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ENGINEERING DESIGN STANDARD

EDS 06-0016

LV NETWORK EARTHING DESIGN

Network(s):	EPN, LPN, SPN
Summary:	This standard details the design requirements for the earthing of low voltage (LV) networks.

Author:	Stephen Tucker	**Date:**	11/12/2024
Approver:	Paul Williams	**Date:**	16/12/2024

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Revision Record

Version	9.1	**Review Date**	13/11/2029
Date	11/12/2024	**Author**	Stephen Tucker

Reason for update: Clarification of the requirement for an additional earth electrode at each LV overhead line cable termination.

What has changed:

- Sections 5.2.3 & 5.7 revised to clarify that the requirement for an additional earth electrode at overhead line cable terminations applies to overhead mains only.

Version	9.0	**Review Date**	13/11/2029
Date	13/11/2024	**Author**	Stephen Tucker

Reason for update: Alignment with EDS 08-1101, EDS 08-2000 and the LV Jointing Manual.

What has changed:

- Section 3 revised and updated to include new abbreviations.
- Section 5.2.3 amended to include the IDNO boundary at a cable joint for all new IDNO connections and the requirement for an additional earth electrode at each LV overhead line cable termination (Figure 5-2).
- Section 5.5 revised to refer to the load balance requirements of EDS 08-2000.
- Section 5.7 revised and includes the requirement for an additional earth electrode at each LV overhead line cable termination.
- Section 13.2 neutral bonding changed to 50mm^2 to align with LV jointing manual (Table 13-2).
- Document reviewed.

Version	8.0	**Review Date**	26/11/2028
Date	26/11/2023	**Author**	Stephen Tucker

Reason for update: Updated to align with ENA EREC G12/5 and other earthing standards.

What has changed:

- Section 1 legacy summary removed.
- Section 5 restructured to align with ENA EREC G12/5.
- Section 5.2.3 neutral earth requirements in Figure 5-1 revised to align more closely with ENA EREC G12/5 in and new additional earth electrode diagram added as Figure 5-2.
- Section 6 earth terminal section added.
- Section 10 & 11 converting existing network and customers to PME aligned with ECS 06-0026.
- Section 12 looped services section re-written.
- Appendix A neutral current diversion section updated.
- Appendix B legislation section updated.
- Earthing system appendix removed and replaced with reference to EDS 06-0017.
- Minor wording changes throughout document.
- Document reviewed.

Version	7.1	**Review Date**	30/08/2024
Date	12/03/2021	**Author**	Stephen Tucker

Reason for update: References updated.

What has changed: Reference to withdrawn document EDS 06-0018 changed to EOS 06-0006.

Version	7.0	**Review Date**	30/08/2024
Date	30/08/2019	**Author**	Stephen Tucker

Reason for update: Periodic review to align with other earthing standards.

What has changed:

- Section 5 design criteria section restructured.
- Section 5.2.1 end-of-main electrode requirements for IDNO network boundary included.
- Section 10 reference to ECS 06-0026 added.

Version	6.0	**Review Date**	31/07/2019
Date	31/07/2015	**Author**	Stephen Tucker

Reason for update: Updated to align with other earthing standards.

What has changed:

- Section 5.2.1 simplification of neutral conductor earthing requirements.
- Section 13.1 revision of earth electrodes.
- Appendix A broken neutral explanation added.
- Appendix on typical electrode systems removed as it is covered in ECS 06-0023.

Version	5.0	**Review Date**	17/01/2017
Date	31/12/2013	**Author**	Stephen Tucker

Reason for update: Updated to align with ENA EREC G12/5.

What has changed:

- Section 5.2.1, 9 & 10 further clarity around the use of additional PME electrodes on underground networks added.
- Section 9 earth resistance value for introducing CNE into SNE networks changed back to 10Ω in line with revised ENA EREC G12/4 requirements.

Version	4.0	**Review Date**	12/04/2018
Date	12/04/2013	**Author**	Stephen Tucker

Reason for update: Updated to align with other standards.

What has changed:

- Section 6.3.4 legacy cable section removed.
- Section 10 earthing of service joints for PME conversion removed.

Version	3.1	**Review Date**	23/04/2015
Date	06/07/2012	**Author**	Stephen Tucker

Minor updates to ensure consistency with other standards and greater use of aluminium conductors. Document reviewed for publishing on G81 website.

Version	3.0	**Review Date**	22/04/2015
Date	17/11/2011	**Author**	Stephen Tucker

Underground cable sections revised. PNB section added.

Version	2.2	**Review Date**	01/06/2015
Date	29/09/2011	**Author**	Stephen Tucker

Reclassification of document from Earthing Design Manual Section 6.

Version	2.0	**Review Date**	01/06/2015
Date	01/06/2010	**Author**	Stephen Tucker
Completely rewritten to provide a more consistent and practical approach. Customer installation earthing moved to Section 7 of the Earthing Design Manual.			
Version	1.0	**Review Date**	31/03/2011
Date	31/03/2008	**Author**	Stephen Tucker/ Rob Weller
Original.			

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1 Introduction

This standard 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 ENA EREC G12/5 and also reflects the requirements of BS 7671:2018+A2:2022 where relevant.

Guidance on the earthing associated with customer installations, including situations where an earth terminal can or cannot be provided is included in EDS 06-0017.

