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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 earthing of low voltage (LV) networks.

Owner:	Allan Boardman	**Date:**	31/07/2015
Approved By:	Steve Mockford	**Approved Date:**	11/08/2015

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Revision Record

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Why has the document been updated: Updated to provide consistency with other earthing standards. **What has changed:** • Simplification of neutral conductor earthing requirements (Section 5.2). • Revision of earth electrodes (Section 6.1). • Appendix on typical electrode systems removed as it is covered in ECS 06-0023. • Broken neutral explanation added (Appendix C).			
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Further clarity around the use of additional PME electrodes on underground networks added (Sections 5.2, 5.3.2 and 5.3.3). Earth resistance value for introducing CNE into SNE networks changed back to 10Ω in line with revised ENA ER G12/4 requirements (Sections 5.3.2)			
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Original			

Contents

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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 ENA ER G12/4 and has also reflects the requirements of BS 7671:2008 (2011) incorporating Amendment No 3: 2015 (IET 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 3).
- LV Earthing Standard (Section 4).
- PME Network Design (Section 5).
- LV Earthing Requirements (Section 6).
- References (Section 7).
- 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) for specific applications 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[1]

Term	Definition
CNE	Combined Neutral and Earth. A cable where the neutral and protective functions are combined in a single conductor
Customer/Consumer	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 occupied by 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
DNO	Distribution Network Operator. See distributor
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
Earth Loop Impedance (ELI)	See Earth Fault Loop Impedance
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 Zs. The part of the earth fault loop impedance which is external to the customer installation is denoted by the symbol Ze.
Earthing Systems	See separate definitions and Appendix B for further details
Earthing Terminal	The main earth terminal for an installation is usually located close to the incoming service. If provided by UK Power Networks as part of a PME supply (TN-C-S) this will be directly connected to the supply neutral conductor at the supply terminals
EMC	Electromagnetic Compatibility
EPR	Earth Potential Rise (EPR) or Rise of Earth Potential (ROEP). EPR or ROEP is 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
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

[1] *Definitions taken from the Electricity Safety, Quality and Continuity Regulations 2002.
**Definitions taken from BS 7671.

Term	Definition
IDNO	Independent Distribution Network Operator
Inset Network	Privately owned electricity supply network, owned and operated by a licensed Independent Distribution Network Operator (IDNO), supplied at a boundary point or points from the DNO network
Low-voltage (LV)	LV refers to any voltage less than 1000V. The LV network refers to the 400V distribution system
Multi-service	Any electric line through which energy may be supplied to two, three or four adjacent customers from any distributing main or substation
NetMap	UK Power Networks graphical information system (GIS)
Protective Multiple Earthing (PME (TN-C-S)	Protective Multiple Earthing 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
Residual Current Device (RCD)	An RCD is a current operated device which measures the imbalance between phase and neutral currents, and if this leakage current exceeds a pre-set level will operate to interrupt the current flow. Typical domestic RCDs have a 30mA operating threshold
ROEP	Rise of earth potential. See EPR
Secondary (Distribution) Substation	An HV/LV substation typically transforming 22kV, 20kV, 11kV or 6.6kV to 400V
SNE	Separate Neutral and Earth. A cable where the neutral and protective functions are provided by separate conductors
Service Line*	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	See Service Line
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
TN-C-S	See PME
TN-S	See Cable Sheath Earth/Separate Continuous Earth Wire
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 (typically buried earth rods and/or 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
UK Power Networks (Operations) Ltd	UK Power Networks (Operations) Ltd consists of three electricity distribution networks as follows: • Eastern Power Networks plc (EPN) • London Power Network plc (LPN) • South Eastern Power Network plc (SPN)

4 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 LV 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 5 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 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[2] and uncertainty when isolating the supplies. Refer to EDS 06-0017 for further information on multiple supplies.

[2] 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 EMC issues etc. Furthermore, equipotential bonding conductors may carry neutral current resulting in overheating and consequential fire risk. Refer to EDS 06-0017 for further information.

5 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.

5.1 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) 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 to ensure they are permanently connected.
- 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 5.2).
- The resistance of the supply neutral conductor to the earth shall not exceed 20Ω at any point (refer to Section 6.3).
- Loads shall be shown uniformly distributed across the phases along a main at the design stage (refer to Section 5.5).

