IEC 60092-503

Edition 3.0 2021-10

INTERNATIONAL STANDARD

Electrical installations in ships –
Part 503: Special features – AC supply systems with voltages in the range of above 1 kV up to and including 36 kV

IEC 60092-503:2021-10(en)

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CONTENTS

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ELECTRICAL INSTALLATIONS IN SHIPS –

Part 503: Special features – AC supply systems with voltages in the range of above 1 kV up to and including 36 kV

FOREWORD

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IEC 60092-503 has been prepared by IEC technical committee 18: Electrical installations of ships and of mobile and fixed offshore units. It is an International Standard.

This third edition cancels and replaces the second edition published in 2007. This edition constitutes a technical revision.

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

a) modified the scope, increasing the voltage from 15 kV to 36 kV;
b) reference to IEC 61936-1 added:
c) included relevant parts of the IEC 62271 series;
d) removed low-impedance earthed neutral systems;
e) updated 7.7 on system test;

f) added requirements for switchgear and switchboards.

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

Draft	Report on voting
18/1734/FDIS	18/1742/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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

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

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- withdrawn,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

INTRODUCTION

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

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

ELECTRICAL INSTALLATIONS IN SHIPS –

Part 503: Special features – AC supply systems with voltages in the range of above 1 kV up to and including 36 kV

1 Scope

This part of IEC 60092 is applicable to AC supply systems with voltages from 1 kV up to and including 36 kV. The requirements contained in other parts of the IEC 60092 series apply where appropriate, subject to the exceptions stated in the clauses of this document.

2 Normative references

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

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

IEC 60038, *IEC standard voltages*

IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60071-1, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60076 (all parts), *Power transformers*

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

IEC 60092-201, *Electrical installations in ships – Part 201: System design – General*

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

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

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

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 60092-353, *Electrical installations in ships – Part 353: Power cables for rated voltages 1 kV and 3 kV*

IEC 60092-354, *Electrical installations in ships – Part 354: Single- and three-core power cables with extruded solid insulation for rated voltages 6 kV (U_m = 7,2 kV) up to 30 kV (U_m = 36 kV)*

IEC 60282-1, *High-voltage fuses – Part 1: Current-limiting fuses*

IEC 60282-2, *High-voltage fuses – Part 2: Expulsion fuses*

IEC 60502 (all parts), *Power cables with extruded insulation and their accessories for rated voltages from 1 kV (U_m = 1,2 kV) up to 30 kV (U_m = 36 kV)*

IEC 60502-1, *Power cables with extruded insulation and their accessories for rated voltages from 1 kV (U_m = 1,2 kV) up to 30 kV (U_m = 36 kV) – Part 1: Cables for rated voltages of 1 kV (U_m = 1,2 kV) up to 3 kV (U_m = 3,6 kV)*

IEC 60502-2, *Power cables with extruded insulation and their accessories for rated voltages from 1 kV (U_m = 1,2 kV) up to 30 kV (U_m = 36 kV) – Part 2: Cables for rated voltages from 6 kV (U_m = 7,2 kV) up to 30 kV (U_m = 36 kV)*

IEC TS 60815-1, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information and general principles*

IEC TS 60815-2, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 2: Ceramic and glass insulators for a.c. systems*

IEC TS 60815-3, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 3: Polymer insulators for a.c. systems*

IEC 62271-100, *High-voltage switchgear and controlgear – Part 100: Alternating-current circuit-breakers*

IEC 62271-102, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*

IEC 62271-106, *High-voltage switchgear and controlgear – Part 106: Alternating current contactors, contactor-based controllers and motor-starters*

IEC 62271-200:2021, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

IEC 62271-201, *High-voltage switchgear and controlgear – Part 201: AC solid-insulation enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

IEC/IEEE 80005-1, *Utility connections in port – Part 1: High voltage shore connection (HVSC) systems – General requirements*

3 Terms and definitions

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

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

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

3.1
high-impedance earthed neutral
IT system where the neutral is earthed through an impedance with numerical value equal to, or higher than, the capacitive reactance between phase and earth

3.2
category A machinery space
spaces and trunks which contain:

1) internal combustion machinery used for main propulsion; or
2) internal combustion machinery used for purposes other than main propulsion where such machinery with an accumulated total power output of not less than 375 kW; or
3) any oil-fired boiler or oil fuel unit.

