit the passage of current at least three times the fuse rating for fuse-protected circuits or 1,5 times the tripping current of any circuit-breaker used to protect the circuit.

5.2.3 Earthing of non-current-carrying parts

The purpose of earthing and bonding of non-current-carrying parts of an electrical system is to reduce the danger of shock to personnel and to minimize damage to equipment from the effects of earth currents. These can occur from failures of insulation of live conductors, induced voltages and currents. (See also Clause 11).

For AC systems in steel-hulled vessels, the presence of a large comparative cross-section area of metal for earth return paths enables a simple method of earthing and earth bonding (TT and IT systems) in which non-current-carrying parts can be connected directly to the hull of the vessel. A vessel with a non-metallic hull requires to be provided with protective conductors (which may be separate from the neutral conductor (TN-S) or not separate from the neutral conductor (TN-C)).

Exposed non-current-carrying conductive parts of electrical machines or equipment shall be earthed unless the machine or equipment is:

- a) supplied at DC or AC safety voltage, or;
- b) supplied at a voltage not exceeding AC 230 V nominal by an isolating transformer supplying only one consuming device, or;
- c) be constructed in accordance with the principle of double insulation (see 6.5).

5.2.4 Protective conductor in AC systems

The AC protective conductor(s) shall be provided with a final connection to the hull of a metallic hull vessel, or if the vessel has a non-metallic hull a final connection from the main earth terminal to the external main earthing plate (see 11.3) of the vessel. On larger installations, a main earth conductor bus bar may be used to connect all protective conductors at one location before the final connection is made.

The protective conductor final connection shall be made at a location above any anticipated water accumulation.

5.3 Earth bonding conductors

In DC and AC systems the earth bonding should be such as to give substantially equal potential and sufficiently low earth fault loop impedance to ensure correct operation of protective devices. Extraneous conductive parts which are connected to hull of a steel vessel by permanent and reliable metal to metal joints of negligible impedance need not be bonded by separate earth bonding conductors.

Every earth bonding conductor shall be of copper or other corrosion-resistant material and shall be securely installed and protected where necessary against damage and where necessary against electrolytic corrosion.

An earth bonding conductor may be insulated and the colour of the insulation for DC and AC installations shall be green and yellow stripes. This colour combination shall not be used for current-carrying conductors.

5.4 Balance of loads in three-phase AC systems

The current-consuming units shall be so grouped in the final circuits that the load on each phase will, under normal conditions, be balanced as far as possible at the individual distribution and section boards as well as the main switchboard.

5.5 Shore connection arrangements

5.5.1 General

Where a vessel requires an AC supply from shore, it shall:

- a) either have a permanently attached flexible cable equipped with a plug compatible with the shore socket-outlet, or use;
- b) a detachable cable equipped as follows:
 - at the shore end, with a plug compatible with the shore socket-outlet,
 - at the ship end, with a ship connector compatible with the ship inlet.

See Figure 1.

The vessel's AC neutral shall be arranged to be earthed only at the shore supply when the shore supply is switched to supply the vessel's AC system i.e. the vessel's AC neutral shall be disconnected from the vessel's earth when shore power is connected unless the vessel is fitted with an isolating transformer (see 5.5.4).

Means shall be provided for checking the polarity or the phase sequence (for three-phase AC) of the incoming supply in relation to the vessel's system.

5.5.2 Vessel connections

Only one vessel shall be connected at any one time to a single shore supply socket-outlet. Clause A.1 provides details of the connection instructions advised for inclusion in the vessel owner's manual (ISO 10240) and details of the information to be included at the shore power supply location in accordance with IEC 60364-7-709.

The flexible shore power cable shall be provided with the following connecting arrangements:

- a) a plug conforming to IEC 60309-1 or IEC 60309-2 when interchangeability is required to connect to the shore socket-outlet;
- b) a flexible cable, type 245 in IEC 60245-4 or equivalent, which is either permanently connected to the vessel or connected to a ship connector conforming to IEC 60309-1, or IEC 60309-2, to connect to a ship inlet on board the vessel.

