

## ENGINEERING DESIGN STANDARD

### EDS 06-0016

#### LV NETWORK EARTHING DESIGN

**Network(s):** EPN, LPN, SPN

**Summary:** This standard details the design requirements for earthing of low voltage (LV) networks.

**Originator:** Stephen Tucker      **Date:** 12/04/2013

**Approved By:** Steve Mockford      **Approved Date:** 01/07/2013

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#### Document History

(The document history notes below are intended as a guide only and may not cover all of the changes. If you wish to make use of this document it should be read in full.)

Version	Date	Details	Originator
4.0	12/04/2013	Earthing of service joints for PME conversion removed (section 7.3.3) and section 7.3.4 removed	Stephen Tucker
3.1	06/07/2012	Minor updates to ensure consistency with other standards and greater use of aluminium conductors. Document reviewed for publishing on G81 website	Stephen Tucker
3.0	17/11/2011	Underground cable sections revised. PNB section added	Stephen Tucker
2.2	29/09/2011	Reclassification of document from Earthing Design Manual Section 6	Stephen Tucker

<b>Version</b>	<b>Date</b>	<b>Details</b>	<b>Originator</b>
2.0	01/06/2010	Completely rewritten to provide a more consistent and practical approach. Customer installation earthing moved to Section 7 of the Earthing Design Manual	Stephen Tucker
1.0	31/03/2008	Original	Stephen Tucker/ Rob Weller

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## 1 Introduction

This standard (previously Section 6 of the Earthing Design Manual) details the earthing design requirements for low voltage (LV) networks. It supersedes all previous EPN, LPN and SPN specific guidance on PME network design, and brings together a common approach to system design and operation.

The standard is based on the best practice from the latest draft of ENA ER G12/4 and has also been updated to reflect the requirements of BS 7671:2008 (2011) – IEE Wiring Regulations Seventeenth Edition.

Although this standard covers most aspects of LV network earthing there will be some situations where advice from an earthing specialist is required, refer to EDS 06-0001 for further details.

The earthing design for secondary distribution substation (including the substation LV earth) and pole-mounted equipment are covered respectively in EDS 06-0014 and EDS 06-0015.

Earthing associated with customer installations, including the provision of an earth terminal, is detailed in EDS 06-0017.

This standard is divided into the following sub-sections:

- Definitions (Section 4).
- LV Earthing Standard (Section 5).
- PME Network Design (Section 6).
- LV Earthing Requirements (Section 7).
- References (Section 8).
- Regulations (Appendix A).
- LV Earthing Systems (Appendix B).

Significant changes from existing practice or previous versions:

- The statutory requirements from the Electricity, Supply Quality and Continuity (ESQC) regulations 2002 are included in the text.
- The guidance from the latest draft of ENA G12/4 is included.
- The requirements from BS 7671:2008 (2011) are included.
- The additional PME earth electrode requirements, at each branch and service joint, introduced in version 1 of this standard have been removed as they are deemed unnecessary for modern cables and current network construction.
- The electrodes, bonding conductors and labels have all been reviewed.
- All earthing requirements for LV customer installations including the provision of PME terminals and special situations have been removed and are now included in EDS 06-0017.
- The use of protective neutral bonding (PNB) is reinstated.

## 2 Scope

This standard applies to the earthing design for all new LV networks and existing LV networks where a material alteration is to take place.

This document is intended for internal and external use.

### 3 Glossary and Abbreviations

Term	Definition
EPR	Earth potential rise
ROEP	Rise of earth potential
NetMap	UK Power Networks graphical information system (GIS).

### 4 Definitions<sup>1</sup>

#### Combined Neutral and Earth (CNE)

Typically used to describe a cable with a combined neutral and earth metallic outer sheath with a PVC covering, or overhead line with a combined neutral and earth conductor.

#### Customer

Any person who has responsibility for premises connected by agreement to distribution networks owned by UK Power Networks.

#### Customer's Installation

The electrical apparatus under the control of the customer on the customer's premises together with the wiring connecting this apparatus to the supply terminals. A cut-out and meter shall not form part of the customer's installation (unless additional metering is supplied by the customer e.g. landlord's supplies).

#### Customer's Premises

Any area or building in the sole occupation of the customer.

#### Distributing Main (or Main)

A low voltage electric line which connects a source of voltage to one or more service lines, or directly to a single customer's installation.

#### Distributor\*

A person who owns or operates a network, except for a network situated entirely offshore or where that person is an operator of a network within the meaning of Part I of the Railways Act 1993.

#### Earth Electrode

A metal rod, plate, stranded or strip conductor buried in the earth for the purpose of providing a connection with the general mass of earth.

#### Earth Loop Impedance (ELI) or Earth Fault Loop Impedance (EFLI)

The impedance of the earth fault current loop starting and ending at the point of earth fault. This impedance is denoted by the symbol  $Z_s$ . The part of the earth fault loop impedance which is external to the customer installation is denoted by the symbol  $Z_e$ .

<sup>1</sup> \*Definitions taken from the Electricity Safety, Quality and Continuity Regulations 2002.

**Earthing Systems (refer to Appendix B for further details)****Protective Multiple Earthing (PME)**

PME is the most common form of earthing provided at new installations. A single conductor for neutral and earthing functions is utilised and an earth terminal is provided at the customer's installation. The customer's earthing may be connected to this terminal providing the relevant requirements in BS 7671 are satisfied. In some cases it is not appropriate to provide a PME earth terminal, either due to the nature of the distribution system or due to the type of installation itself.

**Cable Sheath Earth/Separate Continuous Earth Wire**

Cable sheath earth and separate continuous earth wire arrangements are often found on supplies to older properties, or occasionally where PME facilities are unavailable. Separate conductors for neutral and earthing functions are utilised and an earth terminal is provided at the customer's installation. The customer's earthing may be connected to this terminal providing the relevant requirements in BS 7671 are satisfied.

**Independent Local Earthing (TT)**

Independent local or TT earthing is common in older installations and is also used where PME cannot be provided. An earth terminal is not provided and the customer is responsible for providing the earth electrode system (buried earth rods and conductor). Where local earthing is employed, the installation normally has to be protected by a residual current device (RCD) in order to comply with BS 7671.

**Earthing Terminal**

The main earth terminal for an installation, usually sited close to the incoming service. If an earth terminal is provided by UK Power Networks as part of a PME supply (TN-C-S), the main earth terminal will usually be directly connected to the supply neutral conductor at the cut-out position.