Guidance on the practical application of this standard for the provision of earth terminals, cut-out earthing requirements, resolving earth fault loop impedance (EFLI) issues, maintaining the correct earthing during repairs and alterations to SNE services, and upgrades to PME is included in ECS 06-0026.

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.

For secondary earthing design (including the substation LV earth) refer to EDS 06-0014.

For pole-mounted equipment earthing design refer to EDS 06-0015.

For the earthing design associated with customer installations, including the provision of an earth terminal, refer to EDS 06-0017.

3 Glossary and Abbreviations

Term[1]	Definition
ABC	Aerial Bundled Conductor
CNE	Combined Neutral and Earth. A cable where the neutral and protective functions are combined in a single conductor
Customer	Any person who has responsibility for premises connected by agreement to distribution networks owned by UK Power Networks
Customer's Premises	Any area or building occupied by the customer
DNO	Distribution Network Operator.
Earth Electrode	A metal rod, plate or strip conductor buried in the earth for the purpose of providing a connection with the general mass of earth
ELI	Earth Loop Impedance. See Earth Fault Loop Impedance
EFLI*	Earth Fault Loop Impedance. The impedance of the earth fault current loop starting and ending at the point of earth fault. This impedance is denoted by the symbol Zs. The part of the earth fault loop impedance which is external to the customer installation is denoted by the symbol Ze
EMC	Electromagnetic Compatibility
EPR	Earth Potential Rise. The potential (or voltage) rise that occurs on any metalwork due to the current that flows through the ground when an earth fault occurs on the HV or LV network
GSA	UK Power Networks Geospatial Analytics application
Hybrid Network**	A network originally designed as TN-S (made up of Separate Neutral and Earth (SNE) cable) where Combined Neutral and Earth (CNE) cable (normally associated with a TN-C-S system) has been inserted over time due to fault repairs, diversions or new connections
HV	High Voltage. Any voltage exceeding LV (as defined by The Electricity Safety Quality and Continuity Regulations 2002). In the context of this document, HV refers to 20kV, 11kV, 6.6kV, 3kV and 2kV
IDNO	Independent Distribution Network Operator
Looped Service	A looped service occurs where two or more properties share the same service, e.g. a connection to the live-side of the cut-out or a connection to the service
LV	Low Voltage. A voltage exceeding 50V (rms) measured between phases (or phase to earth) but not exceeding 1000V phase to phase or 600V phase to earth (as defined by The Electricity Safety Quality and Continuity Regulations 2002)
Main	A low voltage underground cable or overhead line which connects a substation to either a pot end earth, an overhead line earth or to another substation
NetMap	UK Power Networks graphical information system (GIS)
NCD	Neutral Current Diversion
PILC	Paper Insulated Lead Sheathed Cable

[1] * Definitions from BS 7671.
** Definitions from ENA EREC G12.

Term[1]	**Definition**
PME Enabled Networks**	A hybrid network where neutral-earth bonds are installed in accordance with the ESQCR. PME enabled networks enable a connected service to offer a PME earth terminal. PME enabled networks enable the retention of earths from SNE cables at service connections provided they meet the relevant criteria
PME	Protective Multiple Earthing. A form of TN-C-S earthing. Refer to EDS 06-0017 for further information
RCD*	Residual Current Device. 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
Secondary Substation	A substation with an operating voltage of 20kV, 11kV or 6.6kV and may include transformation to 400V. Also termed 'Distribution Substation'
SNE	Separate Neutral and Earth. A cable where the neutral and protective functions are provided by separate conductors
Service	A low voltage underground cable or overhead line, which connects a customer to a main or directly to a substation
Service Termination	The cut-out where the service cable terminates
TN-C-S*	Terre Neutral-Combined-Separate. A system in which the neutral and protective functions are combined into a single conductor in part of the system. A DNO earth terminal can be provided at the customer's installation. Refer to EDS 06-0017 for further information
TN-S*	Terre Neutral-Separate. A system having separate neutral and protective conductors throughout the system. A DNO earth terminal can be provided at the customer's installation. Refer to EDS 06-0017 for further information
TT*	Terre Terre. 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. A DNO earth terminal is **not** provided at the customer's installation. Refer to EDS 06-0017 for further information
UK Power Networks Ltd	UK Power Networks (Operations) Ltd consists of three electricity distribution networks: • Eastern Power Networks plc (EPN). • London Power Network plc (LPN). • South Eastern Power Networks plc (SPN).

4 LV Earthing Standard

All new low voltage mains and services shall be constructed to PME standards described in Section 5 using combined neutral earth (CNE) cables and/or 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 5.

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 (refer to Appendix A) and uncertainty when isolating the supplies. Refer to EDS 08-1103 for further guidance on multiple supplies.

5 Design Criteria

5.1 Secondary Substation Earthing

In secondary substations supplying LV networks, the earth potential rise (EPR) on the LV neutral/earth shall not exceed the applicable touch voltage limit during an HV earth fault.

If calculations show that under high voltage earth fault conditions the transfer voltage from the HV system can exceed this value, the HV and LV earthing systems shall be electrically segregated. The physical segregation shall be such that the above requirement is achieved.

For further details on secondary substation earthing and the separation of HV/LV earths refer to EDS 06-0014.