[SOURCE: SOLAS, Chapter II-1, Part A, regulation 3.17]

3.3
main circuit
all the conductive parts of an assembly included in a circuit which is intended to transmit electrical energy

[SOURCE: IEC 60050-441:1984, 441-13-02]

4 General requirements

4.1 Environmental conditions

Environmental conditions shall be in accordance with relevant requirements of IEC 60092-101.

4.2 System design

System design shall be in accordance with relevant requirements of IEC 60092-201.

4.3 Personnel safety

Particular attention shall be given to the safety of personnel during the installation, operation and maintenance of equipment. This shall include

– manuals and instructions for transport, storage, installation, operation and maintenance,
– special tools required for operation, maintenance and testing,
– safe working procedures developed for specific locations, and
– safe earthing measures.

High voltage equipment shall be designed to limit the risk of arcing faults and contain possible arcing faults in such a way that the risk for operators is reduced to a level acceptable to the appropriate authority during internal fault conditions.

4.4 Operational safety

Control and protection systems shall take into account that continuous power supply is essential to ship's safety. The design shall be such that unnecessary tripping or de-energisation is avoided.

4.5 Integrity of external power supply

If the power supply is divided into more than one switchboard, in order to provide power supply availability in case of a single point failure (typically under fire condition), it shall be designed and protected such that any single point failure does not jeopardize overall functionality of the other switchboards.

4.6 Electrical and mechanical interlockings

Interlocks between different components of the equipment are provided for reasons of safety and for convenience of operations. The following provisions are mandatory for main circuits.

Apparatus installed in main circuits, the incorrect operation of which can cause damage, or which are used for assuring isolating distances during maintenance work, shall be provided with locking facilities (for example provision for padlocks).

Access to operation of a circuit-breaker, switch or contactor in the switchboard shall be limited by a "safety system" which co-ordinates other apparatus involved such as motors, transformers, generators, switchboards, etc. Back-feeding through transformers and shut off of starting air and oil to engines shall be taken into consideration.

Earthing switches having a short-circuit making capacity less than the rated peak withstand current of the circuit shall be interlocked with the associated disconnectors.

NOTE According to 7.2.1, the requirements of IEC 62271-200 are applicable. See IEC 62271-200:2021, 6.12 a), for removable parts of assemblies, and IEC 62271-200:2021, 6.12 b), for other parts of assemblies.

4.7 Selection criteria for distribution systems

The neutral earthing method shall be carefully selected, considering the following:

– selection of insulation level;
– characteristics of overvoltage – limiting devices – such as spark gaps or surge arresters;
– selection of protective relays;
– design of earthing system.

NOTE 1 The method of neutral earthing strongly influences the fault current level and the fault current duration.

NOTE 2 The choice of the type of neutral earthing is normally based on the following criteria:

– continuity of supply required for the network;
– limitation of damage to equipment caused by earth faults;
– selective elimination of faulty sections of the network;
– detection of fault location;
– touch and step voltages;
– operation and maintenance aspects.

A galvanically connected system has only one method of neutral earthing. Different galvanically independent systems may have different methods of neutral earthing. If different neutral earthing configurations can occur during normal or abnormal operating conditions, equipment and protective system shall be designed to operate under these conditions.

4.8 Distribution systems network earthing

One of the following distribution systems shall be used:

– three-phase three-wire with high-impedance earthed neutral; or
– three-phase three-wire with isolated neutral (IT system).

