

BS 7430:2011+A1:2015



BSI Standards Publication

Code of practice for protective earthing of electrical installations

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Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 December 2011. It was prepared by Technical Committee GEL/600, *Earthing*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 7430:2011, which is withdrawn.

Information about this document

Text introduced or altered by Amendment No. 1 is indicated in the text by tags **A1** **A1**. Minor editorial changes are not tagged.

Relationship with other publications

This revision of BS 7430 takes into account changes in legislation (implementation of the Electricity Safety, Quality and Continuity Regulations 2002 as amended [1]) and changes in and publication of other relevant industry standards such as BS 7671:2008+A3:2015, BS EN IEC 61936-1:2011 and BS EN 50522:2011.

Legislation

In Great Britain earthing of an electricity supply system is governed by the Electricity Safety, Quality and Continuity Regulations 2002 as amended (ESQCR) [1] and the Electricity at Work Regulations 1989 [2]. **A1** In Northern Ireland, the Electricity Safety, Quality and Continuity Regulations 2012 (Northern Ireland) as amended [ESQCR (NI)] apply [3]. **A1**

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

The word “should” is used to express recommendations of this standard. The word “may” is used in the text to express permissibility, e.g. as an alternative to the primary recommendation of the Clause. The word “can” is used to express possibility, e.g. a consequence of an action or an event.

Notes and commentaries are provided throughout the text of this standard. Notes give references and additional information that are important but do not form part of the recommendations. Commentaries give background information.

Contractual and legal considerations

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

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

1 Scope

This British Standard primarily provides recommendations and guidance on meeting the requirements for the earthing of electrical installations, including:

- a) protective earthing of low voltage installations to  BS 7671:2008+A3:2015 .
- b) the interface between LV and HV substations of 11 000/400 V to  BS EN 61936-1:2010+A1:2014  within buildings; and
- c) protective earthing and changeover switch arrangements for generators supplying low voltage installations.

The earthing of a system or installation is generally provided for reasons of safety.

This British Standard applies only to land-based installations in and around buildings. It does not apply to:

- 1) ships, aircraft or offshore installations;
- 2) earthing of medical equipment [see BS EN 60601 (all parts)];
- 3) special problems encountered with solid state electronic components;
- 4) equipment sensitive to static electricity;
- 5) requirements for functional earthing;
- 6) earthing of overhead lines between electrical installations; or
- 7) the internal earthing of equipment.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 215-2:1970, *Specification for aluminium conductors and aluminium conductors, steel-reinforced for overhead power transmission – Aluminium conductors, steel-reinforced* (withdrawn)

BS 729, *Specification for hot dip galvanized coatings on iron and steel articles* (withdrawn)

BS 951, *Electrical earthing – Clamps for earthing and bonding – Specification*

BS 1400, *Specification for copper alloy ingots and copper alloy and high conductivity copper castings* (withdrawn)

BS 1449:1991 (all parts), *Steel plate, sheet and strip* (withdrawn)

BS 1473:1972, *Specification for wrought aluminium and aluminium alloys for general engineering purposes – Rivet, bolt and screw stock*

BS 1474:1987, *Specification for wrought aluminium and aluminium alloys for general engineering purposes: bars, extruded round tubes and sections* (withdrawn)

BS 1561:1997, *Founding – Grey cast irons*

BS 1562:1997, *Founding – Malleable cast irons*

BS 1377-3, *Methods of test for soils for civil engineering purposes – Part 3: Chemical and electro-chemical tests*

 Text deleted 

- BS 2871-1:1971, *Specification for copper and copper alloys – Tubes – Part 1: Copper tubes for water, gas and sanitation* (withdrawn)
- BS 2871-2:1972, *Specification for copper and copper alloys – Tubes – Part 2: Tubes for general purposes* (withdrawn)
- BS 2871-3:1972, *Specification for copper and copper alloys – Tubes – Part 3: Tubes for heat exchangers* (withdrawn)
- BS 2873:1969, *Specification for copper and copper alloys – Wire* (withdrawn)
- BS 2874:1986, *Specification for copper and copper alloy rods and sections (other than forging stock)* (withdrawn)
- BS 3288-1, *Insulator and conductor fittings for overhead power lines – Part 1: Performance and general requirements*
- BS 7375, *Distribution of electricity on construction and demolition sites – Code of practice*
- BS 7671:2008+A3:2015 , *Requirements For Electrical Installations – IEE Wiring Regulations – Seventeenth edition*
- BS EN 485-2:2008, *Aluminium and aluminium alloys – Sheet, strip and plate – Part 2: Mechanical properties*
- BS EN 586-2:1994, *Aluminium and aluminium alloys – Forgings – Part 2: Mechanical properties and additional property requirements*
- BS EN 755-2:2008, *Aluminium and aluminium alloys – Extruded rod/bar, tube and profiles – Part 2: Mechanical properties*
- BS EN 1011-4, *Welding – Recommendations for welding of metallic materials – Part 4: Arc welding of aluminium and aluminium alloys*
- BS EN 1652:1998, *Copper and copper alloys – Plate, sheet, strip and circles for general purposes*
- BS EN 1780-1:2002, *Aluminium and aluminium alloys – Designation of alloyed aluminium ingots for remelting, master alloys and castings – Part 1: Numerical designation system*
- BS EN 1982:2008, *Copper and copper alloys – Ingots and castings*
- BS EN 10025-2:2004, *Hot rolled products of structural steels – Part 2: Technical delivery conditions for non-alloy structural steels*
- BS EN 10088-1:2005, *Stainless steels – List of stainless steels*
- BS EN 10263-4:2001, *Steel rod, bars and wire for cold heading and cold extrusion – Technical delivery conditions for steels for quenching and tempering*
- BS EN 12163:2011, *Copper and copper alloys – Rod for general purposes*
- BS EN 12165:2011, *Copper and copper alloys – Wrought and unwrought forging stock*
- BS EN 12167:2011, *Copper and copper alloys – Profiles and bars for general purposes*
- BS EN 12420:1999, *Copper and copper alloys – Forgings*
- BS EN 12449:1999, *Copper and copper alloys – Seamless, round tubes for general purposes*
-  Text deleted 
- BS EN 13601:2002, *Copper and copper alloys – Copper rod, bar and wire for general electrical purposes*

BS EN 50122-1, *Railway applications – Fixed installations – Electrical safety, earthing and the return circuit – Part 1: Protective provisions against electric shock*

BS EN 50122-2, *Railway applications – Fixed installations – Electrical safety, earthing and the return circuit – Part 2: Provisions against the effects of stray currents caused by d.c. traction systems*

 Text deleted 

BS EN 50522:2011, *Earthing of power installations exceeding 1 kV a.c.*

BS EN 60228:2005, *Conductors of insulated cables*

BS EN 60309/IEC 60309 (all parts), *Plugs, socket-outlets and couplers for industrial purposes*

BS EN 61010 (all parts), *Safety requirements for electrical equipment for measurement, control, and laboratory use*

 Text deleted 

 BS EN 61140, *Protection against electric shock – Common aspects for installation and equipment* 

BS EN 61557/IEC 61557 (all parts), *Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures*

 BS EN 61936-1:2010+A1:2014 , *Power installations exceeding 1 kV a.c. – Part 1: Common rules*

 Text deleted 

BS EN 62305-2, *Protection against lightning – Part 2: Risk management*

BS EN 62305-3, *Protection against lightning – Part 3: Physical damage to structures and life hazard*

BS EN 62035-4, *Protection against lightning – Part 4: Electrical and electronic systems within structures*

BS IEC 60050-195, *International electrotechnical vocabulary – Part 195: Earthing and protection against electric shock*

 Text deleted 

ER G59, *Recommendations for the connection of embedded generating plant to the Regional Electricity Companies' distribution systems*

ER G83, *Recommendations For The Connection Of Small-Scale Embedded Generators (Up To 16 A Per Phase) In Parallel With Public Low-Voltage Distribution Networks*

ER G84, *Recommendations for the Connection of Mobile Generating Sets to Public Distribution Networks*

ER S36-1, *Identification and Recording of "Hot Sites" – Joint Electricity Industry/BT Procedure*

ISO/IEC Guide 51, *Safety aspects – Guidelines for their inclusion in standards*

IEC 60050-604, *International electrotechnical vocabulary – Part 604: Generation, transmission and distribution of electricity – Operation*

IEC Guide 104, *The preparation of safety publications and the use of basic safety publications and group safety publications*

PD 970:2005, *Wrought steels for mechanical and allied engineering purposes – Requirements for carbon, carbon manganese and alloy hot worked or cold finished steels*

3 Terms and definitions

For the purposes of this British Standard, the terms and definitions given in  BS 7671:2008+A3  and BS IEC 60050-195, together with the following apply.

