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Mobile and fixed offshore units –
Electrical installations –

Part 2:
System design

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

MOBILE AND FIXED OFFSHORE UNITS – ELECTRICAL INSTALLATIONS –

Part 2: System design

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 61892-2 has been prepared by IEC technical committee 18: Electrical installations of ships and of mobile and fixed offshore units.

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

FDIS	Report on voting
18/965/FDIS	18/995/RVD

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

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

IEC 61892 consists of the following parts, under the general title: *Mobile and fixed offshore units – Electrical installations:*

Part 1: General requirements and conditions

Part 2: System design

Part 3: Equipment

Part 4: Cables[1)]

Part 5: Mobile units

Part 6: Installation

Part 7: Hazardous areas

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

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- withdrawn;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

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

[1)] Under consideration. Before IEC 61892-4 is published, reference is made to the IEC 60092-35X series.

INTRODUCTION

IEC 61892 forms a series of International Standards intended to enable safety in the design, selection, installation, maintenance and use of electrical equipment for the generation, storage, distribution and utilisation of electrical energy for all purposes in offshore units, which are being used for the purpose of exploration or exploitation of petroleum resources.

This part of IEC 61892 also incorporates and co-ordinates, as far as possible, existing rules and forms a code of interpretation, where applicable, of the requirements of the International Maritime Organisation, a guide for future regulations which may be prepared and a statement of practice for offshore unit owners, constructors and appropriate organisations.

This standard is based on equipment and practices, which are in current use, but it is not intended in any way to impede development of new or improved techniques.

The ultimate aim has been to produce a set of International standards exclusively for the offshore petroleum industry.

MOBILE AND FIXED OFFSHORE UNITS – ELECTRICAL INSTALLATIONS –

Part 2: System design

1 Scope

This part of IEC 61892 contains provisions for system design of electrical installations in mobile and fixed units used in the offshore petroleum industry for drilling, production, processing and for storage purposes, including pipeline, pumping or 'pigging' stations, compressor stations and exposed location single buoy moorings.

It applies to all installations, whether permanent, temporary, transportable or hand-held, to a.c. installations up to and including 35 000 V and d.c. installations up to and including 750 V.(a.c. and d.c. voltages are nominal values)

This standard does not apply either to fixed equipment used for medical purposes or to the electrical installations of tankers.

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.

IEC 60038:2002, *IEC standard voltages*

IEC 60092-101:2002, *Electrical installations in ships – Part 101: Definitions and general requirements*

IEC 60092-504:2001, *Electrical installations in ships – Part 504: Special features – Control and instrumentation*

IEC 60447, *Basic and safety principles for man-machine interface, marking and identification – Actuating principles*

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

IEC 60617-DB:2001[2)] *Graphical symbols for diagrams – Architectural and topographical installation plans and diagrams*

IEC 60947-2:2003, *Low voltage switchgear and controlgear – Part 2: Circuit-breakers*

IEC 61000-2-4, *Electromagnetic compatibility (EMC) – Part 2-4: Environment – Compatibility levels in industrial plants for low-frequency conducted disturbances*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

2) "DB" refers to the on-line IEC database.

IEC 61511, (all parts), *Functional safety – Safety instrumented systems for the process industry sector*

IEC 61892-1:2001, *Mobile and fixed offshore units – Electrical installations – Part 1: General requirements and conditions*

IEC 61892-3, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment*

IEC 61892-5:2000, *Mobile and fixed offshore units – Electrical installations – Part 5: Mobile units*

IEC 61892-7:1997, *Mobile and fixed offshore units – Electrical installations – Part 7: Hazardous areas*

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

SOLAS, *International Convention for the Safety of Life at Sea*

IMO MODU Code:1990, *Code for the Construction and Equipment of Mobile Offshore Drilling Units,*

3 Terms and definitions

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

NOTE The definitions included in this part are those having general application in the IEC 61892 series. Definitions applying to particular apparatus or equipment are included in the other parts of IEC 61892.

3.1
a.c. systems of distribution

3.1.1
single-phase two-wire a.c. system
system comprising two conductors only, between which the load is connected

NOTE In some countries this is designated as a two-phase system

3.1.2
three-phase three-wire a.c. system
system comprising three conductors connected to a three-phase supply

3.1.3
three-phase four-wire a.c. system
system comprising four conductors of which three are connected to a three-phase supply and the fourth to a neutral point in the source of supply

3.2
appropriate authority
governmental body with whose rules a unit is required to comply

3.3
availability
the state of an item of being able to perform its required function
[IEV 603-05-04]

3.4
back-up protection[3)]
equipment or system which is intended to operate when a system fault is not cleared in due time because of:

– failure or inability of a protective device closest to the fault to operate, or

– failure of a protective device, other than the protective device closest to the fault, to operate

3.5
centralized control
control of all operations of a controlled system from one central control position

3.6
computer-based system
system that consists of one or more programmable electronic devices with their connections, peripherals and software necessary to carry out automatically specified functions

3.7
continuity of service [3)]
condition. that after a fault in a circuit has been cleared, the supply to the healthy circuits is re-established

NOTE See circuit 3 in Figure 1.

3.8
continuity of supply
condition that during and after a fault in a circuit, the supply to the healthy circuits is permanently ensured

NOTE See circuit 3 in Figure 1.

3.9
control functions
functions intended to regulate the behaviour of equipment or systems

3.10
control position (control station)
group of control devices by which an operator can control the performance of a machine, apparatus, process or assembly of machines and apparatus

3.11
d.c. systems of distribution

3.11.1
two-wire d.c. system
system comprising two conductors only, between which the load is connected

3.11.2
three-wire d.c. system
system comprising two conductors and a middle wire, the supply being taken from the two outer conductors or from the middle wire and either outer conductor, the middle wire carrying only the difference-current

3.12
diversity factor (demand factor)
ratio of the estimated total load of a group of consumers under their normal working conditions to the sum of their nominal ratings

[3)] The International Electrotechnical Vocabulary (IEV) definition for this term is not applicable for this standard.

3.13
fail-to-safe
principle by which a failure or malfunction of a component of the system causes its output to automatically adjust to a predetermined safe state

[IEV 191-15-04 modified]

3.14
function
elementary operation performed by the system which, in conjunction with other elementary operations (system functions), enables the system to perform a task

3.15
high voltage
the set of voltage levels in excess of low voltage

[IEV 601-01-27 modified]

3.16
hull-return system
system in which insulated conductors are provided for connection to one pole or phase of the supply, the structure of the unit or other permanently earthed structure being used for effecting connections to the other pole or phase

3.17
integrity
capability of a system to satisfactorily perform the required functions under all the stated conditions within a stated period of time

[IEV 191-19-07 modified]

3.18
low voltage
a set of voltage levels used for the distribution of electricity and whose upper limit is generally accepted to be 1 000 V a.c.

[IEV 601-01-26]

3.19
machinery control room
room or spaces where centralized controls and measuring and monitoring equipment for main equipment and essential auxiliary machinery are located together with the appropriate means of communication

3.20
maintainability
ability of an item under given condition of use, to be retained in, or restored to, a state in which it can perform a required function, when maintenance is performed under given conditions and using stated procedures and resources

[IEV 191-02-07]

3.21
monitoring functions
functions intended to collect data from equipment and systems for the purpose of display and recording

3.22
over-current
a current exceeding the rated current

[IEV 441-11-06]

3.23
over-current discrimination
co-ordination of the operating characteristics of two or more over current protective devices such that, on the incidence of over-currents within stated limits, the device intended to operate within these limits does so, while the other(s) does (do) not

[IEV 441-17-15]

3.24
overload
operating conditions in an electrically undamaged circuit, which cause an over-current

[IEV 441-11-08]

3.25
partial discrimination (partial selectivity)[4)]
over-current discrimination where, in the presence of two or more over-current protective devices in series, the protective device closest to the fault effects the protection up to a given level of short-circuit current without causing the other protective devices to operate

3.26
primary distribution system
system having electrical connection with the main source of electrical power

3.27
rated load
highest value of load specified for rated conditions

3.28
reliability
the probability that an item can perform a required function under given conditions for a given time interval

[IEV 191-12-01]

3.29
safety functions
functions intended to prevent harm or danger to personnel

3.30
secondary distribution system
system having no electrical connection with the main source of electrical power, e.g. isolated therefrom by a double-wound transformer or motor-generator

3.31
short-circuit
accidental or intentional conductive path between two or more conductive parts forcing the electric potential difference between these conductive parts to be equal to or close to zero

[IEV 195-04-11]

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4) The International Electrotechnical Vocabulary (IEV) definition for this term is not applicable for this standard.

3.32
software
program, procedures and associated documentation pertaining to the operation of a computer system and including application (user) program, middleware and operating system (firmware) program

3.33
sources of electrical power

3.32.1
emergency source of electrical power
source of electrical power intended to supply the emergency system in the event of failure of the supply from the main source of electrical power

3.32.2
main source of electrical power
source of electrical power intended to supply all services necessary for maintaining the unit in normal operational and habitable condition

3.34
system
collection of components organised to accomplish a specific function or set of functions

3.35
total discrimination (total selectivity)[5)]
over-current discrimination where, in the presence of two or more over-current protective devices in series, the protective device on the load side effects the protection without causing the other protective devices to operate

3.36
usability
extent to which a system can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use

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5) The International Electrotechnical Vocabulary (IEV) definition for this term is not applicable for this standard.

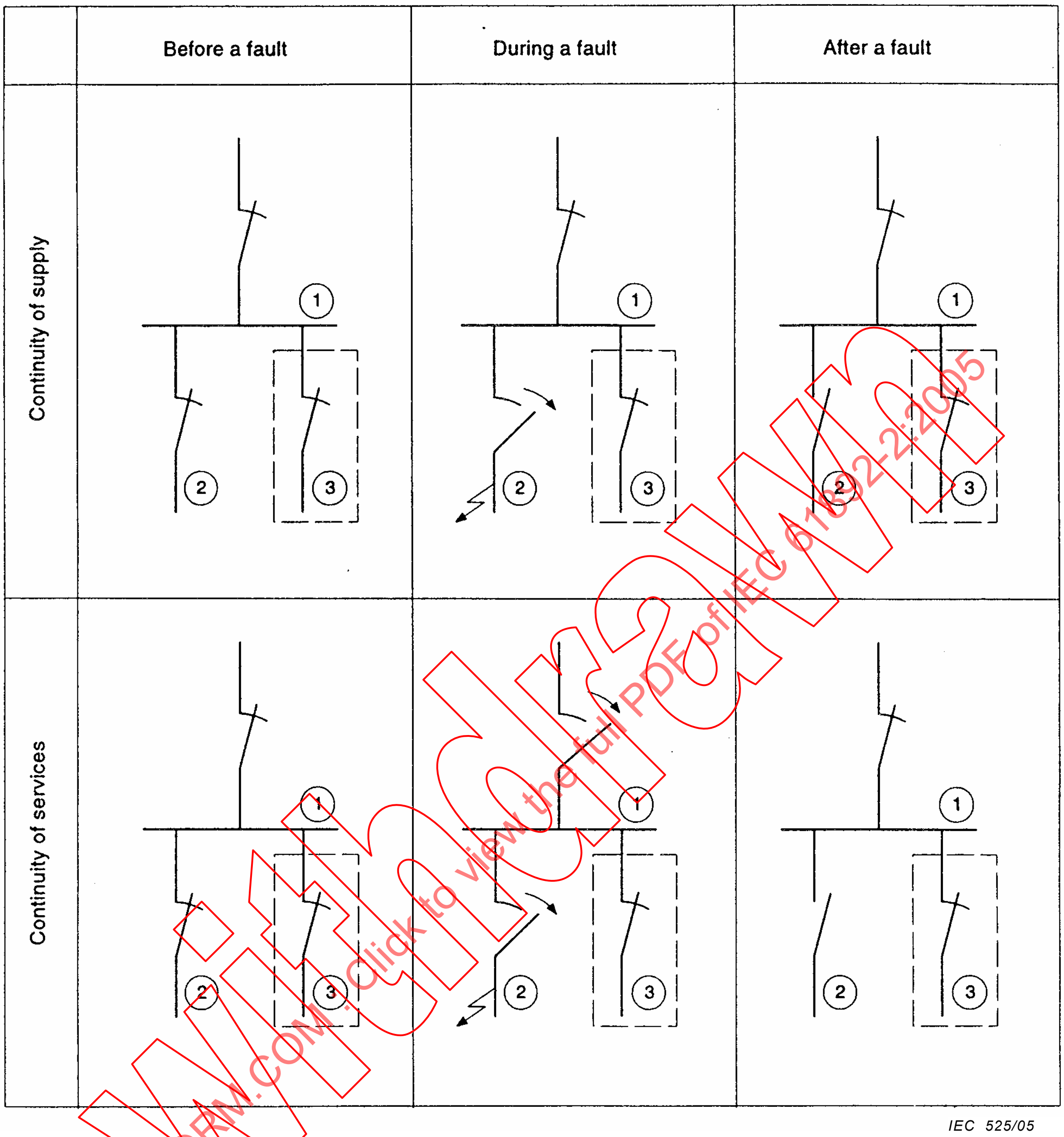


Figure 1 – Continuity of supply/continuity of service

4 Sources of electrical power

4.1 General

Electrical installations shall be such that:

4.1.1 All electrical services necessary for maintaining the unit in normal operational and habitable condition shall be assured without recourse to the emergency source of electrical power.

