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**Environmental Engineering (EE);
Earthing and bonding of 400 VDC data and telecom
(ICT) equipment**

Reference

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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
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Foreword

This draft European Standard (EN) has been produced by ETSI Technical Committee Environmental Engineering (EE), and is now submitted for the combined Public Enquiry and Vote phase of the ETSI standards EN Approval Procedure.

The present document has been produced within the framework of the following considerations:

- a) Datacommunications and Telecommunications (ICT) equipment is generally installed in data and telecom centres and held in racks, cabinets or other mechanical structures;
- b) the existing ITU-T and CCIR Recommendations and CENELEC standards in such matters do not ensure the required standardization at the equipment level;
- c) network operators and equipment providers agreed to standardize on a bonding configuration that facilitates:
 - compliance with functional requirements including Electromagnetic Compatibility (EMC) aspects of emission and immunity;
 - compatible building and equipment provisions;
 - installation of new data and telecom centres as well as expansion or replacement of installations in existing data and telecom centres with equipment coming from different suppliers;
 - a structured installation practice;
 - simple maintenance rules;
 - contracting on a common basis;
 - cost effectiveness in development, manufacturing, installation and operation.

Proposed national transposition dates	
Date of latest announcement of this EN (doa):	3 months after ETSI publication
Date of latest publication of new National Standard or endorsement of this EN (dop/e):	6 months after doa
Date of withdrawal of any conflicting National Standard (dow):	6 months after doa

Introduction

The present document addresses earthing and bonding of data and telecom (ICT) equipment in data and telecom centres when implementing a direct current interface up to 400 VDC defined in EN 300 132-3-1 [1] in relation to safety, functional performance and EMC. The present standard may also be applicable for ICT equipment in other locations such as: street cabinets, containers, subscriber's buildings, BTS:s etc.

The general principles for electrical installations from a safety perspective are based on the IEC 60364-series of standards, and where appropriate on information published by ITU-T to provide for the proper functioning of those installations.

1 Scope

The present document applies to earthing and bonding of ICT equipment installed in data and telecom centres and similar installations operating within the normal service voltage range up to 400 VDC defined in EN 300 132-3-1 [1].

Earthing and bonding network of the building (CBN), the bonding network of the equipment (SRPP), and the interconnection between these two networks are treated in the present document. It contributes to the standardization of telecommunication and datacom equipment installation.

It also co-ordinates with the pre-conditions of the installation to achieve the following targets:

- safety from electrical hazards;
- continuity of service requiring:
 - reliable signal reference;
 - satisfactory Electromagnetic Compatibility (EMC) performance.

The present document defines earthing and bonding configuration down to the equipment level in order to facilitate the installation, operation and maintenance of data and telecom centres in data and telecom buildings or similar installations independent of the equipment supplier.

The specification of ICT equipment and of the pre-conditions of installation is subject to agreement of the parties (e.g. the supplier and the purchaser). Annex A can be used in the procedure to achieve an agreement.

The present document does not cover safety and EMC aspects of the equipment. Those aspects are covered by other relevant standards.

The present document applies to the installation of ICT equipment in data and telecom centres. The present standard may also be applicable for ICT equipment in other locations, e.g.:

- street cabinet
- container
- subscriber's building
- BTS

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at <http://docbox.etsi.org/Reference>.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

2.1 Normative references

The following referenced documents are necessary for the application of the present document.

- [1] ETSI EN 300 132-3-1: "Environmental Engineering (EE); Power supply interface at the input to telecommunications and datacom (ICT) equipment; Part 3: Operated by rectified current source, alternating current source or direct current source up to 400 V; Sub-part 1: Direct current source up to 400 V".

- [2] IEC 60364-1: "Low-voltage electrical installations - Part 1: Fundamental principles, assessment of general characteristics, definitions".
- [3] IEC 60364-4-41: "Low-voltage electrical installations - Part 4-41: Protection for safety - Protection against electric shock".
- [4] IEC 60364-5-54: "Low-voltage electrical installations - Part 5-54: Selection and erection of electrical equipment - Earthing arrangements and protective conductors".
- [5] IEC 60050: "International Electrotechnical Vocabulary".
- [6] IEC 60950-1: "Information technology equipment - Safety - Part 1: General requirements".
- [7] IEC 62305-series: "Protection against lightning".
- [8] CENELEC EN 50310: "Application of equipotential bonding and earthing in buildings with information technology equipment".
- [9] ETSI EN 300 253: "Environmental Engineering (EE); Earthing and bonding of telecommunication equipment in telecommunication centres".
- [10] CENELEC EN 41003: "Particular safety requirements for equipment to be connected to telecommunication networks and/or a cable distribution system".
- [11] IEC/TR 60479-5: "Effects of current on human beings and livestock - Part 5: Touch voltage threshold values for physiological effects".
- [12] CENELEC EN 50174-2: "Information technology -Cabling installation -Part 2: Installation planning and practices inside buildings".
- [13] CENELEC EN 50162:"Protection against corrosion by stray current from direct current systems".

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

- [i.1] ITU-T Recommendation K.27: "Bonding configurations and earthing inside a telecommunication building".
- [i.2] CENELEC EN 55022: "Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement".
- [i.3] ITU-T Recommendation L.1200: "Specification of DC power feeding system interface".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

3.1.1 IEC definitions

The following definitions (IEC reference in parentheses) with respect to earthing and bonding are introduced by the IEC 60050 [5] and are used within the present document to maintain conformity.

earth (195-01-03): part of the Earth which is in electric contact with an earth electrode and the electric potential of which is not necessarily equal to zero earthing arrangement

earthing conductor (195-02-03): conductor which provides a conductive path, or part of the conductive path, between a given point in a system or in an installation or in equipment and an earth electrode

earth electrode (195-02-01): conductive part, which may be embedded in a specific conductive medium, e.g. concrete or coke, in electric contact with the Earth

earthing network (604-04-07): part of an earthing installation that is restricted to the earth electrodes and their interconnections

equipotential bonding (195-01-10): provision of electric connections between conductive parts, intended to achieve equipotentiality

exposed-conductive-part (826-12-10): conductive part of equipment which can be touched and which is not normally live, but which can become live when basic insulation fails

extraneous-conductive-parts (195-06-11): conductive part not forming part of the electrical installation and liable to introduce an electric potential, generally the electric potential of a local earth

functional-equipotential-bonding (826-13-21): equipotential bonding for operational reasons other than safety

insulation monitoring device (IMD): monitoring device sending an alarm when the insulation leakage current attains a given value under specified conditions without interrupting the power supply

line conductor (826-14-09): conductor which is energized in normal operation and capable of contributing to the transmission or distribution of electric energy but which is not a neutral or mid-point conductor

live part (826-12-08): conductor or conductive part intended to be energized in normal operation, including a neutral conductor, but by convention not a PEN conductor or PEM conductor or PEL conductor

main earthing terminal (826-13-15): terminal or busbar which is part of the earthing arrangement of an installation and enabling the electric connection of a number of conductors for earthing purposes

mid-point (MP) (826-14-04): common point between two symmetrical circuit elements whose opposite ends are electrically connected to different line conductors of the same circuit

NOTE: MP is an abbreviation for "mid-point" defined and used in the present document.

mid-point conductor (M) (826-14-08): conductor electrically connected to the mid-point and capable of contributing to the distribution of electric energy

neutral conductor (N) (826-01-03): conductor connected to the neutral point of a system and capable of contributing to the transmission of electrical energy

PEN conductor (826-13-25): conductor combining the functions of both a protective earthing conductor and a neutral conductor

PEM conductor (826-13-26): conductor combining the functions of both a protective earthing conductor and a mid-point conductor

PEL conductor (826-13-27): conductor combining the functions of both a protective earthing conductor and a line conductor

protective bonding conductor (195-02-10): protective conductor provided for protective-equipotential-bonding

protective earthing conductor (PE) (826-13-23): protective conductor provided for protective earthing

protective-equipotential-bonding (826-13-20): equipotential bonding for the purposes of safety

residual current device (RCD) (442-05-02): mechanical switching device designed to make, carry and break currents under normal service conditions and to cause the opening of the contacts when the residual current attains a given value under specified conditions

residual current monitoring device (RCM) : monitoring device sending an alarm when the residual current attains a given value under specified conditions without interrupting the power supply

IT, TN-C, TN-S, and TT systems (see IEC 60364-1 [2]): The codes used have the following meanings:

First letter – Relationship of the power system to earth:

T = direct connection of one point to earth;

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

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

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

N = direct electrical connection of the exposed-conductive-parts to the earthed point of the power system

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

S = protective function provided by a conductor separate from the neutral conductor or from the earthed line conductor.

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

3.1.2 Other definitions

The following definitions, specific to telecommunication installations and not covered by the IEC 60050 [5], are used within the present document. Correspondence to ITU-T Recommendation K.27 [i.1] and ETSI are indicated where appropriate.

bonding mat: essential means to provide a SRPP by a discernible, nearly regular mesh structure

NOTE: The bonding mat may be located either below or above a collection of equipment constituting a system block.

Bonding Network (BN), (ITU-T Recommendation K.27 [i.1]): set of interconnected conductive structures that provides an "electromagnetic shield" for electronic systems and personnel at frequencies from Direct Current (DC) to low Radio Frequency (RF)

NOTE: The term "electromagnetic shield" denotes any structure used to divert, block or impede the passage of electromagnetic energy. In general, a BN need not be connected to earth but all BNs considered in the present document will have an earth connection.

Common Bonding Network (CBN), (ITU-T Recommendation K.27 [i.1]): principal means for effective bonding and earthing inside a telecommunication building

NOTE: It is the set of metallic components that are intentionally or incidentally interconnected to form the principal BN in a building. These components include: structural steel or reinforcing rods, metallic plumbing, Alternating Current (AC) power conduit, PE conductors, cable racks and bonding conductors. The CBN always has a mesh topology and is connected to the earthing network.

DC return conductor: (L-) conductor of the +400 VDC secondary DC supply and (L+) conductor of the -48 V or -60 V secondary DC supply

NOTE: The DC conductor may or may not be connected to earth.

Isolated Bonding Network (IBN): bonding network that has a single point of connection ("SPC") to either the common bonding network or another isolated bonding network

NOTE: All IBNs considered here will have a connection to earth via the SPC.

ICT equipment: ICT refers to technologies that provide access to information through telecommunications. It is similar to Information Technology (IT), but focuses primarily on communication technologies. This includes the Internet, wireless networks, cell phones, and other communication mediums.

MESHed Bonding Network (MESH-BN), (ITU-T Recommendation K.27 [i.1]): 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

NOTE 1: Consequently, the MESH-BN augments the CBN.

NOTE 2: See Figure 1 of the present document.