**Electric Line\***

Any line which is used or intended to be used for carrying electricity for any purpose and includes, unless the context otherwise requires:

- a) Any equipment connected to any such line for the purpose of carrying electricity.
- b) Any wire, cable, tube, pipe, insulator or other similar thing (including its casing or coating) which surrounds or supports, or is associated with, any such line.

**Multi-service**

Any electric line through which energy may be supplied to two, three or four adjacent customers from any distributing main or substation.

**Residual Current Device (RCD)**

An RCD is a current operated device which measures the imbalance between phase and neutral currents. If this unbalance or 'leakage current' exceeds a preset level it will operate to interrupt current flow. Typical domestic RCDs will have a 30mA operating threshold.

**Secondary Substation**

An HV/LV substation typically transforming 11(6.6)kV to 400V.

**Separate Neutral and Earth (SNE)**

Typically used to describe a cable or overhead line with an earthed sheath or additional earth wire in addition to a neutral conductor.

**Service Line\* (or Service)**

Any electric line which either connects a street electrical fixture, or no more than four customers' installations in adjacent buildings, to a distributing main.

**Service Termination**

The cut-out where the service cable terminates.

**Street Electrical Fixture\***

A permanent fixture which is, or is intended to be, connected to a supply of electricity and which is in, on, or is associated with a highway.

**Supplier\***

A person who contracts to supply electricity to consumers.

## 5 LV Earthing Standard

The Electricity Safety, Quality and Continuity Regulations 2002 (24(4)) (refer to Appendix A) state that a distributor shall make an earthing terminal available when installing a new low voltage connection or replacing an existing connection, unless it is inappropriate for reasons of safety.

UK Power Networks' standard is to provide an earth terminal from a PME system wherever it is appropriate to do so. EDS 06-0017 (Customer Installation Earthing Design) details the situations where it may be inappropriate to provide an earth terminal from a PME system.

Therefore all new low voltage mains and services shall be constructed to PME standards described in Section 6 using combined neutral earth (CNE) cables and overhead lines to enable an earth terminal to be provided.

Whenever major work (e.g. refurbishment, diversion etc.) is carried out on the low voltage distribution network, it shall be brought up to PME standards where appropriate, as described in Section 6.

Generally only one service and earth terminal shall be provided to a customer or a building. Multiple services to a single customer or building are **not** recommended practice since this causes problems due to neutral current diversion<sup>2</sup> and uncertainty when isolating the supplies. Refer EDS 06-0017 for further information on multiple supplies.

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<sup>2</sup> Out of balance three-phase loads and single-phase loads cause current to flow in the neutral conductor. Neutral current diversion occurs when multiple PME supplies are provided to the same building and an alternative path exists, for example through the structural steelwork of a building and an earth bond, to the other neutral/earth terminal. The natural passage of neutral current through the structural steelwork can give rise to magnetic field problems both close to the steelwork and at the source which may cause interference to VDUs etc. Furthermore, equipotential bonding conductors may carry neutral current resulting in overheating and consequential fire risk. Refer to EDS 06-0017 for further information.

## 6 Design Criteria

This section describes the requirements for PME networks and is split into the following sub-sections:

- General requirements.
- Supply neutral conductor earthing.
- Underground cable networks.
- Overhead line networks.
- Load balance.
- Protective neutral bonding (PNB).
- Earth fault loop impedance.

### 6.1 General Requirements

The following general requirements apply to all new and existing low voltage networks to enable PME to be used:

- For combined HV and LV earthing systems, the earth potential rise (EPR) or rise of earth potential (ROEP) at the secondary substation supplying the PME network shall not exceed 430V during a HV earth fault. If the EPR exceeds 430V the HV and LV earthing systems shall be segregated. Refer EDS 06-0014 for further details on secondary substation design.
- Protective devices shall not be included in the supply neutral conductor or any earthing connection.
- The integrity of the supply neutral conductor shall be maintained throughout the network and should be considered during the design, construction, maintenance and operation of the distribution system.
- The supply neutral conductor shall be connected to earth (or the supply neutral conductor of another main) at other points throughout the network in addition to the LV earth at or near to the secondary substation (refer to Section 6.2).
- The resistance of the supply neutral conductor to the earth shall not exceed  $20\Omega$  at any point (refer to Section 7.3).
- Loads shall be shown uniformly distributed across the phases along a main at the design stage (refer to Section 6.5).

### 6.2 Supply Neutral Conductor Earthing Requirements

In addition to the main LV neutral earth at or near the substation, the supply neutral conductor shall be connected at other points to earth electrodes, or to the supply neutral conductor of another main to ensure that the resistance of the supply neutral conductor does not exceed  $20\Omega$  at any point on the network.

The additional earth connections will also ensure that the potential of the supply neutral conductor is as close to that of true earth as possible, and provide resilience against open-circuit neutral conditions, therefore reducing the likelihood of the neutral rising to undesirable voltage levels. This means that the combined neutral/earth conductor will be earthed at multiple locations.

Additional neutral earth electrodes, as specified in Section 7.1, shall be installed as follows:

- At the end of each main. Alternatively, connecting the supply neutral conductor to that of another main with a separate path back to the substation will serve the same purpose.
- At additional locations on overhead line systems to ensure the distance between electrodes is not more than six spans.
- At the end of any branch or service supplying more than four customers.
- At the end of any branch or service supplying more than one customer and longer than 40 metres.
- At the end of any branch or service supplying street furniture with a PME earth terminal.

These arrangements are illustrated in Figure 6-1.