5.2 Supply Neutral Conductor

5.2.1 General

Protective devices shall not be included in the supply neutral conductor or any earthing connection on the LV network.

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.

All reasonable precautions shall be taken to ensure continuity of the supply neutral conductor.

5.2.2 Size

The supply neutral conductor in any three-phase four-wire, or single-phase three-wire (split phase) main or service shall not be less than half the equivalent cross-sectional area of the phase conductor.

The supply neutral conductor in any single-phase two-wire or two-phase three-wire main or service shall be not less than the equivalent cross-sectional area of the phase conductor, with recommended minimum values of 10 mm² for copper conductors and 16 mm² for aluminium conductors.

5.2.3 Earthing Requirements

In addition to the transformer LV neutral earth electrode at or near the secondary substation, the supply neutral conductor shall be connected to an earth electrode or another main to ensure that the earth resistance of the supply neutral conductor (measured relative to earth) does not exceed 20Ω at any point on the network. The additional neutral earth electrode requirements based on ENA EREC G12 are shown in Figure 5-1.

The additional earth connections also ensure that the voltage of the supply neutral conductor is as close to that of earth as possible, and provide resilience against broken neutral conditions, therefore reducing the likelihood of the neutral rising to undesirable voltage levels (refer to Appendix A).

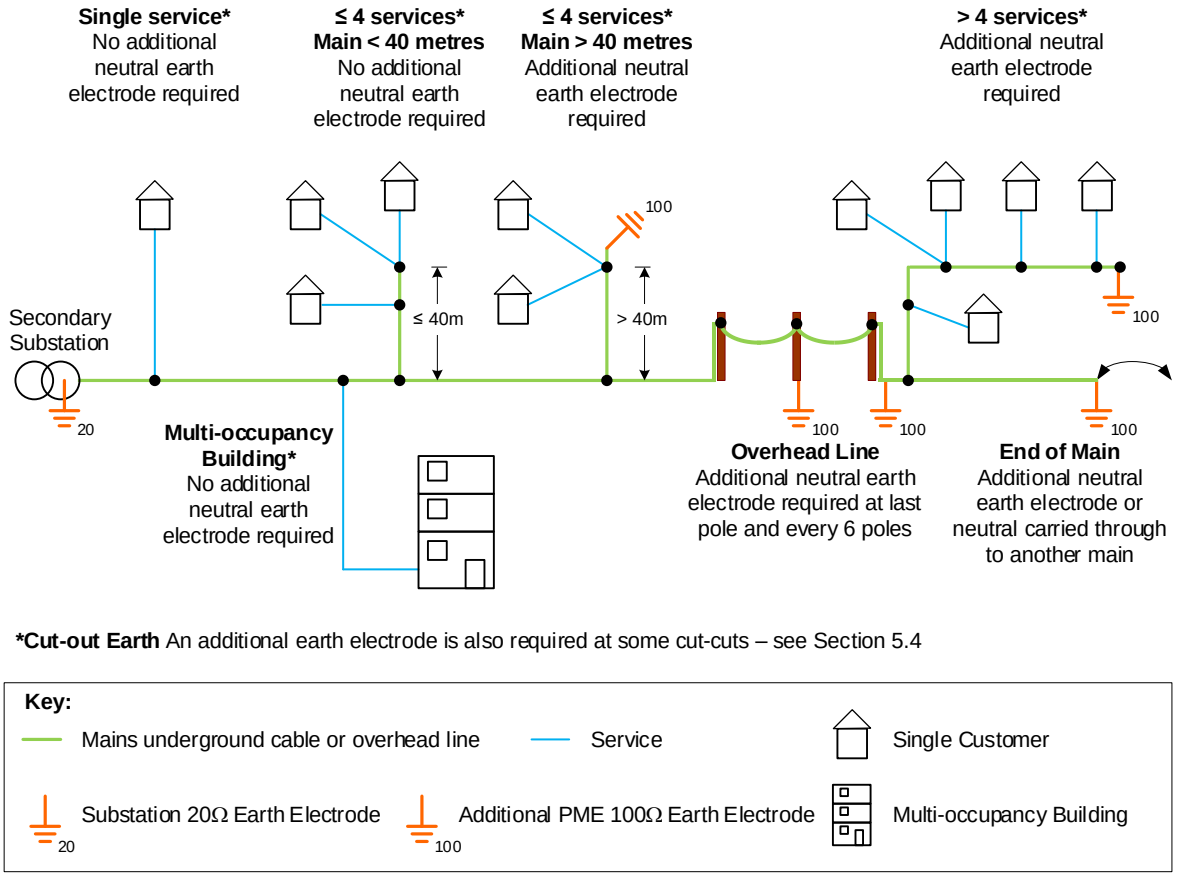

Figure 5-1 – ENA EREC G12 Supply Neutral Conductor Earthing Requirements for PME

However, for ease and consistency of application across UK Power Networks distribution networks an additional earth electrode (using the electrode specified in Section 13.1) shall be installed at the following locations as shown in Figure 5-2:

- The pot end at the end of an LV underground main.
- The last pole of an LV overhead main.
- Every six poles/spans of an LV overhead main.
- At each LV overhead main cable termination.
- All cut-outs above 100A where practical.
- The IDNO network boundary in accordance with EDS 08-1101.

