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Low-voltage electrical installations - Part 1: Fundamental principles, assessment of general characteristics, and definitions

Installations électriques à basse tension - Partie 1: Principes fondamentaux, détermination des caractéristiques générales et définitions

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

Low-voltage electrical installations - Part 1: Fundamental principles, assessment of general characteristics, and definitions

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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IEC 60364-1 has been prepared by IEC technical committee 64: Electrical installations and protection against electric shock. It is an International Standard.

This sixth edition cancels and replaces the fifth edition published in 2005. This edition constitutes a technical revision.

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

a) the entire document has been restructured and renumbered, maintaining the numbering of the (sub)clauses which are preceded with the part number, i.e. 1.1, 1.2, etc.;
b) the scope has been expanded to include new areas of application and has been restructured;
c) in 1.5.2.2.2, the topic of safety services and standby electric supply systems has been added;

d) in 1.5.2.14, the topic of energy efficiency has been included;

e) in 1.5.2.15, the topic of prosumer electrical installations has been included;

f) in 1.5.3.5, the requirement for an equivalent safety level for the use of new materials and innovations for which no product standards exist yet has been added;

g) in 1.5.4.3, the recommendation to assess the effectiveness of protective measures for the safety of human beings and livestock to be maintained by periodic verification during the entire lifetime of the installation has been added;

h) Table 3 shows the symbol for the newly introduced "system-referencing-conductor (SRC)";

i) the number of figures showing the type of electric system in AC and DC systems is limited to illustrate requirements.

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

Draft	Report on voting
64/2760/FDIS	64/2776/RVD

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

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

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

A list of all parts in the IEC 60364 series, published under the general title *Low-voltage electrical installations*, can be found on the IEC website.

The reader's attention is drawn to the fact that Annex B lists all of the "in-some-country" clauses on differing practices of a less permanent nature relating to the subject of this document.

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

- reconfirmed,
- withdrawn, or
- revised.

1.1 Scope

1.1.1 Scope of this document

This part of IEC 60364 defines the scope and objective of the IEC 60364 series and specifies the fundamental safety requirements for an electrical installation.

This document addresses the fundamental principles, assessment of general characteristics and definitions of low-voltage electrical installations.

1.1.2 Scope of the IEC 60364 series

The IEC 60364 series specifies the rules for the design, erection, and verification of low-voltage electrical installations. The rules are provided for the safety of human beings (persons), livestock and property against dangers and damage which can arise from the intended use of low-voltage electrical installations and for the proper functioning of those installations.

EXAMPLE A non-comprehensive list of electrical installations or systems includes:

- residential premises;
- commercial premises;
- public premises;
- industrial premises;
- agricultural and horticultural premises;
- prefabricated buildings;
- caravans, caravan sites and similar sites;
- construction sites, exhibitions, fairs and other installations for temporary purposes;
- marinas;
- external lighting and similar installations;
- medical locations;
- mobile or transportable units;
- photovoltaic systems;
- stationary secondary batteries;
- low-voltage generating sets;
- temporary connected batteries (e.g. electric vehicle).

NOTE 1 "Premises" covers the land and all facilities including buildings belonging to it.

The IEC 60364 series covers

- electrical installations with nominal voltages not exceeding 1 000 V AC or 1 500 V DC; for AC, the preferred frequencies which are taken into account in this document are 50 Hz and 60 Hz. The use of other frequencies is not excluded;
- circuits, other than the internal wiring of apparatus, operating at voltages exceeding 1 000 V AC or 1 500 V DC and derived from an installation having a nominal voltage not exceeding 1 000 V AC or 1 500 V DC, for example, discharge lighting, electrostatic precipitators;
- fixed wiring for information and communication technology (ICT), signalling, etc., including installation and support of fibre optic cables;
- wiring systems and cables not specifically covered by the standards for appliances.

The IEC 60364 series applies to:

– a new installation; and
– an addition or alteration to an installation; and
– parts of an existing installation affected by an addition or alteration; and
– the design of functional aspects, such as energy efficiency, local production and storage of energy (prosuming).

The IEC 60364 series applies to any kind of low-voltage electrical installation or system, except:

a) electric traction equipment, including rolling stock and signalling equipment;
b) electric circuits and electrical equipment for automotive purposes within motor vehicles;
c) electrical installations of ships and of mobile and fixed offshore units;
d) electrical installations in aircraft;
e) public street-lighting installations which are part of the public electric power network;
f) installations in mines and quarries.

Electrical equipment is dealt with only in so far as its selection and application in the installation are concerned.

The IEC 60364 series does not apply to the selection and erection of the following electrical equipment:

1) radio interference suppression equipment, except where it affects the safety of the installation;
2) electric fences;
3) external lightning protection systems for buildings (LPS);

NOTE 2 Atmospheric phenomena are covered in IEC 60364-1 but only in so far as effects on the electrical installations are concerned (e.g. with respect to the selection of surge protective devices).

4) electrical equipment of machines.

The IEC 60364 series is not intended to apply to low-voltage public distribution networks.

1.2 Normative references

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

IEC 60050-195, *International Electrotechnical Vocabulary (IEV) - Part 195: Earthing and protection against electric shock,* available at https://www.electropedia.org

IEC 60050-826, *International Electrotechnical Vocabulary (IEV) - Part 826: Electrical installations,* available at https://www.electropedia.org

1.3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-195, IEC 60050-826 and the following apply.

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

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

1.3.1
diversity
<of electric load> prospective simultaneous demand of a group of electric loads

1.3.2
generating set
<in an electrical installation> equipment converting non-electrical energy into electrical energy

1.4 Structure of the IEC 60364 series

The IEC 60364 series consists of six main parts:

– IEC 60364-1 (this document): Fundamental principles, assessment of general characteristics and definitions

  This document defines the scope and objective of the IEC 60364 series and specifies the fundamental safety requirements for an electrical installation.

– IEC 60364-4 series: Protection for safety

  These documents specify the requirements for protection, taking into account the fundamental safety requirements given in this document.

– IEC 60364-5 series: Selection and erection of equipment

  These documents specify requirements for the selection and erection of electrical equipment to fulfil the safety requirements of the IEC 60364-4 series and the fundamental safety requirements given in this document.

– IEC 60364-6: Verification

  This document specifies the requirements for verification and testing to show compliance with the requirements of the other parts of the IEC 60364 series. Requirements for reporting the verifications and testing are also given.

– IEC 60364-7 series: Requirements for special installations or locations

  These documents specify specific requirements for special installations or locations. These requirements either modify, replace or complement the requirements of the other parts of the IEC 60364 series.

– IEC 60364-8 series: Functional aspects

  These documents specify requirements related to functional aspects only. However, these requirements can impact the safety requirements of the other parts of the IEC 60364 series.

Annex A gives additional information on the structure.

1.5 Fundamental principles

1.5.1 Protection for safety

1.5.1.1 General

The requirements stated in 1.5.1.2 to 1.5.2.8 are intended to provide for the safety of human beings, livestock and property against dangers and damage which can arise from the intended use of an electrical installation, including its connected current-using equipment, under all operating conditions. The requirements to provide for the safety of livestock are applicable in locations intended for them.

NOTE In electrical installations, hazards that can arise include:

– electric shock;
– excessive temperatures likely to cause burns, fires and other harmful effects;
– ignition of a potentially explosive atmosphere;
– undervoltages, overvoltages and electromagnetic influences likely to cause or result in injury or damage;
– power supply interruptions or interruption of safety services;
– arcing likely to cause fire, burns or blinding effects, excessive pressure, or toxic gases;
– mechanical movement of electrically activated equipment.

1.5.1.2 Protection against electric shock

1.5.1.2.1 Basic protection

Protection shall be provided against dangers to human beings and livestock that can arise from contact with live parts.

This protection may be achieved by one of the following methods:

– preventing a current from passing through the body of a human being or livestock;
– limiting the current which can pass through a body to a non-hazardous value.

1.5.1.2.2 Fault protection

Protection in the event of a fault shall be provided against dangers to human beings and livestock that can arise from contact with exposed-conductive-parts.

This protection may be achieved by one, or a combination, of the following methods:

– preventing a current resulting from a fault from passing through the body of a human being or livestock;
– limiting the magnitude of a current resulting from a fault, which can pass through the body of a human being or livestock, to a non-hazardous value;
– limiting the duration of a current resulting from a fault, which can pass through the body of a human being or livestock, to a non-hazardous time period.

1.5.1.2.3 Additional protection

In cases where basic protection and fault protection is not considered sufficient for the protection of human beings and livestock, additional protection shall be provided.

1.5.1.3 Protection against thermal effects

The electrical installation shall be arranged so that human beings, livestock, property and the environment adjacent to the electrical equipment are protected against harmful thermal effects caused by the electrical equipment and their connections.

EXAMPLE Thermal effects can be the following:

– combustion;
– degradation of materials;
– electric arcing;
– burns resulting from high temperatures.

1.5.1.4 Protection against overcurrent

Human beings and livestock shall be protected against injury, and property shall be protected against damage due to excessive temperatures or electromechanical stresses caused by overcurrent likely to arise in conductors.

Protection may be achieved by limiting overcurrent to a safe value or duration, or both.

1.5.1.5 Protection against fault current

Human beings and livestock shall be protected against injury, and property shall be protected against damage caused by fault current.

Protection may be achieved by:

– limiting fault current to a safe value; or
– limiting the duration of the fault current.

1.5.1.6 Protection against voltage disturbances

Human beings and livestock shall be protected against injury, and property shall be protected against any harmful effects, as a consequence of a fault between live parts of circuits supplied at different voltages.

Human beings and livestock shall be protected against injury, and property shall be protected against damage, as a consequence of overvoltages such as those originating from atmospheric events or from switching.

Human beings and livestock shall be protected against injury, and property shall be protected against damage, as a consequence of undervoltage and any subsequent voltage recovery.

1.5.1.7 Protection against power supply interruptions

Where danger or damage is foreseen to arise due to an interruption of the power supply, provisions shall be made in the installation or installed equipment.

1.5.1.8 Protection against the effects of electromagnetic interference

The installation shall have an adequate level of immunity against electromagnetic disturbances.

