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Small craft — Electrical systems — Alternating and direct current installations

Petits navires — Installations électriques — Installations à courant alternatif et continu

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 188, *Small craft*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 464, *Small craft*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This fifth edition of ISO 13297 cancels and replaces ISO 13297:2014 and ISO 10133:2012, which have been technically revised.

The main changes compared to the previous editions are as follows:

— combined the standard for alternating current (ISO 13297:2014) and the standard for direct current (ISO 10133:2012) into a single marine electrical standard.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Small craft — Electrical systems — Alternating and direct current installations

IMPORTANT — The colours represented in the electronic file of this document can be neither viewed on screen nor printed as true representations. For the purposes of colour matching, see ISO 3864-4, which provides colorimetric and photometric properties together with, as a guideline, references from colour order systems.

1 Scope

This document specifies the requirements for the design, construction and installation of the following types of DC and AC electrical systems, installed on small craft either individually or in combination:

a) extra-low-voltage direct current (DC) electrical systems that operate at nominal potentials of 50 V DC or less;

b) single-phase alternating current (AC) systems that operate at a nominal voltage not exceeding AC 250 V.

This document does not cover the following:

— electrical propulsion systems of direct current less than 1 500 V DC, single-phase alternating current up to 1 000 V AC, and three-phase alternating current up to 1 000 V AC, which are addressed by ISO 16315;

— any conductor that is part of an outboard engine assembly and that does not extend beyond the outboard engine manufacturers supplied cowling;

— three-phase AC installations that operate at a nominal voltage not exceeding 500 V AC, which are addressed by IEC 60092-507.

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.

ISO 7010:2019, *Graphical symbols — Safety colours and safety signs — Registered safety signs*

ISO 8846:1990, *Small craft — Electrical devices — Protection against ignition of surrounding flammable gases*

ISO 10240:2019, *Small craft — Owner's manual*

IEC 60309-2:1999, *Plugs, socket-outlets and couplers for industrial purposes — Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP code)*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
craft's ground/earth
protective grounding
connection, provided for safety purposes, that is established by a conducting connection with the common ground/earth (potential of the earth's surface)

3.2
equipotential bonding conductor
normally non-current-carrying conductor used to put various *exposed conductive parts* (3.15) of direct current electrical devices and *extraneous conductive parts* (3.33) at a substantially equal potential

3.3
engine negative terminal
terminal on the engine, starter or solenoid to which the negative battery cable is connected

3.4
main grounding
earthing point
main point that provides connection for the DC negative conductor, AC *protective grounding conductor* (3.10) and bonding conductor to the craft's ground that is established by a conducting connection (intended or accidental) with the common ground (potential of the earth's surface)

Note 1 to entry: It can include any conductive part of the wetted surface of the hull in permanent contact with the water, depending on the overall system design.

3.5
overcurrent protection device
device designed to interrupt the circuit when the current flow exceeds a predetermined value for a predetermined time

EXAMPLE A *fuse* (3.29) or circuit breaker.

3.6
residual current device
RCD
electro-mechanical switching device or association of devices designed to make, carry and break currents under normal service conditions and to cause the opening of contacts when the residual current attains a given value under specified conditions

Note 1 to entry: RCDs serve to reduce the risk of injury to people from electrical shock hazard, and damage to equipment from leakage of stray currents to earth or to other circuits.

3.7
polarization transformer
transformer that automatically orientates the neutral and *active (phase) conductors* (3.12) in the system in the same polarity orientation as the *polarized system* (3.17) of the craft

3.8
isolation transformer
transformer installed in the shore power supply circuit on a craft to electrically isolate all the normally *live conductors* (3.11) and the *protective conductor* (3.10) on the craft from the AC system conductors of the shore power supply

3.9
neutral conductor
conductor intentionally maintained at ground potential and capable of contributing to the transmission of electrical energy

3.10
protective conductor
protective grounding conductor
conductor, not normally carrying current, used for some measure of protection against electric shock, for electrically connecting any of the following parts of electrical equipment to the craft's ground/earth and to the shore AC grounding conductor through the shore power cable:

a) *exposed conductive parts* (3.15) of electrical equipment;

b) *extraneous conductive parts* (3.33);

c) the main grounding (earthing) terminal;

d) earth electrode(s);

e) the earth point of a source, or an artificial neutral

3.11
live conductor
conductor or conductive part intended to be energized in normal use, including a *neutral conductor* (3.9)

3.12
active (phase) conductor
conductor that is maintained at a difference of potential from the *neutral conductor* (3.9) or *protective conductor* (3.10)

Note 1 to entry: In a system that does not include a neutral or protective conductor, all conductors are considered active conductors.

3.13
ignition-protected
<equipment> designed and constructed to give protection against ignition of surrounding flammable gases

Note 1 to entry: The protection against ignition of surrounding flammable gases is covered in ISO 8846:1990.

3.14
system voltage
nominal voltage supplied to the craft from a power source

3.15
exposed conductive part
conductive part of electrical equipment, which can be touched and which is not normally live, but which can become live under fault conditions

3.16
panel board
switchboard
assembly of devices for the purpose of controlling and/or distributing electrical power

Note 1 to entry: It can include devices such as circuit breakers, *fuses* (3.29), switches, instruments, and indicators.

3.17
polarized system
system in which the *live conductors* (3.11) (active and neutral) are connected in the same relation to all terminals on devices or receptacles (socket outlets) in a circuit

3.18
fully insulated two-wire DC system
system in which both positive and negative poles remain isolated from the ground (earth), e.g. not connected to the water through a metallic hull, the propulsion system or earthed through the AC *protective conductor* (3.10)

Note 1 to entry: Some systems can use a momentary ground connection for engine starting purposes and can remain isolated.

3.19
self-limiting
device whose maximum output is restricted to a specified value by its magnetic or electrical characteristics

3.20
two-wire DC system with negative ground
system in which the DC negative is connected to the ground

3.21
shore power appliance inlet
fitting designed for mounting on a craft, of a shrouded male type, to connect to the female connector on the craft end of the shore power cable in order to make the electrical connection for transmission of electrical energy

3.22
trip-free 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 circuit conditions such as those of overload or short circuit, and which is designed so that the resetting means cannot be manually held in place to override the current-interrupting mechanism

3.23
accessible
capable of being reached for inspection, removal or maintenance without removal of permanent craft structure

3.24
readily accessible
capable of being reached for use, inspection, removal or maintenance without the use of tools

3.25
sheath
uniform and continuous tubular protective covering of metallic or non-metallic material around one or more insulated conductors

Note 1 to entry: Examples of appropriate materials include moulded rubber, moulded plastic, woven sleeving or flexible tubing.

3.26
conduit
part of a closed wiring system of circular or non-circular cross-section for insulated conductors and/or cables in electrical installations, allowing them to be drawn in and/or replaced

3.27
cable trunking
system of closed enclosures comprising a base with a removable cover intended for the complete surrounding of insulated conductors, cables, cords and for the accommodation of other electrical equipment

3.28
double-pole circuit breaker
device intended to interrupt both the *neutral conductor* (3.9) and *active (phase) conductors* (3.12) in a circuit simultaneously when a designated current is exceeded for a predetermined time

3.29
fuse
protective device that interrupts the circuit irreversibly when the current flow reaches a specified value for a specific time

[SOURCE: ISO 8820-1:2014, 3.2, modified – Note 1 to entry has been deleted.]