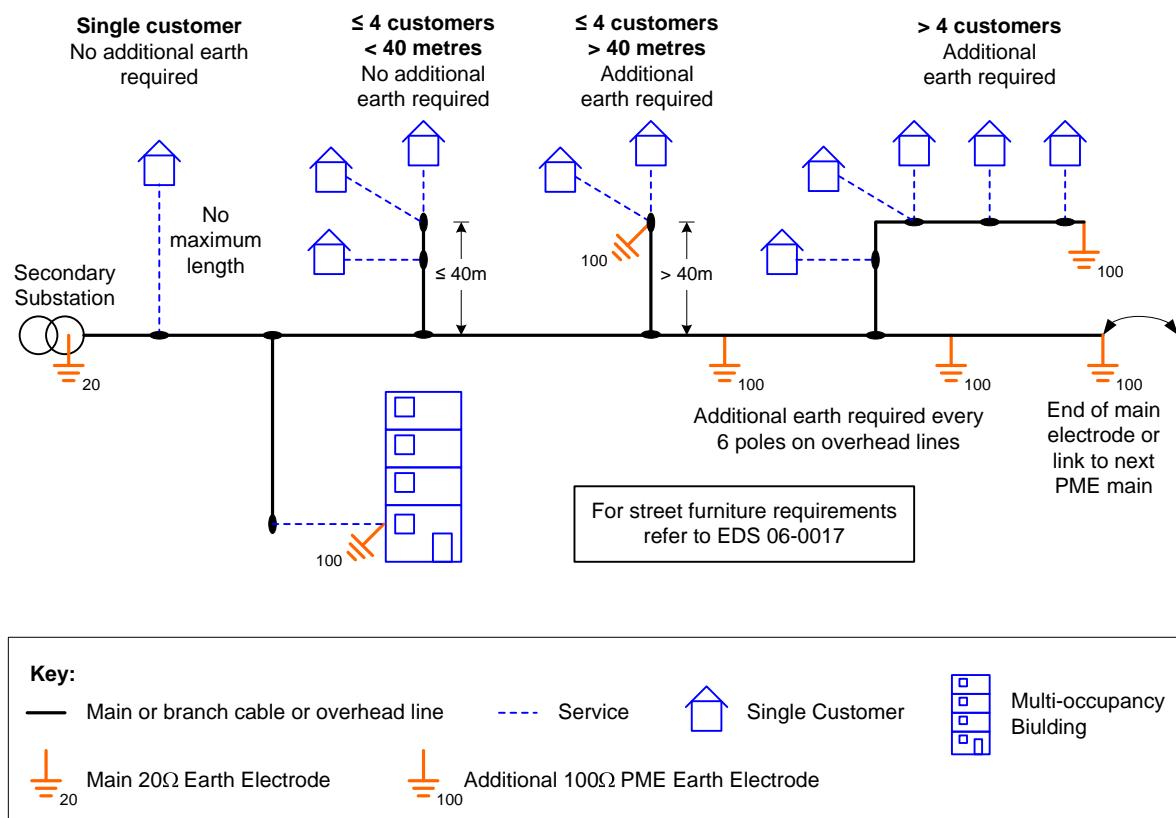


Figure 6-1 – Supply Neutral Conductor Earthing Requirements for PME

### 6.3 Underground Cable Networks

#### 6.3.1 New Underground Cable Networks

New underground networks shall use CNE cable and an earth terminal shall be provided from the PME system wherever possible.

#### 6.3.2 Converting Existing Underground Cable Networks to PME

The opportunity shall be taken wherever possible to upgrade existing networks to PME. Any extension or modification shall use CNE cables. Figure 6-2 shows the typical application of

CNE cables in existing networks. The following requirements shall be applied when CNE cables are introduced into SNE networks:

- The neutral conductor of the CNE cable shall be connected to the neutral conductor and sheath earth conductor of the SNE cable at the transition joint.
- An earth electrode shall be installed at the transition joint furthest from the secondary substation. **Note:** A length of SNE cable with more than 15m of non-insulated cable in direct contact with the ground will normally provide a suitable connection with earth and satisfy this requirement.
- Further electrodes shall be installed on the CNE cable in accordance with the requirements for new PME networks.

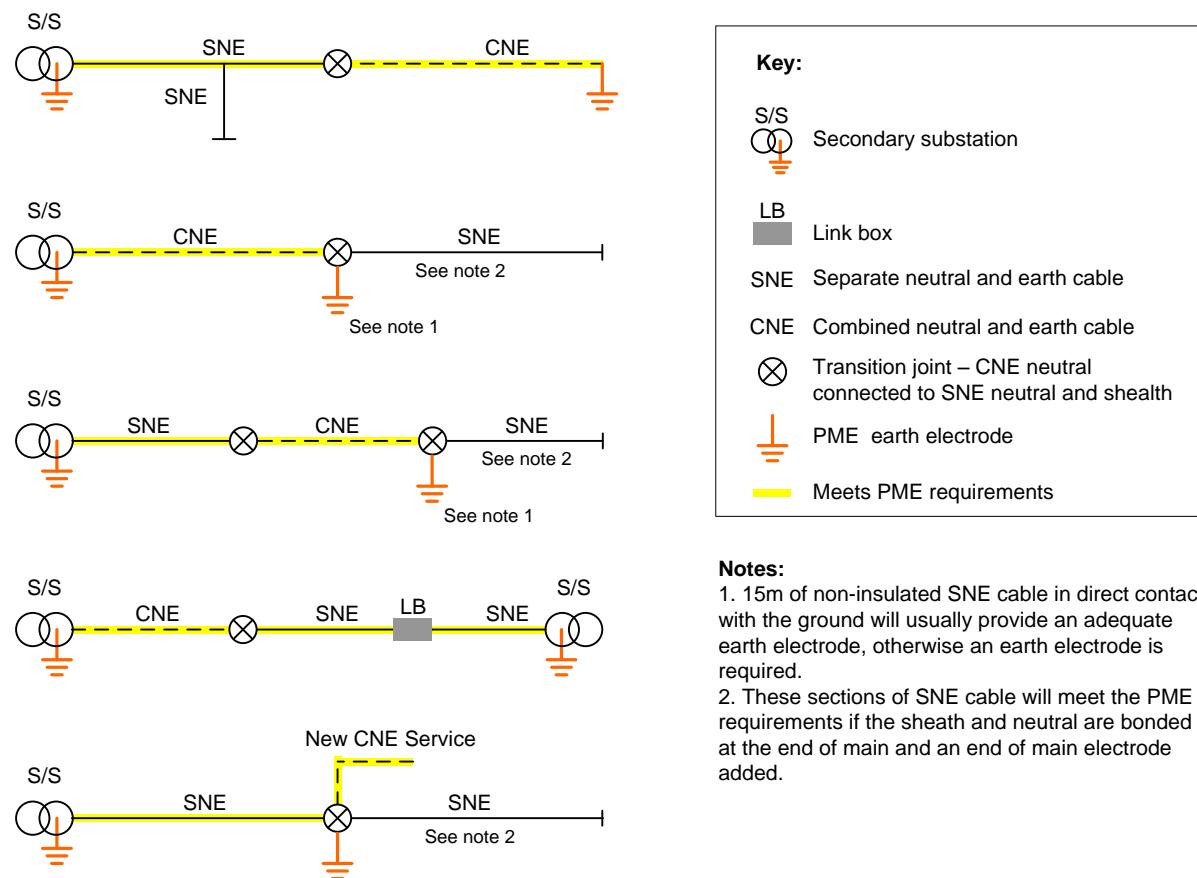


Figure 6-2 – Typical Application of CNE Cables in Existing Networks

All reasonable precautions shall be taken to ensure that customers supplied via SNE cables are not adversely affected by repairs, modifications or additions to existing networks. When a CNE cable is introduced into a SNE network, existing customers may retain a SNE service provided:

