

CONSOLIDATED VERSION

VERSION CONSOLIDÉE



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

**Installations électriques à basse tension –
Partie 4-44: Protection pour assurer la sécurité – Protection contre les
perturbations de tension et les perturbations électromagnétiques**



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LOW-VOLTAGE ELECTRICAL INSTALLATIONS –

Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances

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This Consolidated version of IEC 60364-4-44 bears the edition number 2.2. It consists of the second edition (2007-08) [documents 64/1600/FDIS and 64/1609/RVD] and its corrigenda 1 (2010-05) and 2 (2011-10), its amendment 1 (2015-09) [documents 64/2032/FDIS and 64/2073/RVD] and its corrigendum (2016-08), and its amendment 2 (2018-01) [documents 65C/684/FDIS and 65C/691/RVD]. The technical content is identical to the base edition and its amendments.

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendments 1 and 2. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

International Standard IEC 60364-4-44 has been prepared by IEC technical committee 64: Electrical installations and protection against electric shock.

The document 64/1600/FDIS, circulated to the National Committees as Amendment 3, led to the publication of the new edition.

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

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

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

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

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INTRODUCTION

Part 4-44 of IEC 60364 covers the protection of electrical installations and measures against voltage disturbances and electromagnetic disturbances.

The requirements are arranged into four clauses as follows:

- | | |
|------------|---|
| Clause 442 | 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 |
| Clause 443 | Protection against overvoltages of atmospheric origin or due to switching |
| Clause 444 | Measures against electromagnetic influences |
| Clause 445 | Protection against undervoltage |

LOW-VOLTAGE ELECTRICAL INSTALLATIONS –

Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances

440.1 Scope

The rules of this Part of IEC 60364 are intended to provide requirements for the safety of electrical installations in the event of voltage disturbances and electromagnetic disturbances generated for different specified reasons.

The rules of this part are not intended to apply to systems for distribution of energy to the public, or power generation and transmission for such systems (see the scope of IEC 60364-1) although such disturbances may be conducted into or between electrical installations via these supply systems.

440.2 Normative references

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

IEC 60038:~~1983~~ 2009, *IEC standard voltages*

IEC 60050-604:1987, *International Electrotechnical Vocabulary – Chapter 604: Generation, transmission and distribution of electricity – Operation*

IEC 60364-1, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*

IEC 60364-4-41:2005, *Electrical installations of buildings – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60364-5-52, *Low-voltage electrical installations – Part 5-52: Selection and erection of electrical equipment – Wiring systems*

IEC 60364-5-53:2001, *Electrical installations of buildings - Part 5-53: Selection and erection of electrical equipment - Isolation, switching and control*

IEC 60364-5-53:2001/AMD1:2002

IEC 60364-5-53:2001/AMD2:2015

IEC 60364-5-54:2002, *Electrical installations of buildings – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective bonding conductors* ¹

IEC 60479-1:2005, *Effects of current on human beings and livestock – Part 1: General aspects*

IEC 60664-1:2007, *Insulation co-ordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60950-1, *Information technology equipment – Safety – Part 1: General requirements*

IEC 61000-2-5:1995, *Electromagnetic compatibility (EMC) – Part 2: Environment – Section 5: Classification of electromagnetic environments – Basic EMC publication*

¹ A third edition is currently in preparation.

IEC 61000-6-1, *Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity for residential, commercial and light-industrial environments*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments*

IEC 61000-6-3, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for residential, commercial and light-industrial environments*

IEC 61000-6-4, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments*

IEC 61156 (all parts), *Multicore and symmetrical pair/quad cables for digital communication*

IEC 61196-7, *Coaxial communication cables – Part 7: Sectional specification for cables for BCT cabling in accordance with ISO/IEC 15018 – Indoor drop cables for systems operating at 5 MHz – 3 000 MHz*

IEC 61558-2-1, *Safety of power transformers, power supplies, reactors and similar products – Part 2-1: Particular requirements for tests for separating transformers and power supplies incorporating separating transformers for general applications*

IEC 61558-2-4, *Safety of power transformers, power supply units and similar – Part 2-4: Particular requirements for isolating transformers for general use*

IEC 61558-2-6, *Safety of power transformers, power supply units and similar – Part 2-6: Particular requirements for safety isolating transformers for general use*

IEC 61558-2-15, *Safety of power transformers, power supply units and similar – Part 2-15: Particular requirements for isolating transformers for the supply of medical locations*

IEC 61643 (all parts), *Low-voltage surge protective devices*

IEC 61643-11:2011, *Low-voltage surge protective devices – Part 11: Surge protective devices connected to low-voltage power systems – Requirements and test methods*

IEC 61643-22, *Low-voltage surge protective devices – Part 22: Surge protective devices connected to telecommunications and signalling networks – Selection and application principles*

IEC 61936-1, *Power installations exceeding 1 kV a.c. – Part 1: Common rules*

IEC 62305 (all parts), *Protection against lightning*

IEC 62305-1, *Protection against lightning – Part 1: General principles*

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

IEC 62305-4, *Protection against lightning – Part 4: Electrical and electronic systems within structures*

ISO/IEC 11801-1, *Information technology – Generic cabling for customer premises – Part 1: General requirements*

ISO/IEC 14763-2:2012, *Information technology – Implementation and operation of customer premises cabling – Part 2: Planning and installation*
ISO/IEC 14763-2:2012/AMD1:2015

ISO/IEC TR 29106, *Information technology – Generic cabling – Introduction to the MICE environmental classification*

441 (Vacant)**442 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****442.1 Field of application**

The rules of this clause provide requirements for the safety of low-voltage installation in the event of

- a fault between the high-voltage system and earth in the transformer substation that supplies the low-voltage installation,
- a loss of the supply neutral in the low-voltage system,
- a short-circuit between a line conductor and neutral,
- an accidental earthing of a line conductor of a low-voltage IT-system.

The requirements for the earthing arrangement at the transformer substation are given in IEC 61936-1.

442.1.1 General requirements

As Clause 442 covers faults between a high-voltage line and the earth in the HV/LV substation, it gives rules for the designer and installer of the substation. It is necessary to have the following information concerning the high-voltage system:

- quality of the system earthing;
- maximum level of earth fault current;
- resistance of the earthing arrangement.

The following subclauses consider four situations as proposed in 442.1, which generally cause the most severe temporary overvoltages such as defined in IEC 60050-604:

- fault between the high-voltage system(s) and earth (see 442.2);
- loss of the neutral in a low-voltage system (see 442.3);
- accidental earthing of a low-voltage IT system (see 442.4);
- short-circuit in the low-voltage installation (see 442.5).

442.1.2 Symbols

In Clause 442 the following symbols are used (see Figure 44.A1):

I_E	part of the earth fault current in the high-voltage system that flows through the earthing arrangement of the transformer substation.
R_E	resistance of the earthing arrangement of the transformer substation.
R_A	resistance of the earthing arrangement of the exposed-conductive-parts of the equipment of the low-voltage installation.
R_B	resistance of the earthing arrangement of the low-voltage system neutral, for low-voltage systems in which the earthing arrangements of the transformer substation and of the low-voltage system neutral are electrically independent.
U_0	in TN- and TT-systems: nominal a.c. r.m.s. line voltage to earth

in IT-systems: nominal a.c. voltage between line conductor and neutral conductor or mid point conductor, as appropriate

- U_f power-frequency fault voltage that appears in the low-voltage system between exposed-conductive-parts and earth for the duration of the fault.
- U_1 power-frequency stress voltage between the line conductor and the exposed-conductive-parts of the low-voltage equipment of the transformer substation during the fault.
- U_2 power-frequency stress voltage between the line conductor and the exposed-conductive-parts of the low-voltage equipment of the low-voltage installation during the fault.

NOTE 1 The power-frequency stress voltage (U_1 and U_2) is the voltage that appears across the insulation of low-voltage equipment and across surge protective devices connected to the low-voltage system.

The following additional symbols are used in respect of IT-systems in which the exposed-conductive-parts of the equipment of the low-voltage installation are connected to an earthing arrangement that is electrically independent of the earthing arrangement of the transformer substation.

- I_h fault current that flows through the earthing arrangement of the exposed-conductive-parts of the equipment of the low-voltage installation during a period when there is a high-voltage fault and a first fault in the low-voltage installation (see Table 44.A1).
- I_d fault current, in accordance with 411.6.2, that flows through the earthing arrangement of the exposed-conductive-parts of the low-voltage installation during the first fault in a low-voltage system (see Table 44.A1).
- Z impedance (e.g. IMD internal impedance, artificial neutral impedance) between the low-voltage system and an earthing arrangement.

NOTE 2 An earthing arrangement may be considered electrically independent of another earthing arrangement if a rise of potential with respect to earth in one earthing arrangement does not cause an unacceptable rise of potential with respect to earth in the other earthing arrangement. See IEC 61936-1.

442.2 Overvoltages in LV-systems during a high-voltage earth fault

In case of a fault to earth on the HV-side of the substation, the following types of overvoltage may affect the LV-installation:

- power frequency fault-voltage (U_f);
- power frequency stress-voltages (U_1 and U_2).

Table 44.A1 provides the relevant methods of calculation for the different types of overvoltages.

NOTE 1 Table 44.A1 deals with IT systems with a neutral point only. For IT systems with no neutral point, the formulae should be adjusted accordingly.

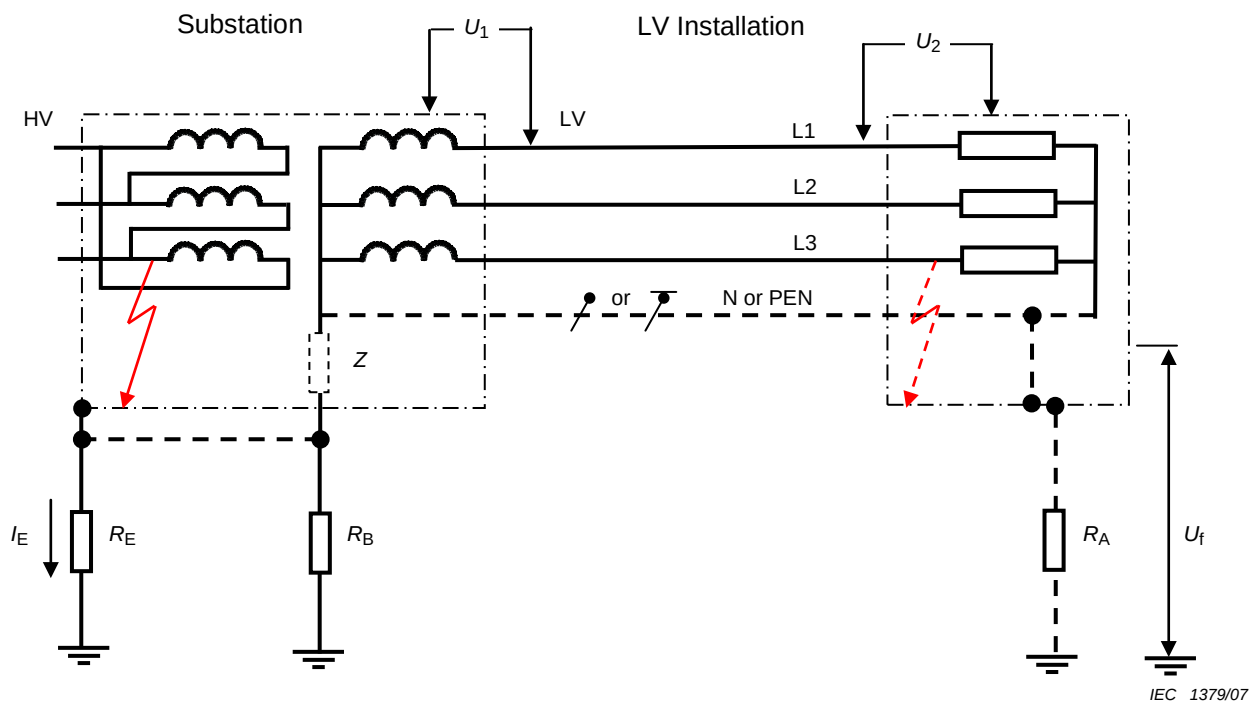


Figure 44.A1 – Representative schematic sketch for possible connections to earth in substation and LV-installation and occurring overvoltages in case of faults

Where high- and low-voltage earthing systems exist in proximity to each other, two practices are presently used:

- interconnection of all high-voltage (R_E) and low-voltage (R_B) earthing systems;
- separation of high-voltage (R_E) from low-voltage (R_B) earthing systems.

The general method used is interconnection. The high- and low-voltage earthing systems shall be interconnected if the low-voltage system is totally confined within the area covered by the high-voltage earthing system (see IEC 61936-1).

NOTE 2 Details of the different types of system earthing (TN, TT, IT) are shown in IEC 60364-1.

Table 44.A1 – Power-frequency stress voltages and power-frequency fault voltage in low-voltage system

Types of system earthing	Types of earth connections	U_1	U_2	U_f
TT	R_E and R_B connected	U_0 *)	$R_E \times I_E + U_0$	0 *)
	R_E and R_B separated	$R_E \times I_E + U_0$	U_0 *)	0 *)
TN	R_E and R_B connected	U_0 *)	U_0 *)	$R_E \times I_E$ **)
	R_E and R_B separated	$R_E \times I_E + U_0$	U_0 *)	0 *)
IT	R_E and Z connected R_E and R_A separated	U_0 *)	$R_E \times I_E + U_0$	0 *)
		$U_0 \times \sqrt{3}$	$R_E \times I_E + U_0 \times \sqrt{3}$	$R_A \times I_h$
	R_E and Z connected R_E and R_A interconnected	U_0 *)	U_0 *)	$R_E \times I_E$
		$U_0 \times \sqrt{3}$	$U_0 \times \sqrt{3}$	$R_E \times I_E$
	R_E and Z separated R_E and R_A separated	$R_E \times I_E + U_0$	U_0 *)	0 *)
		$R_E \times I_E + U_0 \times \sqrt{3}$	$U_0 \times \sqrt{3}$	$R_A \times I_d$

*) No consideration needs to be given.