Consideration shall be given to any anticipated electromagnetic emission generated by the installation or installed equipment.

1.5.2 Design

1.5.2.1 General

For the design of the electrical installation, the following shall be taken into account:

– the protection of human beings, livestock and property in accordance with 1.5.1;
– the proper functioning of the electrical installation for the intended use;
– the foreseeable future needs (e.g. increased capacity, energy storage possibilities).

The information required as a basis for design is listed in 1.5.2.2 to 1.5.2.5. The requirements with which the design shall comply are stated in 1.5.2.6 to 1.5.2.13. Other aspects to be considered are given in 1.5.2.14 to 1.5.2.19.

The electrical installations shall be designed so that the operation of a device or the insertion of an external connection cannot intentionally create a fault.

1.5.2.2 Power supplies

1.5.2.2.1 Characteristics of power supplies

In order to design a safe installation, relevant characteristics of the power supply or power supplies are required. The characteristics of a power supply shall be determined by calculation, measurement or enquiry (e.g. from the distribution system operator, manufacturer). Changes to the characteristics of a power supply can affect the safety of the installation.

EXAMPLE A supply can be a network, generators, power converter equipment, inverters, transformers.

The following characteristics, as applicable, shall be determined:

a) nature of current: alternating current or direct current, or both;
b) function of conductors:
   1) for alternating current:
      i) line conductor(s);
      ii) neutral conductor;
      iii) mid-point conductor;
      iv) protective conductor;
   2) for direct current:
      i) line conductor(s);
      ii) mid-point conductor;
      iii) protective conductor;

   The function of some conductors may be combined in a single conductor.
c) the presence of galvanic separation;
d) values and tolerances:
   1) voltage and voltage tolerances;
   2) voltage interruptions, voltage fluctuations and voltage dips;
   3) frequency and frequency tolerances;
   4) maximum allowable current;
   5) prospective short-circuit currents;

   NOTE 1 For voltages and frequencies, see IEC 60038.
e) protective provisions inherent in the power supply;
f) bi-directional energy flow;

g) particular requirements of the operator of the supply network, e.g. distribution system operator (DSO).

NOTE 2 In some countries, a DSO is also referred to as a distribution network operator (DNO).

1.5.2.2.2 Electric supply systems for safety services and standby electric supply systems

Where the provision of safety services or a standby system are required, the characteristics of the sources of the power supply for these systems shall be assessed separately. Such supplies shall have adequate capacity, reliability and rating and appropriate change over time for the operation specified.

NOTE 1 Safety services can be required by the authorities concerned with fire precautions and other conditions for emergency evacuation of the premises, or by the person specifying the installation.

NOTE 2 Standby supplies can be required by the person specifying the installation.

Where there is an electric supply system for safety services or a standby electric supply system, all of the following shall be determined:

– source of power supply;
– circuits to be supplied by the electric source for safety services;
– circuits to be supplied by the standby electric source.

1.5.2.3 Nature of demand

The demand of the installation shall be determined to facilitate an energy-efficient, economic, reliable and safe design.

Based on the demand, the number and type of circuits required shall be determined by:

– location of points of power demand;
– loads to be expected on the various circuits;
– sources to be expected on the various circuits;
– pattern of an individual demand;
– daily and yearly variation of demands;
– diversity (1.3.1);
– any special conditions such as harmonics;
– requirements for control, signalling, information and communication technology, etc;
– electrical energy efficiency;
– anticipated future demand if specified.

1.5.2.4 External influences

The design of the electrical installation shall take into account the external influences to which it will be subjected.

1.5.2.5 Cross-sectional area of conductors

The cross-sectional area of conductors shall be determined considering both normal operating conditions and fault conditions, taking into account:

a) their specified maximum temperatures;

b) the voltage drop;

c) the electromechanical stresses likely to occur due to overcurrents;

d) other mechanical stresses to which the conductors can be subjected;

e) the maximum impedance with respect to the functioning of the protection against fault currents;

f) the method of installation;

g) the harmonic currents;

h) energy efficiency.

1.5.2.6 Type of wiring and methods of installation

For the choice of the type of wiring and the methods of installation, the following shall be taken into account:

– characteristics of the locations;

– characteristics of the structure supporting the wiring;

– accessibility of wiring to human beings and livestock;

– voltage;

– the electromechanical stresses likely to occur due to overcurrents;

– electromagnetic interference;

– external influences to which the wiring can be subjected during the erection of the electrical installation or when in service.

1.5.2.7 Protective equipment

The characteristics of protective equipment shall be determined with respect to its function, for example, the protection against the effects of:

– overload current;

– short-circuit current;

– earth fault current;

– overvoltage;

– undervoltage and no voltage;

– arcs.

The protective equipment shall operate at values of current, voltage and time which are suitably related to the characteristics of the circuits, including determination of unidirectional or bidirectional current flow, and to the possibilities of danger.

1.5.2.8 Emergency switching off

Where, in case of danger, there is the necessity for the immediate interruption of the power supply to current-using equipment or to a part of the installation, an interrupting device shall be installed to disconnect the current-using equipment or part of the installation from all sources in the installation. The interrupting device shall be installed in such a way that it can be easily recognized and effectively and rapidly operated.

1.5.2.9 Isolation

Devices shall be provided for the isolation of the electrical installation, circuits or individual items of electrical equipment as required for inspection, maintenance, repair and fault correction.

1.5.2.10 Functional switching

Devices shall be provided for the switching of the electrical installation, circuits or individual items of electrical equipment as required for normal operation.

1.5.2.11 Prevention of mutual detrimental influence

The electrical installation shall be arranged in such a way that no mutual detrimental influence will occur between electrical installations and non-electrical installations. Electromagnetic interference shall be taken into account.

1.5.2.12 Accessibility of electrical equipment

The electrical equipment shall be arranged to provide:

– sufficient space for the initial installation and later replacement of individual items of electrical equipment;

– accessibility for operation, inspection, testing, commissioning, fault detection, maintenance and repair.

1.5.2.13 Additions and alterations to an installation

No addition or alteration, temporary or permanent, shall be made to an existing installation, unless it has been ascertained that the rating and the condition of any existing associated equipment will be adequate for the altered circumstances. Furthermore, the earthing and bonding arrangements, if necessary for the protective measure applied for the safety of the addition or alteration, shall be adequate.

1.5.2.14 Electrical energy efficiency

During design and erection of low-voltage electrical installations, consideration shall be given to optimizing the use of electric energy of the installation, i.e. the electrical energy efficiency, including features for local production and storage of electric energy.

1.5.2.15 Local production and storage of electric energy (prosumer)

Systems for local production and systems for storage of electric energy shall be considered. Where such systems are utilized in parallel with other sources, the operating modes shall be considered.

1.5.2.16 Communication means

Where a communication means is installed to control equipment of the installation and is connected to an information and communication technology (ICT) system external to the electrical installation (e.g. circuit-breaker, smart meter, energy management system, building management system), cybersecurity shall be considered.

1.5.2.17 Documentation for the electrical installation

Every electrical installation shall be provided with appropriate documentation.

NOTE Documentation for the installation can be stored in an electronic format.

1.5.2.18 Division of installation

Every installation shall be divided into circuits, as necessary, to:

- avoid danger and minimize inconvenience in the event of a fault;
- facilitate safe inspection, testing and maintenance;
- take into account any danger that can arise from the failure of a single circuit;
- reduce the possibility of unwanted tripping of RCDs due to excessive currents flowing in the protective conductor under normal conditions;
- mitigate the effects of electromagnetic interferences (EMI);
- facilitate the implementation of electrical energy efficiency measures;
- allocate circuits for a specific purpose.

Circuits shall be arranged so as to prevent indirect energizing of circuits intended to be isolated.

1.5.2.19 Signs and notices

Where necessary for safety purposes, suitable warning signs or notices, or both, shall be provided.

Signs shall be provided to identify distribution board(s) and circuit(s) intended to remain live in the event of loss of a power supply.

1.5.3 Selection of electrical equipment

1.5.3.1 General

Every item of electrical equipment used in electrical installations shall comply with the appropriate IEC standard.

Where there are no appropriate standards, the item of equipment concerned shall be selected by agreement between involved parties. The involved parties shall confirm that the equipment provides at least the same degree of safety as that afforded by compliance with the IEC 60364 series. Such use shall be recorded in the appropriate documentation.

Except for testing purposes, equipment shall not include components or devices that intentionally create a fault, for example to operate a protective device.

1.5.3.2 Characteristics

1.5.3.2.1 General

Every item of electrical equipment selected shall have suitable characteristics appropriate to the values and conditions on which the design of the electrical installation (see 1.5.2) is based and shall, in particular, fulfil the requirements in 1.5.3.2.2 to 1.5.3.2.5.

1.5.3.2.2 Voltage

Electrical equipment shall be suitable for the nominal voltage of the installation (DC value or AC RMS value) as well as overvoltages likely to occur.

In an IT system, single-phase equipment shall be suitable for the line-to-line voltage.

For certain equipment, it can be necessary to take account of the lowest voltage likely to occur.

1.5.3.2.3 Current

All electrical equipment shall be selected with respect to:

– the maximum current which it has to carry in normal conditions,

– the current likely to be carried in abnormal conditions and the expected duration of the current flow (e.g. limited by the operating time of a protective device).

1.5.3.2.4 Frequency

Equipment shall be suitable for the frequencies likely to occur in the circuit.

1.5.3.2.5 Power

Equipment selected for its power characteristics shall be suitable for all intended operational conditions taking into account the diversity of the loads.

For the diversity, consideration shall be given to all operating modes, i.e. short-term operation, intermittent operation, cyclic operation, and continuous operation and the simultaneous use of one item of electrical equipment with other items of electrical equipment.

1.5.3.3 External influences

Electrical equipment shall be selected so as to withstand safely the stresses to which it can be subjected, caused by the external influences (see 1.5.2.4). If, however, an item of equipment does not have by design the properties corresponding to its location, it may be used on condition that it is provided with appropriate protection during the erection of the installation.

1.5.3.4 Prevention of harmful effects

Electrical equipment shall be selected so that it will not cause harmful effects on other equipment or impair the power supply during normal service including switching operations. In this context, the factors which can have an influence include, for example:

– power factor;

– inrush current;

– asymmetrical load;

– harmonics;

– transient overvoltages generated by equipment in the installation;

– electromagnetic interference (EMI).