- A continuous metallic earth return path exists to the source substation, and;
- They are connected to a continuous length of non-insulated metallic sheathed cable in direct contact with the ground, sufficient to limit the rise of potential under open-circuit neutral conditions. These criteria will be satisfied if the length of metallic cable sheath in contact with the ground is sufficient to give a resistance to earth of 20Ω or less. Table 6-1 specifies the length required to achieve this in different soil conditions.

Table 6-1 – Non-insulated Sheathed Cable Lengths Required to Achieve 20Ω

Typical Soil Type	Resistivity (Ωm)	Length (m)
Loams, garden soils etc.	25 or less	4
Chalk	50 or less	8
Clay	100 or less	15
Marsh/Peat	200 or less	29
Sand/Gravel/Clay mix	300 or less	43
Slate/Shale/Rock	500 or less	71

If these conditions cannot be satisfied the service shall be converted to PME (provided the installation complies with the BS 7671 bonding requirements), or a TT earthing system shall be used.

### 6.3.3 Converting Existing Customers to PME

Customers with an existing separate neutral and earth, connected to an SNE cable network can be converted to a combined neutral and earth (PME) provided the following requirements are satisfied:

- The customer's installation complies with BS 7671.
- A new PME cut-out is installed.
- There are no shared metallic services (water, gas etc) with other properties (e.g. flats). If there are shared metallic services **all** properties shall be converted to PME and the neutrals bonded together in accordance with the rules for multi-occupancy buildings detailed in EDS 06-0017.
- The SNE cable is replaced with a CNE cable (or the neutral and earth are combined at the service joint and at the cut-out).
- An earth electrode is installed at the service joint. **Note:** A length of SNE cable with more than 15m of non-insulated cable in direct contact with the ground will normally provide a suitable connection with earth and satisfy this requirement.

**Note:** It is **not** permitted to simply bond the neutral and earth at the cut-out.

### 6.3.4 Looped Services

When alterations are made to any cable associated with a SNE cable looped<sup>3</sup> service arrangement, with cable sheath earth terminals provided by UK Power Networks, the earthing systems at the looped property and the house connected to the primary<sup>4</sup> service shall remain the same as each other. If one property is converted to PME, with the other retaining a SNE cable sheath earth, there would be a risk of differences in potential between un-bonded metalwork within the SNE earthed property in the event of an open circuit neutral fault on the primary service. Refer to EDS 08-0129 for further information.

<sup>3</sup> A looped service is a service that is derived from a connection to another service cable, either by an underground cable joint on or from the live-side cut-out terminals of the primary service.

<sup>4</sup> The primary service is the service that connects directly to the mains cable and to which the loop service connects.

## 6.4 Overhead Line Networks

New overhead line networks are constructed using aerial bundled conductors (ABC) and will be suitable for PME.

Existing open-wire low voltage overhead line networks are also suitable for PME. If an overhead line network is encountered that is not PME, it shall be converted to PME before any other work proceeds.

Low voltage overhead line PME networks shall satisfy the following requirements:

- The HV and LV earths on pole-mounted transformers shall be segregated as specified in EDS 06-0015.
- The supply neutral conductor shall be connected in such a way to minimise corrosion or breakage risks. (Single line tap type connections for neutral line conductors, tier type cable box neutrals or transformer neutral connections are not acceptable).
- The supply neutral conductor shall be connected to an earth electrode or the supply neutral conductor of another main at the final support of every main.
- Additional earth electrodes shall be installed every six spans along the overhead line and at the end of each section of overhead line.
- The cable sheaths and metallic cable boxes on poles supporting cable terminations shall be connected to the supply neutral conductor.
- Any multi-service, group service position or under-eaves wiring supplying more than four customers shall be fitted with an earth electrode.

The following additional requirements shall be applied when open-wire overhead line networks with continuous earth wires are replaced with ABC:

- All sections of associated main and any other main likely to be used as an alternative supply between the secondary substation and the customer shall be constructed to the PME requirements outlined above.
- Any service aerial earth wires shall be removed.
- Customers utilising a SNE service shall be converted to PME (provided the installation complies with the BS 7671 bonding requirements) or a TT earthing system shall be used. However, existing customers beyond the ABC may retain a SNE service provided they are connected to a continuous length of non-insulated metallic sheathed cable in direct contact with the ground sufficient to limit the rise of potential under open-circuit neutral conditions. These criteria will be satisfied if the length of metallic cable sheath in contact with the ground is sufficient to give a resistance to earth of  $20\Omega$  or less. Table 6-1 specifies the length required to achieve this in different soil conditions.

## 6.5 Protective Neutral Bonding (PNB)

Although PME is the preferred option protective neutral bonding (PNB) may provide a better solution in circumstances where it is not practical to install the LV earth at the transformer. In a PNB earthing system the LV neutral conductor is connected to an earth electrode at a point remote from the transformer at or near the customer's supply terminals (refer to Appendix B for further details).

PNB may only be used if the following criteria are satisfied:

- A maximum of four customers.
- The connection to earth shall be made as close as possible to customer's supply terminals and no more than 40m from the furthest customer.
- The earth electrode shall have a maximum resistance of  $20\Omega$ .
- The earth electrode shall be a minimum of 8m from any HV earth or HV metallic sheath cable.
- The metallic sheaths of any LV cables shall also be connected to the earth electrode.
- The transformer tank and associated HV metalwork shall be connected to the HV earth electrode.
- A PNB earth terminal shall be treated as a PME earth terminal and the appropriate labelling applied (Refer to EDS 06-0017).

Various PNB arrangements are illustrated in Figure 6-3 and Figure 6-4.