**) See 442.2.1 second paragraph.

With existing earth fault in the installation.

NOTE 3 The requirements for U_1 and U_2 are derived from design criteria for insulation of low-voltage equipment with regard to temporary power-frequency overvoltage (see also Table 44.A2).

NOTE 4 In a system whose neutral is connected to the earthing arrangement of the transformer substation, such temporary power-frequency overvoltage is also to be expected across insulation which is not in an earthed enclosure when the equipment is outside a building.

NOTE 5 In TT- and TN-systems the statement “connected” and “separated” refers to the electrical connection between R_E and R_B . For IT-systems it refers to the electrical connection between R_E and Z and the connection between R_E and R_A .

442.2.1 Magnitude and duration of power-frequency fault voltage

The magnitude and the duration of the fault voltage U_f (as calculated in Table 44.A1) which appears in the LV installation between exposed-conductive-parts and earth, shall not exceed the values given for U_f by the curve of Figure 44.A2 for the duration of the fault.

Normally, the PEN conductor of the low-voltage system is connected to earth at more than one point. In this case, the total resistance is reduced. For these multiple grounded PEN conductors, U_f can be calculated as:

$$U_f = 0,5 R_E \times I_E$$

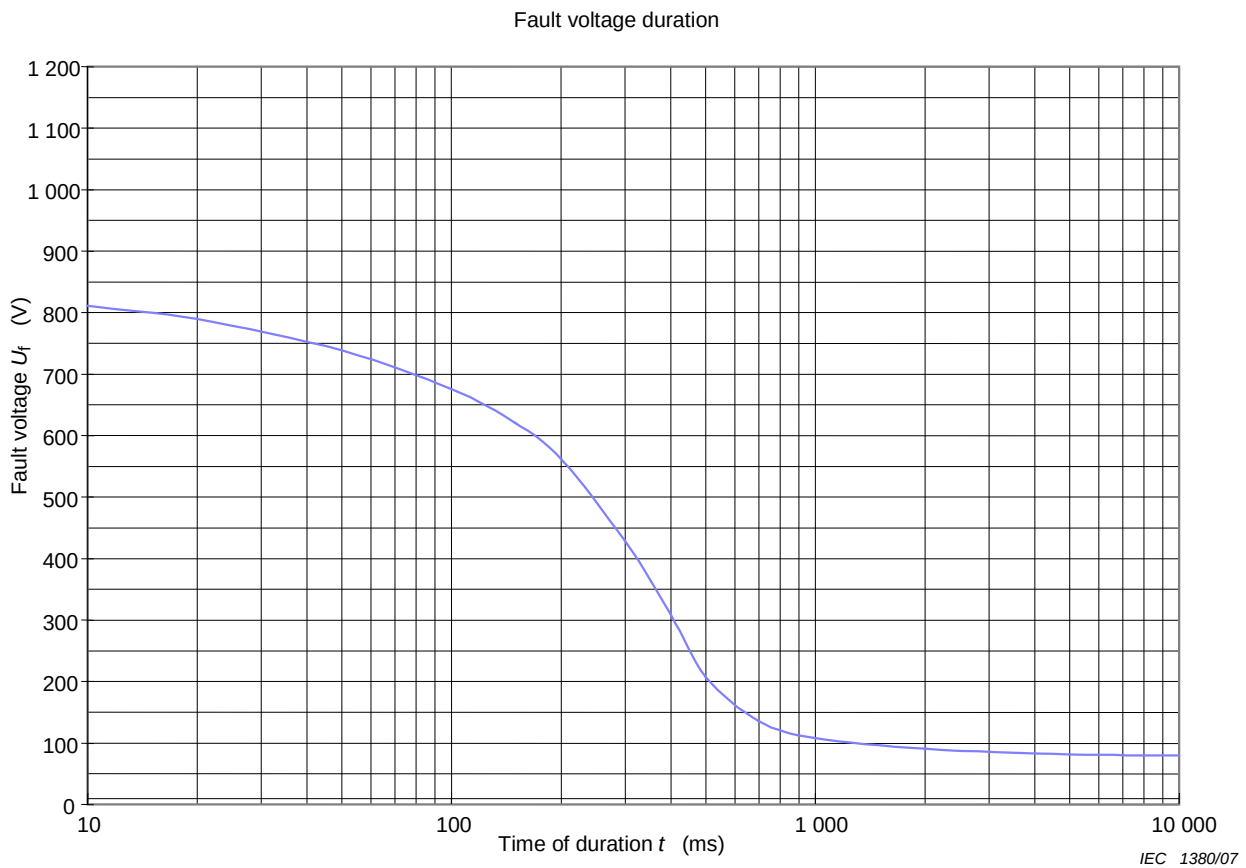


Figure 44.A2 – Tolerable fault voltage due to an earth-fault in the HV system

NOTE The curve shown in Figure 44.A2 is taken from IEC 61936-1. On the basis of probabilistic and statistical evidence this curve represents a low level of risk for the simple worst case where the low voltage system neutral conductor is earthed only at the transformer substation earthing arrangements. Guidance is provided in IEC 61936-1 concerning other situations.

442.2.2 Magnitude and duration of power-frequency stress voltages

The magnitude and the duration of the power-frequency stress voltage (U_1 and U_2) as calculated in Table 44.A1 of the low-voltage equipment in the low-voltage installation due to an earth fault in the high-voltage system shall not exceed the requirements given in Table 44.A2.

Table 44.A2 – Permissible power-frequency stress voltage

Duration of the earth fault in the high-voltage system t	Permissible power-frequency stress voltage on equipment in low-voltage installations U
>5 s	$U_0 + 250$ V
≤ 5 s	$U_0 + 1\,200$ V
In systems without a neutral conductor, U_0 shall be the line-to-line voltage.	
NOTE 1 The first line of the table relates to high-voltage systems having long disconnection times, for example, isolated neutral and resonant earthed high-voltage systems. The second line relates to high-voltage systems having short disconnection times, for example low-impedance earthed high-voltage systems. Both lines together are relevant design criteria for insulation of low-voltage equipment with regard to temporary power frequency overvoltage, see IEC 60664-1. NOTE 2 In a system whose neutral is connected to the earthing arrangement of the transformer substation, such temporary power-frequency overvoltage is also to be expected across insulation which is not in an earthed enclosure when the equipment is outside a building.	

442.2.3 Requirements for calculation of limits

Where required by Table 44.A1, the permissible power-frequency stress voltage shall not exceed the value given in Table 44.A2.

Where required by Table 44.A1, the permissible power-frequency fault voltage shall not exceed the value given in Figure 44.A2.

The requirements of 442.2.1 and 442.2.2 are deemed to be fulfilled for installations receiving a supply at low-voltage from a public electricity distribution system.

To fulfil the above requirements, coordination between the HV-system operator and the LV-system installer is necessary. Compliance with the above requirements mainly falls into the responsibility of the substation installer/owner/operator who needs also to fulfil requirements provided by IEC 61936-1. Therefore the calculation for U_1 , U_2 and U_f is normally not necessary for the LV system installer.

Possible measures to fulfil the above requirements are e.g.

separation of earthing arrangement between HV and LV;

change of LV system earthing;

reduction of earth resistance R_E .

442.3 Power-frequency stress voltage in case of loss of the neutral conductor in a TN and TT system

Consideration shall be given to the fact that, if the neutral conductor in a multi-phase system is interrupted, basic, double and reinforced insulation as well as components rated for the voltage between line and neutral conductors can be temporarily stressed with the line-to-line voltage. The stress voltage can reach up to $U = \sqrt{3} U_0$.

442.4 Power-frequency stress voltage in the event of an earth fault in an IT system with distributed neutral

Consideration shall be given to the fact that, if a line conductor of an IT system is earthed accidentally, insulation or components rated for the voltage between line and neutral conductors can be temporarily stressed with the line-to-line voltage. The stress voltage can reach up to $U = \sqrt{3} U_0$.

442.5 Power-frequency stress voltage in the event of a short-circuit between a line conductor and the neutral conductor

Consideration shall be given to the fact that if a short-circuit occurs in the low-voltage installation between a phase conductor and the neutral conductor, the voltage between the other line conductors and the neutral conductor can reach the value of $1,45 \times U_0$ for a time up to 5 s.

443 Protection against transient overvoltages of atmospheric origin or due to switching

443.1 General

Clause 443 ~~deals with~~ specifies requirements for protection of electrical installations against transient overvoltages of atmospheric origin transmitted by the supply distribution system including direct strikes to the supply system and against switching overvoltages. Clause 443 does not specify requirements for protection against transient overvoltage due to direct or nearby lightning strokes on the structure.

NOTE 1 For risk management for protection against transient overvoltage due to direct or nearby lightning strokes on the structure, see IEC 62305-2.

In general, switching overvoltages ~~are~~ have lower amplitude than transient overvoltages of atmospheric origin and therefore the requirements regarding protection against transient overvoltages of atmospheric origin normally cover protection against switching overvoltages.

~~NOTE 1 Statistical evaluations of measurements have shown that there is a low risk of switching overvoltages higher than the level of overvoltage category II. See 443.2.~~

~~Consideration shall be given to the overvoltages which can appear at the origin of an installation, to the expected keraunic level and to the location and characteristics of surge protective devices, so that the probability of incidents due to overvoltage stresses is reduced to an acceptable level for the safety of persons and property, as well as for the continuity of service desired.~~

If no transient overvoltage protection against disturbances of atmospheric origin is installed, protection against switching overvoltages may need to be provided.

NOTE 2 Overvoltages due to switching can be longer in duration and can contain more energy than the transient overvoltages of atmospheric origin. See 443.4.

The ~~values~~ characteristics of transient overvoltages of atmospheric origin depend on factors such as:

- the nature of the supply distribution system (underground or overhead);
- ~~– and~~ the possible existence of ~~a~~ at least one surge protective device (SPD) upstream of the origin of the installation;
- ~~– and~~ the voltage level of the supply system.

~~This clause provides guidance where protection against overvoltages is covered by inherent control or assured by protective control. If the protection according to this clause is not provided, insulation co-ordination is not assured and the risk due to overvoltages shall be evaluated.~~

~~This clause does not apply in case of overvoltages due to direct or nearby lightning. For protection against transient overvoltages due to direct lightning, IEC 62305-1, IEC 62305-3,~~

~~IEC 62305-4 and the IEC 61643 series are applicable. This clause does not cover overvoltage through data transmission systems.~~

~~NOTE 2 3~~ As regards transient overvoltages of atmospheric origin, no distinction is made between earthed and unearthed systems.

~~NOTE 3~~ Switching overvoltages generated outside the installation and transmitted by the supply network are under consideration.

~~NOTE 4~~ The risk due to overvoltages is considered in IEC 61662 and its amendment 1.

Protection against transient overvoltages is provided by the installation of surge protective devices (SPDs).

Selection and installation of SPDs shall be in compliance with Clause 534 of IEC 60364-5-53:2001, IEC 60364-5-53:2001/AMD1:2002 and IEC 60364-5-53/AMD2:2015.

If there is a need for SPDs on the power supply lines, additional SPDs on other lines such as telecom lines are also recommended.

Requirements for protection against transient overvoltages transmitted by data transmission systems are not covered by Clause 443. See IEC 61643-22.

Clause 443 does not apply to installations where the consequences caused by overvoltages affect:

- a) structures with risk of explosion;
- b) structures where the damage may also involve the environment (e.g. chemical or radioactive emissions).

443.2 Void

443.3 Terms and definitions

443.3.1

urban environment

area with a high density of buildings or densely populated communities with tall buildings

Note 1 to entry: A town centre is an example of an urban environment.

443.3.2

suburban environment

area with a medium density of buildings

Note 1 to entry: Town outskirts are an example of a suburban environment.

443.3.3

rural environment

area with a low density of buildings

Note 1 to entry: The countryside is an example of a rural environment.

443.3.4

surge protective device

SPD

device that contains at least one non-linear component that is intended to limit surge voltages and divert surge currents

Note 1 to entry: An SPD is a complete assembly, having appropriate connecting means.

Note 2 to entry: This note applies to the French language only.

[SOURCE: IEC 61643-11:2011, 3.1.1]

443.3.5

calculated risk level

CRL

calculated value of risk used to evaluate the need for transient overvoltage protection

Note 1 to entry: This note applies to the French language only.

443.3.6

rated impulse voltage

U_W

impulse withstand voltage value assigned by the manufacturer to the equipment or to a part of it, characterizing the specified withstand capability of its insulation against transient overvoltages.

[SOURCE: IEC 60664-1:2007, 3.9.2, Modified — symbol added]

443.4 Overvoltage control

Protection against transient overvoltage shall be provided where the consequence caused by overvoltage affects:

- a) human life, e.g. safety services, medical care facilities;
- b) public services and cultural heritage, e.g. loss of public services, IT centres, museums;
- c) commercial or industrial activity, e.g. hotels, banks, industries, commercial markets, farms.

For all other cases, a risk assessment according to 443.5 shall be performed in order to determine if protection against transient overvoltage is required. If the risk assessment is not performed, the electrical installation shall be provided with protection against transient overvoltage.

However the transient overvoltage protection is not required for single dwelling units where the total economic value of the electrical installation to be protected is less than 5 times the economic value of the SPD located at the origin of the installation.

