IEC 60364-4-44

Edition 3.0 2024-12

INTERNATIONAL STANDARD

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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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IEC 60364-4-44:2024-12(en)

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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW-VOLTAGE ELECTRICAL INSTALLATIONS –

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

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

This third edition cancels and replaces the second edition published in 2007, Amendment 1:2015 and Amendment 2:2018. This edition constitutes a technical revision.

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

a) the structure of the document has been updated in accordance with the ISO/IEC Directives, Part 2:2021: the terms, definitions and symbols have been regrouped under a new Subclause 440.3, the tables and figures have been renumbered;

b) Clause 443 has been amended to better introduce the DC SPD and to improve some of the wording.

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

Draft	Report on voting
64/2696/FDIS	64/2737/RVD

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

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

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

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

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

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

- reconfirmed,
- withdrawn, or
- revised.

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INTRODUCTION

This part 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 transient overvoltages of atmospheric origin or due to switching
Clause 444	Measures against electromagnetic influences
Clause 445	Protection against undervoltage

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LOW-VOLTAGE ELECTRICAL INSTALLATIONS –

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

440 Protection against voltage disturbances and electromagnetic disturbances

440.1 Scope

This part of IEC 60364 provides requirements for the safety of electrical installations in the event of voltage disturbances and electromagnetic disturbances generated for different specified reasons.

The requirements of this document 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 can be conducted into or between electrical installations via these supply systems.

440.2 Normative references

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

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

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

IEC 60364-5-53:2019, *Low-voltage electrical installations – Part 5-53: Selection and erection of electrical equipment – Devices for protection for safety, isolation, switching, control and* monitoring
IEC 60364-5-53:2019/AMD1:2020
IEC 60364-5-53:2019/AMD2:2024

IEC 60364-5-54:2011, *Low-voltage electrical installations – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective* conductors
IEC 60364-5-54:2011/AMD1:2021

IEC 60664-1:2020, *Insulation coordination for equipment within low-voltage supply systems – Part 1: Principles, requirements and tests*

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

IEC 61196-7, *Coaxial communication cables – Part 7: Sectional specification for cables for BCT cabling in accordance with ISO/IEC 11801-4 – Indoor drop cables for systems operating at 5 MHz – 6 000 MHz*

IEC 61936-1, *Power installations exceeding 1 kV AC and 1,5 kV DC – Part 1: AC*

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

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

ISO/IEC 14763-2:2019, *Information technology – Implementation and operation of customer premises cabling – Part 2: Planning and installation*

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

440.3 Terms, definitions and symbols

440.3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60364-1 and the following apply.

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

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

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440.3.1.1
urban environment
area with a high density of buildings or densely populated communities with tall buildings

EXAMPLE Town centre.

440.3.1.2
suburban environment
area with a medium density of buildings

EXAMPLE Town outskirts.

440.3.1.3
rural environment
area with a low density of buildings

EXAMPLE The countryside.

440.3.1.4
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.

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

440.3.1.5
calculated risk level
CRL
calculated value of risk used to evaluate the need for transient overvoltage protection

440.3.1.6
rated impulse voltage
U_W
value of the impulse withstand voltage 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 60664-1:2020, 3.1.19, modified – In the term, "withstand" has been deleted and the symbol U_{imp} has been replaced with U_W.]

440.3.1.7
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)

Note 1 to entry: 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.

440.3.1.8
bonding ring conductor
BRC
earthing bus conductor in the form of a closed ring

Note 1 to entry: Normally the bonding ring conductor, as part of the bonding network, has multiple connections to the CBN that improves its performance.

440.3.1.9
common equipotential bonding system
common bonding network
CBN
equipotential bonding system providing both protective-equipotential-bonding and functional-equipotential-bonding

[SOURCE: IEC 60050-195:2021, 195-02-25]

440.3.1.10
equipotential bonding
set of electric connections intended to achieve equipotentiality between conductive parts

[SOURCE: IEC 60050-195:2021, 195-01-10]

440.3.1.11
earth-electrode network
ground-electrode network (US)
part of an earthing arrangement comprising only the earth electrodes and their interconnections

[SOURCE: IEC 60050-195:2021, 195-02-21]

440.3.1.12
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

Note 1 to entry: The MESH-BN augments the CBN.

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440.3.1.13
by-pass equipotential bonding conductor
parallel earthing conductor
PEC
earthing conductor connected in parallel with the screens of signal or data cables in order to limit the current flowing through the screens

440.3.2 Symbols

In this document, the following symbols are used (see Figure 1).

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_o in TN- and TT-systems: nominal AC RMS line voltage to earth

in IT-systems: nominal AC 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 1).

I_d fault current 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 1).

Z impedance (e.g. IMD internal impedance, artificial neutral impedance) between the low-voltage system and an earthing arrangement.

NOTE 2 An earthing arrangement can 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.

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441 Void

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

442.1.1 General

This Clause 442 provides 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.

442.1.2 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 442.2, 442.3, 442.4 and 442.5 consider four situations as proposed in 442.1, which generally cause the most severe temporary overvoltages such as defined in IEC 60050-614:

- 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).

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

442.2.1 General

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 1 provides the relevant methods of calculation for the different types of overvoltages.

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

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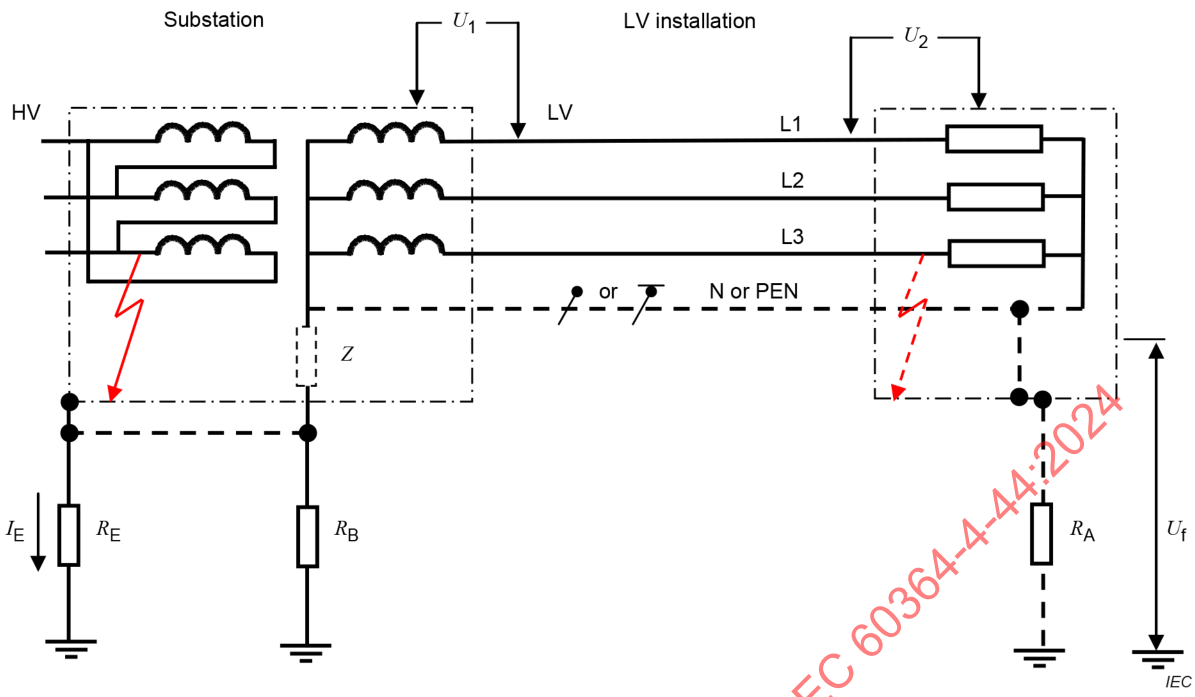

Figure 1 – Representative schematic diagram for possible connections to earth in substation and LV-installation and occurring overvoltages in case of faults

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

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Table 1 – 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_o [a]	$R_E \times I_E + U_o$	0 [a]
	R_E and R_B separated	$R_E \times I_E + U_o$	U_o [a]	0 [a]
TN	R_E and R_B connected	U_o [a]	U_o [a]	$R_E \times I_E$ [b]
	R_E and R_B separated	$R_E \times I_E + U_o$	U_o [a]	0 [a]
IT	R_E and Z connected R_E and R_A separated	U_o [a]	$R_E \times I_E + U_o$	0 [a]
		$U_o \times \sqrt{3}$	$R_E \times I_E + U_o \times \sqrt{3}$	$R_A \times I_h$
	R_E and Z connected R_E and R_A interconnected	U_o [a]	U_o [a]	$R_E \times I_E$
		$U_o \times \sqrt{3}$	$U_o \times \sqrt{3}$	$R_E \times I_E$
	R_E and Z separated R_E and R_A separated	$R_E \times I_E + U_o$	U_o [a]	0 [a]
		$R_E \times I_E + U_o \times \sqrt{3}$	$U_o \times \sqrt{3}$	$R_A \times I_d$

Key

(grey shading) With existing earth fault in the installation.

a No consideration shall be given.

b See 442.2.2 second paragraph.

NOTE 2 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 2).

NOTE 3 In a system whose neutral is connected to the earthing arrangement of the transformer substation, such temporary power-frequency overvoltage is also expected across insulation which is not in an earthed enclosure when the equipment is outside a building.

NOTE 4 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.