5.2 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 20Ω 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 (refer to Appendix C). This means that the combined neutral/earth conductor will be earthed at multiple locations.

The additional neutral earth electrodes are illustrated in Figure 5-1 and shall be installed as follows:

- In the pot-end 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.
- In the pot-end at the end of any branch or service supplying more than four customers.
- In the pot-end at the end of any branch or service supplying more than one customer and longer than 40m.
- In the pot-end at the end of any branch or service supplying street furniture with a PME earth terminal.
- At additional locations on overhead line systems to ensure the distance between electrodes are not more than six spans.

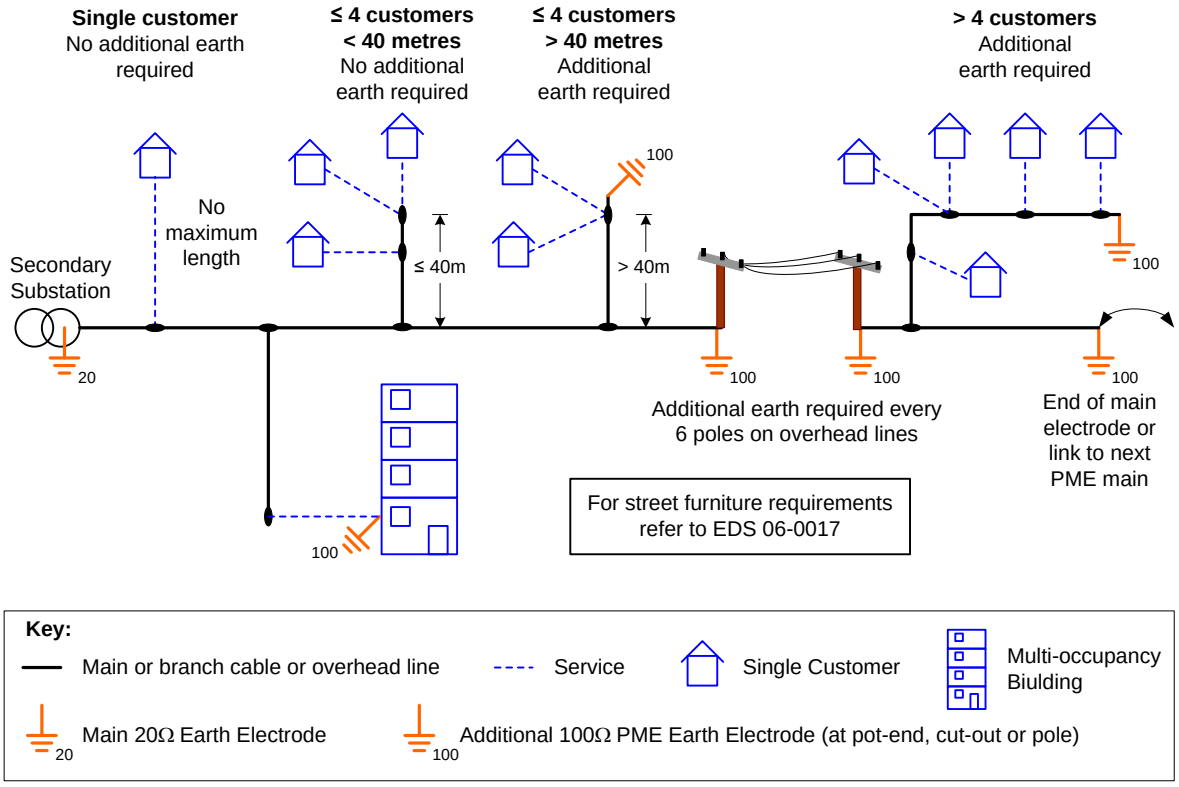

Figure 5-1 – Supply Neutral Conductor Earthing Requirements for PME

However for ease of application the neutral conductor shall be connected to earth (using the electrode specified in Section 6.1) as follows:

- All pot-ends on underground cable networks.
- All cut-outs above 100A for large services and multi-occupancy buildings. **Note:** The earth is usually placed in the cable trench outside the building.
- Not more than every six spans on LV overhead line networks.
- At the boundary with an inset network.

Note: Earth electrodes shall not be installed in any joint.