MESHed Isolated Bonding Network (MESH-IBN), (ITU-T Recommendation K.27 [i.1]): type of IBN in which the components of the IBN (e.g. equipment frames) are interconnected to form a mesh-like structure

NOTE: This may, for example, be achieved by multiple interconnections between cabinet rows, or by connecting all equipment frames to a metallic grid (a "bonding mat") extending beneath the equipment. The bonding mat is, of course, insulated from the adjacent CBN. If necessary the bonding mat could include vertical extensions, resulting in an approximation to a Faraday cage. The spacing of the grid is chosen according to the frequency range of the electromagnetic environment.

normal service voltage range: range of the steady-state voltage at the A3 interface over which the equipment will maintain normal service

NOTE: A3 as defined in EN 300 132-3-1 [1].

power supply:

- **primary supply:** public mains or, under emergency conditions, a locally generated AC supply
- **secondary supply:** supply to the ICT equipment, racks or system block, derived from the primary supply
- **tertiary supplies:** supplies to the ICT equipment, derived from the secondary supply

system: regularly interacting or interdependent group of items forming a unified whole

system block: functional group of equipment depending in its operation and performance on its connection to the same system reference potential plane, inherent to a MESH-BN

System Reference Potential Plane (SRPP): conductive solid plane, as an ideal goal in potential equalizing, is approached in practice by horizontal or vertical meshes

NOTE 1: The mesh width thereof is adapted to the frequency range to be considered. Horizontal and vertical meshes may be interconnected to form a grid structure approximating to a Faraday cage.

NOTE 2: The SRPP facilitates signalling with reference to a common potential.

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AC	Alternating Current
BN	Bonding Network
BTS	Base Transceiver Station
CB	Circuit Breaker
CBN	Common Bonding Network
CM	Common Mode
DC	Direct Current
DC-C	Common DC return (2-wire)
DC-I	Isolated DC return (3-wire)
EMC	ElectroMagnetic Compatibility
IBN	Isolated Bonding Network
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IMD	Insulation Monitoring Device
IT	See section 3.1.1 IEC Definitions.
ITU-T	International Telecommunication Union-Telecommunication
LPS	Lightning Protection System
M	Mid-point conductor
MESH-BN	MESHed Bonding Network
MESH-IBN	MESHed Isolated Bonding Network
MET	Main Earthing Terminal
MP	Mid-Point
N	Neutral conductor
PE	Protective Earthing conductor
PEL	combined Protective Earthing conductor and Line conductor

PELV	Protective Extra Low Voltage
PEM	combined Protective Earthing conductor and Mid-point conductor
PEN	combined Protective Earthing conductor and Neutral conductor
RCD	Residual Current Device
RCM	Residual Current Monitoring device
RF	Radio Frequency
SELV	Safety Extra Low Voltage
SRPP	System Reference Potential Plane
TN	See section 3.1.1 IEC Definitions
TN-C	See section 3.1.1 IEC Definitions.
TN-S	See section 3.1.1 IEC Definitions.
TT	See section 3.1.1 IEC Definitions.
VAC	Volts Alternating Current
VDC	Volts Direct Current

4 General requirements

The earthing and bonding arrangements for 400 VDC interface A3 (stipulated in EN 300 132-3-1 [1]) treated in the present document are intended to be implemented on new sites as well as on existing sites.

NOTE 1: The interface A3 is equivalent to the interface X in ITU-T Recommendation L.1200 [i.3].

The earthing and bonding arrangements for 400 VDC interface A3 are intended to co-exist with the earthing and bonding arrangements according to EN 300 253 [9] valid for -48 VDC interface A and according to EN 50310 [8] valid for ICT equipment powered by 230 VAC, without any adverse effects on safety and continuity of service.

NOTE 2: If no specific voltage is stated in connection to expressions like "ICT equipment" , "ICT system", etc. in the text below, the normal service voltage range for interface A3 is presumed as defined in EN 300 132-3-1 [1].

4.1 Safety from electrical hazards

IEC 60364 series of standards lay down the rules for the design, erection, and verification of electrical installations. These standards shall be complied with to provide for safety of persons and property against dangers and damage which may arise in the electrical installations and to provide for the proper functioning of those installations.

The installation material involved shall provide sufficiently high voltage, current, temperature ratings according to the relevant safety standards to avoid electric shock, risk of fire, or damage to the equipment under normal or faulty operating conditions within an equipment or the distribution network, or due to the impact of induced voltage and current, e.g. by lightning.

The design of ICT equipment shall meet relevant product standard such as IEC 60950-1 [6] and EN 41003 [10].

- For safety reasons all exposed-conductive-parts (e.g. equipment chassis) of 400 VDC ICT equipment (class I) shall be provided with a protective earthing conductor (PE).

Class II equipment with conductive chassis shall either be galvanically isolated from the chassis of class I equipment or be provided with a protective earthing conductor (PE). For these reasons only ICT equipment of type "class I" are recommended and presumed for the earthing arrangement presented in the present document.

The conductors involved shall provide sufficiently high current conducting capability and low impedance according to the relevant safety standards to avoid electric shock, risk of fire, or damage to the equipment under normal or faulty operating conditions within an equipment or the distribution network, or due to the impact of induced voltage and current, e.g. by lightning. See references IEC 60364-5-54 [4] and EN 50174-2 [12].

4.2 Signal reference

Reliable signal reference shall be provided by a SRPP dedicated at least to a functional unit or a system block. To avoid undue functional distortion or risk of component failure, the SRPP shall provide sufficiently low impedance up to the highest frequency to be regarded by using a metal plane or a meshed configuration having adequate mesh dimensions, e.g. a bonding mat. The frequency band to be covered shall include the spectral components of transients caused by switching, short circuits and atmospheric discharges.

NOTE: Signal reference to the SRPP does not always imply signal return via the SRPP.

4.3 EMC performance

Measures to gain a satisfactory EMC performance shall be assisted by a SRPP. The SRPP shall provide sufficiently low impedance for efficient connection of filters, cabinets and cable shields. The requirement to avoid undue emission of or susceptibility to electromagnetic energy under normal operating conditions may govern the properties of the SRPP ahead of what is required in clause 4.2. The EMC requirements addressed include the discharge of electrostatic energy.

NOTE: Relevant safety standards allow a class I equipment to have Y-capacitors as decoupling capacitance from the line and neutral conductor respectively to exposed conductive parts. Due to this fact class I equipment is normally much easier to comply with the class B EMC requirements. See reference EN 55022 [i.2].

5 Requirements on bonding networks

5.1 Bonding configurations

Bonding configurations can be addressed at a building level (i.e. CBN), at an installation level (i.e. merging of CBN and MESHed Bonding Network (MESH-BN)) and at an equipment level (i.e. MESH-BN).

ITU-T Recommendation K.27 [i.1] deals with bonding configurations of -48 VDC powered telecommunication equipment. Bonding configuration for 400 VDC at equipment, installation and building level shall explicitly be implemented as MESH-BN according to the directives in the present document.

NOTE: Other earthing topologies than MESH-BN are not in the scope of the present document, but are covered in ITU-T Recommendation K.27 [i.1], such as Star-IBN and MESH-IBN, which sometimes are implemented.

5.2 CBN within a building for data and telecom centres

Each building for telecom and data centres shall be provided with a CBN having sufficiently low impedance and high current conducting capability to meet the general requirements of clause 4.

The earthing conductor and the equipotential bonding conductors should be coloured in accordance to international and national regulations.

The main earthing terminal of the CBN shall be extended by a bonding ring conductor along the inside perimeter of the building. As a basic element of the CBN, a ring conductor shall at least comprise the system block by its outer perimeter. An extension of the ICT equipment installation inside a building requires to augment such a minimum CBN version into a three dimensional grid structure, approximating a Faraday cage (see Figure 1). The impact of interfering energy in an exposed location or the need for information security enforces the provision of shielded rooms as a maximum requirement to the CBN.

For further details about earthing and bonding arrangement in buildings refer to the publication IEC 60364-5-54 [4].

Annex A gives information about the implementation principles for the CBN, thereby following ITU-T Recommendation K.27 [i.1], clause 4.2.1.

5.3 BN within a data and telecom centre

Within a system block of ICT equipment and between different system blocks, the BN shall be of the mesh type. The MESH-BN shall provide sufficiently low impedance and high current conducting capability to meet the general requirements in clause 4.

The MESH-BN shall interconnect shelves, cabinets, rack rows, cable racks, ducts, distribution frames, cable shields and bonding mat to constitute the required SRPP.

All metallic parts of the MESH-BN shall form an electrically continuous whole. This does not necessarily require bonding by additional bonding straps, but that improvements should be taken into account when determining the finishes and fastening methods to be used. The mechanical structure comprised by the MESH-BN shall form part of the SRPP.

As an example, Figure 2 addresses interconnections within a system block, essential to a MESH-BN. This example follows the implementation principles for the MESH-BN outlined in ITU-T Recommendation K.27 [i.1], clause 4.2.2.

The cable shields shall be connected to the rack.

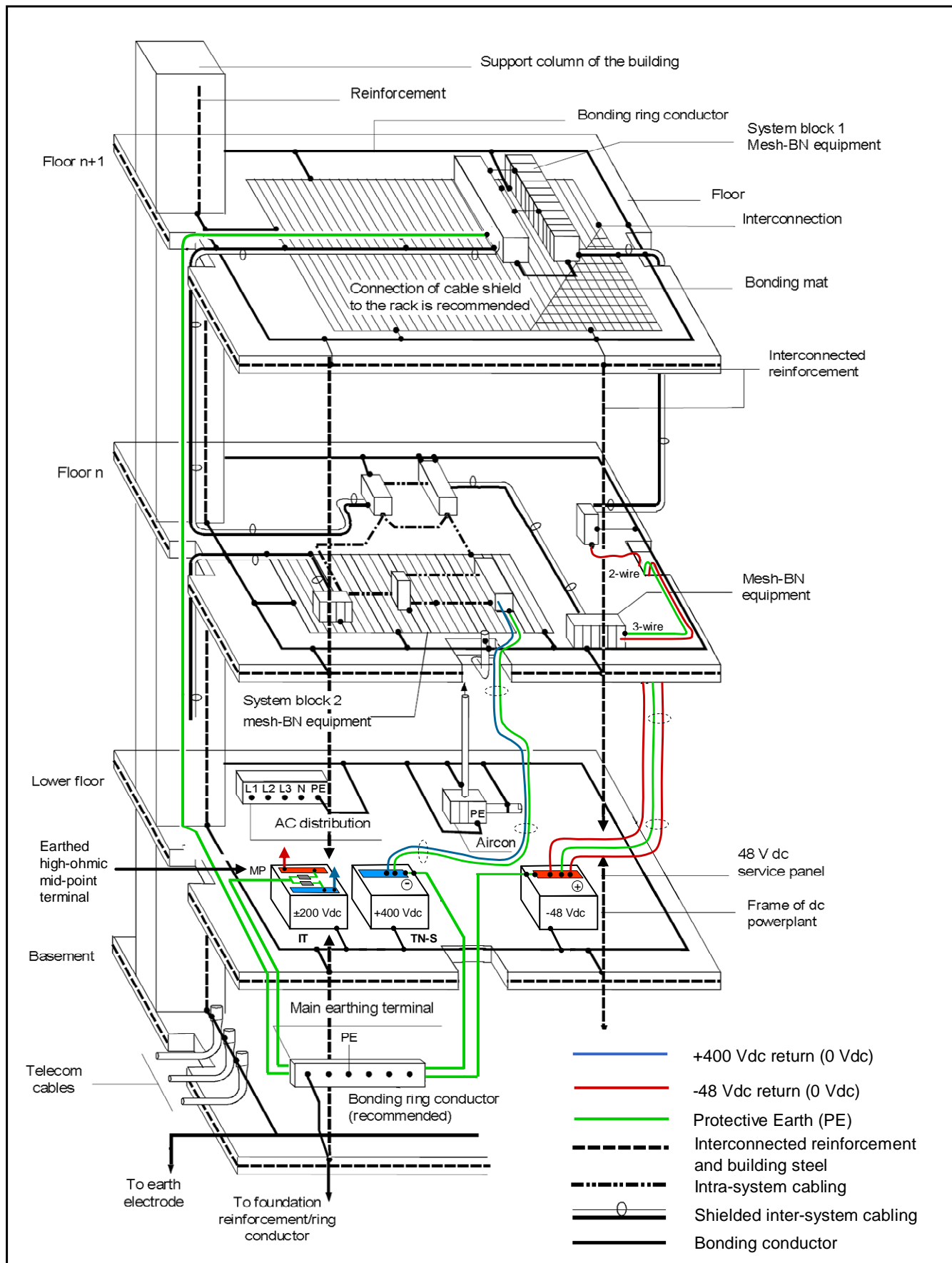


Figure 1: Example of a CBN/MESH-BN installation inside a telecommunication building

5.4 Merging of CBN and MESH-BNs

All BNs of ICT systems and their associated protective earthing conductors shall be connected to the CBN.