3.1 earth grid

earth electrode in the form of two overlapping groups of buried, parallel, horizontal electrodes, usually laid approximately at right angles to each other, with the electrodes bonded at each intersection

3.2 earth potential

electric potential with respect to the general mass of earth which occurs in, or on the surface of, the ground around an earth electrode when an electric current flows from the electrode to earth

3.3 earth potential rise

voltage between an earthing system and reference earth
[BS EN 50522:2011]

3.4 earth resistance

resistance to earth of an earth electrode or earth grid

3.5 earthing system

arrangement of connections and devices necessary to earth equipment or a system separately or jointly
[IEC 60050-604, 604-04-02]

3.6 global earthing system

equivalent earthing system created by the interconnection of local earthing systems that ensures, by the proximity of the earthing systems, that there are no dangerous touch voltages

NOTE 1 Such systems permit the division of the earth fault current in a way that results in a reduction of the earth potential rise at the local earthing system. Such a system could be said to form a quasi equipotential surface.

NOTE 2 The existence of a global earthing system may be determined by sample measurements or calculation for typical systems. Typical examples of global earthing systems are in city centres; urban or industrial areas with distributed low- and high-voltage earthing.

[BS EN 50522:2011]

3.7 hot site

substation where the rise of earth potential, under the maximum earth fault condition, can exceed the value either 430 V or 650 V depending upon the fault clearance time

3.8 potential gradient (at a point)

rate of change of voltage measured at that point in the direction in which it is a maximum

3.9 transferred potential

potential rise of an earthing system caused by a current to earth transferred by means of a connected conductor (for example a metallic cable sheath, PEN conductor, pipeline, rail) into areas with low or no potential rise relative to reference earth resulting in a potential difference occurring between the conductor and its surroundings

NOTE 1 The definition also applies where a conductor, which is connected to reference earth, leads into the area of the potential rise.

NOTE 2 Transferred potentials can result in electrocution paths through the human body other than the "touch voltage" path, e.g. hand to hand.

[BS EN 50522:2011]

3.10 (effective) touch potential

voltage between conductive parts when touched simultaneously

NOTE The value of the effective touch voltage may be appreciably influenced by the impedance of the person in electric contact with these conductive parts.

[BS IEC 60050-195, 195-05-11, modified]

3.11 prospective touch potential

voltage between simultaneously accessible conductive parts when those conductive parts are not being touched

[IEV 195-05-09, modified]

3.12 step voltage step potential

voltage between two points on the earth's surface that are 1 m distant from each other, which is considered to be the stride length of a person

[BS IEC 60050-195, 195-05-12]

3.13 transferred potential

potential rise of an earthing system caused by a current to earth transferred by means of a connected conductor (for example a metallic cable sheath, PEN conductor, pipeline, rail) into areas with low or no potential rise relative to reference earth resulting in a potential difference occurring between the conductor and its surroundings

NOTE 1 The definition also applies where a conductor, which is connected to reference earth, leads into the area of the potential rise.

NOTE 2 Transferred potentials can result in electrocution paths through the human body other than the "touch voltage" path, e.g. hand to hand.

[BS EN 50522:2011]

4 Earthing principles

4.1 Fundamental rule of protection against electric shock

BS EN 61140 gives fundamental principles and requirements which are common to electrical installations, systems and equipment or necessary for their co-ordination, for installations, systems and equipment without a voltage limit. BS EN 61140 states that the fundamental rule of protection against electric shock is that:

- ...hazardous-live-parts shall not be accessible and accessible conductive parts shall not be hazardous live:
- either under normal conditions (operation in intended use, see ISO/IEC Guide 51, 3.13 and absence of a fault); or
- under single-fault conditions (see also IEC Guide 104, 2.8).

The system and equipment standards are being amended to comply with BS EN 61140 so that the fundamental rule is met and to adopt the same terminology.

In order to achieve the principles within BS EN 61140 within electrical installations standards, ^{A1} BS 7671:2008+A3 ^{A1} makes certain requirements for the earthing of an installation and its sub-structure in order to achieve safety. With the exception of earth free locations, the main requirement under single fault conditions is for automatic disconnection of supply with selecting cable impedances in order to achieve certain touch voltages.

4.2 Supply system earthing

4.2.1 Legislation

In Great Britain the earthing of an electricity supply system is covered by the requirements of the Electricity Safety Quality and Continuity Regulations 2002 as amended (ESQCR) [1]. Part II, *Protection and Earthing* is particularly relevant to users of this standard. Guidance is given in DTI publication *Guidance on the Electricity Safety, Quality and Continuity Regulations* [4].

^{A1} In Northern Ireland, the Electricity Safety, Quality and Continuity Regulations 2012 (Northern Ireland) as amended [ESQCR (NI)] apply [3]. ^{A1} The general provisions in the ESQCR [1] apply to both overhead and underground systems of supply.

The regulations require that every network at whatever voltage be connected with Earth and that the connection is maintained under fault conditions [Regulation 8(1)]. This requirement is designed primarily to preserve the security of the system by ensuring that the potential on each conductor is restricted to such a value as is consistent with the level of insulation applied. Every supply neutral conductor (of LV networks) is required to be connected with earth generally at the source of voltage [Regulation 8 (3(b))].

The regulations include a particular requirement where the neutral and protective conductors are combined that is in protective multiply earthed (PME) systems (see Regulation 9). This is the most common system adopted, see Figure 3.

4.2.2 High voltage (HV) power supply systems

NOTE Requirements for earthing HV installations are given in

^{A1} BS EN 61936-1:2010+A1:2014 ^{A1} and BS EN 50522:2011. See also Clause 5.

4.2.3 Classification of low voltage systems

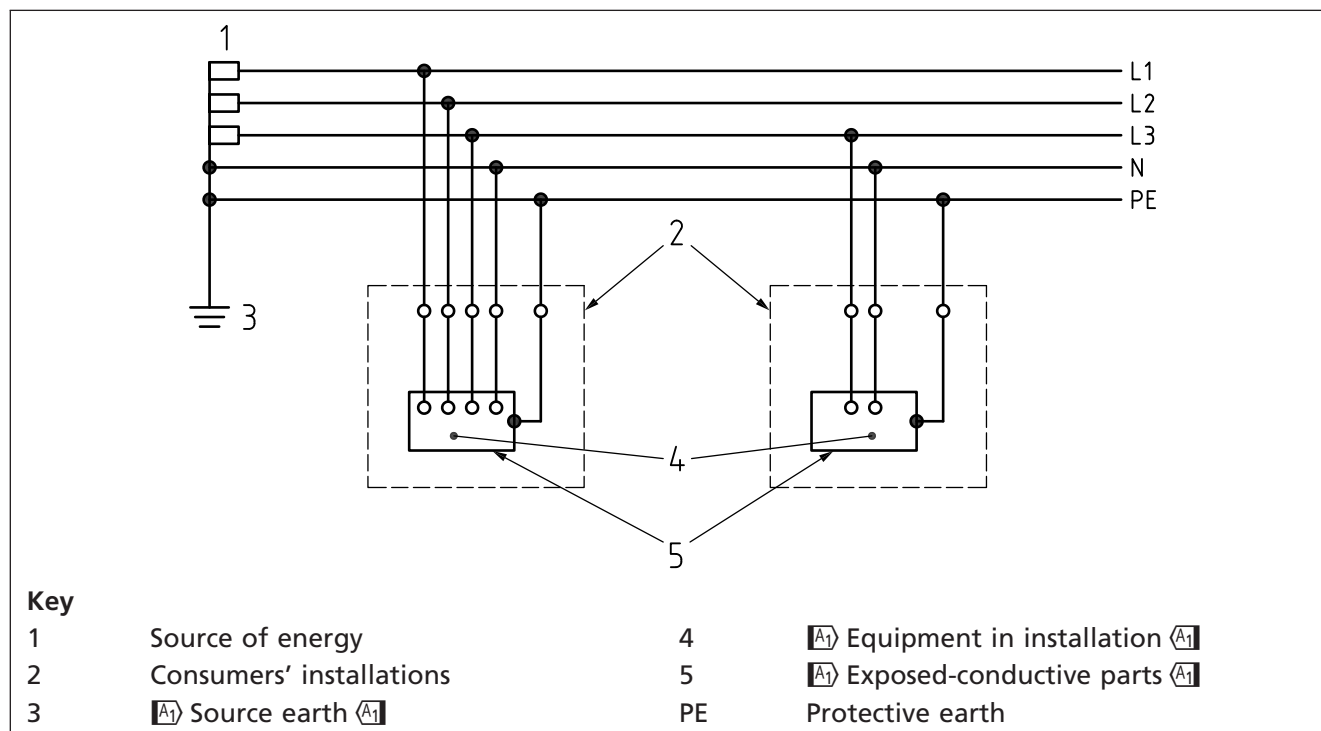
4.2.3.1 General

For the purpose of this standard the following earthing systems are defined: TN-S, TN-C, TN-C-S, TT and IT.

4.2.3.2 TN-S system

In a TN-S (Figure 1) the Neutral and Protective conductors should be kept separate throughout the system and the source is solidly earthed.