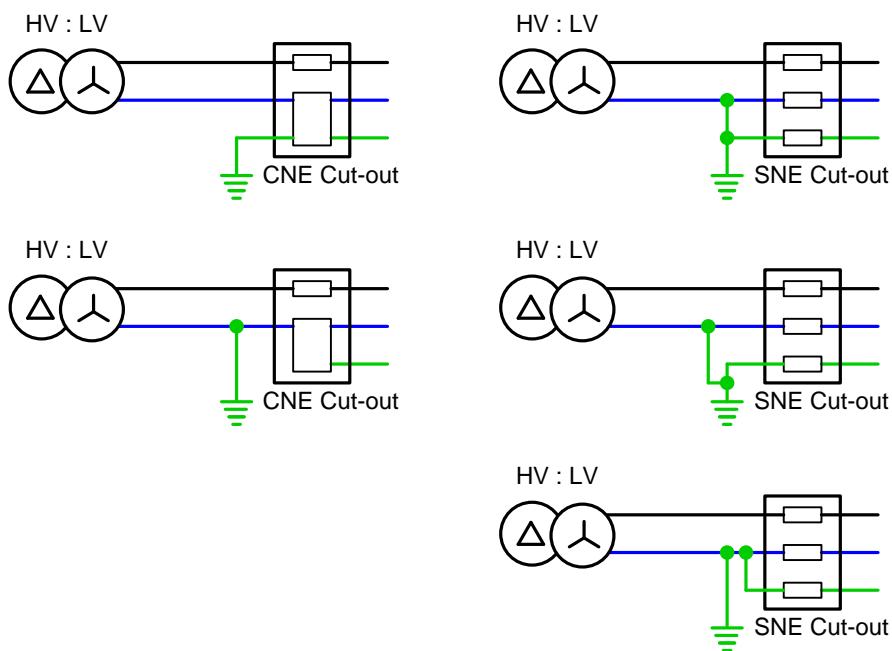


Figure 6-3 – PNB Options using CNE and SNE Cut-outs

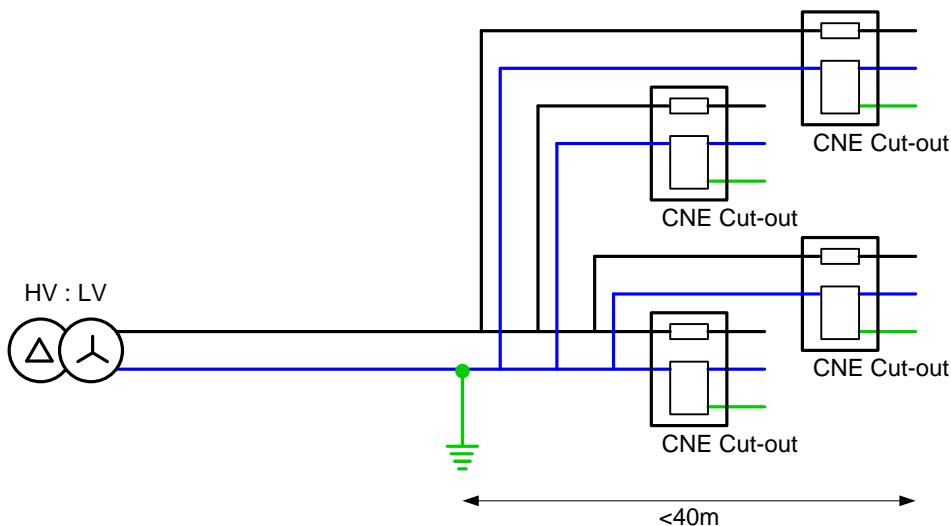


Figure 6-4 – PNB for up to Four Customers

## 6.6 Load Balance

The voltage which appears on the supply neutral conductor (and consequently on customers' exposed metalwork) beyond a broken neutral position is influenced by the load balance on the main. If the load is uniformly distributed across the phases along the main, the neutral voltage rise is theoretically zero beyond a neutral break and will be low in practice. Maintaining good load balance will therefore minimise neutral voltage rise and consequent risk of shock under broken neutral conditions. Good load balance will also minimise neutral voltage rise under normal operating conditions, reduce losses, and maximise the load capacity available from the assets concerned. It is the best way to reduce risks associated with broken neutrals and is an extremely important factor in network operation and design.

Therefore designs for new networks and alterations to existing networks shall clearly indicate the phase to which customers shall be connected. Furthermore this shall be clearly communicated to those making the service connections.

When legacy single-phase or two-phase SNE cable networks are replaced with modern three-phase CNE cable, particular care should be taken to balance load. Wherever possible, cable sheaths and neutrals at the ends of SNE cables should be bonded and interconnected.

## 6.7 Earth Fault Loop Impedance

For guidance on earth fault loop impedance refer to EDS 08-0136 (new network design) or EDS 06-0004 (existing networks).

## 7 LV Earthing Requirements

### 7.1 Earth Electrodes

The permitted earth electrodes are given in Table 7-1. Refer to Appendix C for a complete range of electrode sizes for different values of soil resistivity.

**Note:** The use of rod electrodes is preferred but due to practical difficulties, particularly in urban areas where damage can be caused to other services, cable electrodes are acceptable.

Table 7-1 – Earth Electrodes

Electrode Type	Location	Cable Size	Electrode
Rod	Cable Joints	Up to 35mm <sup>2</sup>	2.4m earth rod connected via 35mm <sup>2</sup> PVC covered copper cable
		> 35mm <sup>2</sup>	2.4m earth rod connected via 70mm <sup>2</sup> PVC covered copper cable
Cable	Cable Joints – New	Up to 35mm <sup>2</sup>	2 x 2m of 35mm <sup>2</sup> <b>bare</b> copper cable loosely wrapped around the joint
		> 35mm <sup>2</sup>	2 x 2m of 70mm <sup>2</sup> <b>bare</b> copper cable loosely wrapped around the joint
	Cable Joints – Existing	Up to 35mm <sup>2</sup>	2m of 35mm <sup>2</sup> <b>bare</b> copper cable laid directly in the trench
		> 35mm <sup>2</sup>	2m of 70mm <sup>2</sup> <b>bare</b> copper cable laid directly in the trench

### 7.2 Bonding Connections

The minimum size of earthing and bonding connections are given in Table 7-2. Below ground, i.e. buried, earthing and bonding conductors shall be copper. Above ground bonding conductors may be copper, aluminium or corrosion protected steel of the appropriate cross sectional area.