The MESH-BN shall augment the CBN including the main earthing terminal by multiple interconnections to the CBN (see Figure 1).

5.5 Cabling within and between BNs

Power distribution cables and signal cables within and between MESH-BNs shall be run tightly along the members of the augmented CBN.

There shall be a separation distance of at least 100 mm between groups of AC mains cables and groups of signal cables on one and the same cable rack, unless adequate shielding is provided.

Cable shields shall be bonded directly to racks, cabinets or to the dedicated SRPP at least at each end. Circumferential connections are most effective and therefore are recommended.

NOTE: It is recognized that where a new system has to be cabled to existing equipment, it has previously been considered feasible to avoid the connection of cable shields at the existing equipment end. However, the consequent solution of the present document is to provide a lower impedance path via improved bonding between the equipment locations, thereby enabling connection of cable shields at least at each end.

6 Requirements for power distribution

6.1 DC power distribution of secondary supply

6.1.1 General

The DC power distribution shall route line conductors close together. Live parts, including each line conductor (L+ and L-) shall be completely covered with insulation which can only be removed by destruction. The insulation is intended to prevent contact with live parts.

The laying of the DC power distribution shall comply with relevant installation standards concerning voltage rating, ambient temperature and current carrying capacity of the cables.

The ICT equipment, the insulation shall comply with the relevant product standard.

Exposed-conductive-parts shall be connected to a protective earthing conductor (PE) under the specific conditions for each type of system earthing as specified below in Figure 1.

The line conductor and the protective earthing conductor shall be capable of carrying over-currents in the case of a fault between a line conductor of the 400 VDC secondary supply and the MESH-BN. See IEC 60364-5-54 [4].

Simultaneously accessible exposed-conductive-parts shall be collectively earthed to the same earthing system of which the MESH-BN is an integral part.

The maximum DC voltage drop along each dedicated DC power return conductor for -48 VDC arrangements shall be designed to be less than 1 V. The calculation shall take into account the maximum load current on the associated supply conductor at maximum or minimum source voltage respectively under normal operating conditions.

NOTE: One concern of this requirement is to avoid electrochemical corrosion by stray currents. See EN 50162 [13].

6.1.2 System earthing arrangement

The definitions used in this clause are based on IEC 60364-1 [2].

The DC power distribution of the secondary supply serving the ICT system shall conform to the requirements of the IT or TN-S system.

6.1.2.1 IT system with earthed high-ohmic mid-point (MP) terminal

Figure 3 shows a preferred symmetrical IT system earthing arrangement for 400 VDC. This arrangement is based on the IT system earthing type 2 according to IEC 60364-1 [2] (see Figure E.2 in Annex E) but modified for adaptation to one 400 V power source instead of a series connection of two 200 V power sources.

The high-ohmic mid-point terminal (MP) of the power plant powering the ICT equipment shall be connected to the Main Earthing Terminal (MET).

The high-ohmic mid-point terminal (MP) is the common point between two symmetrical high-ohmic resistors (typically $> 50 \text{ k}\Omega$) whose opposite ends are electrically connected to the different line conductors (L+ and L-) of the same circuit.

In cases where an IT system is used for reasons of continuity of supply, automatic disconnection is not usually required on the occurrence of a first fault (single fault) to an exposed-conductive-part or to earth. This is valid on condition that an Insulation Monitoring Device (IMD) or a Residual Current Monitoring device (RCM) indicates the first fault by an audible and/or visual signal which shall continue as long as the fault persists. See further requirements in Annex B.

After the occurrence of a first fault, conditions for automatic disconnection of supply in the event of a second fault occurring on a different live conductor shall be as stipulated in normative clause B.1.2.

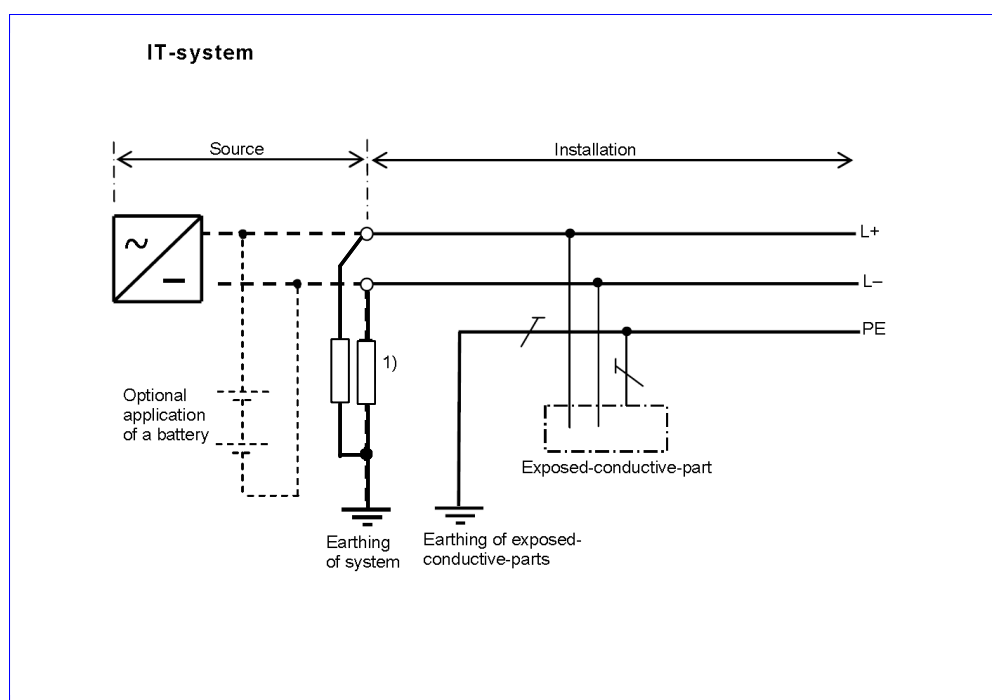


Figure 2: IT system with earthed high-ohmic mid-point terminal (MP)

Figure 3 illustrates an implementation of "IT system with earthed high-ohmic mid-point terminal (MP)" from the power source via the cable system to the ICT equipment. The main Earthing Terminal (MET) is the common earthing point for the high-ohmic mid-point (MP) of the source as well as for the protective earthing conductor (PE).

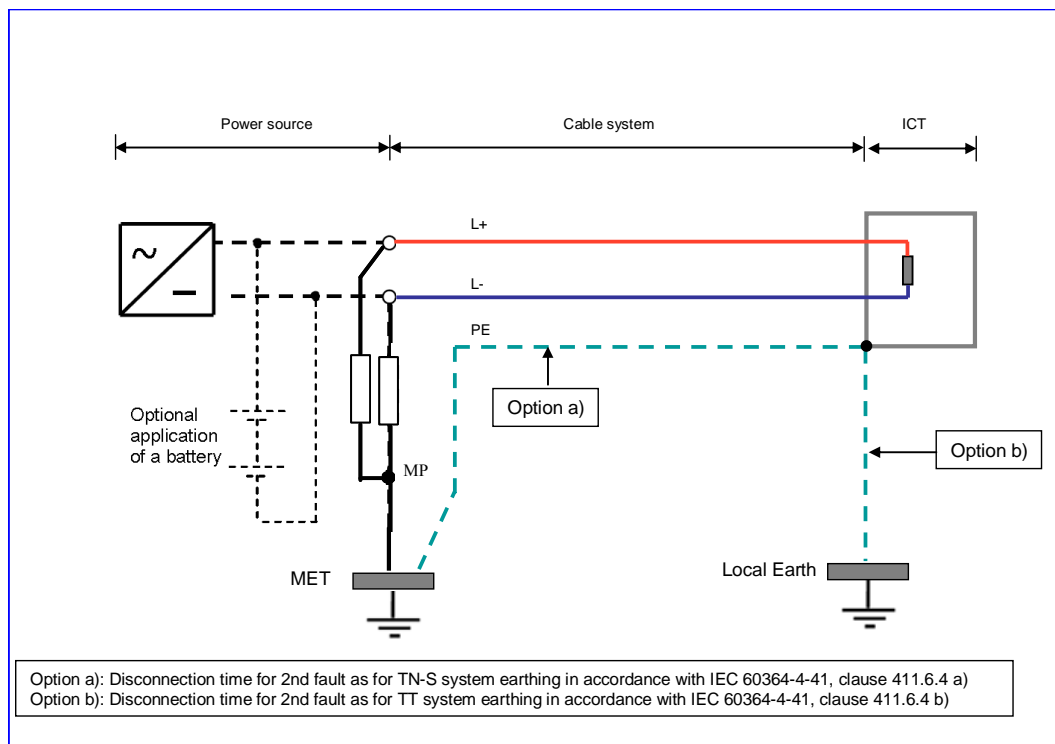


Figure 3: Implementation of IT system with earthed high-ohmic mid-point (MP) terminal

6.1.2.2 TN-S system with earthed negative line terminal (L-)

Figure 4 shows a possible system earthing arrangements (TN-S) for 400 VDC according to IEC 60364-1 [2].

The negative line terminals (L-) of the power plant powering the ICT equipment shall be connected to the Main Earthing Terminal (MET).

The earthed line conductors (L-) shall be separated from the PE-conductor throughout the installation.

In TN-S system earthing a protective device shall automatically interrupt the supply to the line conductor of a circuit or equipment in the event of a fault of negligible impedance between the line conductor and an exposed-conductive-part within the disconnection time required. See clause B.1.1.

Annex A gives information about necessary agreements if DC return-conductors of a single equipment group are not integrated into the merged CBN/MESH-BN.