1.5.3.5 New materials, inventions and innovations

The degree of safety of installations using new materials, inventions, innovations or methods shall not be less than that obtained by compliance with the IEC 60364 series.

1.5.4 Erection and verification of electrical installations

1.5.4.1 Erection

1.5.4.1.1 Good workmanship by electrically skilled persons or electrically instructed persons, competent in such work, and proper materials shall be used in the erection of the electrical installation. The installation of electrical equipment shall take account of manufacturers' instructions.

1.5.4.1.2 The characteristics of the electrical equipment, as determined in accordance with 1.5.3.2, shall not be impaired during erection.

1.5.4.1.3 Electrical equipment shall be installed in such a manner that the temperature limits specified for the design are not exceeded.

1.5.4.1.4 All electrical equipment likely to cause high temperatures or electric arcs shall be placed or guarded so as to minimize the risk of ignition of flammable materials. Where the temperature of any exposed parts of electrical equipment is likely to cause injury to human beings or livestock, those parts shall be so located or guarded as to prevent accidental contact therewith.

1.5.4.1.5 Measures shall be taken to avoid incorrect connection of circuits, e.g. conductor function.

1.5.4.1.6 Connections between conductors, and between conductors and other electrical equipment, shall be made in such a way that contact is safe and reliable.

1.5.4.1.7 The intended function of a conductor shall be identified at least at its terminations and should be identified throughout its length.

1.5.4.2 Initial verification

Electrical installations shall be verified to confirm that the installation complies with the requirements of the IEC 60364 series. The initial verification shall be carried out on a new installation, before it is put into service. For an addition or alteration to an existing installation, initial verification shall be applied to the part of the installation affected by the addition or alteration. The results of the verification shall be recorded in appropriate documentation.

1.5.4.3 Periodic verification

An electrical installation should be subjected to periodic verification:

– to assess the effectiveness of the protective measures; and
– to evaluate the condition of the electrical installation.

The results of the verification shall be recorded in appropriate documentation.

1.6 Assessment of general characteristics

An assessment shall be made of the following characteristics of the electrical installation:

– the purposes for which the electrical installation is intended to be used, its general structure and its power sources;
– the external influences to which it is exposed;
– the compatibility of its electrical equipment;
– its maintainability;
– the necessity for continuity of service;
– cybersecurity for equipment having communication means.

Those characteristics shall be taken into account with respect to:

– the design of the electrical installations;
– the choice of methods of protection for safety;
– the selection and erection of electrical equipment.

1.7 Electrical installations

1.7.1 General structure of an electrical installation

An electrical installation is defined as an assembly of electrical equipment to fulfil specific purposes. The definition does not restrict the term for a particular purpose.

An electrical installation can consist of one or more of the following:

– production of electric energy, e.g. sources;
– distribution of electric energy, e.g. distribution network;
– use of electric energy, e.g. loads.

An electrical installation can contain equipment for all three purposes, thus be independent from any other electrical installations. In many cases, an electrical installation does not contain equipment for the production of electric energy, thus that installation is dependent on energy supply from an external installation, for example being supplied from a distribution network of a utility.

Some types of electrical equipment can operate either as current-using equipment or as a source (e.g. battery storage systems).

1.7.2 Maximum demand and diversity

For economic and reliable design of an installation, the maximum demand shall be determined. In determining the maximum demand of an installation or part thereof, diversity can be taken into account.

1.8 Conductor arrangement

1.8.1 General

The following characteristics shall be determined:

– arrangements of live conductors under normal operating conditions;
– arrangement of the earthing of the system.

NOTE 1 In Figure 9 to Figure 19 illustrating AC systems, the colours used for the line conductors are brown for L1, black for L2 and grey for L3. According to IEC 60445, the colours applied do not indicate phase sequence.

NOTE 2 In Figure 20 to Figure 29 illustrating DC systems, the colour used for the positive line conductors, L+, is red in accordance with IEC 60445. According to IEC 60445, the colour designation of the negative line conductor, L-, is white. White is not visible on a white background, therefore, the colour used is black.

1.8.2 Live conductors

1.8.2.1 Live conductors in AC circuits

Figure 1 to Figure 6 show different combinations of live conductors in AC systems.

Live conductors in AC systems can be arranged as:

– single-phase two-wire with:
  - two line conductors (see Figure 1); or
  - a line and a neutral conductor derived from a three-phase four-wire system (see Figure 2);
– single-phase three-wire with two line conductors and mid-point conductor, phase angle 0° (line conductors out of phase by 180° with respect to the mid-point) (see Figure 3);

– two-phase three-wire with different phase angles (see Figure 4);
– three-phase three-wire with star or delta connection of the source (see Figure 5); or
– three-phase four-wire (see Figure 6).

Figure 1 – Single-phase two-wire system with two line conductors

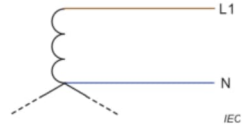


Figure 2 – Single-phase two-wire system derived from a three-phase four-wire system

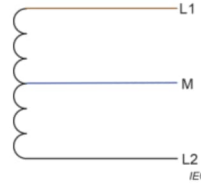
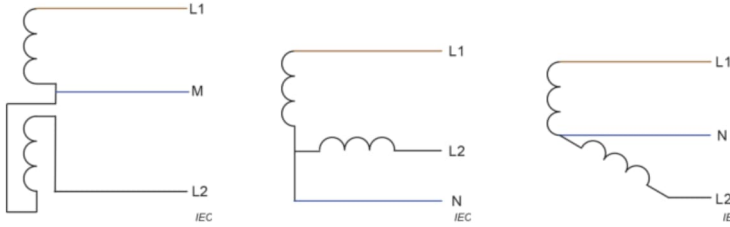


Figure 3 – Single-phase three-wire system



a) Phase angle 180° **b) Phase angle 90°** **c) Phase angle 120°**

NOTE The winding symbols in the drawings are positioned to illustrate the different phase angles.

Figure 4 – Two-phase three-wire system

a) Star connection

b) Delta connection

Figure 5 – Three-phase three-wire system

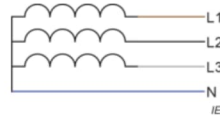


Figure 6 – Three-phase four-wire system

In installations where the loads are connected between lines, it is possible that the distribution of a neutral conductor is not necessary.

1.8.2.2 Live conductors in DC circuits

Live conductors in DC systems can be arranged as:

– two-wire with two line conductors (see Figure 7);

– three-wire with two line conductors and a mid-point conductor (see Figure 8).

NOTE In this document the source of supply for DC systems is illustrated by using a converter-symbol with the indication that the secondary side is DC. The symbol also indicates that the DC system is electrically separated from any other system. The source for the DC system can be any kind of DC supply and is not considered relevant for this document.

Figure 7 – Two-wire system

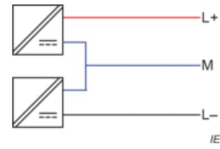


Figure 8 – Three-wire system

1.8.3 Protective conductors

1.8.3.1 General

Protective conductors are those conductors used for protective purposes. Protective conductors are classified into:

– protective earthing conductors;
– protective bonding conductors.

In a protective conductor the electrical continuity shall be maintained. Accordingly, no switching device shall be inserted.

1.8.3.2 Protective earthing conductors

1.8.3.2.1 General

Protective earthing conductors are those protective conductors used for protective earthing purposes.

The protective earthing conductor may be provided with multiple connections to earth.

1.8.3.2.2 PEN conductors

A PEN conductor is a conductor where the function of a protective earthing conductor is combined with the function of a neutral conductor. By definition, the PEN is not a live conductor but a conductor carrying an operating current.

1.8.3.2.3 PEL conductors

A PEL conductor is a conductor where the function of a protective earthing conductor is combined with the function of a line conductor. By definition, the PEL is not a live conductor but a conductor carrying an operating current.

1.8.3.2.4 PEM conductors

A PEM conductor is a conductor where the function of a protective earthing conductor is combined with the function of a mid-point conductor. By definition, the PEM is not a live conductor but a conductor carrying an operating current.

1.8.3.3 Protective bonding conductors

Protective bonding conductors are those protective conductors provided between conductive parts intended to achieve equipotentiality between those parts for the purposes of safety.

1.8.4 System-referencing-conductors

A system-referencing-conductor (SRC) is a conductor between a live part and an earthing arrangement, enabling the live part to be substantially at the potential of the earthing arrangement. The SRC is neither a neutral conductor nor a protective conductor.

NOTE The application of SRC, shown in Figure 9, Figure 10, Figure 11, Figure 12 and Figure 13, is given to help define the characteristic behaviour of the electric systems.

1.9 Types of electric systems

1.9.1 General

Electric systems are described in accordance with the following:

First letter – Indicates how live parts of the electric system are related to earth:

T = one live part is directly connected to earth;

I = all live parts are isolated from earth, or one live part is connected to earth through a high impedance.

Second letter – Indicates how exposed-conductive-parts are earthed:

T = exposed-conductive-parts are connected to earth, independent of the earthing of the live parts of the electric system;

N = exposed-conductive-parts are connected to the earthed point where the live parts are connected to earth.

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

S = live conductors and protective earthing conductors are separated from each other;

C = the function of a live conductor is combined with the function of a protective earthing conductor to form a single PEN, PEM or PEL conductor.

The connection of live parts to earth can be provided on either side of a converter that does not provide electrical separation.

The types of electric systems considered for AC installations are shown in Table 1 and those considered for DC installations are shown in Table 2.

Table 3 shows the symbols used to indicate conductor functions.

Table 1 – Types of electric systems considered for AC installations

Electric system		Live parts relationship to earth	Arrangement of live conductors and protective earthing conductors	Earthing of exposed-conductive-parts where necessary
TN	TN-C	The neutral conductor, the mid-point conductor or a line conductor is connected to earth via the system-referencing-conductor (SRC).	The neutral conductor, mid-point conductor or a line conductor is combined with the protective earthing conductor in one common PEN, PEM or PEL conductor.	Exposed-conductive-parts are connected via protective earthing conductors to the same earthing arrangement to which the SRC is connected.
	TN-C-S		From the source, the neutral conductor, mid-point conductor or a line conductor is combined with the protective earthing conductor in one common PEN, PEM or PEL conductor. Then, at a certain point, the neutral conductor, the mid-point conductor or the line conductor is separated from the protective earthing conductor.	
	TN-S		Live conductors and protective earthing conductors are kept separate throughout the system except for the connection of the SRC.	