Note: Earth electrodes shall not be installed in any joint in accordance with ECS 02-0415; earth electrodes should be installed at a pot end or from a link box.

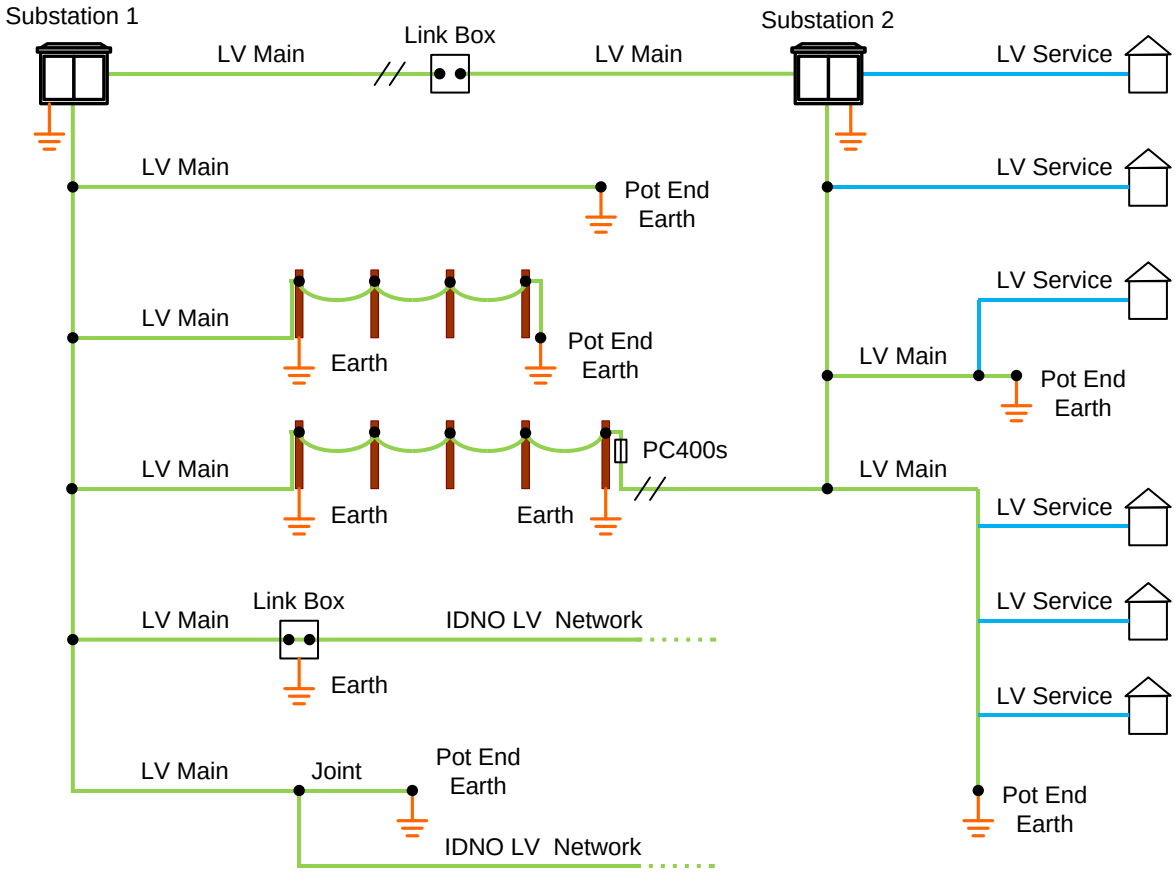

Figure 5-2 – Additional Earth Electrode Requirements

5.3 LV Earth Resistance

The resistance of the supply neutral conductor to earth shall not exceed 20Ω at any point. To achieve this value the earth electrode resistance values given in Table 5-1 shall be used.

Table 5-1 – Earth Electrode Resistance Values.

Electrode	Resistance Value
Transformer neutral earth electrode	20Ω
Additional earth electrode	100Ω

5.4 Cut-out Earth

For cut-out earthing refer to ECS 06-0026.

5.5 Load Balance

The voltage that appears on the supply neutral conductor (and consequently on any customer 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 load balance will therefore minimise neutral voltage rise and consequent risk of shock under broken neutral conditions. Load balance will also minimise neutral voltage rise under normal operating conditions, reduce losses, and maximise the load capacity available from connected assets.

For the design of new LV networks (and alterations to existing networks) careful consideration shall be given to ensure load balance. Refer to EDS 08-2000 for further guidance.

Where 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.

5.6 New Underground Cable Networks

New underground networks shall use CNE cable to form a PME network.

5.7 Overhead Line Networks

New overhead line networks shall be constructed using aerial bundled conductors (ABC) to form a PME network.

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 additional earth electrode at the following locations:
  - Every six poles/spans of the LV overhead main.
  - Each LV overhead main cable termination.
  - The last pole of the LV overhead main.
- The cable sheaths and metallic cable boxes on poles supporting cable terminations shall be connected to the supply neutral conductor.

6 Earth Terminal

The Electricity Safety, Quality and Continuity Regulations 2002 (24(4)) (refer to Appendix B) 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.

Therefore, an earth terminal shall be provided from the PME system wherever appropriate, however there are some situations where it may not be appropriate. For further information on earthing terminal requirements refer to EDS 06-0017.