3.30
galvanic isolator
device which can be installed in series with the AC *protective conductor* (3.10) of the shore power cable to block low voltage DC galvanic current flow, but permits the passage of AC normally associated with the protective conductor

3.31
inverter
device powered by a DC source, designed primarily to provide AC power at a required voltage and frequency

3.32
inverter/charger
device designed to supply either AC power to a craft's electrical system or to utilize the craft's AC electrical distribution system to charge or maintain a battery or batteries supplying DC

3.33
extraneous conductive part
conductive part liable to introduce a potential, generally ground/earth potential, and not forming part of the electrical installation

3.34
ground plate
means to conduct the electrical current from a craft's conductive element to the water

3.35
craft
small craft
recreational boat, and other watercraft using similar equipment, of up to 24 m length of hull (L_H)

Note 1 to entry: The measurement methodology for the length of hull is defined in ISO 8666.

[SOURCE: ISO 8666:2020, 3.15, modified – Note 1 to entry has been added.]

4 General requirements, DC and AC systems

4.1 The hull of a metallic hull craft shall not be used as a circuit conductor.

4.2 Craft equipped with both DC and AC electrical systems shall have their distribution from either separate panel boards, or from a common one with a partition, or from other positive means to separate clearly the AC and DC sections from each other, and these shall be clearly identified.

4.3 Wiring diagrams to identify circuits, components and conductors shall be included with the craft.

After completing an AC installation, it is recommended to perform a system test according to Annex C.

4.4 Switches and controls shall be marked to indicate their function, unless the purpose of the switch is obvious and its operation cannot, under normal operating conditions, cause a hazardous condition.

5 General requirements, DC systems

5.1 The system type shall be either a fully insulated two-wire DC system or a two-wire DC system with negative ground. Engine-mounted wiring systems can use the engine block as the grounded conductor.

For DC systems with a negative ground, the main grounding/earthing point shall be either:

a) the engine negative terminal; or

b) a main grounding bus of sufficient current carrying capacity.

Systems with multiple battery banks shall have a common negative connection. Exceptions to this are for dedicated power systems isolated from craft systems, e.g. propulsion systems that are clearly identified as part of the isolated system.

5.2 An equipotential bonding conductor, if fitted, shall be connected to the craft's main grounding/earthing point.

5.3 Protective devices such as trip free circuit breakers or fuses shall be provided at the source of power, e.g. the panel board (switchboard), to interrupt any overload current in the circuit conductors before heat can damage conductor insulation, connections or wiring system terminals.

5.3.1 The selection, arrangement and performance characteristics shall allow:

a) maximum continuity of service to healthy circuits when fault conditions exist in other circuits, through selective operation of the various protective devices; and

b) protection of electrical equipment and circuits from damage due to overcurrents, by coordination of the electrical characteristics of the circuit or apparatus and the tripping characteristics of the protective devices.

5.4 All DC equipment shall be capable of function within a voltage range of 75 % to 133 % of nominal voltage at the battery terminals, e.g.:

— for a 12 V system: 9 V to 16 V;

— for a 24 V system: 18 V to 32 V;

— for a 48 V system: 36 V to 64 V.

EXCEPTION Where the circuit includes equipment requiring a higher minimum voltage, the specified minimum voltage shall be used in the calculation of the conductor size in accordance with Annex A.

5.5 The length and cross sectional area of conductors in each circuit shall be such that the calculated voltage drop shall not exceed 10 % of the nominal voltage.

5.6 Equipment vital to safety, where the voltage drop is critical, shall be supplied with the proper voltage to achieve the rated performance.

NOTE 1 See Annex A for voltage drop calculations.

NOTE 2 A 3 % voltage drop is acceptable for this equipment.

NOTE 3 Examples of circuits that can be dependent on a minimum voltage drop include:

a) panel board/switchboard main conductors;

b) navigation lights;

c) bilge blowers;

d) bilge pumps.

6 General requirements, AC systems

6.1 The protective conductor insulation shall be green or green with a yellow stripe. Neither colour shall be used for current-carrying conductors.

NOTE The equipotential bonding conductor of the DC electrical system also uses green or green with a yellow stripe insulation and is connected to various exposed conductive parts of DC electrical devices, other extraneous conductive parts and the DC negative ground/earth.

6.2 For craft having a fully insulated DC system, the AC protective conductor shall be connected to:

a) for metallic hulled craft, the hull;

b) for non-conductive hulls, the craft's external ground/earth or ground plate.

6.3 The AC protective conductor(s) shall be provided with a final (single) connection to the hull of a metallic hull craft, or, if the craft has a non-metallic hull, to the main grounding/earthing point of the craft.

6.4 On metallic hulls, the point of connection of the protective conductor shall be located above any anticipated water accumulation.

6.5 Metallic housings or enclosures of permanently installed AC electrical appliances shall be connected to the protective conductor system in the craft.

6.6 Individual circuits shall not be capable of being energized by more than one source of electrical power at a time. Each shore power inlet, generator or inverter is a separate source of electrical power. The transfer from one power source circuit to another shall be made by a means which opens all current-carrying conductors, active (phase) and neutral, before closing the alternate source circuit, to prevent arc-over between contacts, and should be interlocked by mechanical or electromechanical means. A device that simultaneously breaks both current carrying conductors, active (phase) and neutral, shall be used when changing power sources.

The requirements for overcurrent protection are found in Clause 13. A combination of power sources can be used provided that:

a) the device is constructed and tested to an applicable recognized standard;

b) the device includes protection to prevent backfeeding to shore power (anti-islanding protection);

c) the device includes personnel protection against backfeeding;

d) the installation is performed according to the manufacturer's instructions.

6.7 Energized parts of electrical equipment shall be guarded against accidental contact by the use of enclosures conforming to at least IEC 60529:1989-IP 2X or other protective means which shall not be used for non-electrical equipment. Access to energized parts of the electrical system shall require the use of hand tools or be at least IP 2X, unless otherwise specified. A suitable warning sign shall be displayed (see 7.2).

6.8 The neutral conductor shall be grounded (earthed) only at the source of power, i.e. at the onboard generator, the secondary windings of the isolation or polarization transformer, the shore power

connection or inverter. The shore power neutral shall be grounded (earthed) through the shore power cable and shall not be grounded (earthed) on board the craft or:

a) for systems using an isolation transformer or polarization transformer, both the generator or inverter neutral and the transformer secondary neutrals may be grounded at the AC main grounding bus instead of at the generator, inverter, or transformer secondaries;

b) for systems using an isolation transformer or polarization transformer, or no shore power provision, both the generator or inverter neutral and the transformer secondary neutrals may be ungrounded provided double-pole protection and switching is installed.

6.9 When a galvanic isolator is fitted in the protective conductor, failure of the isolator shall not result in an open circuit.

6.10 If the polarity of the system must be maintained for the proper operation of the electrical devices in the system, reverse polarity indicating devices providing a continuous visible or audible signal shall be installed in shore power systems and shall respond to the reversal of the active (phase) and the neutral conductors. Otherwise, a branch circuit shall be provided with overcurrent protection in only the active (phase) conductor.

Reverse polarity indicating devices are not required on craft employing:

a) unpolarized systems using double-pole branch circuit protection;

b) polarization or isolation transformers that establish polarity on the craft.

NOTE 1 Reverse polarity indicating devices might not respond to reversals of a live conductor and the protective conductor.

NOTE 2 Reverse polarity indicating devices respond to the reversal of an active (phase) conductor or grounded conductor only when there is continuity of the protective conductor to shore.