Figure 1 TN-S system

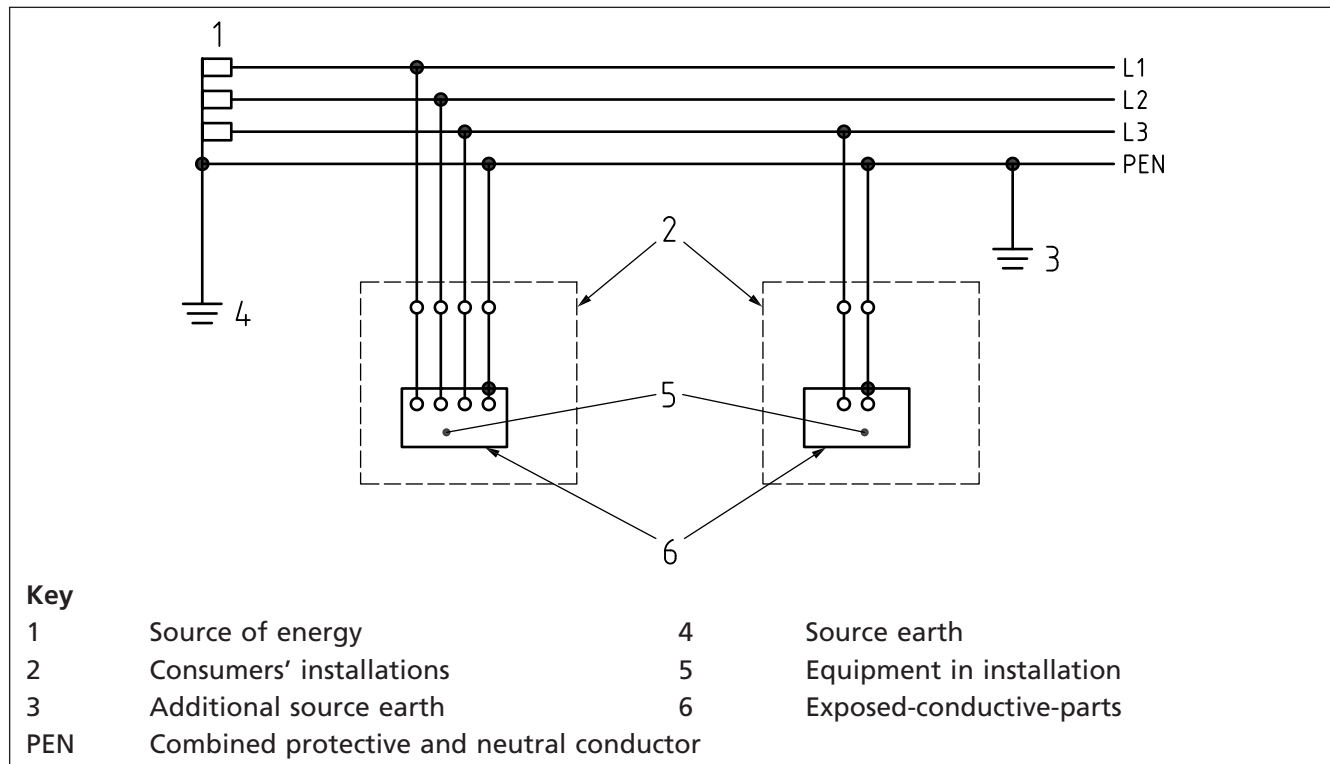
**COMMENTARY ON 4.2.3.2**

A TN-S system has a particular disadvantage that in the event that the protective conductor becomes open circuit, there is no indication that a fault has occurred and installations can unknowingly be left without an earth. In the event of an earth fault all of the exposed-conductive-parts within a consumer installation may be raised to a hazardous potential. Earth fault protection devices will not operate as there will be no flow of current to earth.

4.2.3.3 TN-C system

In a TN-C system (Figure 2) the neutral and protective functions should be combined in a single conductor (PEN) throughout the entire system. Multiple connections to earth are recommended along the PEN conductor and the source is solidly earthed.

Figure 2 TN-C system

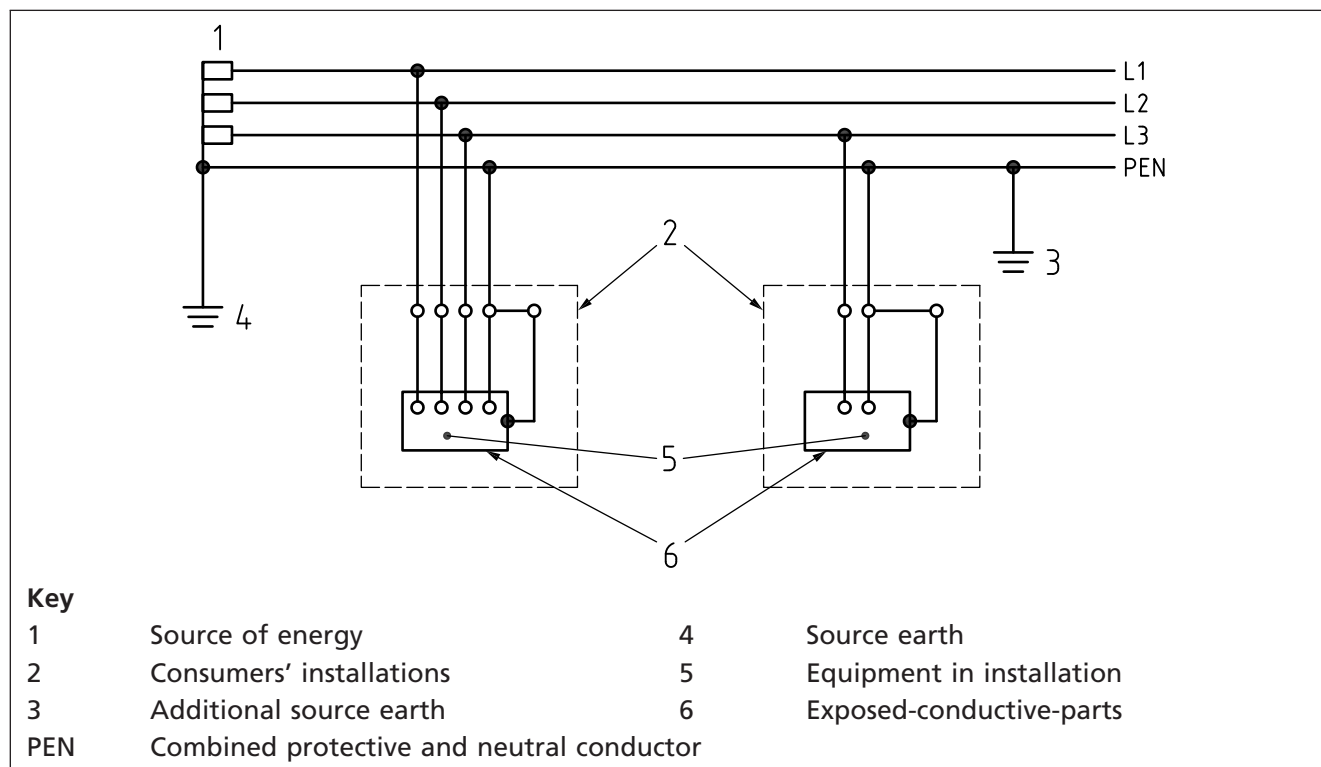
**COMMENTARY ON 4.2.3.3**

The need for multiple earth connections is because if the neutral becomes open-circuit for any reason, the exposed-conductive-parts will rise to line to earth voltage in the case of single-phase connections and a value up to line to earth voltage in the case of three-phase connections, depending on the degree to which the load is unbalanced.

4.2.3.4 TN-C-S system

In a TN-C-S system, (Figure 3) the neutral and protective functions should be combined in a single conductor (PEN) from the source (solidly earthed) up to the consumers intake. Multiple connections to earth are recommended along the PEN conductor. Within the consumer's installation the neutral and protective conductors should be kept separate.