NOTE 1 National Committees can modify the exception criteria related to single dwelling units or to not apply it.

Protection against switching overvoltages should be considered in the case of equipment likely to produce switching overvoltages or disturbances exceeding the values according to the overvoltage category of the installation e.g. where a LV generator supply the installation or where inductive or capacitive loads (e.g. motors, transformers, capacitor banks, etc.), storage units or high current loads are installed.

NOTE 2 Annex B provides guidance for overvoltage control where utility provided SPDs are installed on overhead lines.

For a low-voltage installation supplied from a high-voltage distribution network through a separate transformer (i.e. an industrial application), additional means for protection against overvoltages due to lightning should be installed on the high-voltage side of the transformer.

443.5 Risk assessment method

NOTE 1 For protection of a structure and its electrical systems against lightning and surges of atmospheric origin, IEC 62305 applies

Calculated risk level (CRL) is used to determine if protection against transient overvoltages of atmospheric origin is required. The CRL is found by the following formula

$$CRL = f_{env} / (L_P \times N_g)$$

where

- f_{env} is an environmental factor and the value of f_{env} shall be calculated according to Table 443.1.

Table 443.1 – Calculation of f_{env}

Environment	f_{env}
Rural and suburban environment	$85 \times F$
Urban environment	$850 \times F$

The value of coefficient F shall be taken equal to 1 for all installations. However, National Committees may adjust the value of coefficient F from 1 to 3 for dwellings.

- N_g is the lightning ground flash density (flash per km² per year) relevant to the location of the power line and connected structure;

NOTE 2 According to IEC 62305-2:2010, Clause A.1, 25 thunderstorm days per year are equivalent to a value of 2,5 flashes per km² per year. This is derived from the formula $N_g = 0,1 \times T_d$, where T_d is the number of thunderstorm days per year (keraunic level).

- the risk assessment length L_P is calculated as below:

$$L_P = 2 L_{PAL} + L_{PCL} + 0,4 L_{PAH} + 0,2 L_{PCH}$$

where

L_{PAL} is the length (km) of low-voltage overhead line;

L_{PCL} is the length (km) of low-voltage underground cable;

L_{PAH} is the length (km) of high-voltage overhead line;

L_{PCH} is the length (km) of high-voltage underground cable.

The total length ($L_{PAL} + L_{PCL} + L_{PAH} + L_{PCH}$) is limited to 1 km or by the distance from the first overvoltage protective device installed in the power network to the entrance of the installation whichever is the smaller.

If the distribution networks lengths are totally or partially unknown then L_{PAL} shall be taken equal to the remaining distance to reach a total length of 1 km.

For example, if only the distance of underground cable is known (e.g. 100 m), then the L_{PAL} shall be taken equal to 90 m. An illustration of an installation showing the lengths to consider is given in Figure 443.1.



- 1 origin of the installation
- 2 LV/HV transformer
- 3 surge arrester (overvoltage protective device)

If $CRL \geq 1\,000$, no protection against transient overvoltages of atmospheric origin is needed;

If $CRL < 1\,000$, protection against transient overvoltages of atmospheric origin is required.

443.26 Classification of rated impulse voltages (overvoltage categories)

~~NOTE 1—Overvoltage categories are defined within electrical installations for the purpose of insulation co-ordination and a related classification of equipment with impulse withstand voltages is provided, see Table 44B.~~

~~The impulse withstand voltage (overvoltage category) is used to classify equipment energized directly from the mains.~~

~~Impulse withstand voltages for equipment selected according to the nominal voltage are provided to distinguish different levels of availability of equipment with regard to continuity of service and an acceptable risk of failure. By selection of equipment with a classified impulse withstand voltage, insulation co-ordination can be achieved in the whole installation, reducing the risk of failure to an acceptable level.~~

~~NOTE 3—Transient overvoltages transmitted by the supply distribution system are not significantly attenuated downstream in most installations.~~

Clause 443.6 gives information on the overvoltage category of the equipment.

NOTE 1 Overvoltage categories are defined within electrical installations for the purpose of insulation coordination and a related classification of equipment with rated impulse voltages is provided (see IEC 60364-5-53:2001/AMD2:2015, Table 534.1).

The rated impulse voltage is used to classify equipment energized directly from the low-voltage electrical installation into overvoltage category.

Rated impulse voltages for equipment selected according to the nominal voltage are provided to distinguish different levels of availability of equipment with regard to continuity of service and an acceptable risk of failure.

Inherent overvoltage control based only on the impulse voltage withstand of the equipment in accordance with IEC 60664-1 might not be sufficient, because:

- transient overvoltages transmitted by the supply distribution system are not significantly attenuated downstream in most installations. Insulation coordination can be achieved in the whole installation, by transient overvoltage protection of the equipment corresponding to the classified rated impulse voltage, reducing the risk of failure to an acceptable level;
- in installations supplied by a completely buried low-voltage system not including overhead lines, surge currents and partial lightning currents are distributed via the underground cables;
- equipment is often connected to two different services, e.g. power line and data line. Field experience shows that much surge related damage is experienced on this kind of equipment.

It is necessary to consider the rated impulse voltage U_W (see IEC 60664-1) of the most sensitive equipment to be protected in the system or, in cases where a temporary loss of function of equipment is critical, the equipment level immunity (see IEC 61000-4-5).

443.26.2 Relationship between impulse withstand Rated impulse voltages of equipment and overvoltage categories

The following points shall be noted:

- a) Equipment with a rated impulse ~~withstand~~ voltage corresponding to overvoltage category IV is suitable for use at, or in the proximity of, the origin of the installation, for example upstream of the main distribution board. Equipment of category IV has a very high impulse withstand capability providing the required high degree of reliability, and shall have a rated impulse voltage not less than the value specified in Table 443.2.

NOTE 1 Examples of such equipment include electricity meters, primary overcurrent ~~protection~~ protective devices and ripple control units.

- b) Equipment with a rated impulse ~~withstand~~ voltage corresponding to overvoltage category III is suitable for use in the fixed installation downstream of and including the main distribution board, providing a high degree of availability, and shall have a rated impulse voltage not less than the value specified in Table 443.2.

NOTE 2 Examples of such equipment include distribution boards, circuit-breakers, wiring systems (see IEC 60050-826:2004, 826-15-01), including cables, busbars, junction boxes, switches, socket-outlets) in the fixed installation, and equipment for industrial use and some other equipment, e.g. stationary motors with permanent connection to the fixed installation.

- c) Equipment with a rated impulse ~~withstand~~ voltage corresponding to overvoltage category II is suitable for connection to the fixed ~~electrical~~ installation, providing a ~~normal~~ degree of availability normally required for current-using equipment, and shall have a rated impulse voltage not less than the value specified in Table 443.2.

NOTE 3 Examples of such equipment include household appliances and similar loads.

- d) Equipment with a rated impulse ~~withstand~~ voltage corresponding to overvoltage category I is only suitable for use in the fixed installation ~~of buildings~~ where ~~protective means are applied~~ SPDs are installed outside the equipment to limit transient overvoltages to the specified level, and shall have a rated impulse voltage not less than the value specified in

Table 443.2. Therefore, equipment with a rated impulse withstand voltage corresponding to overvoltage category I shall not have direct connection to a public supply system should preferably not be installed at or near the origin of installation.

NOTE 4 Examples of such equipment include those containing electronic circuits like computers, appliances with electronic programmes home electronics, etc.

~~443.3 Arrangements for overvoltage control~~

~~Overvoltage control is arranged in accordance with the following requirements.~~

~~443.3.1 Inherent overvoltage control~~

~~This subclause does not apply when a risk assessment according to 443.3.2.2 is used.~~

~~Where an installation is supplied by a completely buried low-voltage system and does not include overhead lines, the impulse withstand voltage of equipment in accordance with Table 44B is sufficient and no specific protection against overvoltages of atmospheric origin is necessary.~~

NOTE 1 A suspended cable having insulated conductors with earthed metallic screen is considered as equivalent to an underground cable.

~~Where an installation is supplied by or includes a low-voltage overhead line and the keraunic level is lower than or equal to 25 days per year (AQ 1), no specific protection against overvoltages of atmospheric origin is required.~~

NOTE 2 Irrespective of the AQ value, protection against overvoltages may be necessary in applications where a higher reliability or higher risks (e.g. fire) are expected.

~~In both cases, consideration regarding protection against transient overvoltages shall be given to equipment with an impulse withstand voltage according to overvoltage category I (see 443.2.2).~~

~~443.3.2 Protective overvoltage control~~

~~The decision as to which of the following methods are applied in a country with regard to the provision of surge protective devices (SPDs) is left to the national committee based on the local conditions.~~

~~In all cases, consideration regarding protection against transient overvoltages shall be given to equipment with an impulse withstand voltage according to overvoltage category I (see 443.2.2).~~

~~443.3.2.1 Protective overvoltage control based on conditions of external influences~~

~~Where an installation is supplied by, or includes, an overhead line, and the keraunic level of the location is greater than 25 days per year (AQ 2), protection against overvoltages of atmospheric origin is required. The protection level of the protective device shall not be higher than the level of overvoltage category II, given in Table 44B.~~

NOTE 1 The overvoltage level may be controlled by surge protective devices applied close to the origin of the installation, either in the overhead lines (see Annex B) or in the building installation.

NOTE 2 According to Clause A.1 of IEC 62305-3, 25 thunderstorm days per year are equivalent to a value of 2,5 flashes per km² per year. This is derived from the formula

$$N_{g-} = 0,1 \cdot T_d$$

where

N_g —is the frequency of flashes per km² per year;

T_d —is the number of thunderstorm days per year (keraunic level).

443.3.2.2 Protective overvoltage control based on risk assessment

NOTE 1 A method of general risk assessment is described in IEC 61662. As far as Clause 443 is concerned, an essential simplification of this method has been accepted. It is based on the critical length d_c of the incoming lines and the level of consequences as described below.

The following are different consequential levels of protection:

- a) consequences related to human life, e.g. safety services, medical equipment in hospitals;
- b) consequences related to public services, e.g. loss of public services, IT centres, museums;
- c) consequences to commercial or industrial activity, e.g. hotels, banks, industries, commercial markets, farms;
- d) consequences to groups of individuals, e.g. large residential buildings, churches, offices, schools;
- e) consequences to individuals, e.g. residential buildings, small offices.

For levels of consequences a) to c), protection against overvoltage shall be provided.

NOTE 2 There is no need to perform a risk assessment calculation according to Annex C for levels of consequences a) to c) because this calculation always leads to the result that the protection is required.

For levels of consequences d) and e), requirement for protection depends on the result of a calculation. The calculation shall be carried out using the formula in Annex C for the determination of the length d , which is based on a convention and called conventional length.

Protection is required if:

$$d > d_c$$

where

d —is the conventional length in km of the supply line of the considered structure with a maximum value of 1 km;

d_c —is the critical length;

d_c in km, is equal to $\frac{1}{N_g}$ for level of consequences d) and equal to $\frac{2}{N_g}$ for level of consequences e) where N_g is the frequency of flashes per km² per year.

If this calculation indicates that an SPD is required, the protection level of these protective devices shall not be higher than the level of overvoltage category II, given in Table 44B.

443.4 Required impulse withstand voltage of equipment

Equipment shall be selected so that its rated impulse withstand voltage is not less than the required impulse withstand voltage as specified in Table 44B. It is the responsibility of each product committee to require the rated impulse withstand voltage in their relevant standards according to IEC 60664-1.

Table 44.B 443.2 – Required rated impulse ~~withstand~~ voltage of equipment U_w

Nominal voltage of the installation ^a V		Voltage line to neutral derived from nominal voltages a.c. or d.c. up to and including V	Required rated impulse ~~withstand~~ voltage of equipment ^c kV			
Three-phase systems ^b	Single-phase systems with middle point		Equipment at the origin of the installation Overvoltage category IV (equipment with very high rated impulse voltage) IV	Equipment of distribution and final circuits Overvoltage category III (equipment with high rated impulse voltage)	Appliances and current-using equipment Overvoltage category II (equipment with normal rated impulse voltage)	Specially protected equipment Overvoltage category I (equipment with reduced rated impulse voltage)
			For example, energy meter, telecontrol systems	For example, distribution boards, switches socket-outlets	For example, distribution domestic appliances, tools	For example, sensitive electronic equipment
120/208	~~120-240~~	150	4	2,5	1,5	0,8
230/400 ^{b,d} 277/480 ^b	–	300	6	4	2,5	1,5
400/690	–	600	8	6	4	2,5
1 000	–	1 000	12	8	6	4
1 500 d.c.		1 500 d.c.			8	6

^a According to IEC 60038:2009.

^b In Canada and USA, for voltages to earth higher than 300 V, the **rated** impulse ~~withstand~~ voltage corresponding to the next highest voltage in this column applies.

^c This **rated** impulse ~~withstand~~ voltage is applied between live conductors and PE.

^d For IT systems operations at 220-240 V, the 230/400 row shall be used, due to the voltage to earth at the earth fault on one line.

444 Measures against electromagnetic influences

444.1 General

Clause 444 provides basic recommendations for the mitigation of electromagnetic disturbances. Electromagnetic Interference (EMI) may disturb or damage information technology systems or information technology equipment as well as equipment with electronic components or circuits. Currents due to lightning, switching operations, short-circuits and other electromagnetic phenomena may cause overvoltages and electromagnetic interference.

These effects are most severe

- where large metal loops exist; and

- where different electrical wiring systems are installed in common routes, e.g. for power supply and for signalling information technology equipment within a building.

The value of the induced voltage depends on the rate of rise (di/dt) of the interference current, and on the size of the loop.

