IMP/010/011 - Code of Practice for Earthing LV Networks and HV Distribution Substations

1. Purpose

The purpose of this document is to ensure the company achieves its requirements with respect to the Electricity Act 1989 (as amended) (the Act), the Electricity Safety, Quality, and Continuity (ESQC) Regulations 2002, the Electricity at Work (EAW) Regulations 1989, the Distribution Licences and The Distribution Code, by laying out the way in which Northern Powergrid will develop efficient, co-ordinated and economical earth systems on the Low Voltage (LV) networks and at High Voltage (HV) distribution substations.

This document supersedes the following documents, all copies of which should be destroyed.

Reference	Version	Date	Title
IMP/010/011	3.0	Jan 2018	Code of Practice for Earthing LV Networks and HV Distribution Substations

This Code of Practice contains detailed policy and practice on earthing of LV Networks and HV distribution substations. Section 3.20 provides basic information regarding HV and LV earthing of distribution substations.

2. Scope

The Code of Practice applies to all LV networks, services and HV distribution substations in Northern Powergrid (Northeast) plc and Northern Powergrid (Yorkshire) plc, the licensed distributors of Northern Powergrid and to the providers of connections to those networks.

It is not intended for this policy to be applied retrospectively with the exception of locations identified as having inadequate earth networks or those where work is being carried out on the network to satisfy the requirements of the ESQC Regulations 2002 as detailed in section 3.3.2 of this code of practice.

All new networks shall be equipped with earth systems in accordance with this Document

2.1. Table of Contents

3. Policy

3.1. Assessment of Relevant Drivers

The key internal business drivers relating to earthing of networks are:

- safety,
- financial; and
- quality of supply.

The external business drivers relating to the Application of earthing to distribution networks are detailed in the following sections.

3.1.1. Requirements of the Electricity Act 1989 (as amended)

The Electricity Act 1989 (as amended) ('the Act') lays down the core legislative framework for Northern Powergrid's operations as a distributor. Specifically, it gives force to the ESQC Regulations 2002, and in section 9 creates the key obligation to develop and maintain an efficient, co-ordinated and economical system of electricity distribution. Discharge of this obligation shall be supported in this document by providing guidelines on efficient application of earth systems to the wider network.

3.1.2. Requirements of the Electricity Safety, Quality and Continuity (ESQC) Regulations 2002.

The ESQC Regulations 2002 impose a number of obligations on the business, mainly relating to quality of supply and safety. All the requirements of the ESQC Regulations that are applicable to the application of earthing shall be complied with, specifically:

Reg. No	Text	Application to this Policy
3(1)(b)	…distributors…shall ensure that their equipment is so constructed…as to prevent danger…or interruption of supply, so far as is reasonably practicable	This will be achieved by installation of earth systems to standard designs by trained personnel.
6	A…distributor shall be responsible for the application of such protective devices to his network as will, so far as is reasonably practicable, prevent any current, including any leakage to earth, from flowing in any part of his network for such a period that that part of his network can no longer carry that current without danger.	This will be achieved by installation of systems and conductors to provide a low impedance path back to source for earth fault currents as far as is reasonably practicable
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	This will be achieved by installation of system conductors to minimise damage and accidental disconnection
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.	This will be achieved by installation of earth systems and conductors of sufficient rating and in such a manner as to prevent disconnection
8(2)a	A generator or distributor shall, in respect of any high voltage network which he owns or operates, ensure that – the network is connected with earth at, or as near as is reasonably practicable to, the source of voltage but where there is more than one source of voltage in that network, the connection with earth need only be made at one such point	This will be achieved by design of the network
8(2)b	A generator or distributor shall, in respect of any high voltage network which he owns or operates, ensure that – the earth electrodes are designed, installed and used in such a manner so as to prevent danger occurring in any low voltage network as a result of any fault in the high voltage network	This will be achieved through standard designs and where appropriate the separation between the HV and LV earth electrodes.