Table 7-2 – Bonding Connections

Connection Type	Copper or Copper Equivalent
Main LV earth at secondary substation i.e. connection between transformer neutral (star-point) and earth	Refer to EDS 06-0014 for the requirements
Between neutral busbar and earth busbar at secondary substation	
LV earth at pole-mounted sites	Refer to EDS 06-0015 for the requirements

Connection Type	Copper or Copper Equivalent
Between supply neutral conductor and PME earth electrode	For cable sizes up to 35mm <sup>2</sup> : 50mm <sup>2</sup> PVC covered aluminium cable or 35mm <sup>2</sup> PVC covered copper cable
Between supply neutral conductor and link box or feeder pillar steelwork	For cable sizes greater than 35mm <sup>2</sup> : 95mm <sup>2</sup> PVC covered aluminium cable or 50mm <sup>2</sup> PVC covered copper cable
Between sheath of SNE cable and neutral of CNE cable	
At customer's premises between service neutral and main earthing terminal	16mm <sup>2</sup> or half the size of the neutral meter tail, whichever is the larger. <b>Note:</b> This is usually built into the cut-out
At customer's premises between the main earthing terminal and the earth bar of the consumer unit  <b>Note:</b> The bonding between the main earthing terminal and the consumer unit is the responsibility of the consumer. It is given here for information only.	16mm <sup>2</sup> or half the size of the neutral meter tail, whichever is the larger

### 7.3 Earth Resistance Values

The resistance of the supply neutral conductor to the general mass of earth shall not at any point exceed 20Ω. To achieve this value the earth electrode resistance values given in Table 7-3 shall be used.

Table 7-3 – Earth Electrode Resistance Values.

Electrode	Resistance Value	Electrode Systems
Main LV Earth	20Ω	Refer to Appendix C
Additional PME Earth	100Ω	

## 8 References

EDS 06-0001 Earthing Standard

EDS 06-0004 Earth Fault Loop Impedance Requirements (internal document only)

EDS 08-0129 Underground Services up to 100A

EDS 08-0133 Underground Services to Unmetered Street Furniture

EDS 08-0136 LV Network Design

EDS 06-0014 Secondary Substation Earthing Design

EDS 06-0015 Pole-mounted Equipment Earthing Design

EDS 06-0017 Customer Installation Earthing Design

EDS 06-0018 NetMap Earthing Information System (internal document only)

EDS 08-0136 LV Network Design

ENA ER G12/4 Requirements for the Application of Protective Multiple Earthing to Low Voltage Networks

IEC 60364 Electrical Installations for Buildings

The Electricity Safety, Quality and Continuity Regulations (ESQC) 2002 as amended (2006)

BS 7671:2008 incorporating Amendment No 1: 2011 – Requirements for Electrical Installations (IEE Wiring Regulations Seventeenth Edition)

## Appendix A – ESQC Regulations

The Electricity Safety, Quality and Continuity Regulations 2002 contain a number of clauses covering earthing. A summary of these is given below:

### Continuity of the Supply Neutral Conductor and Earthing Connections

Regulation 7(1) A generator or distributor shall, in the design, construction, maintenance or operation of his network, take all reasonable precautions to ensure continuity of the supply neutral conductor.

Regulation 7(2) No generator or distributor shall introduce or retain any protective device in any supply neutral conductor or any earthing connection of a low voltage network which he owns or operates.

### General Requirements for Connection with Earth

Regulation 8(1) A generator or distributor shall ensure that, so far as is reasonably practicable, his network does not become disconnected from earth in the event of any foreseeable current due to a fault.

Regulation 8(3) A generator or distributor shall, in respect of any low voltage network which he owns or operates ensure that:

- a) the outer conductor of any electric line consisting of concentric conductors shall be connected with earth.
- b) every supply neutral conductor is connected with earth at, or as near as is practical, to the source of voltage, except that where there is only one point in a network at which consumers' installations are connected to a single source of voltage, that connection may be made at that point, or at another point nearer to the source of voltage.
- c) no impedance shall be inserted in any connection with earth of a low voltage network other than that required for the operation of switching devices or instruments, or equipment for control, telemetry or metering.

Regulation 8(5) A consumer shall not combine the neutral and protective functions in a single conductor in his installation.

Regulation 8(5) Paragraphs (1) to (4) shall not apply to a generator's network which is situated within a generating station if, and only if, adequate alternative arrangements are in place to prevent danger.

### Protective Multiple Earthing

Regulation 9(1) This regulation applies to distributors' low voltage networks in which the neutral and protective functions are combined.

Regulation 9(2) In addition to the neutral with earth connection required under regulation 8(4)(b), a distributor shall ensure that the supply neutral conductor is connected with earth at:

- a) a point no closer to the source of voltage (as measured along the distributing main) than the junction between the distributing main and the service line (the supply neutral conductor of the latter being connected to the protective conductor of a consumer's installation) which is most remote from the source.
- b) such other points as may be necessary to prevent, so far as is reasonably practicable, the risk of danger arising from an accidental disconnection of any such connection with earth.

Regulation 9(3) Paragraph (2)(a) shall only apply where the supply neutral conductor of the service line referred to in paragraph (2)(a) is connected to the protective conductor of a consumer's installation.

Regulation 9(4) The distributor shall not connect his combined neutral and protective conductor to any metalwork in a caravan or boat.

### **Equipment on a Consumer's Premises**

Regulation 24 (1) A distributor or meter operator shall ensure that each item of his equipment which is on a consumer's premises, but which is not under the control of the consumer (whether forming part of the consumer's installation or not), is:

- a) suitable for its purpose.
- b) installed and, so far as is reasonably practicable, maintained so as to prevent danger.
- c) protected by a suitable fusible cut-out or circuit-breaker which is situated as close as is reasonably practicable to the supply terminals.

Regulation 24(2) Every circuit breaker or cut-out fuse forming part of the fusible cut-out mentioned in paragraph (1)(c) shall be enclosed in a locked or sealed container as appropriate.

Regulation 24(3) Where they form part of his equipment, which is on a consumer's premises but which is not under the control of the consumer, a distributor or meter operator (as appropriate) shall mark permanently, so as clearly to identify the polarity of each of them, the separate conductors of low voltage electric lines which are connected to supply terminals, and such markings shall be made at a point which is as close as is practicable to the supply terminals in question.

Regulation 24(4) Unless he can reasonably conclude that it is inappropriate for reasons of safety, a distributor shall, when providing a new connection at low voltage, make available his supply neutral conductor or, if appropriate, the protective conductor of his network for connection to the protective conductor of the consumer's installation.

Regulation 24(5) In this regulation the expression "new connection" means the first electric line, or the replacement of an existing electric line, to one or more consumer's installations.