Power cables carrying large currents with a high rate of rise of current (di/dt) (e.g. the starting current of lifts or currents controlled by rectifiers) can induce overvoltages in cables of information technology systems, which can influence or damage information technology equipment or similar electrical equipment.

In or near rooms for medical use, electric or magnetic fields associated with electrical installations can interfere with medical electrical equipment.

This clause provides information for architects of buildings and for designers and installers of electrical installations of buildings on some installation concepts that limit electromagnetic influences. Basic considerations are given here to mitigate such influences that may result in disturbance.

444.2 (void)

NOTE This clause is reserved for future input.

444.3 Definitions

See IEC 60364-1 for basic definitions. For the purposes of this document, the following definitions apply:

444.3.1

bonding network BN

set of interconnected conductive structures that provides an “electromagnetic shield” for electronic systems at frequencies from direct current (DC) to low radio frequency (RF)

[3.2.2 of ETS 300 253:1995]

NOTE The term “electromagnetic shield” denotes any structure used to divert, block or impede the passage of electromagnetic energy. In general, a BN does not need to be connected to earth but BN considered in this standard are connected to earth.

444.3.2

bonding ring conductor

BRC

an earthing bus conductor in the form of a closed ring

[3.1.3 of EN 50310:2000]

NOTE Normally the bonding ring conductor, as part of the bonding network, has multiple connections to the CBN that improves its performance.

444.3.3

common equipotential bonding system

common bonding network

CBN

equipotential bonding system providing both protective-equipotential-bonding and functional-equipotential-bonding

[IEV 195-02-25]

444.3.4

equipotential bonding

provision of electric connections between conductive parts, intended to achieve equipotentiality

[IEV 195-01-10]

444.3.5

earth-electrode network

ground-electrode network (US)

part of an earthing arrangement comprising only the earth electrodes and their interconnections

[IEV 195-02-21]

444.3.6

meshed bonding network

MESH-BN

bonding network in which all associated equipment frames, racks and cabinets and usually the DC power return conductor, are bonded together as well as at multiple points to the CBN and may have the form of a mesh

[3.2.2 of ETS 300 253:1995]

NOTE The MESH-BN augments the CBN.

444.3.7

by-pass equipotential bonding conductor/

parallel earthing conductor

PEC

earthing conductor connected in parallel with the screens of signal and/or data cables in order to limit the current flowing through the screens

444.4 Mitigation of electromagnetic interference (EMI)

Consideration shall be given by the designer and installer of the electrical installation to the measures described below for reducing the electric and magnetic influences on electrical equipment.

Only electrical equipment, which meets the requirements in the appropriate EMC standards or the EMC requirements of the relevant product standard shall be used.

444.4.1 Sources of EMI

Electrical equipment sensitive to electromagnetic influences should not be located close to potential sources of electromagnetic emission such as

- switching devices for inductive loads,
- electric motors,
- fluorescent lighting,
- welding machines,
- computers,
- rectifiers,
- choppers,
- frequency converters/regulators,
- lifts,
- transformers,
- switchgear,
- power distribution busbars.

444.4.2 Measures to reduce EMI

The following measures reduce electromagnetic interference.

- a) For electrical equipment sensitive to electromagnetic influences, surge protection devices and/or filters are recommended to improve electromagnetic compatibility with regard to conducted electromagnetic phenomena.
- b) Metal sheaths of cables should be bonded to the CBN.
- c) Inductive loops should be avoided by selection of a common route for power, signal and data circuits wiring.
- d) Power and signal cables should be kept separate and should, wherever practical, cross each other at right-angles (see 444.6.3).
- e) Use of cables with concentric conductors to reduce currents induced into the protective conductor.
- f) Use of symmetrical multicore cables (e.g. screened cables containing separate protective conductors) for the electrical connections between convertors and motors, which have frequency controlled motor-drives.
- g) Use of signal and data cables according to the EMC requirements of the manufacturer's instructions.
- h) Where a lightning protection system is installed,
 - power and signal cables shall be separated from the down conductors of lightning protection systems (LPS) by either a minimum distance or by use of screening. The minimum distance shall be determined by the designer of the LPS in accordance with IEC 62305-3;
 - metallic sheaths or shields of power and signal cables should be bonded in accordance with the requirements for lightning protection given in IEC 62305-3 and IEC 62305-4.
- i) Where screened signal or data cables are used, care should be taken to limit the fault current from power systems flowing through the screens and cores of signal cables, or data cables, which are earthed. Additional conductors may be necessary, e.g. a by-pass equipotential bonding conductor for screen reinforcement; see Figure 44.R1.

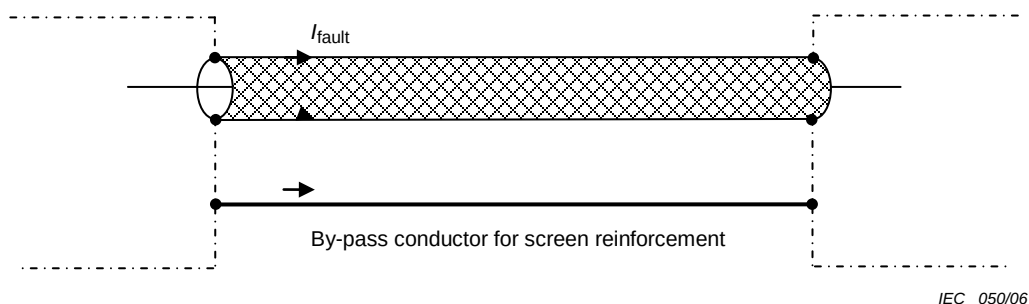


**Figure 44.R1 – By-pass conductor for screen reinforcement
to provide a common equipotential bonding system**

NOTE 1 The provision of a by-pass conductor in proximity to a signal, or data, cable sheath also reduces the area of the loop associated with equipment, which is only connected by a protective conductor to earth. This practice considerably reduces the EMC effects of lightning electromagnetic pulse (LEMP).

- j) Where screened signal cables or data cables are common to several buildings supplied from a TT-system, a by-pass equipotential bonding conductor should be used; see Figure 44.R2. The by-pass conductor shall have a minimum cross-sectional area of 16 mm² Cu or equivalent. The equivalent cross-sectional area shall be dimensioned in accordance with 544.1 of IEC 60364-5-54.

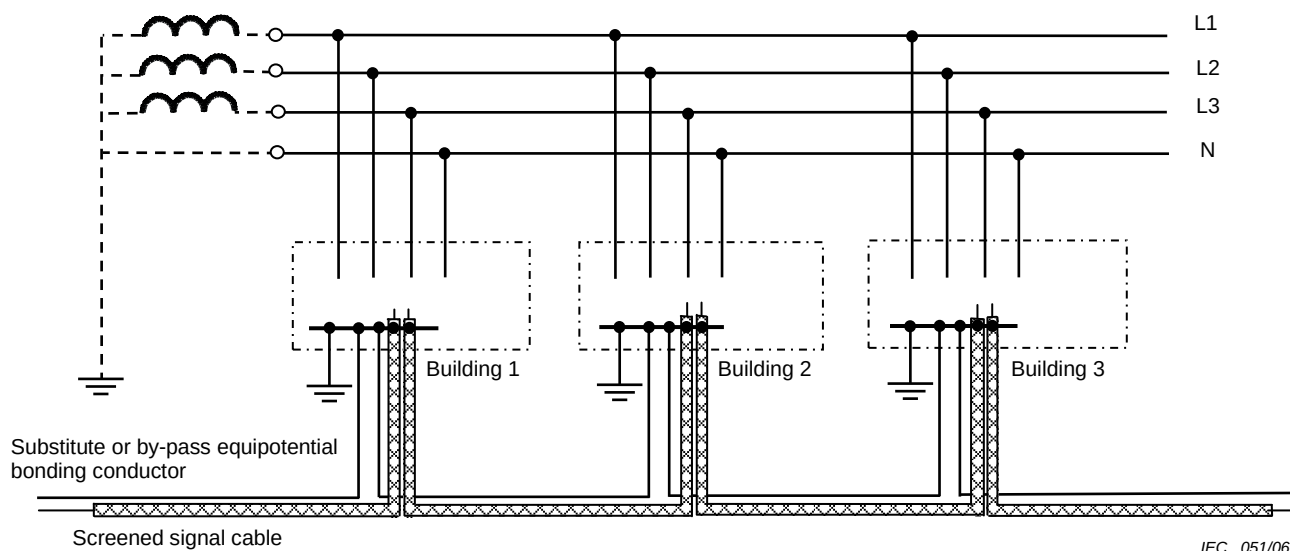


Figure 44.R2 – Example of a substitute or by-pass equipotential bonding conductor in a TT-system

NOTE 2 Where the earthed shield is used as a signal return path, a double-coaxial cable may be used.

NOTE 3 It is recalled that if the consent according to 413.1.2.1 (last paragraph) cannot be obtained, it is the responsibility of the owners or operators to avoid any danger due to the exclusion of those cables from the connection to the main equipotential bonding.

NOTE 4 The problems of earth differential voltages on large public telecommunication networks are the responsibility of the network operator, who may employ other methods.

NOTE 5 In the Netherlands, a by-pass equipotential bonding conductor, connecting the earthing systems of several TT installations together, is permitted only if fault protection, in accordance with 413.1.4, remains effective in the case of failure of any single RCD.

- k) Equipotential bonding connections should have an impedance as low as possible
 - by being as short as possible,
 - by having a cross-section shape that results in low inductive reactance and impedance per metre of route, e.g. a bonding braid with a width to thickness ratio of five to one.
- l) Where an earthing busbar is intended (according to 444.5.8) to support the equipotential bonding system of a significant information technology installation in a building, it may be installed as a closed ring.

NOTE 6 This measure is preferably applied in buildings of the telecommunications industry.

444.4.3 TN-system

To minimize electromagnetic influences, the following subclauses apply.

444.4.3.1 It is recommended that TN-C systems should not be maintained in existing buildings containing, or likely to contain, significant amounts of information technology equipment.

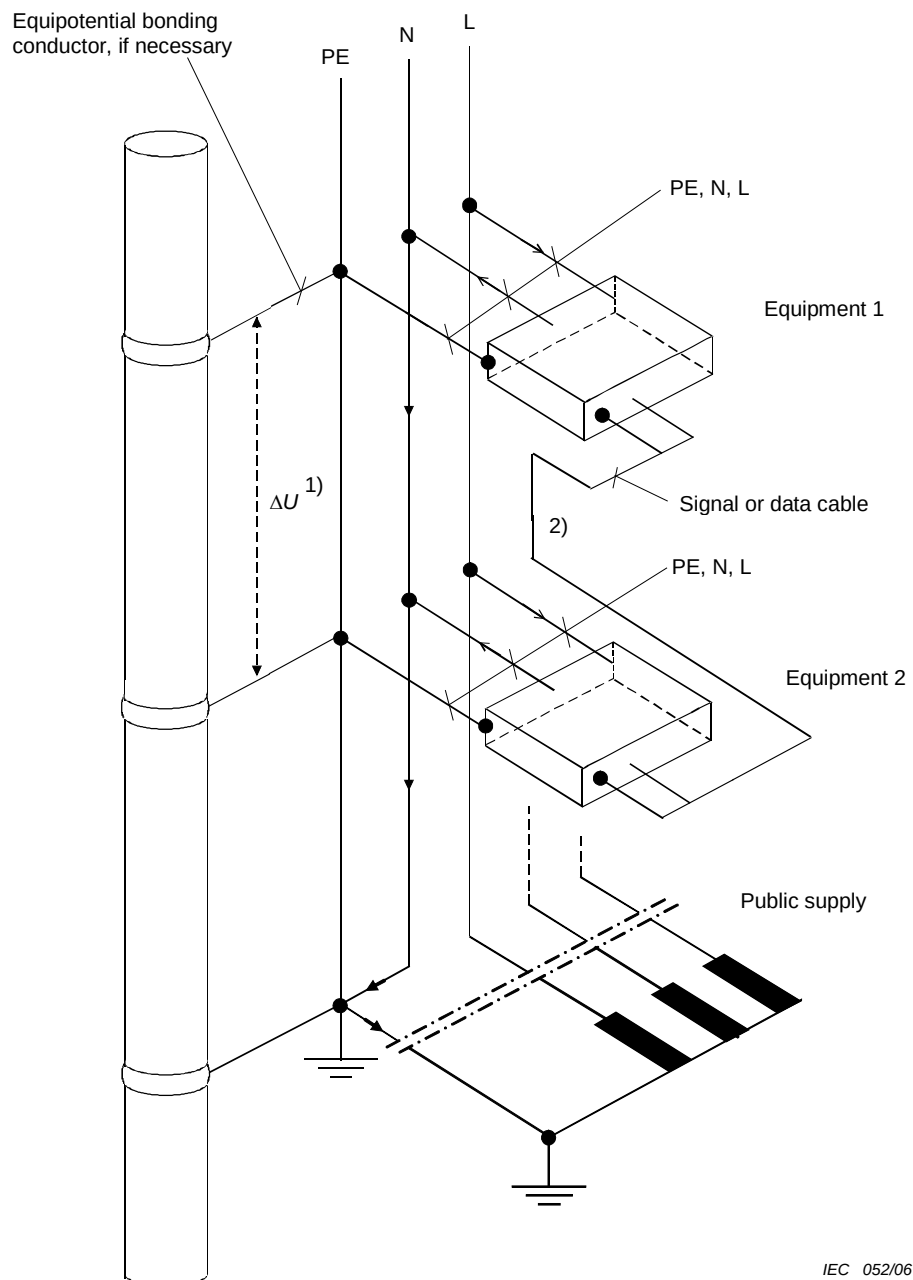
TN-C-systems shall not be used in newly constructed buildings containing, or likely to contain, significant amounts of information technology equipment.