442.2.2 Magnitude and duration of power-frequency fault voltage

The magnitude and the duration of the fault voltage U_f (as calculated in Table 1) 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 2 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:

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

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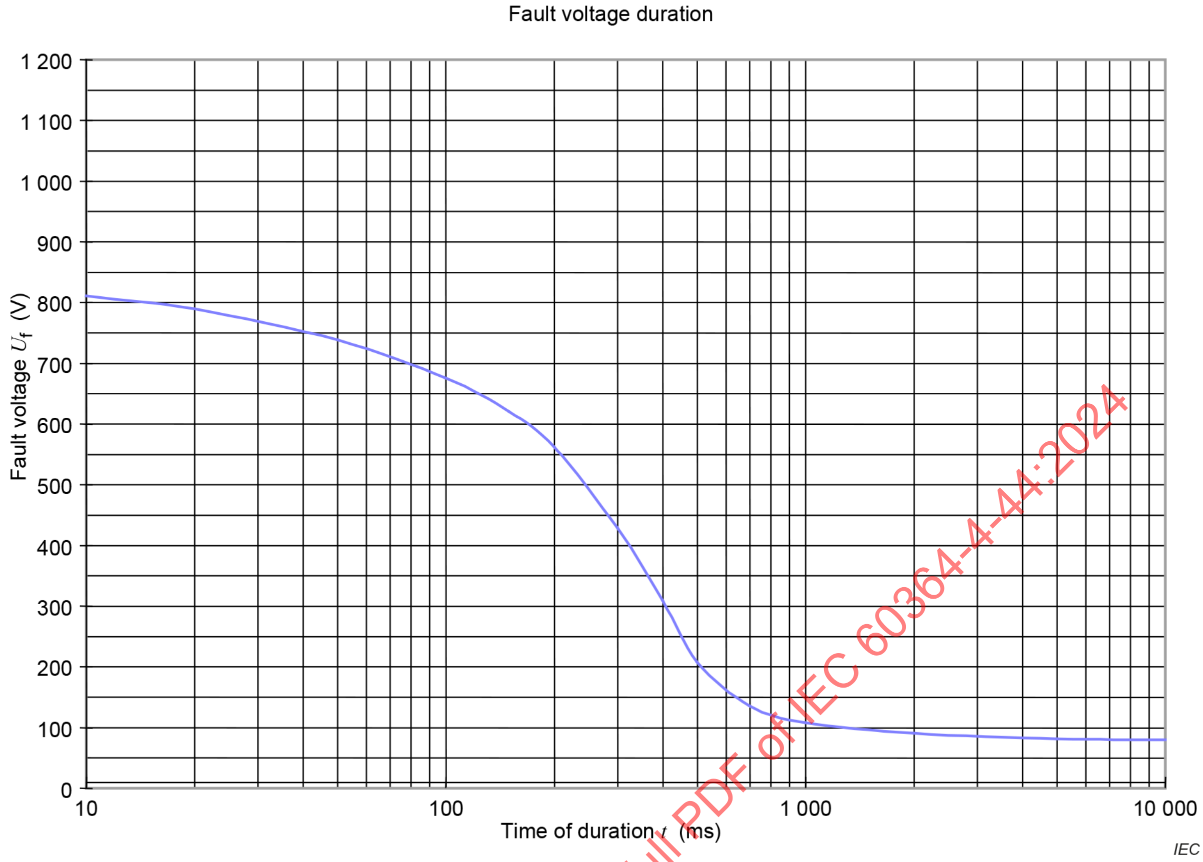

NOTE On the basis of probabilistic and statistical evidence this curve represents a low level of risk for the simple worst case where the low-voltage system neutral conductor is earthed only at the transformer substation earthing arrangements. Guidance is provided in IEC 61936-1 concerning other situations.

SOURCE: IEC 61936-1:2021, Figure 12

Figure 2 – Tolerable fault voltage due to an earth-fault in the HV system

442.2.3 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 1 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 2.

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Table 2 – 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_o + 250 V
≤ 5 s	U_o + 1 200 V

In systems without a neutral conductor, U_o 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 expected across insulation which is not in an earthed enclosure when the equipment is outside a building.

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442.2.4 Requirements for calculation of limits

Where required by Table 1, the permissible power-frequency stress voltage shall not exceed the value given in Table 2.

Where required by Table 1, the permissible power-frequency fault voltage shall not exceed the value given in Figure 2.

The requirements of 442.2.2 and 442.2.3 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 for whom it is also necessary 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 for example:

- 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 $U = \sqrt{3}\ U_o$.

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 $U = \sqrt{3}\ U_o$.

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 × 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 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 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.

If no transient overvoltage protection against disturbances of atmospheric origin is installed, it can be necessary for protection against switching overvoltages 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 characteristics of transient overvoltages of atmospheric origin depend on factors such as:

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

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

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

Selection and installation of SPDs shall be in compliance with IEC 60364-5-53:2019, Clause 534 and IEC 60364-5-53:2019/AMD2:2024, Clause 534.

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.

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

a) structures with a risk of explosion;

b) structures where the damage can also involve the environment (e.g. chemical or radioactive emissions).

443.2 Void

443.3 Void

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 five times the economic value of the SPD located at the origin of the installation.

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, for example where a LV generator supplies the installation or where inductive or capacitive loads (e.g. motors, transformers, capacitor banks), storage units or high current loads are installed.

NOTE 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 62305-2 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

$$\text{CRL} = f_{\text{env}} / (L_{\text{P}} \times N_{\text{g}})$$

where

– f_{env} is an environmental factor and the value of f_{env} shall be calculated according to Table 3;

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Table 3 – Calculation of f_{env}

Environment	f_{env}
Rural and suburban environment	85 × F
Urban environment	850 × F

The value of coefficient F shall be taken equal to 1 for all installations.

– N_g is the lightning ground flash density (flash per km^2 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 km^2 per year. This is derived from the formula N_g = 0,1 × Td, where Td 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 the low-voltage overhead line;

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

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

L_{PCH} is the length (km) of the 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 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 the 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 3.

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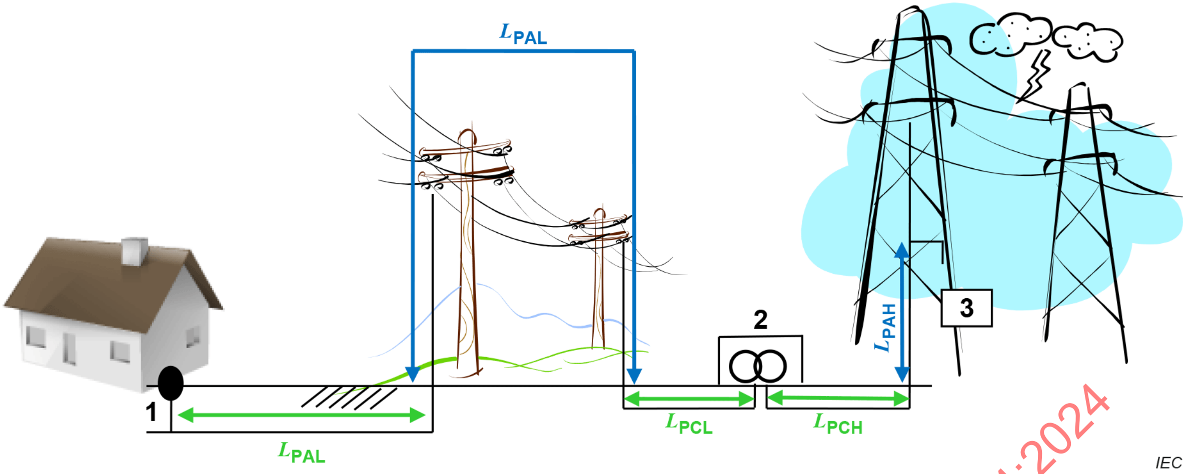

Key

1 origin of the installation

2 LV/HV transformer

3 surge arrestor (overvoltage protective device)

Figure 3 – Illustration of an installation showing the lengths to consider

If CRL ≥ 1 000, no protection against transient overvoltages of atmospheric origin is required;

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

NOTE 3 Examples of calculations of CRL are given in Annex A.

443.6 Classification of rated impulse voltages (overvoltage categories)

443.6.1 Purpose of classification of rated impulse voltages (overvoltage categories)

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

NOTE 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 in Table 4.

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.

It is possible that inherent overvoltage control based only on the impulse voltage withstand of the equipment in accordance with IEC 60664-1 is not 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.

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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).

443.6.2 Rated impulse voltages of equipment and overvoltage categories

The following points shall be noted:

a) Equipment with a rated impulse voltage corresponding to overvoltage category IV is suitable for use at, or in the proximity of, the point where the electrical installation is connected to an external electric power network (either public or private), 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 4.

NOTE 1 Examples of such equipment include energy meters, protective devices and ripple control units, telecontrol systems.

b) Equipment with a rated impulse voltage corresponding to overvoltage category III is suitable for use in the electrical 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 4.

NOTE 2 Examples of such equipment include distribution boards, local generation, circuit-breakers, wiring systems including cables, busbars, junction boxes, switches, socket-outlets (see IEC 60050-826:2022, 826-15-01), and equipment for industrial use and some other equipment, e.g. stationary motors.

c) Equipment with a rated impulse voltage corresponding to overvoltage category II is suitable for connection to the electrical installation, providing a degree of availability normally required for current-using equipment, and shall have a rated impulse voltage not less than the value specified in Table 4.

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

d) Equipment with a rated impulse voltage corresponding to overvoltage category I is only suitable for use where measures are taken to reduce transient overvoltages and temporary overvoltages to not exceed the value specified in Table 4.

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Table 4 – Required rated impulse voltage of equipment U_W

Nominal voltage of the installation V	Voltage line to neutral or mid-point derived from nominal voltages AC or DC up to and including V	Required rated impulse voltage of equipment[a] kV			
		Overvoltage category IV (equipment with very high rated impulse voltage)	Overvoltage category III (equipment with high rated impulse voltage)	Overvoltage category II (equipment with normal rated impulse voltage)	Overvoltage category I (equipment with reduced rated impulse voltage)
120/208	150	4	2,5	1,5	0,8
230/400[b c] 277/480[c]	300	6	4	2,5	1,5
400/690	600	8	6	4	2,5
1 000	1 000	12	8	6	4
1 250 (for DC only)	1 250 (for DC only)	12	8	6	4
1 500 (for DC only)	1 500 (for DC only)	15	10	8	6

[a] This rated impulse voltage is applied between live conductors and PE.

[b] For IT systems having line-to-line voltage from 220 V to 240 V, the 230/400 row shall be used, due to the voltage to earth at the earth fault on one line.

[c] In Canada and the USA, for voltages to earth higher than 300 V, the rated impulse voltage corresponding to the next highest voltage in this column applies.

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444 Measures against electromagnetic influences

444.1 General

Clause 444 provides basic recommendations for the mitigation of electromagnetic disturbances. Electromagnetic interference (EMI) can 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 can 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 444 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 can result in disturbance.

444.2 Void

NOTE This clause is reserved for future input.

444.3 Void

444.4 Mitigation of electromagnetic interference (EMI)

444.4.1 General

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.

444.4.2 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 or regulators,
– lifts,
– transformers,
– switchgear,
– power distribution busbars.

444.4.3 Measures to reduce EMI

The following measures reduce electromagnetic interference.

a) For electrical equipment sensitive to electromagnetic influences, surge protection devices or filters, or both, 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).

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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.

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 can be necessary, e.g. a by-pass equipotential bonding conductor for screen reinforcement; see Figure 4.