Figure 3 TN-C-S system

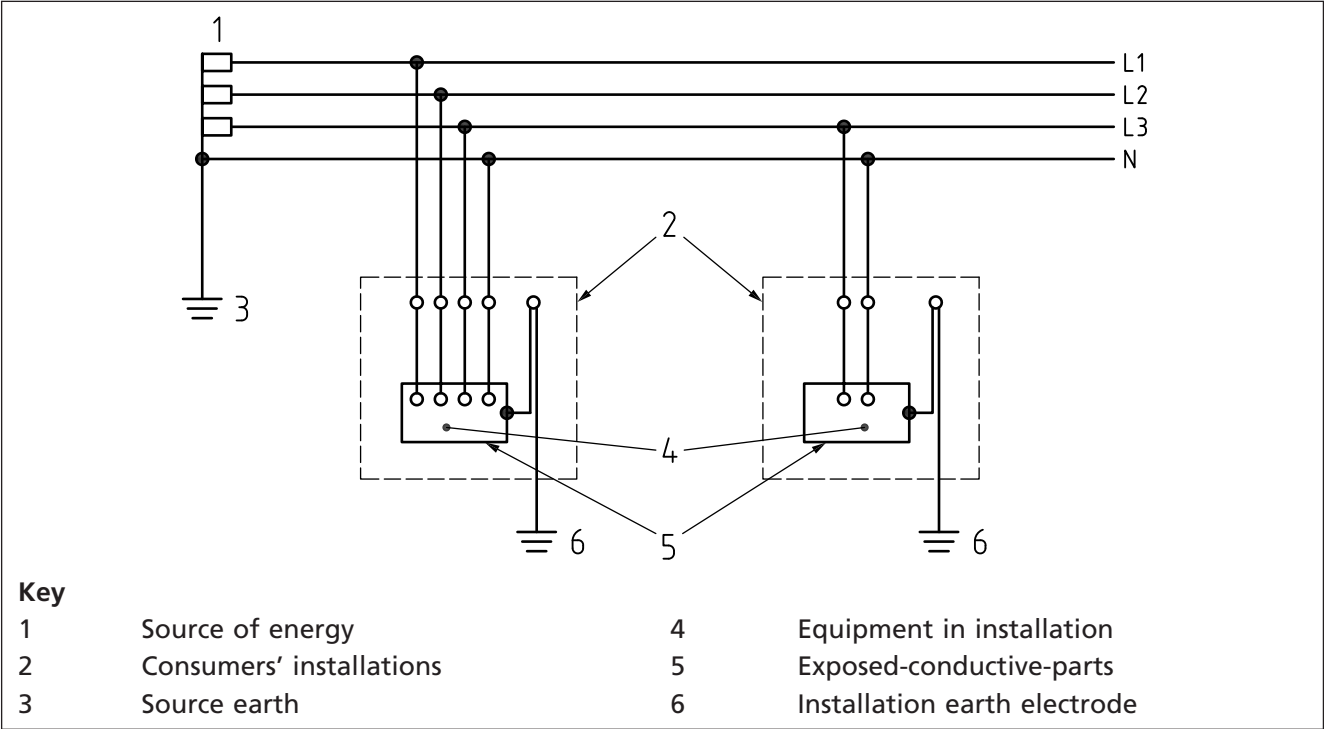
**COMMENTARY ON 4.2.3.4**

The TN-C-S system is also known as a "protective multiple earthed" (PME) system. The PEN conductor, which is referred to as a combined neutral and earth (CNE) conductor, is earthed at the source and extremities of the distribution mains and points in-between; hence the reference to multiple earthing. Multiple earthing of the CNE conductor ensures that if the conductor becomes open-circuit for any reason, exposed-conductive-parts remain connected to earth; under such conditions the supply voltage between the installation line and neutral conductors is substantially reduced and consumers will experience unacceptable voltage variations.

4.2.3.5 TT installation

A TT system (Figure 4) has a solidly earthed source; the exposed-conductive-parts of the consumer's installation are earthed through an installation earth electrode which is electrically independent of the source earth.

Figure 4 TT system



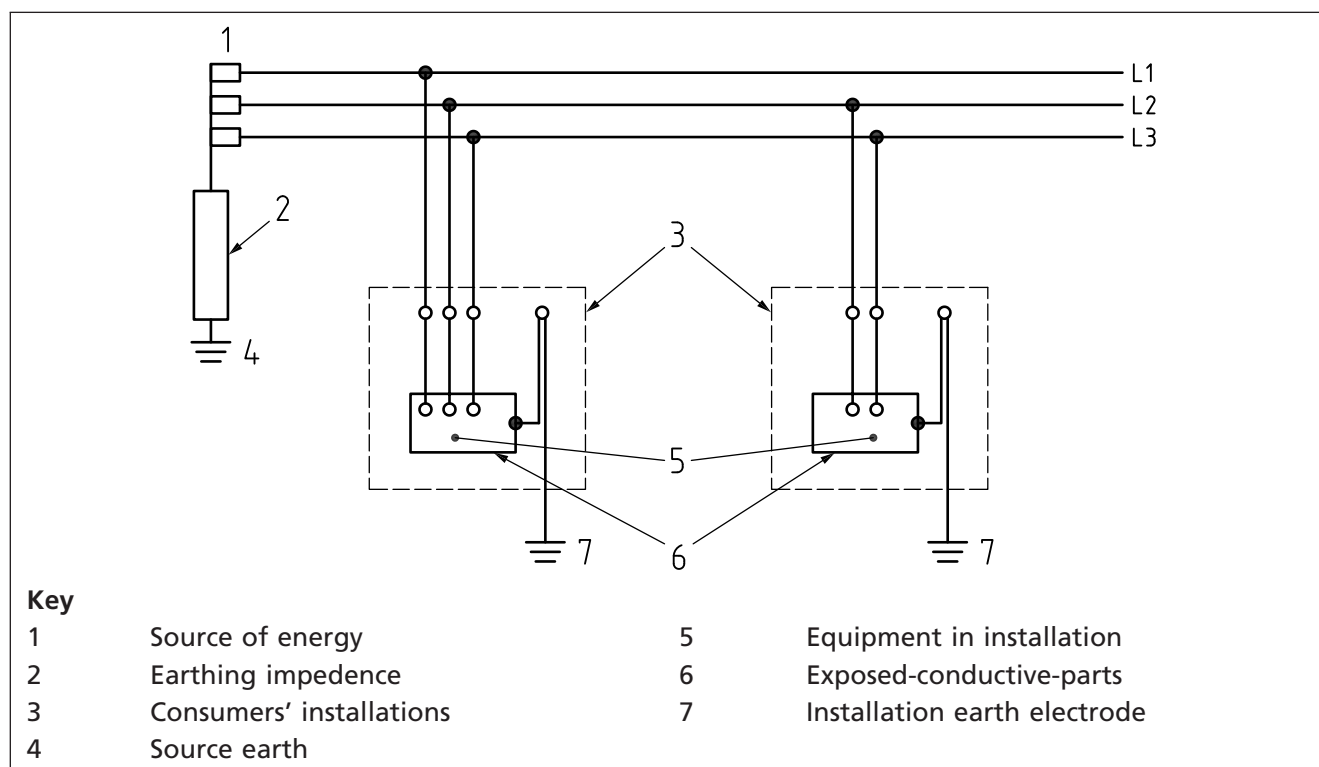
COMMENTARY ON 4.2.3.6

In the TT system the earth fault loop impedance is generally high as the fault path includes the earth electrode resistance of the supply and the earth electrode resistance of the consumer's installation.

4.2.3.6 IT system

An IT system (Figure 5) has the source either connected to earth through an earthing impedance or is isolated (Insulated) from the earth. All of the exposed-conductive parts of an installation are connected to an earth electrode in a similar manner to a TT arrangement.

Figure 5 IT system

**COMMENTARY ON 4.2.3.7**

Generally an IT system would be chosen in locations such as medical centres and mines where the supply has to be maintained even in the event of a fault, and where the connection with earth is difficult (for example a mobile generator).

4.3 Installation earthing – Low-voltage (LV) installation earthing

The purpose of earthing the non-current carrying metalwork of plant and equipment of a low-voltage installation is to:

- a) provide for a low earth fault loop impedance to facilitate automatic disconnection of supply in the event of a fault to exposed-conductive-parts; and
- b) limit the rise of potential under earth-fault conditions of non-current carrying metalwork with respect to earth to increase the safety of persons and animals in proximity to such metalwork.

Extending the earthing arrangement of an installation within a building by use of protective equipotential bonding of exposed-conductive-parts and extraneous-conductive-parts increases the safety of persons and animals by reducing touch voltages between such parts and it can also eliminate dangerous sparking.

The performance requirements for earthing of LV installations (e.g. disconnection times, conductor sizes) are specified in [BS 7671:2008+A3](#).

Attention is drawn to the fact that [BS 7671:2008+A3](#), Regulation **411.3.2.6** has a relaxation:

411.3.2.6 Where automatic disconnection according to Regulation **411.3.2.1** cannot be achieved in the time required by Regulation **411.3.2.2**, **411.3.2.3** or **411.3.2.4**, as appropriate, supplementary equipotential bonding shall be provided in accordance with Regulation **415.2**. Also, Regulation **411.4.9** permits RCD protection to be used to satisfy the requirements of these regulations and maximum values of earth fault loop impedance are now provided in Table 41.5 within this standard.

4.4 Current-using equipment

The purpose of earthing current-using equipment is similar to that for earthing electrical installations. However, for certain standards, e.g. those in the BS EN 60335 series, automatic disconnection of supply is not required in the event of a fault to accessible conductive parts (see BS EN 60335-1:2002+A14, Clause 27).

27 Provision for earthing

27.1 Accessible metal parts of class 0I appliances and class I appliances that may become live in the event of an insulation fault, shall be permanently and reliably connected to an earthing terminal within the appliance or to the earthing contact of the appliance inlet. Earthing terminals and earthing contacts shall not be connected to the neutral terminal.

The fuse in the BS 1363 plug fitted to appliances in the UK is not required by the relevant part of BS EN 60335; its rating is selected to provide protection to the flexible cable supplying the appliance.

In the remainder of Europe, plug fuses are not required.

5 HV/LV interface

Specific requirements that should be followed for high voltage installations including substations are found in [\[A1\]](#) BS EN 61936-1:2010+A1:2014 [\[A1\]](#) and BS EN 50522:2011. Requirements that should be followed for the protection of LV installations against temporary overvoltages due to earth faults in an HV supply system are given in [\[A1\]](#) BS 7671:2008+A3 [\[A1\]](#), Section **442**.