NOTE For tankers, see IEC 60092-502.

For isolated neutral systems, transient overvoltages can occur in the event of intermittent earth faults, and special consideration should be given to the dielectric strength of insulation.

If the neutral point of the system is connected to earth with an impedance (resistance or reactance), the induced overvoltage will be considerable on the occurrence of an earth fault and special consideration should be given to the dielectric strength of the insulation.

Means of disconnection shall be fitted in the neutral earthing connection. Locking arrangements shall be considered.

4.9 Divided system

Where a high impedance earthed system is divided into two or more sections, intended for separate operation, means for neutral earthing shall be provided for each section.

If it is possible to join two or more sections, the possibility of circulating currents shall be evaluated, and a proper plan or actions shall be taken into consideration (for example, leaving only one point earthed).

5 Insulation

5.1 Selection of insulation level

5.1.1 General

The insulation level shall be chosen according to the established highest voltage for installation U_m.

Insulation coordination shall be in accordance with IEC 60071-1.

NOTE Due to the conditions on board ships, certain equipment requires an insulation level higher than that of the nominal voltage of the system in accordance with IEC 60071-1 and IEC 60071-2.

5.1.2 Lightning impulse withstand voltage

The earthing conditions (isolated or high impedance earthing), for high-voltage ship-board installations are listed in Table 1.

NOTE The values are on the basis of the higher values for the lightning impulse withstand voltage in IEC 61936-1:2021, Table 2.

5.1.3 Consideration of rated withstand voltages

Dielectric tests for equipment with lower clearances than shown in Table 1 shall be based on the highest voltage U_m for the installation.

5.2 Verification of clearance and creepage distances

5.2.1 Clearance distance

Clearance and creepage distances for equipment are normally specified in the relevant product standard.

Where no product standard is available, the following two options are available.

– Option 1: Evidence that the minimum clearance distances based on U_m of Table 1 are kept and performance of a short-duration power-frequency withstand voltage test in accordance with IEC 60060-1. Test values shall be based on U_m according to Table 1.

– Option 2: If the minimum clearances in air are not maintained for chosen insulation level (see 5.1), appropriate dielectric tests (i.e. short-duration power-frequency withstand voltage tests and lightning impulse withstand voltage test) in accordance with IEC 60060-1 shall be performed. Test values shall be based on U_m according to Table 1.

Table 1 – Minimum clearance

Maximum RMS voltage for apparatus U_m [a] kV	Short-duration power-frequency withstand RMS voltage kV	Rated lightning impulse withstand voltage 1,2/50 µs U_{rB} kV	Minimum clearance phase-to–earth and phase-to-phase N mm
3,6	10	40	60
7,2	20	60	90
12	28	75	120
17,5	38	95	160
24	50	125	220
36	70	170	320
40,5	80	200	360
[a] See Table 2.			

5.2.2 Creepage distance

All equipment shall have satisfactory creepage distances.

Unless otherwise specified, the minimum specific creepage distance of insulators shall comply with the recommendations of IEC TS 60815-1, IEC TS 60815-2 and IEC TS 60815-3 for the level of pollution specified at the place of installation.

Where the level of pollution cannot be specified, the following values apply:

– 25 mm/kV in busbar systems;

– 16 mm/kV downstream, after circuit-breaker and fuses.

5.3 Voltage and frequency

Voltage and frequency shall be chosen in accordance with IEC 60038. The maximum nominal system voltage is 36 kV. The preferred values for nominal voltages for ship supply systems are stated in Table 2. If the system is intended to operate at variable frequency range, it shall be ensured that all affected equipment is designed to operate within entire range.

Table 2 – AC three-phase systems having a nominal voltage above 1 kV and up to and including 36 kV

Nominal system voltage [a] kV	Nominal frequency Hz	Highest voltage for equipment kV
3	50 or 60	3,6
3,3		3,6
6		7,2
6,6		7,2
10		12
11		12
15		17,5
20		24
22		24
33		36
35		40,5

[a] The table is based on IEC 60038. Values are RMS voltages between phases.