### **Earthing of Metalwork**

Regulation 10(1) Subject to paragraph (2), and without prejudice to any other requirement as to earthing, a generator, distributor or meter operator, as the case may be, shall ensure that any metalwork enclosing, supporting or otherwise associated with his equipment in a network and which is not intended to serve as a phase conductor is, where necessary to prevent danger, connected with earth.

Regulation 10(2) Paragraph (1) shall not apply:

- a) to any metalwork attached to, or forming part of, a wooden pole support, the design and construction of which is such as to prevent, so far as is reasonably practicable, danger within 3m of the ground from any failure of insulation or failure of insulators.
- b) to any wall-mounted metal bracket carrying an overhead line not connected with earth, where the line is both supported by an insulator and the part of the line in contact with the insulator is itself surrounded by insulation.

## Appendix B – Earthing Systems

### B.1 IEC Standard for the Naming of Earthing Systems

Mains electricity systems are categorised in IEC 60364 according to how the earthing is implemented. The common ones are TN-C-S, TN-S and TT. In these descriptions, 'system' refers to both the supply and the installation, and 'live parts' includes the neutral conductor. These conventions are used in BS 7671.

First letter (refers to supply networks):

- T – The live parts in the system have one or more direct connects to earth (i.e. via the neutral).
- I – The live parts in the system have no connection to earth or are connected only through a high impedance.

Second Letter (refers to the customer's installation):

- T – All exposed conductive parts are connected via earth conductors to a local earth connection.
- N – All exposed conductive parts are connected to the earth provided by the supply network.

Remaining Letters:

- C – Combined neutral and earth functions (same conductor).
- S – Separate neutral and protective earth functions (separate conductors).

**Note:** The letters are derived from the French language: T – Terre (earth), N – Neutre (neutral), S – Séparé (separate), C – Combiné (combined) and I – Isolé (isolated).

### B.2 BS 7671 Definitions

#### **TN (Terra-Neutral)**

A system having one or more points of the source of energy directly earthed, the exposed conductive-parts of the installation being connected to that point by protective conductors. TN systems may be subdivided as described below.

#### **TN-C (Terra-Neutral-Combined)**

A system in which neutral and protective functions are combined in a single conductor throughout the system.

#### **TN-S (Terra-Neutral Separated)**

A system having separate neutral and protective conductors throughout the system.

#### **TN-C-S (Terra-Neutral-Combined-Separated)**

A system in which neutral and protective functions are combined in a single conductor in part of the system.

#### **TT (Terra-Terra)**

A system having one point of the source of energy directly earthed, the exposed-conductive parts of the installation being connected to earth electrodes electrically independent of the earth electrodes of the source.

### B.3 TN-S (Terra-Neutral Separated)

In a TN-S earthing system (refer to Figure B-1), the incoming supply has a single point of connection between the supply neutral and earth at the supply transformer. The supply cables have separate neutral and protective earth conductors (SNE) **for the complete system**, and there is no bonding between the neutral and earth conductors, except at the supply transformer. The neutral conductor may be a fourth core, or a split concentric cable may be used with part of the concentric conductor insulated and used as the neutral. The sheath or a separate conductor is used to provide the protective earth. The customer is provided with an earth terminal connected to the sheath of the service cable or to the separate earth conductor.

**Note:**

- TN-S was the default earthing system pre-1978 before PME became commonplace.
- Since all extensions and repairs use CNE cable it shall be assumed that all networks will have the neutral and protective earth conductors combined for at least part of the system; they will therefore be TN-C-S. The only exceptions will be dedicated supplies to single customers using a separate earth conductor.

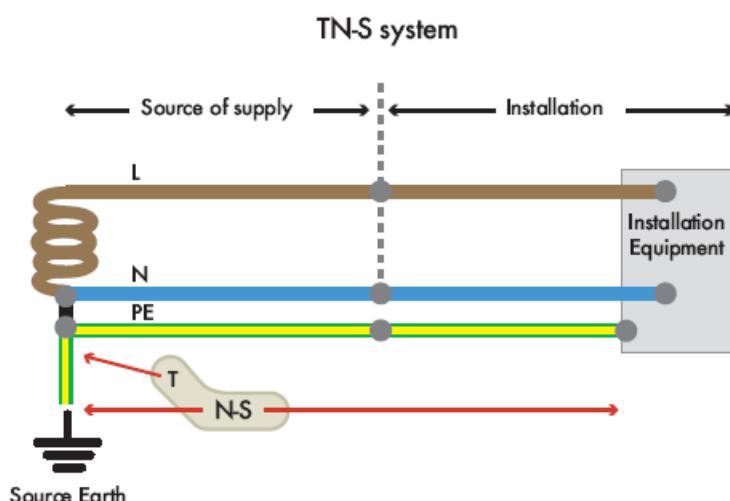


Figure B-1 – TN-S Earthing System

### B.4 TN-C-S (Terra-Neutral-Combined-Separated)

The TN-C-S earthing system is a combination of TN-C and TN-S earthing systems. The supply cables have a combined neutral and earth (CNE) metallic outer sheath with a PVC covering (TN-C). The supply neutral conductor also serves as the protective earth and an earth terminal is provided from it. The supply on the customers side is TN-S, i.e. the neutral and earth are separate and only linked at the service termination. Both PME and PNB are examples of the TN-C-S earthing system.

**Note:** If any part of a network has CNE cable, or has SNE cable with the sheath and neutral bonded at any point other than at the transformer neutral terminal, the complete system is classified as TN-C-S.

PME is a variant of the TN-C-S earthing system but additional earth electrodes are connected to the neutral (Figure B-2).