Electric system	Live parts relationship to earth	Arrangement of live conductors and protective earthing conductors	Earthing of exposed-conductive-parts where necessary
TT	The neutral conductor, the mid-point conductor or a line conductor is connected to earth via the SRC.	Live conductors and protective earthing conductors are kept separate throughout the system. Protective earthing conductors are not connected to the earthing point at the source. Protective earthing conductors are not supplied from the source.	Exposed-conductive-parts are connected to an earthing arrangement that is electrically independent of the earthing arrangement to which the SRC is connected.
IT	The live conductors are isolated from earth, or one live conductor is connected to earth through a high impedance.	Live conductors and protective earthing conductors are kept separate throughout the system.	Exposed-conductive-parts are connected to an earthing arrangement provided in the installation.

Figure 9 to Figure 19 show examples of commonly used three-phase systems. The sources illustrated show the secondary side of a transformer.

Table 2 – Types of electric systems considered for DC installations

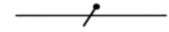
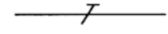
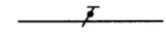
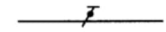
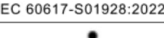
Electric system		Live parts relationship to earth	Arrangement of live conductors and protective earthing conductors	Earthing of exposed-conductive-parts where necessary
TN	**TN-C**	The mid-point conductor or a line conductor is connected to earth via the system-referencing-conductor (SRC).	The mid-point conductor or a line conductor is combined with the protective earthing conductor in one common PEM conductor or PEL conductor.	Exposed-conductive-parts are connected via protective earthing conductors to the same earthing arrangement to which the SRC is connected.
	TN-C-S		From the source, the mid-point conductor or a line conductor is combined with the protective earthing conductor in one common PEM conductor or PEL conductor. Then, at a certain point, the mid-point conductor or line conductor is separated from the protective earthing conductor.	
	TN-S		Live conductors and protective earthing conductors are kept separate throughout the system except for the connection of the SRC.	
TT		The mid-point conductor or a line conductor is connected to earth via the SRC.	The mid-point conductor and protective earthing conductors are kept separate throughout the system. Protective earthing conductors are not connected to the earthing point at the source. Protective earthing conductors are not supplied from the source.	Exposed-conductive-parts are connected to an earthing arrangement that is electrically independent of the earthing arrangement to which the SRC is connected.
IT		The live conductors are isolated from earth, or one live conductor is connected to earth through a high impedance.	Live conductors and protective earthing conductors are kept separate throughout the system.	Exposed-conductive-parts are connected to an earthing arrangement provided in the installation.

NOTE 1 "Electric systems" were formerly referred to as "system earthings".

NOTE 2 Attention is drawn to the risk of corrosion in TT, TN-C, TN-C-S DC electric systems.

Figure 20 to Figure 29 show examples of DC systems. The sources illustrated show a power electronic converter with electrical separation.

Table 3 – Designations and symbols indicating the conductor function, used in Figure 9 to Figure 29

Conductor function	Designation in accordance with IEC 60445	Symbol in accordance with IEC 60617
AC line conductors	L1, L2, L3	IEC 60617-S00001:2001-07
DC line conductors	L+, L-	IEC 60617-S00001:2001-07
Neutral conductor	N	 IEC 60617-S00446:2001-07
Mid-point conductor	M	 IEC 60617-S00446:2001-07
Protective earthing conductor	PE	 IEC 60617-S00447:2001-07
PEN conductor	PEN	 IEC 60617-S01929:2021-02
PEM conductor	PEM	 IEC 60617-S01929:2021-02
PEL conductor	PEL	 IEC 60617-S01928:2022-09
System-referencing-conductor	SRC	 IEC 60617-S01927:2021-02

1.9.2 Types of electric systems for alternating current

1.9.2.1 TN systems

1.9.2.1.1 General

One live part shall be directly connected by an SRC to an earthing arrangement.

Where exposed-conductive-parts of the electrical installation shall be connected to the earthing arrangement, protective earthing conductors shall be provided to connect the exposed-conductive-parts to the earthed point where the live parts are connected to earth.

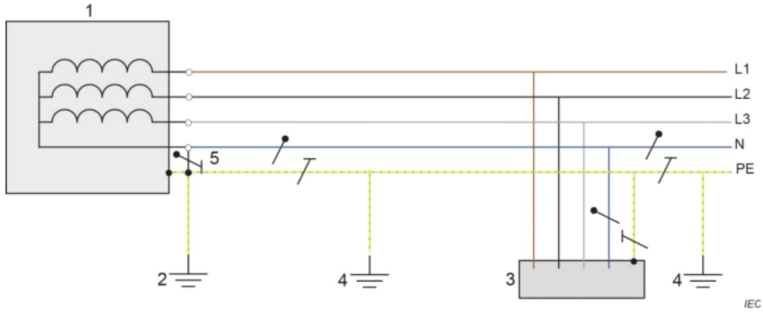
The neutral conductors, mid-point conductors or the earthed line conductors, and the protective earthing conductors shall be arranged as follows:

– the neutral conductors or mid-point conductors and protective earthing conductors shall be separated throughout the system (see Figure 9), or
– the neutral conductors or mid-point conductors and the earthed line conductors shall be combined with the function of protective earthing conductor in one single conductor in parts of the system (see Figure 10 and Figure 11), or
– the neutral conductors or mid-point conductors and the earthed line conductors shall be combined with the function of protective earthing conductor in one single conductor throughout the system.

Additional earthing of the protective earthing conductor may be provided.

A live conductor shall not be provided with more than one connection to a conductor having a protective earthing function at any given time throughout the electric system.

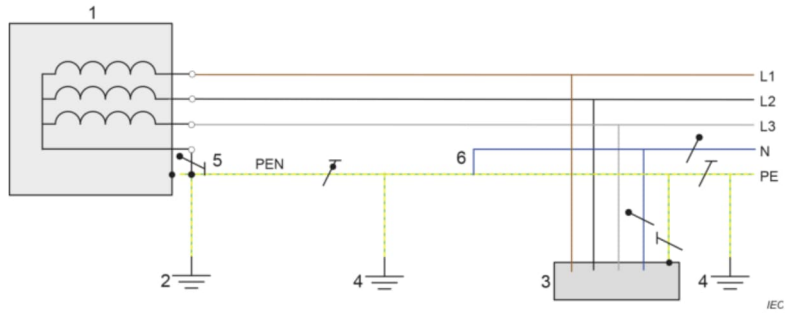
1.9.2.1.2 System with a single source



Key

1 source
2 earth electrode for earthing of the system at the source
3 electrical equipment with exposed-conductive-part
4 additional earth electrode which may be provided throughout the system
5 SRC

Figure 9 – Example of an AC TN-S system with separate neutral conductor and protective earthing conductor throughout the system



Key

1 source

2 earth electrode for earthing of the system at the source

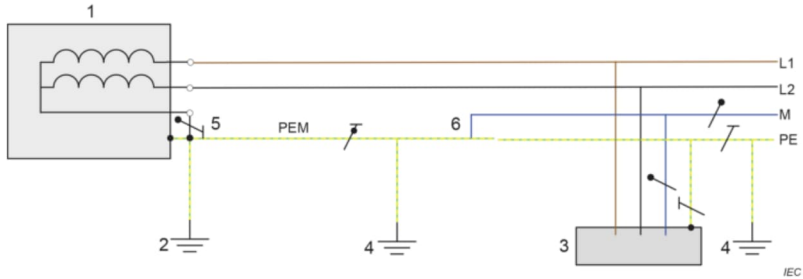
3 electrical equipment with exposed-conductive-part

4 additional earth electrode which may be provided throughout the system

5 SRC

6 separation of neutral conductor from a PEN conductor

Figure 10 – Example of an AC TN-C-S system with a PEN conductor separated into a protective earthing conductor and a neutral conductor



Key

1 source

2 earth electrode for earthing of the system at the source

3 electrical equipment with exposed-conductive-part

4 additional earth electrode which may be provided throughout the system

5 SRC

6 separation of mid-point conductor from a PEM conductor

NOTE The mid-point conductor and protective earthing conductor functions are combined in a single conductor in a part of the system.

Figure 11 – Example of an AC TN-C-S single-phase system with a PEM conductor separated into a protective earthing conductor and a mid-point conductor

1.9.2.1.3 System with more than one source

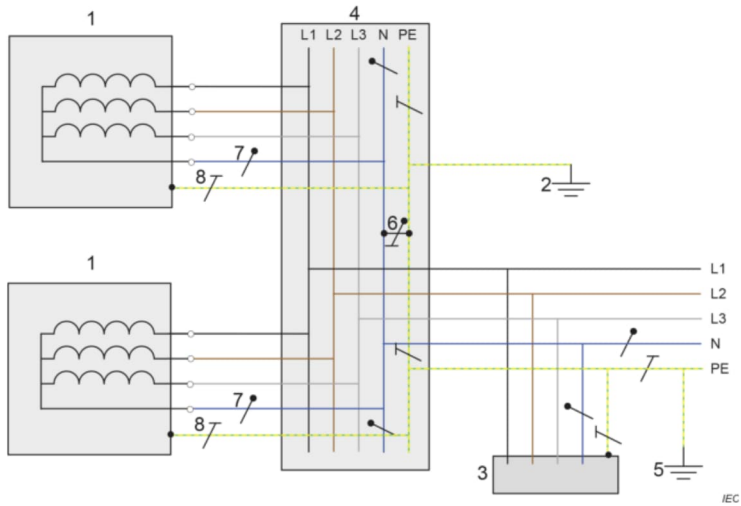
For TN system installations with more than one source, an inappropriate design of the installation can cause some operating currents to flow through unintended paths. These currents can cause:

- fire;
- corrosion;
- electromagnetic interference;
- electric shock.