4.1.2 Electrical services essential for safety shall be assured also under various emergency conditions.

4.1.3 When a.c. generators are involved, the design basis of the system shall include the effect of inrush current of e.g. large motors, transformers, capacitors and chokes, connected to the system. The voltage drop due to such current shall not cause any motor already operating to stall or to have any adverse effect on other equipment in use.

NOTE Consideration regarding harmonic distortions should be given to installations with a high load from power semiconductor systems.

4.1.4 The voltage profile of the system shall be confirmed by studies as defined in Clause 9. Voltage tolerances are given in IEC 61892-1. The total voltage drop between generators or transformers and load shall not exceed the following values:

AC systems:	– normal continuous load	6 %
	– motor starting	20 %
DC systems:		10 %

NOTE 1 The voltage drop should be calculated from the distribution board where regulating facilities are included, that is, supplied by a transformer with tappings or a generator.

NOTE 2 Voltage drop calculations should take account of the power factor of the load. Where this is not known, a value of 0,85 for normal a.c. loads and 0,3 for motor starting conditions is recommended.

NOTE 3 Where specific loads require closer tolerances for voltages in order to maintain functionality or performance, then specific calculations should be made to confirm values of voltage drop, particularly in cables.

NOTE 4 Operating limit values for generators are given in IEC 60034-22.

4.2 Main source of electrical power

4.2.1 The main source of electrical power shall consist of at least two generator sets. For fixed units other sources of electrical power supply arrangements may be acceptable subject to approval by the appropriate authority.

For small installations where renewable sources of energy are used, for example photovoltaic cells or wind generators, stationary batteries shall be provided to guarantee the distribution of the electrical power during the time without sun or wind. The batteries' autonomy shall be in accordance with the appropriate authority.

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

a) normal operational conditions and safety;

 NOTE It is not required that full operation with maximum load shall be maintained with one generator being stopped.

b) minimum comfortable conditions of habitability;

 NOTE Minimum comfortable conditions of habitability include at least adequate services for lighting, cooking, heating, domestic refrigeration, mechanical ventilation, sanitary and fresh water.

4.2.3 Where transformers, converters or similar appliances constitute an essential part of the electrical supply system required by 4.2.1, the system shall be so arranged as to ensure the same continuity of supply as stated in 4.2.2.

4.3 Emergency source of electrical power

4.3.1 A self-contained emergency source of electrical power shall be provided as required by the appropriate authority. Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency source of electrical power may, in exceptional cases and for periods of short duration, be used to supply non-emergency circuits subject to agreement by the appropriate authority.

NOTE For units where the main source of electrical power is located in two or more spaces which have their own systems, including power distribution and control systems, completely independent of the systems in the other spaces and such that a fire or other casualty in any one of the spaces will not affect the power distribution from the others, or to the services required by 4.7.1, the requirements of 4.3.1 may be considered satisfied without an additional emergency source of electrical power, subject to approval of the appropriate authority.

The power available, duration of supply and services provided for safety in an emergency shall be as required by the appropriate authority.

4.3.2 Where the emergency source of electrical power is a generator it shall be:

a) driven by a suitable prime-mover with an independent supply of fuel and cooling medium;

b) started automatically upon failure of the supply from the main source of electrical power to the emergency system, and it shall be automatically connected to the emergency system;

c) provided with a transitional source of emergency electrical power according to 4.3.4.

NOTE 1 Further consideration should be given to other conditions affecting the emergency generator prime-mover such as environmental conditions, etc.

NOTE 2 For starting arrangements of emergency generators, see 4.9.

4.3.3 Where the emergency source of electrical power is an accumulator battery it shall be capable of:

a) carrying the emergency electrical load without recharging whilst maintaining the voltage of the battery throughout the discharge period within ±12 % of its nominal voltage;

b) automatic connection to the emergency switchboard in the event of failure of the main source of electrical power supply; and

c) immediately supplying at least those services required for the transitional source of electrical power in 4.3.4.

4.3.4 The transitional source of emergency electrical power required in Item c) of 4.3.2 shall consist of an accumulator battery suitably located for use in an emergency which shall operate without recharging whilst maintaining the voltage of the battery throughout the discharge period within ±12 % of its nominal voltage and so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power the services which are required by the appropriate authority. The capacity shall be sufficient for a period of at least 30 min or for the period defined by the appropriate authority.

For mobile units, reference shall be made to IMO 1989 MODU CODE 5.3.10.

NOTE A UPS system is acceptable as a transitional source of emergency power.

4.3.5 Provision shall be made for the testing at regular intervals of the complete emergency power system and shall include the testing of the automatic starting arrangements. Testing at regular intervals shall also cover load operation.

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

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

4.3.7 During changeover from the main source of electrical power to the emergency source of electrical power, an uninterruptible power supply (UPS) system shall ensure uninterrupted duty for consumers which require continuous power supply, and for consumers which may malfunction upon voltage transients.

4.4 Additional requirements for periodically unattended machinery spaces

4.4.1 Units intended for operation with periodically unattended machinery spaces shall comply with 4.4.2 to 4.4.8 inclusive.

4.4.2 Where electrical power is normally supplied by one of the unit's generating sets, arrangements such as load shedding, shall be provided to ensure that the safety of the unit with regard to station-keeping, propulsion and steering, is at least equivalent to that of a unit having the machinery space manned.

4.4.3 In the event of failure of the generating set(s) in service, provision shall be made for the automatic starting and connection to the main switchboard of a stand-by generating set of sufficient capacity to supply those services necessary to ensure that the safety of the unit with regard to station-keeping, propulsion and steering, is at least equivalent to that of a unit having the machinery space manned.

4.4.4 The arrangement shall permit automatic re-starting of all essential services, which may be sequentially started if necessary.

4.4.5 The automatic starting system and characteristics of the stand-by generating set shall be such as to permit the stand-by generator to carry its full load as quickly as is safe and practicable, subject to a maximum of 45 s.

4.4.6 Arrangements shall be provided to prevent more than one automatic closing of a given generator circuit breaker under short-circuit conditions.

4.4.7 If the electrical power is normally supplied by more than one generator operating in parallel, provisions shall be made by means such as load shedding or by appropriate separation of the switchboard busbar to ensure that, in the event of loss of one of these generating sets, the remaining set(s) are kept in operation without overload to permit station-keeping, propulsion and steering, and to ensure the safety of the unit.

4.4.8 Requirements relating to safety and alarm systems are specified in Clause 12.

4.5 General requirements for renewable sources of electrical power

4.5.1 Photovoltaic System

The system shall be sized in a way that guarantees the power for normal operating conditions and ensures the supply of the loads even in periods of "no sun".

When sizing the system, the following shall be taken into consideration:

– environmental conditions;
– geographic location;
– solar radiation;
– days foreseen with "no sun";
– required energy by the loads (Wh/day);
– energy for preferential load supply;
– rated voltage and current;

- photovoltaic module maintenance coefficient;
- safety factor;
- efficiency of storage battery.

NOTE For information on photovoltaic design and systems reference should be made to IEC 60904 series and IEC 61194.

4.5.2 Eolic System

The system shall be sized in a way that guarantees the power for normal operating conditions and ensures the supply of the loads even in periods of “wind lull”.

When sizing the system, the following shall be taken into consideration:

- environmental conditions;
- geographic location;
- ventilation;
- days foreseen with “wind lull”;
- required energy by the loads (Wh/day);
- energy for preferential load supply;
- rated voltage and current;
- wind generator maintenance coefficient;
- safety factor;
- efficiency of storage battery.

To allow for periods when there is no wind an alternative means of charging batteries shall be installed.

NOTE 1 To allow for safe maintenance of wind generator systems a suitable means of braking should be fitted to the turbines together with a safe means of access.

NOTE 2 For information on wind energy systems reference should be made to AWEA standards 3.1 and 6.1.

4.6 Arrangement and location

4.6.1 The generating plant, switchboards and batteries shall be separated from any hazardous areas according to IEC 61892-7. Batteries, e.g. for nav-aid systems, may be accepted in hazardous areas, provided the batteries with enclosure are certified for the area in question.

NOTE The hazardous area generated by the battery itself is not covered by this requirement.

4.6.2 The emergency source of electrical power, any associated transforming equipment, the emergency switchboard and related cables shall not be located in any space(s) containing the main source of electrical power or other equipment presenting a fire risk nor in any room or compartment having direct access to such space(s).

For mobile and floating production units the location shall be on or above the uppermost continuous deck or equivalent and shall be readily accessible from the open deck.

Rooms or compartments in which the emergency source of electrical power, any associated transforming equipment, or the emergency switchboard are located shall be separated from any machinery space containing the main source of electrical power, by classified partitions as defined in the International Convention for the Safety of Life at Sea.

For fixed units the requirement for separation of the main and emergency power plant shall be in accordance with the requirements of the appropriate authority.

The emergency power system shall be arranged so as to permit total electrical separation from the main power system. During normal service, interconnection from the main switchboard shall supply power to the emergency switchboard provided that automatic interruption of the interconnection at the emergency switchboard is ensured in the event of failure of the main source of electrical power.

The functioning of the emergency power systems shall be ensured in the event of fire in the space(s) containing the main source of electrical power.

NOTE The emergency switchboard should be installed as near as is practicable to the emergency source of power.

4.7 Output

4.7.1 The emergency source of electrical power shall be sufficient to supply all those services that are essential for safety in a case of emergency for at least 18 hours or for the time defined by the appropriate authority. Due regard shall be paid to such services as may have to be operated simultaneously.

The most common services are the following:

a) navigation and obstruction signals and lights;
b) lighting of all zones essential for survival such as escapeways, personnel lift cars and trunks, landing pads, boat boarding stations;
c) external communication systems;
d) fire detection, fire alarms and emergency fire-fighting equipment operating on electric power;
e) equipment, operating on electric power, at life-saving stations serving platform disembarkation;
f) emergency shutdown systems;
g) safety telecommunication systems;
h) general alarm;
i) equipment to be used in connection with the drilling process in case of an emergency (for example Blow Out Preventer systems);
j) equipment essential for the immediate safety of diving personnel;
k) gas detection and gas alarm;
l) internal communication systems required in an emergency;
m) any other emergency or essential system;
n) lighting of machinery spaces to allow essential operations and observations under emergency conditions and to allow restoration of service;
o) all power-operated watertight door systems;
p) all lighting relative to helicopter operations and landing;
q) all permanently installed battery chargers servicing equipment required to be powered from an emergency source;
r) sufficient number of bilge and ballast pumps to maintain safe operations during emergency conditions.

4.7.2 Navigation and obstruction signals and lights, which may be required for marking of offshore units, shall be provided with power for a period of 4 days without external power supply.

4.8 Additional requirements for electrical emergency power systems

4.8.1 Prime movers for emergency generators shall have as few automatic safety functions as possible in order to ensure continuous operation. Normal motor and generator protection shall be provided if running unattended for test of the emergency generator or if it is used as a harbour generator.

4.8.2 An indicator shall be mounted in a suitable place to indicate when an emergency battery is discharging.

NOTE Battery backed light fittings do not do this in general. Trip of supply to emergency lighting shall give alarm at a manned position.

4.8.3 For floating units the emergency generator and its prime mover and any emergency accumulator battery shall be designed to function at full rated power when upright and when inclined up to the maximum angle of heel in the intact and damaged condition, as stated in IEC 61892-5.

4.9 Starting arrangements for emergency generators

4.9.1 Emergency generators shall be capable of being readily started in their cold condition down to a temperature of 0 °C. If this is impracticable, or if lower temperatures are likely to be encountered, consideration shall be given to the provision and maintenance of heating arrangements, applicable to the appropriate authority, so that ready starting will be assured.

4.9.2 Each emergency generator, which is arranged to be automatically started, shall be equipped with starting arrangements acceptable to the appropriate authority with a storage energy capability of at least three consecutive starts. A second source of energy shall be provided for an additional three starts within 30 min unless hand (manual) starting can be demonstrated to be effective.

4.9.3 Where both the main and secondary start arrangements are electrical, the systems shall be independent and include two chargers, and two batteries.

NOTE Consideration should be given to the provision of two starter motors.

4.9.4 Provision shall be made to maintain the stored energy at all times.

4.9.5 All starting, charging and energy-storing devices shall be located in the emergency generator room. These devices shall not be used for any purpose other than the operation of the emergency generator set. This does not preclude the supply to the air receiver of the emergency generator set from the main or auxiliary compressed air system through a non-return valve fitted in the emergency generator room.

4.9.6 When automatic starting is not required by these requirements, and where it can be demonstrated as being effective, hand (manual) starting is permissible, such as manual cranking, inertia starters, manual hydraulic accumulators, or power cartridges.

4.9.7 For a unit which is normally manned the readiness of the emergency generator to start shall be indicated in a manned location, for example the control room.

5 System earthing

5.1 General

Clause 5 gives requirements and recommendations for system earthing, i.e. an intentional connection of the neutral point of the electrical power supply system to hull or structure.

NOTE 1 The intent of the requirements is to promote broad application of the fewest varieties of system earthing patterns that will satisfy operational and safety requirements. Even minor deviations in design are to be avoided.

NOTE 2 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.

