BRITISH STANDARD

Code of practice for installation of electrical and electronic equipment in ships

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Foreword

Publishing and supersession information

This British Standard was published by BSI and came into effect on 26 July 2006. It was prepared by Technical Committee JPEL/18, *Electrical installations of ships*. It supersedes all editions of the "*Regulations for the Electrical and Electronic Equipment of Ships*" (the IEE "Blue Book"), which are withdrawn.

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JPEL/18 wishes to acknowledge the participation of the following organizations in the drafting of this code of practice.

British Electrotechnical and Allied Manufacturers' Association (BEAMA)

British Cables Association (BCA)

British Marine Equipment Association (BMEA)

British Rig Owners Association (BROA)

British Waterways Board

Electrical Contractors Association (ECA)

Engineering Equipment and Materials Users' Association (EEMUA)

Association for the Instrumentation, Control and Automation Industry in the UK (GAMBICA)

Health and Safety Executive (HSE)

Institute of Marine Engineering, Science and Technology (IMar EST)

Institution of Engineering and Technology (IET)

Institution of Engineers and Shipbuilders in Scotland

Institution of Incorporated Engineers (IIE)

International Marine Contractors Association (IMCA)

Lloyd's Register

Maritime and Coastguard Agency (MCGA)

MOD — UK Defence Standardization

SELECT

UK Offshore Operators Association (UKOOA)

The production of this British Standard has required careful comparison of the text of the "Blue Book" with the relevant IEC standards.

This British Standard indicates only additional requirements or recommendations for UK industry that (BS) IEC 60092 lacks entirely or, in the opinion of JPEL/18, does not cover adequately, although frequent reference is made to other relevant standards and publications. References to the applicable parts of (BS) IEC 60092 are given at the beginning of each clause.

Use of this document

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification, and particular care should be taken to ensure that claims of compliance are not misleading.

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Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

In particular, attention is drawn to the statutory regulations listed as items [1] to [22] in the bibliography.

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1 Scope

This British Standard gives recommendations for the design, installation and maintenance of electrical equipment for the generation, storage, conversion, distribution and utilization of electrical energy for all purposes in ships of all descriptions, including, where relevant, inland and harbour craft, but excluding ships of war.

NOTE For vessels smaller than 500 grt or with a length less than 50 m, IEC 60092-507 provides a basic standard for small vessel electrical installations, including direct current systems not exceeding 50 V and alternating current systems not exceeding 250 V single phase or 500 V three phase.

These recommendations are intended to provide satisfactory operation and safety, especially from fire and electrical shock, of installed equipment and portable and transportable equipment which is intended to be connected to the ship's electrical distribution system. They relate principally to requirements for the installation, utilization, inspection and testing, but certain recommendations for the construction of electrical and electronic equipment are included.

This British Standard is not applicable to the internal wiring of manufactured apparatus that is not wired on board. It is not intended to provide for every circumstance – those of a special character may require appropriate advice.

2 Normative references

The following referenced documents are indispensable for the application 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.

BS 21, *Specification for pipe threads for tubes and fittings where pressure-tight joints are made on the threads (metric dimensions).*

BS 196, *Specification for protected-type non-reversible plugs, socket-outlets cable-couplers and appliance-couplers with earthing contacts for single phase a.c. circuits up to 250 volts.*

BS 1363 (all parts), *13 A plugs, socket-outlets and adaptors.*

BS 1387, *Specification for screwed and socketed steel tubes and tubulars and for plain end steel tubes suitable for welding or for screwing to BS 21 pipe threads.*

BS 1597, *Specification for limits and methods of measurement of electromagnetic interference generated by marine equipment and installations.*

BS 3135, *Specification for gas turbine acceptance test.*

BS 3456 (all parts), *Specification for safety of household and similar electrical appliances.*

BS 3863 (all parts), *Guide for gas turbines procurement.*

BS 4167 (all parts), *Specification for electrically-heated catering equipment.*

BS 4568-1, *Specification for steel conduit and fittings with metric threads of ISO form for electrical installations — Part 1: Steel conduit, bends and couplers.*

BS 4999 (all parts), *General requirements for rotating electrical machines.*

BS 5308-1, *Instrumentation cables — Part 1: Specification for polyethylene insulated cables.*

BS 5308-2, *Instrumentation cables — Part 2: Specification for PVC insulated cables.*

BS 5467, *Electric cables — Thermosetting insulated, armoured cables for voltages of 600/1000 V and 1900/3300 V.*

BS 5514 (all parts), *Reciprocating internal combustion engines: performance.*

BS 6004, *Electric cables — PVC insulated, non-armoured cables for voltages up to and including 450/750 V, for electric power, lighting and internal wiring.*

BS 6231, *Specification for PVC-insulated cables for switchgear and controlgear wiring.*

BS 6290-4, *Lead-acid stationary cells and batteries — Part 4: Specification for classifying valve regulated types.*

BS 6346, *Electric cables — PVC insulated, armoured cables for voltages of 600/1000 V and 1900/3300 V.*

BS 6351-1, *Electric surface heating— Part 1: Specification for electric surface heating devices.*

BS 6351-2:1983, *Electric surface heating — Part 2: Guide to the design of electric surface heating systems.*

BS 6351-3, *Electric surface heating — Part 3: Code of practice for the installation, testing and maintenance of electric surface heating systems.*

BS 6500, *Electric cables — Flexible cords rated up to 300/500 V, for use with appliances and equipment intended for domestic, office and similar environments.*

BS 6622, *Specification for cables with extruded cross-linked polyethylene or ethylene propylene rubber insulation for rated voltages from 3.8/6.6 kV up to 19/33 kV.*

BS 6626, *Code of practice for maintenance of electrical switchgear and control gear for voltages above l kV and up to and including 36 kV.*

BS 6724, *Electric cables — Thermosetting insulated, armoured cables for voltages of 600/1000 V and 1900/3300 V, having low emission of smoke and corrosive gases when affected by fire.*

BS 6883, *Elastomer insulated cables for fixed wiring in ships and on mobile and fixed offshore units — Requirements and test methods.*

BS 7027, *Specification for limits and methods of measurement of the immunity of marine electrical and electronic equipment to conducted and radiated electromagnetic interference.*

BS 7211, *Electric cables — Thermosetting insulated, non-armoured cables for voltages up to and including 450/750 V, for electric power, lighting and internal wiring, and having low emission of smoke and corrosive gases when affected by fire.*

BS 7629 (all parts), *Specification for 300/500 V fire resistant electric cables having low emission of smoke and corrosive gases when affected by fire.*

BS 7655-2 (all parts), *Specification for insulating and sheathing materials for cables — Part 2: Cross-linked elastomeric sheathing compounds.*

BS 7671, *Requirements for electrical installations — IEE Wiring Regulations.*

BS 7846, *Electric cables — 600/1000 V armoured fire-resistant cables having thermosetting insulation and low emission of smoke and corrosive gases when affected by fire.*

BS 7889, *Electric cables — Thermosetting insulated, unarmoured cables for a voltage of 600/1000 V.*

BS 7917, *Elastomer insulated fire resistant (limited circuit integrity) cables for fixed wiring in ships and on mobile and fixed offshore units — Requirements and test methods.*

BS 7919, *Electric cables - Flexible cables rated up to 450/750V, for use with appliances and equipment intended for industrial and similar environments.*

BS EN 50085-1, *Cable trunking systems and cable ducting systems for electrical installations — General requirements.*

BS EN 50086-1, *Specification for conduit systems for cable management — Part 1: General requirements.*

BS EN 50086-2 (all parts), *Specification for conduit systems for cable management — Part 2: Particular requirements.*

BS EN 50117 (all parts), *Coaxial cables.*

BS EN 60034-15, *Rotating electrical machines — Part 15: Impulse voltage withstand levels of rotating a.c. machines with form-wound stator coils.*

BS EN 60045-1, *Guide to steam turbine procurement — Part 1: Guide to steam turbine procurement.*

BS EN 60079-10, *Electrical apparatus for explosive gas atmospheres — Part 10: Classification of hazardous areas.*

BS EN 60079-14, *Electrical apparatus for explosive gas atmospheres — Part 14: Electrical installations in hazardous areas (other than mines).*

BS EN 60228, *Conductors of insulated cables.*

BS EN 60298, *A.C. metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV.*

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

BS EN 60335 (all parts), *Specification for safety of household and similar electrical appliances.*

BS EN 60335-2-36, *Specification for safety of household and similar electrical appliances — Part 2-36 — Particular requirements —*

Particular requirements for commercial electric cooking ranges, ovens, hobs and hob elements.

BS EN 60335-2-37, *Specification for safety of household and similar electrical appliances — Part 2-37 — Particular requirements — Particular requirements for commercial electric deep fat fryers.*

BS EN 60335-2-38, *Specification for safety of household and similar electrical appliances — Part 2-38 — Particular requirements — Particular requirements for commercial griddles and griddle grills.*

BS EN 60335-2-39, *Specification for safety of household and similar electrical appliances — Part 2-39 — Particular requirements — Particular requirements for commercial multi-purpose cooking pans.*

BS EN 60439 (all parts), *Specification for low-voltage switchgear and controlgear assemblies.*

BS EN 60622, *Secondary cells and batteries containing alkaline or other non-acid electrolytes — Sealed nickel-cadmium prismatic rechargeable single cells.*

BS EN 60470, *High-voltage alternating current contactors and contactor-based motor starters.*

BS EN 60669-1, *Switches for household and similar fixed electrical installations — Part 1: General requirements.*

BS EN 60702-1, *Mineral insulated cables and their terminations with a rated voltage not exceeding 750 V — Part 1: Cables.*

BS EN 60945, *Maritime navigation and radio communication equipment and systems — General requirements — Methods of testing and required test results.*

BS EN 60947-4-1, *Specification for low-voltage switchgear and controlgear — Part 4-1: Contactors and motor-starters — Electromechanical contactors and motor-starters.*

BS EN 60953-1, *Rules for steam turbine thermal acceptance tests — Part 1: High accuracy for large condensing steam turbines.*

BS EN 60953-2, *Rules for steam turbine thermal acceptance tests — Part 2: Wide range of accuracy for various types and sizes of turbines.*

BS EN 61008-1, *Specification for residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs) — Part 1: General rules.*

BS EN 61056-1, *Portable lead-acid cells and batteries (valve-regulated types) — Part 1: General requirements, functional characteristics — Methods of test.*

BS EN 61241-1, *Electrical apparatus for use in the presence of combustible dust — Part 1: Protection by enclosures "tD".*

BS EN 61241-14, *Electrical apparatus for use in the presence of combustible dust — Part 14: Selection and installation.*

BS EN 61386-1, *Conduit systems for cable management — Part 1: General requirements.*

BS EN 61386-21, *Conduit systems for cable management — Part 21: Particular requirements — Rigid conduit systems.*

BS EN 61386-22, *Conduit systems for cable management — Part 22: Particular requirements — Pliable conduit systems.*

BS EN 61386-23, *Conduit systems for cable management — Part 23: Particular requirements — Flexible conduit systems.*

BS EN 61558-2-5, *Safety of power transformers, power supply units and similar — Part 2-5: Particular requirements for shaver transformers and shaver supply units.*

BS EN 61951-1, *Secondary cells and batteries containing alkaline or other non-acid electrolytes — Portable sealed rechargeable single cells — Part 1: Nickel-cadmium.*

BS EN 62271-200, *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.*

BS ISO 3046 (all parts), *Reciprocating internal combustion engines.*

BS IEC 60092-303, *Electrical installation in ships — Part 303: Equipment — Transformers for power and lighting.*

BS IEC 60092-304, *Electrical installation in ships — Part 304: Equipment — Semiconductor converters.*

BS IEC 60092-401:1980, *Electrical installation in ships — Part 401: Installation and test of completed installation.*

BS IEC 60092-502, *Electrical installation in ships — Part 502: Tankers — Special features.*

BS IEC 60092-504:2001, *Electrical installation in ships — Part 504: Special features — Control and instrumentation.*

BS IEC 60533:1999, *Electrical and electronic installations in ships — Electromagnetic compatibility.*

IEC 60092-352, *Electrical installation in ships — Part 352: Choice and installation of cables for low-voltage power systems.*

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

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

IEC 62281, *Safety of primary and secondary lithium batteries during transport.*

3 Terms and definitions

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

3.1 appropriate authority

governmental body, or Classification Society, or both, to whose rules and regulations ships have to conform

3.2 dynamic position control system

control computer(s), input sensors (including manual control of set points) and output actuators, together with associated cabling and power supplies

3.3 vented cell

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

3.4 sealed cell

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

NOTE The cell might be equipped with a safety device to prevent a dangerously high internal pressure and designed to operate during its life in its original sealed state.

3.5 valve-regulated battery

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

NOTE The cell or battery cannot normally receive additions to the electrolyte.

3.6 extra low voltage (1)

voltage not exceeding 50 V a.c. r.m.s between conductors or between any conductor and earth in a circuit isolated from the electricity supply by means such as a safety isolating transformer or converter with separate windings

3.7 extra low voltage (2)

voltage not exceeding 50 V d.c. between conductors or between any conductor and earth in a circuit isolated from higher voltage circuits

3.8 low voltage

voltage normally exceeding extra-low voltage, but not exceeding 1 000 V a.c. or 1 500 V d.c. between conductors or 600 V a.c. or 900 V d.c. between any conductor and earth

3.9 high voltage

voltage normally exceeding low voltage

4 General requirements

NOTE This clause supplements the provisions of BS IEC 60092-101.

4.1 Voltage and frequency

4.1.1 Voltage and frequency variations within electrical systems are prescribed in BS IEC 60092-101.

4.1.2 In circuits supplied by batteries, the voltage variations given in BS IEC 60092-101 are likely to be exceeded, particularly where the battery is normally on floating service. The apparatus supplied should function satisfactorily within the maximum voltage variations likely to be met in all operating conditions.

NOTE Batteries supplying the emergency services required by SOLAS [1] should be capable of carrying the emergency electrical load without recharging whilst maintaining the voltage of the battery throughout the discharge period within 12% above or below the rated voltage.

4.1.3 All apparatus should function satisfactorily during sustained voltage variations within 10% below or 6% above the rated voltage of the system and a.c. apparatus should function satisfactorily at frequencies within plus or minus 5% of the rated frequency of the system.

4.1.4 The supply system should be arranged so that the transient conditions during starting of machines, etc., which are greater than those defined in **4.1.3** will not cause maloperation of or damage to other equipment, e.g.:

i) where pole changing deck machinery is involved, a dip of 15% and a recovery time of less than 0.2 second may be suitable;

ii) where pole changing deck machinery is not involved, a dip of 15% and a recovery time of less than 1 second may be suitable.