6 Electrical protection

6.1 General

In addition to the general requirements of IEC 60092-202, the requirements in 6.2 to 6.4 apply.

6.2 Voltage-transformer protection

Voltage-transformers for control and instrumentation with primary side connected between phases (line voltage) shall be protected against short circuit by fuses on the primary and on the secondary sides. Fuses may be omitted in circuits to voltage detectors in generator voltage regulators.

Voltage-transformers of moulded type or oil filled voltage-transformers for control and instrumentation with primary side connected between phase and neutral or earth (phase voltage) are accepted without short circuit protection on the primary side. Short circuit proof wiring shall be used.

6.3 Overvoltage protection

Overvoltage protection shall be arranged for lower voltage systems supplied through transformers from high-voltage systems. This may be

– a neutral voltage limiter at the secondary winding of the transformer, or
– direct earthing of the lower voltage system at the secondary winding of the transformer, or
– a metallic screen connected to earth between primary and secondary windings of a transformer (with additional means of protection, i.e. transformer differential protection). Ground fault trip on the high voltage side is required.

6.4 Earth-fault monitoring

In systems where outgoing feeders will not be automatically isolated in case of an earth fault, the insulation of the equipment shall be designed for the phase-to-phase voltage. Each primary or secondary insulated distribution system shall have a device or devices to continuously monitor electrical insulation to earth. In case of abnormally low insulation values, an alarm shall be given at a manned control station.

NOTE The transient overvoltages during earth fault are included in the values in Table 1 and Table 2.

7 High voltage equipment

7.1 General

7.1.1 Ingress protection

Equipment shall be protected according to the minimum requirements of Table 3.

Table 3 – Minimum IP ratings

Location	Equipment			
	Switchgear and control gear	Generators, motors	Transformers, semi-conductor converter, neutral point resistors	Terminal boxes for all kind of equipment
Locked electrical operational rooms accessible only to authorized personnel	IP 32	IP 23	IP 23	IP 44
Compartments accessible only to authorized personnel (category A machinery spaces) and zones below deck (e.g. thruster rooms)	IP 42	IP 43	IP 44	IP 44
Open deck (outdoor)	Not permitted for indoor equipment as listed above			IP 56

7.1.2 Earthing of current and voltage transformers

The secondary winding of current and voltage transformers shall be earthed. The earthing conductor shall be of copper and have a minimum cross-section area of 4 mm^2. The earthing conductor may be connected direct to the earthed enclosure of the transformer or to an earthed support.

7.1.3 Safe earthing measures

Safety earthing and short-circuiting shall be carried out by means of fixed earthing switches, portable earthing equipment or other suitable earthing equipment which is approved by the appropriate authority.

Arrangements making it possible to establish local safety earthing shall be provided where cables are terminated.

NOTE See also IEC 61936-1:2021, 8.4.5.

7.1.4 Accumulation of moisture and condensation

Effective means shall be provided to prevent accumulation of moisture and condensation within the equipment, for example by anticondensation or space heater, unless the equipment is installed in a dry space.

7.1.5 Liquid cooling

Where used, means shall be provided to indicate liquid coolant leakage and generate an alarm.

To prevent damage to electrical parts, liquid cooling systems shall be arranged to prevent entry of conductive liquids into the equipment.

7.1.6 Terminals

Terminals of rated voltages above 1 kV shall not be in the same terminal box as terminals of voltages below 1 kV, unless measures have been taken to ensure that access to the latter terminals can be obtained without danger.

Terminals of motors shall be arranged in terminal boxes.

Wherever practicable, all conductors shall be effectively covered with suitable insulating material. If the conductors are not insulated, phases shall be separated from earth and from each other by substantial barriers of suitable insulating material or by increasing the air gap between conductors.