5.2 General requirements

5.2.1 System earthing shall be considered for all electrical power supply systems in order to control and keep the system's voltage to earth within predictable limits. It shall also provide for a flow of current that will allow detection of an unwanted connection between the system conductors and earth, which should instigate automatic disconnection of the power system from conductors with such undesired connections to earth. For an IT system (see Clause 6) an alarm shall be given at a manned control centre.

NOTE Guidance to a system for the investigation of earth faults should be available.

5.2.2 The magnitude and duration of a potential earth fault current shall not exceed the design capacity of any part of the electrical power supply system.

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

NOTE For installations in hazardous areas, see IEC 61892-7.

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

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

5.2.5 AC uninterruptible power systems (UPS) shall have an isolated neutral.

5.3 Neutral earthing methods

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

– directly earthed (TN system);
– impedance earthed (IT system);
– isolated (IT system).

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

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

5.4 Neutral earthing for systems up to and including 1 000 V

5.4.1 The neutral point shall either be directly connected to earth or through an impedance.

NOTE 1 Earthed neutral systems should be achieved by connecting the neutral point directly to earth. The earth loop impedance shall be low enough to permit the passage of a current at least three times the fuse rating for fuse protected circuits or one and a half times the tripping current of any excess current circuit breaker used to protect the circuit.

NOTE 2 In the case of impedance earthing, the impedance should be such that the earth fault current is slightly higher than the capacitive current of system. The maximum earth fault should however be limited to:

– 100 A per generator;
– 100 A per transformer.

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

NOTE The neutral is defined for a polyphase only (see IEV 601-03-10).

5.5 Neutral earthing for systems above 1 000 V

5.5.1 Earthed neutral systems shall limit the earth fault current to an acceptable level either by inserting an impedance in the neutral connection to earth or by an earthing transformer. Direct earthing shall not be used for these systems.

NOTE The prospective earth fault current should be at least three times the values of current required to operate any earth fault protective devices.

5.5.2 In the case of impedance earthing, the maximum earth fault shall be limited to a current that a generator normally can withstand for a prolonged time without damage to the core.

NOTE In the case of impedance earthing, the impedance should be such that the earth fault current is higher than the capacitive current of system. The maximum earth fault should be discussed with the equipment manufacturer. In the absence of precise values the following can be taken as a guide:

Voltage	Generator	Transformer
11 kV	20 A per generator	20 A per transformer
6,6 kV	20 A per generator	20 A per transformer
690 V	100 A per generator	100 A per transformer

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

NOTE 1 For systems where the earth fault current exceeds 5 A, automatic tripping devices should be provided. Where the earth fault current does not exceed 5 A, an indicator should be provided as an alternative to an automatic tripping device.

NOTE 2 For supply to hazardous areas, an additional requirement is given in 5.3 of IEC 61892-7.

5.6 Generators operated in parallel with source transformers

5.6.1 Where direct connected generators are or may be operated in parallel with source transformers, the neutral earthing arrangements shall provide for either system operating independently. The neutral earthing equipment shall, wherever practical, be identically rated for all power sources.

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

5.6.3 Where the normal ratings of the source transformer and parallel running generators are significantly different, the resistor rating selection shall be dictated by the requirement to ensure that the most insensitive earth fault protection on any incoming or outgoing circuit operates positively with the smallest possible source of earth fault current connected to the system.

5.7 Earthing resistors, connection to hull/structure

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

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

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

Table 1 – Summary of principal features of the neutral earthing methods

Means of earthing	Not intentionally earthed "Isolated"	Impedance earthed	Directly earthed
System voltage	All methods are potentially applicable (but note higher voltage systems are likely to have higher VA earth fault levels, which may make directly earthed connections, or low impedance methods, unattractive)		
Overvoltages	The most significant overvoltages are due to causes not influenced by the method of neutral earthing		
Electric shock risk	All major installations are potentially lethal whatever method of neutral earthing is used		
Use of residual current device for electrical safety	Will normally not function	Use of residual current device with 30 mA operating current should be considered	Acceptable
Use of 3-phase 4-wire supply	Not acceptable	Acceptable	Acceptable
Earth fault current magnitude	Depends on system capacitance but usually very low, e.g. 1 A	Depends on impedance value, typically 5 A – 400 A	May be up to 50 % greater than symmetrical 3-phase value
Sustained operation with earth fault	Normally possible	May be possible but not advisable, depending on impedance value	Not possible
Minimum earth fault protection required	Alarm or indication	Alarm/indication, earth fault relay, over-current protection, depending on impedance	Over-current protection
Switchgear fault rating	May be rated on normal phase to phase or 3-phase symmetrical fault value		May have to be rated on single-phase-to earth or phase-to-phase-to-earth value
Earth fault location	Faults not self-revealing Must normally be located manually unless core balance current transformers are fitted	If relays fitted, faults self-revealing. Otherwise must be located manually	Faults are self-revealing on over-current
Fire risk	Very low, provided that earth fault current does not exceed 1 A. Prolonged fault may present a hazard	Risk of igniting flammable gases. High impedance faults can lead to burning at fault location.	
Flash hazard (phase-to-earth	Low -------------------------Increasing ---High		
Availability of suitable equipment	Similar generation & distribution equipment is applicable on all systems		Allows use of land based equipment designed for TN-S systems

6 Distribution systems

6.1 DC distribution systems

6.1.1 Types of distribution systems

The following types of distribution systems are considered as standard:

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

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

c) two-wire insulated – IT system.

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

The requirement does not preclude, under conditions approved by the appropriate authority, the use of:

– impressed current cathodic protective systems;

– limited and locally earthed systems, e.g. engine starting systems;

– insulation level monitoring devices provided the circulation current does not exceed 30 mA under the most unfavourable conditions.

NOTE 1 The distribution system codes used have the following meanings:

First letter – Relationship of the power system to earth:

T = direct connection of one point to earth;

I = all live parts isolated from earth, or one point connected to earth through an impedance.

Second letter – Relationship of the exposed–conductive–parts of the installation to earth:

T = direct electrical connection of exposed–conductive–parts to earth, independently of the earthing of any point of the power system;

N = direct electrical connection of the exposed–conductive–parts to earthed point of the power system (in a.c. systems, the earthed point of the power system is normally the neutral point or, if a neutral point is not available, a phase conductor).

Subsequent letter(s) if any – Arrangement of neutral and protective conductors:

S = protective function provided by a conductor separate from the neutral or from the earthed line (or in a.c. systems earthed phase) conductor;

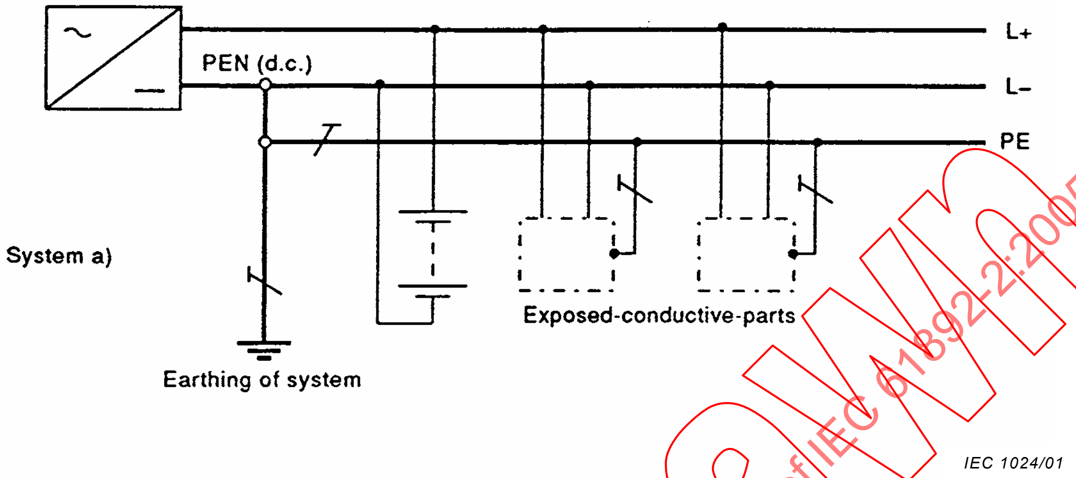
C = neutral and protective functions combined in a single conductor (PEN conductor).

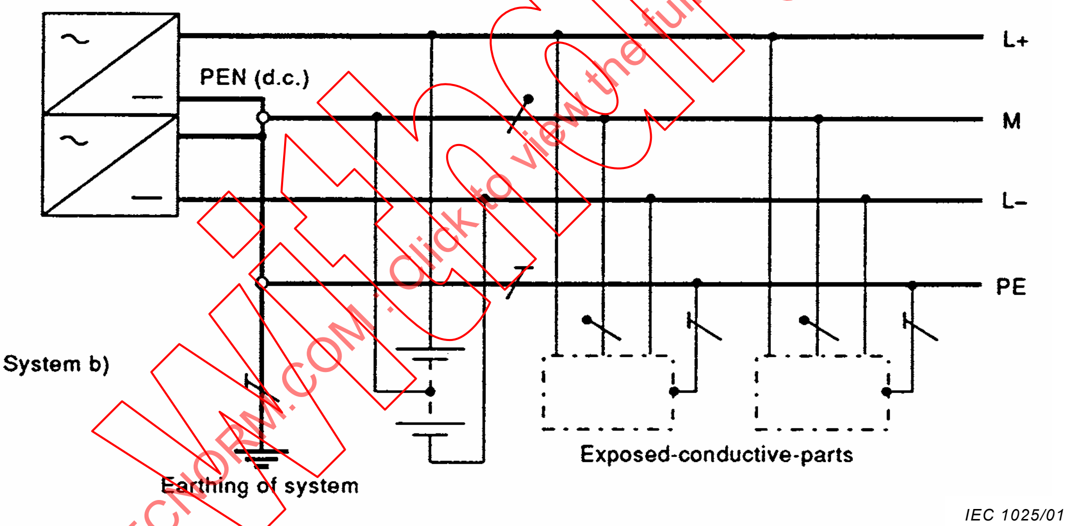
NOTE 2 In earthed d.c. systems electrochemical corrosion should be considered.

NOTE 3 Where the following figures 2 – 5 show earthing of a specific pole of a two–wire d.c. system, the decision whether to earth the positive or the negative pole should be based upon operational circumstances or other considerations.

6.1.1.1 TN d.c. systems

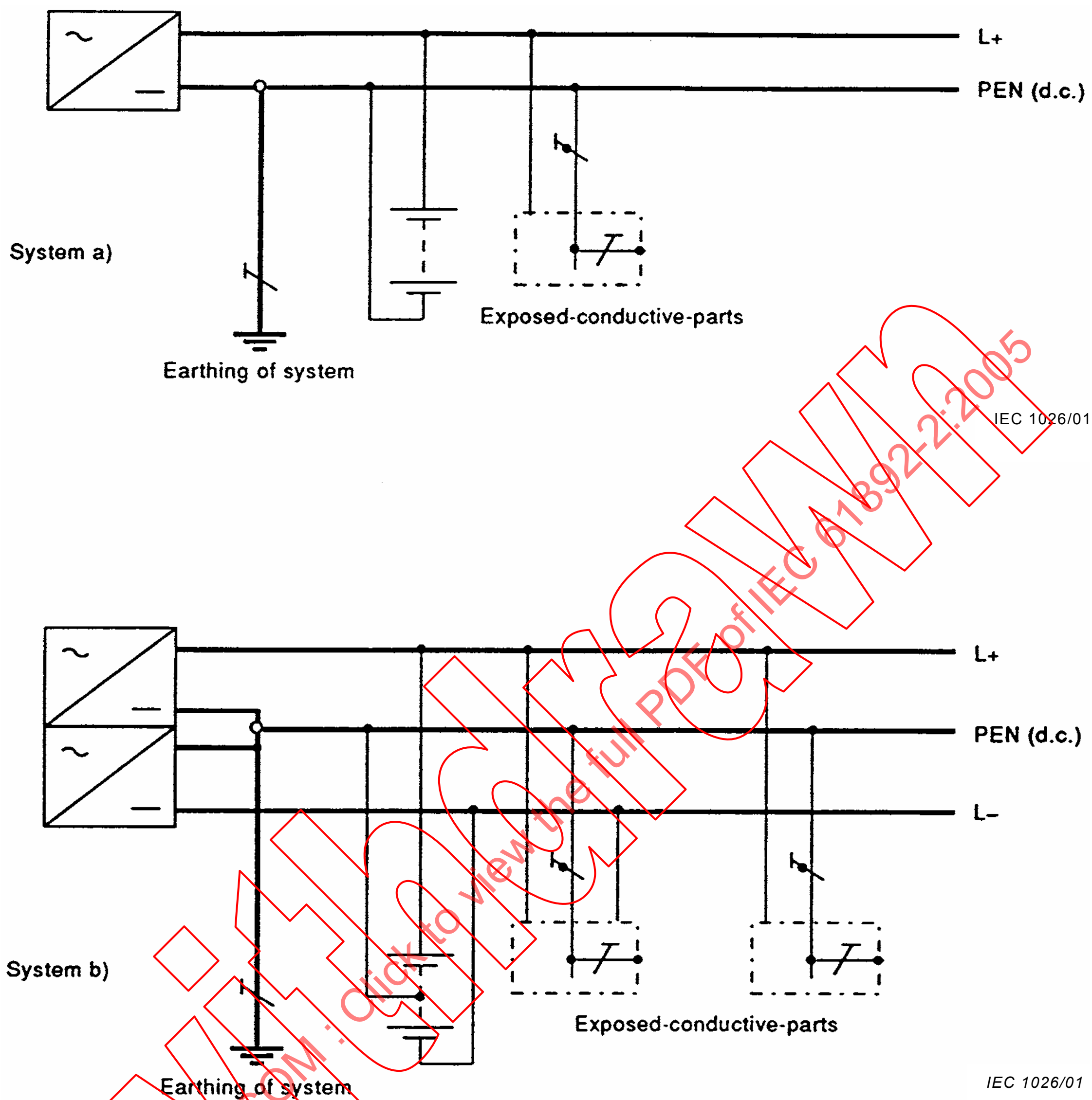
Figures 2, 3 and 4 illustrate a TN-S d.c. system, a TN-C d.c. system and a TN-C-S d.c. system respectively.