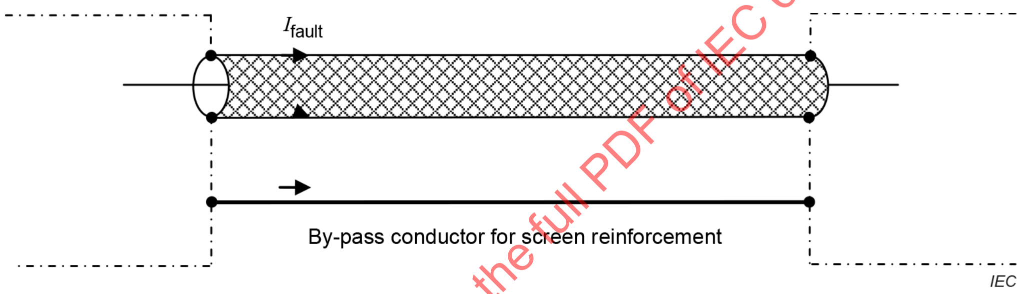

Figure 4 – By-pass conductor for screen reinforcement to provide a common equipotential bonding system

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 5. The by-pass conductor shall have a minimum cross-sectional area of 16 mm^2 Cu or equivalent. The equivalent cross-sectional area shall be dimensioned in accordance with IEC 60364-5-54:2011, 544.1.

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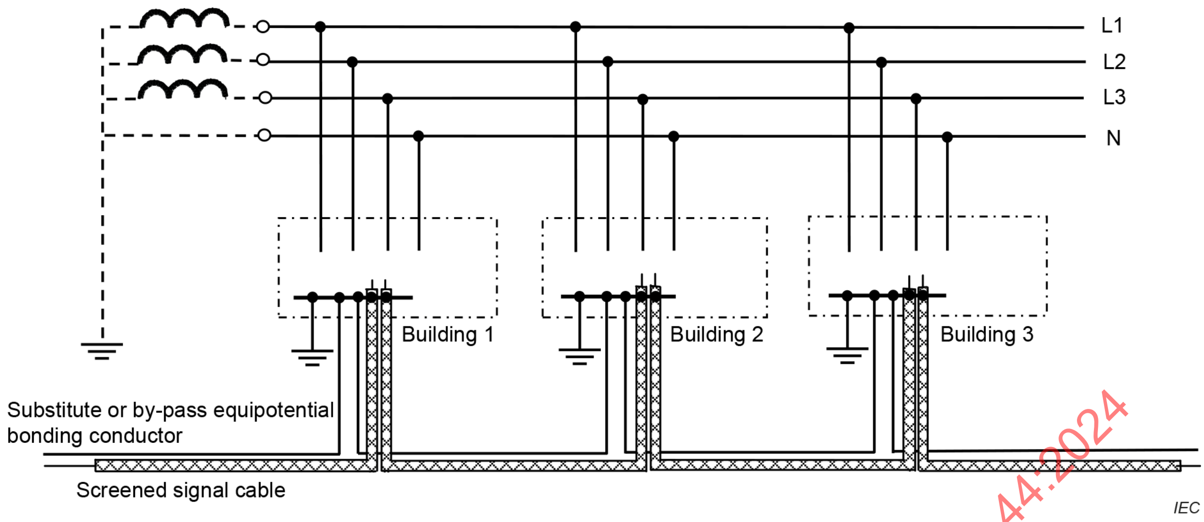

Figure 5 – Example of a substitute or by-pass equipotential bonding conductor in a TT-system

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

NOTE 3 It is recalled that if the consent according to IEC 60364-4-41:2005, 411.3.1.2 and IEC 60364-4-41:2005/AMD1:2017, 411.3.1.2 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 can employ other methods.

NOTE 5 In the Netherlands, a by-pass equipotential bonding conductor, connecting the earthing sytems of several TT installations together, is permitted only if fault protection, in accordance with IEC 60364-4-41:2005, 411.3.1.2 and IEC 60364-4-41:2005/AMD1:2017, 411.3.1.2, 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 444.5.7) 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.

444.4.4 TN-system

444.4.4.1 To minimize electromagnetic influences, the following Subclauses 444.4.4.2 to 444.4.4.5 apply.

444.4.4.2 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.

444.4.4.3 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 6.

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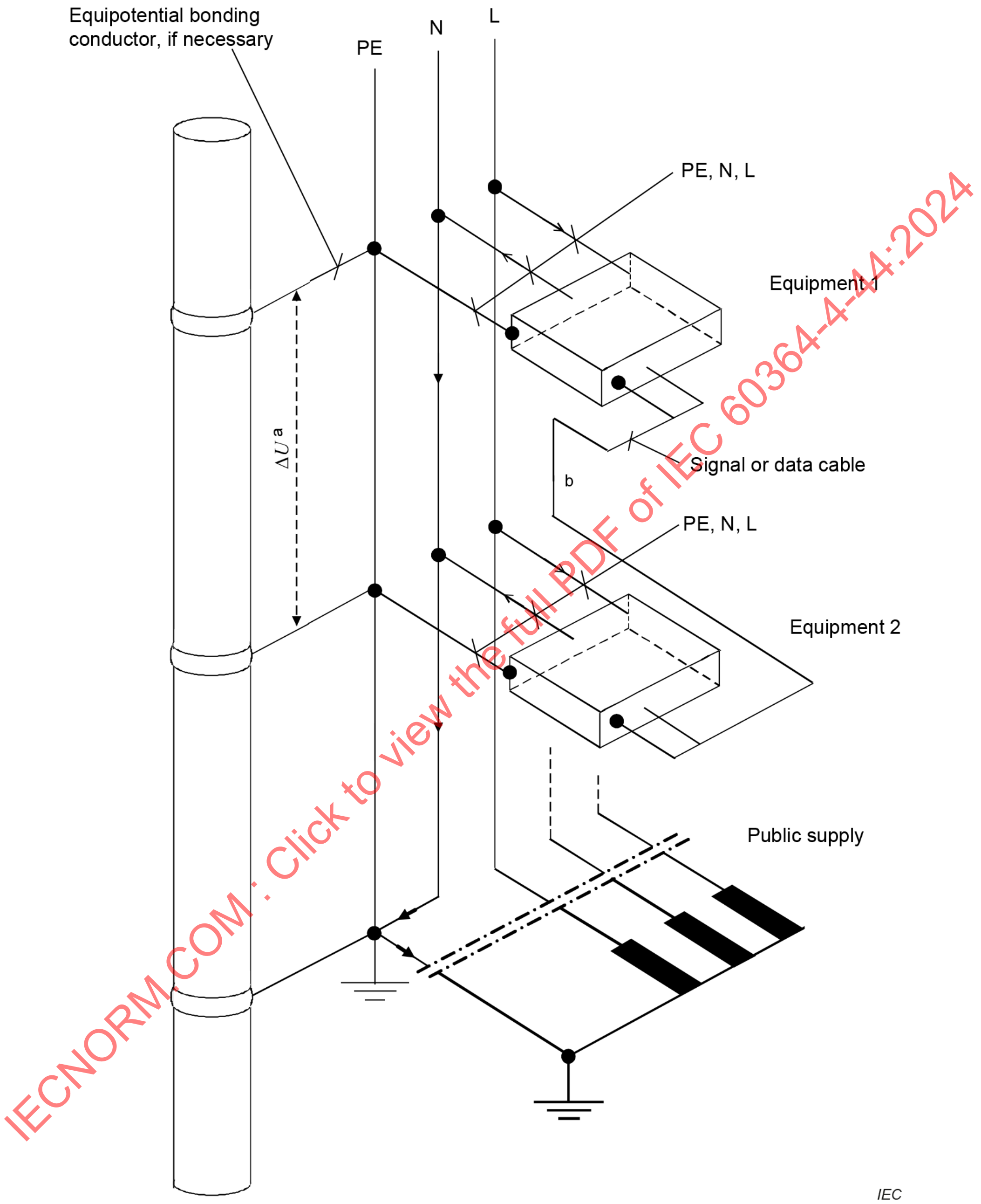
In newly constructed buildings, TN-S systems shall be installed downstream of the origin of the installation; see Figure 6.

The effectiveness of a TN-S-system may be enhanced by use of a residual current monitoring device, RCM, complying with IEC 62020-1:2020.



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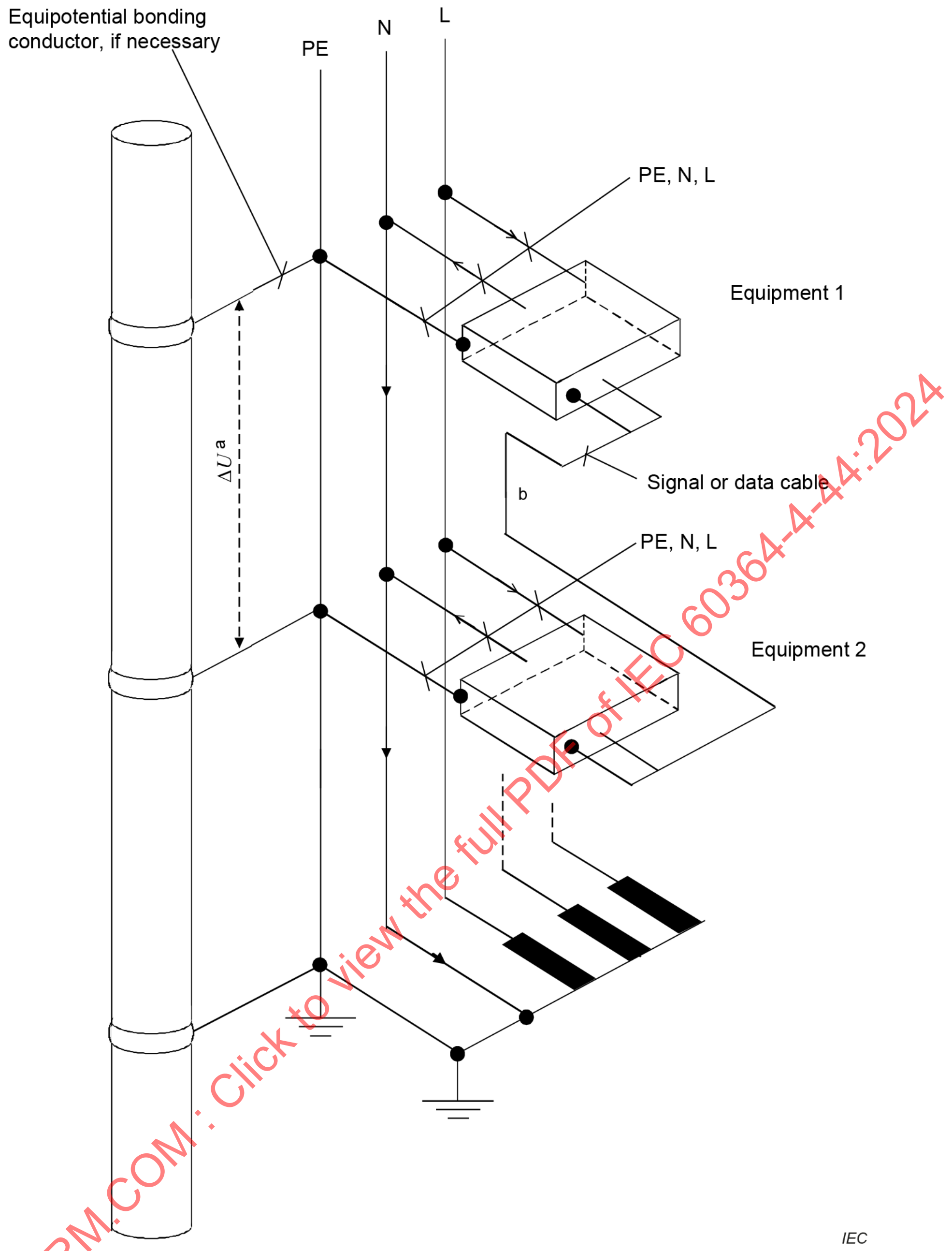
[a] No voltage drop ΔU along the PE conductor under normal operation conditions.