4.2 Design of equipment

4.2.1 All apparatus should be of a design appropriate to the situation in which it is likely to be used and its mode of installation should take account of the conditions likely to be encountered in service. Examples of such conditions are:

i) exposure to moisture and salt laden atmosphere, sea spray, high wind velocity or ice formation;

ii) exposure to abnormal vibration or shock;

iii) exposure to excessively high or low temperatures; and

iv) exposure to explosive mixtures of gases, dusts and circumstances where there is an abnormal risk of fire or explosion.

4.2.2 The design of equipment should provide accessibility to all parts requiring inspection or replacement in service.

4.2.3 Electrical and electronic equipment which may operate under automatic or remote control should do so without risk of damage to plant or injury to personnel.

4.2.4 Cognisance shall be taken of the requirements of BS IEC 60533 and BS EN 60945, as appropriate, with respect to EMC of the electrical equipment and systems of the installation.

4.2.5 Cooling air and water temperatures

Apply the latest version of SOLAS [1].

4.2.6 Inclination of ship

Apply the latest version of SOLAS [1].

4.2.7 Special consideration should be given to materials for items associated with systems which would be required to operate as long as possible in a fire, e.g. cables for certain alarms and shutdown systems, navigation lights, communication systems, emergency lighting, etc.

4.2.8 Where liquid coolants are used, consideration should be given to the detection of liquids in an equipment enclosure and provision of an alarm indication. In addition, for semiconductor converters, flow of coolant should be monitored to operate an alarm in the event of significant reduction of flow.

NOTE Attention is drawn to the need to guard against the leakage of coolant into the cooling liquid, e.g. where liquid to liquid heat exchangers are fitted.

4.2.9 Apparatus should be provided with suitable cable glands, bushings or conduit entries. All entries should maintain the degree of protection provided by the enclosure of the associated apparatus. (See **8.2.8.**)

4.2.10 The means of fixing current-carrying parts should be independent of the means of making electrical connection thereto.

4.2.11 Apparatus should be provided with suitable terminals, clearly marked, placed in an accessible position convenient for external connections. The terminals should be effectively secured and should be so spaced and/or shielded as to minimize the risk of accidental earthing or short-circuiting. Adequate clearance should be allowed between the cable entries and terminals so that cables can be drawn in and connected without damage.

Enclosures containing delicate apparatus should be provided with means to allow easy termination of cables without exposing such apparatus to the possibility of damage.

4.2.12 Enclosures of fixed apparatus which are liable to exceed a temperature of 80 °C should be so located or guarded as to prevent persons coming accidentally into contact with such equipment.

4.3 Installation, location and protection of equipment

4.3.1 Electrical equipment should, as far as practicable, be so placed that it is not exposed to risk of mechanical damage or excessive vibration. If equipment must be installed in locations subject to vibration, e.g. steering compartments, consideration should be given to mounting it on anti-vibration mountings. In this case, metal enclosures are to be provided with flexible arrangements for earthing.

4.3.2 Electrical equipment should be so selected and located or protected that the effects of exposure to sea air, water, steam, oil or oil fumes, spray, ice formation, etc., is minimized. It should be located well clear of boilers, steam, oil or water pipes, and engine exhaust pipes or manifolds, unless specifically designed for such locations. If pipes must be run adjacent to electrical equipment there should be no joints in the immediate vicinity of the equipment.

NOTE Where sprinkler heads or water spraying devices are fitted for fire-fighting, consideration should be given to the siting of electrical equipment which would be seriously affected by the inadvertent operation of the extinguishing arrangement. This is particularly applicable to switchgear and switch rooms, where a suitable alternative method of extinguishing should be used.

4.3.3 Horizontal rotating machines should, where practicable, be installed fore-and-aft to minimize the effects of rolling. Where a machine is installed athwartships or vertically, the design of bearings and the arrangement for their lubrication should be adequate to withstand the rolling encountered in heavy weather and operation for prolonged periods under the conditions specified by the appropriate authority.

4.3.4 Where an item of equipment or enclosure contains live parts that are not capable of being isolated by a single device, a warning notice should be placed in such a position that any person gaining access to live parts will be warned of the need to use the appropriate isolating devices, unless an interlocking arrangement is provided so that all the circuits concerned are isolated.

4.3.5 In every ship in which electric power is used for essential services the generators, switchgear, motors and associated control gear for such services should be so situated or protected that they will continue to operate satisfactorily in the event of partial flooding by bilge water above the tank top in the space in which they are situated. The design criterion for “partial flooding” should be assumed to be a depth of water 1/12th beam, but not exceeding a depth of 1.5 m. Where this recommendation is impracticable for horizontally mounted propulsion motors, the minimum requirement is watertight to underside of the motor shaft.

4.4 Electrical equipment in flammable and/or explosive dust atmospheres

4.4.1 BS IEC 60092 gives details of electrical equipment permitted on board tankers intended for the carriage in bulk of oil cargoes and other types of ships where oil or liquids of similar hazards are processed, handled or stored.

NOTE Reference should be made to BS IEC 60092-506 and BS IEC 60092-502.

4.4.2 Because of the potential dangers introduced by electrical equipment and the difficulty in maintaining its safe characteristics in service, such equipment should not be installed where flammable gases/vapours or explosive dusts are liable to accumulate, except where it is essential and it conforms to **4.4.3**.

4.4.3 Where risk of explosion from flammable gases/vapours could arise, equipment should be of a safe type, certified for the gases/vapours involved and should conform to BS EN 60079 or with an equivalent national or international standard.

4.4.4 Where a risk of explosion from combustible dusts could arise, equipment should conform to BS EN 61241-1 and BS EN 61241-14, or with an equivalent national or international standard.

4.4.5 Clause **13** gives details of electrical equipment permitted in battery compartments.

4.4.6 Sub-clause **14.2** details the requirements for trace heating systems.

4.4.7 Statutory requirements as listed in [1], [3], [9] and [18], govern the electrical equipment permitted on board the following types of ships:

- ships carrying dangerous chemicals in bulk;
- ships carrying liquefied gases in bulk;
- ships carrying dangerous goods and materials hazardous only in bulk;
- ships with spaces for carrying vehicles with fuel in their tanks for their own propulsion.

4.4.8 Electrical equipment for use in stores containing paint or other flammable fluids should be of a certified safe type. All switches and protective devices should interrupt all poles or phases and should be located in a non-hazardous area. Such switches and protective devices should be suitably labelled for identification purposes.

4.4.9 Electrical equipment for use in other spaces/areas where flammable gases/vapours and/or explosive dusts are liable to accumulate or where explosive materials are handled or stored is to be of a type acceptable to the appropriate authority.

NOTE 1 BS EN 60079-10, BS EN 60079-14 and BS EN 60079-17 give guidance on the installation and maintenance of electrical equipment for use in potentially explosive atmospheres.

NOTE 2 Special precautions may be necessary where risk of explosion from combustible dusts and flammable gases/vapours could arise simultaneously.

NOTE 3 Radio/radar transmitters coexist frequently in many shipping operations, particularly where bulk flammable cargoes are being transported. BS 6656:2002, 12.3 and Table 9, give guidance on the precautions to be taken to avoid inadvertent ignition of flammable materials by radio frequency radiation.

5 Earthing and bonding

*NOTE This clause supplements the provisions of BS IEC 60092-401 and BS EN 60092-507. The details given in **5.1** to **5.4** apply directly to ships with metallic hulls. Additional requirements for ships with non-metallic hulls are detailed in **5.5**.*

5.1 System earthing

*NOTE **5.1** should apply to earthed d.c. systems in so far as it is appropriate.*

5.1.1 Earthed neutral or insulated systems are acceptable. For earthed systems in tankers and in other ships of similar hazard, see BS IEC 60092-502.

NOTE For further information see Annex B.

5.1.2 Earthed neutral systems should be so designed that the potential earth fault current:

a) will not exceed the design capacity of any part of the systems; and

b) is of sufficient magnitude to operate any protection or indication device.

5.1.3 The earthing system adopted must take account of, and limit to acceptable values, possible harmonic circulating currents.

5.1.4 L.V. earthed neutral systems may be achieved by connecting the neutral point directly to earth. The earth loop impedance should be low enough to permit the passage of a current at least three times the fuse rating for fuse protected circuits or 1.5 times the tripping current of any excess current circuit breaker used to protect the circuit.

5.1.5 H.V. earthed neutral systems should be achieved by inserting impedance in the neutral connection to earth to limit the earth fault current to an acceptable level. The prospective earth fault current should be at least three times the value of current required to operate any earth fault protection devices. In the case of high impedance earthing, the impedance should be such that the earth fault current is slightly higher than the capacitive current of the system. Solid earthing is not recommended for H.V. systems.

5.1.6 Where an earthed system is divided into two or more sections, means for neutral earthing should be provided for each section.

5.1.7 All earthing resistors/impedances should be connected to the ship's hull. In addition, earthing resistors/impedances should be bonded together on the hull side of the resistance/impedance. The means of bonding should be separate from that provided at the ship's hull for radio, radar and communications circuits in order to minimize possible interference.

5.1.8 Efficient means should be provided for detecting defects in the insulation of the system. For systems where the earth fault current exceeds 5 A, automatic tripping devices are to be provided. Where the earth fault current does not exceed 5 A, an indicator may be provided as an alternative to an automatic tripping device (see also **5.3** and **B.3.2.2**).

5.2 Earthing of non-current-carrying parts

5.2.1 Unless specifically included in the exemptions listed in BS IEC 60092-401, all exposed-conductive-parts and extraneous-conductive-parts should be bonded to the ship's hull. The bonding should be such as to give a substantially equal potential and a sufficiently low earth fault loop impedance to ensure correct operation of protective devices. The bonding should be achieved by means of a separate earth conductor unless the parts under consideration are installed as follows.

Metal frames or enclosures of apparatus mounted in direct contact with the ship's hull will normally exhibit a low resistance to earth and no supplementary bonding should be necessary if the supplies to the apparatus and their protection arrangements are in accordance with Table 1.

5.2.2 Extraneous-conductive parts which are connected to the ship's hull by permanent and reliable metal-to-metal joints of negligible impedance need not be bonded by separate earthing conductors. Separate supplementary bonding should be provided in situations where this addition is deemed to be necessary.

Table 1 **Supply conditions for which supplementary bonding is not required**

System voltage	Protection arrangements not requiring supplementary bonding
110 V up to and including 440 V	Protective device rating 32 A or less; or RCD protected
55-0-55 V	Fuse rating 16 A or less; or MCB rating 32 A or less; or RCD protected
24 V	Fuse rating 6 A or less; or MCB rating 10 A or less; or RCD protected

5.2.3 The earthing of installations in hazardous areas should conform to the requirements of the appropriate authority or BS EN 60079-10 or BS EN 60079-14 where appropriate.

5.3 Earth indication

5.3.1 Every insulated distribution system, whether primary or secondary, should be provided with means to give initially audible and visual, then continuous visual, warning of abnormally low levels of insulation.

5.3.2 Every earth indicating device should be so designed that the flow of current to earth through it is as low as practicable, but in no case should exceed 30 mA.

5.3.3 Where an earth-indicating system using either two or three lamps, as appropriate, is adopted, earth-indicating lamps should be of the metal filament type. The system employing a single lamp should not be used. To facilitate comparison of the brilliance of earth-indicating lamps they should be of clear glass and should be placed not more than 150 mm apart.

5.4 Cables

Recommendations for the earthing and bonding of cables for electromagnetic compatibility are given in Annex C.

5.5 Additional requirements for ships with non–metallic hulls

5.5.1 A main earth conductor bar should be provided at a suitable location, for example, the main switchboard, to which all non-current-carrying parts not exempted in BS IEC 60092-401 should be connected.

5.5.2 The main earth conductor bar should be connected to the main earthing plate described in BS IEC 60092-401 by a copper conductor having a minimum cross-sectional area of 64 mm^2, preferably of solid strip construction.

5.5.3 To minimize electromagnetic interference, earthing connections should be run with the associated power cables wherever practical. Three-core cable is preferred for lighting circuits.

5.5.4 Earthing connections of equipment, which are sensitive to electromagnetic interference, should be made directly to the main earth conductor bar of the main earthing plate.

5.5.5 The earthing system in accordance with this clause and the lightning protective system in accordance with Clause **20** should be run separately down to the pillars at the main earthing plate.

5.5.6 To dissipate possible charge build-up in ships with non-metallic hulls constructed of high resistivity materials (surface and volume resistivities greater than 10^8 ohms and 10^6 ohm-metres, respectively) it is recommended that all metallic objects over 0.6 m in length and over 0.4 m^2 in surface area are earthed.

NOTE It may be desirable to bond to the main earth system all metal parts which are in direct contact with the sea, in order to minimize the effects of electrolytic corrosion.

6 Application of diversity factors

NOTE This clause supplements the provisions of BS IEC 60092-201.

6.1 General

6.1.1 The diversity factor for power circuits should take account of the known and anticipated conditions. The calculations should be based on the full load ratings of motors and the characteristics of the generators.

6.1.2 The diversity factor applied, where justifiable, to the loading calculation of cables, switchgear and generators supplying groups of winch motors or crane motors should be based upon the estimated duty cycle of the motors in the group, taking into account the frequency and duration of motor starting loads.

6.2 Assessment curves

6.2.1 For series resistance controlled d.c. motors, assessment curves in Figure 1a) have been found to be satisfactory.

6.2.2 For variable voltage/current controlled equipment such as Ward Leonard or thyristor apparatus operating on d.c. or a.c. systems, assessment curves in Figure 1b) have been found to be satisfactory.

6.2.3 For a.c. cage induction motors, assessment curves in Figure 1c) have been found to be satisfactory if the associated a.c. generators conform to **8.2.10**.

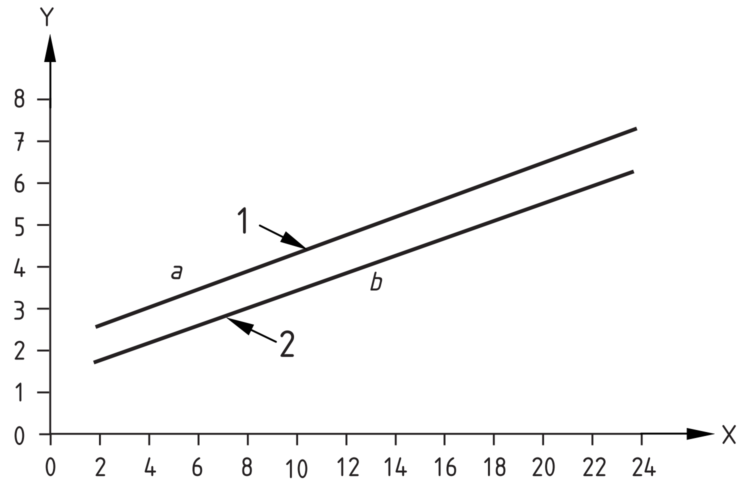
6.2.4 In each case, curve "a" represents the factor to be applied for assessing generators and curve "b" applies to cables and switchgear.