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

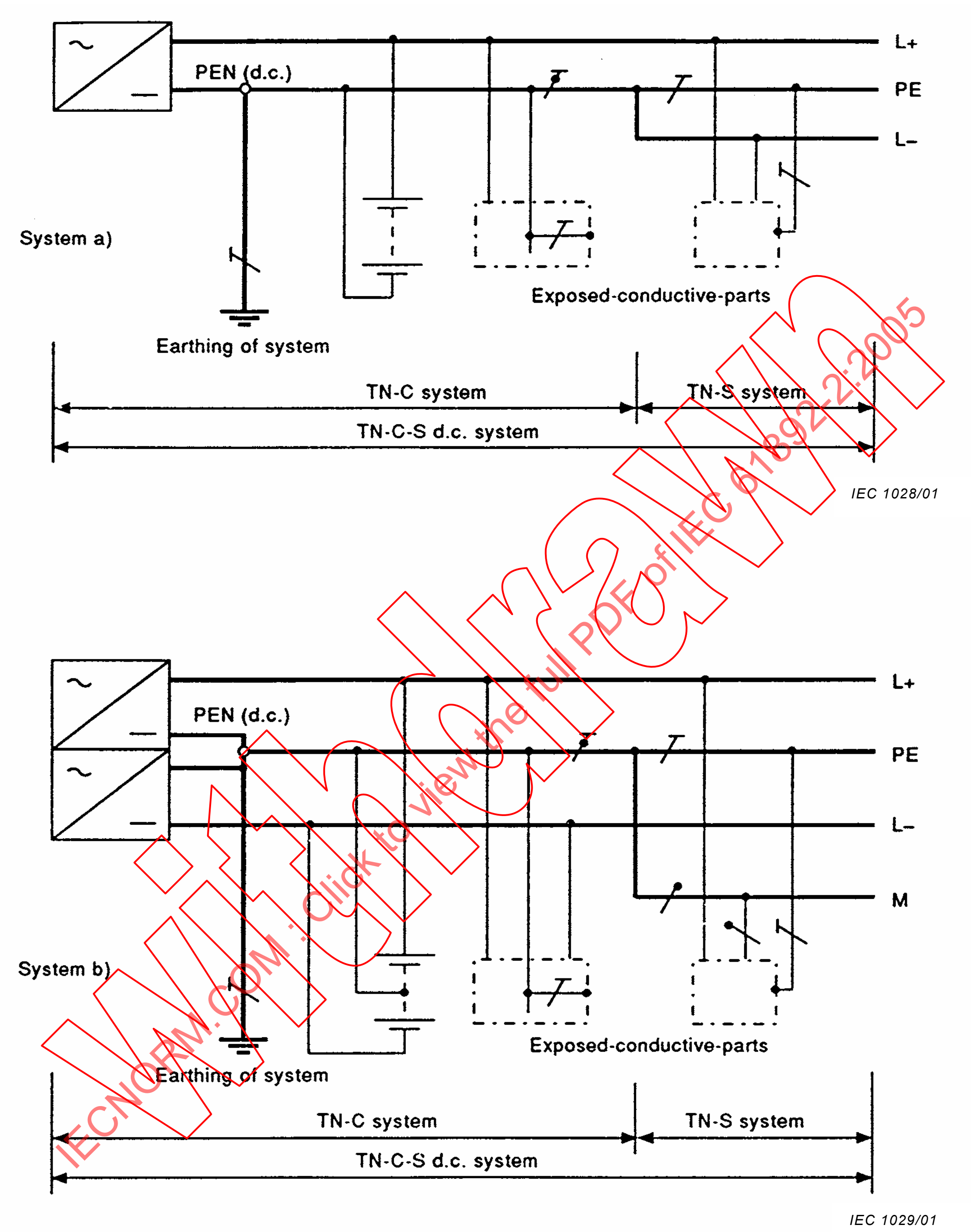
Figure 2 – TN-S d.c. system



The functions of the earthed line conductor (for example L–) in system a) and the protective conductor are combined in one single conductor PEN (d.c.) throughout the system, or the earthed middle wire conductor (M) in system b) and protective conductor are combined in one single conductor PEN (d.c.) throughout the system.

NOTE TN-C systems are not allowed in hazardous areas, see IEC 61892–7.

Figure 3 – TN-C d.c. system



The functions of the earthed line conductor (for example L–) in system a) and protective conductor are combined in one single conductor PEN (d.c.) in parts of the system, or the earthed middle wire conductor (M) in system b) and protective conductor are combined in one single conductor PEN (d.c.) in parts of the system.

Figure 4 – TN-C-S d.c. system

6.1.1.2 IT d.c. systems

Figure 5 illustrates an IT d.c. system.

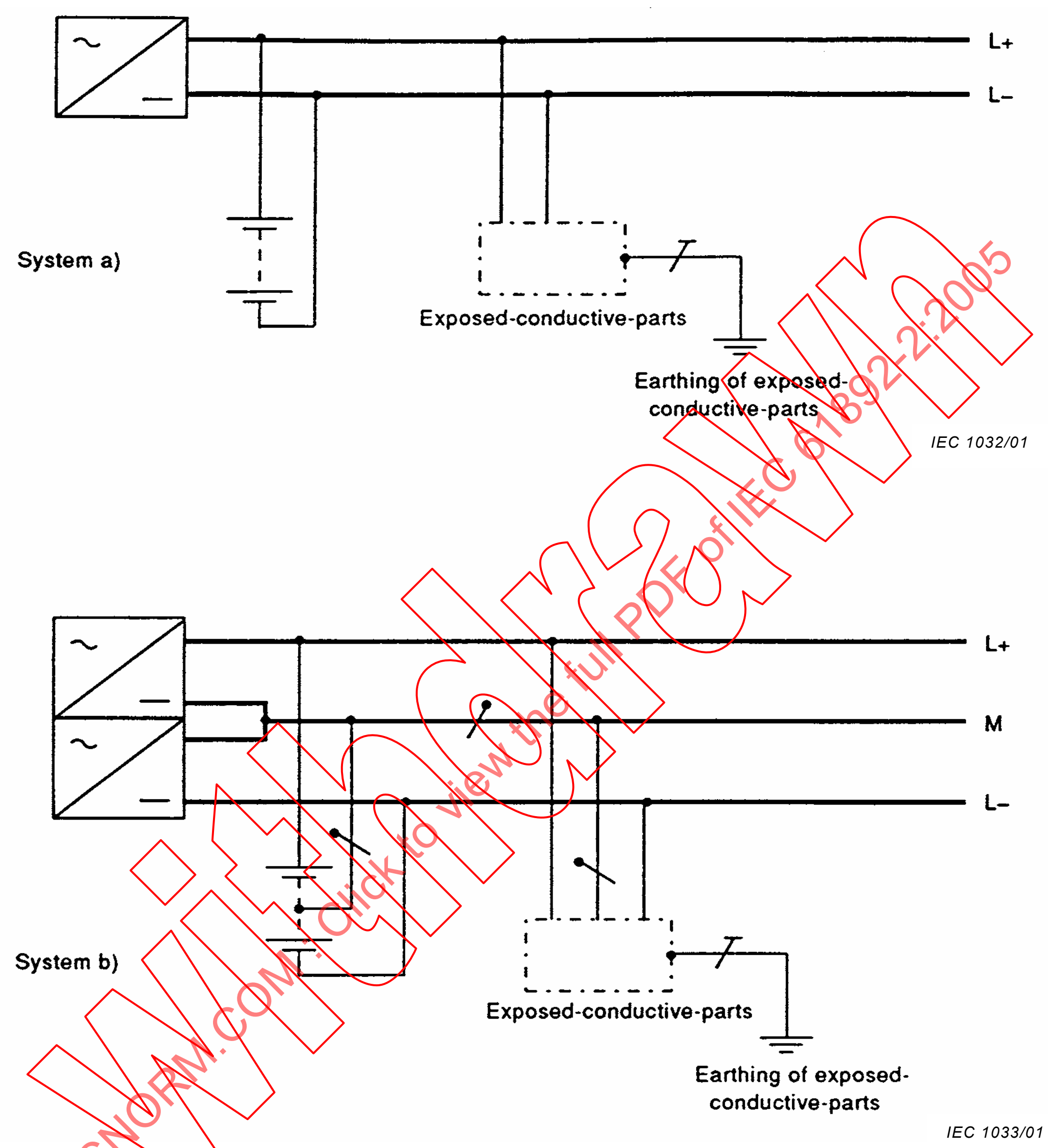


Figure 5 – IT d.c. system

6.1.1.3 DC voltages

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

Table 2 – Voltages for d.c. systems

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

6.2 AC distribution systems

6.2.1 Primary a.c. distribution systems

The following systems are recognised as standard for primary distribution:

- three-phase three-wire insulated, or impedance earthed – IT system;
- three-phase three-wire with neutral earthed – TN system;
- three-phase four-wire with neutral earthed but without structure or hull return – TN system.

6.2.2 Secondary a.c. distribution systems

The following systems are recognised as standard for secondary distribution:

- three-phase three-wire insulated, or impedance earthed – IT systems;
- three-phase three-wire with neutral earthed – TN systems;
- three-phase four-wire with neutral earthed but without structure or hull return – TN systems.
- single-phase two-wire insulated – IT systems;
- single-phase two-wire with one pole earthed – TN systems;
- single-phase two-wire with mid-point of system earthed for supplying lighting and socket-outlets – TN systems;
- single-phase three-wire with mid-point earthed but without structure or hull return – TN systems.

NOTE The code used has the following meanings:

First letter – Relationship of the power system to earth:

T = direct connection of one point to earth;

I = all live parts isolated from earth, or one point connected to earth through an impedance.

Second letter – Relationship of the exposed–conductive–parts of the installation to earth:

T = direct electrical connection of exposed–conductive–parts to earth, independently of the earthing of any point of the power system;

N = direct electrical connection of the exposed–conductive–parts to earthed point of the power system (in a.c. systems, the earthed point of the power system is normally the neutral point or, if a neutral point is not available, a phase conductor).

Subsequent letter(s) if any – Arrangement of neutral and protective conductors:

S = protective function provided by a conductor separate from the neutral or from the earthed line (or in a.c. systems earthed phase) conductor;

C = neutral and protective functions combined in a single conductor (PEN conductor).

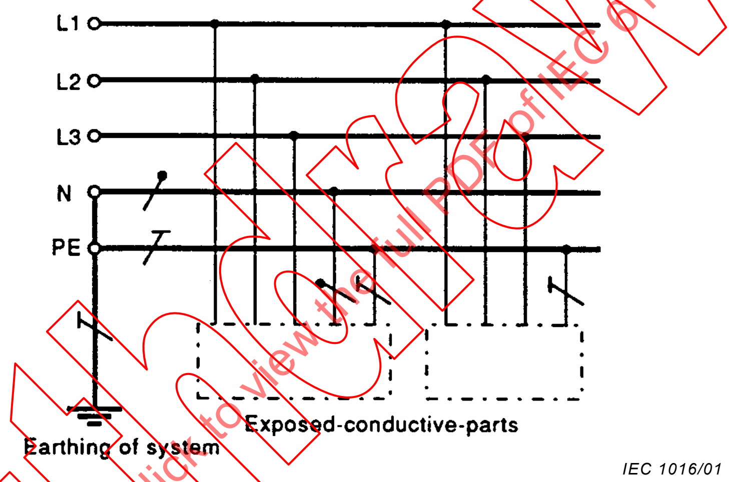
6.2.2.1 TN a.c. systems

TN power systems have one point directly earthed, the exposed conductive parts of the installation being connected to that point by protective conductors. Three types of TN system are considered according to the arrangement of neutral and protective conductors as follows:

– TN-S system (see Figure 6): in which throughout the system, a separate protective conductor is used;

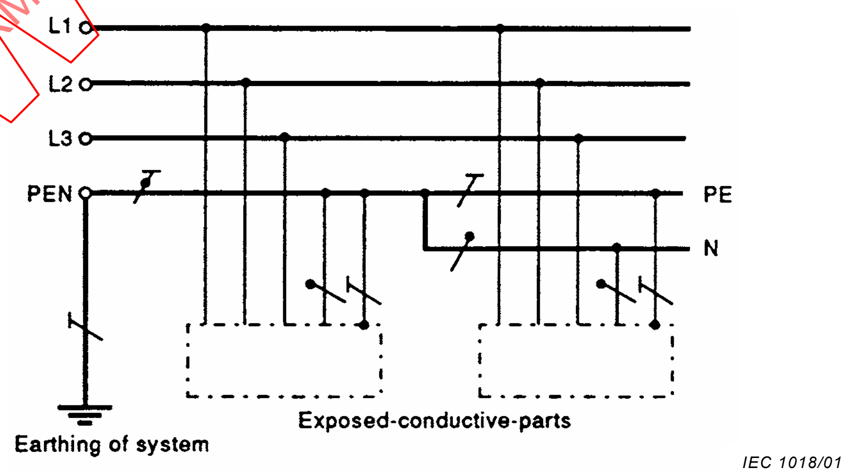
– TN-C–S system (see Figure 7): in which neutral and protective functions are combined in a single conductor in a part of the system;

– TN-C system (see Figure 8): in which neutral and protective functions are combined in a single conductor throughout the system.