[b] Loops of limited area formed by signal or data cables.

Figure 6 – 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

444.4.4.4 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 7.



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[a] No voltage drop ΔU along the PE conductor under normal operation conditions.

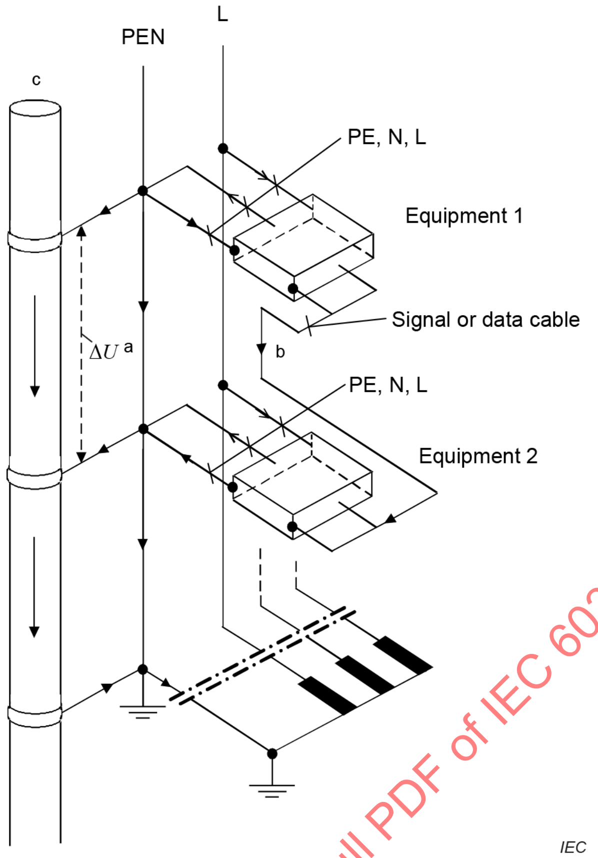
[b] Loops of limited area formed by signal or data cables.

Figure 7 – Avoidance of neutral conductor currents in a bonded structure by using a TN-S system downstream of a consumer's private supply transformer

444.4.4.5 Where an existing installation is a TN-C-S system (see Figure 8), signal and data cable loops should be avoided by

– changing all TN-C parts of the installation shown in Figure 8 into TN-S, as shown in Figure 6, or

– where this change is not possible, by avoiding signal and data cable interconnections between different parts of the TN-S installation.



[a] Voltage drop ΔU along PEN in normal operation.

[b] Loop of limited area formed from signal or data cables.

[c] 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 8 – TN-C-S system within an existing building installation

444.4.5 TT system

In a TT system, such as that shown in Figure 9, consideration should be given to overvoltages which can exist between live parts and exposed-conductive-parts when the exposed-conductive-parts of different buildings are connected to different earth electrodes.

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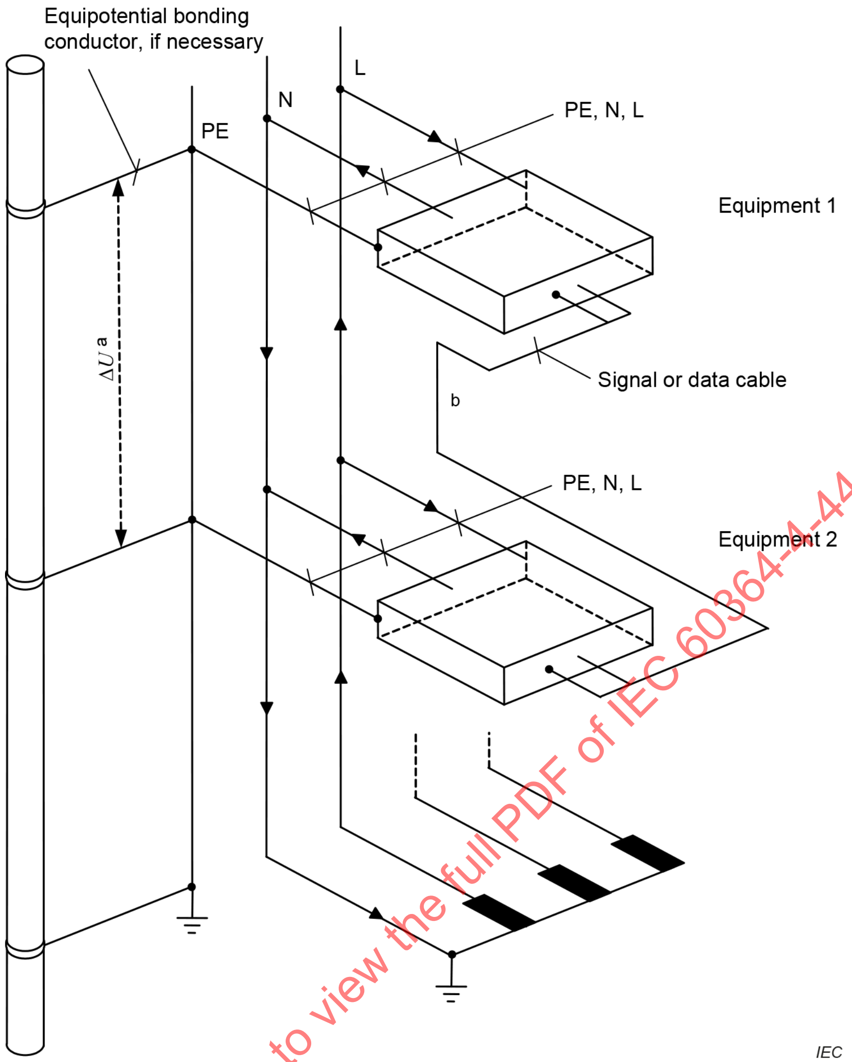

[a] Voltage drop ΔU along PEN in normal operation.

[b] Loop of limited area formed from signal or data cables.

Figure 9 – TT system within a building installation

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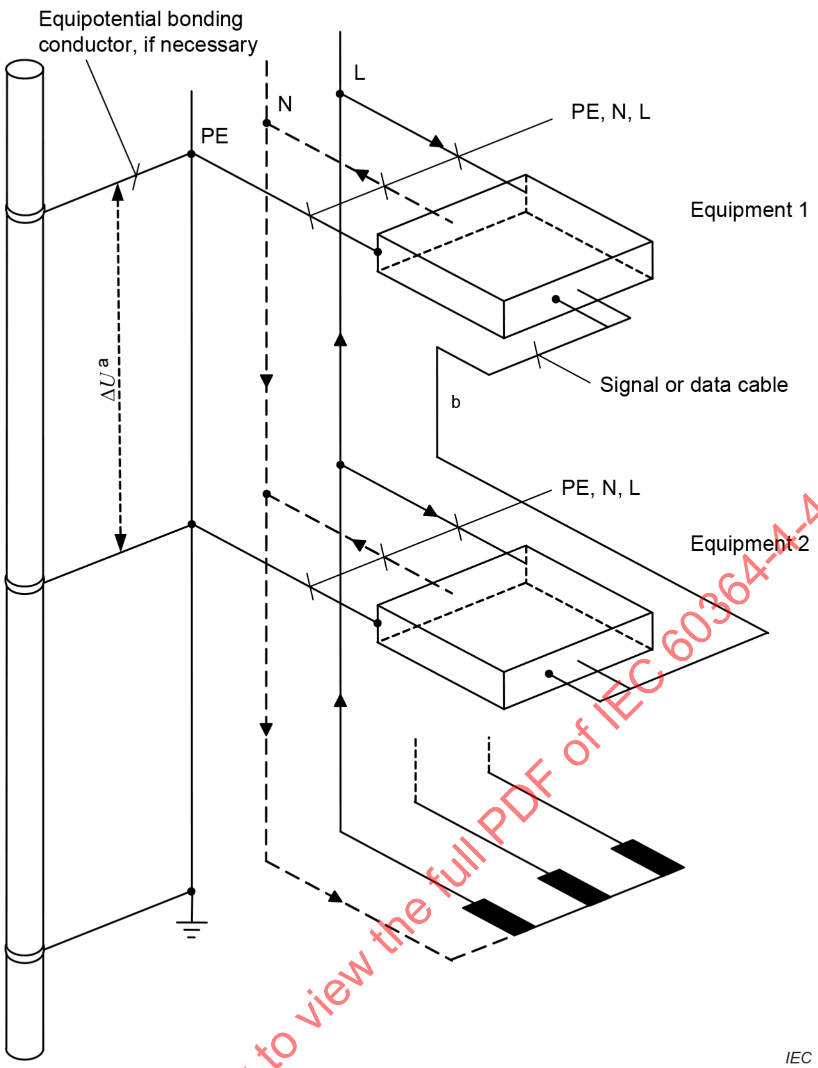
444.4.6 IT system

In a three-phase IT system (see Figure 10), 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.

Electronic equipment directly supplied between the line conductor and neutral should be designed to withstand such a voltage between the line conductor and exposed-conductive-parts; see corresponding requirement from IEC 62368-1:2023 for information technology equipment.