Installations with more than one source shall be designed so as to reduce the probability for current in the protective earthing conductors under normal situation to a minimum. Except where provisions are implemented to ensure that neutral conductors connected to a local source, when operating as the only source, are substantially at the same potential as earth, all of the following apply.

- No direct connection between the neutral point of a transformer or of a generating set and earth shall be established (see key item 1 in Figure 12 and Figure 13).
- The neutral conductor connecting the neutral point of a transformer or a generating set to the (main) distribution board shall be insulated and shall not be connected to any current-using equipment (see key item 7 in Figure 12 and Figure 13).
- Only one SRC between the interconnected neutral points of the sources and the earthing arrangement shall be provided in the installation. This SRC shall be located at or inside the (main) distribution board as a connection between the neutral conductor and the protective earthing conductor (see key item 6 in Figure 12 and Figure 13).
- The protective earthing conductor in the (main) distribution board shall be connected to an earth electrode via the main earthing terminal (see key item 2 in Figure 12 and Figure 13).
- Downstream of the (main) distribution board, the neutral conductor and the protective earthing conductor shall not be interconnected. However, additional earthing of the protective earthing conductor in the installation may be provided (see key item 5 in Figure 12 and Figure 13).
- Where a local source is intended to operate as the only source, the local source should be connected to the main distribution board (see Figure 12), or the circuits between the main distribution board and distribution boards to which the local source is connected, shall not be provided with means for disconnection of the neutral conductor without using a tool or a key (see key item 10 in Figure 13).
- In a TN-C-S system with at least one local source and one external source an SRC shall be installed as part of the electrical installation.

Where an installation is extended with more generating sets, the safety within the installation shall be maintained for every foreseeable combination of the generating sets.



Key

1 local source intended to operate in island mode

2 earth electrode for earthing of the system

3 electrical equipment with exposed-conductive-part

4 main distribution board

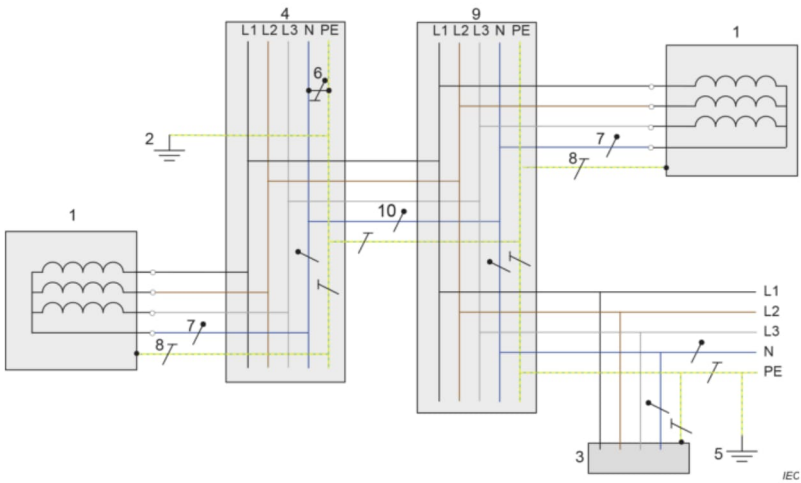
5 additional earth electrode which may be provided throughout the installation

6 SRC

7 neutral conductor connecting the neutral point of the local source to the distribution board

8 protective earthing conductor for protective earthing of exposed-conductive-parts of the local source

Figure 12 – Example of an AC TN-S multiple source system with two local sources connected to the main distribution board



Key

1 local source intended to operate in island mode

2 earth electrode for earthing of the system

3 electrical equipment with exposed-conductive-part

4 main distribution board

5 additional earth electrode which may be provided throughout the installation

6 SRC

7 neutral conductor connecting the neutral point of the local source to the distribution board

8 protective earthing conductor for protective earthing of exposed-conductive-parts of the local source

9 sub-distribution board

10 neutral conductor between (main) distribution board and sub-distribution board where a local source is connected

Figure 13 – Example of an AC TN-S multiple source system with two local sources and two distribution boards

Where an installation is supplied from an external distribution system (either public or private), especially where the distribution system is originating from outside a building housing the installation, the following shall be considered.

a) One live conductor of the distribution system shall be provided with an SRC within the distribution system itself, independent of any electrical installations being connected to it. The earthing of the distribution system cannot rely upon an SRC installed in one of the electrical installations as that installation can be disconnected.

b) An electrical installation with a local source, intended to operate in island mode, can be disconnected from the distribution system. Therefore, it cannot be assumed that a live part of the installation is effectively connected to earth, as it is possible that the SRC in the distribution system is not present.

Where an electrical installation with a local power source is connected to a distribution system and supplied with a PEN conductor:

c) an earth electrode shall be provided in the installation; and

d) in some cases, an SRC is required.

1.9.2.2 TT system

1.9.2.2.1 General

One live part shall be directly connected by an SRC to an earthing arrangement.

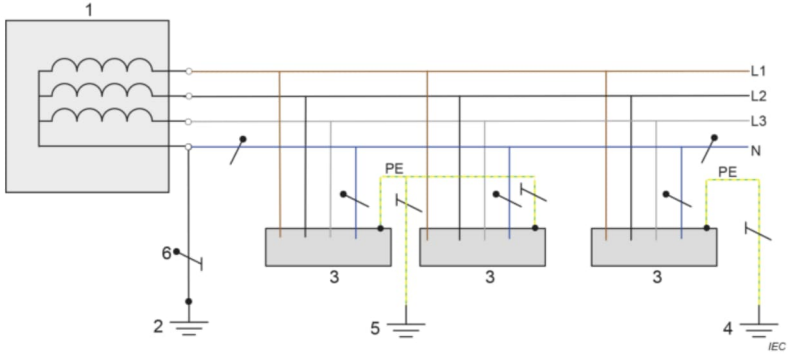
Where exposed-conductive-parts of the electrical installation are connected to an earthing arrangement, this earthing arrangement shall be electrically independent of the earthing arrangement to which the SRC is connected.

The neutral conductors, mid-point conductors or the earthed line conductors, and the protective earthing conductors shall be separated throughout the installation.

Additional earthing of the protective earthing conductors may be provided. This additional earthing shall be electrically independent from the earthing arrangement to which the SRC is connected.

1.9.2.2.2 System with single source

Figure 14 gives an example of a TT system arrangement.



Key

1 source

2 earth electrode for earthing of the system at the source

3 electrical equipment with exposed-conductive-part

4 individual protective earthing of an exposed-conductive-part in the installation

5 grouped protective earthing of exposed-conductive-parts in the installation

6 SRC

Figure 14 – Example of an AC TT system

1.9.2.2.3 System with more than one source

For TT system installations with more than one source, an inappropriate design of the installation can cause some operating currents to flow through unintended paths. These currents can cause:

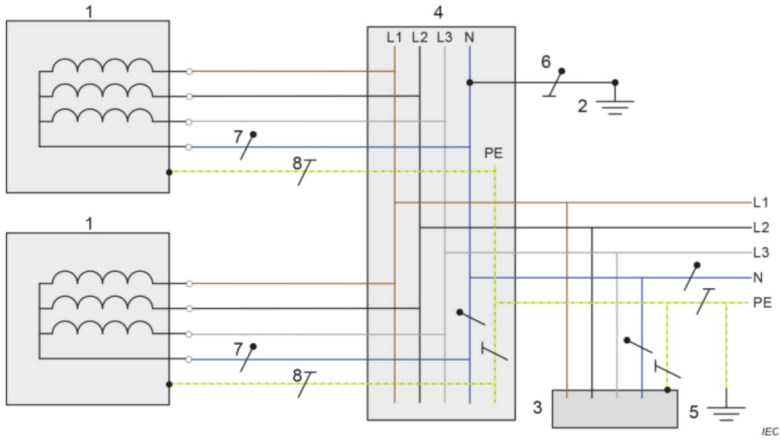
– fire;
– corrosion;
– electromagnetic interference;
– electric shock.

Installations with more than one source shall be designed so as to reduce the probability of current in the protective earthing conductors under normal conditions to a minimum. Except where provisions are implemented to ensure that neutral conductors connected to a local source, when operating in island mode, are substantially at the same potential as earth, all of the following apply.

– No direct connection between the neutral point of a transformer or a generating set and earth is established, see key item 1 in Figure 15 and in Figure 16.
– The neutral conductor connecting the neutral point of a transformer or a generating set to the (main) distribution board is insulated and is not connected to any current-using equipment, see key item 7 in Figure 15 and key items 7 and 10 in Figure 16.
– Only one SRC between the interconnected neutral points of the sources and an earth electrode shall be provided. This SRC shall be located inside the (main) distribution board, see key item 6 in Figure 15 and key item 6 in Figure 16.
– The exposed-conductive-parts in the installation are earthed to a separate, independent earth electrode. See key item 5 in Figure 14.

Where an installation is extended with more generating sets, the safety within the installation shall be maintained for every foreseeable combination of the generating sets.

Figure 15 shows an installation with two local sources only and the earthing electrode for the system earthing and the earth electrode for the earthing of the exposed-conductive-parts are electrically independent of each other.



Key

1 local sources within the electrical installation

2 earth electrode for earthing of the system (of the sources at only one point)

3 electrical equipment with exposed-conductive-part

4 distribution board

5 earth electrode for the earthing of exposed-conductive-parts

6 SRC

7 conductor between the neutral point of the source and the distribution board

8 protective earthing conductor for protective earthing of the source

Figure 15 – Example of an AC TT multiple source system with two local sources

Where an installation is supplied from an external distribution system, especially where the distribution system is originating from outside a building housing the installation, the principles laid out in Figure 15 shall be amended for the following reasons.

a) One live conductor of the distribution system shall be provided with an SRC within the distribution system itself, independent of any electrical installations being connected to it. The earthing of the distribution system cannot rely upon an SRC installed in one of the electrical installations as that installation can be disconnected.