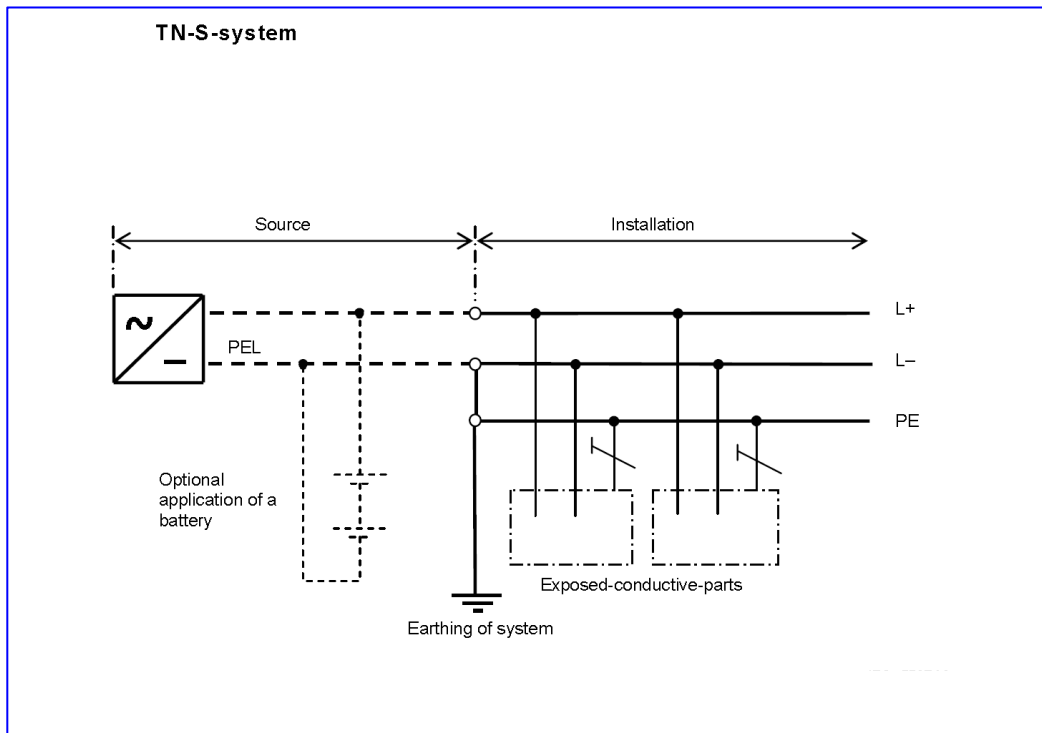


Figure 4: TN-S system with earthed negative line terminal (L-)

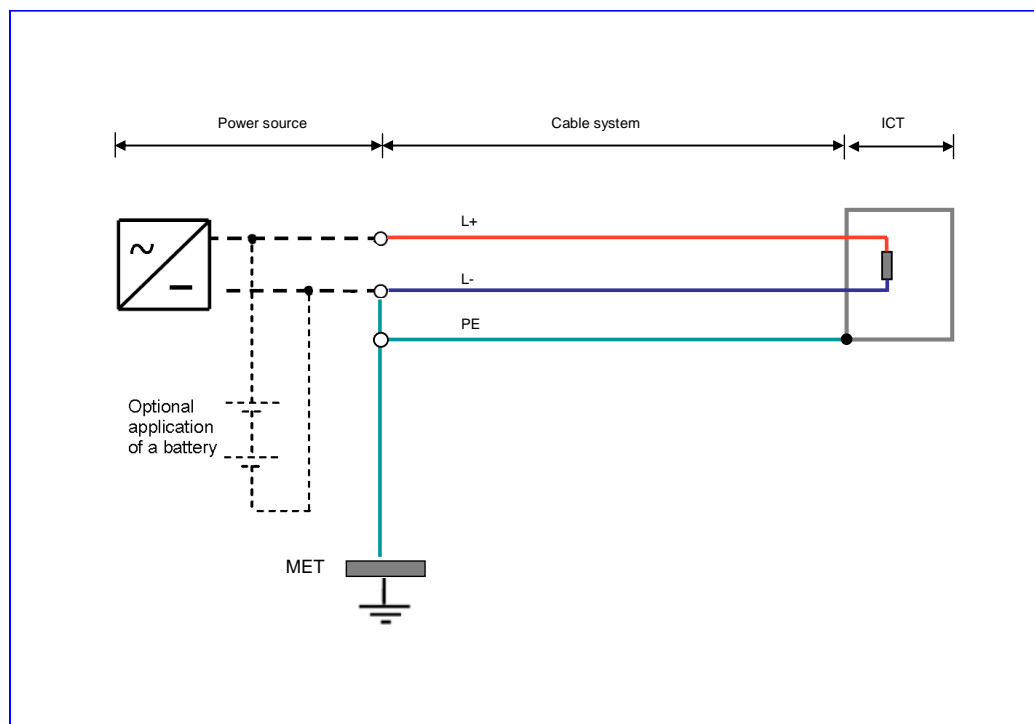


Figure 5: Implementation of TN-S system with earthed negative line terminal (L-)

6.2 DC power distribution of tertiary supplies

The reference potential terminal of tertiary power supplies shall be connected to the MESH-BN.

6.3 AC mains distribution and bonding of the protective conductor

The definitions used in this clause are based on IEC 60364-4-41 [3].

The AC power distribution inside a telecommunication building shall conform to the requirements of the TN-S system. This requires that there shall be no PEN conductor within the building. This is a pre-condition to the requirements in clause 5 of the present document.

6.4 AC power distribution from tertiary power supply

The neutral point of a tertiary AC power supply (inverter) shall be derived by bonding the terminal of the star point (3-phase), or of an outer conductor (single phase) respectively, to the MESH-BN at the source only. The distribution to the assigned loads shall follow the rules of the TN-S system.

If different configurations resembling an IT system, powered by tertiary AC power supply, have to be used (e.g. to provide remote feeding or the uninterruptible power supply of a sub-arrangement), the appropriate safety precautions shall be implemented without degrading the effectiveness of the general requirements in clause 4.

See Annex E for further details about AC mains distribution and bonding of the protective conductor.

Annex A (normative): Rationale about CBN co-ordination

In the case of a telecommunication centre there are two main subjects needing co-ordination with respect to EMC:

- the building and its related ordinary installations;
- the telecommunication equipment and its interconnection.

New buildings shall provide adequate preconditions constituting a CBN by:

- a reliable foundation earth electrode system, i.e. a ring conductor immediately beneath the first concrete bed;

NOTE: This electrode system qualifies prior to a ring conductor along the outer perimeter of a building.

- welded joints of building steel or concrete reinforcement rods (see IEC 62305-series [7]) and a sufficient number of access terminals to these highly conductive elements;
- an enhanced outdoor Lightning Protection System (LPS) co-ordinated with the building structure (see IEC 62305-series [7]);
- service pipes and air-conditioning ducts interconnected according to the CBN strategy, including potential equalization in excess of safety regulations;
- mains power supply installation as required for the TN-S principle, i.e. without any PEN section downstream from the main earthing terminal and regardless of the principle applied to the mains distribution section upstream.

Telecommunication equipment which is designed to the present document can be installed and interconnected to the CBN outlined above. The resulting MESH-BN (see Figure 1) should easily conform to EMC requirements.

Some existing buildings of telecommunication centres do not provide a CBN sufficient to meet the operational requirements. When a decision is made to extend or replace existing telecommunication installations in such buildings, the objective should be to move towards a CBN by enhancements.

Besides the fact that such enhancements require consultation on the spot, two subjects can be addressed in general:

- outdoor lightning protection shall be installed according to IEC 62305-series [7] including a ring conductor as an essential member of the earthing network. The LPS may be improved with conductive roof layers, closely spaced down conductors or application of metallic facades;
- unacceptable interference from the outdoor power distribution section can be mitigated by a separation transformer dedicated to the building or by an equivalent measure. An indoor installation according to the rules of the IT system or TT system can be upgraded by additional PE conductors and dedicated equipotential bonding conductors, thereby reducing the mesh width. A residual current protection may also be adapted if necessary.

An existing CBN can be augmented by the telecommunication installation regarding dedicated ring conductors per room and floor, cable ducts/troughs/racks and any other supporting metal work. In contrast to the traditional practice to indulge into a restricted number of conductors with enlarged cross sectional area, it is recommended to aim at a large conductive surface, e.g. by providing bonding at both side bars, at joints within the run of a ladder type cable rack.

As outlined above, co-ordination resulting in an overall CBN/MESH-BN is recommended even in existing telecommunication centres. Installation of new equipment with deviation into the Meshed Isolated Bonding Network (MESH-IBN), as defined in ITU-T Recommendation K.27 [i.1] and depicted in Figure B-2 of ITU-T Recommendation K.27 [i.1], is considered appropriate in exceptional situations only, such as a deficiency of an adequate lightning protection of the building, or a CBN with an interfering PEN section, or incompatibility with already installed telecommunication equipment.

Nevertheless, a MESH-IBN type installation according to ITU-T Recommendation K.27 [i.1] needs co-ordination concerning the routing of cables and the bonding of their shields. In addition, maintenance procedures have to be extended to isolation inspection or monitoring.

Annex B (normative): Requirements for fault protection

The requirements used in this annex are based on IEC 60364-4-41 [3].

B.1 Protective earthing

B.1.1 TN and TT System Earthing

Table B.1

	Final circuits < 32 A Max disconnection time ¹⁾ 400Vdc	Other circuits ²⁾ Max disconnection time ¹⁾ 400Vdc
TN	400 ms	5 s
TT ³⁾	200 ms	1 s

¹⁾ Disconnection is permitted either by OCP or RCD

²⁾ Distribution circuits and circuits not covered by 411.3.2.2

Note this also includes final circuits > 32 A

³⁾ For final circuits < 32 A: Where in TT systems the disconnection is achieved by an overcurrent protective device and the protective equipotential bonding is connected with all extraneous-conductive-parts within the installation, the maximum disconnection times applicable to TN systems may be used.

NOTE 1: The disconnection may be provided by a overcurrent protection device (CB, fuse etc.) or an RCD.

NOTE 2: Final circuits < 32 A refers to a final circuit with a maximum load current of 32 A.

B.1.2 IT System Earthing

B.1.2.1 First fault on one of the live conductors

For IT systems, automatic disconnection is not usually required on the occurrence of a first fault.

In cases where an IT system is used for reasons of continuity of supply, an insulation monitoring device shall be provided to indicate the occurrence of a first fault from a live part to exposed-conductive-parts or to earth. This device shall initiate an audible and/or visual signal which shall continue as long as the fault persists.

NOTE: It is highly recommended that a first fault be eliminated with the shortest practicable delay. In large installation with many power link covered by the same earth fault detector, it is highly recommended to use an automatic detection system to discriminate the power line where is the fault.

Automatic disconnection with the maximum disconnection times according to Table B.1 is not imperative provided that the following condition is fulfilled:

- in DC systems $R_A \times I_d \leq 120 \text{ V}$ (see chapter 411.6.2 of IEC 60364-4-41 [3]).

where:

R_A is the sum of the resistance in Ω of the earth electrode and protective conductor for the exposed-conductive-parts;

I_d is the fault current in A of the first fault of negligible impedance between a line conductor and an exposed-conductive-part. The value of I_d takes account of leakage currents and the total earthing impedance of the electrical installation.

B.1.2.2 Second fault on a different live conductor

After the occurrence of a first fault, conditions for automatic disconnection of supply in the event of a second fault occurring on a different live conductor shall be as follows:

- a) Where exposed-conductive-parts are interconnected by a protective earthing conductor collectively earthed to the same earthing system, the conditions similar to a TN system apply and the following conditions shall be fulfilled where the neutral conductor is not distributed in AC systems and in DC systems where the mid-point conductor is not distributed:

$$2 \times I_a \times Z_s \leq U$$

or where the neutral conductor or mid-point conductor respectively is distributed:

$$2 \times I_a \times Z'_s \leq U_0$$

where:

U_0 is the nominal AC or DC voltage, in V, between line conductor and neutral conductor or mid-point conductor, as appropriate;

U is the nominal AC or DC voltage in V between line conductors;

Z_s is the impedance in Ω of the fault loop comprising the line conductor and the protective conductor of the circuit;

Z'_s is the impedance in Ω of the fault loop comprising the neutral conductor and the protective conductor of the circuit;

I_a is the current in A causing operation of the protective device within the time required in the table above.