[a] Voltage drop ΔU along PEN in normal operation.

[b] Loop of limited area formed from signal or data cables.

Figure 10 – IT system within a building installation

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444.4.7 Multiple-source supply

444.4.7.1 General

For multiple-source power supplies, the provisions in 444.4.7.2 and 444.4.7.3 shall be applied.

NOTE Where multiple earthing of the star points of the sources of supplies is applied, neutral conductor currents can flow back to the relevant star point, not only via the neutral conductor, but also via the protective conductor as shown in Figure 11. 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 can interfere with electronic equipment. Harmonic currents produce similar electromagnetic fields but they attenuate more rapidly than those produced by fundamental currents.

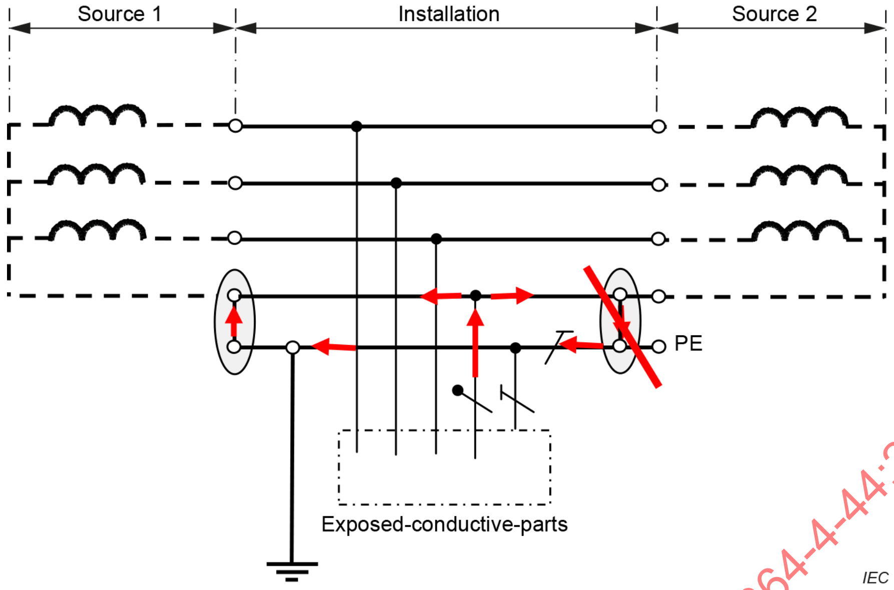

Figure 11 – TN multiple-source power supply with a non-suitable multiple connection between PEN and earth

444.4.7.2 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 12.

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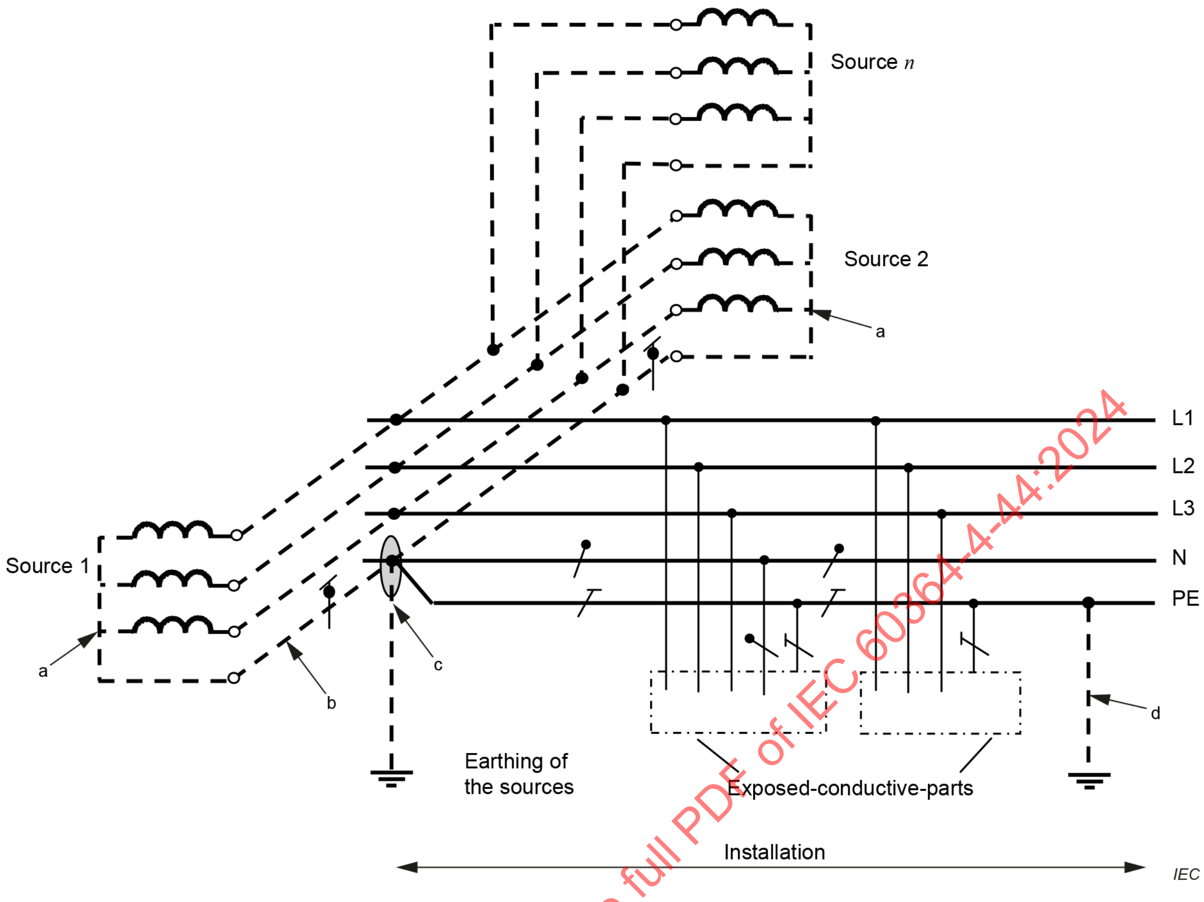

[a] No direct connection from either transformer neutral points or generator star points to earth is permitted.

[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 12 – TN multiple-source power supplies to an installation with connection to earth of the star points at one and the same point

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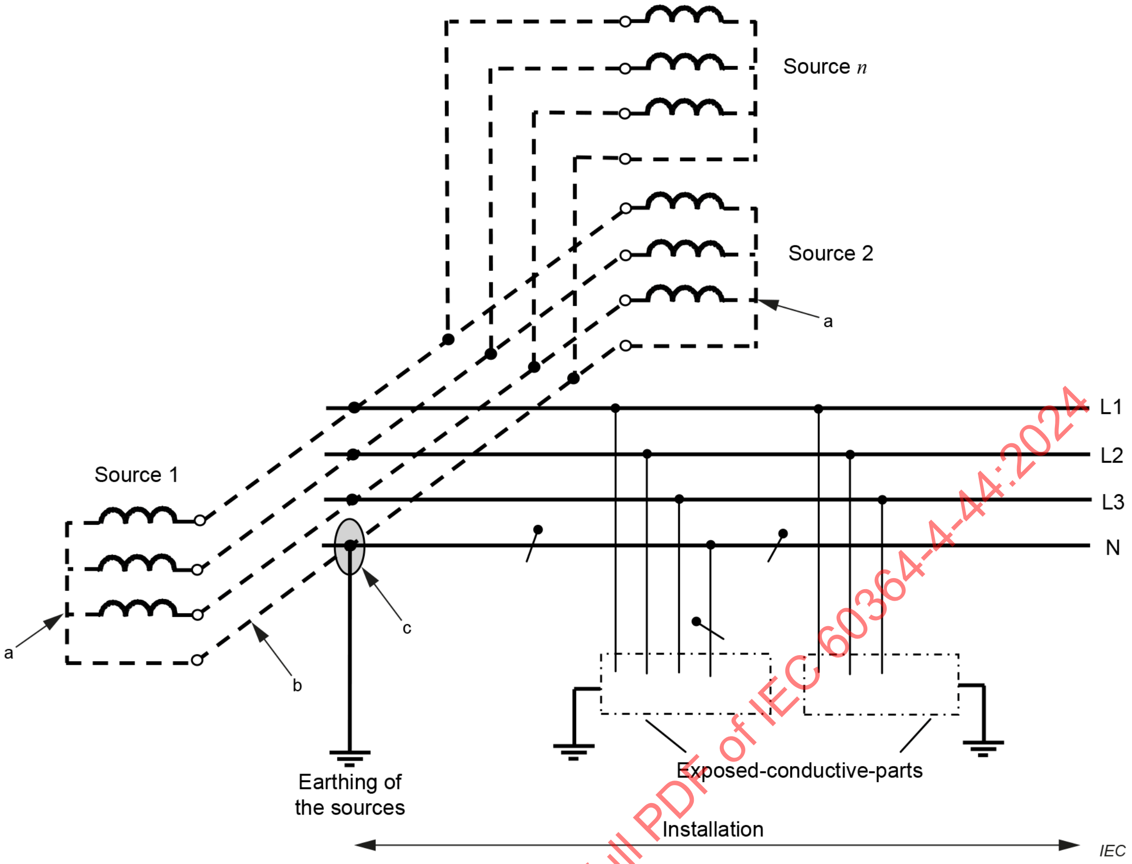
444.4.7.3 TT multiple-source power supplies

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 13.



[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 star points, 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 13 – TT multiple-source power supplies to an installation with connection to earth of the star points at one and the same point

444.4.8 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 Figure 14, Figure 15 and Figure 16.