For vessels which are fitted with AC generation supplying on-board systems, an interlocked changeover switch shall prevent parallel connection between the shore power supply and the on-board generation. The changeover switch shall be of a type suitable for isolation and shall include all phases and neutral. The vessel's changeover switch shall be provided with an indicator in order to show when the shore supply is energized.

5.5.3 Information and connection instructions

Information and instructions shall be provided giving full information on the system of supply, the nominal voltage and frequency of the vessel's system and the procedure for carrying out the connection. Information on the phase sequence for three-phase AC systems shall also be given for three-phase connections.

The instructions provided on board the vessel shall include as a minimum that detailed in A.1.2.

5.5.4 Galvanic isolation provided by an isolation transformer

An isolation transformer may be fitted between the shore inlet and the electrical distribution system on board a pleasure craft or small vessel to provide a means of galvanic isolation. Such an installation incorporating an isolation transformer shall conform to the following provisions:

- a) Be generally designed, constructed and installed in accordance with the IEC 61558 series. In particular an isolation transformer used for the purpose of galvanic isolation shall conform to IEC 61558-2-4:2009. Subclause 19.1.1 of IEC 61558-2-4:2009 for class 1 transformers not intended to be connected to the mains supply by a plug, specifies that the insulation between the input windings and the body connected to earth (i.e. the shore supply earth by means of the protective conductor in the shore supply cable) shall consist of at least basic insulation rated for the input voltage. The insulation between the output windings and the body connected to earth is specified as consisting of at least basic insulation (rated for the output voltage).

Where there are isolation transformers with intermediate conductive parts (e.g. the iron core) not connected to the body and located between the input and output windings then 19.1.1 of IEC 61558-2-4:2009 applies which specifies that the insulation between the input and output windings consists of double or reinforced insulation (rated for the working voltage). Sub clauses 19.1.2 and 19.1.3 of IEC 61558-2-4:2009 provide acceptable alternatives where the body is not connected to the shore supply earth via the protective conductor of the shore supply cable.

- b) An RCD with a rated residual operating current $I_{\Delta n}$ not exceeding 30 mA and an operating time not exceeding 40 ms at a residual operating current of $5 I_{\Delta n}$ shall be fitted to each circuit for socket outlets energized by the output windings of the isolation transformer or an overall RCD of the same type shall be fitted as recommended in 6.2.
- c) The impedance of the isolating transformer shall be taken into account when establishing the required earth fault loop impedances in the small vessel's LV AC electrical installation when connected to a shore supply.

5.5.5 Galvanic isolation provided by a diode type galvanic isolator

A diode type galvanic isolator may be fitted in the protective conductor circuit between the protective earth terminal of a small vessel and the protective conductor terminal of the ship inlet on board a small vessel.

Where fitted a diode type galvanic isolator shall conform to each of the following provisions:

- a) Be designed and installed such that there shall be no significant adverse effect on earth fault loop impedance caused by the fitting of a diode type galvanic isolator in the protective conductor circuit between the small vessel and the shore supply, and that the correct operation of the OCB (Overcurrent Breaker) and RCD included in the shore supply arrangements conforming to IEC 60364-7-709 shall not be impeded when a fault-to-earth occurs in an LV AC electrical installation of a small vessel. Diode type galvanic isolators shall also conform to type tests or approvals according to the relevant national rules or standards for small vessels connecting to an LV AC shore supply in those jurisdictions;
- b) The maximum potential difference across the galvanic isolator in the protective earth circuit shall not exceed 1,5 V r.m.s. for a fault-to-earth in the LV AC electrical installation of a small vessel;
- c) A diode type galvanic isolator shall be capable of conducting an energy let-through (I^2t) of the OCB incorporated in the shore supply without detriment. If the galvanic isolator device is subject to energy let-through or an induced energy surge in excess of this, the diodes shall either melt to a low residual resistance state of less than 0,1 Ω or shall be able to withstand the maximum I^2t allowed by the permitted limiting temperature of the circuit protective conductor circuit including the shore supply cable;
- d) A diode type galvanic isolator shall be able to conduct 1,5 times the rated circuit current without detriment indefinitely (nominally 24 A r.m.s. for a 16 A rated single phase supply, and 48 A r.m.s. for a 32 A single phase or three phase supply). The maximum temperature of any enclosure/casing at rated current shall not exceed 80 °C for metallic or 90 °C for non-metallic, at an ambient temperature of 35 °C;
- e) A diode type galvanic isolator shall have a degree of protection of IP55 if to be installed without any other means of protection in a machinery space or IP20 if to be installed in a suitable enclosure in a machinery space or in a closed navigation or accommodation space.