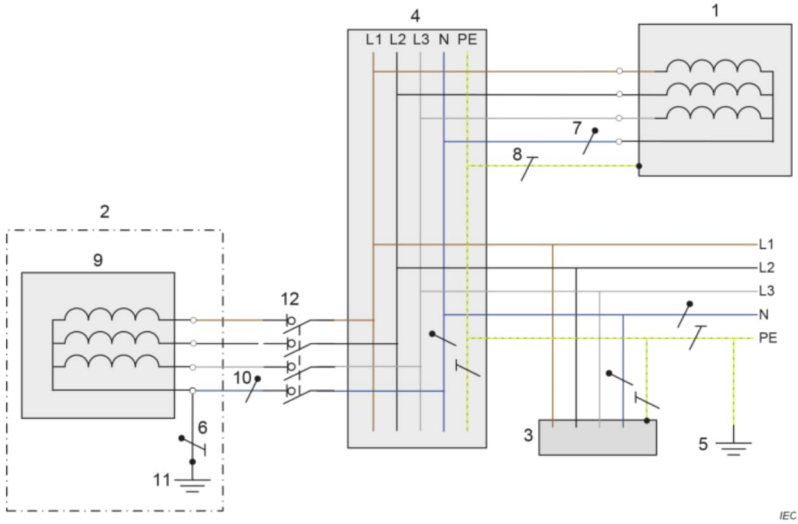
b) An electrical installation with a local source, intended to operate in island mode, can be disconnected from the distribution system. Therefore, it cannot be assumed that a live part of the installation is effectively connected to earth, as it is possible that the SRC in the distribution system is not present.

A fundamental characteristic of a TT electric system is that the earth electrode provided for earthing of the SRC is electrically independent of the earth electrode used for earthing of the exposed-conductive-parts. Therefore, where an electrical installation with a local source is connected to a distribution system, special measures shall be taken as follows:

1) when the live conductors from the external distribution system are disconnected, the installation is operated as an IT installation, see Figure 16, or

2) where an earth electrode can be provided that is electrically independent from the one used for earthing of exposed-conductive-parts, an SRC is established when the live-conductors from the external distribution system are disconnected, enabling the neutral conductor of the installation to be connected to an earth-electrode, see Figure 17, or

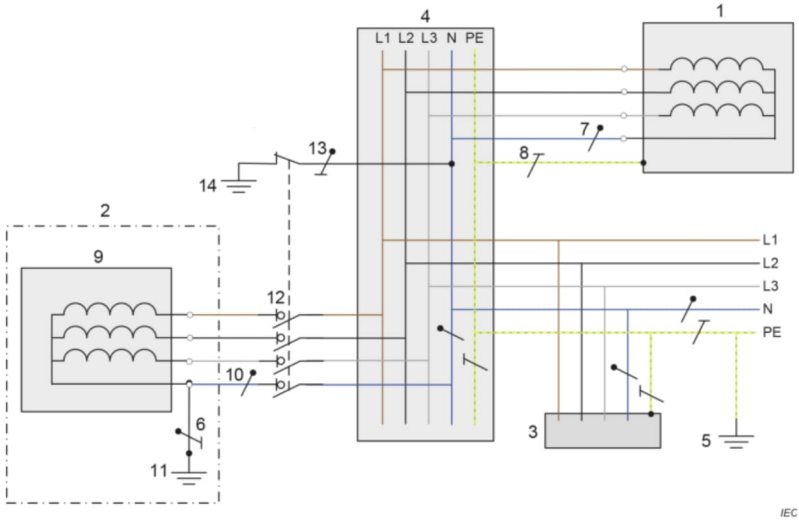
3) where an earth electrode that is electrically independent from the one used for earthing of exposed-conductive-parts cannot be provided, and exposed-conductive-parts are connected to the same earth electrode, an SRC is established between the neutral conductor of the installation and the protective earthing conductors used for protective earthing of exposed-conductive-parts when the installation is disconnected from the external distribution system, and the installation operates as a TN system, see Figure 18.



Key

1 local source
2 external distribution system
3 electrical equipment with exposed-conductive-part
4 distribution board
5 earth electrode for the earthing of exposed-conductive-parts
6 SRC
7 conductor between the neutral point of the local source and the distribution board
8 protective earthing conductor for protective earthing of the local source
9 external source, within the external distribution system
10 neutral conductor between external source and distribution board
11 earth electrode for the earthing of the system at the external source (e.g. the distribution network)
12 means for isolation from the external supply, here illustrated by a switch-disconnector

Figure 16 – Example of an external source in an AC TT supply system with a local source in an installation operating as an IT installation when disconnected from the external source



Key

1 local source

2 external distribution system

3 electrical equipment with exposed-conductive-part

4 distribution board

5 earth electrode for the earthing of exposed-conductive-parts

6 SRC at the external source

7 conductor between the neutral point of the local source and the distribution board

8 protective earthing conductor for protective earthing of the local source

9 external source, within the external distribution system

10 neutral conductor between external source and distribution board

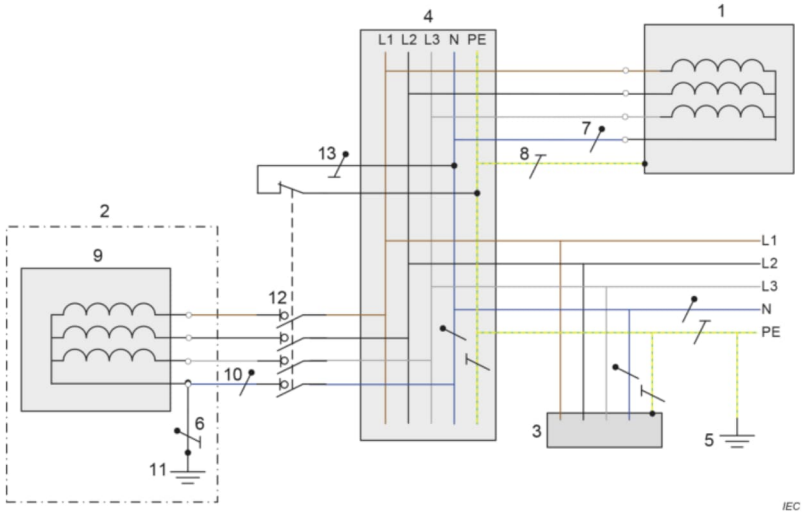
11 earth electrode for the earthing of the system at the external source (e.g. the distribution network)

12 means for disconnection of live conductors from the external supply, here illustrated by a switch-disconnector, interlocked with an SRC switching device

13 SRC when operating in island mode

14 earth electrode for earthing of the system, when operating in island mode

Figure 17 – Example of an external source in an AC TT supply system with a local source in an installation operatingas a TT installation when disconnected from the external source



Key

1 local source

2 external distribution system

3 electrical equipment with exposed-conductive-part

4 distribution board

5 earth electrode for the earthing of exposed-conductive-parts and for earthing of the system in island mode

6 SRC at the external source

7 conductor between the neutral point of the local source and the distribution board

8 protective earthing conductor for protective earthing of the local source

9 external source, within the external distribution system

10 neutral conductor between external source and distribution board

11 earth electrode for the earthing of the system at the external source (e.g. the distribution network)

12 means for disconnection of live conductors from the external supply, here illustrated by a switch-disconnector, interlocked with an SRC switching device

13 SRC when operating in island mode

Figure 18 – Example of an external source in an AC TT supply system with a local source in an installation operating as a TN installation when disconnected from the external source

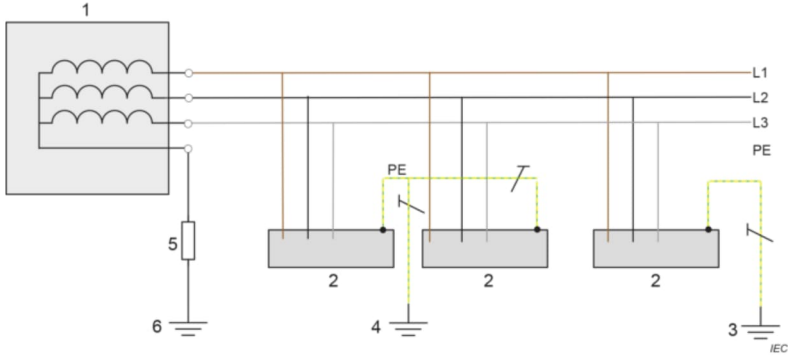
1.9.2.3 IT system

1.9.2.3.1 General

All live parts shall be insulated from the earthing arrangement, or one live part shall be connected through a high impedance to an earth electrode.

Where the live parts are connected to earth by an impedance, the impedance shall be high enough to ensure that the protective measures for protection against electric shock specified for the IT system are not undermined by the presence of the impedance. Where protective earthing of the exposed-conductive-parts of the electrical installation is required, an earthing arrangement shall be provided in the installation.

Figure 19 gives an example of an IT system arrangement.



Key

1 source

2 electrical equipment with exposed-conductive-part

3 earth electrode for earthing of an individual exposed-conductive-part

4 earth electrode for earthing of a group of exposed-conductive-parts

5 impedance for earthing of the system at the source, if present

6 earth electrode for the earthing of the impedance at the source

Figure 19 – Example of an AC IT system with exposed-conductive-parts earthed individually or in groups by protective earthing conductors

1.9.2.3.2 System with more than one source

In IT systems with more than one source and where high impedance earthing is used, consideration shall be given to maintaining the effectiveness of the high impedance in all operational modes.

1.9.3 Types of electric systems for direct current

1.9.3.1 General

Where a live part in a DC system is to be earthed, the decision whether to earth the positive line, the negative line or the mid-point shall consider operational conditions, local habits or other aspects (e.g. corrosion).

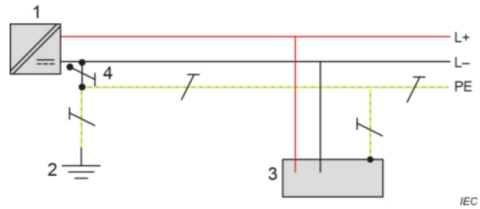
Where multiple sources are used, consideration shall be given to minimizing currents in the protective earthing conductors.

1.9.3.2 TN systems

One live conductor shall be directly connected by an SRC to an earthing arrangement. Where exposed-conductive-parts of the electrical installation are required to be connected to the earthing arrangement, protective conductors shall be provided to connect the exposed-conductive-parts to the earthed point where the live parts are connected to earth. Examples of arrangements of the mid-point conductors or the earthed line conductors, and the protective conductors are shown in Figure 19 to Figure 24.