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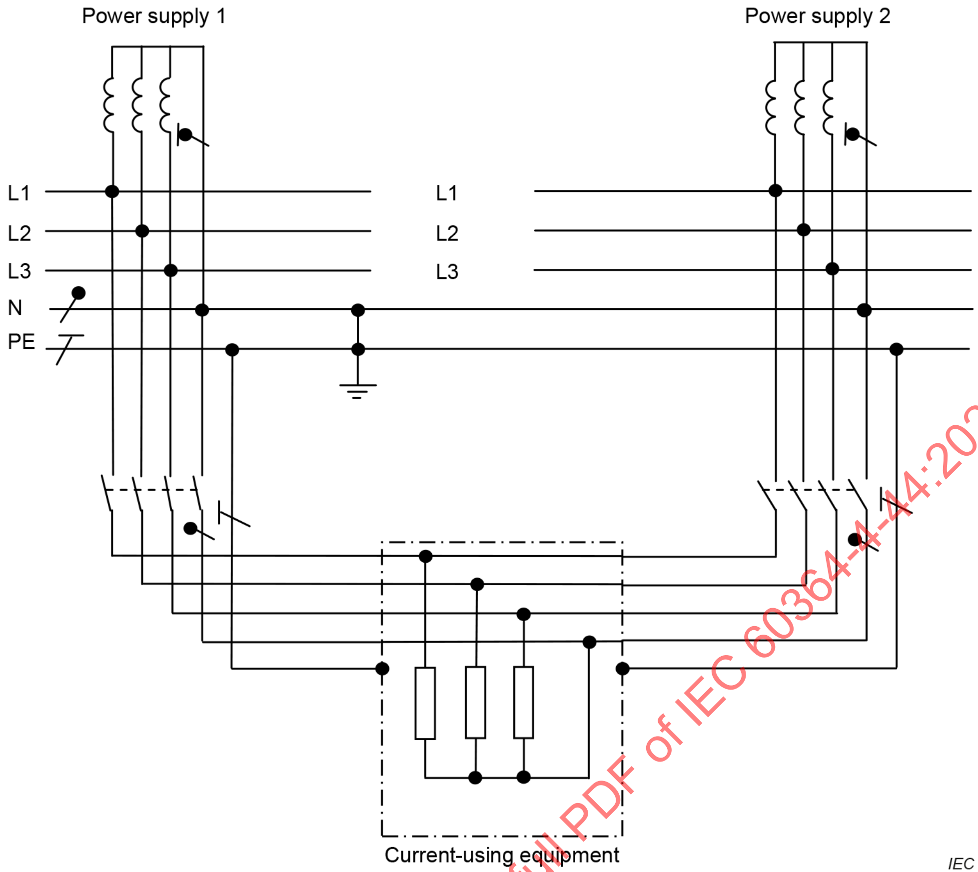

NOTE This method prevents electromagnetic fields due to stray currents in the main supply system of an installation. The sum of the currents within one cable will be zero. It ensures that the neutral current flows only in the neutral conductor of the circuit, which is switched on. The 3rd harmonic (150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

Figure 14 – Three-phase alternative power supply with a 4-pole switch

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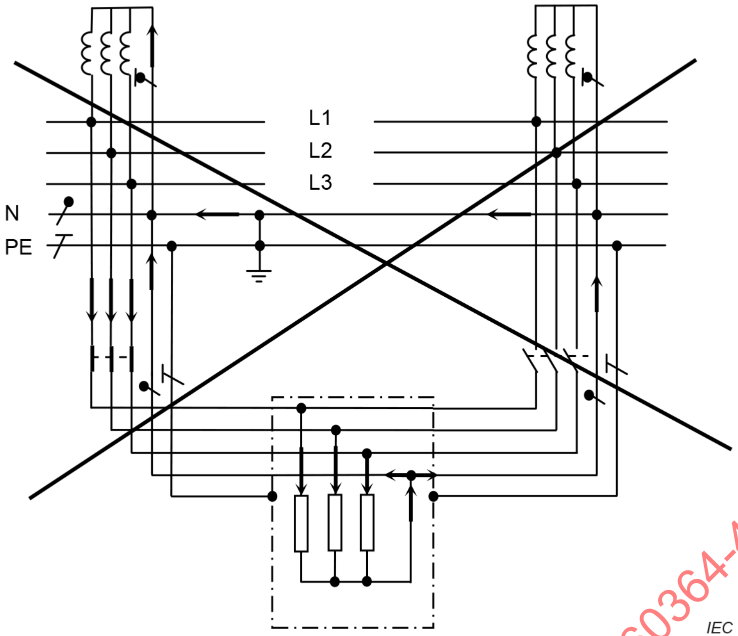

NOTE A three-phase alternative power supply with an unsuitable 3-pole switch will cause unwanted circulating currents, that will generate electromagnetic fields.

Figure 15 – Neutral current flow in a three-phase alternative power supply with an unsuitable 3-pole switch

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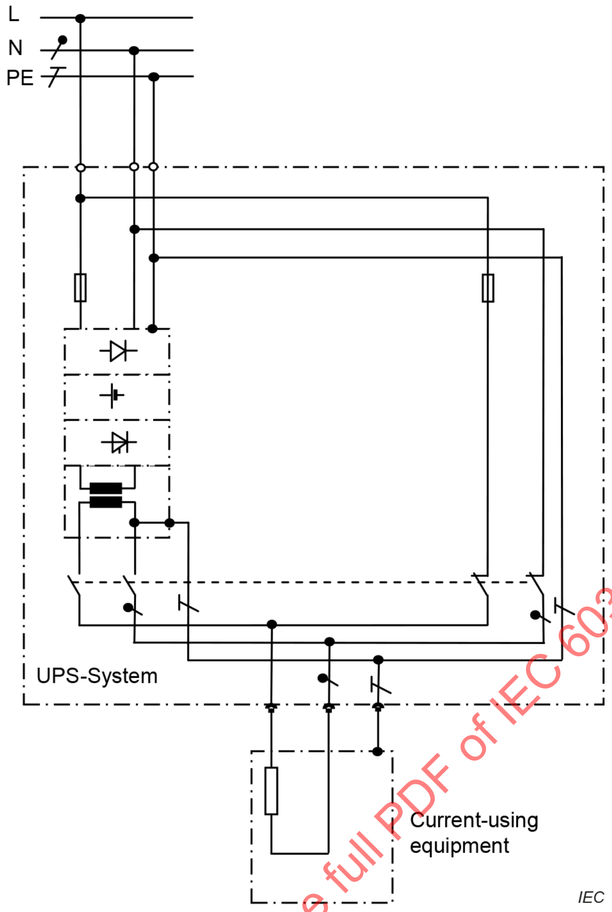

The earth connection to the secondary circuit of a UPS is not mandatory. If the connection is omitted, the supply in the UPS-mode will be in the form of an IT system and, in by-pass mode, it will be the same as the low-voltage supply system.

Figure 16 – Single-phase alternative power supply with 2-pole switch

444.4.9 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 17.

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

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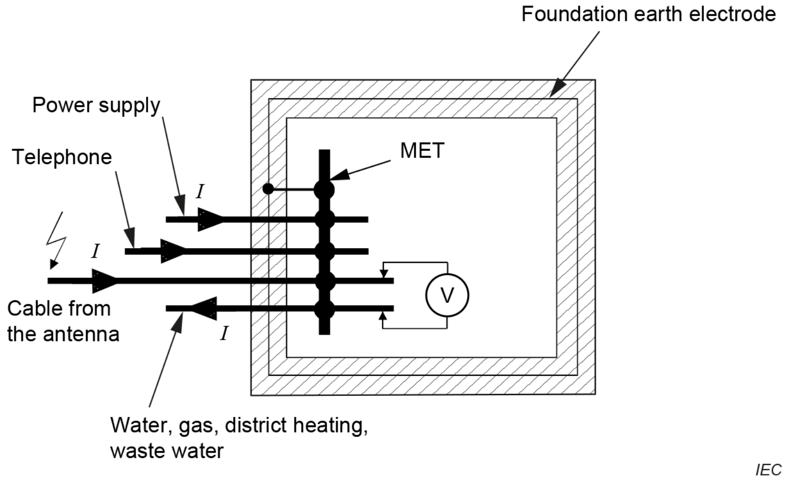

Key

MET main earthing terminal

I induction current

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

Figure 17 – Armoured cables and metal pipes entering the buildings (examples)

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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) and access shall be provided for their maintenance.

444.4.10 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.

EXAMPLES Microwave signal transformers for isolation as described in IEC 61558-2-1, IEC 61558-2-4, IEC 61558-2-6, IEC 61558-2-15 and IEC 62368-1.

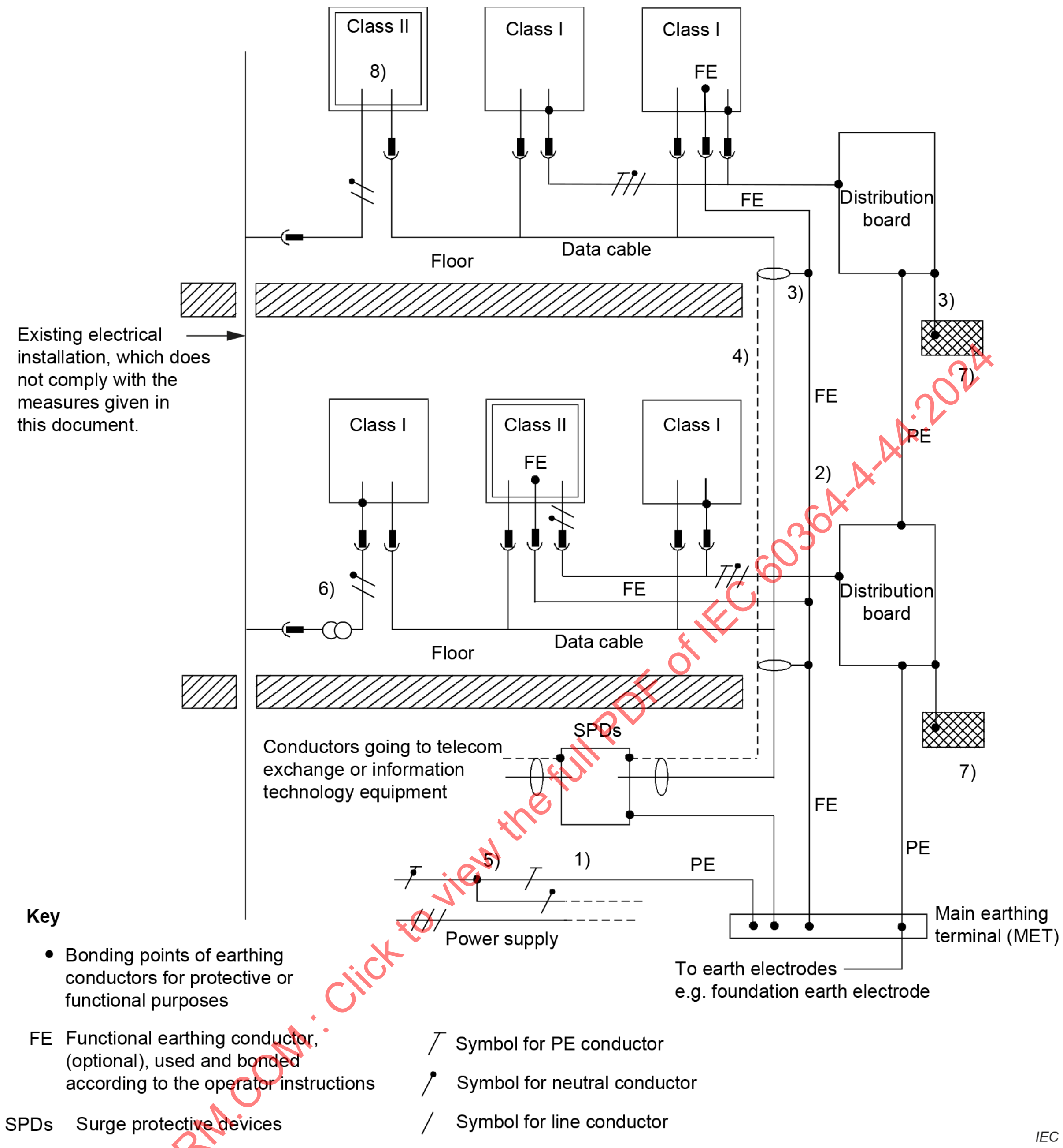
NOTE 1 The problem of earth differential voltages on large public telecommunication networks is the responsibility of the network operator, who can employ other methods.