- f) In case of failure of the galvanic isolator the continuity of the protective conductor shall be maintained.

6 Protection against electric shock in AC and DC systems with voltage exceeding safety voltage

6.1 Protection against direct contact

Live parts shall be protected against accidental contact by the use of enclosures in accordance with 4.7.2 or be completely covered by basic insulation which can only be removed by destruction.

Horizontal top surfaces of barriers or enclosures which are readily accessible shall be provided with a degree of protection of at least IPXXD or IP4X.

All exposed non-current-carrying conductive parts shall be connected to earth either via the protective conductor (AC) or by connection direct to the hull of a steel vessel.

6.2 Automatic disconnection of supply to final circuit or equipment

A protective device (fuse, circuit-breaker or RCD) shall automatically disconnect the supply to the circuit or equipment in the event of a fault between a live part and an exposed non-current-carrying conductive part.

For AC systems a residual-current protective device will provide a substantial degree of personnel protection in most circumstances in locations where the risk of accidental contact is increased. On vessels with relatively small single-phase AC electrical installations powered intermittently from a shore supply, a single RCD protecting the whole of the vessel's AC system shall be fitted or those circuits supplying socket outlets shall be provided with a RCD. It should be noted that not every marina or boat yard have RCD-protected shore power outlets as standard. The residual current device should have a rated residual operating current not exceeding 30mA and an operating time not exceeding 40 ms at a residual current of 150 mA.

6.3 Earthed neutral AC system (TN system)

In earthed neutral systems the source is connected direct to earth, and all exposed conductive parts of the installation shall be connected to the earthed point of the vessel's power system by protective conductor(s).

In earthed neutral systems, the protective arrangements for final circuits particularly to locations in confined or exceptionally damp spaces where particular risk due to conductivity may exist shall be:

- a) an overcurrent protective device and,
- b) a residual-current protective device with sensitivity of 30 mA maximum for final circuits to locations where there is an increased risk of personal contact with live conductive parts.

6.4 Non-neutral earthed AC system (IT-type system)

IT-type systems are permissible when continuity of service is requested; otherwise, a TN system is acceptable. In IT systems the vessel's phase conductor(s) is insulated from earth and the star point either isolated from earth or deliberately connected to earth through sufficiently high impedance.

In IT-type systems, it is permissible for a single fault between a live part and an exposed conductive part to occur without automatic disconnection, provided that earth monitoring or permanent insulation controller is fitted. A second fault shall result in automatic disconnection. A prospective touch voltage exceeding AC 50 V shall not persist for a time sufficient to cause a risk of harmful physiological effect in a person.

Special arrangements may need to be made for essential services in IT type systems.

In IT-type systems, the protective arrangements particularly to locations in confined or exceptionally damp spaces where particular risk due to conductivity may exist, shall be:

- a) an overcurrent protective device and,
- b) a residual-current protective device with sensitivity of 30 mA maximum for final circuits to locations where there is an increased risk of personal contact with live conductive parts.

6.5 Use of class II equipment

Protection by use of class II equipment given in IEC 61140 or by equivalent insulation is intended to prevent the appearance of dangerous voltages on accessible parts of electrical equipment due to a fault in the basic insulation.

7 Protection against over-current and fault-current in AC and DC systems

7.1 General

Every circuit shall be protected against overload and short-circuit by a fuse or circuit-breaker.

Fuses and circuit-breakers used shall be selected from those manufactured in accordance with the appropriate IEC standard.

Final circuits connected to a distribution panel or switchboard shall be protected, unless otherwise specified, by a fuse or circuit-breaker. These circuits may be controlled by single-pole switches when they are supplied at a voltage not exceeding safety voltage or else by multi-pole switches, unless in dry spaces within the accommodation.