7 Earth Fault Loop Impedance (EFLI)

For guidance on EFLI refer to EDS 08-2000, EDS 06-0004 and ECS 06-0026.

8 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.

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 20Ω.
- 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 considered a PME earth terminal and the appropriate labelling applied (refer to ECS 06-0026).

Various PNB arrangements are illustrated in Figure 8-1 and Figure 8-2.

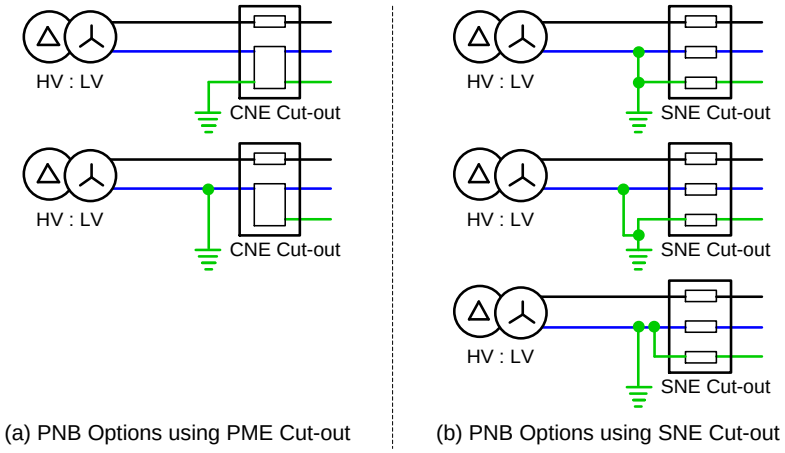

Figure 8-1 – PNB Options using CNE and SNE Cut-outs

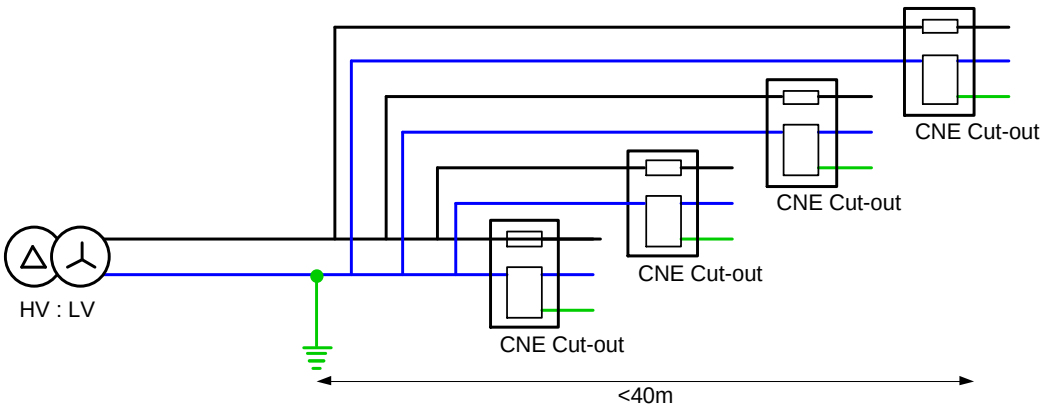

Figure 8-2 – PNB for up to Four Customers

9 Converting Existing 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 9-1 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 is required at the transition furthest from the secondary substation.

  Note: A length of metallic sheathed (PILC) SNE 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 detailed in Section 5.2.3.