5.3 Underground Cable Networks

5.3.1 New Underground Cable Networks

New underground networks shall use CNE cable and an earth terminal shall be provided from the PME system wherever it is appropriate. However there are some situations where it may not be appropriate; refer to EDS 06-0017 for further details.

5.3.2 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 5-2 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 is required at the transition joint furthest from the secondary substation. However a length of lead sheathed 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 above.

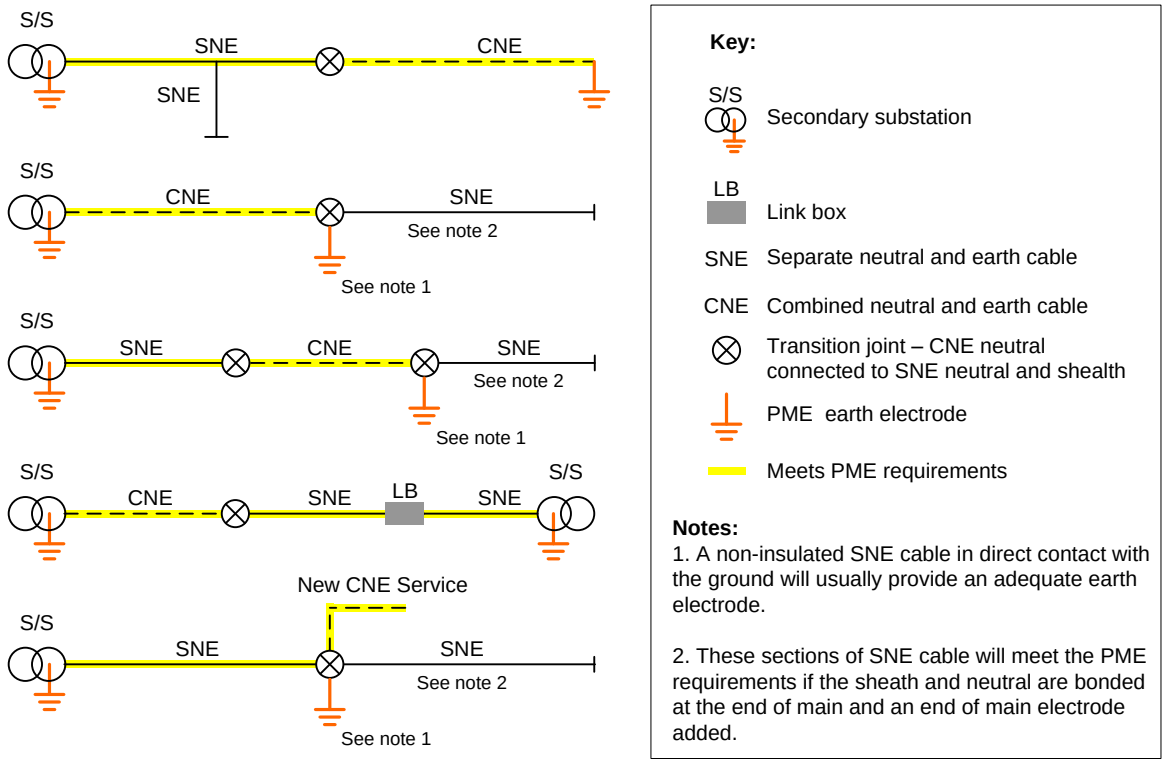

Figure 5-2 – Typical Application of CNE Cables in Existing Networks

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 10Ω or less. Table 5-1 specifies the length required to achieve this in different soil conditions (refer to NetMap for soil resistivity data and EDS 06-0018 for further information).

Table 5-1 – Non-insulated Sheathed 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), or a TT earthing system shall be used.

5.3.3 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) supply 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 in the same building). 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 required at the service joint. However a length of SNE 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[3].

[3] Appendix C explains the implications of only bonding the neutral and earth at the cut-out.

5.3.4 Looped Services

When alterations are made to any cable associated with a SNE cable looped[4] 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 main[5] 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 main service. Refer to EDS 08-0129 for further information.

[4] 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 main service.
[5] The main service is the service that connects directly to the mains cable and to which the loop service connects.

5.4 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. If the supplies are single-phase they should be reconfigured to ensure phase balance across all three phases as much as possible.