7 Marking, AC systems

7.1 Shore power inlets shall be marked to indicate voltage and current; they shall also be marked with the electricity warning symbol (ISO 7010:2019-W012) and the "refer to instruction manual/booklet" symbol (ISO 7010:2019-M002).

7.2 A permanently mounted waterproof warning sign shall be located at the panel board on the craft. The sign shall include the information shown in Figure 1 a) or 1 b).

General warning sign
ISO 7010-W001

Warning; Electricity
ISO 7010-W012

Warning;
Flammable material
ISO 7010-W021

Refer to instruction
manual/booklet
ISO 7010-M002

a) Suggested warning sign using symbols

WARNING — To minimize shock and fire hazards:
1) **Turn off craft's shore power connection switch before connecting or disconnecting shore power cable.**
2) **Connect shore power cable to craft's inlet before connecting to shore power source.**
3) **If incorrect polarity is indicated, immediately disconnect cable.**
4) **Disconnect shore power cable at shore power source first.**
5) **Close shore power inlet cover tightly.**
DO NOT ALTER SHORE POWER CABLE CONNECTORS

b) Suggested warning sign with text in language appropriate to the country of use

Item 3 is required only if a polarity indicator is installed in the system.

Items 2, 4 and 5 are not required for permanently connected shore power cable installations.

Figure 1 — Suggested warning signs

7.3 Electrical equipment shall be marked or identified to indicate:

a) manufacturer's identification;

b) model number or designation;

c) electrical rating, in volts and amperes or volts and watts;

d) phase and frequency, if applicable;

e) ignition protection, if applicable, in accordance with ISO 8846:1990.

8 Batteries, DC systems

8.1 Batteries shall be permanently installed in a dry, ventilated location above anticipated bilge water level.

8.2 Batteries shall be installed in a manner to restrict their movement horizontally and vertically considering the intended use of the craft, including trailering if applicable. A battery, as installed, shall not move more than 10 mm in any direction when exposed to a force corresponding to twice the battery weight.

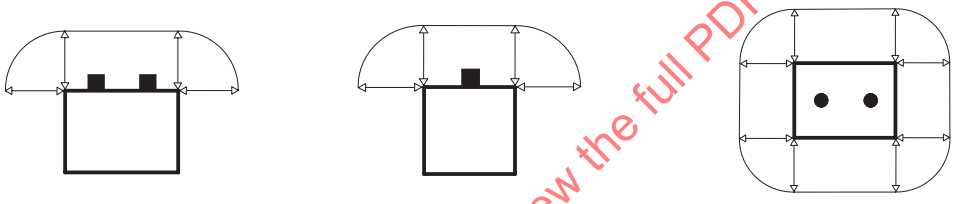
8.3 Batteries as installed in the craft shall be capable of inclinations of up to 30° without leakage of electrolyte. Means shall be provided in monohull sailing craft for containment of any spilled electrolyte up to inclinations of 45°.

8.4 Batteries shall be installed, designed or protected so that metallic objects cannot come in unintentional contact with any battery terminal.

8.5 Batteries, as installed, shall be protected against mechanical damage at their location or within their enclosure.

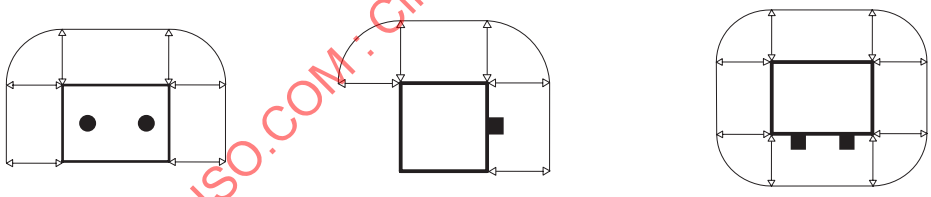
8.6 Batteries shall not be installed directly above or below a fuel tank or fuel filter without an intervening deck or structure to isolate fuel components.

8.7 Any metallic component of the fuel system within 300 mm and above the battery top, as installed, shall be electrically insulated. See Figure 2.



Front **Side** **Top**

a) Top terminal battery



Front **Side** **Top**

b) Side terminal battery

All indicated distances are min. 300 mm.

Figure 2 — Free space around battery

8.8 Battery cable terminals shall not depend on spring tension for mechanical connection to the battery terminals.

8.9 Battery ventilation shall be provided to prevent the accumulation of explosive gases which might be emitted from batteries.

9 Battery-disconnect switch, DC systems

9.1 A battery-disconnect switch shall be installed in the positive conductor of a system with grounded/earthed negative or the positive and negative conductor (simultaneously switched) of a fully insulated two-wire DC system. The disconnect switch shall be installed in a readily accessible location, and as close as practical to the battery or group of batteries. The following constitute exceptions:

a) outboard-powered craft with engine starting and navigation lighting circuits only;

b) electronic devices with protected memory and protective devices such as bilge pumps and alarms if individually protected by a circuit breaker or fuse as close as practical to the battery terminal;

c) engine/fuel tank compartment ventilation exhaust blower if separately protected by a fuse or circuit breaker as close as practical to the battery terminal;

d) charging devices which are intended to be used when the craft is unattended (e.g. solar panels, wind generators) if individually protected by a fuse or circuit breaker as close as practical to the battery terminal.

9.2 Battery switch ratings - The 30-second rating of a battery switch shall not be less than the maximum cranking current of the largest engine cranking motor that it serves. The minimum continuous rating of a battery switch shall be the total of the ampacities of the main overcurrent protection devices connected to the battery switch, or the ampacity of the feeder cable to the switch, whichever is less

9.3 Remote controlled battery disconnect switches, if used, shall also permit safe manual operation.

10 Power source options, AC systems

10.1 Power for the AC system shall be supplied by one of the following means:

a) single shore power cable, power inlet, wiring and components with a capacity to supply the required design system load;

b) separate shore power cables, power inlets, wiring and components with a capacity to supply the required design system loads;

c) inverter supplying AC power from the craft's DC system;

d) onboard AC generator(s) supplying the required system load;

e) combination of shore power cable(s), onboard generator(s), inverters or inverter/chargers used simultaneously if the craft's circuitry is arranged such that the load connected to each source is isolated from the other sources or supplies are combined in accordance with 6.6.

10.2 The shore power cable(s) alone or with onboard generator(s) capacity shall be at least as large as the required system load(s).

10.3 Except for the system indicated in the Note below, the power feeder conductor from the AC generator shall be protected at the generator with overcurrent protection devices with a rating such that 120 % of the generator nominal output is not exceeded.

NOTE Self-limiting (self-adjusting) generators whose maximum overload current does not exceed 120 % of its rated current output do not require additional external overcurrent protection.

See Annex D for examples of AC system diagrams.

11 Inverters and inverter/chargers, AC systems

11.1 Permanently installed inverters and inverter/chargers shall be non-rotating power inverters supplying less than 250 V rms AC at a frequency of 50 Hz or 60 Hz, and shall:

a) be designed to operate up to an ambient temperature of 50 °C;

b) be designed to withstand an ambient temperature of 70 °C without damage or, if intended for installation in an engine compartment, 80 °C;

c) be automatically controlled;

d) provide isolation of the AC output from the DC supply circuit;

e) have controls which are readily accessible;

f) be located in a ventilated, dry, readily accessible site where ambient temperatures do not exceed the manufacturers operating temperature rating;

NOTE Inverters can be located in an accessible location if the controls are mounted in a readily accessible location.

g) be mounted away from heat sources;

h) be mounted not less than 500 mm above foreseeable levels of bilge water.