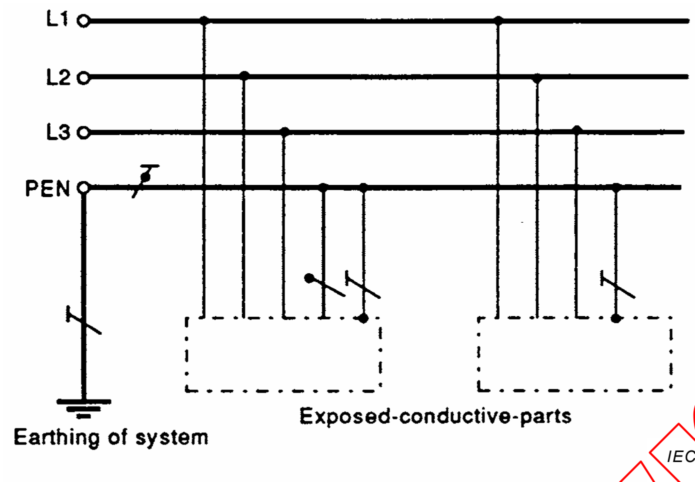
Separate neutral and protective conductors are used throughout the system.

Figure 6 – TN-S a.c. system



Neutral and protective functions are combined in a single conductor in a part of the system.

Figure 7 – TN-C-S a.c. system



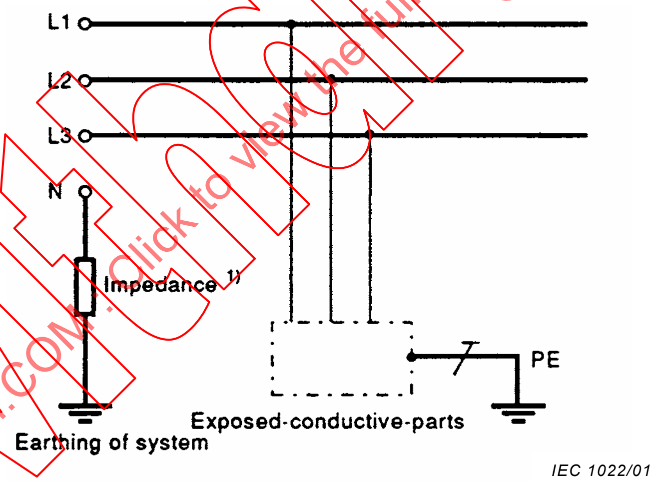
Neutral and protective functions are combined in a single conductor throughout the system.

NOTE TN–C systems are not allowed in hazardous areas, see IEC 61892–7.

Figure 8 – TN-C a.c. system

6.2.2.2 IT a.c. systems

The IT power system has all live parts isolated from earth or one point connected to earth through an impedance, the exposed–conductive–parts of the electrical installation being earthed independently or collectively to the earthing of the system (see Figure 9).

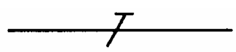


1) The system may be isolated from earth. The neutral may or may not be distributed.

Figure 9 – IT a.c. system

Remark – The following is an explanation of the symbols used in Figures 2 to 9 inclusive (see IEC 60617-11):

 Neutral conductor (N)

 Protective conductor (PE)

 Combined protective and neutral conductor (PEN)

6.2.3 AC voltages and frequencies

Tables 3 and 4 give the maximum voltages allowed and the recommended values of nominal voltages and frequencies for a unit's service systems of supply.

Voltage and frequency shall be chosen in accordance with IEC 60038. The values applicable are given in Tables 3 and 4.

In Table 3, the three-phase four-wire systems and single-phase three-wire systems include single-phase circuits (extensions, services, etc.) connected to these systems. The lower values in the first and second columns of Table 3 are voltages to neutral and the higher values are voltages between phases. When one value only is indicated, it refers to three-wire systems and specifies the voltage between phases. The lower value in the third column is the voltage to neutral and the higher value is the voltage between lines.

Two series of highest voltages for equipment are given in Table 4, one for 50 Hz and 60 Hz systems (Series I), the other for 60 Hz systems (Series II – North American practice). It is recommended that only one of the series should be used in any one country. It is also recommended that only one of the two series of nominal voltages given for Series I should be used in any one country.

Table 3 – AC systems having a nominal voltage between 100 V and 1 000 V inclusive and related equipment

Three-phase four-wire or three-wire systems		**Single-phase three-wire systems**
Nominal voltage V		**Nominal voltage V**
50 Hz	**60 Hz**	**60 Hz**
–	120/208	120/240
–	240	–
230/400 [a]	277/480	–
400/690 [a]	480	–
–	347/600	–
1 000	600	–

NOTE 440 V and 690 V systems are also used for 60 Hz systems, e.g. for drilling applications and FPSOs.

[a] The nominal voltage of existing 220/380 V and 240/415 V systems shall evolve toward the recommended value of 230/400 V. The transition period should be as short as possible and should not exceed the year 2003. At the end of this transition period, the tolerance of 230/400 V ± 10 % should have been achieved; after this the reduction of this range will be considered. The above considerations apply also to the present 380/660 V value with respect to the recommended value 400/690 V.

Table 4 – AC three-phase systems having a nominal voltage above 1 kV and not exceeding 35 kV and related equipment [a]

Series I			Series II	
Highest voltage for equipment kV	Nominal system voltage kV		Highest voltage for equipment kV	Nominal system voltage kV
3,6 [b]	3,3 [b]	3 [b]	4,40 [b]	4,16 [b]
7,2 [b]	6,6 [b]	6 [b]	–	–
12	11	10	–	–
–	–	–	13,2 [c]	12,47 [c]
–	–	–	13,97 [c]	13,2 [c]
–	–	–	14,52 [b]	13,8 [b]
(17,5)	–	(15)	–	–
24	22	20	–	–
–	–	–	26,4 [c]	24,94 [c]
36 [d]	33 [d]	–	–	–
–	–	–	36,5 [c]	34,5 [c]
40,5 [d]	–	35 [d]	–	–

NOTE 1 It is recommended that in any one country the ratio between two adjacent nominal voltages should be not less than two.

NOTE 2 In a normal system of Series I, the highest voltage and the lowest voltage do not differ by more than approximately ±10 % from the nominal voltage of the system. In a normal system of Series II, the highest voltage does not differ by more then +5 % and the lowest voltage by more than –10 % from the nominal voltage of the system.

[a] These systems are generally three-wire systems unless otherwise indicated. The values indicated are voltages between phases.

The values indicated in parentheses should be considered as non-preferred values. It is recommended that these values should not be used for new systems to be constructed in future.

[b] These values should not be used for public distribution systems.

[c] These systems are generally four-wire systems.

[d] The unification of these values is under consideration.

6.2.4 Control voltage

For distribution systems above 500 V the control voltage shall be limited to 250 V, except when all control equipment is enclosed in the relevant control gear and the distribution voltage is not higher than 1 000 V.

7 Distribution system requirements

7.1 Earthed distribution systems

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

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

7.2 Methods of distribution

7.2.1 The output of the unit's main source of electric power can be supplied to the current consumers by the way of either:

a) branch system, or

b) meshed network or ring-main.

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

7.3 Balance of loads

7.3.1 Balance of load on three-wire d.c. systems

Current-consuming units connected between an outer conductor and the middle wire shall be grouped in such a way that, under normal conditions, the load on the two halves of the system is balanced as far as possible within 15 % of their respective load at the individual distribution and section boards as well as the main switchboard.

7.3.2 Balance of loads in three- or four-wire a.c. systems

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

7.4 Final circuits

7.4.1 General

A separate final circuit shall be provided for every motor required for an essential service and for every motor rated at 1 kW or more. Final circuits rated above 16 A shall supply not more than one appliance.

7.4.2 Final circuits for lighting

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

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

In the absence of precise information regarding lighting loads of final circuits it should be assumed that every lampholder requires a current equivalent to the maximum load likely to be connected to it.

7.4.3 Final circuit for lighting in accommodation spaces.

Final circuit for lighting in accommodation spaces may, as far as practicable, include socket-outlets. In that case, each socket-outlet counts for 120 W.

7.4.4 Final circuits in offices and workshops.

Final sub circuits in offices and workshops cannot be evaluated as 120 W for a socket-outlet but need to be evaluated according to actual/estimated load.

7.4.5 Final circuits for heating

Each heater shall be connected to a separate final circuit except that up to ten small heaters of total connected current rating not exceeding 16 A may be connected to a single final circuit.

7.5 Control circuits

7.5.1 Supply systems and nominal voltages

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

Where external control systems are grouped in a console, unless individually protected against accidental contact and properly marked, the control voltage shall not exceed 250 V.

7.5.2 Circuit design

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

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

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

7.5.3 Motor control

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

Where reverse-current braking of a motor is provided, provision shall be made for the avoidance of reversal of the direction of rotation at the end of braking, if such reversal may cause danger.

7.5.4 Protection

Short-circuit protection shall be provided for control circuits including signal devices.

Where a fault in a signal device would impair the operation of essential services, such devices are to be separately protected.

7.5.5 Arrangement of circuits

For essential duties, consideration shall be given to monitoring associated control circuits to ensure, as far as is practicable, that such circuits are readily available for service.

7.6 Socket-outlets

7.6.1 Socket-outlets for portable lamps and small domestic appliances may be grouped together as mentioned in 7.4.

7.6.2 Socket-outlets for systems above 250 V shall be rated not less than 16 A.

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

7.6.4 Socket outlets rated above 16 A such as welding socket outlets can be grouped and do not need to be rated for simultaneous full load for all outlets. The circuit protection shall ensure that all circuit components including cables are fully protected independent of the possible actual load.

7.7 Shore connections for mobile units

7.7.1 Where arrangements are made for the supply of electric power from a source on shore or elsewhere, a suitable termination point shall be installed on the unit for the convenient reception of the flexible cable from the external source. Fixed cables of adequate rating shall be provided between the termination point and the main or emergency switchboard.

7.7.2 An earth terminal shall be provided for connecting the hull to an appropriate earth.

7.7.3 The shore connection shall be provided with an indicator at the main or emergency switchboard in order to show when the cable is energised.

7.7.4 Means shall be provided for checking the polarity (for d.c.) or the phase sequence (for three-phase a.c.) of the incoming supply in relation to the unit's system.

7.7.5 At the connection box a notice shall be provided giving full information on the system of supply and the nominal voltage (and frequency if a.c.) of the unit's system and the procedure for carrying out the connection.

7.7.6 Provisions shall be made for securing the trailing cables to the framework so that mechanical stress is not applied to the electrical terminals.

7.7.7 Any transformer used for shore-connection shall be of the double-wound type.

7.7.8 The maximum short-circuit rating of the distribution system shall be higher than the short-circuit level of the shore supply system.

7.8 Motor circuits

7.8.1 Starting of motors

Each motor above 1,0 kW shall be provided with separate controlgear ensuring satisfactory starting of the subject motor. Depending on the capacity of the generating plant or the cable network, it may be necessary in certain cases to limit the starting current to an acceptable value.

The supply of the motor controlgear auxiliary circuits or the design of this equipment shall be such that proper functioning is not affected by the voltage drop on the main circuit during starting.

7.8.2 Means of disconnection

Means shall be provided for the disconnection of the full load from all live poles of supply mounted on or adjacent to a main or auxiliary distribution switchboard. A disconnecting switch in the switchboard may be used for this purpose. Otherwise, a disconnecting switch within the controlgear enclosure or a separate enclosed disconnecting switch shall be provided.

7.8.3 Starters remote from motors

When the starter or any other apparatus for disconnecting the motor is remote from the motor, either a minimum of one of the following shall be arranged or equal safety shall be obtained:

- provision shall be made for locking the circuit disconnecting in the "off" position, or
- an additional disconnecting-switch should be fitted near the motor, or
- the fuses in each live pole or phase should be so arranged that they can be readily removed.

7.8.4 Master-starter system

For special applications a single master-starter system (i.e. a starter used for controlling a number of motors successively) can be used. The apparatus shall provide, for each motor, under-voltage and over-current protection and means of disconnection not less effective than that required for systems using a separate starter for each motor.

Where the master starter is of the automatic type, suitable alternative or emergency means shall be provided for manual operation.

8 Diversity (demand) factors

8.1 Final circuits

The cables of final circuits shall be rated in accordance with their connected load.

8.2 Circuits other than final circuits

Circuits supplying two or more final circuits shall be rated in accordance with the total connected load subject, where justifiable, to the application of a diversity (demand) factor in accordance with 8.3 and 8.4.