NOTE Any TN-C installation is likely to have load or fault current diverted via equipotential bonding into metallic services and structures within a building.

444.4.3.2 In existing buildings supplied from public low-voltage networks and which contain, or are likely to contain, significant amounts of information technology equipment, a TN-S system should be installed downstream of the origin of the installation; see Figure 44.R3A.

In newly constructed buildings, TN-S systems shall be installed downstream of the origin of the installation; see Figure 44.R3A.

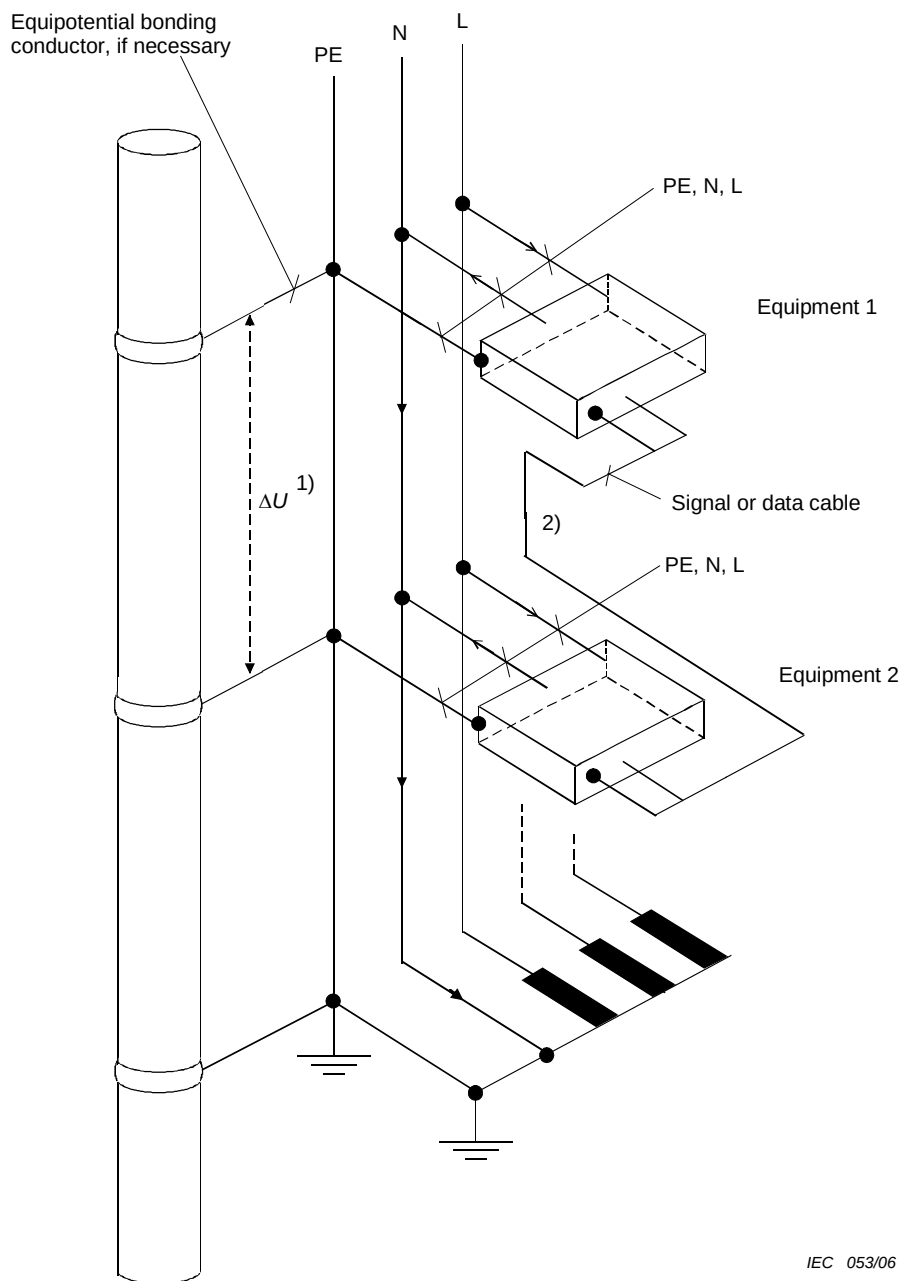
NOTE The effectiveness of a TN-S-system may be enhanced by use of a residual current monitoring device, RCM, complying with IEC 62020.



- 1) No voltage drop ΔU along the PE conductor under normal operation conditions
- 2) Loops of limited area formed by signal or data cables

Figure 44.R3A – Avoidance of neutral conductor currents in a bonded structure by using the TN-S system from the origin of the public supply up to and including the final circuit within a building

444.4.3.3 In existing buildings where the complete low-voltage installation including the transformer is operated only by the user and which contain, or are likely to contain, significant amounts of information technology equipment, TN-S systems should be installed; see Figure 44.R3B.



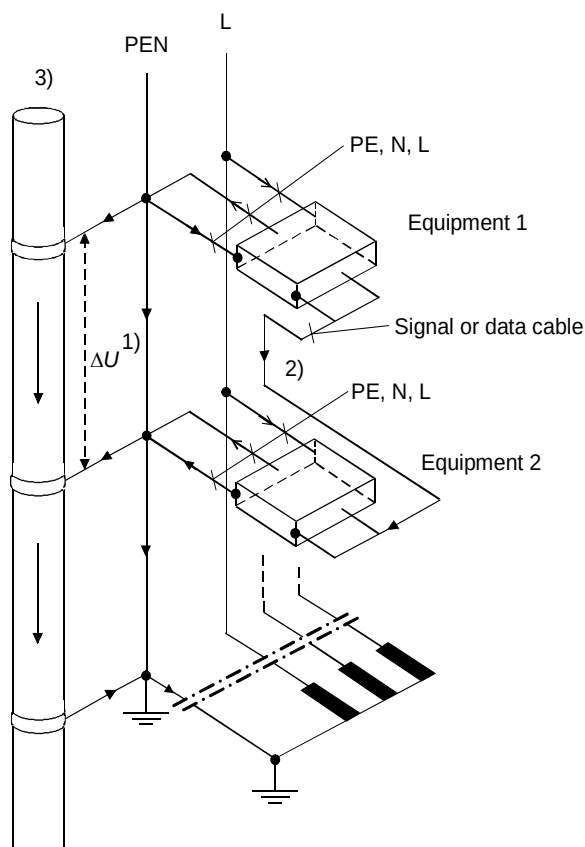
IEC 053/06

- 1) No voltage drop ΔU along the PE conductor under normal operation conditions
- 2) Loops of limited area formed by signal or data cables

Figure 44.R3B – Avoidance of neutral conductor currents in a bonded structure by using a TN-S system downstream of a consumer's private supply transformer

444.4.3.4 Where an existing installation is a TN-C-S system (see Figure 44.R4), signal and data cable loops should be avoided by

- changing all TN-C parts of the installation shown in Figure 44.R4 into TN-S, as shown in Figure 44.R3A, or
- where this change is not possible, by avoiding signal and data cable interconnections between different parts of the TN-S installation.



IEC 054/06

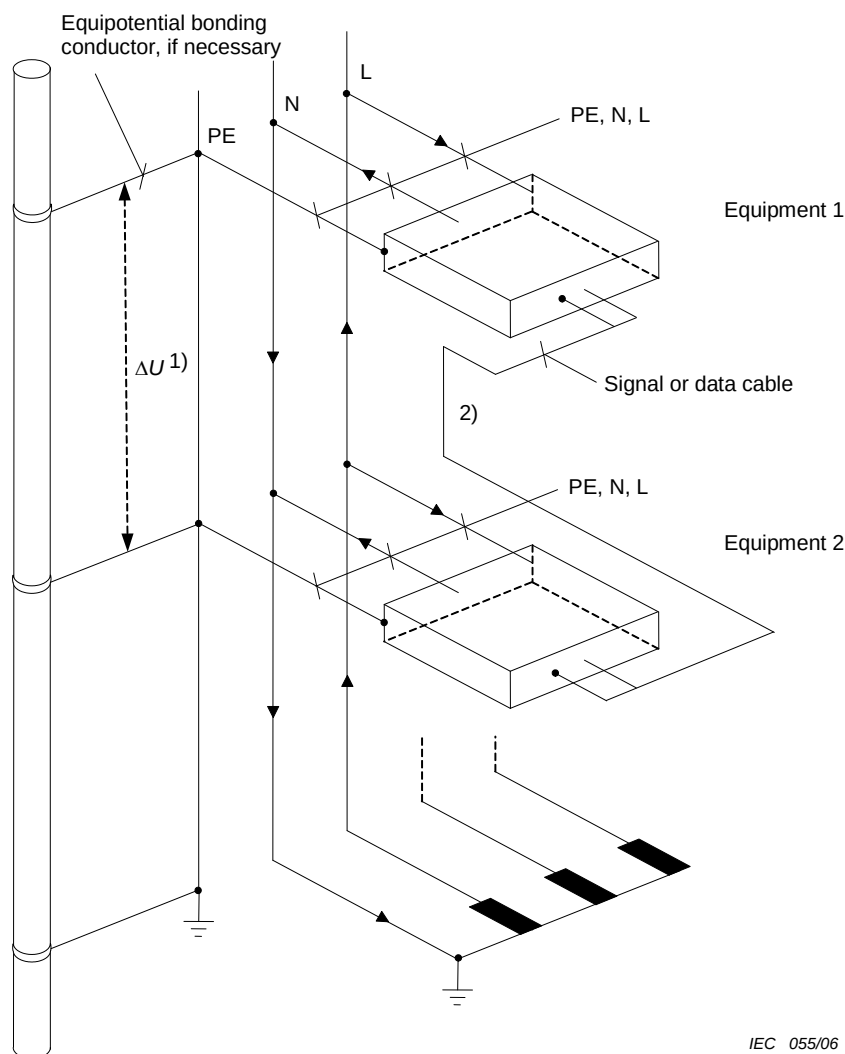
- 1) Voltage drop ΔU along PEN in normal operation
- 2) Loop of limited area formed from signal or data cables
- 3) Extraneous-conductive-part

NOTE In a TN-C-S system, the current, which in a TN-S system would flow only through the neutral conductor, flows also through the screens or reference conductors of signal cables, exposed-conductive-parts, and extraneous-conductive-parts such as structural metalwork.

Figure 44.R4 – TN-C-S system within an existing building installation

444.4.4 TT system

In a TT system, such as that shown in Figure 44.R5, consideration should be given to overvoltages which may exist between live parts and exposed-conductive-parts when the exposed-conductive-parts of different buildings are connected to different earth electrodes.



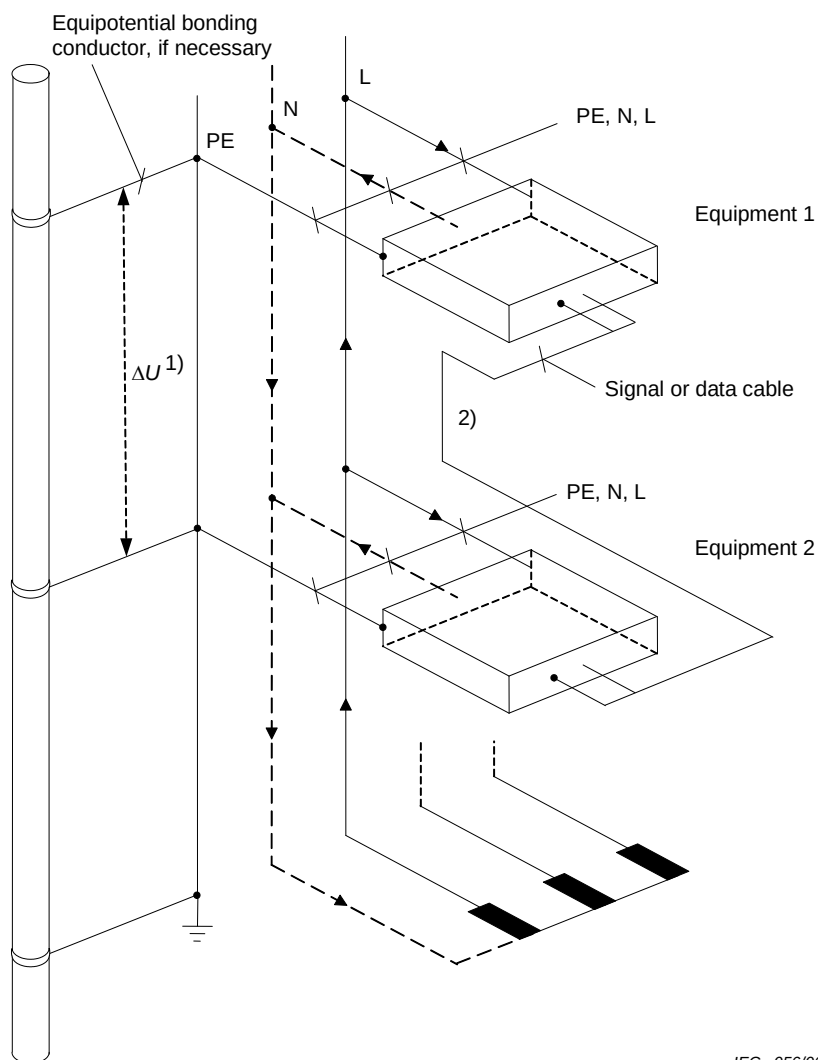
- 1) Voltage drop ΔU along PEN in normal operation
- 2) Loop of limited area formed from signal or data cables

Figure 44.R5 – TT system within a building installation

444.4.5 IT system

In a three-phase IT system (see Figure 44.R6), the voltage between a healthy line-conductor and an exposed-conductive-part can rise to the level of the line-to-line voltage when there is a single insulation fault between a line conductor and an exposed-conductive-part; this condition should be considered.