8(3)b	A generator or distributor shall, in respect of any low voltage network which he owns or operates, ensure that - every supply neutral conductor is connected with earth at, or as near as is reasonably practicable to, the source of voltage except that where there is only one point in a network at which consumer's 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	This will be achieved by design of the network
8(4)	A consumer shall not combine the neutral and protective functions in a single conductor in his consumer's installation	Those who need to provide information to customers made aware of this requirement through this Code of Practice
9(1)	This regulation applies to distributors' low voltage networks in which the neutral and protective functions are combined	This will be achieved by installation of earth systems to the requirements laid down in this Code of Practice
9(2)	(2) In addition to the neutral with earth connection required under regulation 8(3)(b) a distributor shall ensure that the supply neutral conductor is connected with earth at - (a) a point no closer to the distributor's source of voltage (as measured along the distributing main) than the junction between that distributing main and the service line which is most remote from the source; and (b) such other points as may be necessary to prevent, so far as is reasonably practicable, the risk of danger arising from the supply neutral conductor becoming open circuit.	This will be achieved by installation of earth systems to the requirements laid down in this Code of Practice
9(4)	The distributor shall not connect his combined neutral and protective conductor to any metalwork in a caravan or boat	This will be achieved by following the guidance in this Code of Practice
10	This regulation requires 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 (there are exceptions for metalwork connected to wood poles more than 3 metres clearance from ground level)	This will be achieved by following the guidance in this Code of Practice
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	This will be achieved by following the guidance in this Code of Practice.

Part V11 Paragraph 24, Sections (4) & (5) of the ESQC Regulations states that: -

(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.”

(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.

Paragraph 24 of the ESQC Regulations specifically excludes the connection of the distributors combined neutral and protective conductors to any metalwork in a caravan or boat. Further information on locations where an earth terminal should not be offered is given in Section 3.15 of this Code of Practice.

The general Northern Powergrid policy is to ensure that an earth terminal can be provided so that, when an installation has been designed to the current edition of the IET Regulations for Electrical Installations (BS7671), a customer's fuse will operate in the event of an earth fault on the customer's installation.

In order to ensure adequate current flows, the best method is to use a continuous metallic return path between the customer's earth terminal and the transformer neutral point. The soil is inadequate for the purpose of carrying earth fault current because of its high resistance. Metallic water pipes, although often used in the past, are unsuitable because of the increasing use of non-metallic pipes and inserts, and the potential high resistance to earth.

The continuous metallic return path will be provided by cable sheath, by separate cable conductor, by protective multiple earthing (PME) or by protective neutral bonding (PNB). PME and PNB are means whereby the neutral conductor, apart from its normal function of carrying load current, provides the metallic return path for earth fault currents from the customer's premises to the substation transformer neutral. The adequacy of the return path is determined by its loop impedance.

In addition the use of protective multiple earths, interconnection of neutrals and good load balancing where possible will normally ensure that, even if the neutral breaks, any customer will be left with at least one earth connection on that portion of the neutral still connected to the installation. This will in most cases tend to hold down the potential of the neutral and consequently the voltage applied to the frames of customer owned metallic apparatus, to a reasonable value.

3.1.3. The Health and Safety at Work etc. Act 1974

Section 2(1) states that ‘It shall be the duty of every employer to ensure; so far as is reasonably practicable, the health, safety and welfare at work of all his employees’. Section 3(1) also states that ‘It shall be the duty of every employer to conduct his undertaking in such a way as to ensure, so far as is reasonably practicable, that persons not in his employment who may be affected thereby are not thereby exposed to risks to their health or safety’.

This is addressed in this code of practice by specifying the requirements of earth systems.

3.1.4. Electricity at Work Regulations

The UK Electricity at Work Regulations (Statutory Instrument 1989, No 635) was made under the 1974 Health and Safety at Work Act. Regulation 8 relates to earthing which quotes “Precautions shall be taken, either by earthing or by other suitable means, to prevent danger arising when any conductor (other than a circuit conductor) which may reasonably foreseeable become charged as a result of either the use of a system, or a fault in a system, becomes so charged; and, for the purposes of ensuring compliance with this regulation, a conductor shall be regarded as earthed when it is connected to the general mass of earth by conductors of sufficient strength and current-carrying capability to discharge electrical energy to earth.”

These requirements are met within this code of practice by common referencing to earth, connection of plant to earth and equipotential bonding.