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

444.4.11 Inside buildings

Where there are problems in existing building installations due to electromagnetic influences, the following measures may improve the situation; see Figure 18:

1) use of metal-free fibre optic links for signal and data circuits, see 444.4.10;
2) use of Class II equipment;
3) use of double winding transformers in accordance 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.



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Reference	Description of the illustrated measures	Subclause or standard
1)	Cables and metal pipes enter the building at the same place	444.4.9
2)	Common route with adequate separations and avoidance of loops	444.4.3
3)	Bonding leads as short as possible, and use of earthed conductor parallel to a cable	IEC TR 61000-2-5 444.4.3
4)	Signal cables screened or conductors twisted pairs	444.4.13
5)	Avoidance of TN-C beyond the incoming supply point	444.4.4
6)	Use of transformers with separate windings	444.4.11
7)	Local horizontal bonding system	444.5.4
8)	Use of class II equipment	444.4.11

Figure 18 – Illustration of measures in an existing building

444.4.12 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.

444.4.13 Signal cables

Shielded cables 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, it is possible that the concept of dedicated and independent earth electrodes connected to an equipotential conductor network will 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 19.

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 444.4.11.

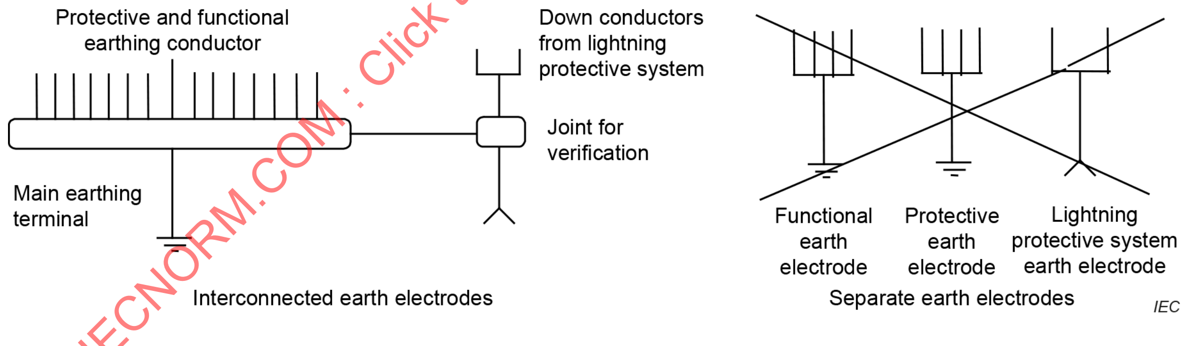

Figure 19 – Interconnected earth electrodes

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 20.

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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 22.

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

444.5.3.1 General

The four basic structures described in the following Subclauses 444.5.3.2 to 444.5.3.5 may be used, depending on the importance and vulnerability of equipment.

444.5.3.2 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 23 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.

444.5.3.3 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 20.

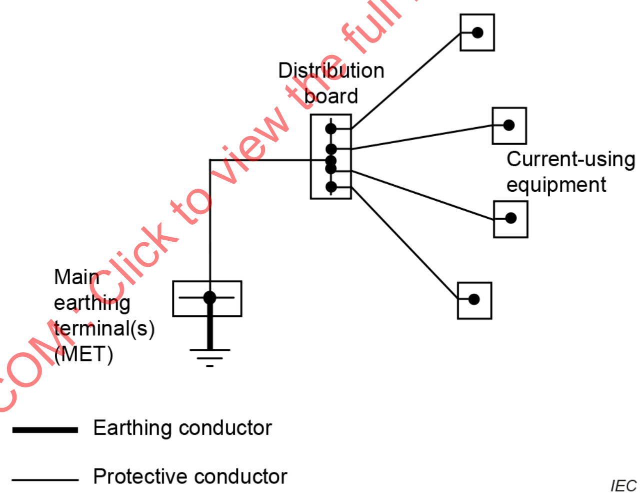

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Figure 20 – Examples of protective conductors in star network

444.5.3.4 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 21.

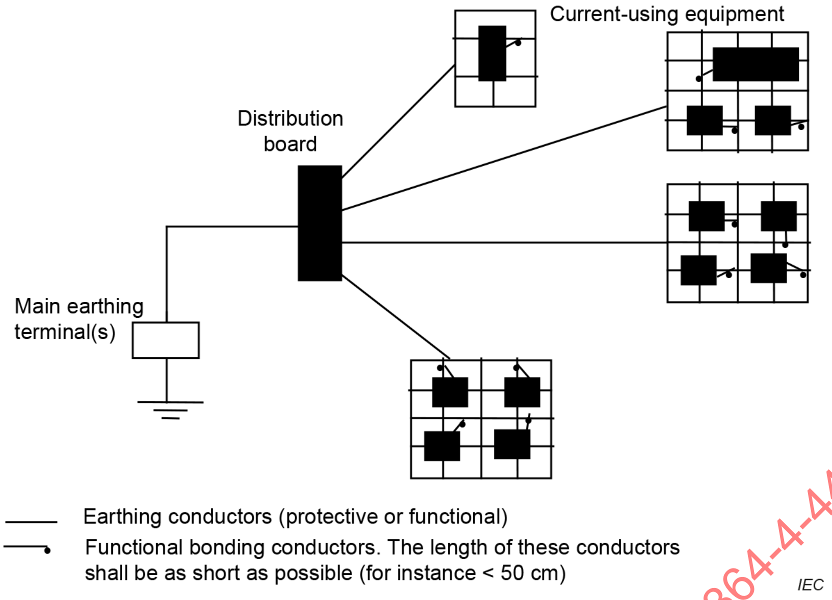

Figure 21 – Example of multiple meshed bonding star network

444.5.3.5 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 22.

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.

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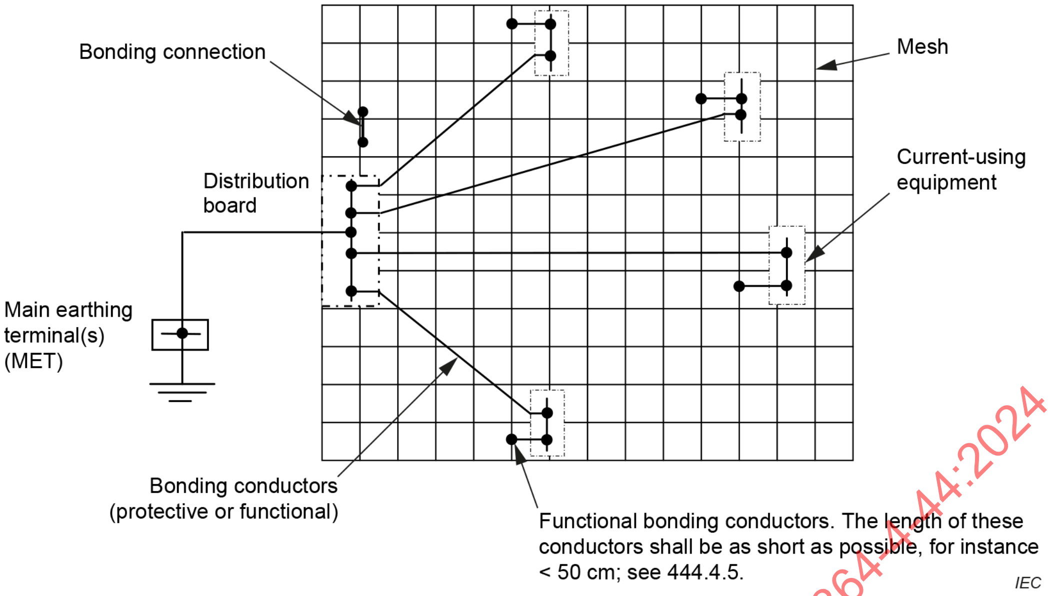

The area covered by a mesh shall have overall dimensions; the mesh-size refers to the dimensions of square spaces enclosed by the conductors forming the mesh.

Figure 22 – 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 23 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.