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 10Ω or less. Table 5-1 specifies the length required to achieve this in different soil conditions.

5.5 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 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 treated as a PME earth terminal and the appropriate labelling applied (Refer to EDS 06-0017).

Various PNB arrangements are illustrated in Figure 5-3 and Figure 5-4.

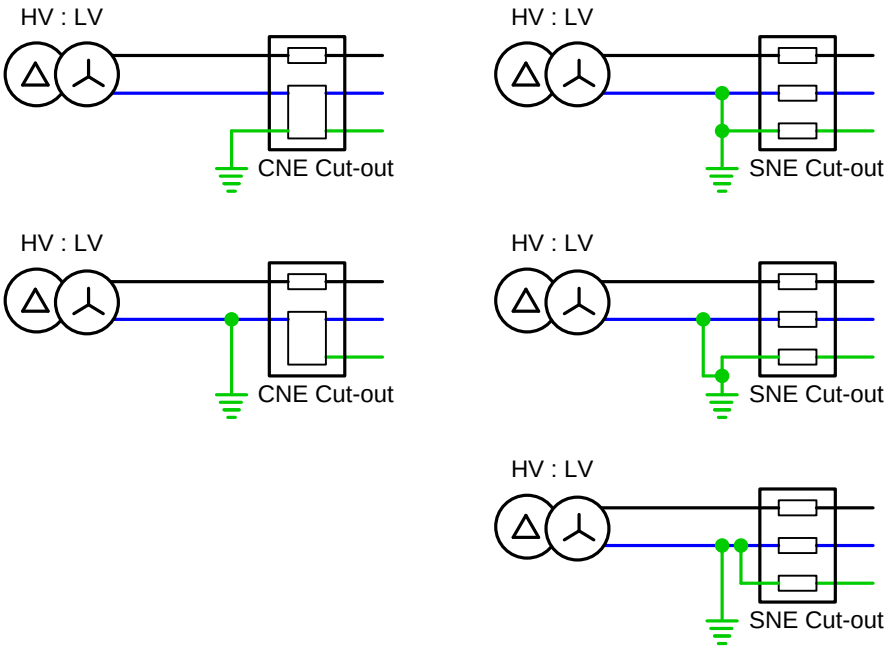

Figure 5-3 – PNB Options using CNE and SNE Cut-outs

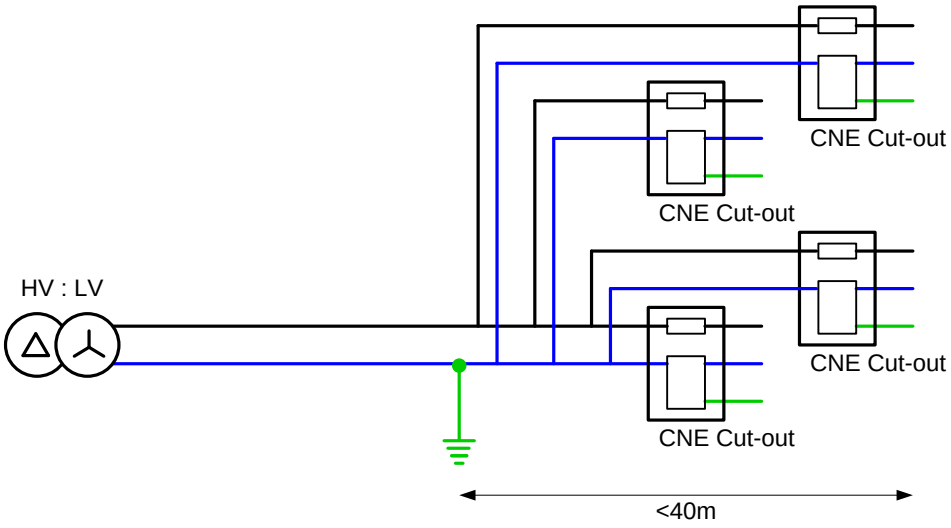

Figure 5-4 – PNB for up to Four Customers

5.6 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.

5.7 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).