6.2.5 All the assessment curves are based on motors of equal rating; if they are of different values suitable computations would be necessary. All the diversity factors should be taken as minima, and cables, switchgear and generators supplying winch motors and crane motors should be capable of carrying continuously (subject to voltage drop) the currents calculated by applying a diversity factor to the total connected load of winch motors and/or crane motors.

6.2.6 Where the cables feeding winch motors and/or crane motors supply in addition other equipment, the current upon which the cross-sectional area of the conductors of the cables is based should allow for the coincidence of the various loads.

NOTE The term "full load" applies to the full load kW (or current) or full load kVA input of the winch or crane motor at its maximum shaft output rating.

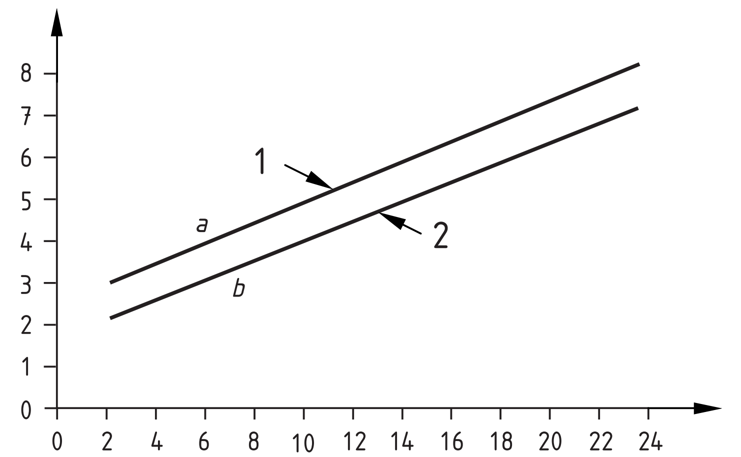
Figure 1 **Assessment curves**



Number of d.c. resistance controlled winches or cranes

NOTE 1 In the case of cranes with hoist, luff and slew motions, the sum of the kW inputs (or currents) of the driving motors should be allowed for.

a) DC system



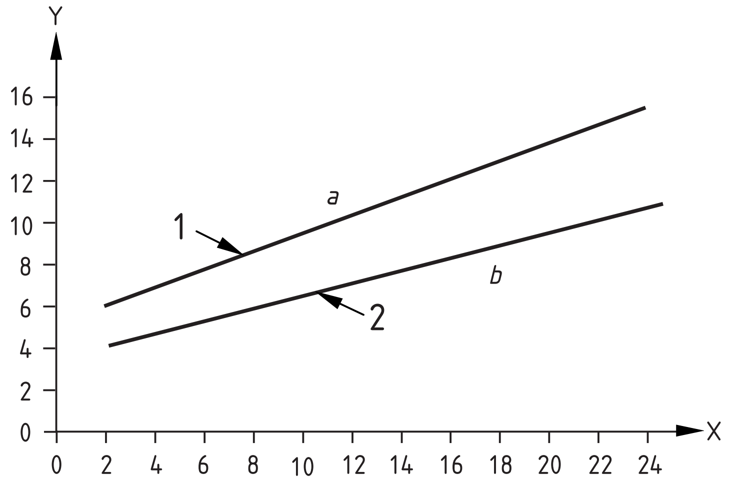
Number of Ward Leonard controlled winches or cranes

NOTE 2 In the case of cranes employing Ward Leonard Control with hoist, luff and slew motions, the sum of the kW inputs of the driving motors should be allowed for.

b) Ward Leonard control for dc and ac system

(continued)

Figure 1 **Assessment curves** *(Continued)*



Number of cage induction controlled winches or cranes

NOTE 3 In the case of pole changing, 3-speed motors, the kVA of the middle speed winding should be allowed for. In the case of cranes with hoist, luff and slew motions, the sum of the kVA inputs of the driving motors should be allowed for.

c) AC systems

Key

1 = generators

2 = cables and switchgear

NOTE 4 d.c. systems: generator kW load = kW input of one winch or crane × K

$$\textit{a.c. systems: generator kVA load} = \frac{\text{kW input of one winch or crane} \times \text{K}}{0.8\ \text{pf}}$$

K = times full load kW input of kW [as in a) and b)] or kVa [as in c)] input (or current) of one winch or crane motor.

6.3 Refrigerated containers

A diversity factor may be applied for refrigerated containers when deciding the capacity of generators and distribution transformers. The final decision can only be reached by consideration of the type of container, the cargo mix between chilled and frozen and the ratio of hot to pre-cooled containers for the applicable trade.

7 Distribution

NOTE This clause supplements the provisions of BS IEC 60092-201 and BS IEC 60092-204.

7.1 General

7.1.1 If a cable is looped from board to board without passing through a protective device, the cable conductors should be of the same cross-section throughout.

7.1.2 Switches in conductors of insulated distribution systems should open all lines simultaneously.

7.2 Final sub-circuits

7.2.1 A final sub-circuit having a rating exceeding 16 A, but not exceeding 32 A, may supply two or more cooking appliances where these are installed in one space. In the absence of precise data the current demand should be assessed as the first 10 A of the total rated current of the connected cooking appliances, plus 30% of the remainder of the total rated current of the connected cooking appliances.

7.2.2 In dry areas of accommodation spaces, and in spaces having similar environmental conditions, ring final sub-circuits each protected by a 30 A or 32 A fuse or miniature circuit breaker may be installed to serve socket outlets conforming to BS 1363 (all parts), provided that one pole of the supply is earthed. The maximum number of socket outlets connected to each ring should be according to the estimated maximum demand of apparatus within the 30 A or 32 A rating, but should not exceed 18. The cables used for such ring final sub-circuits should have a minimum current carrying capacity of 20 A.

7.2.3 Every final sub-circuit should be separately connected to:

a) a distribution board; or

b) a switchboard.

7.2.4 Switches used to control emergency lighting should not be accessible to unauthorized persons.

7.2.5 Except for essential services, a pilot lamp installed as an integral part of an appliance or accessory need not be individually protected provided that the protection device of the main circuit is rated at not more than 16A.

7.3 Navigation lights

7.3.1 General

7.3.1.1 All ships and vessels of every type must conform to the International Regulations for Preventing Collisions at Sea 1972 [22], as amended. Ships of every type and size are required to be provided with “steaming lights” which comprise masthead, side, stern, anchor, not-under-command and, if applicable, special purpose lights. The construction and installation of navigation lights should be to the satisfaction of the appropriate authority.

7.3.1.2 Ships should be provided with primary and alternative lanterns for each of the navigation lights required by the Collision Regulations [22], except that alternative lights are not required for ships less than 24.4 m in length. Primary lanterns should be electric. Alternative lanterns should be electric except that oil lanterns may be used in ships (other than tankers) less than 20 m in length (all lanterns) and less than 50 m in length (all lanterns except masthead).

7.3.1.3 The arrangements described in **7.3.2** and **7.3.3** below apply to all passenger ships and to new cargo ships of 500 tons or over.

7.3.2 Primary electric steaming lanterns with electric alternatives

NOTE The arrangements described in this sub-clause are applicable to all passenger ships and to new cargo ships of 500 tons or over.

7.3.2.1 Each light should be connected by a separate cable to a distribution board reserved for navigation lights, fitted in an accessible place and under control of the officer of the watch.

7.3.2.2 There should be two essentially separate power supply systems to the distribution board; one from the main switchboard and one from the emergency switchboard.

NOTE Where a transitional source of emergency power is required by SOLAS [1] the arrangements should enable the lights to be supplied from this source in addition to the emergency generator.

7.3.2.3 So far as is practicable, the arrangements should be such that a fire, fault or mechanical damage at any one point will not render both systems inoperative; it is accepted, however, that the systems must come together at some point where the changeover can be effected. This should preferably be at or near the distribution board.

7.3.2.4 Each light should be controlled and protected in each insulated pole by a switch and fuse or by a circuit breaker mounted in the distribution board.

7.3.2.5 Each light should be provided with an automatic indicator to give an audible and/or visual alarm in the event of lamp failure. If a visual signal is used, which is connected in series with the steaming light, means to prevent failure of the indicator extinguishing the steaming light should be provided. If an audible device alone is used it should be connected to an independent source of supply, e.g. a battery, and provision should be made for testing this supply.

NOTE 1 The indicator board may be combined with the steaming light distribution board.

NOTE 2 Light failure indicator/alarm systems are not required in vessels under 24.4 m in length.

7.3.2.6 The use of junction boxes in navigation light circuits, other than those provided for connecting the lanterns to the fixed wiring of the electrical installation, should be avoided. Cables for different circuits should not use the same junction box.

7.3.2.7 Where systems at reduced voltage (e.g. 24 V) are used, voltage drop in cables requires particular attention and should not exceed 6% of the nominal voltage.

7.3.3 Electric steaming lanterns with oil alternatives

The arrangements should be as described in **7.3.2** but may be relaxed in accordance with the following.

a) The requirements of **7.3.2.2** may be replaced by the following requirement: provision should be made in the distribution board to change over the navigation lights to an alternative circuit.

b) The requirements of **7.3.2.3** need not apply.

8 Generating plant and motors

NOTE This clause supplements the provisions of BS IEC 60092-301.

8.1 Prime movers

8.1.1 General

8.1.1.1 Prime movers should conform to the requirements of **4.2.2** and **4.2.5.** Electrical apparatus supplied with these prime movers should conform to the requirements of all relevant clauses of the recommendations. Prime movers for driving generators should also comply with the requirements of the relevant standard:

a) Steam turbines — BS EN 60045-1
BS EN 60953-1
BS EN 60953-2

b) Gas turbines — BS 3135
BS 3863 (all parts)

c) Oil engines — BS ISO 3046 (all parts)
BS 5514 (all parts).

8.1.1.2 Where change in operating ambient conditions may significantly alter the relationship between the capabilities of the prime mover and driven generator, appropriate measures should be employed to prevent damage.

Prime movers for driving electric generators intended for supplying essential services should be so rated that the electrical output to meet SOLAS requirements can be met under the relevant operating conditions in **4.2.5**.

8.1.2 Governing characteristics

8.1.2.1 Transient performance for all types of prime mover should at least meet the governing accuracy for Class A1 in BS 5514-4.

8.1.2.2 Each prime mover should be fitted with an emergency overspeed device which operates at a speed not more than 15% above rated speed and has provision for tripping by hand.

8.1.2.3 The governor setting should be capable of adjustment both locally and from a remote switchboard.

8.1.2.4 Each combined prime mover, transmission system and generator should be designed to withstand without damage the effects of the most onerous short-circuit condition at the generator terminals when running at rated voltage and speed. If it can be demonstrated that temporary loss of generating plant will not affect the safety of the ship or its plant, then alternative proposals may be accepted. In such cases an acceptable proposal may be a quickly replaceable shaft, purposely designed to shear without other resultant damage.

NOTE It is recognized that damage to the commutator/brushgear of d.c. generators may result from conditions of short-circuit.

8.1.3 Lubrication

Generating sets dependent on forced lubrication should be arranged to shut down automatically on failure of lubrication.

For some gas-turbine prime movers, a battery-fed d.c. lubrication oil pump may be required to support lubrication oil pressure during run down.

8.2 Generators and motors

8.2.1 Where continuous rating is inappropriate, generators and motors may be assigned ratings to BS 4999 (all parts) or BS EN 60034-1, in accordance with their specified duty.

8.2.2 Where motors are to be operated on a non-sinusoidal and/or variable frequency supply, care should be taken to ensure that any additional heating does not impair the service life of the motor.

8.2.3 Where cooling-water is used, the cooler should be so arranged as to minimize the risk of entry of water into the machine, whether by leakage or condensation in the heat exchanger.

8.2.4 Machines should be so constructed that when running at any and every working speed all revolving parts are well balanced and they should be capable of withstanding over-speeds required by the prime mover.

8.2.5 Consideration should be given in the design of d.c. machines and their protective system to means of minimizing damage in the event of short-circuit.

8.2.6 Every sleeve bearing should be fitted with an inspection cover and means for visual indication of level or flow or pressure, as appropriate to the type of lubrication employed.

8.2.7 Measures should be taken if necessary to avoid the circulation of currents between the shaft and bearings.

NOTE Circulating currents can cause the deterioration of bearing components and also be a possible ignition source of any explosive gas/air mixture which may be present.

8.2.8 Machines should be located so that adequate space is provided to enable convenient access for cables and ease of their connection or termination. (See also **4.2.9**.)

8.2.9 Adjustment of generator voltage

8.2.9.1 Where manual adjustment of terminal voltage is necessary or is provided for the satisfactory operation of generators, the facilities should be provided at the switchboard or at an appropriate control position.

8.2.9.2 For each generator, coupled to its prime mover at any permissible temperature within the working range, the means provided should be capable of adjusting the voltage at any load between no-load and full-load to within:

a) 0.5% of rated voltage for generators of rating exceeding 100 kW; or

b) 1.0% of rated voltage for generators of rating not exceeding 100 kW.

8.2.10 The excitation system provided in accordance with **8.2.9** should be capable of maintaining the voltage under steady-state conditions within plus or minus 2.5% of rated voltage for all loads between zero and rated load, within the range of power factor likely to be encountered in the ship, e.g. 0.5 to Unity, when driven by its prime mover.

The purpose of providing transient performance tolerances in the standards is to ensure that manufacturers and system designers have a verifiable capability at works test. The real concern is to provide a working system on board.

8.2.11 In the limit, the generating plant should have a transient voltage response such that the anticipated motor starting currents can be accommodated without such voltage drop as would cause maloperation of or damage to other equipment.

8.2.12 If generators are intended to run with their neutrals solidly connected together, or connected via a low impedance, the manufacturer(s) should be informed so that the generators can be designed to have a low value of harmonic voltage and/or to operate with the resulting circulating currents. This is particularly important if they are of different designs.

NOTE 1 This condition can arise during synchronizing even if the generators do not run continuously with neutrals inter-connected.