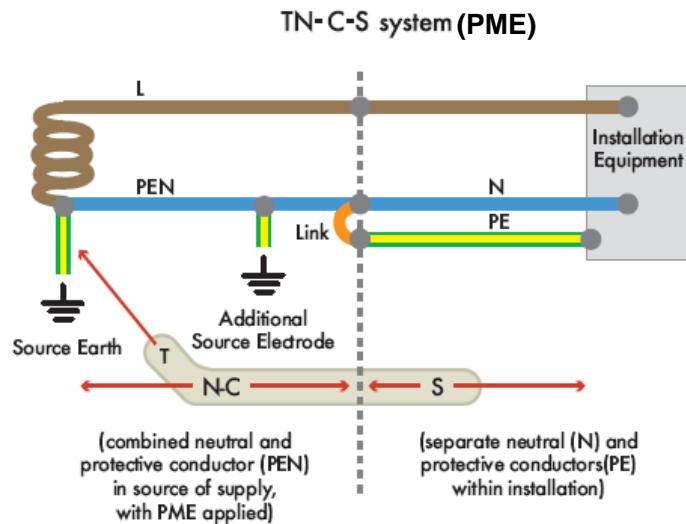


Figure B-2 – PME Earthing System

PNB is another variant of the TN-C-S earthing system and is similar to PME. PNB is generally only used for supplies to a single customer or a small group of customers, e.g. a customer supplied from a pole-mounted transformer. The neutral conductor is only earthed at one point and therefore the transformer and the customer share a common neutral earth. The earth is located closer to the customer than the transformer and often connected at cut-out. The customer's electrical installation requirements are exactly the same as for PME. Refer to Figure B-3.

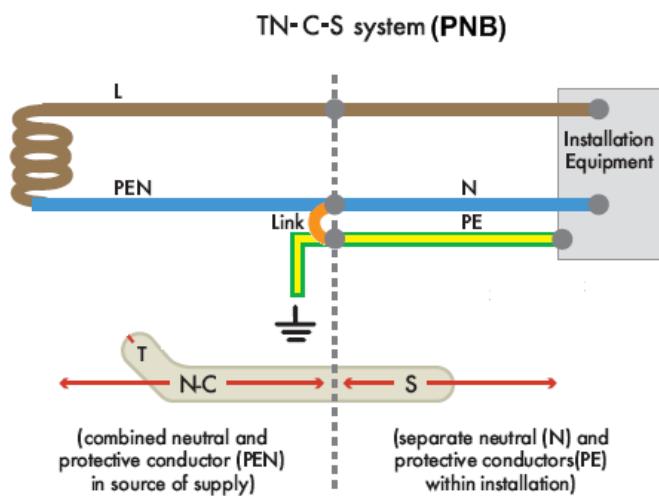


Figure B-3 – PNB Earthing System

## B.5 TT (Terra-Terra)

In a TT earthing system (Figure B-4), the supply is earthed at one or more points and the supply cable sheaths are connected to it. The customer has an independent earth electrode to which any exposed metalwork of the customer's installation is connected. The earth loop impedance is relatively high for this arrangement and therefore a residual current device (RCD) is usually required to protect the customer's installation.

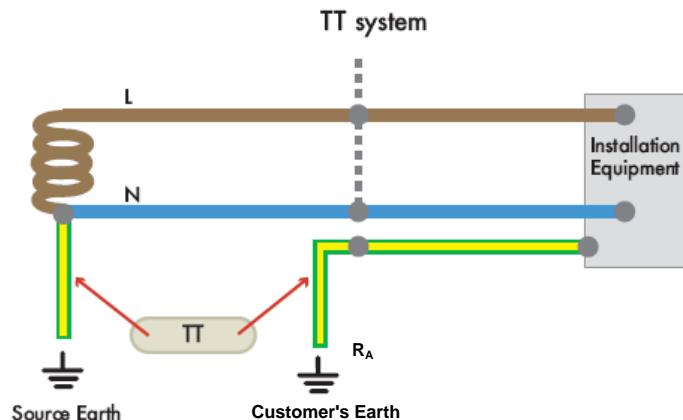


Figure B-4 – TT Earthing System

**Note:**

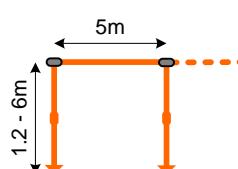
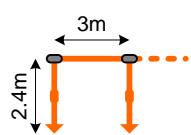
- The resistance of this electrode shall be low enough to ensure that under fault conditions the voltage on exposed metalwork will not exceed 50V. BS 7671:2008 411.5.3 (ii) states that  $R_A I_{\Delta n} \leq 50 \text{ V}$  where  $R_A$  is the customer's electrode resistance and  $I_{\Delta n}$  is the rated residual operating current of the residual current device (RCD). BS 7671:2008 also suggests that  $R_A$  should not exceed  $200\Omega$  otherwise it may not be stable.
- BS 7671:2008 generally requires the use of an RCD for domestic properties, including installations which utilise a distributor's earth terminal; these systems are not TT systems.

## Appendix C – Typical Electrode Systems

Table C-1 shows various options for achieving earth resistance values.

**Note:** NetMap also contains earthing maps showing the earthing requirements to achieve 10Ω and 20Ω earths (refer to EDS 06-0018).

Table C-1 – Earth Electrode Values

Typical Soil Type/Soil Resistivity		10Ω Earth Resistance		20Ω Earth Resistance		100Ω Earth Resistance
		(a)	(b)	(a)	(b)	(c)
Loam	25Ωm	1 x 2.4m	1 x 2.4m	1 x 1.2m	1 x 2.4m	1 x 1.2m
Chalk	50Ωm	1 x 6.0m	2 x 2.4m	1 x 2.4m	1 x 2.4m	1 x 1.2m
Clay	100Ωm	3 x 4.8m	4 x 2.4m	2 x 4.8m	2 x 2.4m	1 x 1.2m
Sand, Gravel, Clay mix	<150Ωm	4 x 4.8m	7 x 2.4m	2 x 4.8m	3 x 2.4m	1 x 2.4m
	<200Ωm	5 x 4.8m	9 x 2.4m	3 x 4.8m	4 x 2.4m	1 x 2.4m
	>200Ωm	Site specific design required			1 x 6m or 2 x 2.4m + 1 x 1.2m	
Slate, Shale, Rock	500Ωm	Site specific design required				
Column (a) denotes		<b>Deep-driven Vertical and Horizontal Electrodes</b> Each deep-driven vertical electrode comprises of 1.2m rods coupled together to form the final vertical length e.g. 4.8m = 4 x 1.2m. Where there is more than one rod required, the spacing between them is 5m. The top of each electrode should be at a minimum depth of 0.6m below ground level.				
Column (b) denotes		<b>Short Vertical and Horizontal Electrodes</b> Each short-vertical electrode comprises of 1.2m rods coupled together to form the final vertical length e.g. 2.4m = 2 x 1.2m. Where there is more than one rod required, the spacing between them is 3m. The top of each electrode should be at a minimum depth of 0.6m below ground level.				
Column (c) denotes		It is assumed that LV PME system additional earths will be installed horizontally although they can be installed vertically if appropriate.				