Where spare circuits are provided on a section or distribution board, an allowance for future increase in load shall be added to the total connected load, before the application of any diversity factor. The allowance shall be calculated on the assumption that each spare circuit requires not less than the average load on each of the active circuits of corresponding rating.

8.3 Application of diversity (demand) factors

A diversity (demand) factor may be applied to the calculation of the cross-sectional area of conductors and to the rating of switchgear, provided that the known or anticipated conditions in a particular part of an installation are suitable for the application of diversity.

8.4 Motive-power circuits - General

The diversity factor shall be determined according to the circumstances. The normal full-load shall be determined on the basis of the rating plate ratings of motors.

In the assessment of diversity factors of a.c. motive power circuits, account shall be taken of the relatively small decrease in current consumption of partially loaded motors.

9 System study and calculations

9.1 General

The final selection of conditions to be covered shall be agreed with the unit's owner, and according to the requirements of the appropriate authority. The studies and calculations shall reflect the installed power rating, and the complexity of the electrical system. Additions and alterations in existing electrical system, temporary or permanent, shall be evaluated accordingly.

In order to confirm the design of the electrical system and to confirm the ratings of the equipment selected system studies shall be carried out. The system studies shall be chosen from:

– electrical load study: to determine major equipment ratings for the life of the unit;
– load flow calculations: to check voltage profiles and circuit loading under steady state conditions;
– short-circuit calculations: to analyse fault currents that might flow under a variety of symmetrical, asymmetrical and unbalanced fault conditions. These shall be used for equipment specification, and control and protective relay application and setting purposes;
– protection discrimination study: to determine electrical protection settings to provide correct protection for plant and appropriate discrimination to isolate minimum amount of plant in the case of a fault;
– power system dynamic calculations: to analyse the transient and dynamic performance of power systems after large load changes and fault disturbances. These shall be used to check the ability of the system to stay in synchronism for the following:
    - induction motor stability after start;
    - re-acceleration and restart schemes;
    - the need and effectiveness of under-frequency load shedding schemes;
    - fault clearance;

  They shall also be used to consider the technical merit of:
    - auto changeover schemes;
    - parallel or open operation, or radial feeders;
    - operations of fault limiting devices;
    - insertion of switched reactors or capacitors;
– calculation of harmonic currents and voltages: to analyse the magnitude and location of harmonic distortions within the power system

9.2 Electrical load study

An electrical load list shall be prepared to establish the electrical power requirements throughout the installation.

NOTE 1 Load estimates should be carried out for all operational conditions, for example:
– drilling;
– maximum power consumption including all systems;
– normal power consumption required for full operation;
– life support;
– emergency;
– minimum load required for full operation with low priority loads disconnected.

NOTE 2 An electrical load profile should be prepared for normal operations, as far as possible, over the entire lifetime of the installation.

NOTE 3 Separate load studies should be carried out to establish the temporary load requirements during pre-operation phases, for example:

– onshore commissioning and testing;
– float out;
– deck mating;
– inshore hook-up and commissioning;
– tow out;
– offshore hook-up and commissioning;
– harbour stay / docking.

9.3 Load flow calculations

Steady state load flow calculations shall be carried out for the operational conditions giving maximum peak load and minimum load based on loads determined in 9.2.

NOTE The following data should be calculated:

– magnitude and phase angle of the busbar voltages;
– active and reactive power production and load at the busbars;
– active and reactive power flow in cables and transformers;
– power losses;
– busbar and cable ampacity at given ambient temperature;
– recommended setting of the transformers tappings;
– voltage rise in long runs of high voltage cables.

9.4 Short-circuit calculations

9.4.1 The fault currents that flow as a result of short-circuits shall be calculated at each system voltage for three phase, "phase-to-phase", and "phase-to-earth" fault conditions. These calculated currents shall be used to select suitably rated equipment and to allow the selection and setting of protective devices to ensure that successful discriminatory fault clearance is achieved.

The fault current shall be calculated for maximum and minimum system supply.

For general information regarding short circuit calculations, reference shall be made to IEC 61363 and IEC 60909 for a.c. systems, and IEC 61660-1 for d.c. systems.

NOTE It is expected that in order to be assured of reasonable accuracy, the study should be based upon a suitable computer software calculation program. The contribution of induction motors should be included in the study, preferably by direct dynamic modelling. The studies should include break and make points for the fault level. In the design stage it is important to ensure that tolerances for equipment should be considered and also that a design margin is allowed to account for later additions. The allowance is best arranged by undertaking the studies showing later additional loads on stream and represented by induction motors. IEC 61363-1 and the IEC 60909 and IEC 61660 series provide methods of short-circuit calculation which may be used when computer programmes are not available or when manual calculations are carried out. These methods all have limitation in accuracy and the selection of the preferred method and decision based upon results will rely on the competency of the engineer making the calculations. For d.c. system short circuit calculations reference is made to IEC 61660-1.

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

NOTE In assessing the transient performance of the system, accurate modelling of any automatic voltage regulator (AVR) action is required. It would also be necessary to model the governor system of any rotating power generators. (See also 9.4.6).

9.4.3 The calculation of fault currents shall include the fault current contributions from generators and synchronous and induction motors, and consideration during the first instant of fault current shall be specified for power semiconductors. Both the a.c. symmetrical and d.c. asymmetrical components of fault currents shall be calculated at all system voltages. Offshore units fed from onshore utility companies shall have fault infeeds obtained from the utility company concerned, and they shall exclude any decrement associated with fault duration, though maximum and minimum values consistent with annual load cycles and anticipating utilities systems switching conditions should be obtained.

NOTE 1 The fault levels of utility company networks are subject to variation due to the amount of generation plants which they may have connected, and also could be subject to variation due to the manner in which the public utility operates the system (for example, line outages will affect fault levels, as will open busbar systems).

NOTE 2 For a.c systems where precise information of their characteristics is lacking, the contribution of induction motors for determining the maximum peak value attainable by the short-circuit current (i.e. the value of the current to be added to the maximum peak value of the short-circuit due to the generators) can be taken as equal to 8 I_n where I_n is the sum of the rated currents of the motors estimated normally when simultaneously in service (I_n is an r.m.s. value). For preliminary calculation, the following r.m.s. values should be used:

- For motors rated more than 100 kW the following figures should be used:

  sub-transient short-circuit current: 6,25 I_n ;
  symmetrical short-circuit current at T/2: 4 I_n ;
  peak value of the short-circuit current: 10 I_n .

- For motors rated less than 100 kW the following figures should be used:

  sub-transient short-circuit current: 5 I_n ;
  symmetrical short-circuit current at T/2: 3,2 I_n ;
  peak value of the short-circuit current: 8 I_n .

The calculations based on these figures have to be confirmed.

NOTE 3 For d.c. systems in the absence of precise information, the contribution of motors in the determination of the maximum value reached by the short-circuit current can be taken as equal to six times the sum of the rated currents of the motors estimated to be normally in service simultaneously.

9.4.4 Three phase balanced fault current calculations shall be carried out to obtain prospective circuit breaker duties and shall include:

9.4.4.1 Asymmetric make capacity. Expressed in peak amperes and calculated half a cycle after fault inception. Both a.c. and d.c. current decrements shall be included for the half cycle.

9.4.4.2 Asymmetric break capability. Expressed in rms. amperes calculated at a time at which the breaker contacts are expected to part and allowing a maximum of 10 ms for instantaneous type protection operation. Both a.c. and d.c. decrements shall be included for the selected time.

9.4.4.3 Symmetrical break capability. Expressed in rms. amperes calculated at a time as defined in 9.4.4.2. This assumes zero d.c. current component and shall allow for a.c. decrement for the selected time.

9.4.5 On systems where the earth fault currents are limited by neutral earthing equipment, the currents should be assumed to include no decrement and shall be considered constant whatever the level of bonding between the conductor and the faulted phase.

9.4.6 Both the a.c. and d.c. components of motor fault current contributions shall be calculated and included in calculation of prospective fault currents.

At the instant of fault inception the a.c. peak symmetrical component and the d.c. component shall be taken to be identical. Both values shall be taken as the peak direct-on-line starting current, this being dictated by the motor locked rotor reactance. Both these currents shall be taken to decay exponentially with time using a.c. and d.c. short-circuit time constants respectively. The a.c. time constant should be determined by using the ratio of the locked rotor reactance and the standstill rotor resistance. The d.c. time constant should be determined by using the locked rotor reactance and the stator resistance.

NOTE Where faults are not directly on the motor terminals, these time constants would be modified (preferably by the integrated computer program) to take account of external impedances to the point of fault.

9.4.7 The calculation of individual fault current contributions shall be carried out for individual motors of significant ratings on the power system. All other motors on the system should be treated as a number of typical equivalent motors of total rating equal to the connected rotating loads, at different locations. The ratings of these equivalent motors shall be selected to be consistent with the actual drives at a given location.

NOTE Generally motors with ratings 1 000 kW or greater should be represented as individual machines. However, where there are multiples of these on a single busbar, they too may be represented by lumped parameters.

9.5 Protection and discrimination study

A co-ordination study shall be carried out to determine the setting of the protective relays and direct acting circuit breakers. See Clause 10.

NOTE The objective of the co-ordination study is to maintain the system continuity by protecting the electrical installations from possible black-outs and over-currents in order to minimise the effects of the fault.

9.6 Power system dynamic calculations

9.6.1 A stability analysis of the electrical power system shall be carried out and shall comprise simulations of the system transient behaviour following disturbances during relevant operational modes of the installation.

NOTE The simulations should include:

– direct on line starting of the largest motors;
– short-circuited feeders with clearance of the fault after set time delay of the protective relays or blowing time of the fuses;
– generator short-circuit with clearance of the fault and generator trip after the set time delay of the protective relays. Based on the analysis, load shedding shall be applied when required;
– generator trip. Based on analysis, load shedding shall be applied when required;
– trip of largest motor (or group of motors) of process plant.

The analysis shall be carried out for the worst case conditions with respect to system stability, which shall be determined separately by each project.

The analysis shall prove that the system will restabilise following the specified disturbances, and that the transient voltage and frequency variations, motor slip, reacceleration and start up times are within acceptable limits.

To verify the stability of the system, the dynamic study shall be closely co-ordinated with the protection and discrimination study.

9.6.2 The studies shall be carried out with proven software programs. Models for generators, automatic voltage regulators, governors, motors, transformers, cables and loads should be sufficiently detailed and proven to give confidence in the results of the studies.

NOTE 1 In addition generator and motor equivalent circuit models and data will be required. Generator models used in dynamic calculations may require models for governor and automatic voltage regulator (AVR) performance. In some cases the data for these models will not be readily available for the actual system to be studied. It will therefore be necessary for some judgement to be made on a suitable set of parameters to complete the dynamic calculations needed for the installation.

NOTE 2 Any computer-based software program equivalent circuit models used for studies and calculations should have appropriate software support and validation checks available.

9.6.3 Generator operating charts shall be prepared to assist in assuring that generators are always likely to be operated within their prescribed stability limits.

NOTE 1 As a supplement to generator operating charts, dynamic models for prime movers and associated controls should as far as practicable be verified against results from string tests with load acceptance and rejection related to the actual generator sets.

NOTE 2 The operating charts should be presented for voltages between 0,95 per unit to 1,05 per unit in steps of 0,05 per unit. The charts should also contain those key machine parameters from which the charts are constructed. e.g. X_d , X_q, etc.

NOTE 3 It is equally important that where system stability models are examined, the specific model for the parameters used has validity. For example, where machine automatic voltage regulators (AVR) and governors are used on particular machines, factory and site test arrangements should be modelled and the predicted and actual behaviour of the machine or system can then be compared with the model. In this manner some form of assurance can be obtained from the system studied.

9.6.4 Transient stability studies shall be carried out on systems which include:

a) dissimilar generators;
b) generators operating in parallel with a utility company;
c) synchronous motors;
d) where power generation busbars are interconnected by appreciable impedance.
e) large process plant systems representing a significant percentage of the supply capacity

These studies shall be used to determine whether synchronous machines are liable to lose synchronism after the most severe single disturbance.

NOTE Generally the most severe fault condition would be a three-phase fault applied at the generator busbars for a fault duration determined by the protecting switchgear, which when cleared results in the disconnection of the largest single fault contributor from the system. However, a number of fault locations followed by plant disconnections should be tried. Process or emergency shutdowns, partial or complete, may represent a major stability problem if initiated in one step.

9.6.5 Where transient stability studies are undertaken, in order to assess the ability of generators to remain in synchronism following a fault disturbance, the steady state operating condition before the fault is applied shall be one in which the spinning reserve of generation is kept at a minimum due to assumed maintenance of the largest onsite generator.

NOTE The primary object should be to identify the maximum acceptable fault clearing time, but secondary objectives, such as the best location of system open bus section points and the relationship between impedance earthing to stability, should also be ascertained from these studies. The studies would be used as support for a particular system design and also to ensure that the protection arrangements would not compromise the expected system performance. In pursuit of this latter factor, the studies may be undertaken with actual protection arrangements, if these are known. In doing this it should be noted that if protection settings were to change, the system response to fault conditions might need to be re-studied.

9.6.6 System stability studies shall be carried out to investigate the voltage and frequency performance of the system after a major disturbance for the period from fault inception to the time when steady state equilibrium is reached. These studies shall require detailed automatic voltage regulator (AVR) and governor modelling as these items assist the return to steady state and will react positively in the time scales likely to be considered.