A live conductor shall not be provided with more than one connection to a conductor having a protective earthing function at any given time throughout the electric system.

Additional earthing of the protective conductors in the installation may be provided.



Key

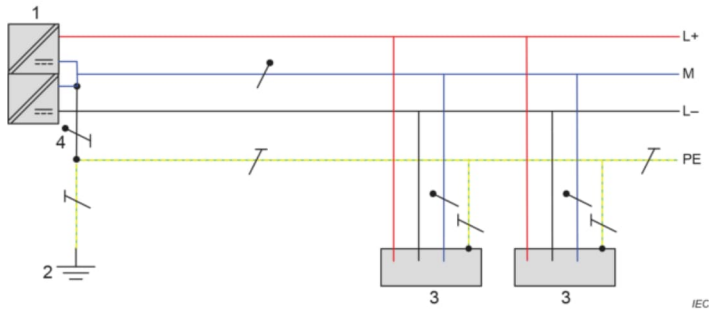
1 source

2 earth electrode for earthing of the system

3 electrical equipment with exposed-conductive-part

4 SRC

Figure 20 – Example of a DC TN-S system without mid-point



Key

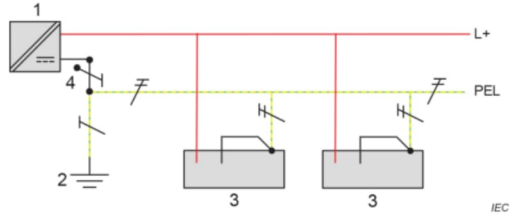
1 source

2 earth electrode for earthing of the system

3 electrical equipment with exposed-conductive-part

4 SRC

Figure 21 – Example of a DC TN-S system with mid-point



Key

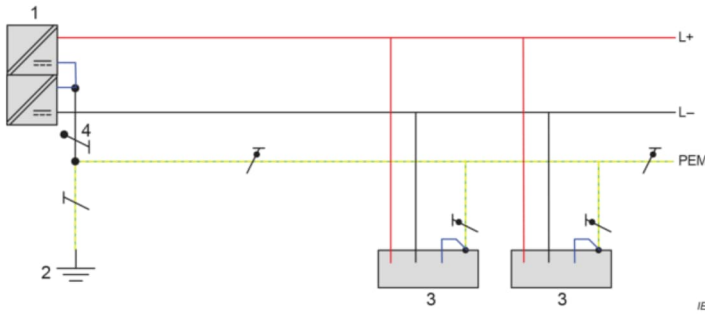
1 source

2 earth electrode for earthing of the system

3 electrical equipment with exposed-conductive-part

4 SRC

Figure 22 – Example of a DC TN-C system without mid-point



Key

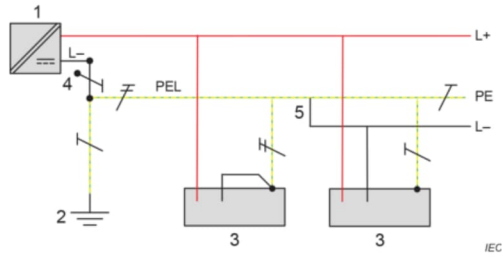
1 source

2 earth electrode for earthing of the system

3 electrical equipment with exposed-conductive-part

4 SRC

Figure 23 – Example of a DC TN-C system with mid-point



Key

1 source

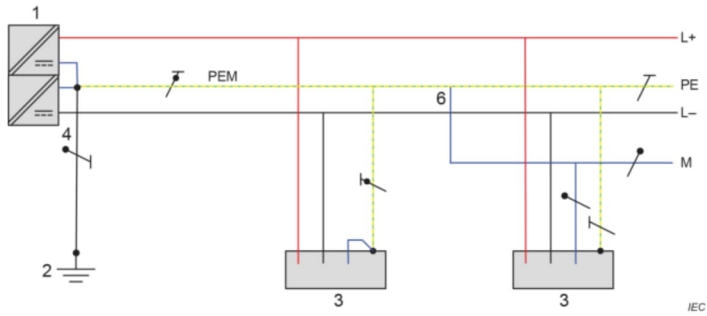
2 earth electrode for earthing of the system

3 electrical equipment with exposed-conductive-part

4 SRC

5 separation of a line conductor from a PEL conductor

Figure 24 – Example of a DC TN-C-S system without mid-point



Key

1 source

2 earth electrode for earthing of the system

3 electrical equipment with exposed-conductive-part

4 SRC

6 separation of the mid-point-conductor from a PEM conductor

Figure 25 – Example of a DC TN-C-S system with mid-point

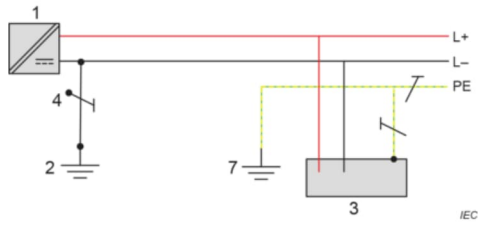
1.9.3.3 TT system

One live part shall be directly connected by an SRC to an earthing arrangement.

Where exposed-conductive-parts of the electrical installation are connected to an earthing arrangement, this earthing arrangement shall be electrically independent of the earthing arrangement to which the SRC is connected.

The mid-point conductors or the earthed line conductors, and the protective earthing conductors shall be separated throughout the installation.

Additional earthing of the protective earthing conductor may be provided. This additional earthing shall be electrically independent from the earthing arrangement to which the SRC is connected.



Key

1 source

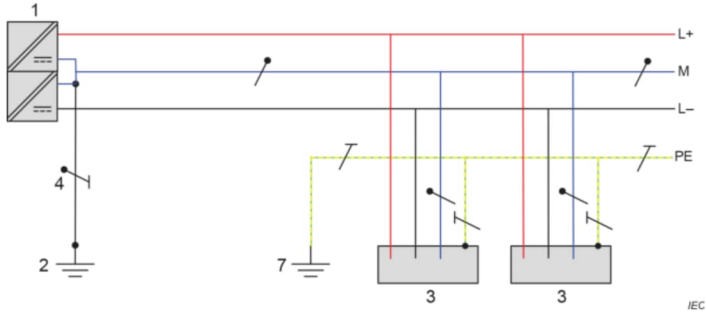
2 earth electrode for earthing of the system

3 electrical equipment with exposed-conductive-part

4 SRC

7 earth electrode for the earthing of exposed-conductive-part(s)

Figure 26 – Example of a DC TT system without mid-point



Key

1 source

2 earth electrode for earthing of the system

3 electrical equipment with exposed-conductive-part

4 SRC

7 earth electrode for the earthing of exposed-conductive-parts

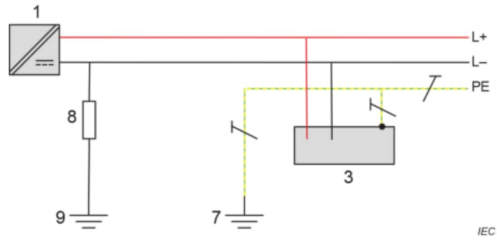
Figure 27 – Example of a DC TT system with mid-point

1.9.3.4 IT system

All live parts shall be insulated from the earthing arrangement or one live part shall be connected through a high impedance to the earthing arrangement.

Where the live parts are connected to earth by an impedance, the impedance shall be high enough to ensure that the protective measures for protection against electric shock specified for the IT system are not undermined by the presence of the impedance. Where protective earthing of the exposed-conductive-parts of the electrical installation is required, an earthing arrangement shall be provided in the installation.

Figure 27 and Figure 28 give examples of IT system arrangement in DC.



Key

1 source

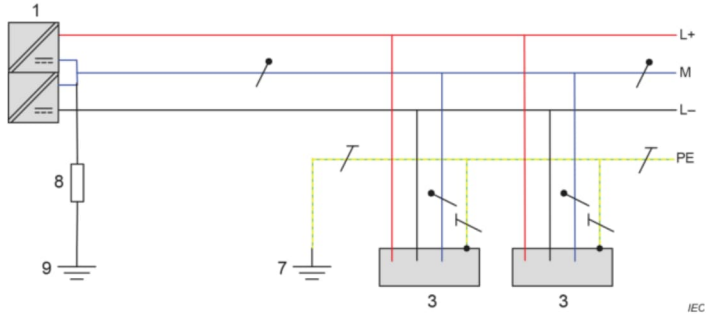
3 electrical equipment with exposed-conductive-part

7 earth electrode for the earthing of exposed-conductive-part(s)

8 high impedance for earthing of the system, if present

9 earthing of the impedance at the source

Figure 28 – Example of a DC IT system without mid-point



Key

1 source

3 electrical equipment with exposed-conductive-part

7 protective earthing of exposed-conductive-parts

8 high impedance for earthing of the system, if present

9 earthing of the impedance at the source

Figure 29 – Example of a DC IT system with mid-point

1.10 Compatibility

1.10.1 Compatibility of characteristics

An assessment shall be made of any characteristics of equipment likely to have harmful effects upon other electrical equipment or other services or likely to impair the power supply, for example, for coordination with concerned parties. Those characteristics include, for example:

- transient overvoltages;
- undervoltage;
- unbalanced loads;
- rapidly fluctuating loads;
- starting currents;
- power factor;
- harmonic currents;
- DC feedback;
- high-frequency oscillations;
- earth leakage currents;
- necessity for additional connections to earth;
- excessive protective conductor currents flowing under normal conditions;
- stray currents;
- direction of current.

1.10.2 Electromagnetic compatibility

All electrical equipment shall meet the appropriate electromagnetic compatibility (EMC) requirements and shall be in accordance with the relevant EMC standards.

Consideration shall be given during the design and erection of the electrical installations to reducing the effect of induced voltage disturbances and electromagnetic interferences (EMI).

Measures are given in IEC 60364-4-44.

1.11 Maintainability

An assessment shall be made of the frequency and quality of maintenance the electrical installation can reasonably be expected to receive during its intended life. The result of the assessment shall be taken into account when applying the requirements of the IEC 60364 series so that:

- any periodic inspection and testing, maintenance and repairs likely to be necessary during the intended life can be readily and safely carried out,
- the protective measures for safety shall remain effective during the intended lifetime of the installation, and
- the reliability of equipment for proper functioning of the electrical installation is appropriate for the intended life.