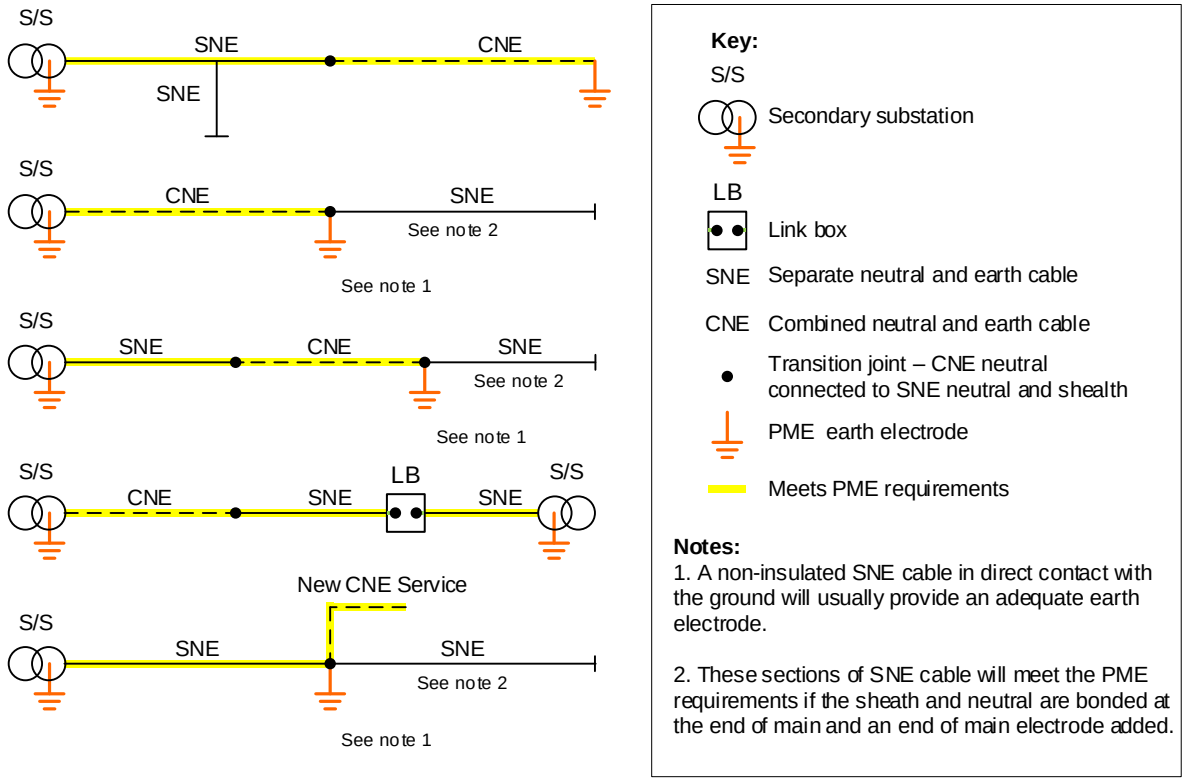

Figure 9-1 – Typical Application of CNE Cables in Existing Networks

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.
- 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 for TN-C-S or can be upgraded), or alternatively a TT earthing system shall be used.
- Existing (SNE) customers connected to underground mains beyond the ABC may retain a SNE service provided they are connected to a continuous length of non-insulated metallic sheathed (PILC) cable in direct contact with the ground sufficient to limit the rise of potential under broken 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 10Ω or less. Table 9-1 specifies the length required to achieve this in different soil conditions.

All reasonable precautions shall be taken to ensure that customers supplied via SNE service cables are not adversely affected by repairs, modifications, or additions to existing networks. Where 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 (PILC) cable in direct contact with the ground, sufficient to limit the rise of potential under broken 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 10Ω or less. Table 9-1 specifies the length required to achieve this in different soil conditions (refer to NetMap and GSA for soil resistivity data, and EOS 06-0006 for further information).

Table 9-1 – PILC Cable Lengths Required to Achieve 10Ω

Typical Soil Type	Resistivity (Ωm)	Length (m)
Loams, garden soils etc.	25 or less	8
Chalk	50 or less	15
Clay	100 or less	29
Marsh/Peat	200 or less	58
Sand/Gravel/Clay mix	300 or less	87
Slate/Shale/Rock	500 or less	115

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

10 Converting Existing Customers to PME

Customers with an existing TN-S earth from an SNE service cable, can be converted to TN-C-S (PME) earth provided the following requirements are satisfied:

- The customer's installation complies with BS 7671 (at least in terms of main protective conductor sizing and equipotential bonding).
- A new PME cut-out is installed.
- There are no shared metallic services (water, gas etc) with other properties (e.g. terrace houses, flats in the same building etc.).
- The neutral and earth are combined using one of the following methods:
  - Install a new CNE service cable from the main to the cut-out.
  - Install a new CNE service cable from at least 1 metre away from the customer property to the cut-out.
  - Combine the neutral and earth conductor in a straight joint at least 1 metre away from the customer property.

It is not permitted to only bond the neutral and earth at the cut-out to provide PME as there is a potential to cause fatal electric shock or property damage under abnormal network conditions (see Appendix A).

Note 1: Some installations are not suitable for PME and shall not be converted to PME for reasons of safety. In such situations (and if there is any doubt), TT earthing should be used.

Note 2: Multiple occupancy buildings may have a single SNE service or may use multiple SNE services from the distribution network. A single service may be converted as detailed above, but multiple SNE services shall not be converted to multiple PME services, nor should there be any mix of earthing types in the building. Refer to EDS 06-0017 for further guidance.

Note 3: All LV distribution networks should generally be assumed to be PME when providing new supplies, even if they were originally constructed using SNE cables. Therefore, all new installations shall meet the TN-C-S requirements for equipotential bonding specified in BS 7671.

Note 4: Connections that specifically require a TN-S earth shall not be supplied from hybrid networks (those with a mix of CNE and SNE cables). Providing an SNE service connected to a CNE cable will not necessarily avoid the potential hazards of a PME network in the event that there is a break in the neutral conductor upstream of the service connection.

11 Repairs and Alterations to SNE Service Cables

Repairs and alterations to SNE service cables shall be based on the following principles:

- Existing TN-C-S (PME) earth from an SNE service – bond the neutral and earth at the cut-out, in the service/mains joint and any joint in-between.
- Existing TN-S earth from an SNE service – maintain separation of the neutral and earth along the entire length of the service from main to cut-out.

This approach ensures the customer's property is not put at risk while accepting some risk to the network (possible future service faults) to minimise the impact to customer service and cost efficiency.

The following practices have the potential to cause fatal electric shock or property damage, under abnormal network conditions, and are therefore not permitted:

- Combining neutral and earth conductors when repairing SNE service cables (compromising the separation between neutral and earth).
- Combining neutral and earthing conductors to provide a PME type supply (a modification to PME can only be achieved safely provided certain other criteria are satisfied).

Refer to ECS 06-0026 for further guidance.

12 Looped Services

The earthing provision for a looped service shall be consistent such that each property uses the same method of earthing i.e. TN-C-S, TN-S or TT.