Adequate space shall be provided to ensure efficient cable terminations.

7.2 Switchgear and controlgear assemblies

7.2.1 Design and construction

Switchboards shall be of metal-enclosed switchgear and controlgear in accordance with IEC 62271-200 with the following supplementary requirements for marine applications:

– environmental conditions specified by IEC 60092-101 shall be taken into account by the design and installation;
– circuit-breakers shall be in accordance with IEC 62271-100;
– earthing switches and disconnectors shall be in accordance with IEC 62271-102;
– contactors and motor starters shall be in accordance with IEC 62271-106;
– AC solid-insulation enclosed switchgear and controlgear shall be in accordance with IEC 62271-201;
– fuses shall be in accordance with IEC 60282-1 and IEC 60282-2.

If vacuum circuit-breakers are used, considerations should be given to the possibility of switching overvoltages.

Main switchboards shall be of metal enclosed type with a loss of service category of LSC2B and a partition class of PM.

Switchboard(s) fed by upstream LSC2B compartments shall have a loss of service continuity category of LSC2 and a partition class of PI or PM according to IEC 62271-200 or solid insulation enclosed switchboards with a loss of service continuity category of LSC2, partition class of PI and protection category of PA or PB according to IEC 62271-201.

On outgoing circuits, if reverse energizing from the load side is not possible, the switchgear may have a loss of service category of LSC2A.

Switchgear and controlgear filled with insulation based on liquids or gases shall only be installed in spaces which are adequately protected.

NOTE See IEC 62271-1:2017, 6.1 and 6.2, for requirements for liquids and gases.

An exhaust fan shall be provided for gases, and leakages of liquid shall be properly collected and contained in a safe space for liquids. An alarm shall be given at a manned control station.

It shall be taken into consideration that, in case of accidental arcing, the fluid may have toxic and corrosive effects.

The fluid's storage containers shall be stored in a separate space with separate venting arrangements.

Measures shall be taken to ensure that, in the event of leakage, gas cannot accumulate unnoticed.

7.2.2 Handrails

Every high voltage switchgear and controlgear assembly shall be provided with a handrail, located on a fixed part, or handles suitably fitted on the front of the switchboard. Where access to the rear of above-mentioned switchboards is necessary for operational or maintenance purposes, a handrail, located on a fixed part, or handles shall be fitted.

7.2.3 Door opening

All doors shall be provided with locking facilities when in the open position.

7.2.4 Encapsulation

Manual open operation of circuit-breaker shall be possible while the doors are closed.

7.2.5 Internal arc classification

High voltage switchgear and controlgear shall be of type internal arc class (IAC) AFLR (restricted to authorized personnel only, for front, rear and lateral side) according IEC 62271-200.

If access to rear is prevented during operation, an IAC accessibility of type AFL (restricted to authorized personnel only, for front and lateral side) is allowed.

If access to lateral and rear is prevented during operation, an IAC accessibility of type AF (restricted to authorized personnel only, for front side) is allowed.

Access to switchgears and controlgears with no internal arc classification shall only be possible if the system is de-engergized.

7.2.6 Continuous (common) busbar compartment

A high voltage switchboard shall have separation between each cubicle. Also, the busbar shall be separated from the compartments in the different cubicles.

A main switchboard divided in two independent and autonomous sections, with interconnecting circuit breakers installed in each section, may be accepted with a continuous busbar compartment, provided that a protection system (e.g. arc monitor or busbar differential protection) is installed which detects internal faults and isolates the affected part of the installation within 100 ms. Alternatively, accidental arcing may be reliable prevented by design measures (e.g. solid insulated busbar systems).

7.2.7 Busbars of main switchboards

The busbars of the main switchboard shall be divided into at least two independent sections using at least a circuit breaker rated for load switching. Connections from generators to important services shall be divided between the sections so that safe operation of the ship is ensured even with any one busbar section out of service.