NOTE Further guidance on the interface between LV and HV subsystems, including examples of earthing layouts, is given in Annex A.

6 Low voltage installations

*NOTE The earthing requirements for low-voltage installations are specified in [\[A1\]](#) BS 7671:2008+A3 [\[A1\]](#). In [\[A1\]](#) BS 7671:2008+A3 [\[A1\]](#), Chapter **44**, requirements for protection of low voltage installations against temporary overvoltages due to earth faults in the high voltage system and due to faults in the low voltage system are detailed. This is considered in Clause 5.*

6.1 Automatic disconnection

COMMENTARY ON 6.1

When an earth fault occurs within an installation, dangerous voltages can appear between conductive parts, and if these parts are simultaneously accessible they might constitute a shock hazard. The severity of any shock experienced by a person at risk depends on, among other factors, the type of current (i.e. a.c. or d.c.), the magnitude of the voltages and the amount of time which the earth fault is allowed to persist.

The earth fault current can also be of such magnitude and duration as to cause an excessive temperature rise in the conductors through which it flows, thereby creating a fire hazard.

BS 7671:2008+A3 includes a number of protective measures which can be applied for protection against earth faults. However, this standard only considers the protective measure known as automatic disconnection of supply. This is the most commonly utilised of the protective measures contained in BS 7671:2008+A3. Furthermore, the others do not depend on earthing and have very limited applications.

ADS is a protective measure in which:

- a) basic protection is provided by basic insulation of live parts or by barriers or enclosures; and*
- b) fault protection is provided by protective earthing, protective equipotential bonding and automatic disconnection in case of a fault.*

A brief summary of the requirements of BS 7671:2008+A3 for automatic disconnection of supply is given in 6.2 to 6.11.

Where automatic disconnection of supply is applied, Class I and Class II equipment may be used.

In designing the protective system of any installation, due account should be taken of the need to ensure that periodic inspection, testing and maintenance can be readily and safely undertaken.

6.2 Earthing of installations

Most installations are part of either a TN system or a TT system, and in both types of installation the exposed-conductive-parts of all the electrical equipment of an installation should be connected by means of circuit protective conductors to the main earthing terminal. The earth fault loop impedance should be sufficiently low for the protective device (fuse, circuit breaker, RCD) to operate in the required time in the event of a fault to earth.

Class II equipment, whether metal encased or insulation encased, embodies in its construction not only basic insulation but also supplementary or reinforced insulation; exposed metalwork of such equipment should not be considered to become live under fault conditions, i.e. is not considered to be an exposed-conductive-part.

The various earthing systems are considered in 4.2.

6.3 Information to be provided on request

As necessary, the owner of an installation, the employer or a contractor should determine from the electricity distributor the relevant information as described in the ESQCR [1] and ESQCR (NI) [3]. The owner or his agent should satisfy themselves that the characteristics of the earth fault current path, including any part of that path provided by a supply undertaking, are suitable for operation of the type of earth fault protection intended for use in the installation concerned.

COMMENTARY ON 6.3

When it is intended to install standby supplies to operate in parallel with the normal supply provided by a supply undertaking, the arrangements have to be agreed with the distributor {see regulation 22(1)(d) of the ESQCR [1] and Regulation 23(1)(d) of the ESQCR (NI) [3]}.

Regulation 28 of the ESQCR [1] and Regulation 29 of the ESQCR (NI) [3] require the distributor to provide certain information as follows (the exact text here is taken from the ESQCR [1]):

28. A distributor shall provide, in respect of any existing or proposed consumer's installation which is connected or is to be connected to his network, to any person who can show a reasonable cause for requiring the information, a written statement of –

- (a) the maximum prospective short circuit current at the supply terminals;
- (b) for low voltage connections, the maximum earth loop impedance of the earth fault path outside the installation;
- (c) the type and rating of the distributor's protective device or devices nearest to the supply terminals;
- (d) the type of earthing system applicable to the connection; and
- (e) the information specified in regulation 27(1), which apply, or will apply, to that installation.

The main bonding to other services, considered in 6.4, might require permission of the undertakings responsible for those services, and such bonding to telephone and telegraphic circuits should not be undertaken unless authorized by those undertakings; guidance is contained in relevant Telecoms industry standards such as  BS 7671:2008+A3  and BS EN 50173 (all parts).

6.4 Protective equipotential bonding

NOTE 1 The protective measure automatic disconnection of supply, requires:

- a) automatic disconnection in the event of a fault to earth;
- b) protective earthing (to facilitate this); and
- c) protective equipotential bonding to reduce touch voltages.

Where the automatic disconnection of supply is adopted, protective equipotential bonding is recommended (see Figure 6), whatever the type of supply system. Bonding, by means of main equipotential bonding conductors, of extraneous-conductive-parts to the main earthing terminal of the installation is recommended; these extraneous-conductive-parts include:

- a) water installation pipes;
- b) gas installation pipes;
- c) other installation pipework and ducting;
- d) central heating and air conditioning systems;
- e) exposed metallic structural parts of the building structure; and
- f) other metallic parts such as cable trays and cable ladder racks.

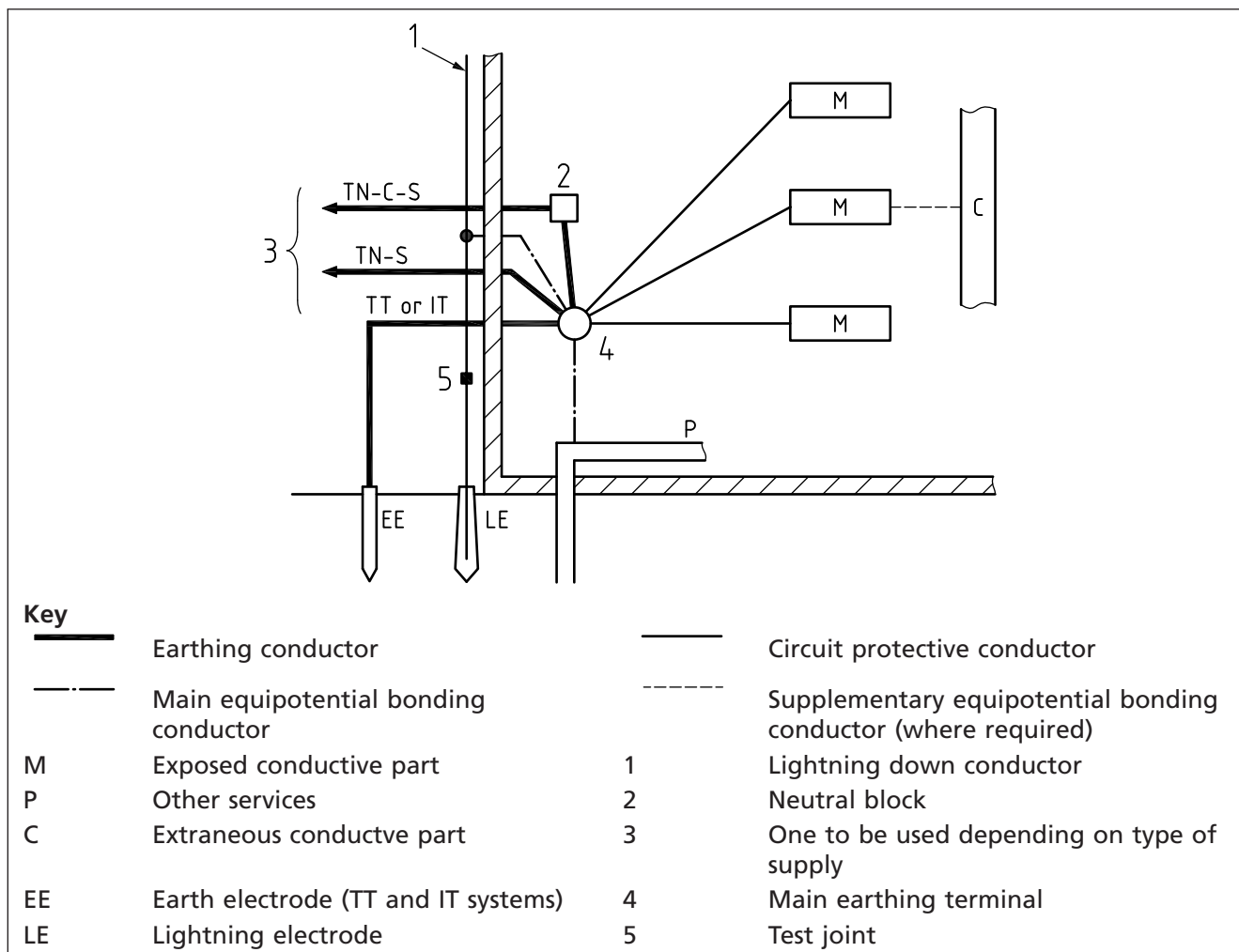
Connection of a lightning protection system to the protective equipotential bonding should be made in accordance with BS EN 62305-4.

NOTE 2 BS EN 62305-4 requires that a bond is made between the lightning protecting system and the installation equipotential bonding system. The responsibility for specifying and installing this bond is that of the organization responsible for the lightning protection system.