NOTE 1: The time stated in Table 41.1 of 411.3.2.2 IEC 60364-4-41 [3] for the TN system is applicable to IT systems with a distributed or non-distributed neutral conductor or mid-point conductor.

NOTE 2: The factor 2 in both formulas takes into account that in the event of the simultaneous occurrence of two faults, the faults may exist in different circuits.

NOTE 3: For fault loop impedance, the most severe case should be taken into account, e.g. a fault on the line conductor at the source and simultaneously another fault on the neutral conductor of a current-using equipment of the circuit considered.

- b) Where the exposed-conductive-parts are earthed in groups or individually, the following condition applies:

$$R_A \times I_a \leq 50 \text{ V}$$

where:

R_A is the sum of the resistances of the earth electrode and the protective conductor to the exposed-conductive-parts;

I_a is the current causing automatic disconnection of the disconnection device in a time complying to that for TT systems in Table 41.1 of 411.3.2.2 or in a time complying to 411.3.2.4 of IEC 60364-4-41 [3].

NOTE 4: If compliance to the requirements of b) is provided by a residual current protective device (RCD) compliance with the disconnection times required for TT systems in Table 41.1 may require residual currents significantly higher than the rated residual operating current $I_{\Delta n}$ of the RCD applied (typically 5 $I_{\Delta n}$).

B.2 Protective equipotential bonding

In each building the earthing conductor, the main earthing terminal and the following conductive parts shall be connected to the protective equipotential bonding:

- a) metallic pipes supplying services into the building, e.g. gas, water;
- b) structural extraneous-conductive-parts if accessible in normal use, metallic central heating and air-conditioning systems;
- c) metallic reinforcements of constructional reinforced concrete, if reasonably practicable.

Annex C (informative): Coexistence of -48 VDC/-60 VDC DC-C (2-wire) and 400 VDC class I equipment in MESH-BN

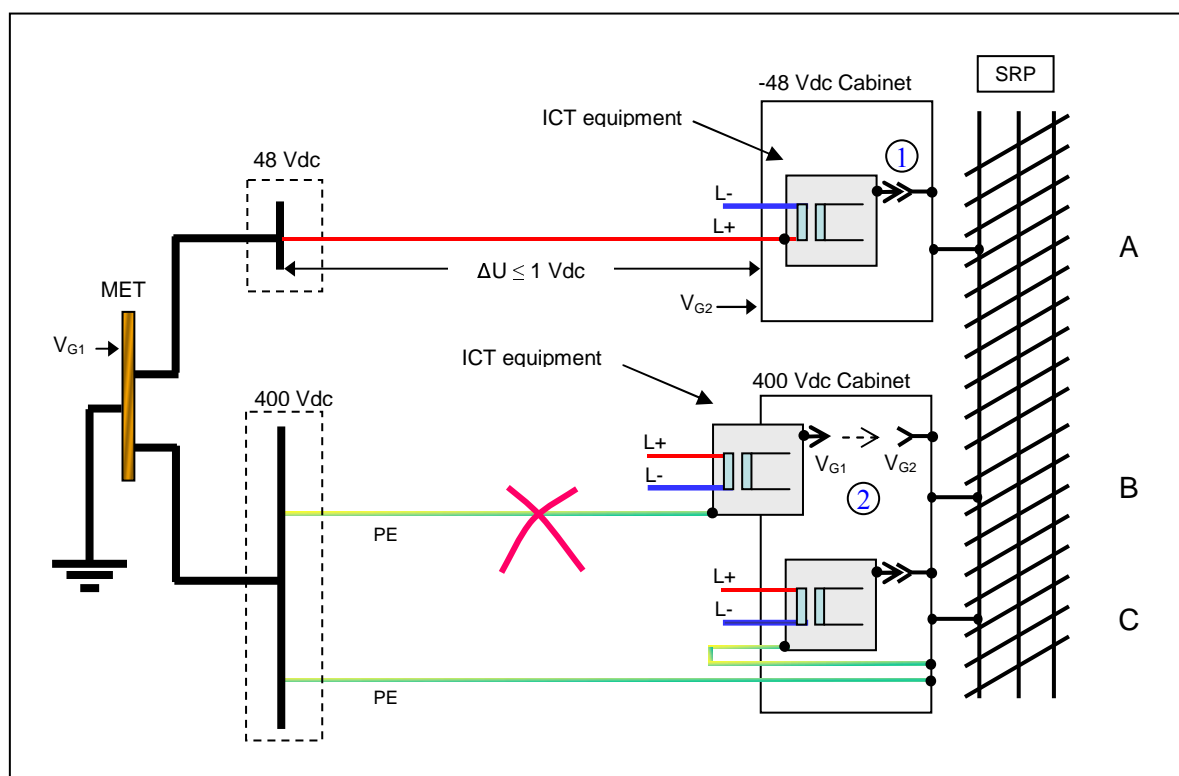
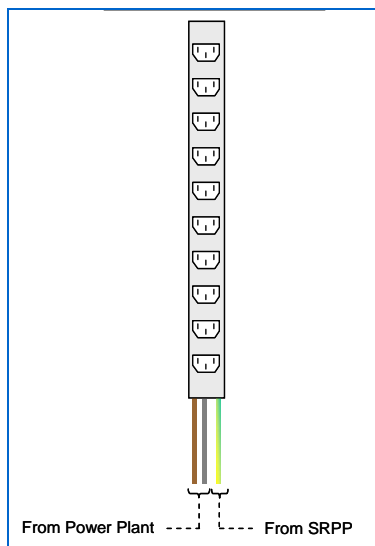


Figure C.1: Risk of electric sparks at coexistence of -48 VDC DC-C (2-wire) and 400 VDC class I (IT and TN-S) in MESH-BN

- 1) Both the -48 VDC cabinet and the 400 VDC cabinet are presumed to be interconnected with the SRPP.
- 2) ① symbolizes the intentional interconnection between the equipment chassis and the cabinet of a fully inserted ICT equipment.
- 3) ② symbolizes an ICT equipment which is about to be plugged-in into cabinet. Notice the voltage potential V_{G1} of the equipment chassis (same as the voltage potential of the MET) and the voltage potential V_{G2} of the cabinet due to the voltage drop along the -48 V return-conductors.
Alt A: The existing DC-C (2-wire) -48 VDC installation gives rise to a voltage drop U along positive return conductors.
Alt B: Risk of electric sparks when replacing unit and/or unplug/plug power connector due to difference in voltage potential.
- 4) **Alt C:** Eliminates the risk of electric sparks due to difference in voltage potential by letting the PE conductor have reference to the SRPP (V_{G2}) instead of the MET (V_{G1})
 Figure C.2 below shows an example of such an implementation.

NOTE: The risk of sparks (between V_{G1} and V_{G2} in Figure C.1) is more or less eliminated applying DC-I (3-wire) -48 VDC power arrangements.



**Figure C.2: Example of connector interface for Alt C:
Multi-way plug & socket**

Annex D (informative): Conductor arrangement and system earthing

TN-S, TT and IT system earthing arrangements are acknowledged by IEC and are fully compliant with all relevant safety standards. For convenience these arrangements are extracted from IEC 60364-1 [2] and reproduced in this annex.

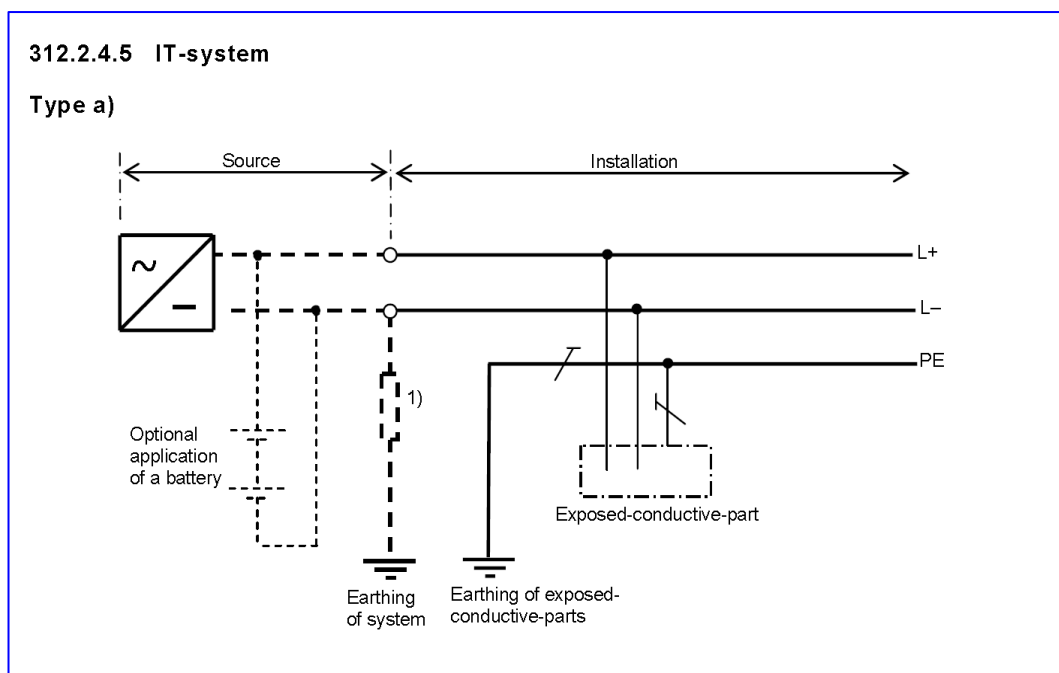


Figure D.1: IT System Earthing, type a)

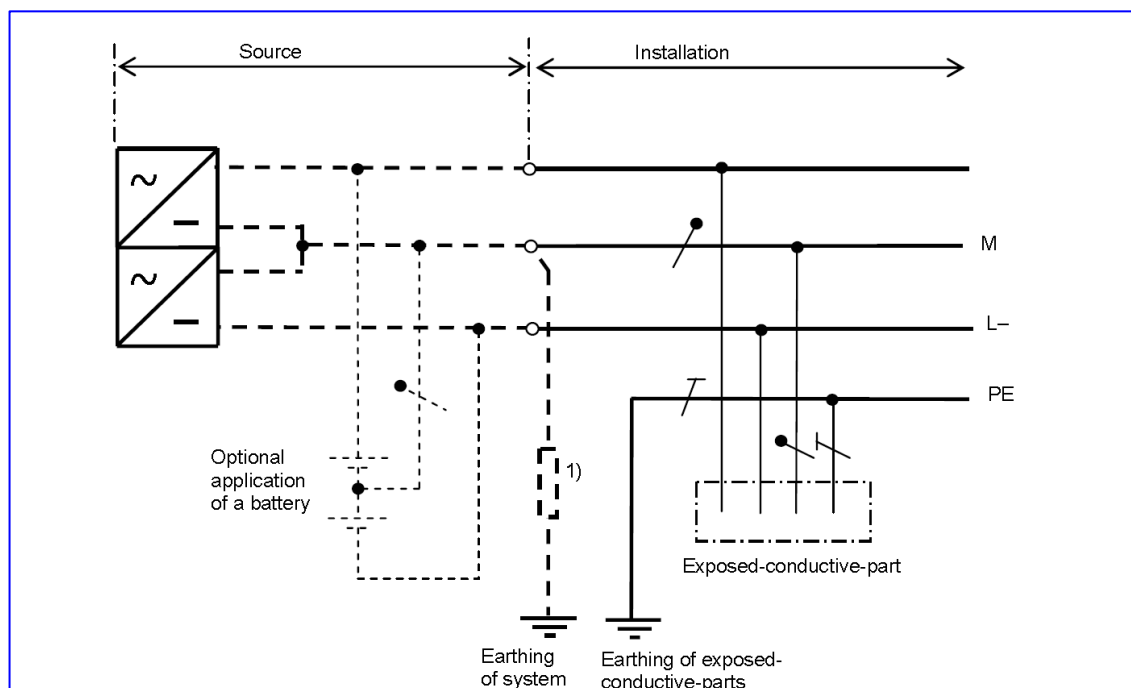


Figure D.2: IT System Earthing, type b)