11.2 Inverter outlet circuits shall be protected in accordance with Clauses 13 and 14.

11.3 If required, inverters and inverter/chargers shall be ignition-protected in accordance with Clause 25 and shall be marked as such by the manufacturer, i.e. “IGNITION-PROTECTED ISO 8846:1990”.

11.4 DC conductor terminals or conductors shall be labelled as follows:

a) DC+, or POS, or +

b) DC–, or NEG, or –

11.5 A separate DC equipotential conductor shall be connected from the metallic case or chassis of the inverter or inverter/charger to the main grounding/earthing point or its bus, and be of an amperage rating equal to the DC positive conductor. This conductor shall not be connected to the DC negative at the inverter or inverter/charger.

If the craft is fitted with an insulated DC system, or if the inverter AC/DC power terminal enclosure is of double-insulated construction, this requirement may not apply.

11.6 Provision shall be made within the inverter or inverter/charger to permit the ready connection of three or more conductors with connectors meeting the requirements of 20.9 and 20.3. The terminals or conductors shall be labelled.

11.7 Inverter or inverter/charger integral switching shall switch all live AC conductors. Integral switching shall also disconnect the grounded (neutral) conductor from ground when an external supply is used.

11.8 Access panels to compartments containing AC connections shall be provided with a label containing a warning about electrical shock hazards. For example:

WARNING — ELECTRICAL SHOCK HAZARD
To avoid electrical shock hazard:
disconnect AC shore power and DC battery power to inverter before opening panel

11.9 All inverter/chargers shall include the following information for the charging system:

a) input voltage, amperage and frequency;

b) nominal output voltage and current;

c) DC output voltage at float or shut off, if applicable;

d) continuous output current at 12 V (24 V or 32 V) at specified input voltage at 25 °C;

e) battery type;

f) warning concerning internal charged capacitor hazard when servicing.

11.10 All inverters shall also include the following information:

a) input voltage and amperage;

b) continuous output current at rated voltage;

c) nominal output voltage and frequency;

d) surge capability and duration.

NOTE See Annex D for inverter and inverter/charger installations.

12 Overcurrent protection, DC systems

12.1 Overcurrent protection shall be provided by one of the following. See Annex E.

a) A manually reset trip-free circuit breaker or a fuse shall be installed within 175 mm of the source of power for each circuit or conductor of the system, measured along the conductor.

b) If the conductor is connected directly to the battery terminal and is contained throughout its entire distance in a sheath or enclosure such as a conduit, junction box, control box or enclosed panel, the overcurrent protection shall be placed as close as practicable to the battery, but not to exceed 1,8 m.

c) If the conductor is connected to a source of power other than a battery terminal and is contained throughout its entire distance in a sheath or enclosure such as a conduit, junction box, control box or enclosed panel, the overcurrent protection shall be placed as close as practicable to the point of connection to the source of power, but not to exceed 1 m.

d) Overcurrent protection is not required in conductors from self-limiting alternators with integral regulators if the conductor is less than 1m, is connected to a source of power other than the battery, and is contained throughout its entire distance in a sheath or enclosure.

e) Conductors less than 175 mm in length are exempt from overcurrent protection requirements.

f) Cranking motor conductors are exempt from overcurrent protection requirements.

12.2 The voltage rating of each fuse or circuit-breaker shall not be less than the nominal circuit voltage; the current rating shall not exceed the value for the smallest size conductor in the circuit.

12.3 In addition to the provisions of 12.1, the ungrounded conductors to a battery charger, alternator or other charging source shall be provided with overcurrent protection within the charging source, or within 1,8 m of the charging source, based on the maximum output of the device.

EXCEPTION Self-limiting devices.

13 Overcurrent protection, AC systems

13.1 General

13.1.1 In unpolarized systems, circuit breakers that open both active (phase) and neutral conductors simultaneously are required.

13.1.2 Fuses shall not be installed in unpolarized systems. If used in polarized systems, fuses shall be located to interrupt the active (phase) conductor.

13.1.3 Overcurrent protection devices for motor loads shall have a predetermined value of amperage consistent with electrical demand of the protected circuit.

13.1.4 All AC motor installations and each motor of a motor-operated device shall be individually protected in accordance with 13.1.3 or by an integral overcurrent or thermal protection device unless the motors do not overheat under continuous locked rotor conditions.

13.1.5 The rating of the overcurrent protection device shall not exceed the maximum current-carrying capacity of the conductor being protected. See Table A.1.

13.2 Supply circuits

13.2.1 Simultaneous (e.g. double pole) circuit breakers shall be installed in conductors to all supply circuits.

13.2.2 A manually reset trip-free circuit breaker shall be installed within 0,5 m of the source of power or, if impractical, the conductor from the source of power to the panel board circuit breaker shall be contained within a protective covering, such as a junction box, control box, enclosed panel board or within conduit or cable trunking or equivalent protective covering. If the location of the main shore power inlet circuit breaker exceeds 3 m from the shore power inlet connection or the electrical attachment point of a permanently installed shore power cable, additional circuit breakers shall be provided within 3 m of the inlet or attachment point to the electrical system in the craft, measured along the conductor.

13.2.3 Overcurrent protection shall be provided for isolation and polarization transformers, including a bank of transformers operating as a unit. Each transformer shall be protected by an individual overcurrent device on the primary side, rated at not more than 125 % of the rated primary current of the transformer.

13.3 Branch circuits

13.3.1 The active (phase) conductor of each branch circuit in a polarized system shall be provided with overcurrent protection, i.e. fuse or circuit breaker, at the point of connection to the main panel board bus.

13.3.2 Both current-carrying conductors of each branch circuit in unpolarized systems shall be provided with overcurrent protection by double-pole circuit breakers and double-pole switches, at the point of connection to the main panel board bus.

NOTE Use of a reverse polarity indicator presumes compliance with 13.3.1.

14 Ground-fault protection/earth-leakage protection, AC systems

14.1 RCDs shall be of the trip-free type.

14.2 The craft shall be provided with earth-leakage protection in all AC (e.g. shore power, inverter, generator) sources by one or more double-pole RCDs having a maximum nominal trip sensitivity of 30 mA and 100 ms maximum trip time.

NOTE Common standards for RCD construction are IEC 60898-2:2016[7], IEC 61009-1:2010[8] and IEC 61543:1995[9].

14.3 The RCD device shall have an internal circuit for manually testing the trip function.

15 Panel boards (switchboards), DC and AC systems

15.1 The front side of panel boards, i.e. the switch and circuit breaker operating face, shall be readily accessible. In DC systems, the rear side, i.e. the terminal and connection side, may be readily accessible, in AC systems the rear side shall be accessible.

15.2 Panel boards shall be permanently marked with the system voltage and frequency.

EXAMPLES 230 V, 50 Hz; 115 V, 60 Hz; 12 VDC.

Electrical controls required for operation of the craft (e.g. horns, navigation lights) should be apparent to the operator when in normal use.

16 Panel boards (switchboards), AC systems

16.1 An AC system panel board with a means of indicating the system on/off status shall be installed.

16.2 A system voltmeter shall be installed on the panel board if the system is designed to supply motor circuits or if an onboard generator is installed.

16.3 A visible means, i.e. voltmeter or lamp, indicating that the inverter is active on line and/or in standby mode, shall be provided at the AC panel board.