Where both main gas pipes and main water pipes enter a location, a common bonding conductor may be used, but in such cases that conductor should be continuous or should be permanently jointed (by soldering or crimping) in order to preserve continuity. Such a bonding conductor may also be used in association with other extraneous-conductive-parts.

The main equipotential bonding connections to the water and gas pipes should be made as near as practicable to their point of entry into the premises. If there is an insulating section or insert at that point, the bonding connection should be made to the metallic pipes on the consumer's side of the section or insert and before branch pipework. Where practicable, the connection should be made within 600 mm of the meter outlet union or at any point of entry to the building if the meter is external (see **BS 7671:2008+A3**, Regulation **544.1.2**).

Figure 6 Earthing arrangement and protective conductors for consumers' installations



6.5 Main earthing terminal

A consumer's LV installation supplied from TN distribution networks should have a main earthing terminal (MET) that is connected to the protective conductor of the source and via this to earth electrodes installed in the electricity distribution supply system.

Where the installation provides electricity supplies to a number of consumers, an independent earth electrode should also be connected to the MET if the main supply has a combined neutral and protective conductor.

In the case of TT and IT systems the MET should be earthed by an independent earth electrode only.

COMMENTARY ON 6.5

The function of the MET is to provide a reference point for the installation. It consists of a terminal or bar provided for the connection of protective conductors, including protective bonding conductors, and conductors for functional earthing.

Although the MET is connected to Earth it is seldom at zero potential because of the potential difference caused by leakage and other currents flowing to Earth.

See also **BS 7671:2008+A3**, **411.4.2**.

6.6 Protective conductors

The generic term “protective conductor” embraces the specific types shown in Figure 6; in any particular case, the function intended should be correctly identified, because this determines which of the numerous requirements prescribed in **BS 7671:2008+A3** are applicable.

COMMENTARY ON 6.6

BS 7671:2008+A3 requires that all protective conductors are suitably protected against mechanical and chemical deterioration and electrodynamic effects.

Two methods are given for determining the cross-sectional area required for a protective conductor. In the first the cross-sectional area is related empirically to that of the associated line conductor (see **BS 7671:2008+A3**, Table 54.7) and in the second method it is calculated using the “adiabatic equation” of **BS 7671:2008+A3**, Regulation **543.1.3**:

543.1.3 The cross-sectional area, where calculated, shall be not less than the value determined by the following formula or shall be obtained by reference to BS 7454.

$$s \geq \frac{I\sqrt{t}}{k}$$

NOTE This equation is an adiabatic equation and is applicable for disconnection times not exceeding 5 s.
where:

- S* is the nominal cross-sectional area of the conductor in mm²
- I* is the value in amperes (rms for a.c.) of fault current for a fault of negligible impedance, which can flow through the associated protective device, due account being taken of the current limiting effect of the circuit impedances and the limiting capability (*I*²*t*) of that protective device
- t* is the operating time of the disconnecting device in seconds corresponding to the fault current *I* amperes
- k* is a factor taking account of the resistivity, temperature coefficient and heat capacity of the conductor material, and the appropriate initial and final temperatures.

Values of *k* for protective conductors in various use or service are as given in Tables 54.2 to 54.6. The values are based on the initial and final temperatures indicated in each Table.

Where the application of the formula produces a non-standard size, a conductor having the nearest larger standard cross-sectional area shall be used.

The advantage of the adiabatic calculation is that it will frequently permit the use of smaller conductor cross-sectional areas but it is not applicable to protective bonding conductors.

For disconnection times exceeding 5 s refer, to BS 7454.

6.7 Earthing conductors

Earthing conductors are protective conductors and should be sized in the same way as other protective conductors (see 6.6), but with specified minimum cross-sectional areas when buried in the ground specified in

BS 7671:2008+A3, Table 54.1.

NOTE 1 Uncoated buried copper is electro-positive to uncoated buried steel and when interconnected by a current-carrying conductor, these metals form an electrochemical cell that can cause accelerated corrosion of steel (see [A1](#) BS EN 14505 [A1](#)). As a rough guide, a direct current of 1 A leaving a buried steel structure can remove nearly 9 kg of metal in 1 year.

Aluminium or copper-clad aluminium conductors should not be used for final connections to earth electrodes. Where a copper conductor is to be joined to aluminium the procedure described in **9.9.4.3** should be followed.

The connection of the earthing conductor to the earth electrode or other means of earthing should be soundly made by the use of compound filled, encapsulated or substantial clamps of non-ferrous material. Where the earthing conductor is to be connected to the metal sheath and armour of a cable, the sheath and armour should be bonded together and the principal connection between the cable and the earthing conductor should be to the metal sheath and should be plumbed.

Alternatively, if a clamp is used for this connection it should be so designed and installed as to provide reliable connection without damage to the cable. Earthing and bonding clamps should conform to BS 951.

NOTE 2 Whilst the connection referred to might be in a link box underground and therefore not readily accessible, [A1](#) BS 7671:2008+A3 [A1](#) stipulates that provision is made in an accessible position for disconnecting the main earthing terminal of an installation from the means of earthing to facilitate measurement of the resistance of the earthing arrangements.

6.8 Circuit protective conductors

When the metallic sheath of a cable is used as a circuit protective conductor, every joint in that sheath should be so made that its current-carrying capacity is not less than that of the sheath and, where non-metallic joint boxes are used, means such as a metal strip having the same effective current-carrying capacity as the largest cable entering the box should be provided to maintain continuity.

When using the metallic sheath or armour, attention should also be paid to the ability of the cable glands and connections to carry prospective earth fault currents and it might be necessary to seek advice from the manufacturers on this aspect. Special precautions may be considered necessary with metal parts of the assembly, particularly gland plates where abrasion resistant finishes, e.g. powder coatings, are used.

Metallic enclosures for cables, such as conduit, ducting and trunking, may be used as circuit protective conductors but where flexible or pliable conduit is used separate protective conductors should be included inside the conduit to maintain the integrity of the earth path. Where conduit and trunking are used, a high standard of workmanship in installation is essential. Joints should be so made such that their current-carrying capacity is not less than that of the conduit itself. Joints should also have the same properties, as regards insulation, mechanical strength and protection, as those of the wiring system or conduit of which they are part. Slackness in joints can result in deterioration in, and even complete loss of, continuity; plain slip or pin-grip sockets should not be used. In the case of unscrewed conduit, the use of lug-grip fitting is recommended, but for outdoor installations and where otherwise subjected to atmospheric corrosion, screwed conduit should always be used, suitably protected against corrosion. In screwed-conduit installations the use of locknuts is recommended. Joints in all conduit systems should be painted overall after assembly.

These precautions ought to be adequate, but periodical tests should be made to verify that electrical continuity is satisfactorily maintained.

NOTE Electrolytic corrosion is liable to occur under damp conditions at contacts between dissimilar metals. Copper and alloys having a high copper content are particularly liable to cause corrosion under these conditions when in contact with aluminium alloys.

When dissimilar metals form part of an electrical circuit, the joints should be clean and assembled free of moisture, and then immediately treated with a suitable medium against the ingress of moisture.

Where damp conditions prevail, the fittings, fixing screws and saddles used to secure aluminium-based alloy conductors should be made of aluminium alloy or suitably protected steel (zinc coated) and the surfaces which are in contact with a conductor should be painted before assembly.

6.9 Installations and locations of increased shock risk

For installations and locations of increased shock risk, additional measures may be considered necessary; these include:

- a) supplementary equipotential bonding;
- b) RCDs with a rated residual current of 30 MA or less; and
- c) protective extra-low voltage (PELV) and separated extra-low voltage (SELV) equipment.

When an installation supplies a number of buildings, main equipotential bonding is essential in each building, so that each has a reference point to which are connected the conductive parts referred to in 6.4. In order to reduce the voltages occurring in the event of an earth fault still further, it is sometimes necessary to install supplementary local equipotential bonding.

6.10 Supplementary bonding – Circuits where disconnection times cannot be met

COMMENTARY ON 6.10

Where the disconnection times of A1 BS 7671:2008+A3 A1 , Chapter 41, cannot be met (typically 0.4 s and 5 s for 230 V TN systems) Regulation 411.3.2.6 requires supplementary bonding in accordance with Regulation 415.2.2:

415.2.2 Where doubt exists regarding the effectiveness of supplementary equipotential bonding, it shall be confirmed that the resistance R between simultaneously accessible exposed-conductive-parts and extraneous-conductive-parts fulfils the following condition:

$$\text{A1} \quad R \leq 50 \, V/I_a \text{ in a.c. systems}$$

$$R \leq 120 \, V/I_a \text{ in d.c. systems } \text{A1}$$

where I_a is the operating current in amperes of the protective device –

- for RCDs, $I_{\Delta n}$.
- for overcurrent devices, the current causing automatic operation in 5 s.

These formulae allow relatively long lengths and are unlikely to require other than standard conductor cross-sectional areas.