NOTE Electronic equipment directly supplied between line conductor and neutral should be designed to withstand such a voltage between line conductor and exposed-conductive-parts; see corresponding requirement from IEC 60950-1 for information technology equipment.



IEC 056/06

- 1) Voltage drop ΔU along PEN in normal operation
- 2) Loop of limited area formed from signal or data cables

Figure 44.R6 – IT system within a building installation

444.4.6 Multiple-source supply

For multiple-source power supplies, the provisions in 444.4.6.1 and 444.4.6.2 shall be applied.

NOTE Where multiple earthing of the star points of the sources of supplies is applied, neutral conductor currents may flow back to the relevant star point, not only via the neutral conductor, but also via the protective conductor as shown in Figure 44.R7A. For this reason the sum of the partial currents flowing in the installation is no longer zero and a magnetic stray field is created, similar to that of a single conductor cable.

In the case of single conductor cables, which carry AC current, a circular electromagnetic field is generated around the core conductor that may interfere with electronic equipment. Harmonic currents produce similar electromagnetic fields but they attenuate more rapidly than those produced by fundamental currents.

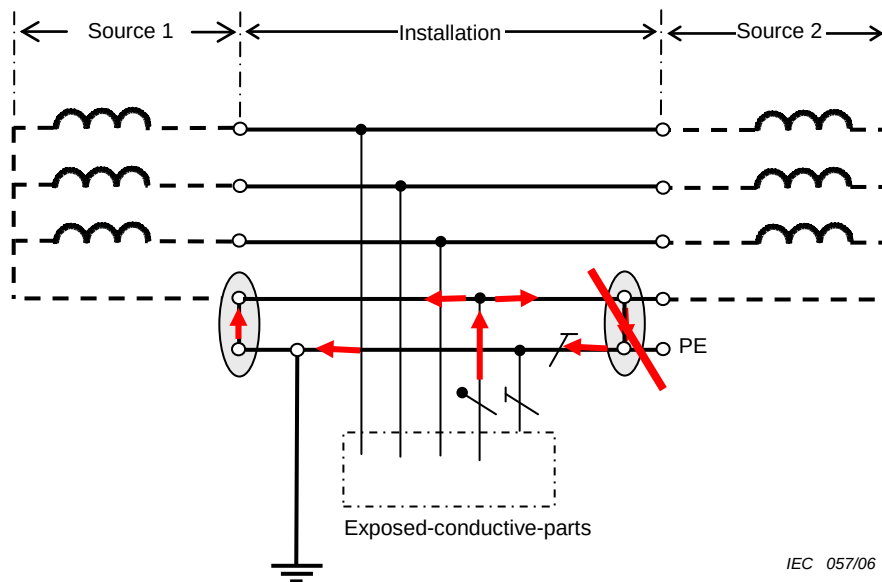
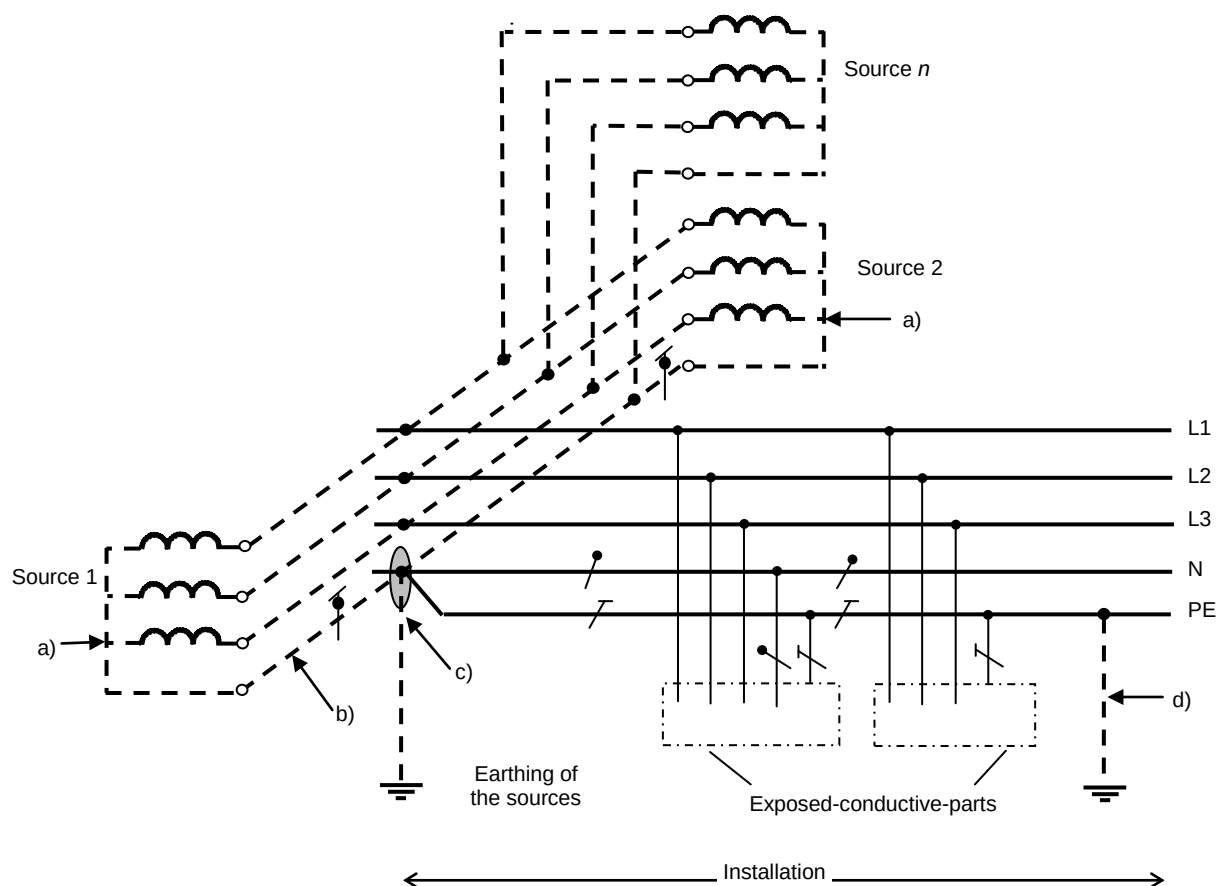


**Figure 44.R7A – TN multiple-source power supply
with a non-suitable multiple connection between PEN and earth**

444.4.6.1 TN multiple source power supplies

In the case of TN multiple-source power supplies to an installation, the star points of the different sources shall, for EMC reasons, be interconnected by an insulated conductor that is connected to earth centrally at one and the same point; see Figure 44.R7B.



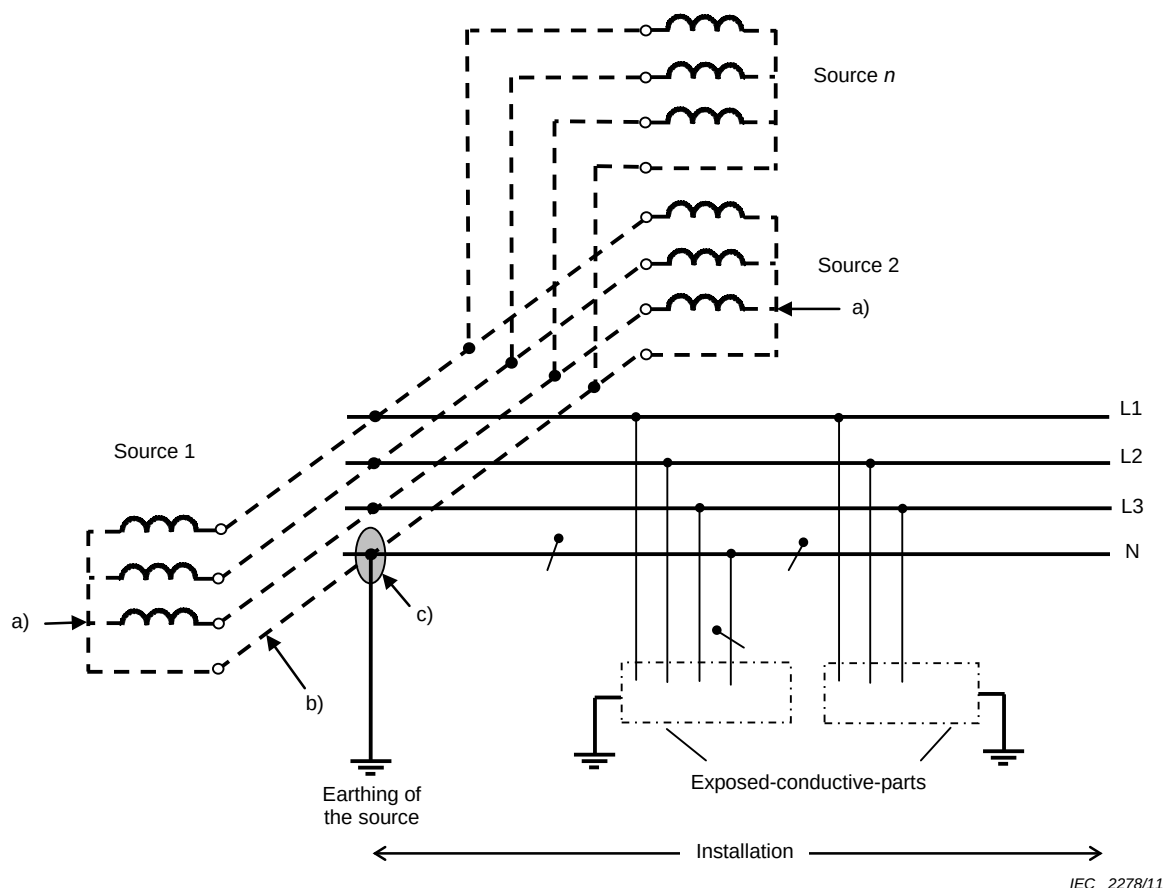
IEC 058/06

- a) No direct connection from either transformer neutral points or generator star points to earth is permitted.
- b) The conductor interconnecting either the neutral points of transformers, or the star-points of generators, shall be insulated. This conductor functions as a PEN conductor and it may be marked as such; however, it shall not be connected to current-using-equipment and a warning notice to that effect shall be attached to it, or placed adjacent to it.
- c) Only one connection between the interconnected neutral points of the sources and the PE shall be provided. This connection shall be located inside the main switchgear assembly.
- d) Additional earthing of the PE in the installation may be provided.

Figure 44.R7B – TN multiple source power supplies to an installation with connection to earth of the star points at one and the same point

444.4.6.2 TT multiple-source power supplies

In the case of TT multiple-source power supplies to an installation, it is recommended that the star points of the different sources are, for EMC reasons, interconnected and connected to earth centrally at only one point; see Figure 44.R8.

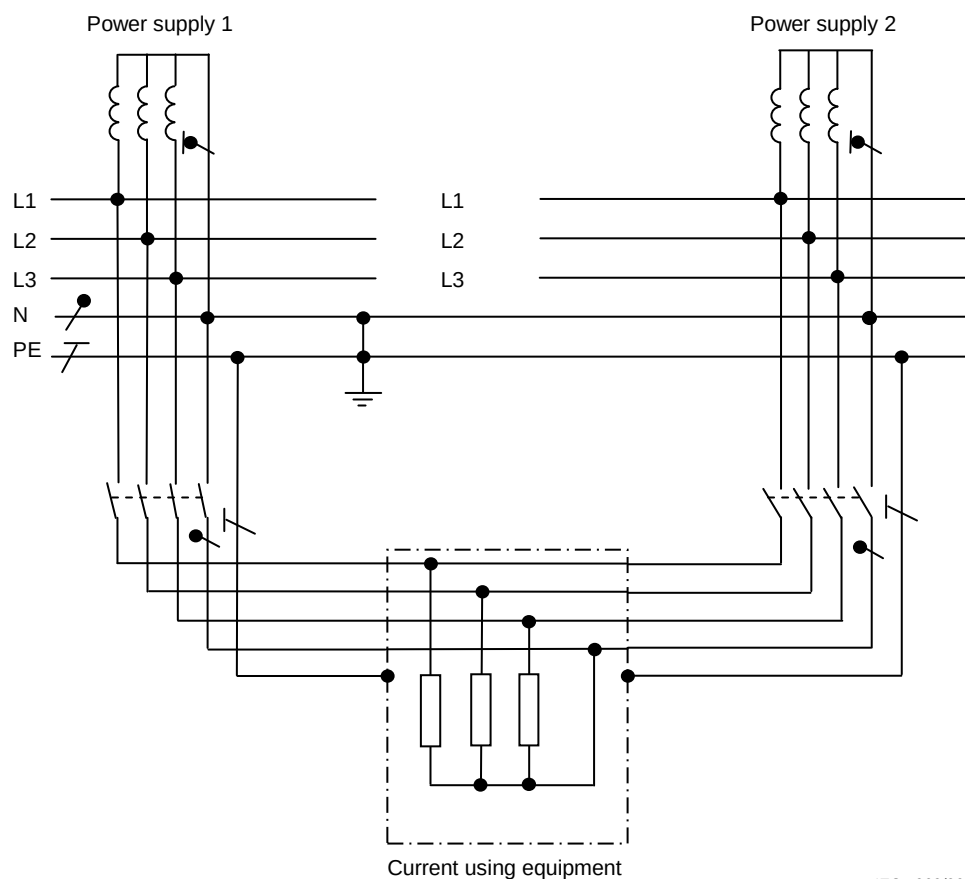


- a) No direct connection from either the transformer star points or the generator star points to earth is permitted.
- b) The conductor interconnecting either the star points of transformers, or generator starpoints, shall be insulated. However, it shall not be connected to current-using-equipment and a warning notice to that effect shall be attached to it, or placed adjacent to it.
- c) Only one connection between the interconnected star points of the sources and the PE shall be provided. This connection shall be located inside the main switchgear assembly.