16.4 A warning label shall be placed at the panel board to indicate that the electrical system includes an inverter. For example:

WARNING — ELECTRICAL SHOCK HAZARD
Craft is equipped with a DC to AC power inverter.
To avoid serious injury or death from electrical shock:
disconnect AC shore power and DC battery power to inverter before opening panel or servicing electrical systems.

17 Conductors, DC and AC systems

17.1 Conductor insulation temperature ratings in engine spaces shall be 70 °C minimum, and the conductor insulation shall be oil-resistant or shall be protected by insulating conduit or sleeving. The conductors shall be derated in an allowable current-carrying capacity in accordance with Annex A.

NOTE For additional conductor specifications, see ISO 6722-1:2011[1].

17.2 Each conductor longer than 175 mm installed separately shall be at least 1 mm^2. Each conductor in a multi-conductor sheath shall be at least 0,75 mm^2 and can extend out of the sheath a distance not exceeding 800 mm.

EXCEPTION Conductors of minimum 0,75 mm^2 used as internal wiring in panel boards.

18 Conductors, DC systems

18.1 Electrical distribution shall use insulated stranded copper conductors, see Table A.1. Conductor insulation shall be of fire-retardant material.

18.2 Conductors shall be sized as a minimum in accordance with Table A.1, or the conductor manufacturers rated current amperage, based on the load to be supplied and allowable voltage drop for the load to be carried. See 5.6.

18.3 All equipotential bonding conductors shall be identified by green or green with yellow stripe insulation, or can be uninsulated strip or braid. Conductors with green or green with yellow stripe insulation shall not be used for current-carrying conductors.

NOTE The protective conductors of the AC electrical system, also uses green or green with yellow stripe insulation and can be connected to the craft engine DC negative terminal.

18.4 Means of identification other than insulation colour for DC positive conductors is permitted if properly identified on the craft wiring diagrams of the electrical system(s).

18.5 All DC negative conductors shall be identified by black or yellow insulation. If the craft is equipped with an AC electrical system which use black insulation for live conductors, yellow insulation shall be used for DC negative conductors of the DC system. Black or yellow insulation shall not be used for DC positive conductors.

18.6 Means of identification other than insulation colour for DC negative conductors if the craft is fitted with multiple independent DC systems is permitted if properly identified on the conductor and craft wiring diagrams of the electrical system(s).

NOTE 1 A colour stripe can be added to conductor insulation for identification in the system.

Craft with AC and DC systems shall avoid the use of brown, white or light blue insulation colour in the DC system, unless clearly separated from the AC conductors and identified as DC.

NOTE 2 For additional conductor specifications see ISO 6722-1:2011[1].

NOTE 3 An example of multiple independent DC systems would be a 12 V and 24 V system or a separate electronics battery bank which do not share the DC negative.

19 Conductors, AC systems

19.1 Conductors and flexible cords shall have a minimum rating of 300 V to 500 V. Conductors and flexible cords shall be multi-strand copper, with cross-sectional areas no smaller than those determined using Table A.1.

NOTE A conductor used for equipment grounding is not considered a current-carrying conductor when referencing Table A.1.

19.2 The insulation temperature rating of conductors and flexible cords outside engine spaces shall be at least 60 °C.

19.3 The protective conductor shall have a cross-sectional area equal to that of the live conductors.

a) For ground/earth continuity conductors (protective conductors) in flexible cables or flexible cords:

   1) a cross-section equal to that of the current-carrying conductor if the latter is less than or equal to 16 mm^2; or

   2) a cross-section equal to 50 % of that of the current-carrying conductor if the latter is greater than 16 mm^2, subject to a minimum of 16 mm^2.

b) For ground/earth continuity conductors (protective conductors) incorporated in fixed multicore cables:

   1) a cross-section equal to that of the main conductors if the latter is less than or equal to 16 mm^2 subject to a minimum of 1,5 mm^2; or

   2) a cross-section of not less than 50 % of the cross-section of the main conductor if the latter is more than 16 mm^2, subject to a minimum of 16 mm^2.

19.4 Active (phase) and neutral conductors of the AC system shall be identified. Identification can be made by insulation colour as defined below, by numbering or by other means on the wiring diagram for the system supplied with the craft. For single-phase systems:

— active (phase) conductors shall be black or brown;

— neutral conductors shall be white or light blue;

— protective conductors shall be green or green with a yellow stripe (see 6.1).

NOTE A coloured stripe can be added to active (phase) and neutral conductor insulations for identification in the system.

Yellow, green or green with a yellow stripe insulation colour shall not be used for active (phase) or neutral conductors of the AC system.

20 System wiring, DC and AC systems

20.1 Conductor connections shall be in locations protected from the weather or in enclosures conforming to IEC 60529:1989 – IP 55 as a minimum. Connections above deck exposed to intermittent immersion shall be in enclosures conforming to IEC 60529:1989 – IP 67 as a minimum.

20.2 Conductors and cables shall be supported throughout their length in conduits, cable trunking or trays, or by individual supports at maximum intervals of 450 mm.

20.3 Conductors which could be exposed to physical damage shall be protected by sheaths, conduits or other equivalent means.

20.4 Conductors of a DC circuit shall not be contained in the same wiring system as an AC circuit, unless one of the following methods of separation is used:

a) for a multicore cable or cord, the cores of the DC circuit are separated from the cores of the AC circuit by an grounded/earthed metal screen of equivalent current carrying capacity to that of the largest core in either circuit;

b) the cables are insulated for their system voltage and installed in a separate compartment of a cable conduit or trunking system;

c) the cables are installed on a tray or ladder where physical separation is provided by a partition;

d) a separate trunking system, conduit or sheathing is used;

e) the DC and AC conductors are fixed directly to a surface and separated by at least 100 mm.

20.5 Current carrying conductors shall be routed above areas where water can accumulate (e.g. bilges), and at least 25 mm above the level at which the automatic bilge pump switch activates.

EXCEPTION If conductors must be routed below anticipated bilge water level, the wiring and connections shall be in enclosures conforming to IEC 60529:1989 - IP67, as a minimum, and there shall be no connection below the foreseeable water level.

20.6 Conductors shall be routed away from exhaust pipes and other heat sources which can damage the insulation. The minimum clearance is 50 mm from water cooled exhaust components and 250 mm from dry exhaust components, unless an equivalent thermal barrier is provided.

20.7 Metals used for terminal studs, nuts and washers shall be corrosion-resistant and galvanically compatible with the conductor and terminal. Aluminium and unplated steel shall not be used for studs, nuts or washers in electrical circuits.

20.8 All conductors shall have suitable terminals installed, i.e. no bare wires to stud or screw connections.

20.9 Screw-clamp terminals or screwless terminal blocks shall clamp conductors to ensure mechanical linkage and electrical contact is properly maintained without damaging the conductor strands. Other terminals shall be of the ring or captive spade type not dependent on screw or nut tightness alone for retention on the screw or stud. Friction type connectors on conductors can be used in circuits not exceeding 20 A if the connection does not separate when subjected to a force of 20 N.

20.10 Twist-on connectors (wire nuts) shall not be used.

20.11 Exposed shanks of terminals shall be protected against accidental shorting by the use of insulation barriers or sleeves, except for those in the grounding system.

20.12 Solderless crimp-on terminals and connectors shall be attached with the type of crimping tool designed for the termination used and for a connection meeting the following requirements:

20.13 Conductor-to-connector and conductor-to-terminal connections shall be capable of withstanding a tensile force equal to at least the value shown in Table 1 for the smaller conductor in the connection, without separating.