6.11 Industrial and commercial installations

6.11.1 General

Many industrial installations take their electrical power from a public distribution network operator at a voltage which might be above 1 000 V a.c.; fault capacities might also be greater than those encountered in domestic premises and great care should be exercised in the design of all protective conductors and their terminations.

Equally important is the consideration that should be given to the effect that earthing might have on the processes employed in some factories.

Where problems related to flammable liquids and gases are concerned, or if there is a need for detailed knowledge of protective earthing that is not directly related to electrical safety, reference should be made to the relevant British Standards.

NOTE Further information is obtainable from the Health and Safety Executive concerning statutes, codes and standards that apply to particular processes.

Where instrumentation and data circuits are involved, particular care should be exercised when interconnecting earthing systems. The designer should also consider transients or circulating currents in the earthing system that might introduce unwanted voltages within electronic circuits by magnetic induction.

There might be occasions, which should be considered, when direct earthing of exposed metalwork could interfere with other systems that employ the general mass of earth as a current transmission path; typical examples are telephony and cathodic protection.

6.11.2 Earth fault loop impedance

As in the case of high voltage supplies, the use of low resistance paths for the return of earth fault current in low voltage industrial systems is necessary, and the total loop impedance should be sufficiently low as to allow the operation of a suitably chosen protective device, fuse, circuit-breaker or RCD within the time given in  BS 7671:2008+A3 .

6.11.3 Single-core cables

Where single-core cables are used in a low voltage installation it is generally preferable to bond and earth all metallic sheaths or armour at both ends of each run (solid bonding). Induced voltages in the sheaths or armour should be reduced to low values and the sheaths or armour may then be used as a protective conductor, in parallel if necessary with an additional conductor. Currents circulating in the armour or sheath reduce the current-carrying capacity of the cables; where this reduction is not acceptable, sheaths and armour may be bonded at one end of a run only (single-point bonding) and a separate protective conductor is then necessary.

NOTE Consideration of the values of standing voltage which will appear at the open circuit ends of the sheaths or armour is covered in 9.12.2.

7 Generators

COMMENTARY ON CLAUSE 7

Three main types of generating set are considered in this Clause:

- a) *small sets having ratings below 10 kW that are not earthed and not operated in parallel with the electricity supply;*
- b) *sets having ratings usually in excess of 10 kW that are normally 3-phase and require earthing; and*

- c) *small-scale embedded generators (up to 16 A/phase) for operation in parallel with public low-voltage distribution networks.*

7.1 Unearthed generating sets (ratings below 10 kW)

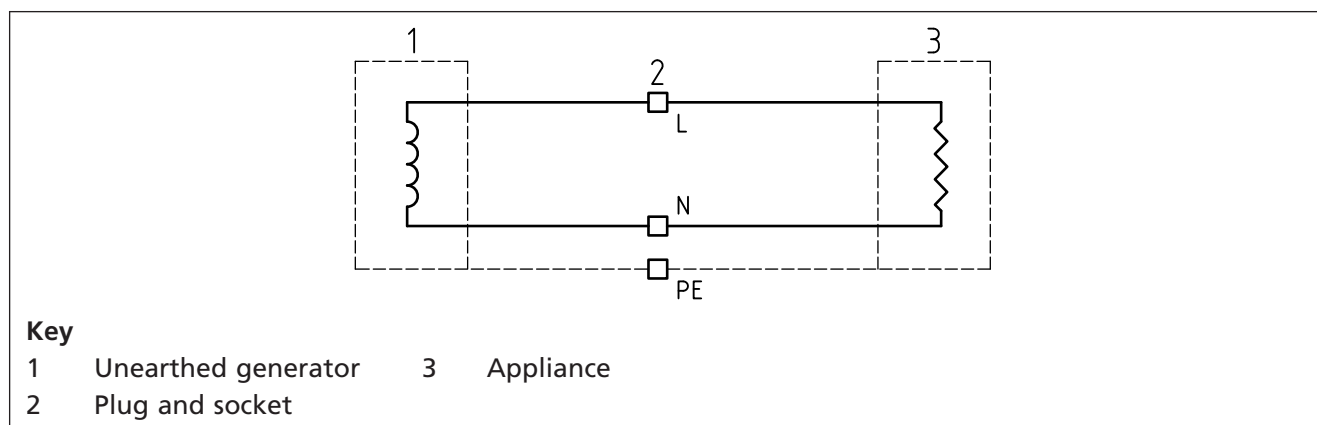
7.1.1 General

NOTE 1 Low-voltage, single-phase generating sets are generally mobile or transportable machines ranging in size from 0.2 kW to 10 kW.

NOTE 2 Winding connections are normally brought out to a socket-outlet in which the third or protective conductor is connected to the generator enclosure.

Small single-phase generators are run as floating systems, i.e. without the winding connected to the frame or to earth, see Figure 7; the generator frame and enclosure should be bonded to all exposed-conductive-parts of the load equipment, using a correctly terminated protective conductor in the connecting cable.

Figure 7 Small low voltage single phase generator run as a floating system



Cables, plugs, socket-outlets and cable couplers should be suitable for their environmental exposure. Cables should be a flexible type which includes a metallic braid or screen suitable for use as a protective conductor.

NOTE 3 The termination of braided cable in domestic type plugs can be difficult. For this reason it might be preferable to select plugs and sockets conforming to BS EN 60309 (all parts).

If a cable without a metallic screen is used, it should be flexible with an extruded oversheath, capable of high abrasion resistance and should contain a separate protective conductor.

Cables, plugs and socket-outlets should be inspected frequently and if defective should be replaced, not repaired; equipment and cables that are in good condition are vital for the continued safety of an unearthed system and form the first line of protection against the risk of shock.

All cables should be as short as practicable and supply compactly located loads, since experience has shown that a compact installation is less likely to suffer insulation damage, causing earth faults, than an extensive one.

It should be noted that RCDs will not operate on a first fault and only on particular second faults.

7.1.2 Protective measure electrical separation

As required by [BS 7671:2008+A3](#), Section **413**, such an unearthed construction in conformity with **7.1.1** should be limited to one item of equipment unless under the supervision of a skilled or instructed person (see [BS 7671:2008+A3](#), Regulation group **418.3**).

7.1.3 Unearthed generators (rating below 10 kW) supplying a fixed installation

Where an unearthed generator is to supply a fixed installation (see Figure 8) it is recommended that automatic disconnection of supply is adopted as follows.

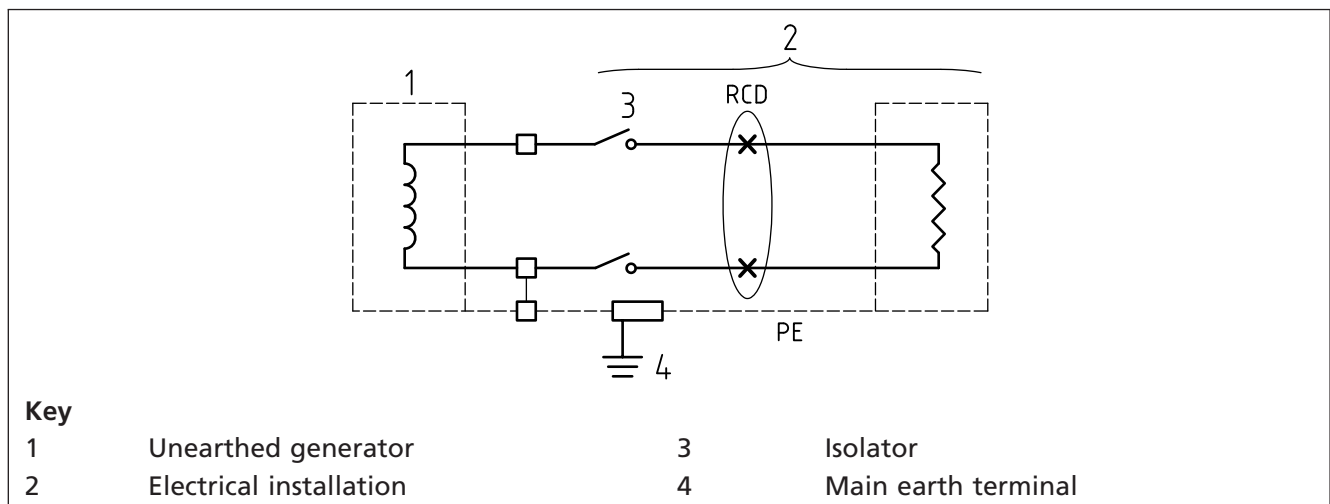
- One pole of a single phase generator should be connected to the installation main earthing terminal.
- The main earthing terminal should be connected to an earth electrode (see Figure 8).
- The installation should conform to [BS 7671:2008+A3](#), with all exposed-conductive-parts and all extraneous-conductive-parts connected to the main earthing terminal.
- The installation should be protected by RCDs.

The installation should conform to the requirements of [BS 7671:2008+A3](#), including those for automatic disconnection of supply (ADS).

The earth electrode should have a resistance to earth not exceeding 200 Ω , (see [BS 7671:2008+A3](#), Table 41.5, Note 2).

The RCD will not provide protection for faults on the generator side of the RCD, and consequently precautions should be taken.