Figure 44.R8 – TT multiple-source power supplies to an installation with connection to earth of the star points at one and the same point

444.4.7 Transfer of supply

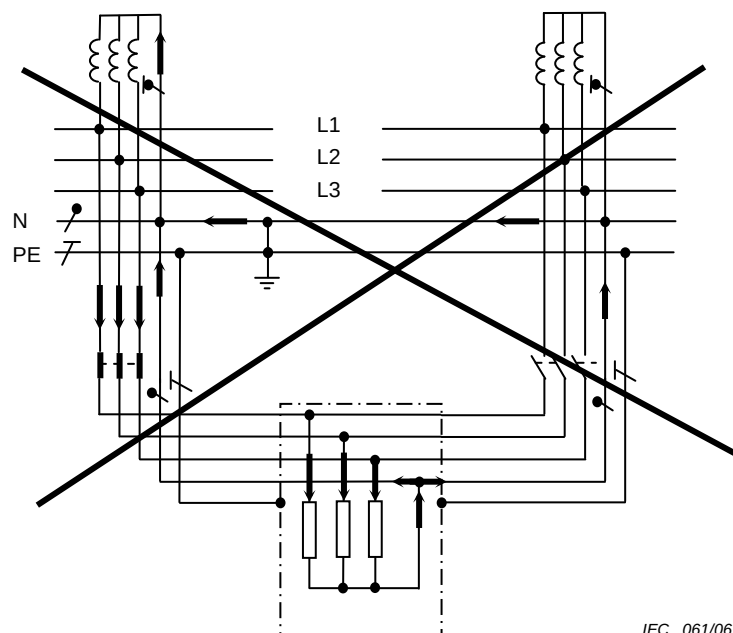
In TN systems the transfer from one supply to an alternative supply shall be by means of a switching device, which switches the line conductors and the neutral, if any; see Figures 44.R9A, 44.R9B and 44.R9C.



IEC 060/06

NOTE This method prevents electromagnetic fields due to stray currents in the main supply system of an installation. The sum of the currents within one cable must be zero. It ensures that the neutral current flows only in the neutral conductor of the circuit, which is switched on. The 3rd harmonic (150 Hz) current of the line conductors will be added with the same phase angle to the neutral conductor current.

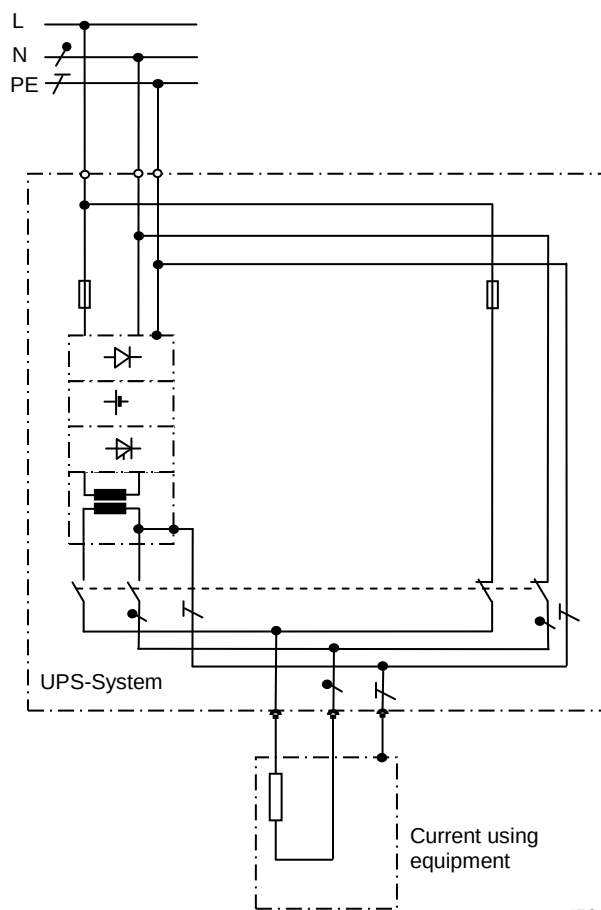
Figure 44.R9A – Three-phase alternative power supply with a 4-pole switch



IEC 061/06

NOTE A three-phase alternative power supply with an unsuitable 3-pole switch will cause unwanted circulating currents, that will generate electromagnetic fields.

Figure 44.R9B – Neutral current flow in a three-phase alternative power supply with an unsuitable 3-pole switch



IEC 062/06

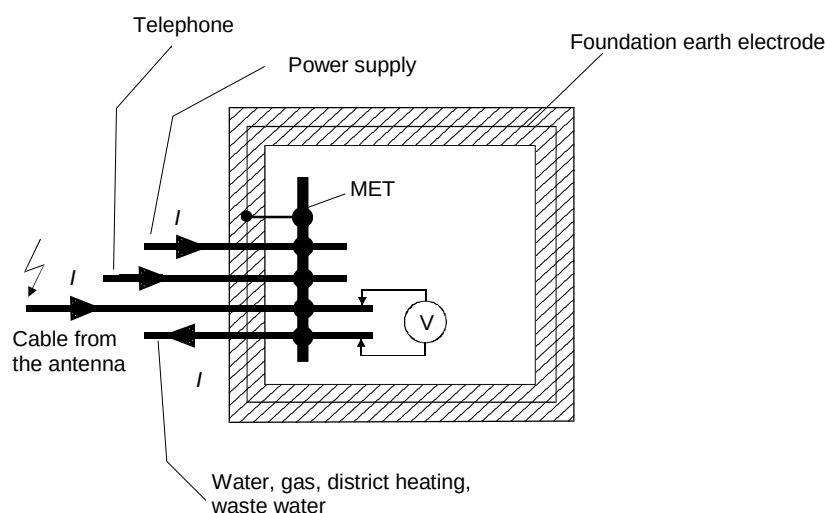
NOTE The earth connection to the secondary circuit of a UPS is not mandatory. If the connection is omitted, the supply in the UPS-mode will be in the form of an IT system and, in by-pass mode, it will be the same as the low-voltage supply system.

Figure 44.R9C – Single-phase alternative power supply with 2-pole switch

444.4.8 Services entering a building

Metal pipes (e.g. for water, gas or district heating) and incoming power and signal cables should preferably enter the building at the same place. Metal pipes and the metal armouring of cables shall be bonded to the main earthing terminal by means of conductors having low impedance; see Figure 44.R10.

NOTE Interconnection is only permitted with the consent of the operator of the external service.



IEC 063/06

MET Main earthing terminal
I Induction current

NOTE A common entry point is preferred, $U \cong 0$ V.

Figure 44.R10 – Armoured cables and metal pipes entering the buildings (examples)

For EMC reasons, closed building voids housing parts of the electrical installation should be exclusively reserved for electrical and electronic equipment (such as monitoring, control or protection devices, connecting devices, etc.) and access shall be provided for their maintenance.

444.4.9 Separate buildings

Where different buildings have separate equipotential bonding systems, metal-free fibre optic cables or other non-conducting systems may be used for signal and data transmission, e.g. microwave signal transformer for isolation in accordance with IEC 61558-2-1, IEC 61558-2-4, IEC 61588-2-6, IEC 61888-2-15 and IEC 60950-1.

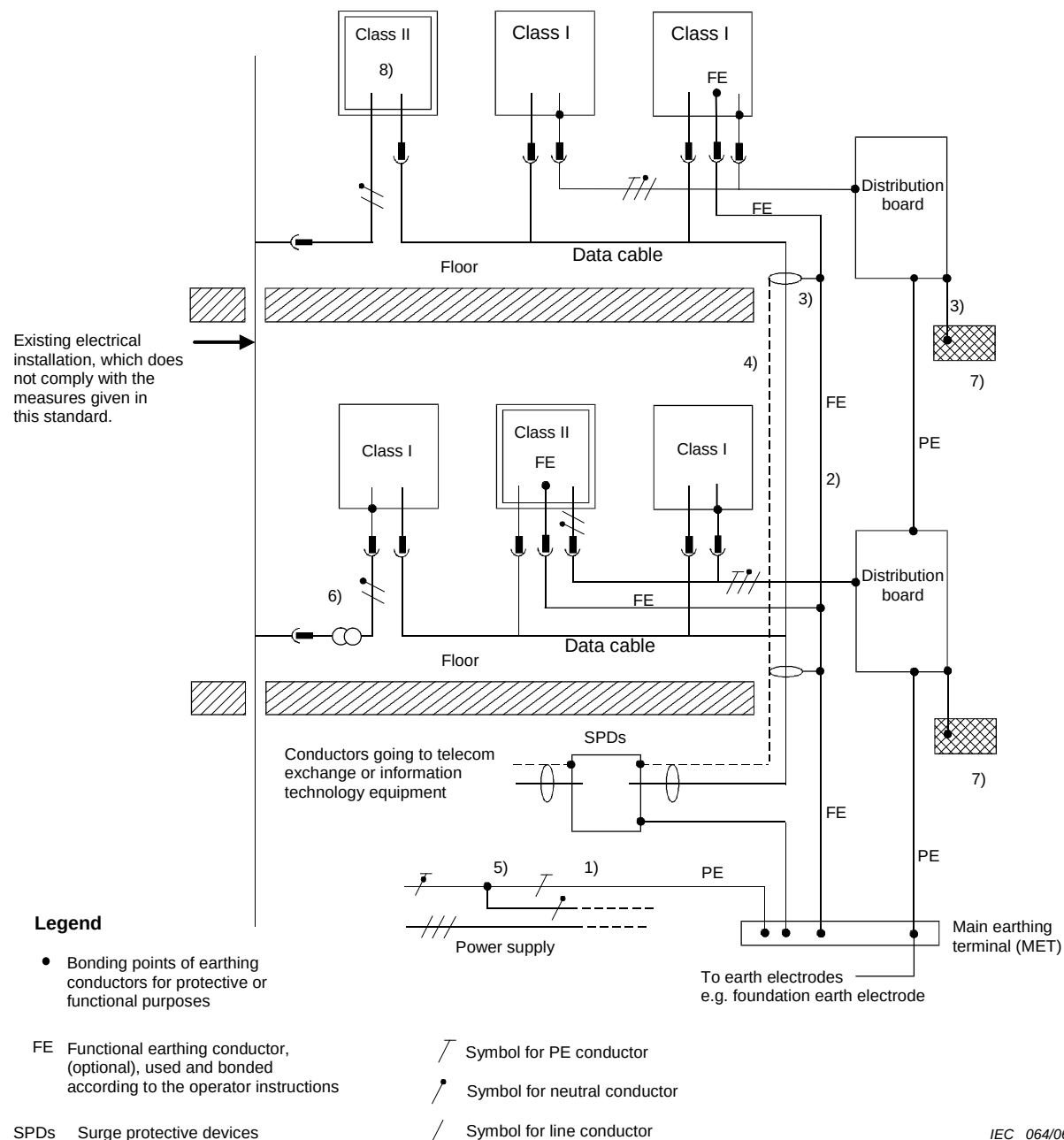
NOTE 1 The problem of earth differential voltages on large public telecommunication networks is the responsibility of the network operator, who may employ other methods.

NOTE 2 In case of non-conducting data-transmission systems, the use of a by-pass conductor is not necessary.

444.4.10 Inside buildings

Where there are problems in existing building installations due to electromagnetic influences, the following measures may improve the situation; see Figure 44.R11:

- 1) use of metal free fibre optic links for signal and data circuits, see 444.4.9;
- 2) use of Class II equipment;
- 3) use of double winding transformers in compliance with IEC 61558-2-1 or IEC 61558-2-4 or IEC 61558-2-6 or IEC 61558-2-15. The secondary circuit should preferably be connected as a TN-S system but an IT-system may be used where required for specific applications.



Reference	Description of the illustrated measures	Subclause/standard
1)	Cables and metal pipes enter the building at the same place	444.4.8
2)	Common route with adequate separations and avoidance of loops	444.4.2
3)	Bonding leads as short as possible, and use of earthed conductor parallel to a cable	IEC 61000-2-5 444.4.2
4)	Signal cables screened and/or conductors twisted pairs	444.4.12
5)	Avoidance of TN-C beyond the incoming supply point	444.4.3
6)	Use of transformers with separate windings	444.4.10
7)	Local horizontal bonding system	444.5.4
8)	Use of class II equipment	444.4.10

Figure 44.R11 – Illustration of measures in an existing building

444.4.11 Protective devices

Protective devices with appropriate functionality for avoiding unwanted tripping due to high levels of transient currents should be selected, e.g. time delays and filters.

444.4.12 Signal cables

Shielded cables and/or twisted pair cables should be used for signal cables.

444.5 Earthing and equipotential bonding

444.5.1 Interconnection of earth electrodes

For several buildings, the concept of dedicated and independent earth electrodes connected to an equipotential conductor network may not be adequate where electronic equipment is used for communication and data exchange between the different buildings for the following reasons:

- a coupling exists between these different earth electrodes and leads to an uncontrolled increase of voltage to equipment;
- interconnected equipment may have different earth references;
- a risk of electric shock exists, specifically in case of overvoltages of atmospheric origin.