NOTE 2 If generator neutrals are inter-connected provision may have to be made for the resultant circulating currents in the machine design and in the protection system, particularly during the period of the synchronization and before the kW load is shared.

NOTE 3 If the generators are intended to have their neutrals earthed or inter-connected, means should be provided to isolate each generator winding for test and maintenance purposes.

8.2.13 For every a.c. motor, the starting current and its duration should be compatible with the mechanical load, the overall characteristics of the supply system and the protective equipment.

Each motor should be rated in accordance with its duty.

8.3 Shaft generator systems

NOTE This sub-clause relates to generators driven from the propulsion plant and includes the generators, synchronous compensators, prime movers, transmissions, excitation circuits, semiconductor converters and control equipment.

8.3.1 Performance

Shaft generator systems should conform to **8.2.1** to **8.2.8**, inclusive.

Semiconductor converters forming part of the shaft generator system should conform to the requirements of Clause **15**.

Where shaft generator systems are to operate in parallel with ship's service generators, they should conform to the requirements of **8.2.9** to **8.2.12**.

The design of the propulsion shaft system including, where applicable, separate power take-off drives for generators should be such as to avoid damaging torsional stress and vibration.

The electrical system should be stable under all operating conditions within the specified range of shaft speed variations and specified speed variation periods.

The capability of the prime mover(s) propeller shaft systems and seating should be adequate to withstand the effects of the most onerous short-circuit conditions at the generator terminals when running at rated voltage and speed.

8.3.2 Construction

A generator mounted in, or connected to, the propeller shaft line should have adequate clearances in normal running and under fault conditions, to avoid damage from dimensional variations as a result of ship structural flexing.

Lubrication should be effective at all operating speeds. Where creep speeds can occur, e.g. with turbine drives, see also **8.3.3**.

8.3.3 Where forced lubrication (pressure or gravity fed) is used on machines in or connected to the propulsion shaft line, temperature and pressure or temperature and flow measuring devices should be fitted and arranged to operate an alarm if the temperature exceeds a predetermined safe value or in the event of oil flow failure (see **8.3.4**). An alternative means of lubrication such as oil rings or oil reservoir should be provided unless:

a) an automatically operated standby oil supply is provided, or

b) the period which elapses before the machine comes to rest after interruption of power does not exceed 30 seconds.

The lubrication of the bearings of machines in or connected to the propulsion shaft line, together with associated gearing and shafting, should be effective at all normal speeds from creep speeds upwards, both ahead and astern, having due regard to the ship's inclination and the angle of shaft rake. The shafts and bearing should not be damaged by slow rotation, whether or not electrical power is applied, or whether such rotation is induced by the propellers, and under all predictable oil temperature conditions. Separate means may be provided to prevent such damage due to slow rotation of the shaft, e.g. a shaft brake.

8.3.4 A switch may, if desired, be provided for silencing the audible alarm(s) referred to in this section to obviate the continuous sounding of the alarm; but in such a case a visual warning device should be automatically switched on to indicate acceptance of the alarm(s).

8.4 Additional requirements for shaft generating systems

8.4.1 Additional requirements for generating systems in which the shaft generators form part of the main source of power required by SOLAS [1] are given in **8.4.2** and **8.4.5**.

8.4.2 The generating system should be capable of continuously delivering the power required to meet SOLAS requirements under all ship manoeuvring conditions, including the propeller being stopped.

8.4.3 The generating system should be at least as effective and reliable as independent generating sets.

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

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

8.5 Other shaft generators

Generators driven from the propulsion plant which do not conform to **8.4** may be used as additional source(s) of power with respect to the power balance, but attention should be given to a quick restoration of electrical power to all auxiliaries necessary for maintaining the ship in operational and safe conditions after an electrical power interruption, e.g. due to a sudden stop of the propulsion plant. The time involved for restoring the above-mentioned services should be as agreed between the manufacturer and purchaser.

NOTE The foregoing recommendations apply also to dual purpose machines whose primary roles is as a shaft generator but that can also serve as an emergency source of propulsion if required.

9 Construction of cables

NOTE This clause supplements the provisions of IEC 60092-350, IEC 60092-351, IEC 60092-353, IEC 60092-354, IEC 60092-359, IEC 60092-373, IEC 60092-374, IEC 60092-375 and IEC 60092-376.

9.1 Standards on construction of cables

In addition to the cables listed in the note to Clause 9, cables from the following list may also be suitable for certain applications.

BS 5308 (both parts)	Instrumentation cables
BS 5467	Armoured cables with thermosetting insulation for voltages of 600/1 000 V and 1 900/3 300 V
BS 6004 [1)]	PVC insulated cables (non-armoured) for voltages up to and including 450/750 V for electric power and lighting
BS 6346	PVC insulated, armoured cables for voltages of 600/1 000 V and 1 900/3 300
BS 6500	Flexible cords rated up to 300/500 V, for use with appliances and equipment intended for domestic, office and similar environments
BS 6622	Cables with extruded cross-linked polyethylene or ethylene propylene rubber insulation for rated voltages from 3.8/6.6 kV up to 19 /33 kV
BS 6724	Armoured cables for electricity supply having thermosetting insulation for voltages of 600/1 000 V and 1 900/3 300 V, having low emission of smoke and corrosive gases when affected by fire

1) These standards nominate solid wire conductors. See **9.2.2**.

BS 6883	Elastomer insulated cables for fixed wiring in ships and on mobile and fixed offshore units
BS 7211 [1)]	Non-armoured thermosetting insulated cables for voltages up to 450/750 V, having low emission of smoke and corrosive gases when affected by fire
BS 7629	300/500 V fire resistant electric cables having low emission of smoke and corrosive gases when affected by fire
BS 7846	600/1 000 V armoured fire resistant electric cables having thermosetting insulation and low emission of smoke and corrosive gases when affected by fire
BS 7889	Non-armoured thermosetting insulated cables for voltages up to 600/1 000 V
BS 7917	Elastomer-insulated fire resistant (limited circuit integrity) cables for fixed wiring in ships and on mobile and fixed offshore units
IEC 60502-1	Power cables with extruded insulation and their accessories for rated voltages of 1 kV (Um = 1.2 kV) and 3 kV (Um = 3.6 kV)
IEC 60502-2	Power cables with extruded insulation and their accessories for rated voltages from 6 kV (Um = 7.2 kV) up to 30 kV (Um = 36 kV)
BS EN 60702-1 [1)]	Mineral insulated cables and their terminations with a rated voltage not exceeding 750 V.

9.2 General

9.2.1 Cables of materials and construction differing from those covered by the standards referred to in **9.1** are not precluded when such materials and construction are acceptable to the appropriate authority.

9.2.2 Unless the particular application allows the use of solid wire conductors, then cables using class 2 or class 5 conductors to BS EN 60228 shall be used.

9.2.3 See BS IEC 60092-401:1980, Clause **2**, Table 2, regarding earthing conductors.

9.2.4 The shape of the cable should be such that its entry into an enclosure will not impair the enclosure's specified degree of protection.

9.2.5 Where cables are required to operate in an area where contamination by oil is likely to occur, the type of oversheath selected should be of an "enhanced oil resistance" grade. In cases where the contamination is severe, the advice of the cable manufacturer should be sought (see the foreword of BS 6883/BS 7917; also Clause **10**).

9.2.6 Every core of a single, twin or multi-core cable for use as fixed wiring should be identifiable at its terminations and, preferably, throughout its length.

10 Selection and installation of cables

NOTE This clause supplements the provisions of IEC 60092-350, IEC 60092-351, IEC 60092-352 and IEC 60092-376.

10.1 Determination of the cross-sectional areas of conductors

In assessing the normal maximum current, account may be taken of any diversity factors that are applicable (see Clause **6**).

Where socket outlets are connected into a final lighting sub-circuit the maximum loading for each outlet should be assumed to be 500 W.

In motor circuits, the effects of starting, and frequency thereof, should be considered to ensure that the rated operating temperature of the associated supply cable(s) is not exceeded.

Where cables are connected in parallel they should be of the same type and length and should have conductors of the same cross-section and be arranged so as to carry substantially equal current

The current-carrying capacity (Ip) of parallel, connected cables should be based on the following formulae:

a) for twin and multi-core cables and single core cables in trefoil: $I\text{p} = \text{I} \times \text{n}$

b) for other single-cored cables: $I\text{p} = 0.9\ \text{I} \times \text{n}$

where:

I is the current rating

n is the number of parallel connected conductors.

Every equalizer connection for use with compound wound generators should have a cross-sectional area of at least 50% of the cross-sectional area of the positive or negative connections to the generator.

For polyphase circuits in which serious imbalance is unlikely to be sustained in normal service, other than discharge lighting, a reduced neutral conductor may be used. However, in all cases the neutral conductor should have a cross-sectional area of at least 50% of the cross-sectional area of the phase conductor.

10.2 Protective covering of cables

Certain cable types referred to in **9.1**, e.g. those conforming to BS 6724, are intended primarily for installation in air in dry environments.

In instances where the construction of a cable does not conform to a standard referred to in **9.1**, it should be ensured that the materials of the protective sheath are compatible with those of the conductor insulation, with the intended operating temperature of the conductor insulation and with the intended environment.

10.3 Cable runs

Cables for control circuits may be bunched with power cables having higher permissible conductor temperatures, providing that the temperature within the bunch does not exceed the permissible temperature of the control cable sheath

Cables having a bare metallic screen, braid or armour should be installed in such a manner that galvanic corrosion by contact with other metals is prevented.

Appropriate personal protective equipment must be worn and particular care taken when installing cables with bare metallic screen, braid or armour.

NOTE 1 An impervious sheath will prevent the armour of different cables coming into contact.

NOTE 2 Impervious sheaths should be maintained intact to exclude the ingress of water.

The internal radius of a bend for the installation of cables should be chosen according to the type of cable and should be not less than the values given in IEC 60092-352.

Long cable runs that may be subjected to movement, such as those mounted on a flying bridge or along the main deck, shall be provided with arrangements to prevent fatigue damage. Such arrangements may comprise adequately supported full or half loops at appropriate intervals with radii to suit the size and type of cable used. If cables cross structural expansion points, loops shall be situated across them.

Attention should be paid to the suitability of the insulating and sheathing materials of these cables with regard to low temperature and other environmental conditions (see **10.6**).

10.4 Installation in metallic pipes, conduits or trunking

10.4.1 Conduits and conduit fittings should, with the exception of inspection and draw-in boxes (see **10.4.2**), conform in all respects to:

BS EN 50086-1 and the relevant parts of BS EN 50086-2; or

BS EN 61386-1 and BS EN 61386-21, BS EN 61386-22 or BS EN 61386-23,

as applicable, and should be heavy gauge and welded or solid drawn. Steel pipes should conform to BS 1387 and be threaded in accordance with BS 21.

10.4.2 Inspection and draw-in boxes should be of metal construction and should be in rigid electrical and mechanical connection with the conduits. The boxes should, in addition, conform to BS 4568-1 and BS EN 61386-1 or BS EN 50085-1, so far as is applicable. For steel conduits or pipes this connection should be obtained by screwing into the box or into a device clamping both sides of the wall of the box.

10.4.3 A space factor of 40 per cent applies to installations where the cables are not drawn round more than two 90° bends conforming to BS 4568-1 and BS EN 61386-1 or BS EN 50085-1, as applicable. Where there are more than two such bends, an appropriate reduction in the number of cables drawn should be made.

10.5 Cable ends

The ends of every conductor should be securely terminated by means which contain all the strands of the conductor.

The ends of every conductor having a nominal cross-sectional area exceeding 2.5 mm^2 should be provided with soldering sockets or with compression type sockets or be connected by means of substantial mechanical clamps. Cable sockets and clamps should be of such dimensions and design that the maximum current likely to flow through them will not cause the rated operating temperature of the cable insulation to be exceeded.

At cable ends, the insulation should not be removed farther than is necessary having regard to the type of termination used. The braid, metal sheath or other covering over the insulation, including the tape (if any), in contact therewith, should be cut back at least 13 mm from the end of the insulation in cables up to 13 mm diameter (measured over the insulation) and at least 25 mm from the end of the insulation in cables of greater diameter. The covering over the insulation should not be cut back beyond the point of entry to the terminal box or fitting.

Where cable cores are not colour or number coded, the cores should be marked for identification at their ends.

10.6 Cables for special applications

*NOTE In general the cables specified in **9.1** are suitable for low temperature operating conditions with the exception that PVC-insulated and sheathed cables constructed from compounds specified in BS 5308-2, BS 5467, BS 6004, BS 6346 and IEC 60502-1 and IEC 60502-2 are unsuitable for installation at temperatures lower than 0 °C.*

Cables selected for installation in ambient temperatures lower than –30 °C should be suitable for the environment and be able to withstand vibration at these low temperatures.

Travelling cable for electric lifts or hoists should be sheathed overall with flame retardant, cross-linked compound.

Where travelling cables are to move partly or wholly inside a hazardous area, a metallic screen should be applied immediately under the outer sheath.

Where flexible cables are required for connection to portable machinery they should conform to the relevant clauses of BS 7919. The sheath should refer to a compound type RS3 in BS 7655-2.3.

Cables for the internal wiring of switchgear should conform to BS 6231 or BS 6883, as applicable.

Cables for use at radio frequencies should conform to the relevant parts of BS EN 50117 and should be installed according to Annex C.

The type of cable to be used for special environments, such as the supply to submersible pumps for water, gas and oil, should be determined after consideration of the function and the special environments.

Cables for underwater applications should be designed to suit the specified conditions and service.

Separate cables should be used for:

a) safety and emergency circuits, in order to improve overall system reliability and reduce the vulnerability of plant to failure which could result from loss of a cable or signal;

b) power, where the circuits require individual short-circuit or over current protection, except for:
   1) control circuit which is a branch off the main circuit - this may be carried in the same cable as the main circuit, provided both the main circuit and the subsidiary are isolated by a common switch, or
   2) where harmonic or other interference produced by thyristor equipment or similar could affect other systems equipment;

c) controls and instrumentation (both analogue and digital), where induced voltage or "cross talk" between circuits would cause malfunction of the system, unless separate circuits within the same cable are individually screened;

d) circuits of differing voltage bands, which should not normally be contained in the same cable.

11 Tables of cable current ratings

NOTE This clause supplements the provisions of IEC 60092-352.

11.1 General

It is recommended that reference is made to the tables in IEC 60092-352. These tables apply to cables employed in the wiring of ships, but do not provide for every condition under which such cables may be used.

The current ratings are based on maximum operating conductor temperatures, as shown in the tables. Where cables are connected in parallel, the factor detailed in **10.1** should be used if necessary.