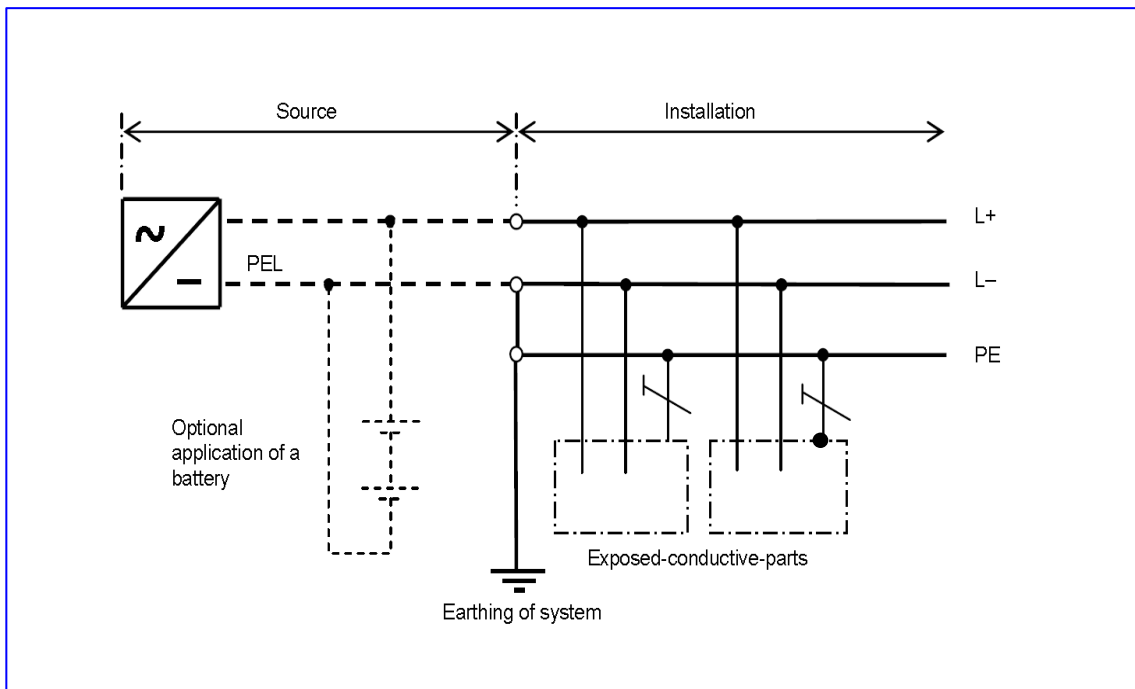


Figure D.3: TN-S System Earthing, type a)

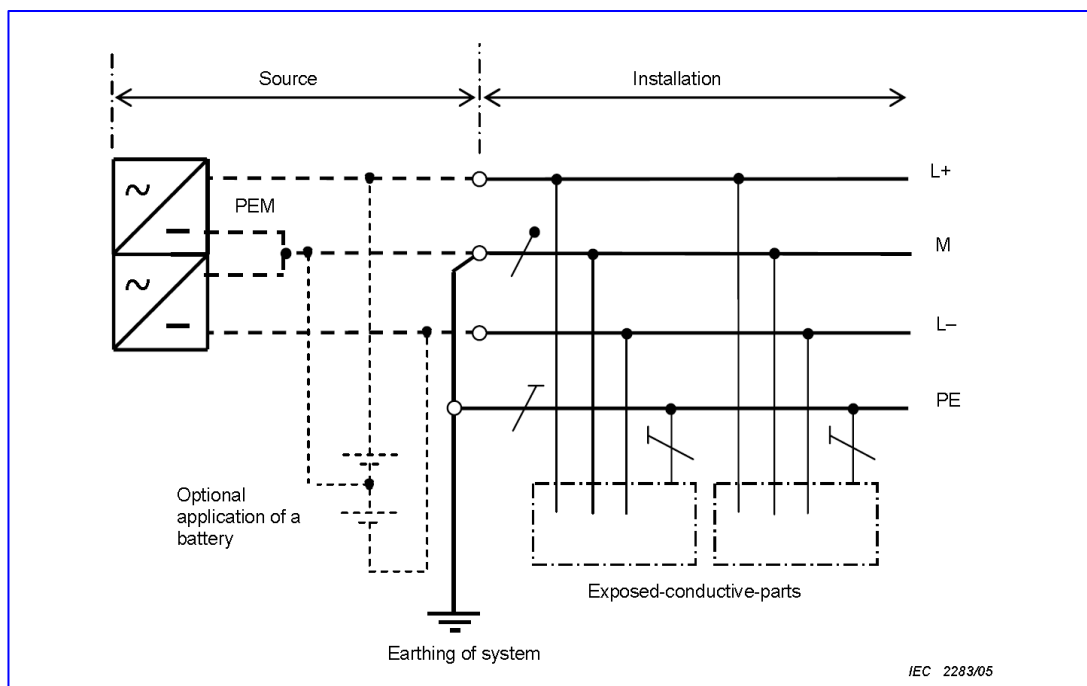


Figure D.4: TN-S System Earthing, type b)

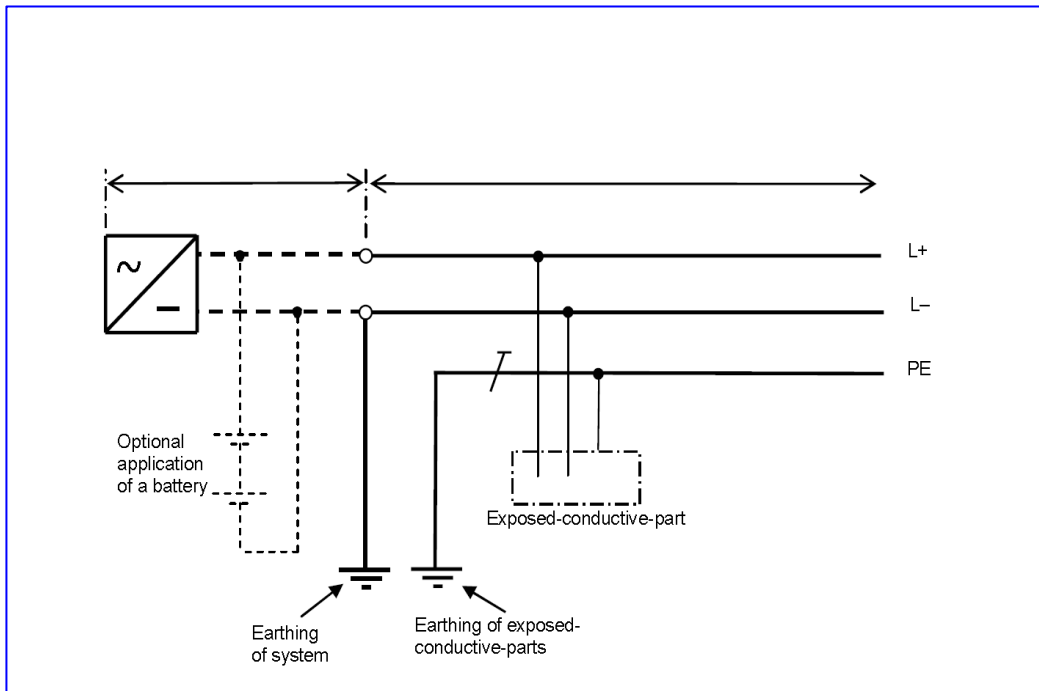


Figure D.5: TT System Earthing, type a)

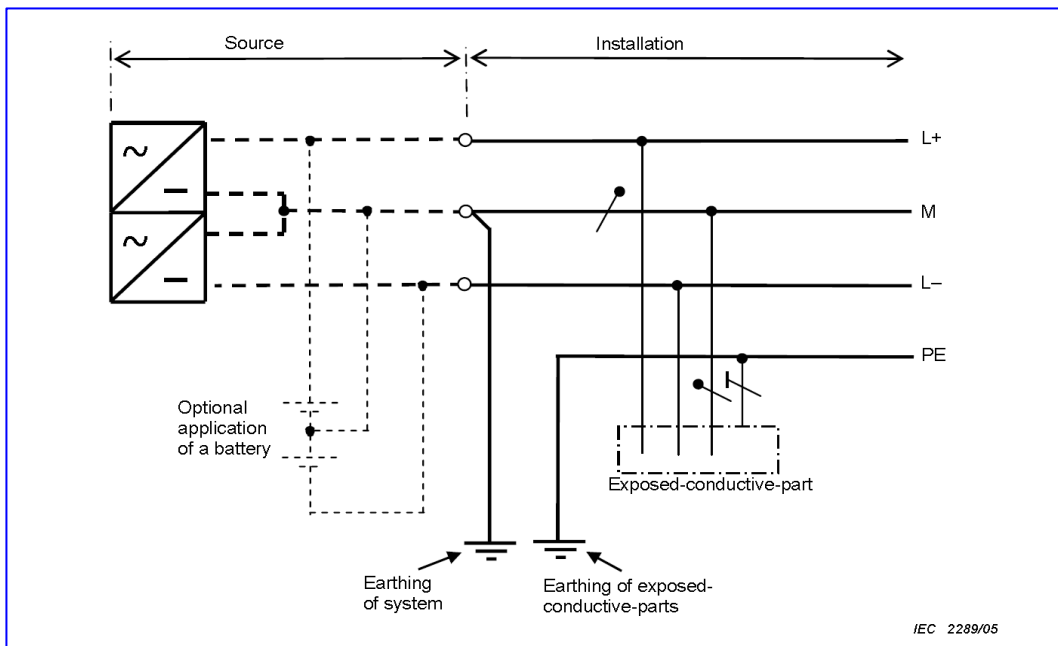


Figure D.6: TT System Earthing, type b)

D.1 General remarks

System grounding is about controlling the current to earth, or ground, within predictable limits.

Empirical data indicates that most of all electrical interruptions are caused by unintentional connection between line conductors and ground (ground fault).

The root cause of connection between line conductors and ground is often a result of an insulation breakdown.

TN-S and TT types of 400 VDC system earthing represent solidly grounded system. However TT system can be disregarded as a concept in 400 VDC since PE arrangement between 400 VDC source and ICT equipment can be managed within the installation at data centres and telecommunication centres. Connection of system conductor to ground in solidly grounded system generates high magnitude of ground-fault current that has to be interrupted within specified time limit (see Table B.1) by protective device to avoid electric shock hazard and risk of fire. The destructive nature of arcing ground faults in solidly grounded systems is well known and is caused by the energy dissipated in the fault. On the other hand TN-S system earthing is simple in its architecture.