Means shall be provided for a visible disconnection of all circuit-breakers and fused circuit-breakers from the busbars.

NOTE Such means can be a disconnector having a visible isolating distance or gap, or a reliable position-indicating device for each movable contact system, or similar visible means, for example, a withdrawable multipole circuit-breaker in its isolating position.

7.2.8 Generator circuits

Generator circuits shall be connected through a circuit-breaker suitable for breaking all load, overload and short-circuit currents.

In addition, a protection device shall be provided to include protection against short circuit or earth fault in the generator or in the cable connection from the generator to the switchboard by disconnection of the generator circuit-breaker and de-excitation of the generator.

The faults on the generator side of a circuit-breaker are regarded as phase-to-earth or phase-to-phase.

In order to minimise damage, consideration shall be given to protection against interwinding faults.

7.2.9 Outgoing circuits

Feeder circuits shall normally be connected through a circuit-breaker suitable for isolation which provides overload and short-circuit protection.

Fuses in contactors and motor starters are acceptable if the fuses can be replaced without any hazard to personnel. Fuses shall not be used for overload protection.

Switchgear for downstream circuits may be used as motor-starters only if the switchgear is designed for the starting current and the stipulated number of switching operations.

NOTE Certain types of fuses have an insufficient breaking capacity at currents between rated load and short circuit.

7.2.10 Power-transformer circuits

If the power transformers are arranged for parallel operation, the secondary side circuits shall be provided with switchgear complying with the requirements of 7.2.9. The switchgear on the secondary side shall be interlocked with the switchgear on the primary side, unless intentionally designed for feedback from low voltage side to high voltage side.

7.2.11 Shore-connection circuits

High voltage shore-connection circuits shall comply with IEC/IEEE 80005-1.

7.2.12 Earthing switches

All busbars, incoming and outgoing circuits shall be equipped with fixed earthing switches. Unless reliable mechanical interlocks are provided, fixed earthing switches shall have adequate making capacity.

Classification of earthing switches shall be at least E1 according to IEC 62271-102.

7.2.13 Earthing of equipment

Earthing conductors from equipment to hull shall be of copper and shall have a cross-section area of at least 35 mm^2. The current density shall not exceed 150 A/mm^2 for copper earthing conductors at the maximum earth fault which may occur.

7.2.14 Auxiliary circuits

When auxiliary power is needed for the operation of breakers and switches, an independent auxiliary power system shall be provided for each of the switchboard sections. As minimum, there shall be a manual change over possibility between the two auxiliary power systems, so that, in case one system fails, all switchboard sections can be operated (after manual change over). The auxiliary power systems shall have sufficient capacity for at least two operations of each circuit-breaker on the system.

7.3 Generators and motors

7.3.1 General

The generators and motors shall be in accordance with the relevant parts of the IEC 60034 series.

7.3.2 Installation

Rotating machines and neutral resistors shall be installed in spaces accessible to authorised personnel only (see Table 3).

NOTE Machinery spaces are generally considered as being accessible only to authorised persons. The same applies to the compartments which normally are kept locked under the responsibility of the ship's officers.

7.3.3 Encapsulation

Cable connection boxes shall be designed in such way that internal arc will not lead to any personnel risk for operators, even during arc fault.

After fault, sufficient protection against inadvertent contact with high voltage shall be maintained.

Pressure relief openings can be used to limit internal pressure in the connection boxes. In such cases, the gas shall be guided away from passageways.

7.3.4 Temperature monitoring

The windings of all rotating machines shall be provided with temperature detectors for monitoring and alarm.

7.3.5 Stator winding circuit arrangement

Generator stator windings shall have all phase ends brought out for connection of the stator protection.

7.3.6 De-excitation

The excitation system shall be so designed that a faulty generator can be de-excited automatically.