Where the load is non-continuous the appropriate rating should be calculated using the factors given in IEC 60092-352.

It should be ensured that the cable still conforms to other requirements.

The factors for ½ hour and 1 hour service have been calculated on the assumption that the intermediate periods of rest are longer than the critical duration, i.e. longer than three times the thermal time constant of the cable.

The factors for intermittent service have been calculated on the assumption of a 10 minute period, with 4 minutes on constant load and 6 minutes without load.

11.2 Voltage drop

Reference should be made to BS 7671 for values of voltage drop. If for those sizes where reactance becomes significant it is required to calculate voltage drop values at a frequency of 50 Hz, the following formulae will apply:

a) Single phase $V_{50}^2 = 0.694\ V_{60}^2 + 0.306\ V_0^2$

b) Three phase $V_{50}^2 = 0.694\ V_{60}^2 + 0.229\ V_0^2$

where:

V_0 is the d.c. volt drop per ampere per metre

V_{60} is the 60 Hz volt drop per ampere per metre

V_{50} is the 50 Hz volt drop per ampere per metre.

When the d.c. volt drop is not tabulated for a 3- or 4-core cable, it can be taken as the value for a 2-core cable of the same conductor size.

The current ratings in the tables are subject to the maximum permissible voltage drop of 4% not being exceeded.

Under special conditions of short duration, such as motor starting, higher voltage drops may be accepted, provided that the operation of connected equipment is not adversely affected.

12 Motor control gear

NOTE This clause supplements the provisions of IEC 60092-201, BS IEC 60092-202, BS IEC 60092-204, BS IEC 60092-301, BS IEC 60092-401, BS IEC 60092-501, BS IEC 60092-502, BS IEC 60092-503 and BS IEC 60092-504.

12.1 Construction and temperature limits

The construction, rating and testing of control gear should be in accordance with BS EN 60439 (all parts), BS EN 60298, BS EN 62271-200, BS EN 60470 or BS EN 60947-4-1, as applicable.

12.2 Glazed windows of enclosing cases should be as small as practicable, consistent with their purpose, and suitable protection should be arranged, where necessary, against accidental breakage.

12.3 Every electric motor should be provided with efficient means of starting and stopping, the latter so placed as to be easily operated by the person controlling the motor. This requirement may be relaxed in special circumstances for motors having a rating of 0.5 kW or less.

12.3.1 Means should be provided to prevent automatic re-starting after a stoppage due to a drop in voltage or complete failure of supply, where unexpected re-starting of the motor might be undesirable.

NOTE 1 This requirement may be relaxed in special circumstances, e.g. where it is admissible to arrange for the starting of a motor at irregular intervals in response to an automatic control device or where a dangerous condition might result from the failure of a motor to start after a temporary interruption of the supply, for example, a steering-gear motor.

NOTE 2 A single device may serve to prevent automatic re-starting of a group of motors.

12.3.2 Means of isolation should be provided, suitably placed, and so connected that all voltages may be removed fro m the motor and all apparatus including any associated automatic circuit-breaker.

NOTE 1 A single means of isolation may be provided for a group of motors and associated control apparatus where, for the purpose of carrying out inspection or other work on any individual motor in the group or on the control apparatus directly associated with such a motor, simultaneous isolation of the whole group is acceptable.

*NOTE 2 The means of isolation referred to in **12.3.2** may be the fuses in each live pole or phase, provided they are so arranged so that they can be readily and safely removed and retained by persons authorized to have access to the motor and associated apparatus. Where small appliances may be safely isolated by a plug and socket arrangement, additional means are not necessary.*

12.3.3 Where necessary for safety, local stopping facilities should be provided.

12.4 Where a single master-starter system (i.e. a starter used for controlling a number of motors successively) is used, the apparatus should provide under-voltage and overcurrent protection and means of isolation for each motor not less effective than required for systems using a separate starter for each motor. Where the starter is of the automatic type, suitable alternative or emergency means should be provided for manual operation. Where motors are provided for duplicated services, the starting portion should be duplicated and means should be provided for the standby unit to be put into immediate operation in the event of failure of one of the starters.

12.5 Emergency stop controls for motor-driven fuel-oil transfer and fuel-oil pressure pumps should be provided at a readily accessible point outside the compartments in which the pumps are situated. The controls should be of the manual re-set type and suitably labelled.

12.6 All power ventilation, except machinery and cargo space ventilation and any alternative ventilation specially provided for control stations outside the machinery spaces, should be fitted with controls so grouped that any fans may be stopped from either of two separate positions which should be situated as far apart as practicable. Controls provided for the power ventilation serving machinery spaces should also be grouped so as to be operable from two positions, one of which should be outside such spaces. Fans serving power ventilation systems to cargo spaces should be capable of being stopped from a safe position outside such spaces. Controls should be of the manual re-set type and suitably labelled.

Exemption: This recommendation does not apply to small fans connected to lighting circuits.

12.7 Motor-driven pumps designed to discharge above the water line in the way of life-boat launching should be provided with emergency stop controls installed in locked boxes having breakable covers, e.g. glass, conveniently located. The controls should be of the manual re-set type and suitably labelled.

12.8 Lifts

12.8.1 Lift electrical equipment should comply with the appropriate requirements of BS 5655.

12.8.2 Lifts, other than those used exclusively for goods, should be arranged so that in the event of failure of the main supply, they will deck automatically using the emergency supply and should then allow the gates to be opened, or should be provided with other satisfactory means for escape of occupants.

NOTE Unless the emergency generator is arranged to start automatically on mains failure the emergency supply should be taken to include the half-hour transitional battery, when fitted.

12.8.3 One lamp in each lift and the alarm facility should be supplied from an emergency power source.

12.9 Magnetic brakes

12.9.1 Series-wound and compound-wound brakes should release on first-step starting current of the motor. Series-wound brakes should hold off under all working conditions, including light running. Equipment that provides electric controlled lowering should be fitted with compound-wound or shunt-wound brakes. If compound-wound, the regenerative current passing through the series coil should not allow the brake to operate.

Shunt brake coils should be so constructed or protected that they are guarded against damage to their windings by inductive discharge. A series resistor and/or discharge resistor may be used.

12.9.2 The temperature rise of coils when tested in accordance with the brake rating should not exceed that permitted on motors with which they are being used. Where the coils are in close proximity to the lining, the brakes should be tested under conditions such that any heat transmitted from the friction surfaces is taken into account. Where the motor with which the brake is being used can run light for periods in excess of the time of its full-load rating, the brake coils should correspond to the light running period.

12.10 Magnetic clutches

The recommendations made in **12.9** for shunt-wound brakes apply generally to magnetic clutches. When the coil is energized, the clutch should take up the drive smoothly and positively. No end-thrust should be exerted from the clutch, the pressure between members being balanced within the clutch itself. Magnetic clutches should be balanced. Suitable means for taking up wear of the linings should be provided. Collector rings for current supply to the clutch should be of non-corrodible material. Double brush-contacts should, preferably, be fitted to provide a positive contact.

13 Batteries

NOTE This clause supplements the provisions of BS IEC 60092-202, BS IEC 60092-401 and BS IEC 60092-305.

13.1 General

13.1.1 The temperature of the battery should be maintained within the range 15 °C to 50 °C, or as recommended by the manufacturer.

13.1.2 Each battery should be provided with a durable name-plate securely attached or, alternatively, fitted adjacent to the battery, bearing the maker's name and type designation, the ampere-hour rating at some specific rate of discharge (preferably that corresponding to the duty for the specific application), the nominal voltage, and, for vented lead-acid batteries requiring electrolyte maintenance, the specific gravity of the electrolyte when the battery is fully charged.

13.1.3 All batteries should be arranged to facilitate ease of installation, replacement and, where necessary, maintenance. Each cell or crate of cells should be accessible from the top and at least one side.

13.1.4 A battery may consist of single cells assembled in crates or trays or upon a stand or stands of wood or other suitable material. Crates or trays should be provided with means to facilitate handling and should preferably not exceed 100 kg in weight; individual cells should not exceed 25 kg in weight. Where metal stands are used, non-absorbent insulation appropriate to the working voltage should be provided between the cells and stands. Similar insulating materials should be employed to restrict movement of the cells which would otherwise arise due to movement of the ship. In addition, metallic stands should be insulated from the structure where a battery has a nominal working voltage exceeding 120 V.

13.1.5 All fittings should be non-corrodible or should be treated with electrolyte-resistant material.

13.2 Construction

The cells of all batteries should be designed to minimize the emission of electrolyte spray.

13.3 Location

13.3.1 No battery compartment should form a means of access to any other compartment.

13.3.2 Where lead acid and alkaline batteries are installed in the same compartment or on the same platform, separate tools, such as hydrometers and topping-up devices, should be provided.

13.3.3 Battery compartments should have gas-tight boundaries where they adjoin accommodation or service spaces, and it is preferable that they should be arranged with access from the open deck.

13.4 Ventilation

13.4.1 The ventilation system for battery boxes and compartments should be separate from other ventilation systems and the ducts should lead to a location in the open air where any gases can be safely diluted. The location should be away from possible sources of ignition and openings to spaces in which gases might accumulate.

13.4.2 Batteries in rooms, compartments or boxes connected to a charging device with a total maximum power output of more than 2 kW should be ventilated by mechanical exhaust.

13.4.3 Where lockers or boxes are provided for batteries in machinery spaces and other well-ventilated compartments, the duct should terminate not less than 900 mm above the battery enclosure.

13.4.4 Boxes for batteries should have ventilation openings near the top to permit escape of gas. Holes for air inlet should be provided on opposite sides of the box as a minimum. The entire box, including openings for ventilation, should be sufficiently weatherproof to prevent entrance of spray or rain.

13.4.5 Impellers of non-metallic material, used in ventilating fans for battery compartments, should be such that sparking due to static discharge is minimized.

13.4.6 All openings through battery compartment bulkheads or decks, other than ventilation openings, should be effectively sealed to reduce the possibility of escape of gas from the battery compartment.

13.5 Electrical installations in battery compartments and rooms

13.5.1 Luminaires should be permanently wired and fitted outside the space so that the space is illuminated through permanently fixed lenses or ports fitted in the bulkhead or deck, so arranged to maintain the gas-tight integrity of the compartment. Alternatively, luminaires of the type certified for use in hydrogen atmospheres may be used within the battery compartment.

13.5.2 Cables should not normally be installed in battery compartments unless they form part of intrinsically safe circuits or are serving permitted equipment within the compartment. Through-runs of cables may be permitted within the compartment where installation elsewhere is impracticable when they should either:

a) be in seamless steel conduit or equivalent, without joints or junction boxes, which is gas-tight to the battery compartment; or

b) include a metallic sheath or braid or wire armour with an electrolyte-resisting, impervious, non-metallic sheath applied over the metallic covering.

13.5.3 Cable penetration arrangements should maintain the gas-tight integrity of the battery compartment.

13.6 Sealed batteries

13.6.1 Special ventilation arrangements to avoid the accumulation of flammable gases are not normally necessary for sealed batteries, provided that precautions are taken to minimize the risk of cell abuse. Causes of cell abuse include:

a) attempts to charge primary cells, mixing used and unused cells, mixing cells of different electrochemical systems, reversing one cell in a set of three or more and the use of any alternative power source provided for the equipment; and

b) short-circuits, which can occur due to poor insulation of the cell enclosure, water ingress into the cell enclosure and unsuitable storage of cells.

*NOTE For batteries in portable apparatus used in hazardous areas, see **4.4.9**, Note 2.*

13.6.2 Guidance on the use of lithium batteries issued by the Health and Safety Executive [23] should be adhered to (see Part 2, **5.9**), as should that in IEC 62281.

13.7 Valve-regulated batteries

13.7.1 General

13.7.1.1 Valve-regulated lead-acid batteries should conform to BS 6290-4 and BS EN 61056-1 and nickel-cadmium batteries to BS EN 61951-1 and BS EN 60622.

13.7.1.2 Where other standards are used, precautions to minimize the risk of a release of gas under normal conditions and risk due to disruption by explosive force in abnormal conditions should be included.

13.7.1.3 Boxes or lockers containing valve-regulated batteries should conform to **13.4.4**.

13.7.2 Charging facilities

13.7.2.1 Where valve-regulated batteries are installed in accordance with BS EN 60623, BS EN 60896-1 and BS EN 60896-2 (see also BS EN 50272-2), a device independent of the normal charging arrangements should be provided to sense and alarm in the event of gas evolution in excess of the manufacturer's design quantity.

13.7.2.2 A suitable warning plate should be fitted to the charger stating:

"Isolate charger before working on battery connections."

13.7.3 In the case of constant voltage changes, consideration should be given to temperature compensation according to the battery manufacturer's recommendations.

14 Heating and cooking appliances

NOTE This clause supplements the provisions of BS IEC 60092-307.

14.1 General

14.1.1 Electric heating and cooking appliances should conform to BS 3456 (all parts), BS 4167 (all parts) and BS EN 60335-2-36, BS EN 60335-2-37, BS EN 60335-2-38 and BS EN 60335-2-39.

14.1.2 All combustible materials in the vicinity of heating and cooking appliances should be protected by suitable non-combustible and thermal-insulating materials.

14.1.3 Every heating and cooking appliance, whether portable or fixed, should be controlled locally by a fixed switch. Where a socket-outlet is provided it should be connected between the switch and the appliance.

When in the "off" position, control switches should isolate the heating elements in all non-earthed poles.

14.1.4 A means by which power to the galley can be cut off in the event of fire should be fitted outside the galley exits in positions not likely to be made inaccessible by such a fire.

14.1.5 Space heaters should be of the convector type, except that heaters of the visible element type may be used provided they are designed and installed in such manner as to minimize the risk of fire.

Portable space heating appliances should not be used. It is desirable that space heaters should be equipped with means to interrupt the current if the temperature exceeds the permissible limit.

14.2 Special requirements for trace and electric surface heating systems

14.2.1 Trace heating systems should conform to BS 6351-1, BS 6351-2 and BS 6351-3.

14.2.2 Systems should meet the requirements of service category 22, in BS 6351-2:1983, Table 1, and be provided with overcurrent protection, residual current protection with trip indication, adequate means of isolating the system from the supply and over-temperature limitation as required by the standard, and be to the satisfaction of the appropriate authority.

14.2.3 Cable or tape units should be provided with either metallic sheath, braid or wire armour.

14.2.4 The cable or tape units should be supplied from an isolating transformer or transformers with secondary circuit earthed and having a secondary voltage not exceeding 254 V.