1.12 Safety services

Safety services are those provisions to protect and warn persons in the event of a hazard, or essential to their evacuation from a location. Such services can be specified by the owner of the installation.

Examples of safety services include:

– emergency escape lighting;
– fire detection and alarm systems;
– installations for fire pumps, firefighter lifts;
– smoke and heat extraction equipment.

Where a safety service is required, a supply system for safety services shall be provided, comprising:

– an electric safety source;
– electric circuits for safety services;
– safety services.

Sources for safety services may be:

– secondary batteries;
– primary cells;
– generator sets independent of the normal supply;
– a separate feeder of the distribution network that is effectively independent of the normal feeder.

1.13 Continuity of service

An assessment shall be made for each circuit where the need for continuity of service is considered necessary during the intended life of the electrical installation. The following should be considered:

– type of electric system;
– selection of the protective devices in order to achieve selectivity;
– subdivision of circuits;
– multiple power supplies;
– use of monitoring devices.

Annex A
(informative)

Structure of the IEC 60364 series

Table A.1 shows how clauses in the different parts of the IEC 60364 series are numbered in order to make the numbering unambiguous.

Table A.2 shows the titles of all parts in the IEC 60364 series.

Table A.1 – Numbering system of the IEC 60364 series

Divisions and subdivisions[a]		Examples
Parts and subparts	Sequentially by the part and subpart number separated by a dash (one or two digits for the subpart).	4-41 (IEC 60364-4-41)
Clauses	Sequentially within each part by the subpart number followed by a single number, with no points.	413 (IEC 60364-4-41)
Subclauses	Sequentially within each part by the part number followed by a single number, with or without a point.	413.5 (IEC 60364-4-41)
Further subclauses (if necessary)	Sequentially within each subclause followed by a further point and subclause number.	542.1.1 (IEC 60364-5-54)
Tables and figures (main body)	Previous editions up to 2023: in some standards, tables and figures are numbered by the part number in which they appear, followed alphabetically by a capital letter. New or future editions: tables and figures are numbered sequentially starting from 1, irrespective of the part number in which they appear.	Table 51A (IEC 60364-5-51) Table 1
Annexes	Sequentially starting from the letter A.	Annex A
Tables and figures (annexes)	Sequentially, preceded by the letter designating that annex followed by a full stop. The numbering starts afresh with each annex.	Figure A.1
[a] Arabic numerals are used except where indicated.		

Table A.2 – Structure of the IEC 60364 series – Low-voltage electrical installations

Part No.	Title
Part 1	Fundamental principles, assessment of general characteristics and definitions
Part 4	Protection for safety
Part 4-41	Protection against electric shock
Part 4-42	Protection against thermal effects
Part 4-43	Protection against overcurrent
Part 4-44	Protection against voltages disturbances and electromagnetic disturbances
Part 5	Selection and erection of electrical equipment
Part 5-51	Common rules
Part 5-52	Wiring systems
Part 5-53	Devices for protection for safety, isolation, switching, control and monitoring
Part 5-54	Earthing arrangements and protective conductors
Part 5-55	Other equipment
Part 5-56	Safety services
Part 5-57	Erection of stationary secondary batteries
Part 6	Verification

Part No.	Title
Part 7[a]	Requirements for special installations or locations
Part 7-701	Location containing a bath or shower
Part 7-702	Swimming pools and fountains
Part 7-703	Rooms and cabins containing sauna heaters
Part 7-704	Construction and demolition site installations
Part 7-705	Agricultural and horticultural premises
Part 7-706	Conducting locations with restricted movement
Part 7-707[b]	Earthing requirements for the installation of data processing equipment
Part 7-708	Caravan parks, camping parks and similar locations
Part 7-709	Marinas and similar locations
Part 7-710	Medical locations
Part 7-711	Exhibitions, shows and stands
Part 7-712	Solar photovoltaic (PV) power supply systems
Part 7-713	Furniture
Part 7-714	External lighting installations
Part 7-715	Extra-low-voltage lighting installations
Part 7-716	ELV DC power distribution over information and communications technology (ICT) cable infrastructure
Part 7-717	Mobile or transportable units
Part 7-718	Communal facilities and workplaces
Part 7-721	Electrical installations in caravans and motor caravans
Part 7-722	Supplies for electric vehicles
Part 7-725[c]	Resilient power supply system
Part 7-729	Operating or maintenance gangways
Part 7-740	Temporary electrical installations for structures, amusement devices and booths at fairgrounds, amusement parks and circuses
Part 7-751[d]	Low voltage generating sets
Part 7-753	Heating cables and embedded heating systems
Part 8	Functional aspects
Part 8-1[e]	Energy efficiency
Part 8-82	Prosumer's low-voltage electrical installations
Part 8-3[f]	Operation of prosumer's electrical installations

[a] Part 7 deviates from Part 1 to Part 6 and Part 8 in that it is divided into clauses in order to have more than nine clauses available for these additional regulations.

[b] Withdrawn.

[c] Under preparation. Stage at the time of publication: IEC DTS 60364-7-725:2025.

[d] Under preparation. Stage at the time of publication: IEC CDV 60364-7-751:2025.

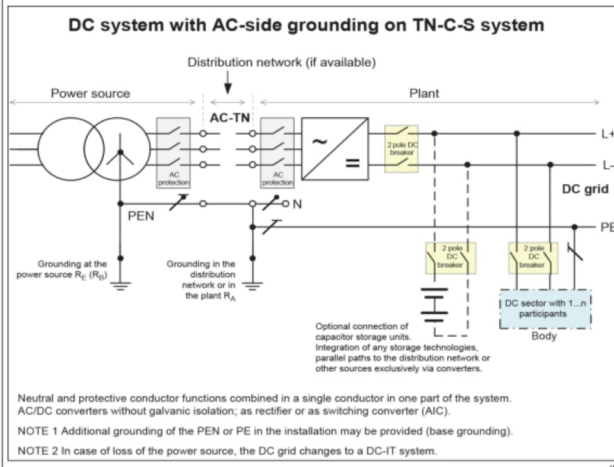
[e] To be consistent with the series numbering, future editions will be numbered 8-81.

[f] To be consistent with the series numbering, future editions will be numbered 8-83.

Annex B
(informative)

List of notes concerning certain countries

Country	Clause No.	Wording
GB	1.3	In the United Kingdom, the following definition applies: **neutral conductor** A conductor connected to the neutral point of a system and contributing to the transmission of electrical energy. The term also means the equivalent conductor of an IT, single-phase or DC system unless otherwise specified in BS 7671 and also identifies either the mid-wire of a three-wire DC circuit or the earthed conductor of a two-wire earthed DC circuit.
NO	1.5.2.3	In Norway, add the following: Where a new installation is established in an IT-system, measures should be taken to facilitate an easy conversion of the installation to be applicable in a TN-system.
AT	1.5.2.14	In Austria, replace the subclause with the following: Energy efficiency measures shall be implemented according national or regional regulations.
AT	1.5.2.15	In Austria, replace the subclause with the following: Local energy production and storage shall be implemented according national or regional regulations.
AT	1.5.2.16	In Austria, replace the subclause with the following: Instructions or recommendations from device or equipment manufacturers as related to cyber security shall be followed.
AT	1.5.4.1.5	In Austria, add the following: 3 phase socket outlets must provide a right rotating field (clockwise direction) when looking at the socket front surface, except the application requires a left rotating field. Such socket outlets shall be clearly and permanently labelled.
AT	1.5.4.1.7	In Austria, add the following: Subclause 1.5.4.1.7 is only applicable to parts of installations which have been erected before the actual identification requirements according to IEC 60364-5-51:2005, 514.3 and IEC 60455 were established in Austria.
GB	1.8.3.1	In the United Kingdom, add the following: Under certain circumstances it is permitted to switch the protective conductor in the UK.
AT	1.9.2.1.3 a)	In Austria, replace the last sentence in 1.9.2.1.3 a) with the following: The distribution network earthing conditions shall not rely upon an additional earthing of that conductor within the electrical installations connected thereto, unless otherwise agreed with the distribution network operator.
AT	1.9.2.2.3, Figure 15	In Austria, add the following: A configuration according Figure 15 is not applicable.
AT	1.9.2.2.3 a)	In Austria, replace the last sentence in 1.9.2.2.3 a) with the following: The distribution network earthing conditions shall not rely upon an additional earthing of that conductor within the electrical installations connected thereto, unless otherwise agreed with the distribution network operator.
AT	1.9.2.2.3, Figure 17	In Austria, add the following: A configuration according Figure 17 is not applicable.
DE	1.9.1	In Germany, add the following: TT systems are not recommended for DC systems due to a higher corrosion risk.

Country	Clause No.	Wording
DE	1.9.3.2	In Germany, add the following: Figure B.1 shows a DC TN-S system with grounding on the AC side without electrical separation of the AC side and DC side.  **Figure B.1 – Diagram of DC system with AC-side grounding [DC-INDUSTRIE]**
DE	1.9.3.3	In Germany, add the following: TT systems are not recommended for DC systems due to inherent corrosion risk.
GB	1.9.2.1.3	In the United Kingdom, add the following: Only one connection between the interconnected neutral points of the sources and the protective earthing conductor may be provided in the installation. This connection shall be located at or near the distribution board (see key item 6 in Figure 12 and Figure 13), unless it is provided within the source.
FR	1.9.2.1.3	In France, add the following: Requirement of clause 1.9.2.1.3 System with more than one source are not applicable and replaced by requirement of IEC 60464-8-82: 82.8.2.2 when several sources are intended to operate in parallel or IEC 60364-5-55.
IE	1.5.2.2.1	In Ireland, add the following: For standard voltages and frequencies see the Distribution Code.

Bibliography

IEC 60617, *Graphical symbols for diagrams*, available at https://std.iec.ch/iec60617

IEC 60038, *IEC standard voltages*

IEC 60364-4-44, *Low-voltage electrical installations - Part 4-44: Protection for safety - Protection against voltage disturbances and electromagnetic disturbances*

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