Table 1 — Tensile force

Conductor size	Tensile force	Conductor size	Tensile force	Conductor size	Tensile force
mm^2	N	mm^2	N	mm^2	N
0,75	40	6	200	50	400
1	60	10	220	70	440
1,5	130	16	260	95	550
2,5	150	25	310	120	660
4	170	35	350	150	770

20.14 No more than four conductor terminals shall be secured to one terminal stud.

21 System wiring, DC systems

21.1 Sheathed conductors and battery conductors to the battery disconnect switch shall be supported at maximum intervals of 300 mm with the first support not more than 1 m from the terminal, other sheathed conductors at maximum intervals of 450 mm.

EXCEPTION Sheathed outboard starter motor conductors.

22 Socket outlets, DC systems

22.1 Socket outlets and matching plugs used on DC systems shall not be interchangeable with those used on AC systems on the craft.

22.2 Socket outlets installed in locations subject to rain, spray or splash shall be in enclosures conforming to IEC 60529:1989 - IP 55, as a minimum, when not in use. Socket outlets mated with the appropriate plug shall also remain sealed in accordance with IEC 60529:1989 - IP 55.

22.3 Socket outlets installed in areas subject to flooding or momentary submersion shall be in enclosures conforming to IEC 60529:1989 - IP 67, as a minimum, and shall also meet these requirements when mated with the appropriate plug.

23 Socket outlets, AC systems

23.1 Shore power appliance inlets shall conform to IEC 60309-2:1999 with a minimum rating of IP 44 when mated with the appropriate plug.

23.2 Socket outlets shall be of the grounding/earthing type with a terminal provided for the protective conductor.

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

23.4 Socket outlets shall have a voltage rating in accordance with the voltage supplied by the power sources.

24 Appliances and equipment, AC systems

24.1 Appliances and fixed AC electrical equipment installed on a craft shall have exposed conductive parts connected to the craft protective conductor, unless the appliance is of double-insulated construction.

24.2 Integral or external overcurrent protection shall be provided.

25 Ignition protection, DC and AC systems

25.1 Electrical components and devices installed in compartments which can contain explosive vapour and gases shall be ignition-protected in accordance with ISO 8846:1990.

NOTE ISO 10088:2013 requires that all electrical components in petrol engines and petrol tank compartments (this applies to the entire engine, as well as all electrical contacts, commutators, brushes, collector rings, switches, relays, generators, fuses, distributors, engine-cranking motors, trim motors, etc.) be ignition-protected and ISO 10239:2014 requires all electrical devices in LPG cylinder lockers and housings to be ignition-protected.

Open compartments having 0,34 m^2 of open area per cubic metre of compartment volume exposed to the open atmosphere outside the craft constitute an exception to this requirement.

26 Owner's manual

Information to be included in the owner's manual is listed in Annex B.

Annex A
(normative)

Conductor requirements

Table A.1 gives allowable continuous current ratings, in amperes, at different temperature ratings and the minimum number of strands for conductors. These values have been determined for an ambient temperature of 30 °C and apply to single conductors and stranding when no more than three conductors are bundled together.

For conductors in engine rooms or when more than three conductors are bundled together, the maximum current rating in Table A.1 shall be derated by the factors given in Table A.2.

Table A.1 — Cross-sectional area conductor, allowable permanent current and stranding

Cross-sectional area	Maximum continuous amperage capacity for single conductors at insulation temperature ratings						Minimum number of strands[b]	
mm^2	60 °C	70 °C	85 °C to 90 °C	105 °C	125 °C	200 °C	Type A	Type B[a]
0,75	6	10	12	16	20	25	16	—
1	8	14	18	20	25	35	16	—
1,5	12	18	21	25	30	40	19	26
2,5	17	25	30	35	40	45	19	41
4	22	35	40	45	50	55	19	65
6	29	45	50	60	70	75	19	105
10	40	65	70	90	100	120	19	168
16	54	90	100	130	150	170	37	266
25	71	120	140	170	185	200	49	420
35	87	160	185	210	225	240	127	665
50	105	210	230	270	300	325	127	1 064
70	135	265	285	330	360	375	127	1 323
95	165	310	330	390	410	430	259	1 666
120	190	360	400	450	480	520	418	2 107
150	220	380	430	475	520	560	418	2 107

[a] Conductors with Type B stranding shall be used for any wiring where frequent flexing is involved during use.

[b] Conductor current ratings may be interpolated for cross-sectional areas between those shown above.

Table A.2 — Derating of maximum current rating in Table A.1

Temperature rating of conductor insulation	Multiply maximum current from Table A.1 by
70 °C	0,75
85 °C to 90 °C	0,82
105 °C	0,86
125 °C	0,89
200 °C	1

Number of conductors bundled	Multiply maximum amperage from Table A.1 by
4 to 6	0,7
7 to 24	0,6
25 or more	0,5
NOTE Derating reductions for temperature and bundling are cumulative.	

As a guideline: the voltage drop (E) at load, in volts, can be calculated using the following formula:

$$E = \frac{0{,}016\,4 \times I \times L}{S}$$

where

S is the conductor cross-sectional area, in square millimetres;

I is the load current, in amperes;

L is the length, in metres, of conductor from the positive power source to the electrical device and back to the negative source connection.

NOTE On a 12 V system, an approximation of a 3 % drop can be obtained by the following:

$$S = \frac{I \times L}{20}$$

Annex B
(normative)

Instructions to be included with owner's manual

There shall be an owner's manual in accordance with ISO 10240:2019.

The owner's manual shall include instructions for the operation and maintenance of the system, including a wiring diagram with conductor identification, details of fuses and breakers used, data relating to individual power sources, maintenance and operating instructions for electrical connections and equipment and at least the following instructions.

a) Do not modify the craft's electrical system or relevant drawings. Installation, alterations and maintenance should be performed by a competent marine electrical technician. Inspect system at least biennially.

b) Disconnect shore power connections when the system is not in use.

c) Connect metallic housings or enclosures of installed electrical appliances to the protective conductor system in the craft (green or green with a yellow stripe conductor).

d) Use double-insulated or grounded (earthed) electrical appliances.

e) If reverse polarity indicator is activated, do not use electrical system. Correct polarity fault before activating the electrical system on the craft.

f) WARNING — Do not allow any part of the shore power cable to hang in the water. An electrical hazard can result which can cause injury or death to nearby swimmers.

g) WARNING — To minimize shock and fire hazards:

   1) turn off craft's shore power connection switch before connecting or disconnecting shore power cable;

   2) connect shore power cable to craft's inlet before connecting to shore power source;

   3) if reverse polarity indicator is activated, turn off craft's shore power connection switch immediately (if fitted);

   4) disconnect shore power cable at shore power source first;

   5) close shore power inlet cover tightly.

h) Do not alter shore power cable connectors, use only compatible cable connectors and shore power receptacles.

i) Instructions on monthly testing of the RCD.

Instruction e) is required for polarized systems with polarity indicator.

Instruction g), second list item, is not required for permanently connected shore power cable installations.

Instruction g), third list item, is required only if reverse polarity indicator is required in the system.