The high resistance between each of the line conductors and earth in symmetrical high ohmic mid-point grounded IT system can limit the ground fault current to a harmless level < 25 mA, i.e. below "curve a" beyond which startle reaction of current becomes possible for a hand-to-hand current path and medium contact area during dry condition according to Figure 21 in IEC/TR 60479-5 [11]. By limiting the ground fault current, the fault can be tolerated on the system until it can be located, and then isolated or removed at a convenient time. High resistance mid-point grounding provides symmetry in IT system earthing that reduces EMC interference and brings the operating voltage magnitude to 50 % of the system operating voltage.

The IT system offers increased continuity of service since automatic disconnection is not usually required on the occurrence of a first fault.

D.2 Ease of ground fault detection with high ohmic mid-point

The following clause describes the rationale for modifying the original *asymmetrical* IT system earthing arrangement in accordance with IEC 60364-1 [2] to a *symmetrical* IT system earthing arrangement.

D.2.1 IT system with (L-) grounded via high impedance

During normal service:

- $L+ / L- = +400 \text{ V} / \approx 0 \text{ V}$ system voltages with reference to ground (1)

NOTE: $\approx 0 \text{ V}$ since close to 0 V via a high-ohmic resistance to ground.

Possible ground faults:

- $L+$ (+400 V) short-circuited to ground (2)
- $L-$ (0 V) short-circuited to ground. (3)

Characteristics during a fault condition (single fault):

- $L+ = +400 \text{ V}$ and $L- = 0 \text{ V}$ system voltage with reference to ground (consequence of (3) above) (4)
- $L- = -400 \text{ V}$ and $L+ = 0 \text{ V}$ system voltage with reference to ground (consequence of (2) above) (5)

At a single fault the operation of the system is not interrupted.

Ground fault detection by asymmetrical supervision:

- Very hard to detect the difference of a correct $L- \approx 0 \text{ V}$ (via high-ohmic resistance) (see (1) above) and a real ground fault $L- = 0 \text{ V}$ due to a short-circuit. (see (3) above).

EMC performance:

- Asymmetrical currents may give rise to difficulties with Common Mode (CM)-chokes in rfi-filters.

D.2.2 IT system with earthed high-ohmic mid-point (MP) terminal

During normal service:

- $L+ / L- = \pm 200 \text{ V}$ system voltages with reference to ground (6)

Possible ground faults:

- $L+ (+200 \text{ V})$ short-circuited to ground (7)

- $L- (-200 \text{ V})$ short-circuited to ground (8)

At a single fault the operation of the system is not interrupted.

Characteristics during a fault condition (single fault):

- $L+ = +400 \text{ V}$ and $L- = 0 \text{ V}$ system voltage with reference to ground (consequence of (8) above) (9)

- $L- = -400 \text{ V}$ and $L+ = 0 \text{ V}$ system voltage with reference to ground (consequence of (7) above) (10)

Ground fault detection by symmetrical supervision:

- Much simpler to detect ground fault by supervising the mid-point and the $\pm 200 \text{ V}$ symmetry of the system voltage.

EMC performance:

- Symmetrical currents eliminate difficulties with Common Mode (CM)-chokes in rfi-filters.

D.3 Impact on body current due to a large number of loads

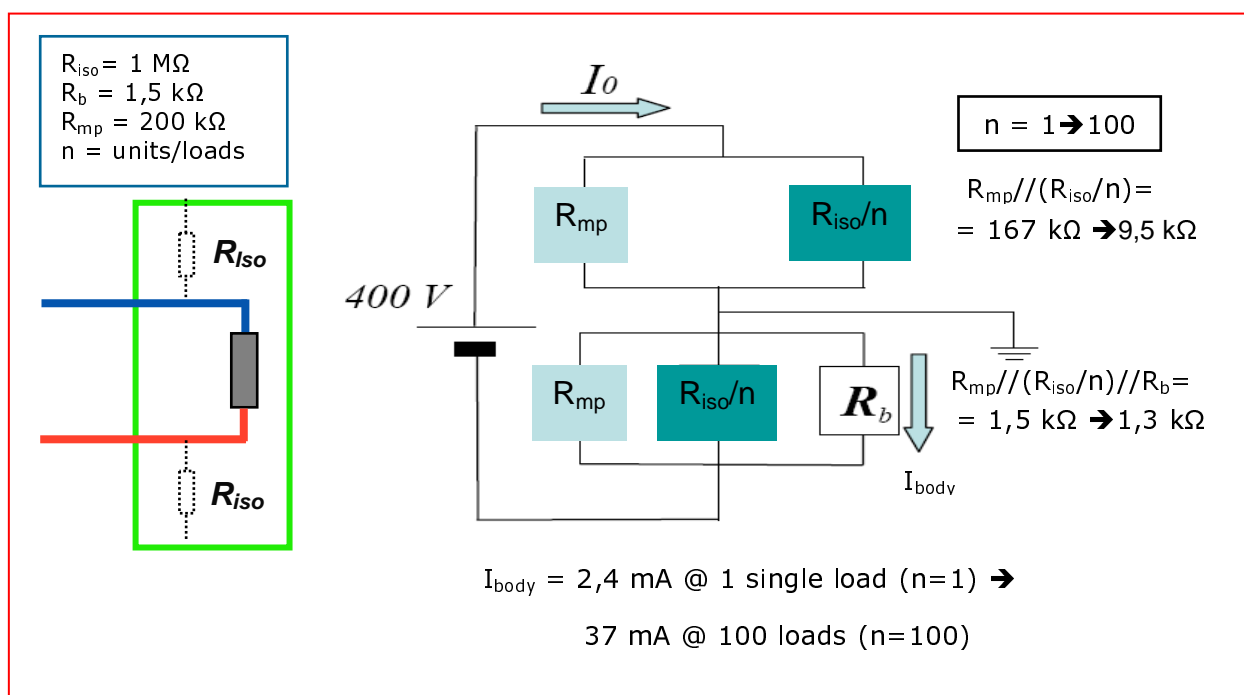


Figure D.7: Conditions for calculating the body current

Figure D.7 shows the impact on the body current I_{body} through a human being have a body resistance $R_b = 1,5 \text{ k}\Omega$ as a function of the number of loads ($n = 1$ to 100), each having insulation between live parts and accessible conductive parts corresponding to a isolation resistance of $R_{\text{iso}} = 1 \text{ M}\Omega$. Each one of the live conductors $L+ / L- (\pm 200 \text{ V})$ are presumed to be connected to ground at the output of the power source by a mid-point resistor $R_{\text{mp}} = 200 \text{ k}\Omega$.

The following values of the body current can be calculated as a function of the number of loads:

- A single load ($n=1$) gives a body current $I_{\text{body}} = 2,4 \text{ mA}$
- At one hundred loads ($n=100$) the give the body current has increased to $I_{\text{body}} = 37 \text{ mA}$

The calculation above and the figure presume "IT system with earthed high-ohmic mid-point terminal" but about the same effects are obtained for "IT system with (L-) grounded via high impedance" and "TN-S system with earthed negative line terminal (L-)".

NOTE 1: The body current refers to the current from one hand of a human being touching the (unisolated) live conductor (+200 V or -200 V) via the feet to ground.

NOTE 2: The specific value of the body resistance may vary from case to case depending which path the current will flow through the body, the environment (wet or dry), etc.

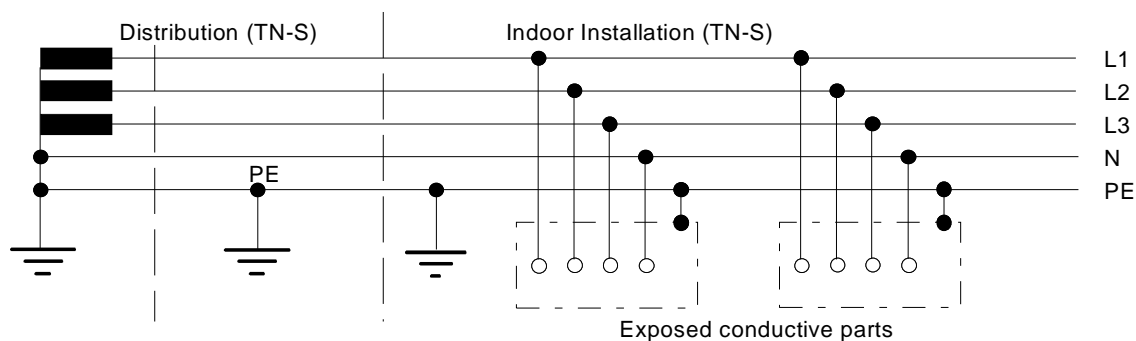
NOTE 3: The values of R_{iso} and R_{mp} in the calculation above are only presumed to show the effect of an increasing number of loads. In an actual installation R_{iso} may be much higher and R_{mp} much lower. The worst-case combination of $R_{\text{iso}} = 1 - 10 \text{ M}\Omega$ and $R_{\text{mp}} = 20 - 200 \text{ k}\Omega$ for $n=100$ would result in a body current in the range $I_b = 5 - 40 \text{ mA}$.

Annex E (normative): AC mains distribution and bonding of the protective conductor

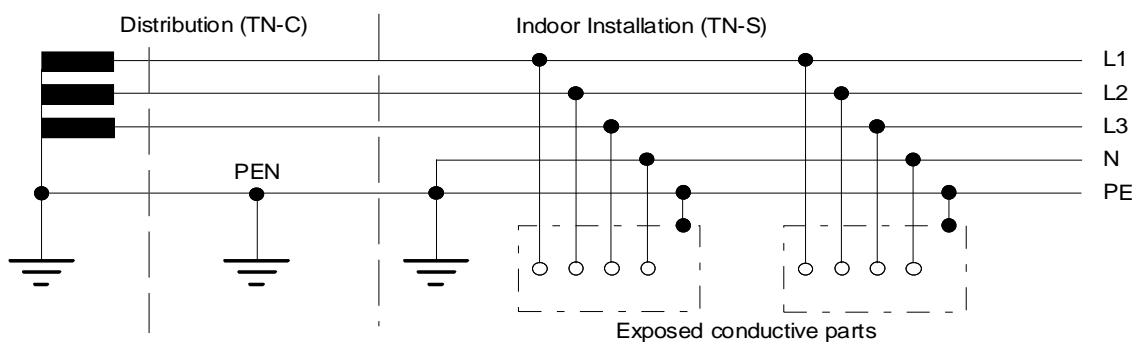
Depending on the outdoor mains distribution network serving a telecommunication building, one of the following requirements shall apply:

- a) service by a TN-S section of the outdoor distribution network:
solely the protective conductor (PE) shall be connected to the main earthing terminal (see Figure E.1, structure 1 and Figure E.2, mode 1);
- b) service by a TN-C section of the outdoor distribution network:
 - 1) the PEN conductor shall be connected to the main earthing terminal only;
 - 2) from the main earthing terminal to and within the consumer locations inside the building the Neutral conductor (N) shall be treated as a live conductor;
 - 3) a dedicated PE shall be provided (see Figure E.1, structure 2 and Figure E.2, mode 2);
- c) service by a TT section of the outdoor distribution network:
 - 1) the PE shall be derived via the main earthing terminal from the earthing network (see Figure E.1, structure 3 and Figure E.2, mode 3);
 - 2) the dimensioning of the PE shall follow the rules of the TN-S system;
- d) service by an IT section of the outdoor distribution network:
indoor installation related to earthing and bonding shall follow the instructions set up for the service by a TT section of the outdoor distribution network.