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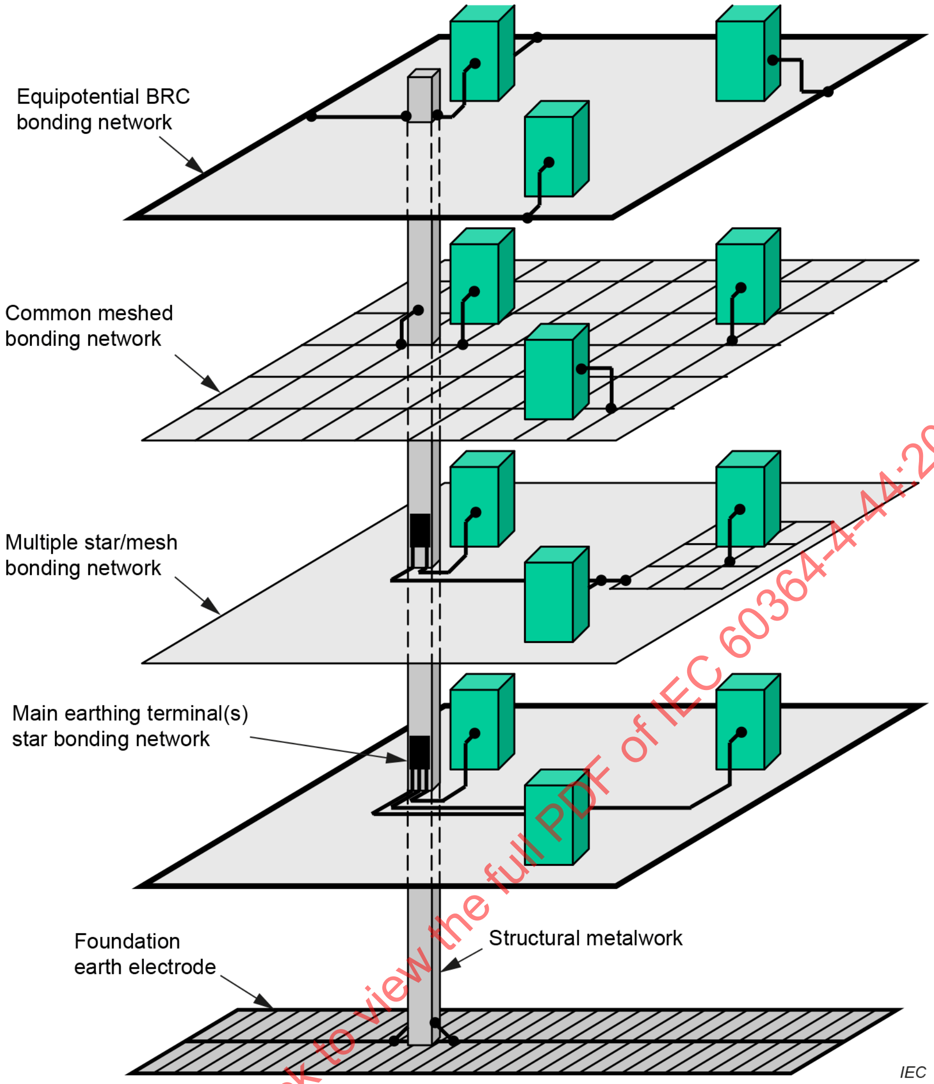

Figure 23 – Example of equipotential bonding networks in structures without lightning protection systems

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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 IEC 60364-5-54:2011, 544.1 are considered satisfactory, independent of the conductor shape; see 444.4.3 b) and k).

444.5.6 Commercial or industrial buildings containing significant amounts of information technology equipment

444.5.6.1 General

The following additional specifications are intended to reduce the influences of electromagnetic disturbances on the information technology equipment operation.

In severe electromagnetic environments, it is recommended that the common meshed bonding star network described in 444.5.3.4 be adopted.

444.5.6.2 Sizing and installation of bonding ring network conductors

Equipotential bonding designed as a bonding ring network shall have the following minimum dimensions:

– flat copper cross-section: 30 mm × 2 mm;
– round copper diameter: 8 mm.

Bare conductors shall be protected against corrosion at their supports and on their passage through walls.

444.5.6.3 Parts to be connected to the equipotential bonding network

The following parts shall also be connected to the equipotential bonding network:

– conductive screens, conductive sheaths or armouring of data transmission cables or of information technology equipment;
– earthing conductors of antenna systems;
– earthing conductors of the earthed pole of DC supply for information technology equipment;
– functional earthing conductors.

444.5.7 Earthing arrangements and equipotential bonding of information technology installations for functional purposes

444.5.7.1 Earthing busbar

Where an earthing busbar is required for functional purposes, the main earthing terminal (MET) of the building may be extended by using an earthing busbar. This enables information technology installations to be connected to the main earthing terminal by the shortest practical route from any point in the building. Where the earthing busbar is erected to support the equipotential bonding network of a significant amount of information technology equipment in a building, it may be installed as a bonding ring network; see Figure 23.

NOTE 1 The earthing busbar can be bare or insulated.

NOTE 2 The earthing busbar is preferably installed so that it is accessible throughout its length, e.g. on the surface of trunking. To prevent corrosion, it can be necessary to protect bare conductors at supports and where they pass throughout walls.

444.5.7.2 Cross-sectional area of the earthing busbar

The effectiveness of the earthing busbar depends on the routing and the impedance of the conductor employed. For installations connected to a supply having a capacity of 200 A per phase or more, the cross-sectional area of the earthing busbar shall be not less than 50 mm^2 copper and shall be dimensioned in accordance with 444.4.3 k).

NOTE This statement is valid for frequencies up to 10 MHz.

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Where the earthing busbar is used as part of a DC return current path, its cross-sectional area shall be dimensioned according to the expected DC return currents. The maximum DC voltage drop along each earthing busbar, dedicated as DC distribution return conductor, shall be designed to be less than 1 V.

444.6 Segregation of circuits

444.6.1 General

Power supply cables (or conductors) and information and communication technology cables which share the same cable management system or the same route, shall be installed according to the requirements of 444.6.

NOTE For the purposes of 444.6, cable management systems are considered to include busbar trunking systems and powertrack systems.

Electrical safety and electromagnetic compatibility may produce different requirements for electrical segregation and electrical separation. Electrical safety always has the higher priority.

444.6.2 Design requirements

The following requirements apply unless 444.6.3 applies.

Where the specification or intended application of the information and communication technology cable is not available, the cable separation distance between the power and information and communication technology cables shall be not less than 200 mm in free air, provided:

– the total current in a LV cable or in a bundle of LV cables does not exceed 600 A,
– the applications supported by the cabling are designed to operate using the information and communication technology cabling installed or to be installed, and
– the information and communication technology cables are:
  - balanced cables having electromagnetic immunity performance in accordance with the IEC 61156 series for Category 5 and above, or
  - coaxial cables having electromagnetic immunity performance in accordance with IEC 61196-7.

In all other cases, the requirements and recommendations of ISO/IEC 14763-2:2019, 7.9.2, apply.

The 200 mm separation distance may be reduced according to Table 5.

Where a screened power cable is used, the separation distance may be reduced in accordance with the specification provided by the screened power cable manufacturer, provided that the screen is earthed at both ends.

Power cables that also carry information and communication technology applications are not considered to be information and communication technology cables.

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Table 5 – Summary of minimum separation distances where the specification or intended application of the information and communication technology cable is not available

Containment applied to the power supply cabling			
Separation without electromagnetic barrier	Open metallic containment A	Perforated metallic containment B	Solid metallic containment C
200 mm	150 mm	100 mm	0 mm

A: Applicable to containment with screening performance (DC-100 MHz) equivalent to welded mesh steel basket of mesh size 50 mm × 100 mm. This screening performance is also achieved with steel tray even if the wall thickness is less than 1,0 mm or the evenly distributed perforated area is greater than 20 %.

B: Applicable to containment with screening performance (DC-100 MHz) equivalent to steel tray of at least 1,0 mm wall thickness and no more than 20 % evenly distributed perforated area. The screens or armouring of power cables are considered to act as perforated metallic containment if they do not meet this constructional equivalent of solid metallic containment.

C: Applicable to containment with screening performance (DC-100 MHz) equivalent to a steel conduit of at least 1,5 mm wall thickness.

The minimum separation between the information and communication technology cables and power supply cables shall include all allowances for cable movement between their fixing points or other restraints (see example in Figure 24).

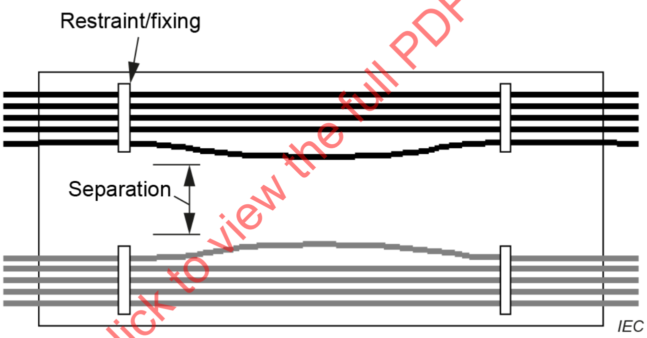

Figure 24 – Example of cable separation distance

The minimum separation requirement applies in three dimensions. However, where information and communication technology cables and power supply cables are required to cross and required minimum separation cannot be maintained, then the angle of their crossing shall be maintained at approximately 90° on either side of the crossing for a distance no less than the applicable minimum separation requirement.

444.6.3 Conditions for zero segregation

No segregation is required between information and communication technology cabling and power supply cabling (other than that required by IEC 60364-5-52) provided that the information and communication technology cabling is application(s)-specific and the application(s) support(s) a zero segregation relaxation.

No segregation is required between information and communication technology cabling and power supply cabling where all the following conditions are met:

– the information and communication technology cables are in accordance with the IEC 61156 series for Category 5 and above, or are coaxial cables having electromagnetic immunity performance in accordance with IEC 61196-7,

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– the environmental classification of the space containing the information and communication technology cabling complies with electromagnetic classification E1 of ISO/IEC TR 29106 (or ISO/IEC 11801-1), and
– the power supply conductors comprising a circuit are either:
  - within an overall sheath and provide a total current no greater than 100 A, or
  - twisted, taped or bundled together and provide a total power no greater than 10 kVA.

444.7 Cable management systems

444.7.1 General

Cable management systems are available in metallic and non-metallic forms. Metallic systems offer varying degrees of enhanced protection to EMI provided that they are installed in accordance with 444.7.3.

444.7.2 Design guidelines

The choice of material and the shape of the cable management system depend on the following considerations:

a) the strength of the electromagnetic fields along the pathway (proximity of electromagnetic conducted and radiated disturbing sources);
b) the authorized level of conducted and radiated emissions;
c) the type of cabling (screened, twisted, optical fibre);
d) the immunity of the equipment connected to the information technology cabling system;
e) the other environment constraints (chemical, mechanical, climatic, fire, etc.);
f) any future information technology cabling system extension.

Non-metallic wiring systems are suitable in the following cases:

– electromagnetic environment with permanently low levels of disturbance;
– the cabling system has a low emission level;
– optical fibre cabling.

For metallic components of cable support systems, the shape (plane, U-shape, tube, etc.), rather than the cross-section, will determine the characteristic impedance of the cable management system. Enclosed shapes are best as they reduce common mode coupling.

Usable space within the cable tray should allow for an agreed quantity of additional cables to be installed. The cable-bundle height shall be lower than the side walls of the cable tray, as shown in Figure 25. The use of overlapping lids improves the cable tray's electromagnetic compatibility performance.

For a U-shape cable tray, the magnetic field decreases near the two corners. For this reason, deep side walls are preferred; see Figure 25.

The depth of the section should be at least twice the diameter of the largest cable being considered.

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