Annex C
(informative)

Recommended system tests

The following system tests should be performed upon completion of the AC installation:

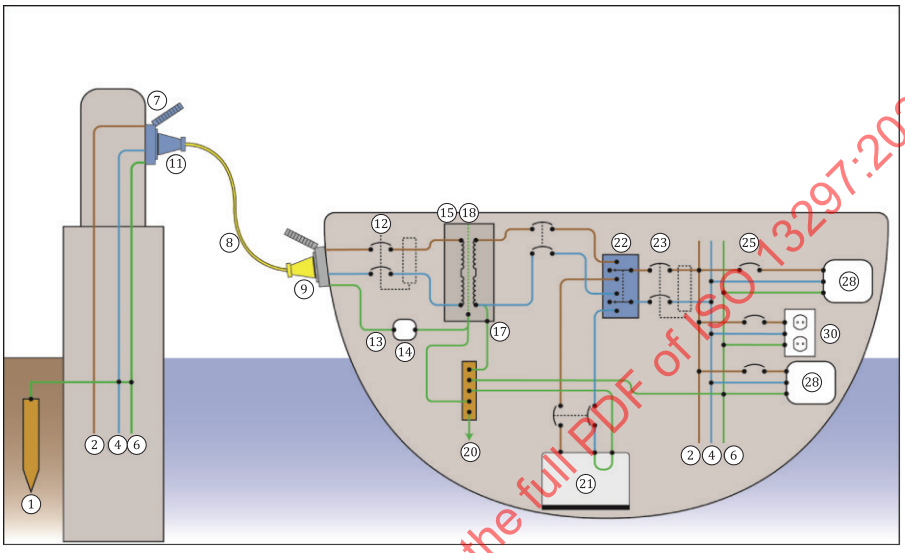
— residual current device (RCD) testing;

— polarity test at distribution and at each outlet.

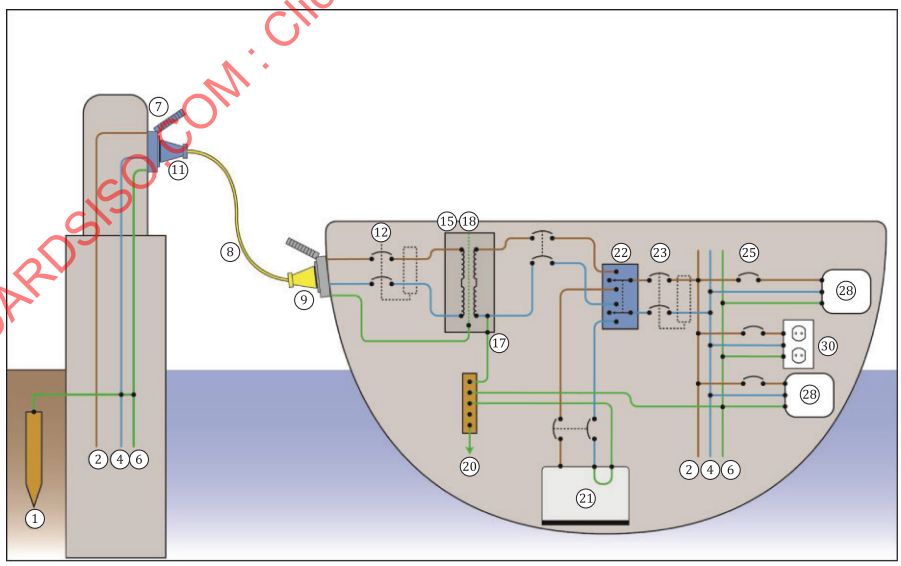
CAUTION — Some electronic equipment can be damaged by high voltages.

Annex D
(informative)

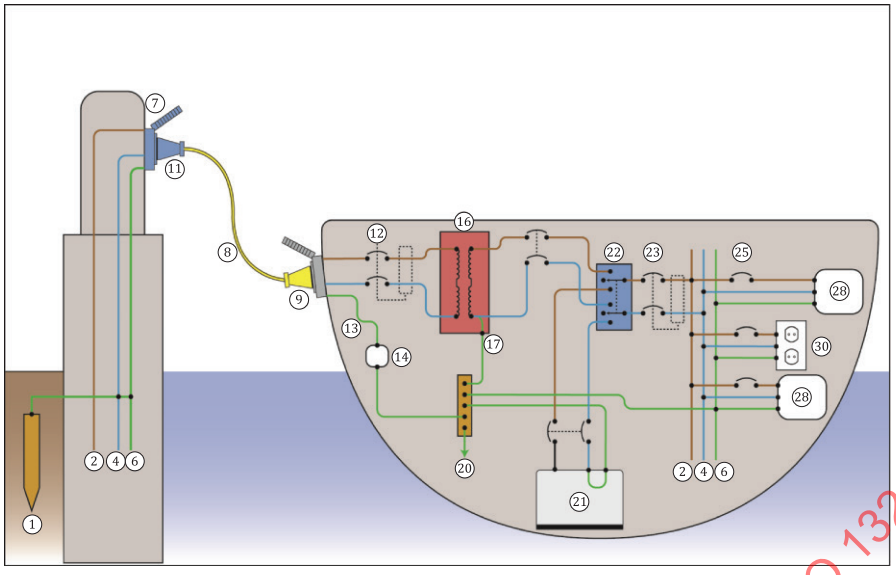
Typical AC system diagrams



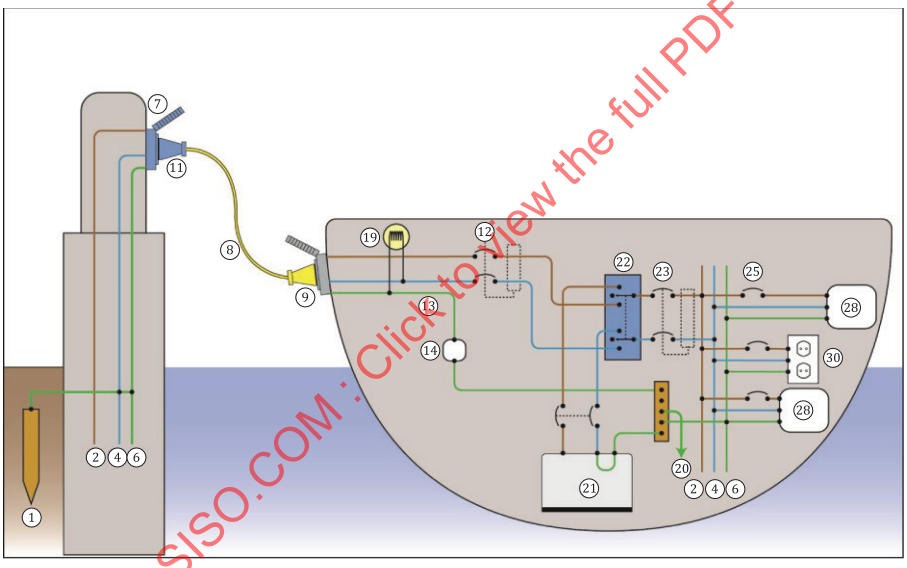
a) Isolation transformer system with a single phase 230 V input and a 230 V output and generator illustrating the use of main AC grounding bus and RCD/shore power disconnect breaker — Shown with input ground connected to crafts ground (via optional galvanic isolator), converting the isolation transformer into a polarizing transformer