6 LV Earthing Requirements

6.1 Earth Electrodes

The permitted earth electrodes are given in Table 6-1. Refer to **Error! Reference source not found.** 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 6-1 – 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)

6.2 Bonding Connections

The minimum size of earthing and bonding connections are given in Table 6-2. 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 6-2 – 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^2: 50mm^2 PVC covered aluminium cable or 35mm^2 PVC covered copper cable For cable sizes greater than 35mm^2: 95mm^2 PVC covered aluminium cable or 70mm^2 PVC covered copper cable
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. **Note:** 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 **Note**: 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^2 or half the size of the neutral meter tail, whichever is the larger

6.3 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 6-3 shall be used.

Table 6-3 – Earth Electrode Resistance Values.

Electrode	Resistance Value
Main LV Earth	20Ω
Additional PME Earth	100Ω

7 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 LV 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 3: 2015 – Requirements for Electrical Installations (IET 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 (Terre-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 (Terre-Neutral-Combined)
A system in which neutral and protective functions are combined in a single conductor throughout the system.

TN-S (Terre-Neutral Separated)
A system having separate neutral and protective conductors throughout the system.

TN-C-S (Terre-Neutral-Combined-Separated)
A system in which neutral and protective functions are combined in a single conductor in part of the system.

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.

B.3 TN-S (Terre-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.

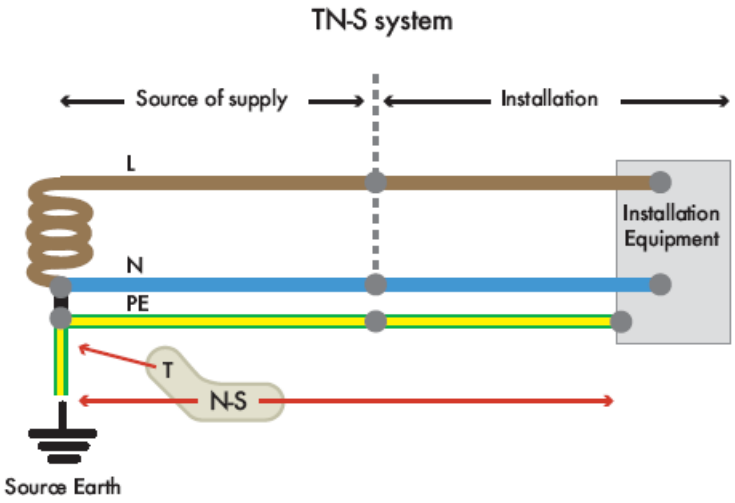

Figure B-1 – TN-S Earthing System

B.4 TN-C-S (Terre-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).

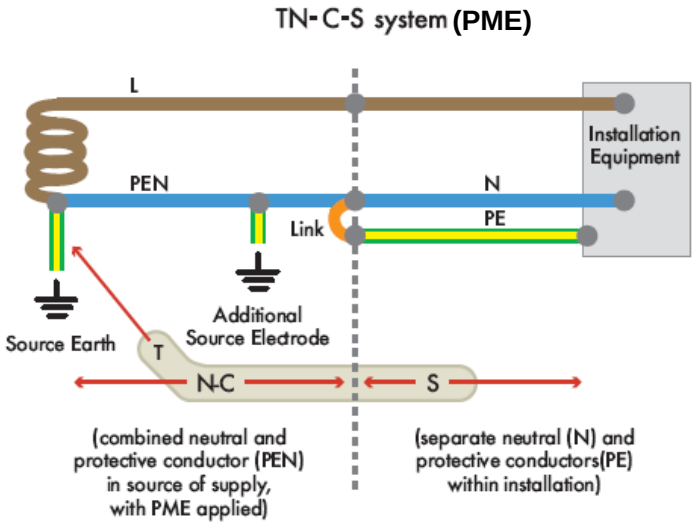

Figure B-2 – PME Earthing System

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.