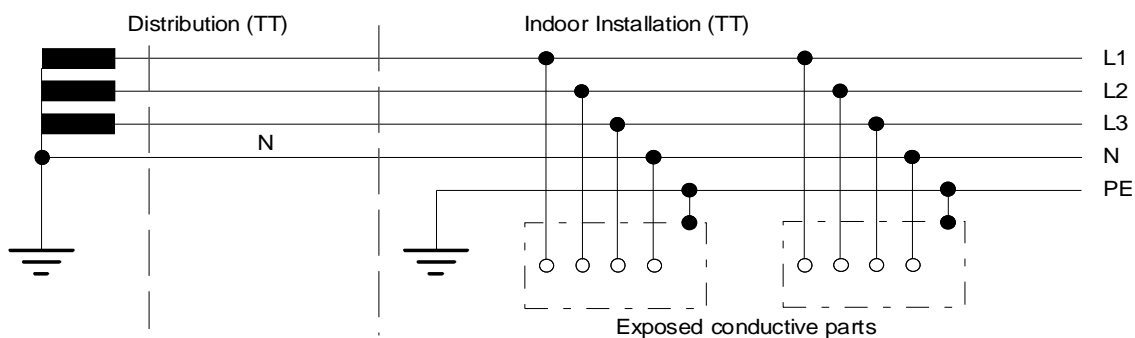
NOTE: Public service by an IT section of the outdoor distribution network is known as a special national condition. As the IT system is liable to deteriorate into a TT system, reference is given in the present document to that related section. For information regarding unacceptable interference by an IT system, see Annex A.

Structure 1

- origin of PE at the main earthing terminal of the power source;
- PE is intentionally earthed intermediately in the distribution and at each main earthing terminal;
- N and PE are separated throughout the distribution, the indoor installation and within each equipment.

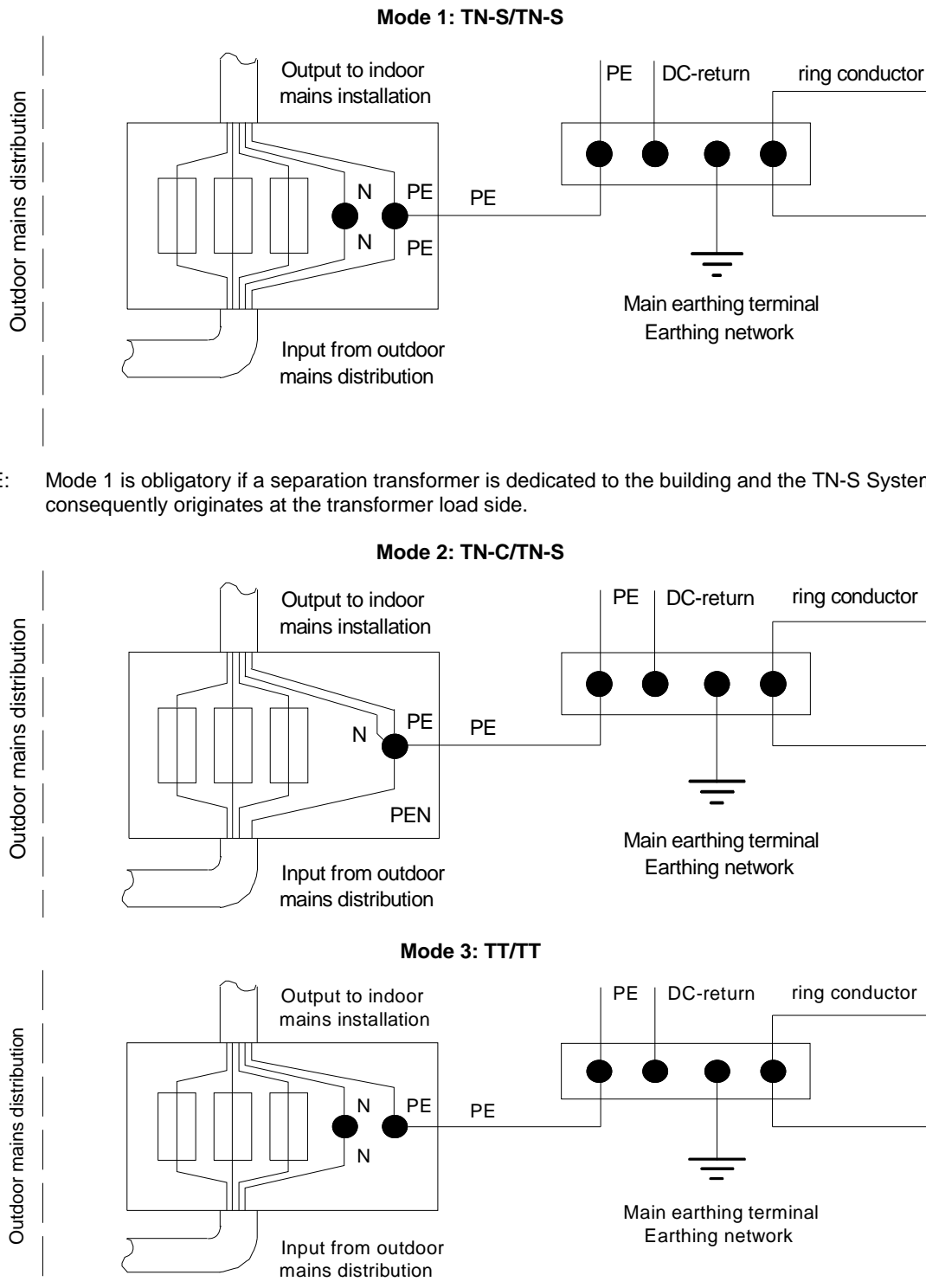
Structure 2

- origin of PEN at the main earthing terminal of the power source;
- PEN is intentionally earthed intermediately in the distribution and at each main earthing terminal;
- origin of N and PE at the main earthing terminal of the indoor installation;
- N and PE are separated throughout the indoor installation and within each equipment.

Structure 3

- origin of PE at the local main earthing terminal of the indoor installation;
- N and PE are separated throughout the indoor installation and within each equipment.

Figure E.1: Conventional mains supply systems (based on IEC Publication 60364, section 312.2)



NOTE: Mode 1 is obligatory if a separation transformer is dedicated to the building and the TN-S System consequently originates at the transformer load side.

Figure E.2: Arrangements for the transition from the outdoor mains distribution network to the indoor mains installation

Annex F (normative): Basic protection and Fault protection

Protection against electric shock includes:

- 1) Basic protection (protection against direct contact); and
- 2) Fault protection (protection against indirect contact) of persons and livestock.

F.1 Basic protection (protection against direct contact)

Basic insulation of live parts is one solution of achieving basic protection, and also the most common method. Another common method to achieve basic protection according to IEC 60364-4-41 [3] is the use of barriers or enclosures. In installations that are controlled or supervised by skilled or instructed persons, basic protection may also be accomplished by the use of obstacles that prevent persons to touch live parts or by placing live parts out of reach. See Annex B of IEC 60364-4-41 [3].

F.1.1 Basic insulation of live parts

According to Annex A of IEC 60364-4-41 [3]:

- a) The insulation is intended to prevent contact with live parts.
- b) Live parts shall be completely covered with insulation which can only be removed by destruction.
- c) For equipment, the insulation shall comply with the relevant standard for the electrical equipment

F.2 Fault protection (protection against indirect contact)

Automatic disconnection of supply is one very common method for class I equipment to achieve fault protection. Disconnection is permitted either with overcurrent protection devices (e.g. circuit breaker) or RCDs.

Other methods are double or reinforced insulation (class II equipment), electrical separation, extra-low-voltage provided by SELV(class III equipment) and PELV. See sections 412, 413 and 414 of IEC 60364-4-41 [3].

F.2.1 Automatic disconnection in case of a fault

According to clause 411.3.2 of IEC 60364-4-41 [3]:

Except as provided by 411.3.2.5 and 411.3.2.6, a protective device shall automatically interrupt the supply to the line conductor of a circuit or equipment in the event of a fault of negligible impedance between the line conductor and an exposed-conductive-part or a protective conductor in the circuit or equipment within the disconnection time required in 411.3.2.2, 411.3.2.3 or 411.3.2.4. See the Table F.1 below.

Table F.1

	Final circuits < 32 A Max disconnection time ¹⁾ 400Vdc	Other circuits ²⁾ Max disconnection time ¹⁾ 400Vdc
TN	400 ms	5 s
TT ³⁾	200 ms	1 s

¹⁾ Disconnection is permitted either by OCP or RCD

²⁾ Distribution circuits and circuits not covered by 411.3.2.2

Note this also includes final circuits > 32 A

³⁾ For final circuits < 32 A: Where in TT systems the disconnection is achieved by an overcurrent protective device and the protective equipotential bonding is connected with all extraneous-conductive-parts within the installation, the maximum disconnection times applicable to TN systems may be used.

F.3 Conclusions

The disconnection time in the table above is valid for "Fault protection":

- To protect against indirect contact, i.e. to protect persons and livestock against hazardous voltage if touching accessible conductive part at the same time as a fault of negligible impedance occurs between the line conductor and an exposed-conductive-part or a protective conductor in the circuit.
- Not only voltages from 400 VDC and above are dangerous to touch, ± 200 VDC is also dangerous to touch and is required to be disconnected in case of a fault when the measure of protection "automatic disconnection of supply" is used. 400 V d.c. is considered to be as safe to use as ± 200 VDC if appropriate protective measures are applied.
- Voltages that are "safe" to touch under all conditions, i.e. voltages that do not require basic protection are defined in IEC 60364-4-41 [3], Section 414.4.5, as 12 VAC or 30 VDC.

NOTE 1: The max disconnection times stated above are to be applied to "Fault Protection" and NOT to a case of direct contact between a person and the bare copper of a live conductor, calculating possible disconnection times of a circuit breaker presuming a certain body impedance.

NOTE 2: Protection against *direct* contact will be done by means of Basic protection.

Annex G (informative): Bibliography

ETSI EN 300 132-3-0: "Environmental Engineering (EE); Power supply interface at the input to telecommunications and datacom (ICT) equipment; Part 3: Operated by rectified current source, alternating current source or direct current source up to 400 V; Sub-part 0: Overview".

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

IEC 60364-5-53: "Low-voltage electrical installations - Part 5-53: Selection and erection of electrical equipment - Isolation, switching and control".

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

CLC/TR 62102: "Electrical safety - Classification of interfaces for equipment to be connected to information and communications technology networks".

EN 302 999: "SAFETY; Remote Power Feeding Installations; Safety requirements for the erection and operation of information technology installations with remote power feeding".

ITU-T handbook: "Earthing of telecommunication installations" (Geneva 1976).

ETSI ETS 300 132-1: "Equipment Engineering (EE); Power supply interface at the input to telecommunications equipment interface; Part 1: Interface operated by Alternating Current (AC)".

ETSI EN 300 132-2: "Environmental Engineering (EE); Power supply interface at the input to telecommunications equipment interface; Part 2: Interface operated by Direct Current (DC)".

ETSI EG 201 147: "Equipment Engineering (EE); Interworking between Direct Current/Isolated (DC-I) and Direct Current/Common (DC-C) electrical power systems".

History

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