14.2.5 The residual current operated circuit breaker should conform to BS EN 61008-1, and should have a trip current no greater than 30 mA.

14.2.6 In situations where the cable or tape units are liable to mechanical damage they should be provided with suitable protection.

14.2.7 Notices are to be provided indicating the location of cables or tapes, and warning personnel not to stand on traced pipes, etc.

14.2.8 Trace heating systems which are installed in hazardous areas should additionally be certified to an appropriate explosion protection standard.

15 Semiconductor converters for power purposes

NOTE This clause supplements the provisions of BS IEC 60092-304.

15.1 The design of semiconductor converters is evolving rapidly, and particular requirements in specifications may become outdated. Care is therefore needed in specifying semiconductor converters that potential risks of novel technology have been identified. An example is the need to consider the specification of machines to operate in conjunction with converters that can give very high rates of change of the output voltage (kV/microsecond). A whole-system approach is advised.

15.2 In addition to the requirements in BS IEC 60092-304, the following should be considered.

a) Semiconductor converters should be rated for their operation duty having due regard to the system transient or peak loading requirements and the thermal capacity of the semiconductor devices.

   Equipment for propulsion or vital services shall be required to withstand, without damage or failure of protective fuses, the transient voltages that might be imposed by the supply system or by malfunction.

b) For converters operating in parallel with other converter equipment, d.c. generators or batteries, precautions should be taken to ensure that, within the specified loading conditions, load sharing is such that overloading of any unit does not occur and that the combination of the paralleled equipment is stable.

c) Where converters are pipe ventilated or closed air-circuit ventilated, means should be provided for measuring the temperature of the cooling air after it has circulated through the equipment and to operate an alarm if this exceeds a pre-determined safe value or in the event of an air flow failure.

d) Anti-condensation heating should be provided.

e) Where there are several converters on the same supply system, means should be provided to decouple the device-firing circuits in order to minimize mutual interference.

f) When filters or capacitors are used to compensate reactive currents, changes of supply system frequency should not cause unacceptable increases of the r.m.s. and peak values of the system voltage.

Fuses used in filter circuits should be monitored.

g) Interference should remain within the limits specified in BS IEC 60533 and special measures may have to be taken to prevent unacceptable conductor-borne interference levels being transmitted to other parts of the ship, particularly by control cables.

15.3 Filters fitted in the power circuit for EMC purposes must be so designed that they are protected against overloading by energy generated elsewhere in the connected system.

15.4 If the cooling water is in contact with live heatsinks, a method for controlling its conductivity must be provided. An alarm shall be activated if the conductivity exceeds a pre-set value.

16 Transformers

NOTE This clause supplements the provisions of BS IEC 60092-303.

16.1 Transformers for marine service are generally rated for a temperature rise 5 °C less than equivalent land-based design, to take account of the advised environment temperatures.

16.2 In addition to the requirements in BS IEC 60092-303, the following should be considered.

a) Means should be provided for isolation of secondary windings, which can be connected to a source of voltage.

b) When transformers are arranged to operate in parallel, means should be provided for the isolation of the primary and secondary windings.

c) A suitable warning label indicating the points of isolation should be provided near the point of access.

d) Where forced cooling is used, it should be possible to operate at reduced power on failure of a pump or fan. Consideration should be given to the provision of suitable temperature-indicating and alarm facilities.

e) Where liquid cooling is used, consideration should be given to the detection of leakage into the enclosure and provision of an alarm indication. In addition, flow of coolant should be monitored to operate an alarm in the event of loss of flow.

17 Accessories

NOTE This clause supplements the provisions of BS IEC 60092-306.

17.1 General

17.1.1 Cable entries should conform to the class of enclosure of the accessory.

17.1.2 Where electrolytic corrosion may occur between a metal enclosure and the surface upon which it is mounted suitable insulating material should be inserted and separate means should be provided to bond the case to earth.

17.2 Switches

17.2.1 Switches should conform to the relevant requirements of BS EN 60669-1 as far as it is applicable. Where the ambient and/or load parameters exceed those in BS EN 60669-1, other appropriate national or international standards should be applied.

17.2.2 In galleys, laundries, bathrooms, machinery and other spaces where moisture may be present, switches should be of watertight or of all-insulated construction.

17.2.3 On weather decks, switches should be of watertight construction IP56 and cable entries provided with watertight glands (see IEC 60092-201).

17.2.4 Every switch or other means of control or adjustment should be so situated as to be normally inaccessible to a person using a fixed bath or shower. This requirement does not apply to electric shaver supply units conforming to BS EN 61558-2-5 or to insulating cords of cord-operated switches.

17.2.5 Every switch not specially designed to break an inductive load of its full rated capacity should:

a) if used to control a discharge-lighting circuit, have a current rating of not less than twice the total steady current which it is required to carry, or

b) if used to control filament lighting and discharge lighting, have a current rating of not less than the sum of the current flowing in the filament lamps and twice the total steady current flowing in the electric discharge lamps.

17.3 Socket-outlets and plugs

17.3.1 Socket-outlets and plugs should conform to the relevant requirements of BS 196, BS 1363 (all parts) or BS EN 60309-2, as appropriate.

17.3.2 Where differing distribution systems supplying socket-outlets are in use, the socket-outlets and plugs should be of such design that an incorrect connection cannot be made.

17.3.3 All 3-phase socket outlets should be of the same phase rotation.

17.3.4 Socket-outlets should not be installed below the floor of machinery spaces and in closed fuel and lubricating oil separator rooms.

17.3.5 In a space containing a fixed bath or shower, there should be no socket-outlets and there should be no provision for connecting a portable appliance except where it is a shaver supply unit conforming to BS EN 61558-2-5.

17.3.6 Socket-outlets for use with electric shavers should be incorporated in a shaver supply unit conforming to BS EN 61558-2-5 when installed in bathrooms or wash places. When installed in other locations they should:

a) be of a type specified in BS EN 61558-2-5;

b) be clearly marked with the words:

"For shavers only"; and

c) be provided with a suitable current-limiting device.

17.3.7 Every plug containing a fuse should be non-reversible and so designed and arranged that no fuse can be connected in an earthed conductor.

17.3.8 Where the supply is direct current, each socket-outlet should be controlled by a switch immediately adjacent thereto or combined therewith. Where the supply is alternating current and the plug is readily withdrawable such a switch need not be provided, except for sockets with a rated current in excess of 16 A, where the socket should be interlocked with a switch such that the plug cannot be inserted or withdrawn when the switch is in the "on" position.

18 Communication and navigation aids

18.1 General

18.1.1 The requirements of this section relate to:

a) equipment for radio communications as defined in Chapter IV of SOLAS [1];

b) equipment for navigation as defined in Chapter V of SOLAS [1];

c) telephone systems, loudspeaker systems and alarm system, as required by SOLAS [1];

d) other similar equipment fitted in addition to SOLAS requirements.

18.1.2 All communication and navigation aid systems should operate from the ship's main source of electrical power as described in Chapter II of SOLAS [1]. Additionally, the systems required to be carried by SOLAS [1] should be provided with access to the ship's emergency source of electrical power as described in Chapter II of SOLAS [1].

18.1.3 Radio communication systems required by SOLAS [1] should also have access to a reserve source of energy as described in Chapter IV of that Convention.

18.1.4 The main emergency and reserve sources of energy for the communication and navigation aids should be conditioned power supplies suitable for the bridge and deck zone as described in BS IEC 60533. The characteristics of these power sources are described in BS IEC 60092-101. Tests to ensure equipment operates satisfactorily under conditions of extreme power supply, excessive conditions, power supply short term variation, power supply failure and electromagnetic disturbances of conducted radio frequency disturbance, fast transients and slow transients are given in BS EN 60945.

18.1.5 Equipment required to be carried by SOLAS [1] should be type approved and comply with the performance standards published by the International Maritime Organization and the relevant IEC/ISO test standards. These are listed in the annexes to the European Commission Directive 96/98/EC on marine equipment [24].

18.1.6 All equipment should meet the EMC requirements as specified in Chapter V of SOLAS [1]. Test methods and limits are given in BS EN 60945. Guidance on electrical and electronic installations in ships to achieve successful operation in the shipboard electromagnetic environment is given in BS IEC 60533.

18.1.7 Requirements for safety precautions against access to dangerous voltages, electromagnetic radio frequency radiation and X-radiation are given in BS EN 60945.

18.1.8 Requirements for the maintenance of hardware and software are given in BS EN 60945.

18.1.9 Further guidance on the installation of radio communication systems and antenna systems is given in COMSAR/Circ.32 [25], published by the IMO.

19 Control and instrumentation

19.1 Environmental and supply conditions

19.1.1 Power supplies

a) All circuits providing emergency services should receive supplies from sources which are available under normal and emergency conditions.

b) In the event of failure of supply to the engine-room telegraph, indication should be given on the bridge.

c) Supplies to programmable electronic systems should be in accordance with **19.3**.

19.1.2 Electromagnetic compatibility

a) Each system should incorporate, as necessary, suitably screened equipment, earthing and arrangement of cabling to ensure that any induced interference between systems in no way impairs the proper effective operation of these systems at all times.

NOTE Precautions may have to be taken against multiple earthing.

b) Where systems are connected to a common source of supply they should be so arranged that no detrimental effects are induced on to the supply which could impair the operation of other apparatus connected on the supply.

c) Equipment should meet the requirements of BS 1597 and BS 7027. Further guidance on electromagnetic compatibility is given in Annex C and BS IEC 60533.

19.2 Computer based systems - safety applications

Computer systems which also provide safety functions (or in the event of their failure would have safety implications affecting the ship, its personnel or the environment) and which are not backed-up by non-computer based devices should be subjected to a comprehensive "failure mode and effects analysis". The results of this analysis are to be to the satisfaction of the appropriate authority.

NOTE To meet the desired availability the design configuration may require features such as redundancy and separation or diversity. Further guidance is available in HSE document, "Programmable Electronic Systems in Safety Related Systems" [26] (see Part 2, 5.6).

19.3 Power supplies

Where redundancy is required the following paragraphs should apply.

a) Power supplies to processors should be arranged to provide automatic transfer facilities from the normal to an alternative supply of suitable quality, e.g. smoothed and stabilized, when necessary.

b) Operation of transfer arrangements should not interrupt or interfere with the safe operation of the ship.

c) Attention should be given to:

- battery capacities;
- battery charging arrangements;
- inverter arrangements;
- system loading;
- system protection;
- earthing arrangements;
- output busbar arrangements of power distribution; and
- synchronizing arrangements to permit transfer of redundant or bypass systems.

20 Lightning protection

NOTE This clause supplements the provisions of BS IEC 60092-401.

20.1 Protective systems

Cables connecting to the shore Earth shall be external to the ship throughout their length.

20.2 Earth terminals

Earth plates of a material other than copper shall have a surface area sufficient to provide a path to Earth of resistance less than or equal to that of the permitted minimum size of copper earth plate.

21 Systems operating at above 1 kV a.c.

21.1 General

21.1.1 Lower voltage systems supplied from the high voltage system should have adequate precautions taken to prevent the lower voltage system being charged by leakage from the high voltage system. Such precautions could, for example, be an earthed screen between the H.V. and L.V. windings on transformers or the L.V. system having its neutral earthed at the transformer.

21.1.2 Access to high voltage equipment by unauthorized personnel is to be prevented, e.g. by the provision of locks and keys, warning notices, etc.

NOTE 1 All keys provided for access should be available only to authorized personnel.

NOTE 2 Only authorized personnel should carry out maintenance, repair and calibration of high voltage equipment and the "permit to work" system is recommended (see BS 6626).

21.2 High voltage tests

21.2.1 General

All equipment should be subjected to appropriate high voltage tests. The test levels recommended apply equally to equipment intended to operate with either earthed neutral or insulated systems.

21.2.2 Rotating machines

Tests of sample coils of machines with form wound stator coils shall be carried out to demonstrate the main and inter turn insulation meet the requirements for the essential stresses in service under normal operating conditions.

Random sample tests for inter turn insulation and main insulation, together with a routine test for all coils after insertion in the stator core, shall be carried out in accordance with BS EN 60034-15.

NOTE Tests for machines with vacuum-impregnated windings should be as agreed between the manufacturers and the purchaser.

21.3 Creepage and clearance distances

The minimum creepage and clearance distances provided for all connections, terminals and similar bare "live" parts should be in accordance with the British Standard listed in the appropriate clause of these recommendations for the apparatus concerned. In cases where the rated voltage is outside that given in the British Standard or where no British Standard is quoted, the minimum creepage and clearance distances given in Table 2 should be provided.

Table 2 **Creepage and clearance distances**

Nominal system voltage	Minimum clearance between phases and to earth mm	Minimum creepage between phases and to earth mm
1 100	25	25
2 400	40	40
3 300	50	50
4 160	60	70
6 600	65	90
11 000	80	125
13 800	85	140
15 000	95	150

21.4 Switchgear, control gear and fuse gear

Facilities should be provided to enable safe maintenance to be carried out in accordance with BS 6626, e.g. safety locks.

22 Dynamic positioning (DP)

22.1 General

The base documents defining the requirements for DP systems are the International Maritime Organization (IMO) Maritime Safety Committee Circular MSC/Circ. 645, "*Guidelines for Vessels with Dynamic Positioning Systems*" [27] and BS IEC 60092-504.

There are also International Marine Contractors Association guidelines for DP systems and several standards.

22.2 DP thrust systems

Information on thruster units for specific types of vessels can be found in IMCA document IMCA M 103 [28].

22.3 DP control system power supplies

Power supplies to the DP control system processors should be conform to **19.3** and BS IEC 60092-504:2001, 6.6 and 10.5.

NOTE Information on control systems related to specific ship types can be found in IMCA Document IMCA M 103 [28].

22.4 DP reference systems

Where hydro-acoustic position referencing systems are used details of their capabilities and the factors involved in optimizing their performance can be found in IMCA document IMCA M 151 [29].

22.5 Where DGPS systems are used for positioning, information on their operational performance can be found in IMCA document IMCA M 155 [30]. Information on MK IV Fanbeam® and CyScan marine laser positioning systems is given in IMCA M 170, Parts 1 and 2 [31].

22.6 DP computers

Information on the implementing of a system for quality assurance, quality control, auditing and change management of software can be found in IMCA document IMCA M 163 [32].

22.7 DP communications

Information on standards of DP communication for specific types of vessels can be found in IMCA document IMCA M 103 [28].

22.8 DP control stations

Information on position control for specific types of vessels can be found in IMCA document IMCA M 103 [28].