Figure 8 Small low voltage generator supplying a fixed installation



7.1.4 Unearthed generators supplying a mobile or transportable unit

[BS 7671:2008+A3](#), Section **717**, and in particular Figure 717.2 should be consulted for constructions for supplying mobile and transportable units.

Where an unearthed generator is to supply a mobile installation it is recommended that the protective measure automatic disconnection of supply be adopted as follows (see Figure 9).

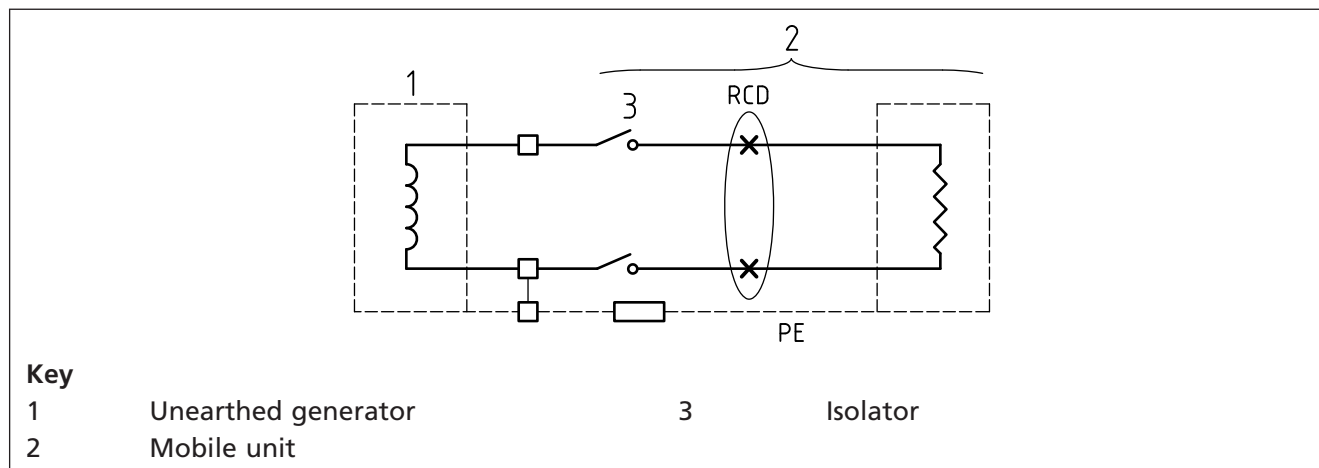
- One pole of a single phase generator should be connected to the installation main earthing terminal.

- b) The installation should conform to BS 7671:2008+A3, with all exposed-conductive-parts and all extraneous-conductive-parts connected to the main earthing terminal.
- c) The installation should be protected by RCDs.
- d) If the unit supplies equipment or socket outlets outside the unit these circuits should be protected by RCDs with a rated residual operating current not exceeding 30 mA and an operating time not exceeding 40 ms at a residual current of $5I_{\Delta n}$, see BS 7671:2008+A3, Section 717 and Regulation 551.4.4.

The installation should conform to the requirements of BS 7671:2008+A3, including those for automatic disconnection of supply.

If practicable, an earth electrode should be connected to the main earthing terminal of the unit with a resistance to earth sufficiently low to operate the RCDs. The RCD will not provide protection for faults on the generator side of the RCD, and consequently precautions should be taken.

Figure 9 Small unearthed generator supplying a mobile or transportable unit



7.2 Earthed generating sets

7.2.1 General

Generating sets may be earthed to limit the potential of line conductors with respect to the general mass of Earth particularly under fault or unbalanced conditions, and earthing is generally necessary as part of the protection against electric shock (see Figure 10 to Figure 12).

Generating sets should be protectively earthed by connecting the frame and the neutral point of the generating set, associated exposed-conductive-parts and extraneous-conductive-parts to a main earthing terminal. The earthing terminal or bar should be connected to an independent earth electrode. The earth loop impedance at any point of the installation should be low enough to ensure operation of the fault protection, and this should be taken into account if the earth electrode forms part of the earth fault loop, such as for a TT system (but not TN).

For independent earth electrodes associated with the local earthing of the star point of generating plant, the earth resistance should not exceed 20 Ω .

NOTE 1 If the generating set is permanently installed, other earthing facilities associated with the installation might be necessary.

NOTE 2 The earthing of the electrical system might require that the neutral point of the a.c. generator is connected to earth, either directly or via an impedance.

Where an installation is supplied by more than one source of energy (e.g. a supply from a distributor and a supply from a generating set), the earthing system of the installation should be designed so that each source that can operate independently of other sources and remain earthed if all the other sources are not connected.

NOTE 3 There are many variations in system design and, for any particular application, the precise method of earthing of each energy source is subject to the recommendations of the equipment supplier and to the system parameters.

NOTE 4 Public low voltage distribution networks have to be directly earthed in conformity to the current ESQCR (Regulations 7 to 10) [1] ^{A1} and ESQCR (NI) [3] ^{A1}. Since an installation connected to a distributors network might be expected to be designed accordingly, direct earthing is also normally adopted for any generating set which supplies such an installation.

Whenever it is intended that a private generating set be used to supply any part of a consumer's system normally supplied by a distributor, the distributor and supplier should be consulted.

NOTE 5 ^{A1} The ESQCR [Regulation 22(1)(d)] [1] and ESQCR (NI) Regulation 23(1)(d) [3] require that, where operation in parallel with a distributors network is intended, the agreement of the distributor has to be obtained first, subject to Regulation 22(2) {Regulation 23(2) in ESQCR (NI) [3]} for generators rated up to a total of 16 A per phase. ^{A1}

7.2.2 References

The following ENA Engineering Recommendations should be consulted where relevant:

- ER G59, *Recommendations for the connection of embedded generating plant to the Regional Electricity Companies' distribution systems*;
- ER G83, *Recommendations For The Connection Of Small-Scale Embedded Generators (Up To 16 A Per Phase) In Parallel With Public Low-Voltage Distribution Networks*;
- ER G84, *Recommendations for the Connection of Mobile Generating Sets to Public Distribution Networks*.

NOTE ER G84 gives recommend working procedures for the connection of small portable generating sets and larger mobile generating sets for the purposes of providing a temporary supply to customers or for network support. It addresses direct connections to the low voltage network and connections via a step-up unit to the high voltage network.

7.2.3 Generating sets having ratings above 10 kW

Generating sets with outputs above 10 kW are normally 3-phase; these types of set may be permanently installed in buildings, enclosed in weatherproof and sound attenuated enclosure, and vehicle or trolley mounted. It should not be assumed that they will be provided with the generator windings connected to a mounting frame.

An independent generator may be installed to supply construction sites (BS 7671:2008, Section 704) or temporary electrical installations (BS 7671:2008, Section 740) as an alternative to a distributor's supply which is as yet unavailable. Such installations though temporary should be robust and conform to the requirements of BS 7671:2008, with a main earthing terminal provided connected to earth, usually by an earth electrode.

7.2.4 Generators operating independently of the supply

In this mode of operation the generating plant should be the only source of supply to an installation. If there is only one machine, both protective and supply system earthing should be achieved by connecting the generator neutral, the generator frame and exposed-conductive-parts and extraneous-conductive-parts to a main earthing terminal and by the use of an independent earth electrode. Where two or more generators are operating in parallel, neutral/earth circulating currents should be dealt with by the methods described in 7.2.6.

7.2.5 Generators providing a changeover supply

In this mode of operation the generating plant may be used to provide a full alternative supply to either the whole or part of an installation. Special attention should be given to the changeover arrangements so that operation in parallel with the incoming supply is not possible. Line and neutral isolation from the incoming supply should be provided.

Where there is only one generating set, the neutral point of its windings, the generator frame, all exposed-conductive-parts and extraneous-conductive-parts should be connected to the main earthing terminal. This earthing terminal should be connected to an independent earth electrode and, where appropriate, to the protective earth terminal provided by the distributor.

7.2.6 Two or more generators operating in parallel (providing a changeover supply)

When two or more generating sets, operating in parallel, are used to supply an installation, the protective earthing of the generator frames and associated metalwork should follow the same procedure as that described for only one generating set. However, the method of supply system earthing for the generator windings should be chosen considering the magnitude of the circulating currents, commonly third harmonic, which can flow in the neutral/earthing conductors.

To overcome such problems, one of the following arrangements should be selected:

- generating sets that have a.c. generators with low harmonic output (e.g. zigzag wound machines);
- star-point switching to connect the star point of only one generator to earth during parallel operation (a star point switching arrangement is shown in Figure 10); it is essential that electrical and mechanical interlocks on the star-point switches ensure the integrity of the neutral/earth connection at all times and under all possible operating conditions;
- a neutral earthing transformer connected between the line conductors and earth; this enables the neutral of the installation to be permanently earthed, with the generators connected to the busbars as three-wire machines (a neutral earthing transformer arrangement is shown in Figure 11); or
- a suitable reactor in the neutral connection of each generator which will attenuate higher frequency currents without offering significant impedance at mains frequency (an earthing arrangement for a single machine operating in changeover mode is given in Figure 12).