Therefore, all protective and functional earthing conductors should be connected to one single main earthing terminal.

Moreover, all earth electrodes associated with a building i.e. protective, functional and lightning protection, shall be interconnected; see Figure 44.R12.

In the case of several buildings, where interconnection of the earth electrodes is not possible or practical, it is recommended that galvanic separation of communication networks is applied, for instance by the use of fibre optic links; see also 444.4.10.

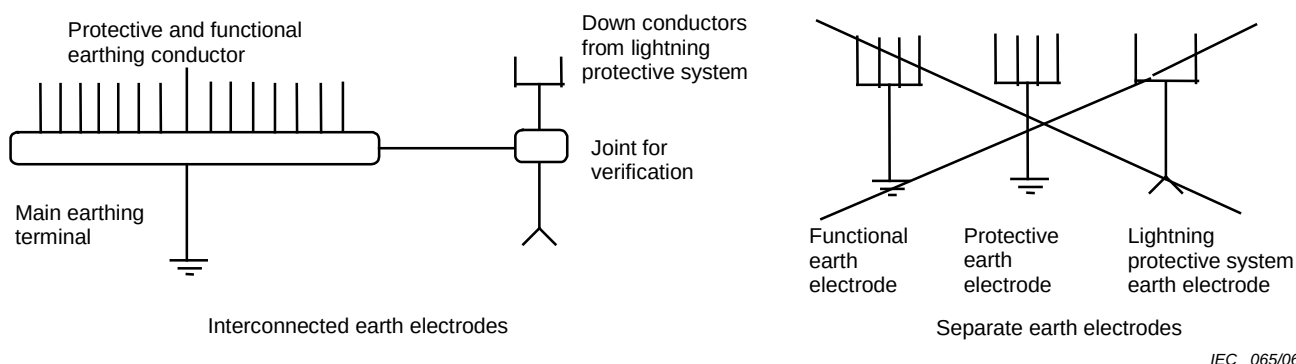


Figure 44.R12 – Interconnected earth electrodes

Protective and functional bonding conductors shall be connected individually to the main earthing terminal in such a way that if one conductor becomes disconnected the connections of all the other conductors remain secured.

444.5.2 Interconnection of incoming networks and earthing arrangements

Exposed-conductive-parts of information technology and electronic equipment within a building are interconnected via protective conductors.

For dwellings where normally a limited amount of electronic equipment is in use, a protective conductor network in the form of a star network may be acceptable; see Figure 44.R13.

For commercial and industrial buildings and similar buildings containing multiple electronic applications, a common equipotential bonding system is useful in order to comply with the EMC requirements of different types of equipment; see Figure 44.R15.

444.5.3 Different structures for the network of equipotential conductors and earthing conductors

The four basic structures described in the following subclauses may be used, depending on the importance and vulnerability of equipment.

444.5.3.1 Protective conductors connected to a bonding-ring conductor

An equipotential bonding network in the form of a bonding ring conductor, BRC, is shown in Figure 44.R16 on the top-floor of the structure. The BRC should preferably be made of copper, bare or insulated, and installed in such a manner that it remains accessible everywhere, e.g. by using a cable-tray, metallic conduit (see the IEC 61386 series), surface mounted method of installation or cable trunking. All protective and functional earthing conductors may be connected to the BRC.

444.5.3.2 Protective conductors in a star network

This type of network is applicable to small installations associated with dwellings, small commercial buildings, etc., and from a general point of view to equipment, that is not interconnected by signal cables; see Figure 44.R13.

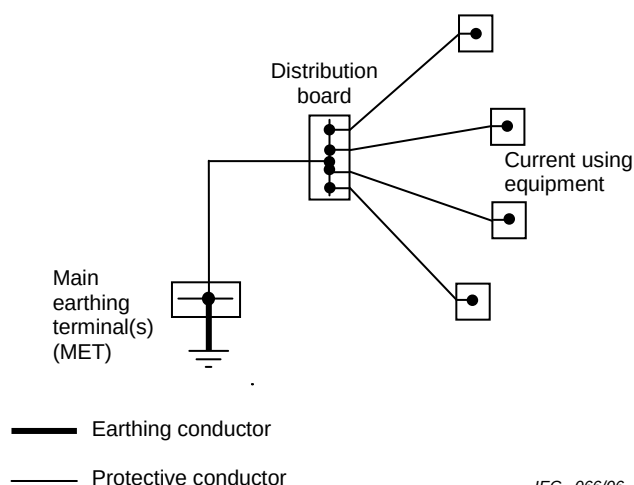


Figure 44.R13 – Examples of protective conductors in star network

444.5.3.3 Multiple meshed bonding star network

This type of network is applicable to small installations with different small groups of interconnected communicating equipment. It enables the local dispersion of currents caused by electromagnetic interference; see Figure 44.R14.

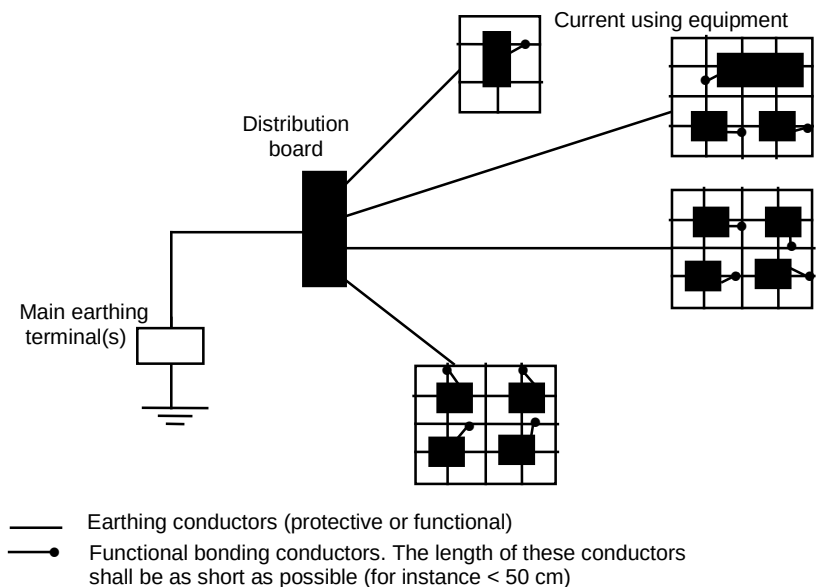


Figure 44.R14 – Example of multiple meshed bonding star network

444.5.3.4 Common meshed bonding star network

This type of network is applicable to installations with high density of communicating equipment corresponding to critical applications; see Figure 44.R15.

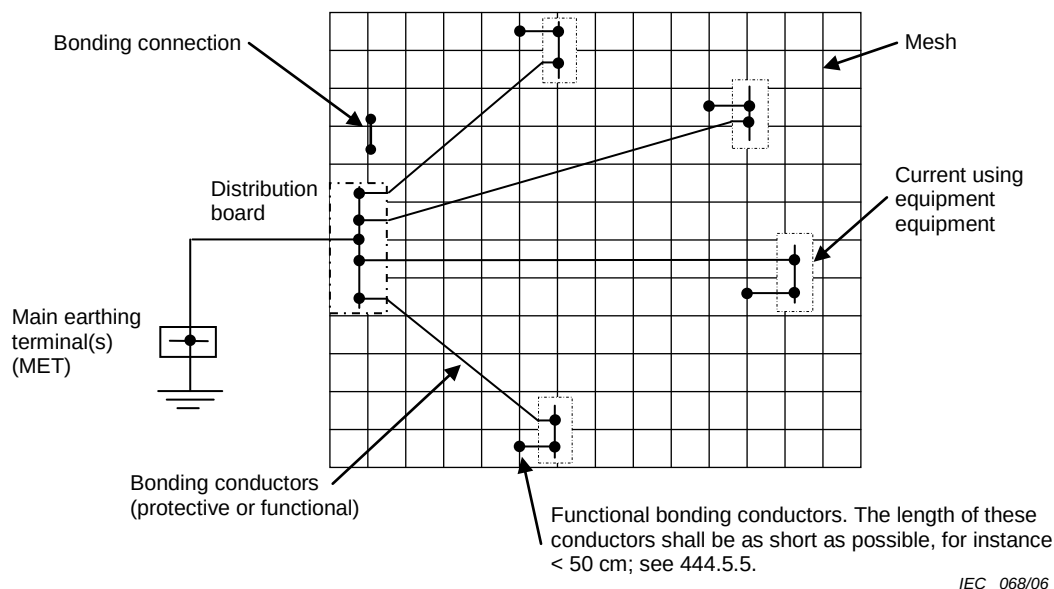
A meshed equipotential bonding network is enhanced by the existing metallic structures of the building. It is supplemented by conductors forming the square mesh.

The mesh-size depends on the selected level of protection against lightning, on the immunity level of equipment part of the installation and on frequencies used for data transmission.

Mesh-size shall be adapted to the dimensions of the installation to be protected, but shall not exceed 2 m × 2 m in areas where equipment sensitive to electromagnetic interferences is installed.

It is suitable for protection of private automatic branch exchange equipment (PABX) and centralized data processing systems.

In some cases, parts of this network may be meshed more closely in order to meet specific requirements.



The area covered by a mesh shall have overall dimensions; the mesh-size refers to the dimensions of square spaces enclosed by the conductors forming the mesh.

Figure 44.R15 – Example of a common meshed bonding star network

444.5.4 Equipotential bonding networks in buildings with several floors

For buildings with several floors, it is recommended that, on each floor, an equipotential bonding system be installed; see Figure 44.R16 for examples of bonding networks in common use; each floor is a type of network. The bonding systems of the different floors should be interconnected, at least twice, by conductors.

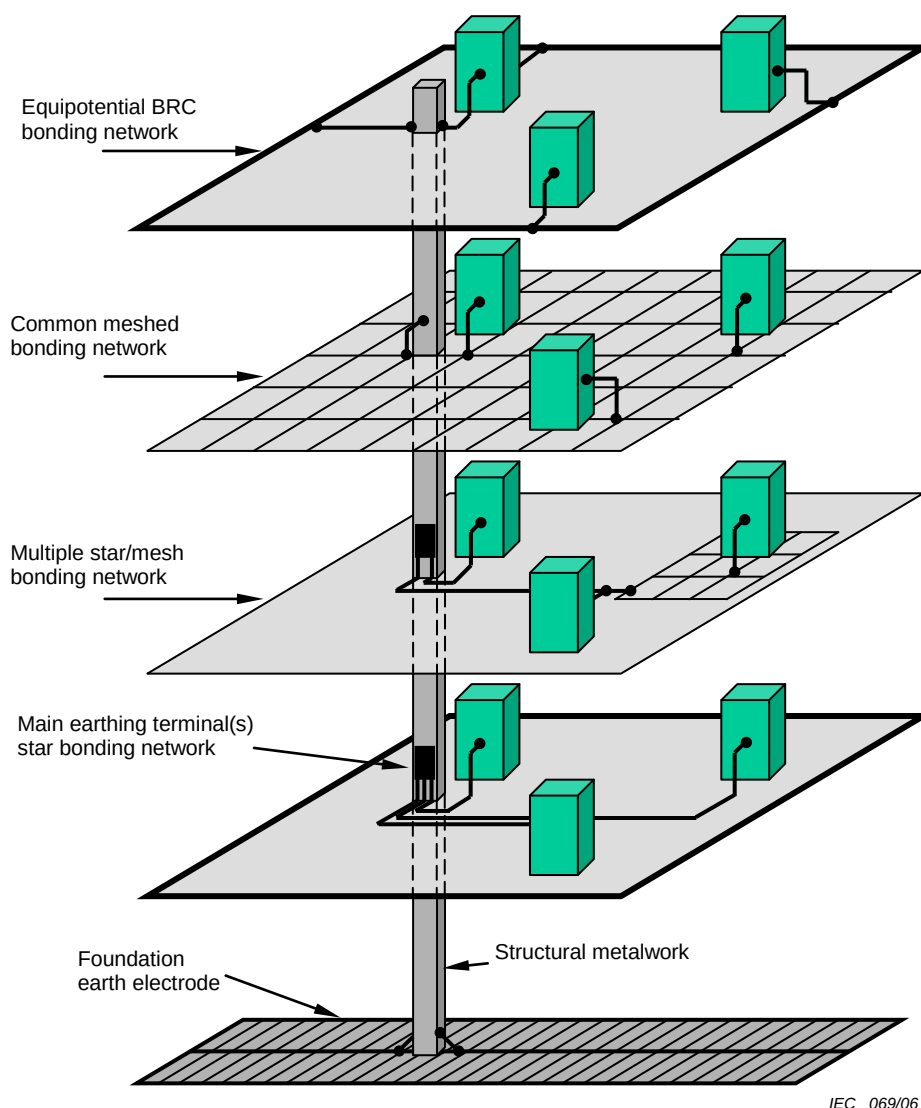


Figure 44.R16 – Example of equipotential bonding networks in structures without lightning protection systems

444.5.5 Functional earthing conductor

Some electronic equipment requires a reference voltage at about earth potential in order to function correctly; this reference voltage is provided by the functional earthing conductor.

Conductors for functional earthing may be metallic strips, flat braids and cables with circular cross section.

For equipment operating at high frequencies, metallic strips or flat braids are preferred and the connections shall be kept as short as possible.

No colour is specified for functional earthing conductors. However, the colours green-and-yellow specified for earthing conductors shall not be used. It is recommended that the same colour is used throughout the whole installation to mark functional earthing conductors at each end.

For equipment operating at low frequencies, cross sectional areas as indicated in 544.1.1 of IEC 60364-5-54 are considered satisfactory, independent of the conductor shape; see 444.4.2 b) and k).