22.9 DP alarms

Information on thruster units and power generation, management and distribution for specific types of vessels can be found in IMCA document IMCA M 103 [28].

22.10 DP alert system

Detailed information on DP alert systems for specific types of vessels can be found in IMCA document IMCA M 103 [28].

22.11 Documentation

Recommendations for the contents of documentation can be found in IMCA document IMCA M 103 [28].

22.12 Training and competence

Recommendations for training of DP personnel can be found in IMCA documents IMCA M 103 [28] and M 117 [33].

22.13 Proximity to other vessels

IMCA Document IMCA M 161 [34] gives information on two-vessel operations for dynamically positioned vessels.

Annex A Guidance on the selection and use of socket-outlets and welding equipment

A.1 General

A.1.1 These notes give guidance on the choice of voltages and equipment for use with socket outlets and on electric shock hazard in the use of electric arc welding equipment.

A.1.2 Compliance of the electrical installation, irrespective of its situation, with the recommendations of **5.2** is assumed.

A.2 Voltages for use with a.c. hand held equipment (for welding purposes, see A.5)

A.2.1 Conditions vary to such an extent and are so difficult to define that precise rules governing the application of appropriate voltages for portable equipment in various locations are not practicable. Furthermore, the susceptibility of individuals to shock varies considerably. It is the purpose of this annex, however, to give guidance as to where particular voltages should be utilized.

A.2.2 In dry areas of the accommodation spaces where the risk is not abnormal, supplies as in BS IEC 60092-201:1994, Table 2(3), are satisfactory for cabin fans, vacuum cleaners, table lamps, etc. Additional safety, if considered necessary, can be obtained by using small local double wound isolating transformers in the manner provided for in BS IEC 60092-201:1994, Table 2[3b)].

A.2.3 For supplies to electric shavers see **17.3.6**.

A.2.4 For hand lamps 24 V is recommended.

A.2.5 In some circumstances a supply not exceeding 115 V, obtained from a transformer of which the mid-point of the secondary (115 V) winding is connected to earth, thus limiting the shock risk to earth to a maximum of 60 V, may be appropriate.

A.2.6 Handheld tools can be obtained for 50 V but current carrying difficulties can arise if lower voltages are chosen. If these supplies are derived from local isolating transformers limited to the supply of only one appliance, safety is further improved. Where a voltage of 50 V or less is not practicable, the alternatives given in BS IEC 60092-201:1994, Table 2(3), are acceptable. Adverse conditions occur, for example, due to water and spray on weather decks and low skin contact resistance as a result of humid conditions in tropical climates. These latter conditions can occur in any location, though they are less likely to arise in the accommodation spaces, and supplies for such appliances as handheld tools should therefore preferably not exceed 50 V.

A.2.7 Where supplies are provided under the terms of item BS IEC 60092-201:1994, Table 2[3b)], experience indicates that the loading of each isolated secondary circuit should be limited to 5 kVA and should supply only one socket outlet.

A.2.8 Under particular conditions any a.c. voltage, even as low as 50 V, can be fatal. Even lower voltages can cause injury due to being thrown off balance by a shock. Very adverse conditions occur where personnel and equipment can become damp while surrounded by conductive surfaces, particularly in restricted spaces and the use of lower voltage equipment is recommended in these circumstances. Where this is impracticable, the recommendations of **A.2.9** or **B.4.2.1** should additionally be followed.

A.2.9 For circuits having adequate earth return path (i.e. one point of the supply is connected to earth) the use of residual current devices (RCD) in addition to other precautions is recommended.

NOTE Reference is made to BS EN 61008-1 and BS EN 61009-1. Particular attention is drawn to the need to select an RCD (RCCB or BCBO) which is resistant to the marine environment, e.g. vibration, salt atmosphere, etc., or which is installed within an enclosure which provides the required degree of protection. Residual current operated circuit breakers of the type specified in BS EN 61008-1 and BS EN 61009-1were formerly known as "high sensitivity current operated earth leakage circuit-breakers" (ELCB).

A.3 Choice of handheld equipment (for welding purposes, see A.5)

Careful consideration should be given to the selection of handheld equipment to ensure that it is suitable for the conditions of use on board ship. Many devices that may be entirely suitable for use ashore may not be adequately designed and constructed to meet marine requirements, particularly temperature, salt laden atmosphere, etc. (see Clause **1**). Because of the risk of tracking across insulation, the use of Class I appliances in preference to Class II is recommended, unless the appliance is solely for use in dry areas of accommodation.

(Class I appliances are provided with facilities for earthing non-current carrying parts. Class II appliances have double insulation and/or reinforced insulation throughout and are without provision for earthing).

A.4 Voltages for use with a.c. portable and transportable equipment

A.4.1 The recommendation for handheld equipment in **A.2** should be followed as far as practicable.

A.4.2 It is recognized, however, that the limits of voltage given are not always practicable for equipment such as submersible pumps, deck scalers, refrigerated containers, etc. In these cases, where three phase supplies up to 500 V may be involved the additional precautions in a) and b) below or a combination are recommended.

a) Circuits which monitor the continuity of the earth connections and automatically disconnect the supply on loss of earth continuity. This arrangement will not, however, be effective when double insulated or all insulated equipment is used since such equipment has no provision for an earth connection.

NOTE Reference is made to BS 4444.

b) Each socket-outlet or group of socket-outlets supplied through an RCD. For this method to be effective the supply must be earthed at one point. In ships with unearthed systems double wound isolating transformers with one point of the secondary winding solidly earthed should be used. See also note to **A.2.9**.

A.5 Electric shock hazard in the use of electric arc welding equipment

A.5.1 The risk from electric shock in the use of electric arc welding equipment in certain special locations, for example, as described in **A.2.8**, is not always appreciated.

A.5.2 Since the effect of shock from direct current is less (at the operating voltages used) than with alternating current, the use of welding sets having a d.c. output, especially those incorporating d.c. generators providing an open circuit (idling) voltage of 70 V or less, is recommended. Direct current obtained from rectified alternating current may, however, contain a degree of a.c. ripple which is excessive and would greatly reduce the advantage provided by pure direct current, in which case it is recommended that the idling voltage be limited to 42 V by provision of voltage reduction safety devices.

A.5.3 Voltage reduction safety devices which limit the "idling" voltage to 25 V or less are also available for use with alternating current electric arc welding plant.

A.5.4 These safety devices are intended to ensure that the idling voltage only is applied until there is contact between the electrode and the "work" when the full open circuit voltage becomes available to strike the arc. Once struck, welding continues in the normal way at the voltage necessary to maintain the arc (normally 25-30 V) until the arc is broken.

A.5.5 Electrode holders should be of the fully insulated type.

A.5.6 When joints in the cables are necessary, the connectors should also be fully insulated and should be designed and used so that live parts are not exposed when disconnected. A "go and return" system where two cables are used from the welding set with one cable solidly clamped to the work piece is recommended in all cases.

A.5.7 Means should be available whereby the current can rapidly be cut off from the electrode holder should the operator get into difficulties. Means of disconnection should be available to the welder for use when changing electrodes.

Annex B Guidance on the treatment of the neutral point

Table B.1 Summary of principal features of the neutral earthing methods

Means of earthing	High reactance "Petersen"	Not intentionally earthed systems "Unearthed" "Isolated"	High resistance	Low reactance	Low resistance	Solid connection
	INTENTIONALLY EARTHED NEUTRAL SYSTEMS (High reactance, High resistance, Low reactance, Low resistance, Solid connection)					
System voltage	All methods are potentially applicable (but note higher voltage systems are likely to have higher VA earth fault levels which may make solid or low impedance methods unattractive)					
Overvoltages	The most significant overvoltages are due to causes not influenced by the method of neutral earthing					
Electric shock risk	All major installations are potentially lethal whatever method of neutral earthing is used					
Use of RCD for electrical safety	◄— See Note 1 of **B.3.2.2** —►					Acceptable
Use of 3-phase 4-wire supply	◄— Not acceptable —►					Acceptable
Earth fault current magnitude	Theoretically may be zero	Depends on system capacitance but usually very low, say 1A	Usually less than 20 A; can approach unearthed value	◄— Typically 200 - 400 A —►		May be up to 50% greater than symmetrical 3-phase value
Sustained operation with earth fault	Possible	Normally possible	May be possible but not advisable	◄— Not possible —►		

(Continued)

Table B.1 **Summary of principal features of the neutral earthing methods** *(Continued)*

	INTENTIONALLY EARTHED NEUTRAL SYSTEMS					
Means of earthing	High reactance "Petersen"	Not intentionally earthed systems "Unearthed" "Isolated"	High resistance	Low reactance	Low resistance	Solid connection
Minimum earth fault protection required	Alarm or indication	Alarm or indication	From alarm/ indication to earth fault relay	From earth fault relay to overcurrent protection		Overcurrent protection
Switchgear fault rating	← Can be rated on normal phase-to-phase or 3-phase symmetrical fault value →					May have to be rated on single phase-to-earth, or phase-to-phase-to-earth value
Earth fault location	Faults not self-revealing and must normally be located manually unless core balance CTs are fitted		If relays fitted, faults self-revealing; otherwise must be located manually	Faults self revealing by overcurrent or relay operation		Faults are self-revealing on overcurrent
Fire risk	Negligible	Very low provided that earth fault current does not exceed 1 A; prolonged fault may present a hazard		Risk of arc igniting flammable gases; high impedance faults can lead to burning at fault location		
Flash hazard (phase-to-earth)	Low ——— Increasing ——— High					
Availability of suitable equipment	← Similar generation and distribution equipment is applicable on all systems →					Allows use of land-based lighting and hotel services equipment

NOTE Within the range of possible neutral earthing impedance magnitudes the "Not Intentionally Earthed" values are not the highest.

B.1 Introduction

B.1.1 Whether or not to intentionally earth the neutral point in marine electrical power systems has been subject to debate ever since a.c. generation and distribution systems were introduced into ships. The continuing debate suggests that there is no single "best" method; therefore, guidance would be helpful to designers in selecting a method for a particular application.

B.1.2 Although an extensive literature exists on the subject of treating the neutral point ("neutral earthing"), little of it deals specifically with marine installations, and the material that is available reflects the range of views upon which systems are most suitable for given applications.

B.2 Methods of treating the neutral point in electrical systems

B.2.1 The neutral point

The neutral point of a healthy balanced, steady state three phase voltage system is defined as the geometric centre of the equilateral voltage vector triangle. In star connected machinery the neutral can be made physically available (for the supply of single phase loads for instance), but in systems with delta connected supplies the neutral point is an artefact and can only be made available by the use of a star connected earthing device.

B.2.2 The neutral point under fault conditions

Under fault conditions the equilateral voltage vector triangle becomes distorted and transient asymmetrical voltages arise. For given types of fault on a system the transient voltages and fault currents are influenced by:

- the impedance between the neutral point and earth; and
- the characteristics of the system in question,

and these are considered below.

B.2.3 Neutral earthing methods

B.2.3.1 On occurrence of a fault from line to earth, the steady state and transient voltages to earth and fault currents vary with the impedance between the neutral point and earth. This impedance is dependent on the treatment of the neutral point and the following methods of intentionally earthing the neutral are available:

- high reactance (also referred to as "Petersen" or "resonant");
- high resistance;
- low reactance;
- low resistance;
- solid connection.

B.2.3.2 Although not intentionally connected to earth, the so-called "unearthed" or "isolated" system is in fact capacitively earthed by the distributed capacitance to earth of the phase conductors throughout the system, together with any interference suppression capacitors.

B.2.3.3 The principal features of these methods are presented in Table B.1.

B.2.4 Marine electrical systems

B.2.4.1 Marine electrical systems have a number of significant characteristics which differentiate them from typical land-based systems. These need to be borne in mind when considering neutral earthing of marine systems.

B.2.4.2 The zero and positive sequence impedance of a.c. generators, which are the usual sources of power, are such that line to neutral fault current can significantly exceed the symmetrical three phase fault value. This is of importance to the rating of switchgear and to potential damage to the core of a generator following an internal fault.

B.2.4.3 The interconnection of the neutral points of generators, particularly those of different sizes or different winding configurations, or even identical generators with different loadings, can give rise to undesirable circulating harmonic currents, especially third harmonic currents.

B.2.4.4 Distribution circuits are geographically compact and distribution is by cable. The proximity of the cables to the hull structure and also of machine windings to earthed stator cores unavoidably gives rise to significant phase to earth capacitance. Typical values lie in the range 1 to 5 mF per phase and this can increase appreciably if interference suppression capacitors are used extensively.

B.2.4.5 Fault power factors are low with the result that the ratio of peak asymmetrical current to r.m.s. symmetrical current is high and tends to the maximum ratio of $2\sqrt{2}:1$.

B.2.4.6 System natural resonant frequences are high, typically 5-10 kHz. At these frequencies, the oscillatory circuit is usually over damped with the result that oscillatory overvoltages are unlikely to occur.

B.2.4.7 Earth return impedances are low due to the metal structure.

B.2.4.8 The wet, salty, high vibration level operating environment is harsh and may cause earth faults to occur, particularly in exposed electrical fittings.

B.2.4.9 Because comprehensive spares may not be carried on board and maintenance personnel may not be sufficiently specialized, the diagnosis of faults and their subsequent repair may not be undertaken until return to port.

B.3 Selection of neutral earthing method

B.3.1 General

B.3.1.1 In view of the wide variety of types and sizes of ships and their associated electrical installations there is no single “best” method for treating the neutral point in marine electrical power systems. Good, safe, correctly engineered installations can be achieved in a number of ways and so each application should be considered and designed on its merits.

B.3.1.2 In order to select a method for a given application, a careful assessment should be made of the relative importance of all technical, operational and commercial factors (see Table B.1). Subjective judgements are mostly unavoidable, but the following considerations should be appreciated when making this assessment:

a) factors not significant to selection of neutral earthing method;

b) factors significant to selection of neutral earthing method;

c) applicability of neutral earthing methods to marine electrical systems.

B.3.2 Factors not significant

B.3.2.1 Although important in their own right, certain factors apply equally however the neutral point is treated and so can be discounted when selecting between methods.

B.3.2.2 ***Electric shock — phase to earth.***

The treatment of the neutral point of the electrical power system has no significant effect on shock risk to personnel. This is because the human tolerance to shock currents is so low that any method of earthing the neutral has the possibility of allowing a potentially lethal current to flow. Even the line to earth capacitive current in unearthed distribution power systems could permit a dangerous current to flow.

NOTE 1 On sub-circuits having a nominal voltage not greater than 660 V, protection against harmful phase to earth shocks can be achieved by means either of the following means:

a) overcurrent protective device;

b) a residual current protective device.