3.2. Key Requirements

Northern Powergrid policy is that all networks shall be so constructed such that an earthing terminal can be made available at every LV supply point and that this will provide a solid metallic return from the earth terminal of the installation back to the substation transformer neutral terminal. Earthing on all LV networks shall be carried out in accordance with the policy and procedures detailed in this Code of Practice. These procedures all comply fully with the ESQC Regulations (2002) and it will not be necessary for field staff to make a detailed study of the regulations.

The details for implementing this policy are set out in the appropriate sections of this Code of Practice. Matters relating to customer installations are to be found in Appendix A of this Code of Practice.

3.2.1. New Networks

All new Northern Powergrid underground and overhead LV networks shall be constructed to the earthing standard required by this Code of Practice so that normally all new customers can be provided with an earthing terminal. (In a few special circumstances it may not be appropriate to offer a terminal examples are discussed in section 3.15 of this document)

3.2.2. Existing Networks

The implementation of this policy ensures that a Northern Powergrid LV customer can have a solid metallic earth-fault return path provided by one of the following means:

a) Protective multiple earthing (PME)

b) The electrically continuous sheaths of separate neutral and earth (SNE) cables

c) Protective neutral bonding (PNB)

The choice between these alternatives will depend on the nature of the existing distribution system and the cost of providing an earthing terminal.

(In a few special circumstances it may not be appropriate to offer a terminal)

3.3. Implementation

3.3.1. New Networks

New underground and overhead networks shall be constructed in accordance with the requirements of this Code of Practice. All customers on such networks shall be offered the use of a Northern Powergrid earth terminal unless it is inappropriate for reasons of safety.

New underground networks shall normally use combined neutral and earth (CNE) cables. However, it shall be permissible to use separate neutral and earth (SNE) cables for services or networks where this is beneficial such as fault repairs or minor extensions to existing SNE networks. For a customer whose installation may require special attention, such as those identified in 3.15 of this Code of Practice, it will not be appropriate to offer a PME supply.

New overhead networks shall use aerial bundled conductors in accordance with the code of practice NSP/004/041 - Code of Practice for the Construction of LV ABC Overhead Lines.

PNB may be adopted for a single customer supplied via an underground or overhead service from a substation. However it is acceptable to provide PME to a single customer and this method should be adopted where practical.

3.3.2. Existing Networks

The earthing arrangements on networks should be checked to see whether it is to the standard described in this Code of Practice whenever any of the following situations occur:-

a) Connecting a new substation into the network, or recovering a substation from the network.

b) Changing a transformer, switchgear or an existing substation.

c) Reinforcing, replacing or extending the network.

d) Repairing the network.

e) Customers' earthing facilities which are provided via metallic water pipes are about to be rendered ineffective by the insertion of non-metallic pipes in distributors or service pipes by the Water Company or plumbing contractors.

f) When the theft of aerial earth-wires has rendered earthing ineffective.

After review, action shall be taken as follows:

(i) If the network is already covered by PME or PNB, or comprises underground cables with electrically continuous separate sheaths or overhead lines with aerial earth-wires throughout, the networks shall require no modification except for the installation of additional earth-points and compression jointing of connections on neutrals and aerial earth-wires to reduce the risk arising from conductor breakage or theft.

(ii) If the network comprises cables having electrically discontinuous sheaths but the number of discontinuities is small, the sheaths shall be made continuous by bonding across the discontinuities.

(iii) In all other cases PME shall be applied to the network in accordance with the requirements of this Code of Practice.

3.4. Provision of Northern Powergrid Earth Terminals

3.4.1. Provision of Northern Powergrid Earth Terminals on Networks with Electrically Continuous Sheaths or Separate Earth Conductors

Where Northern Powergrid has not already provided earth terminals for customers on networks with electrically continuous sheaths or separate earth conductors, Northern Powergrid shall provide an earth terminal.

Such opportunities may arise when:

(a) We provide a new service.

(b) The customer or their electrical contractor asks us to provide an earth terminal.

(c) We change or move the service intake-unit.