During any alterations to the services, it is essential that the same method of earthing is replicated across all properties unless the loop is removed and either becomes or is replaced by a separate service.

Note: If one property is converted to PME, with the other retaining a TN-S earth from a SNE cable, there could be a risk of differences in potential between un-bonded metalwork within the TN-S earthed property in the event of a broken neutral fault on the main or service.

For further information on looped services refer to EDS 08-2101.

13 Installation Requirements

13.1 Earth Electrodes

The permitted earth electrodes are given in Table 13-1.

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 13-1 – Earth Electrodes

Cable Size	Underground Cable Network	Overhead Network
Up to 35mm^2	1.2m earth rod connected via 35mm^2 covered copper cable or 2m of 35mm^2 **bare** copper cable laid directly in trench underneath the LV cable	1.2m earth rod connected via 35mm^2 covered copper cable (below ground) and 95mm^2 covered aluminium cable (above ground)
> 35mm^2	1.2m earth rod connected via 70mm^2 covered copper cable or 2m of 70mm^2 **bare** copper cable laid directly in trench underneath the LV cable	1.2m earth rod connected via 70mm^2 covered copper cable (below ground) and 95mm^2 covered aluminium cable (above ground)

13.2 Bonding Connections

The minimum size of earthing and bonding connections are given in Table 13-2. Below ground, i.e. buried, earthing and bonding conductors shall be copper.

Table 13-2 – Bonding Connections

Connection Type	Minimum Copper Conductor
LV earth at secondary substation i.e. connection between transformer neutral (star-point) and earth	Refer to EDS 06-0014 for requirements
Between neutral busbar and earth busbar at secondary substation	
LV earth at pole-mounted sites	Refer to EDS 06-0015 for requirements
Between supply neutral conductor and PME earth electrode	Minimum 50mm^2
Between supply neutral conductor and link box or feeder pillar steelwork	
Between sheath of SNE cable and neutral of CNE cable	
At customer's premises between service neutral and main earthing terminal	16mm^2 or half the size of the neutral meter tail, whichever is the larger

14 References

14.1 UK Power Networks Standards

ECS 02-0415	LV Jointing Manual
EDS 06-0004	Earth Fault Loop Impedance Requirements (internal document only)
EOS 06-0006	Substation Earthing Data
EDS 06-0014	Secondary Substation Earthing Design
EDS 06-0015	Pole-mounted Equipment Earthing Design
EDS 06-0017	Customer LV Installation Earthing Design
ECS 06-0026	LV Supply Earthing Guide
EDS 08-1101	IDNO Networks
EDS 08-2000	LV Network Design
EDS 08-2101	LV Customer Supplies up to 100A

14.2 National and International Standards

SI 2002 No. 2665	The Electricity Safety, Quality and Continuity Regulations (ESQC) 2002 as amended (2006)
ENA EREC G12/5	Requirements for the Application of Protective Multiple Earthing to Low Voltage Networks
BS 7671:2018+A2:2022	Requirements for Electrical Installations (IET Wiring Regulations 18th Edition)

Appendix A – Neutral Current Diversion (informative)

Neutral current diversion (NCD) can occur in properties due to in appropriate PME conversion (A.1).

NCD can also occur within the structure of a steel-framed building or buildings with shared metallic services, which are supplied with multiple services from a combined neutral and earth network, due to a broken neutral (A.2) or unbalanced load (A.3).

A.1 Broken Neutral – PME Conversion

Figure A-1 (a) shows the current flow under normal conditions.

Figure A-1 (b) and (c) show the current flow under broken neutral conditions with a neutral-earth bond at the cut-out only (b) and at both the cut-out and service joint (c). This demonstrates that there is likely to be significant current flow through the service cable and cut-out during a broken neutral fault if the neutral and earth are only bonded at the cut-out; this could lead to overheating and damage to the service cable or the cut-out and possible fire.

Therefore, when converting existing customers to PME it is important that the requirements detailed in Section 10 are satisfied.