These studies are expected to illustrate successful system recovery. A decreasing oscillatory voltage or frequency result where the average is within acceptable bounds would indicate a satisfactory performance.

9.6.7 System stability studies shall be carried out to consider the effect of the loss of the largest power supply component under a fault condition which causes no other electrical disturbance. Where the transient frequency deviation is predicted to exceed 6 %, under-frequency load-shedding schemes shall be considered. The stability studies shall be used to define the minimum number and magnitude of the various stages of load shedding that will be necessary to keep the frequency loss within acceptable limits.

NOTE Earth faults or mechanical system trip conditions do not normally result in motor loads being tripped by a.c. contactors dropping off under low voltage, and may therefore result in the greatest post-fault generation deficiency.

9.6.8 Induction motor performance studies shall be carried out to demonstrate the ability to start, re-accelerate or restart motor loads without their stalling or tripping under overload. Re-acceleration studies shall determine whether motors re-accelerate after disturbances, for example, when fault conditions or under-voltage conditions have cleared. Where motor restart schemes are required, induction motor performance studies shall be used to define the maximum number and magnitude of the various stages of restart that will be possible after clearance of faults.

9.7 Calculation of harmonic currents and voltages

The content of harmonics in the power system shall be examined when large converters are connected.

The magnitude of the harmonics and the total voltage distortion shall be computed for all main busbars.

On a busbar of any voltage the total harmonic distortion shall not exceed 8 % and no single harmonic distortion shall exceed 5 %., see 4.9.2.2 of IEC 61892-1:2001.

NOTE 1 It may be necessary to feed sensitive equipment from a power system with a restricted content of harmonics, for example from an uninterruptible power supply (UPS) system.

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

NOTE 3 Electrical equipment which required a higher power quality may need additional provisions to be made locally. Where additional equipment is fitted this higher power quality supply, it may be required to be duplicated and segregated to the same degree as the electrical equipment it supplies

NOTE 4 Special attention should be paid to the installation of electrical equipment which may influence the quality of power supply on local basis or react with any harmonics present on the general distribution system.

NOTE 5 Further information regarding harmonics, see IEC 61000-2-4.

10 Protection

10.1 General

10.1.1 Electrical installations shall be protected against accidental over-current, up to and including short-circuit, by appropriate devices. Choice, arrangement and performance of the various protection devices shall provide complete and co-ordinated automatic protection in order to obtain:

– continuity of supply;

– or at least continuity of service through discrimination or any other system of co-ordinated action of the protective devices to maintain supply to healthy circuits in the event of a fault elsewhere (see Figure 1);

– elimination of the effects of faults to reduce damage to the system and the hazard of fire as much as possible.

Under these conditions, the elements of the system shall be designed and constructed to withstand the thermal and electrodynamic stresses caused by the possible over-current, including short-circuit, for the admissible duration.

10.1.2 Devices provided for over-current protection shall be chosen according to the requirements, especially with regard to:

– overload;

– short-circuit;

– earth fault as appropriate.

10.2 Characteristic and choice of protective devices with reference to short-circuit rating

10.2.1 General

Protection against short-circuit shall be provided by circuit-breakers or fuses.

NOTE In some cases, and particularly for high voltage a.c. systems, it shall be noted that certain types of fuses have such characteristics for certain over-currents that they shall be arranged to cause an associated switch to trip these over-currents.

10.2.2 Protective devices

Protective devices for short-circuit protection shall conform to the requirements of the IEC standards concerning circuit-breakers and fuses, but it shall be taken into account that the conditions of the unit installations may differ from the conditions foreseen in those publications, in particular with reference to:

– the short-circuit power factor in an a.c. system in a unit, which may be lower than that assumed as a basis for short-circuit rating of normal distribution circuit breakers;

– the sub-transient and transient component of the a.c. short-circuit current;

– the a.c. and d.c. decrement of short-circuit current.

As a consequence, the ratio between rated breaking capacity and the correlated making capacity of circuit-breakers corresponding to the normal conditions of distribution systems may be inadequate.

In such cases, the circuit-breakers shall be chosen with regard to their short-circuit making capacity, even though their available short-circuit breaking capacity, which complies with normal conditions, may be in excess of the one required for the actual application.

When selectivity with downstream breakers are required for low voltage circuit-breakers with short-circuit release, circuit-breakers of utilisation category B (according to IEC 60947-2) shall be used, and shall be selected according to their rated short-time withstand current capacity.

High voltage circuit-breakers shall comply with IEC 62271-100.

NOTE For final circuits, breakers of category A are acceptable.

10.2.3 Back-up protection

The use of a protective device not having a short-circuit breaking or making capacity at least equal to the maximum prospective short-circuit current at the point where it is installed is allowed, provided that it is backed up by a fuse or by a circuit breaker on the supply side, having at least the necessary short-circuit rating and not being the generator circuit-breaker.

For low voltage systems, the short-circuit performance of the arrangement shall at least be equal to the requirements of IEC 60947-2 for a single circuit-breaker having the same short-circuit performance category as the backed up circuit breaker and rated for the maximum prospective short-circuit level at the supply terminal of the arrangement.

For high voltage systems reference shall be made to IEC 62271-100.

When determining the performance requirements for the above-mentioned back-up protection arrangement, it is permitted to take into account the impedance of the various circuit elements of the arrangement, such as the impedance of a cable connection when the backed-up circuit-breaker is located away from the back-up breaker or fuse.

NOTE For low voltage switchgear further information can be found in IEC 60947-2:2003, Annex A.

10.2.4 Rated short-circuit breaking capacity

The rated short-circuit breaking capacity of every device intended for short-circuit protection shall be not less than the maximum prospective current to be broken at that point in the installation, unless when back-up protection is used in accordance with 10.2.3.

10.2.5 Rated short-circuit making capacity

The rated short-circuit making capacity of every mechanical switching device intended to be closed on a short-circuit shall be adequate for the maximum peak value of the prospective short-circuit current at the point of installation (for exceptions see 10.2.3)

The circuit-breaker shall be able to make the current corresponding to its making capacity without opening within a time corresponding to the maximum time delay required.

10.2.6 Co-ordinated choice of protective devices with regard to discrimination requirements

10.2.6.1 Continuity of supply of healthy circuits under short-circuit conditions shall be achieved by total discrimination.

10.2.6.2 Continuity of service is required, and the operating characteristic of protective devices and of the user equipment shall be co-ordinated and verified.

10.2.6.3 The protective devices shall be capable of carrying, without opening, a current not less that the short-circuit current at the point of application for a time required by a total discrimination, and by partial discrimination up to the given short-circuit current level.

10.3 Choice of protective devices with reference to overload

10.3.1 Mechanical switching devices

Mechanical switching devices provided for overload protection shall have a tripping characteristic (over-current-trip time) adequate for the overload ability of the elements of the system to be protected and for any discrimination requirements.

10.3.2 Fuses for overload protection

The use of fuses for overload protection is permitted up to 320 A, provided they have suitable characteristics, but the use of circuit-breakers or similar devices is recommended above 200 A. For high voltage a.c. systems the use of fuses for overload protection is not acceptable.

10.4 Choice of protective devices with regard to their application

10.4.1 General

Overload and short-circuit protection shall be provided in each non-earthed line.

Short-circuit or overload protective devices shall not interrupt earthed lines unless all the non-earthed lines are disconnected at the same time by multipole switching devices.

10.4.2 Generator protection

10.4.2.1 General

Generators shall be protected against short-circuits and overloads by multipole circuit-breakers. In particular, the overload protection shall be adequate for the thermal capacity of the generator.

NOTE 1 For overloads between 10 % and 50 % the circuit-breaker should be tripped with a time delay corresponding to a maximum of 2 min at not more that 1,5 times the rated current of the generator; however, the figure of 50 % and the time delay of 2 min may be exceeded if this is required by the operating conditions, and if the construction of the generator permits it.

NOTE 2 For over-currents in excess of 50 % where “instantaneous” tripping would be required, co-ordination with the discriminative protection of the system should be included.

NOTE 3 The overload capability of the generator should be confirmed in relation to the protection.

NOTE 4 Consideration should be given to the protective arrangements associated with generators to ensure that they are maintained effective even in the case of substantial reduction of speed.

NOTE 5 Consideration should be given to the choice of protective device used for overload protection of generators which will permit the power to be restored immediately after operation of the overload protective device.

10.4.2.2 Protection against short-circuits and fault currents on the generator side

When generators are intended to operate in parallel, it is necessary to take account of fault currents, which would need to be handled by the generator circuit-breakers if a short-circuit were to occur between the generator and its circuit-breaker.

For generators above 2 MVA rating and for all high voltage generators, protection shall be provided against faults on the generator side of the circuit breaker.

Generators shall be equipped with a suitable protective device or system which, in the case of a short-circuit in the generator or in the supply cable between the generator and its circuit-breaker will de-excite the generator and open the circuit-breaker.

NOTE Some generators may not have current transformers in the star point to provide protection against faults on the generator side of the circuit breaker. This arrangement should be subject to agreement with the unit’s owner and the appropriate authority.

10.4.2.3 Reverse power protection for a.c. generators

AC generators arranged for parallel operation shall be provided with time delayed reverse active power protection.

NOTE The setting of protection devices is recommended in the range 2 % to 6 % of the rated power for turbines and in the range of 8 % to 15 % of the rated power for diesel engines.

A fall of 50 % in the applied voltage shall not render the reverse power protection inoperative, although it may alter the amount of reverse power required to open the breaker.

NOTE The reverse power protection may be replaced by other devices ensuring an adequate protection.

10.4.3 Protection of essential services

Where the load consists of essential services and non-essential services, consideration shall be given to an arrangement which will automatically exclude non-essential services when any one generator becomes overloaded and which will function to prevent the overload ability of the generating sets being exceeded.

10.4.4 Protection of transformers

The primary winding of transformers shall be protected against short-circuits by multipole circuit-breakers or by fuses. Circuit breakers for secondary windings shall be provided when transformers are arranged for parallel operation.

Overload protection shall as a minimum be provided in the secondary winding side.

NOTE Where power can be fed into secondary windings, short-circuit protection will need to be considered in the secondary connections.

10.4.5 Circuit protection

10.4.5.1 Each distribution circuit shall be protected against overload and short-circuits by means of multipole circuit-breakers or by fuses, according to the requirements of 10.2 and 10.3.

NOTE Care should be taken to ensure that the protective arrangements remain effective in the case of the smallest generator supplying power in a system using generators arranged for parallel operation.

10.4.5.2 Cables in parallel formed of conductors of nominal cross-section not less than 50 mm^2 should be considered, from the point of view of protection, as a single cable.

10.4.5.3 Circuits supplying consuming devices having individual overload protection for example motors see 10.4.6, or consuming devices which cannot be overloaded (for example permanently wired heating circuits) may be provided with short-circuit protection only.

10.4.5.4 Socket outlets for portable lamps and small domestic appliances shall be protected with 30 mA residual current devices (RCD).

NOTE RCD has limited value for an IT distribution system.

10.4.6 Motor protection

10.4.6.1 Motors having a power rating exceeding 1,0 kW shall be individually protected against overload.

10.4.6.2 For motors intended for essential services, for example motor for fire water pump, an alarm device may replace overload protection.

10.4.6.3 The protective devices shall be designed to allow current to pass during the normal accelerating period of motors according to the conditions corresponding to normal use. When the time-current characteristics of the overload protective device of a motor are not adequate for the starting period of the motor, the overload protecting device may be rendered inoperative during the accelerating period provided that the protection against short-circuits remains operative and that the suppression of the overload protection is only temporary.

10.4.6.4 Protective devices for continuous duty motors shall have a time delay characteristic which ensures reliable thermal protection of the motors for overload conditions.

10.4.6.5 The protective devices shall be set to limit the maximum continuous current to between 105 % and 120 % of the rated current of the protected motor. Special attention shall be paid to ensure that the necessary correct protection settings are selected for motors operational within hazardous areas.

10.4.6.6 For intermittent duty motors, the current setting and the delay characteristic (as a function of time) for protective devices shall be chosen after considering the actual service conditions.

10.4.6.7 When fuses are used to protect polyphase motor circuits, consideration shall be given to protection against single-phasing.

10.4.7 Protection of lighting circuits

Each lighting circuit shall be protected against overload and short-circuit by suitable devices.

10.4.8 Protection of power from external sources

Cables from external power sources to the main, or emergency switchboard shall be protected against overload and short-circuit by fuses or circuit breakers.

NOTE Requirement for shore connection for mobile units is given in 7.7.

10.4.9 Secondary cells and battery protection

Accumulator (storage) batteries, other than engine starting batteries, shall be protected against overload and short-circuits, with device placed as near as practicable to the batteries unless double insulated cable is used. Emergency batteries supplying essential services shall have short-circuit protection only.

NOTE Two single core cables, each with two independent layers of insulation will meet the requirement of double insulated cable.

10.4.10 Protection of meters, pilot lamps and control circuits.

Protection shall be ensured for indicating and measuring devices by means of fuses or circuit breakers

For other circuits, over-current protection in circuits such as those of voltage regulators should be omitted where loss of voltage might have a serious consequence. If over-current protection is omitted, means shall be provided to prevent risk of fire in the unprotected part of the installation.

Over-current protection shall be placed as near as practicable to the tapping from the supply.