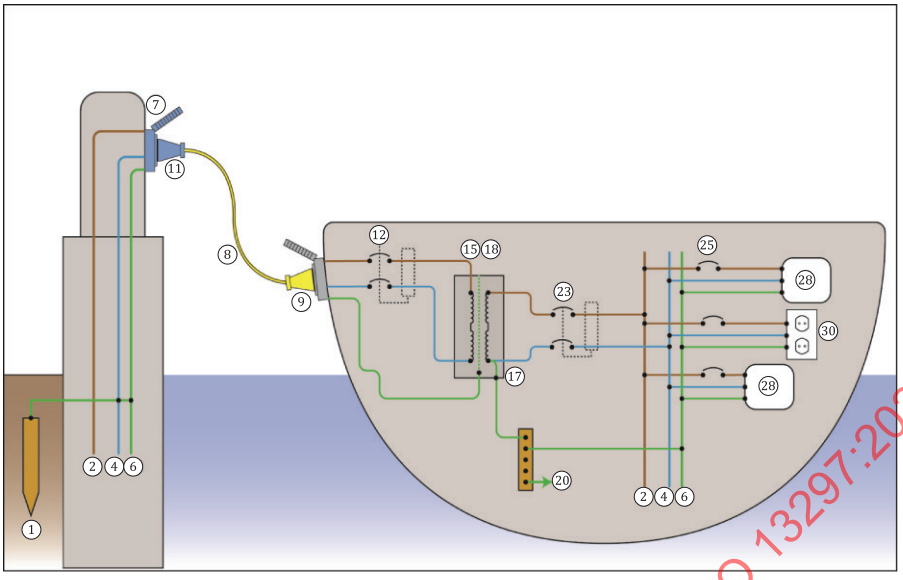
b) Isolation transformer system with a single phase 230 V input and a 230 V output, and generator illustrating the use of main AC grounding bus and RCD/shore power disconnect breaker



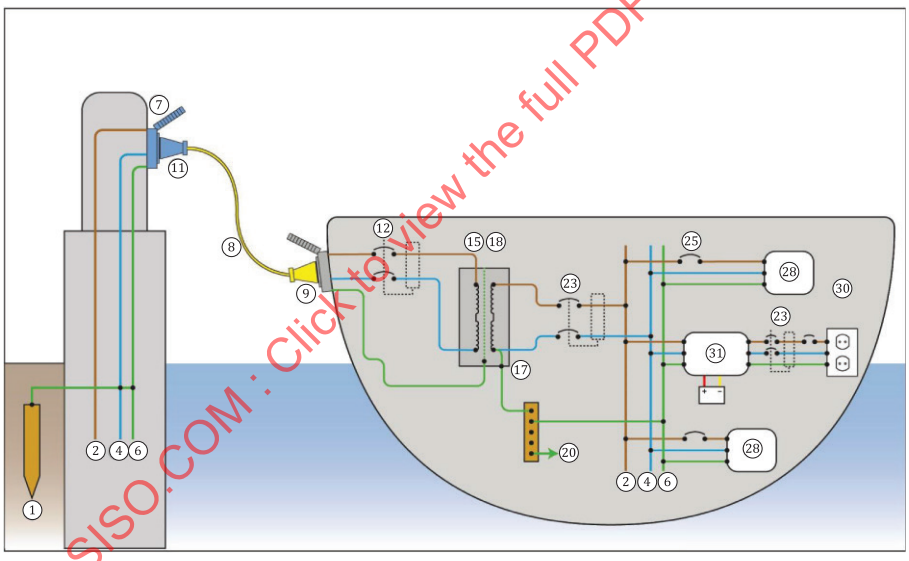
c) Polarization transformer system with a single phase 230 V input and a 230 V output, and generator illustrating the use of main AC grounding bus and RCD/shore power disconnect breaker



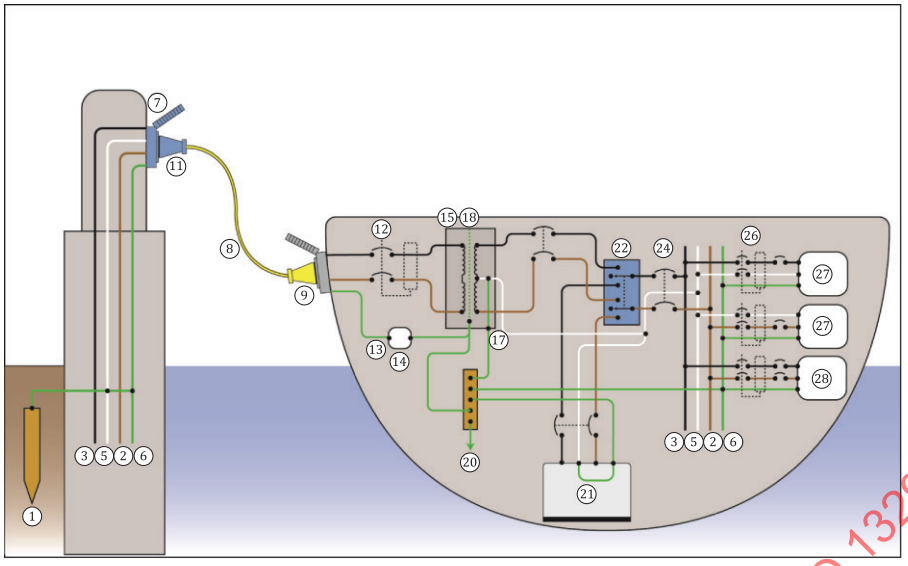
d) Single phase 230 V system with shore grounded (blue) neutral and grounding (green) conductors, and RCD



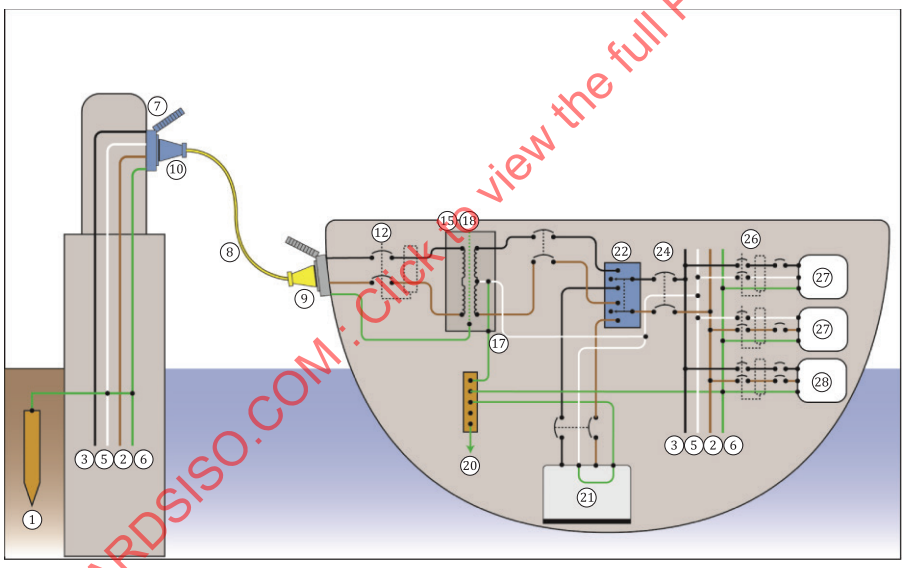
e) Isolation transformer system with single phase 230 V input, 230 V output with craft grounded secondary — Transformer shield grounded on the shore



f) Isolation transformer system with single phase 230 V input, 230 V output with craft grounded secondary — Transformer shield grounded on the shore shown with inverter/charger



g) Isolation transformer system with a single phase 240 V input and a 120 V/240 V output, and generator illustrating the use of main AC grounding bus and RCD/shore power disconnect breaker — Shown with input ground connected to craft's ground (via optional galvanic isolator), converting the isolation transformer into a polarizing transformer



h) Isolation transformer system with a single phase 240 V input and a 120 V/240 V output, and generator illustrating the use of main AC grounding bus and RCD/shore power disconnect breaker