7.4 Transformers and reactors

7.4.1 General

The transformers and reactors shall be in accordance with IEC 60092-303 and the relevant parts of the IEC 60076 series.

Clause 7.4 applies to power transformers, reactors, and neutral earthing transformers.

NOTE Attention is drawn to the fact that difficulties can be experienced if transformers are connected star/star. These difficulties will be associated with earth-fault conditions and third harmonics.

7.4.2 Enclosures and installation

Where transformers are not contained in an enclosure, but a transformer room forms the enclosure of the transformer, the door of the room shall be interlocked with the supply switchgear. See Table 3.

7.4.3 Encapsulation

Transformer enclosures and cable connection boxes shall be designed in such way that internal arc will not lead to any personnel risk for operators, even during arc fault. They shall be designed in accordance with IEC 62271-200:2021, 6.106, regarding criteria to pass the internal arc classification test.

After fault, sufficient protection against inadvertent contact with high voltage shall be maintained.

Pressure relief openings can be used to limit internal pressure in the connection boxes. In such cases, the gas shall be guided away from passageways.

7.4.4 Temperature monitoring

The windings of all transformers and reactors shall be provided with temperature detectors for monitoring and alarm.

NOTE Temperature sensors are normally placed on the lower voltage side.

7.5 Converters

7.5.1 General

Converters shall be designed according to IEC 60092-304.

7.5.2 Encapsulation

Converter enclosures and cable connection boxes shall be designed in such way that internal arc will not lead to any personnel risk for operators, even during arc fault.

After fault, sufficient protection against inadvertent contact with high voltage shall be maintained. See Table 3.

Pressure relief openings can be used to limit internal pressure in the connection boxes. In such cases, the gas shall be guided away from passageways.

7.6 Cables

7.6.1 General

High-voltage cables shall be in accordance with relevant parts of the IEC 60502 series with special requirements for high-voltage cables on ships as given in IEC 60092-350, IEC 60092-353 and IEC 60092-354.

HV equipment shall be installed with fixed mounting. All cables shall be installed on trays with proper fixing.

NOTE HV shore connection (IEC/IEEE 80005-1) is excluded from 7.6.

The rated voltages U_0/U (U_m) of cables in respect of the nominal voltage shall be in accordance with IEC 60502-1 and IEC 60502-2.

7.6.2 Installation

Cables for high-voltage shall be installed separately from cables for low-voltage, for example, not grouped together or installed in the same conduit.

Installation of high-voltage cables in accommodation areas shall be avoided. Where high-voltage cables shall be routed through accommodation areas, the cables shall be installed in enclosed cable transit systems.

Cables for high voltage shall be specially marked with reference to IEC 60092-353.

7.6.3 Conductors and terminations

For terminations and joints not protected by earthed metal screens, the clearance distances between live conductors and between live conductors and earth shall be at least in accordance with 5.2.

If terminations are made in accordance with installation instructions from the manufacturer, these instructions should be considered sufficient documentation if relevant test reports are available for shipboard conditions.

7.6.4 Testing

After installation, with termination kit applied, high voltage cables shall be subjected to high voltage tests, with the voltage applied between the conductors and the screen.

Before and after the high voltage tests, an insulation resistance test shall be carried out.

For cables with rated voltage (U_0/U) above 1,8/3 kV (U_m = 3,6 kV), an AC voltage withstand test may be carried out upon advice from high voltage cable manufacturer.

One of the following test methods shall be used:

– power frequency test at the normal operating voltage of the system, applied for 24 h;
– power frequency test with the phase-to-phase voltage of the system applied between the conductor and the metallic screen or earth for 5 min;
– very low frequency test with 0,1 Hz, sine wave, for 15 min with a test voltage of 3,0 U_0 required for the cable (as required by the system voltage and the system earthing), or
– DC test voltage equal to 4 U_0 applied for 15 min. After completion of the test, the conductors shall be connected to earth for a period sufficifent to remove any trapped electric charge.