10.4.11 Protection of static or solid state devices

Appropriate protection shall be incorporated in the static or solid-state devices for protection of the cells and to protect against the effects of internal short-circuits in the cells.

Protection of the distribution circuit which connects the static or solid state device to the source of power shall be given by means of a circuit-breaker whose tripping characteristics are selected to co-ordinate with melting characteristics of the fuses, if used, so as to ensure protection of the cells against all injurious over-currents.

10.5 Undervoltage protection

10.5.1 Generators

For generators arranged for parallel operation with one another or with a shore power feeder, measures shall be taken to prevent the generator from closing if the generator is not generating and to prevent the generator remaining connected to the busbar if the voltage collapses.

In case of an undervoltage release provided for this purpose, the operation shall be instantaneous when preventing closure of the breaker, but shall be delayed for discrimination purposes when tripping a breaker.

10.5.2 AC and DC motors

10.5.2.1 Motors rated above 1,0 kW shall be provided with either:

a) undervoltage protection, operative on the reduction or failure of voltage, to cause and maintain the interruption of power in the circuit until the motor is deliberately restarted, or

b) undervoltage release operative on the reduction or failure of voltage, but so arranged that the motor restarts automatically and without excessive starting current on restoration of voltage, provided that the start (which may be controlled, e.g. by thermostatic, pneumatic or hydraulic devices) still makes the requisite connection for a restart and that the restarting of all motors does not occur simultaneously if it is necessary to avoid, for example, too large a voltage drop or current surge.

10.5.2.2 The protective devices shall allow the motor to start when the voltage is above 85 % of the rated voltage, and shall without fail operate when the voltage is lower than approximately 20 % of the rated voltage, at rated frequency, and with time delay when necessary.

NOTE Undervoltage protection need not necessarily be provided for motors which have to be continuously available.

10.6 Overvoltage protection

10.6.1 General

Circuits such as generator and external power sources shall be provided with overvoltage protection to avoid damage to the connected equipment.

10.6.2 AC machines

Adequate precautions shall be taken in high-voltage a.c. systems to limit and/or cope with overvoltage due to switching etc. to ensure protection of a.c. machines.

11 Lighting

11.1 General

The design of lighting systems shall be based on safety requirements as well as visibility and visual satisfaction for persons working in the environment. The following guidance lighting levels can be used in the absence of specific authority required levels.

Special consideration shall be made with respect to selection of the light colour with respect to discrimination of colours where required.

The lighting system shall be based on the following separation of the system:

– general lighting system supplied from the main source of electrical power;
– emergency lighting system supplied from the emergency source of electrical power;
– escape lighting system supplied from a battery backup source of electrical power.

The general lighting system can be based on the use of all three above-mentioned systems if all system generally is in use and supplied with power from the main source of electrical power.

The average illumination levels mentioned below are stated as maintained average illuminance, which is understood as the average illumination level at the time where maintenance shall be carried out.

The selection of lighting requirements for operation in potential hazardous areas as per IEC 61892-7 and the philosophy for isolation of ignition sources in case of emergencies shall be complied with.

NOTE It should be possible to vary the lighting level within the control rooms. This is also related to night view in control rooms with windows to the outside.

11.2 General lighting system

The general lighting illumination levels are given in Table 5. Special considerations shall be made for specific work areas such as reading of gauges, meters and the use of visual display units.

Table 5 – General lighting illumination levels

AREA	Normal Lighting		
	Average illuminance E (lux)	Minimum illuminance E (lux)	Maximum illuminance E (lux)
General outdoor areas	50	20	100
General indoor areas, corridors, accommodation etc.	100	40	200
Stairways	150	60	300
Process areas – occasionally manned	150	60	300
Process areas – frequently manned	300	150	450
Drill floor	300	150	450
Control rooms – Laboratories	500	250	750
Engine rooms – Pump rooms	200	80	400
Auxiliary engine rooms	200	80	400
Workshops	300	120	600
Switchboard rooms	300	150	450
Offices	500	250	750
Laundry, galley and mess area	300	120	600
Hospital	300	120	360
Hospital spotlight	1 000	500	1 500
Radio rooms	500	250	750
Emergency hospital (if required)	300	120	360

Verification of the lighting levels shall be made by measurements one meter above floor level in general areas and at actual work places where appropriate levels are required.

NOTE 1 The number of measuring points required for measuring in a given area is based on the area index and must be based on an even grid layout for the whole area.

Area index	Number of points
Below 1	4
1 and up to 2	9
2 and up to 3	16
3 and above	25

The area index is given by the formula:

$k = (a*b)/h(a+b)$

Where k is the area index, a and b are the sides of the room/area and h is the height of luminaires above the work plane.

Any light measurement must be considered in addition to any background light at the place of measurement.

NOTE 2 The initial illumination levels should allow for lamp deterioration and dirt accumulation.

11.3 Emergency lighting system

The emergency lighting level shall, as a minimum be 30 % of the general lighting level requirement. Emergency lighting level shall not be below the escape lighting level requirement as per Table 6.

The location of emergency light fixtures shall be based on the need for light in the emergency operation situation.

The emergency lighting system shall be switched on automatically in the event of failure of the main source of electrical power.

The emergency lighting system shall:

– ensure illumination for safe operation of emergency systems including manual operation areas;
– illuminate all accommodation spaces, control centre, work locations, escape routes; helicopter deck and other possible evacuation locations such as lifeboat stations;
– illuminate the sea where life boats and life rafts are to be launched;
– illuminate the identification system of the unit;
– illuminate all spaces where loss of lighting presents a danger to personnel;
– Illumination systems for control stations that shall be operative under emergency conditions. Hospitals and emergency hospitals, if any, shall be fully operational at all times.

Distribution boards for emergency lighting shall be equipped for remote alarming of tripped circuit to a manned area.

11.4 Escape lighting system

The escape lighting system shall, as a minimum, provide a lighting level to meet the illumination levels given in Table 6. The escape lighting system shall be switched on automatically in the event of failure of the main and emergency power supply.

The location of escape light fixtures shall be based on the need for light in the escape situation.

The escape lighting systems shall:

– have a power supply with minimum 30 min backup time supplied by batteries either integrated or centralised and have a supply from an emergency generator;

  NOTE The backup should take account of the way in which personnel will muster and evacuate a unit, and how such an evacuation is to be carried out; for example by helicopters and their mobilisation time.

– illuminate all accommodation spaces, control centre, work locations, escape routes; helicopter deck and other possible evacuation locations such as lifeboat stations;
– illuminate the sea where life boats and life rafts are to be launched;
– illuminate all spaces where loss of lighting presents a danger to personnel;
– illuminate all locations where operation of safety equipment can be necessary to bring the installation to a safe stage.

Distribution boards for escape lighting shall be equipped for remote alarming of tripped circuit in a manned location.

Table 6 – Escape Lighting illumination levels

AREA	Escape Lighting	
	Average – illuminance E (lux)	Minimum illuminance
General outdoor escape routes	5	1
General indoor escape routes, corridors - Accommodation, etc	5	1
Stairway escape routes	5	1
Process areas - occasionally manned	5	1
Process areas - frequently manned	10	2
Drill floor	20	3
Control rooms	250	125
Engine room - Pump room	10	1
Workshops	10	1
Switchboard rooms	10	2
Offices	10	1
Laundry, galley and mess area	5	1
Hospital	300	120
Hospital spotlight	1000	500
Emergency hospital (if required)	300	120
Radio room	250	125
Loading stations - muster stations	20	3
Overside (sea level)	15	2
Lifeboat - Liferaft stations	20	3
Sea level launching areas	15	2

Verification of the lighting levels shall be made by measurements one meter above floor level in general areas and at actual work places where appropriate levels are required.

NOTE The initial illumination levels should allow for lamp deterioration and dirt accumulation.

11.5 Lighting circuits in machinery spaces, accommodation spaces, open deck spaces, etc.

In spaces such as:

– main and large machinery spaces,
– accommodation spaces,
– large galleys,
– corridors,
– escape routes,
– open deck,

there shall be more than one final circuit for lighting, one of which shall be supplied from the emergency switchboard, in such a way that failure of any one circuit does not reduce the lighting to an insufficient level. Different phases shall be used for supply to adjacent fixtures in those areas to reduce the stroboscopic effect.

Local distribution boards shall be provided for power distribution to the lighting system.

The distribution boards shall be, to the extent possible, located in non-hazardous dry areas.

11.6 Luminaires

11.6.1 Discharge lamp luminaires of voltages above 250 V

Discharge lamp luminaires or installations shall be provided with a multipole disconnecting switch in an accessible location.

Such a switch shall be clearly marked and a warning note shall be placed nearby.

Switches or other current-interrupting devices shall not be installed in the secondary circuit of transformers.

11.6.2 Searchlights

Disconnecting of every searchlight shall be by a multipole disconnecting switch.

12 Control and instrumentation

12.1 Safeguarding

The design of the control equipment shall be such that a failure in the control equipment will lead to the least dangerous condition of the controlled process, and furthermore, such failure shall not render inoperative either, or both, of any reserve automatic or manual controls.

12.2 Supply arrangement

As far as practicable, control and instrumentation circuits and their supply arrangements shall be designed so that failure of the power supply does not damage the installation nor endanger the unit.

12.3 Dependability

Systems shall be suitable for the user, the task and the application. System integrity shall be appropriate for the functions supported, with due regard to factors such as availability, reliability and maintainability.

12.4 Safety

Systems shall be designed such that risk of harm to persons, the environment or the facility is reduced to a level acceptable to the appropriate authority, both in normal operation and under failure conditions. Functions shall be designed on the fail-to-safe principle.

12.5 Segregation

Systems shall be designed such that failure of one component part or sub-system will not unduly affect any other system, sub-system or component and, as far as is practicable, shall be detectable.

Protection (safety) functions shall be independent of control and monitoring (alarm) functions. As far as is practicable, control and monitoring (alarm) functions shall also be independent.

Standby systems, or other redundancy arrangements, are to be functionally independent.

12.6 Performance

Systems shall maintain specified levels of performance in operation, and where necessary, under fault conditions.

Repeatability and accuracy shall be adequate for the proposed use and shall be maintained at their specified value during their expected lifetime and normal use.

Systems shall be stable throughout their operational range.

12.7 Integration

Where safety of personnel may directly depend on correct system operation or failure, such systems shall not be integrated with, or be mutually dependent upon, any other system, except those providing complementary functions.

Where safety may indirectly depend on system operation or failure, the integrity of the integrated system shall be to the satisfaction of the appropriate authority.

12.8 Development activities

Activities undertaken in the development process, from initial design through to eventual realisation, and any modifications in use thereafter, shall be planned and structured in a systematic manner, and are to be properly managed. Persons responsible for carrying out these activities shall be competent to do so.

12.9 Electromagnetic compatibility

For equipment in general, electromagnetic compatibility shall be achieved. For general consideration in this context reference shall be made to IEC 60533.

12.10 Design

12.10.1 Environmental and supply conditions

Equipment shall be designed to operate satisfactorily within the expected environmental and supply conditions, with due regard to the limits specified in Annex B of IEC 60092-101.

12.10.2 Circuit design

Circuits shall be designed to enable efficient test, calibration, maintenance and repair. Preferably, they shall be suitable for repair by unit or card replacement. In some cases, it may be desirable to provide simulation circuits or similar means to check correct operation of the equipment.

12.10.3 Monitoring equipment

Alarm system installations may be combined with monitoring equipment, such as equipment provided with analogue read-outs of measured variables, or with data loggers, or alarm data printers.

12.10.4 Time delays

Alarm channels, where necessary, shall be provided with suitable time delays.

12.10.5 Closed circuits

Normally closed circuits shall be used to prevent non-indication of an alarm due to a broken sensor loop. Alternatively, open circuits may be used, if they are monitored for sensor circuit faults.

12.10.6 Earth faults

Earth fault(s) in alarm sensor circuits shall cause the alarm to operate, or to be indicated in an alternative manner, or otherwise not prevent indication of alarm(s).

12.11 Installation and ergonomics

12.11.1 General

12.11.1.1 Layout

Control positions shall be ergonomically arranged for the convenience of the operator and hence the accuracy and safety of the operation.

Area or group identification shall be considered, especially in complex layouts, for example adequate spacing between display and control groups.

12.11.1.2 Compatibility

The arrangements of indicating instruments and control shall follow a logical sequence. As far as possible, operating movements and the resulting movements of the indicating instruments shall be consistent with each other.

12.11.1.3 Illumination

Instruments and controls shall be illuminated so that they can be clearly read and operated in all ambient light conditions under which they are intended to be operated, without having uncomfortable shadow or glare. If the surrounding illumination makes it difficult to detect an indicator light, a suitable shade shall be provided.

12.11.2 Remote controls

12.11.2.1 Continuous information

At the remote control station, the user shall receive continuous information on the effects of his orders.

12.11.2.2 Independent control

Where control may be effected from more than one location, the failure of any control equipment at one location shall not affect the ability to control from any other location.

12.11.2.3 Exclusive control

Where a process may be controlled from several locations, only one shall be in control of that process at any time.

12.11.2.4 Transfer of control

Actual control shall not be transferred before being acknowledged by the receiving command location unless the command locations are located close enough to allow direct visual and audible contact. Transfer of control shall give audible pre-warning.

12.11.2.5 Main control location

Where a designated main command location is required for operational or safety reasons, or by the appropriate authority; this location shall have the capability to take control without acknowledgement.