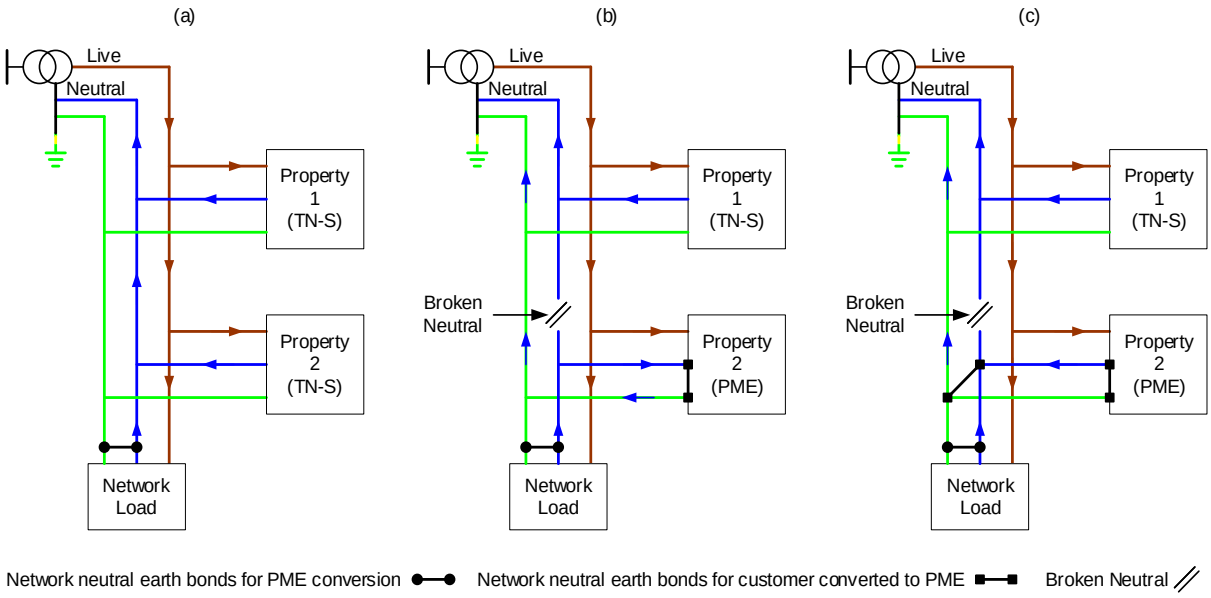

Figure A-1 – Neutral Current Flow in a Network Converted to PME due to a Broken Neutral

A.2 Broken Neutral – Multiple Occupancy Building

When multiple services from a combined neutral and earth network are provided to a steel-framed building, neutral current may flow through the building structure due to a broken neutral on the distribution network. Figure A-2 (a) shows the normal flow of neutral current and Figure A-2 (b) shows the flow of neutral current through the building structure due to a broken neutral.

Neutral current diversion (NCD) and the associated risks can be virtually eliminated if all services are provided from a single point (e.g. intake room, feeder pillar or a secondary substation) on the combined neutral and earth network.

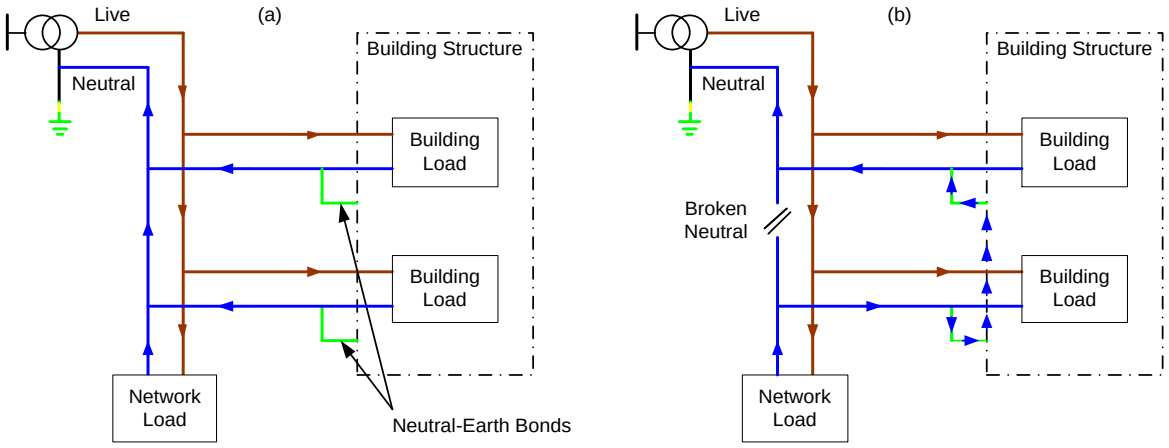

Figure A-2 – Neutral Current Flow in a Multiple Occupancy Building with Multiple Services due to a Broken Neutral

A.3 Unbalanced Load

Unbalanced three-phase loads and single-phase loads cause current to flow in the neutral conductor. NCD occurs when multiple CNE 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 and bonding conductors may result in overheating and consequential fire risk. It is for this reason that BS 7671 recommends certain sizes for customer (protective) equipotential bonding.

Appendix B – Legislation (informative)

The Electricity Safety, Quality and Continuity Regulations 2002 contain several clauses on earthing. A summary of the relevant regulations is included below.

Citation, commencement and interpretation

1 (5) In these Regulations, unless the context otherwise requires:

Distributor means a party that distributes electricity to customers using electrical lines and equipment that they own or operate.

Consumer means any person supplied or entitled to be supplied by a supplier but in regulations 24, 25 and 26 shall not include, in respect of any supply to meet haulage or traction requirements, any person who is an operator of a network within the meaning of Part I of the Railways Act 1993(1).

Consumer's installation means the electric lines situated upon the consumer's side of the supply terminals together with any equipment permanently connected or intended to be permanently connected thereto on that side.

Electric line means 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; and

(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.

Distributing main means a low voltage electric line which connects a distributor's source of voltage to one or more service lines or directly to a single consumer's installation.

Street electrical fixture means 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.

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

Supplier means a person who contracts to supply electricity to consumers.

Continuity of the supply neutral conductor and earthing connections

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.

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

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.

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.

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

8 (5) Paragraphs (1) to (3) shall not apply to a network which is situated within a generating station if, and only if, adequate alternative arrangements are in place to prevent danger.

Protective multiple earthing

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

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.

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.

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

Earthing of metalwork

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.

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.

Equipment on a consumer's premises

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.

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.

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.

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.

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.