Alternatively, after risk assessment, a solidly earthed sub-system can be created using a transformer with earthed secondary windings and utilizing RCDs on the secondary side of the transformer. This RCD should be of high sensitivity having a residual operating current not exceeding 30mA and an operating time not exceeding 40 ms at a residual current of $5 \times I_{\Delta}n$.

NOTE 2 On sub-circuits having a nominal voltage not greater than 240 V, protection against harmful phase to earth shocks may be achieved by means of isolating transformers.

NOTE 3 Further guidance for protection against electric shock is given in Annex A.

B.3.2.3 Overvoltages

The largest and, therefore, most significant overvoltages on marine systems are produced by switching surges, which are independent of the method of treatment of the neutral.

*NOTE The significant system overvoltage that is influenced by the method of system neutral earthing is that caused by the "intermittent earth fault". This can occur on unearthed neutral systems if the arc associated with an earth fault extinguishes and restrikes producing overvoltages at the natural frequency of the system. In marine systems, typical natural frequencies are several kilohertz and system losses are such that these frequencies are normally over damped; hence the associated overvoltages do not occur. Guidance on calculating whether damping in a system is critical is given in **B.5**.*

B.3.2.4 System voltage

System voltage itself is not a determining factor in selecting a neutral earthing method. Satisfactory installations of all types can be engineered at all voltages given in Clause **21**.

B.3.3 Significant factors

B.3.3.1 Earth faults

a) Improvements generally to insulating systems and standards make earth faults less likely to occur, but they are still the most common fault.

b) The majority of earth faults occur in miscellaneous electrical equipment away from the principal power production and distribution systems (e.g. in luminaires, galley, deck fittings, etc.) rather than in switchboards or important motors. There are, therefore, advantages in isolating such equipment or arranging for the faults to be self clearing.

c) In three phase circuits, single phase to earth faults are likely to escalate into phase to phase faults unless steps are taken to reduce this possibility (e.g. by use of phase segregation barriers). This is particularly so for low impedance neutral earthing methods.

d) The occurrence of a solid earth fault on a high impedance or unearthed neutral system will increase the phase to earth voltage stress on the two healthy phases for the duration of the fault. This power frequency overvoltage will not damage equipment in the short term; however, manufacturers have different definitions of the length of time for which this can be tolerated.

B.3.3.2 Continuity of supply

Continuity of supply following a single earth fault is an important argument in favour of the unearthed and high impedance methods, but for it to be a valid one, the earth fault must be such that it would have caused the loss of supply to an essential service.

This requires that:

- the earth fault must occur in the essential service itself or in its associated distribution or control circuits;
- the electrical system must be earth fault free at the time the earth fault occurs on the essential service;
- the earth fault does not escalate into a phase to phase fault which causes the loss of the essential service anyway;
- the essential service is not backed up in some other reliable way, e.g. standby supply or unit.

B.3.3.3 Switchgear rating

The most onerous duty for switchgear in a marine system is dependent upon machine and distribution parameters and will normally be a phase to phase or three phase symmetrical fault. However, with the low impedance neutral earthing methods, the phase-to-earth or phase-to-phase-to-earth fault current can exceed the three phase fault current and so can become the specifying parameter for the switchgear.

B.3.3.4 Availability of suitable electrical equipment

The availability of suitable electrical equipment is not a significant factor for generation and primary distribution equipment because the equipment is similar for both earthed and unearthed systems. However at sub-circuit level unearthed systems require special fittings (e.g. two pole switches, non standard voltages etc.). Many commercial fittings designed for use ashore on solid earthed neutral systems are available but are only single pole devices. This must favour the use of 380 V or 415 V three phase 4 wire systems for lighting and hotel services.

B.3.3.5 Fault location

a) In solidly earthed neutral systems, faults are self clearing either by fuse or circuit-breaker action.

b) In high impedance systems fault location is either:

- expensive, if special fault locating equipment is fitted, or
- laborious and time consuming if the fault is traced by successive isolation of suspect circuits.

In the long term this fault-finding procedure can be more disruptive to the power system than that associated with automatic fault isolation systems, because the total power availability may be reduced.

B.3.3.6 Fire risk

a) Fire risk arises in two ways:

   i) burning at the point of fault, and

   ii) ignition of flammable materials or gases by a fault arc.

b) The risk of burning depends upon the magnitude and duration of the fault current and is, therefore, higher in the solid or low impedance neutral earthed systems, unless earth fault protection is specifically provided by some more sensitive means than overcurrent protection. The ignition hazard is potentially serious in tankers, etc., and every effort should be made to minimize prospective current flow through hazardous areas.

B.3.3.7 Flash hazard

A flash hazard arises when a fault occurs in close proximity to individuals. For interphase faults the hazard is the same for all types of neutral earthing. For single phase to earth faults the hazard is greatest with solid neutral earthing and reduces with increasing neutral earthing impedance.

B.3.4 Applicability to marine electrical systems

B.3.4.1 Unearthed neutral systems

a) Unearthed neutral systems are acceptable for generation and distribution systems of any size. The principal advantages are:

- an earth fault can occur on an essential service without causing loss of supply to that service;
- the otherwise adverse effects of the low zero sequence impedance of the generators on the fault capacity of the switchgear is avoided;
- there is no need for any neutral connection, thus neutral switching and circulating currents are avoided;
- earth fault protection costs are low;
- fire and flash hazards are low;
- small, isolated, unearthed low voltage sub-systems can be inherently safe since the potential earth fault current can be restricted to less than the lethal level.

b) The principal disadvantage is that fault location is a time consuming, tedious manual task, but one which should be carried out quickly to avoid jeopardizing the integrity of supply to essential services should a second fault occur. For this reason it is preferable not to use unearthed supplies for loads prone to earth faults.

B.3.4.2 High reactance earthed neutral systems

The high reactance "Petersen" method is rarely worth considering unless:

- the system capacitive currents are high (e.g. where large numbers of interference suppression capacitors are used);
- there is a paramount need to limit the earth fault current.

B.3.4.3 High resistance earthed neutral systems

a) The high resistance earthed approach is often advocated to control overvoltages, but this is not usually relevant in marine systems.

NOTE Under solid earth fault conditions, a 4 wire system supplying single phase loads can develop significant phase to neutral power frequency overvoltages which could be hazardous.

b) It is possible to limit the earth fault current to a level that allows continued operations with a single fault on the system but the resulting fault current, and hence fire risk, is of necessity larger that it would otherwise have been with the system operated unearthed. The method does allow earth fault relays to be used.

B.3.4.4 Low resistance or low reactance earthed neutral systems

It is only worthwhile considering these low impedance methods if it is desired to obtain the benefits of the solidly earthed approach but the resulting earth fault current would be too high. Low reactance is preferable to low resistance because it is cheaper for a given rating and will offer greater impedance to third harmonic circulating currents, while giving minimum volt drop at fundamental frequency.

B.3.4.5 Solidly earthed neutral systems

a) The solidly earthed system is especially useful for supplying sub-circuits prone to earth faults.

b) At low voltage, 4 wire solidly earthed systems have the advantage of better economy and automatic fault location for the supply of single phase loads.

c) In large systems where power is generated at a high voltage, transformers are automatically required. This creates the opportunity to use 4 wire solidly earthed sub-systems.

d) In ships in which generation can satisfactorily be carried out at 380 V or 415 V, three phase 4 wire solidly earthed systems can also be used thus enabling control and lighting to be supplied without special transformers. For this to be acceptable, the continuity of supply argument needs specific attention together with the effects of parallel generators and third harmonic currents.

NOTE To ensure that they do not fail to danger, control circuits should be solidly earthed in one pole and fused in the second pole (PD 5304).

B.4 Good practice for the selected neutral earthing method

B.4.1 General

B.4.1.1 The treatment of the neutral of a particular installation will depend on the relative importance of the factors discussed in this annex.

B.4.1.2 Where different voltage levels or different types of service are involved, the neutral treatment should be dealt with for each part regardless of the other parts.

B.4.1.3 Once a particular method of neutral earthing has been selected for all or part of a system, attention should be given to the topics listed under the respective method.

B.4.2 Unearthed neutral systems

B.4.2.1 To avoid jeopardizing the main power system through sub-circuit earth faults, consider the use of localized earthed systems for supplying lighting and hotel services.

B.4.2.2 At the design stage, consider what actions can be taken to ease the fault location process by for example:

- adequate cable spacing may facilitate the use of fault locating equipment;
- provision of a "fault making switch" which could be used at a convenient time to temporarily connect the system neutral to earth and thus cause the faulty circuit to be self revealing by operation of its overcurrent protection.

NOTE It may be necessary to use a suitable impedance in series with the switch to limit the earth fault current to the phase to phase or three phase symmetrical value.

B.4.2.3 Estimate the system capacitance fault current at the design stage and then measure it to ensure that the fire hazard is not unacceptable.

B.4.2.4 Assess the benefits offered by phase segregation barriers to reduce the likelihood of earth faults becoming phase faults.

B.4.2.5 Fit double pole switches.

B.4.2.6 Alert the operating staff to the need to remove earth faults as quickly as possibly by specifying that a warning notice should be installed adjacent to the earth fault indication lamps.

B.4.3 Earthed neutral systems

B.4.3.1 General

a) Avoid use of neutral switching arrangements by connecting each generator to earth.

b) Where earth fault relays are used, carry out primary and secondary injection tests and record results for comparison with results taken subsequently.

B.4.3.2 Solidly earthed neutral

a) If generator neutrals are solidly connected, special attention should be paid to circulating harmonic currents.

b) Discrimination should be achieved under earth fault conditions.

c) The switchgear rating should be adequate for the earth fault current duty.

d) Phase to neutral supplies should be switched in the live pole.

e) Single phase loads should be balanced between the phases as far as possible.

f) As far as is practicable, single phase socket-outlets from different phases should not be installed within a single compartment.

g) Inspections should be carried out regularly to check the integrity of the neutral earth connection to the ships structure.

B.5 Calculation for damping of oscillatory overvoltages

B.5.1 Basis

The interconnected generators, motors and cables have distributed inductances and capacitances which combine to form a resonant circuit. Oscillations which occur in this circuit are damped out by the various losses that occur in cables, machine windings, damper bars, etc. If the damping is sufficient, overvoltages cannot build up.

B.5.2 Procedure

B.5.2.1 For each combination of generators, motors, cable lengths, etc., produce an equivalent R-L-C circuit and calculate its natural frequency, $f_{o,}$ by the following formula:

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

NOTE When one phase is faulted to earth, the distributed phase to earth capacitance of that phase is short-circuited, hence producing a modified equivalent circuit. Thus, there are two frequencies for each circuit combination, one for when the fault is made and one for when it is broken.

B.5.2.2 Establish the sources of loss in the circuit and convert to an equivalent resistance "Re" as follows, noting that the losses must be obtained at the natural frequency of the system:

- for cables, use manufacturers' data on effective resistance per unit length at the frequency concerned;
- for machine and transformer winding losses, use the eddy losses at rated current;
- for machine and transformer iron losses, calculate the losses at the appropriate frequency assuming rated volts.

B.5.2.3 Check for damping

a) If R_e is greater than twice $\sqrt{L/C}$, the circuit is critically damped and resonant oscillations cannot be sustained.

b) If R_e is smaller than twice $\sqrt{L/C}$, damped oscillations will occur. However, if the time constant of the decay of these oscillations ($t = L/R_e$) is small compared to the period of restriking of the arcing fault (i.e. mains frequency), overvoltages cannot build up.

Annex C Guidance on electromagnetic compatibility

C.1 Introduction

The developing use of electric/electronic equipment of all types has greatly increased the likelihood of electromagnetic interference between one device and another. Where certain classes of equipment are involved, safety could be affected.

It is essential therefore, for steps to be taken in the design and construction, ideally at the drawing board stage, to ensure that an overall electromagnetically compatible installation will be achieved.

Note has to be taken therefore of the possible susceptibility to interference of each piece of electrical equipment and its own propensity for causing interference. The maximum degree of electric coupling that can be permitted between the various units, interconnecting cables, etc., has to be estimated to ensure that an acceptable electromagnetic environment can be achieved.

BS IEC 60533:1999, Annex B, gives a methodology to enable adequate consideration of EMC matters in the planning, construction and operation stages to be reached.

C.2 Types of interference

Interference energy may be propagated from its source to the affected equipment by one or both of the following:

a) conducted interference, i.e. by conduction along power supply and/or other cables connecting the source to the apparatus;

b) radiated interference, i.e. by direct radiation from the source and its immediate associated cabling into the affected apparatus and its immediate associated wiring.

C.3 Modes of interference propagation and coupling to interference sources

C.3.1 Conducted interference

Two modes of propagation are possible for conducted interference.

a) Symmetric or Differential mode, in which the interference energy is propagated between the "go" and the "return" lines of the connecting cable.

b) Asymmetric or Common mode, in which the interference energy is propagated between one or both of the "go" and "return" lines and earth. In practice this mode is the more significant because the area of the magnetic loop so formed is much greater than that formed in the Symmetric mode.

C.3.2 Types of mutual coupling

Coupling between circuits may be inductive, capacitive or resistive or a combination of these.

a) Inductive coupling — this is the predominant coupling mode in high current, low frequency installations.

b) Capacitive coupling — this is the predominant coupling mode in low current, high impedance installations. Capacitive coupling is particularly important at high frequencies due to the low effective value of capacitive coupling impedances.

c) Resistive coupling — this coupling exists between equipments which share a common resistive path.

C.3.3 Coupling effects of earth currents

Interference can be coupled into cables near a nominal earth plane if the latter carries significant localized interference currents. Such situations need to be avoided in installations where the structure/hull and superstructure, handrails, stays, etc, may effectively form part of the earth return system. Possible causes which need to be considered include:

- cathodic protection systems,
- earth leakage current from high voltage systems,
- earth current from capacitors used for interference suppression,
- power-factor correction,
- RF currents due to the structure/hull acting as a return path for the radio transmitting system,
- the structure/hull acting as a receiving antenna for externally radiated fields, and
- use of arc welding equipment.

C.4 Installation practice designed to reduce interference transmission and pick-up

BS IEC 60533:1999, Annex C, contains guidelines and recommendations for organizational and technical measures to achieve electromagnetic compatibility in ships' equipment.

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BS EN 60034-1, *Rotating electrical machines — Part 1: Rating and performance.*

BS EN 60079-17, *Electrical apparatus for explosive gas atmospheres — Part 17: Inspection and maintenance of electrical installations in hazardous areas (other than mines).*

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