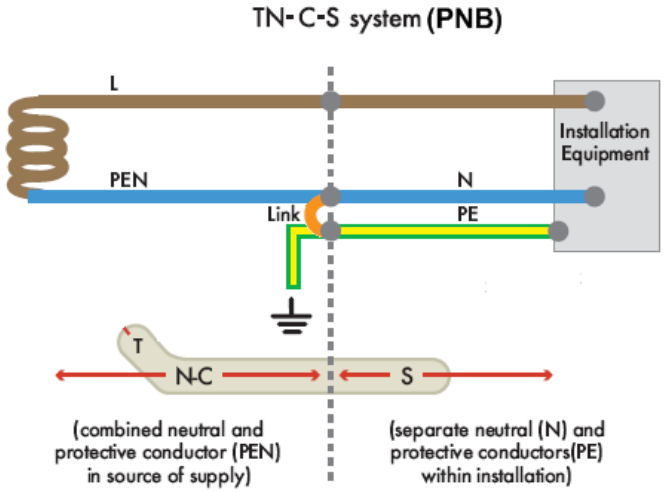

Figure B-3 – PNB Earthing System

B.5 TT (Terre-Terre)

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.

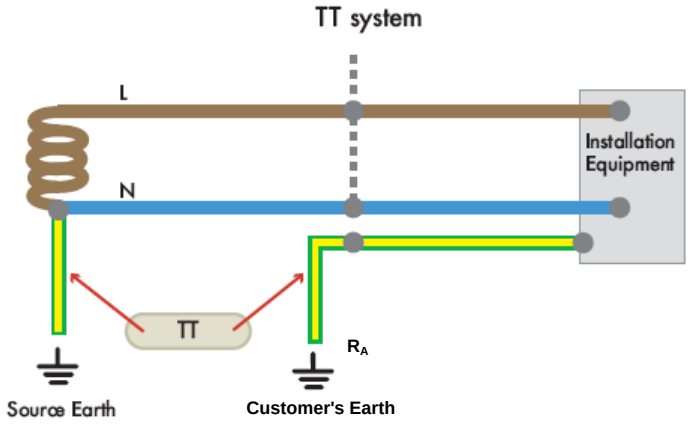

Figure B-4 – TT Earthing System

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 200Ω 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 – Broken Neutral

Figure C-5 (a) shows the current flow under normal conditions.

Figure C-5 (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 5.3.3 are satisfied.

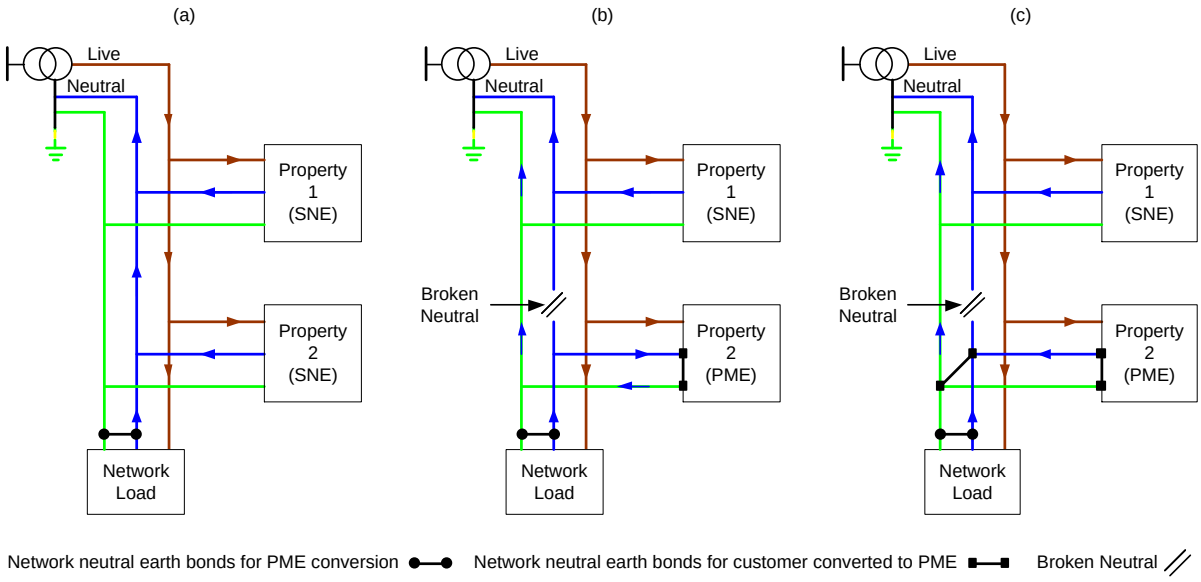

Figure C-5 – Current Flow in a Network Converted to PME due to a Broken Neutral