Each fuse or circuit-breaker at the source of a circuit shall be designed to protect the conductor with the smallest cross section in the circuit being protected.

7.2 Characteristics of protective devices

The operating characteristics of a device protecting a cable against overload shall satisfy the two following conditions:

Each protective device, for AC or DC installations, shall be selected in such a way that:

- a) its rated current or current setting (I_n) is not less than the design current (I_b) of the circuit;
- b) its rated current or current setting (I_n) does not exceed the lowest of the current-carrying capacities (I_z) of any of the conductors in the circuit;
- c) the current (I_2) causing effective operation does not exceed 1,45 times the lowest current-carrying capacity (I_z) of any of the conductors of the circuit;
- d) the breaking and making capacity shall be in accordance with at least the maximum prospective short-circuit or earth-fault current at the point at which the device is installed. However if the short-circuit breaking or making capacity of the device is less than the maximum prospective short-circuit or earth fault current, it shall be backed up by a fuse or circuit-breaker in accordance with IEC 60092-202:1994/AMD 1:1996, 6.1.3 and 6.2.

For adjustable protective devices, the rated current (I_n) shall be the current setting selected.

7.3 DC battery source

7.3.1 Overcurrent protection of main circuit from batteries

A fuse or circuit-breaker shall, as a minimum, be installed in the positive pole of each circuit being supplied by a battery within 200 mm along the cable length from the battery terminals. If this is impractical, each conductor from the battery shall be contained within a protective

covering, such as cable conduit, ducting pipes or trunking, for its entire length from the battery terminals to the circuit protective fuse or circuit-breaker. The following constitute exceptions:

- a) the main power-feed cable from the battery to an engine-cranking motor, if sheathed or supported to protect against abrasion and contact with conductive surfaces;
- b) the main power-feed cable from the battery to the panel-board or switchboard, distribution panel or fuse block, if sheathed or supported to protect against abrasion and contact with conductive surfaces.

However the requirement for a battery isolator switch shall be noted (see 4.9.2). If a circuit-breaker is fitted which is provided with manual lock-off facilities then this device may be used as a means of isolation.

7.3.2 Batteries without output overcurrent protection

When conductors from batteries are not protected against short-circuit and overload, they shall be installed so as to be proof against short-circuits and earth faults by using:

- a) single-core cable without metal sheath, armour, braiding/screen;
- b) single-core insulated cable mounted on supports manufactured from insulating material. Penetrations should be made in insulated material;
- c) uninsulated conductors mounted on insulators and with insulated penetrations;
- d) single-core uninsulated cables in insulated conduits, with one cable in each conduit.

7.4 AC system

7.4.1 Protective devices

Protective devices shall be selected in accordance with IEC 60947-2 or IEC 60898-1. Circuits shall be designed to ensure coordination between protective devices in series.

Over-current and fault-current protective devices shall not interrupt protective conductors.

In three-phase circuits with substantially balanced loads, fault current protection can be limited to a single phase of the circuit being protected. When fuses are used to protect three-phase motor circuits, consideration shall be given to protection against single-phasing.

7.4.2 Final circuits

Final circuits supplied from a switchboard or distribution board, and control circuits for an engine, other than starting and ignition circuits, shall be protected against overload and short-circuit by a protective device in each line pole. Over-current protection devices shall have a short-circuit rating equal to, or in excess of, the calculated short-circuit current at the point where the device is installed. The maximum breaking time shall be in accordance with Table 9.

Table 9 – Recommended maximum breaking times for protective devices

Rated Voltage	50 V < $U_0/U \leq 90$ V		90 V < $U_0/U \leq 230$ V		230 V < $U_0/U \leq 400$ V		$U_0/U > 400$ V	
	AC	DC	AC	DC	AC	DC	AC	DC
Breaking time:-TN or IT or TT systems or DC systems	0,8 s	5 s	0,4 s	5 s	0,2 s	0,4 s	0,1 s	0,1 s
Breaking time:- TT system (when connected to a shore supply)	0,3 s		0,2 s		0,07 s		0,04s	