3.4.2. Provision of Northern Powergrid Earth Terminals on Networks to which PME has been applied

Customers on networks or parts of networks to which PME has been applied shall be offered the use of a Northern Powergrid earth terminal. Before such a terminal can be used, however, customers must ensure the bonding within their installations complies with the requirements laid down in BS7671 (IET Wiring Regulations) summarised in Appendix A of this document.

3.4.3. Adequacy of Existing Bonding

Where a new PME terminal is to be provided the customers bonding must comply with the requirements of BS7671 (IET Wiring Regulations) summarised in Appendix A.

For customers with existing PME terminals, their bonding should be in accordance with the PME requirements at the time the terminal was made available. In general, this bonding will be 10mm^2 however; some installations may have 6mm^2 bonding. This 6mm^2 bonding will be acceptable where the terminal is in use.

When an existing terminal is in use prior to a cut-out change or when an inspection is carried out on an existing installation with 6mm^2 bonding, we will issue a safety notice to the customer to recommend that they change the bonding from 6mm^2 to 10mm^2. PME installations with 2.5mm^2 or 4mm^2 bonding will not be acceptable, and measures must be taken to ensure that the customer's installation is brought up to the requirements of Appendix A.

3.4.4. Provision of an Earth Terminal after a Cut-Out Change

Where no other work is involved other than a cut-out is changed for whatever reason the earthing arrangements shall remain unchanged so that if the existing cut-out provided an SNE earth facility the replacement cut-out shall provide an SNE earth facility even if it can be confirmed that the SNE network has been converted to PME unless the customer can confirm in writing that their installation meets the requirements of BS7671 (IET Wiring Regulations) for the provision of a cut-out with a combined neutral and earth.

3.4.5. Short-Term Safeguards for Customers on Substantial Existing Networks Without Adequate Earth-Return Facilities

There may be networks, such as those purchased from other suppliers, which do not have adequate earthing facilities as defined in Section 3.2.2. In the interim period before these networks are suitably converted, problems may arise concerning the earthing of existing customers' installations. These problems will fall into four groups and will be dealt with as follows:-

(i) On adoption or identification of networks with inadequate earth facilities the customers affected shall be advised in writing to install a residual current device. Design will be informed; the information will be used as an asset condition driver when assessing that part of the network during future works such that earthing facilities defined in Section 3.2.2 can be provided to the customers.

(ii) A request from a customer or his contractor for an earthing terminal. Following an assessment of the network an earth terminal should be made available to the customer if this can be provided without work on the mains cable.

(iii) Northern Powergrid staff may visit customers' installations for miscellaneous reasons such as the reconnection of a supply. If the installation is found to be inadequate then a defect certificate will be left with the customer.

(iv) If a contractor carries out alterations to a customer’s installation and the earthing of that installation is found to be inadequate then the new installation shall not be connected until the earthing arrangement conforms to the current edition of the IET Regulations for Electrical Installations (BS7671) and that situation is confirmed by issue of the relevant BS7671 certificate or by other means of written confirmation that may be agreed.

3.5. PME and Multiple-Earthing Approvals

In the past it was necessary to apply to the Department of Energy for approval to apply MEN (Multiple Earthing of the Neutral) or PME to networks. This has not been the case for many years. Consent was also required to apply PME to private networks.

The Electricity Safety, Quality and Continuity (ESQC) Regulations 2002 allows all Distributors (not necessarily Licensed Distributors) to apply PME to their networks. However it is still necessary for such non Regional Electricity Company networks to meet the requirements of the ESQC regulations.

3.6. Maximum Earth Values at Secondary Distribution Substations

The maximum value for an LV earth electrode at a secondary distribution substation shall be 20 ohm. See Section 3.20 for more detailed information regarding earthing at ground and pole mounted substations including standard arrangements for ground mounted substations

3.7. Earthing Arrangements on New LV Networks

3.7.1. New Underground Networks

New underground networks shall normally use CNE cables with copper neutral/earth conductors and PME shall be adopted. However, it shall be permissible to use SNE cables for services or networks where this is beneficial for safety or economic reasons in such cases the use of SNE cable shall be justified at the design stage.

For new PME networks including extensions to existing networks, obligatory connections of the neutral/earth conductor to earth electrodes shall be made at the end of the main and every branch of the distributor and the neutral/earth conductors of other distributors on branches that interconnect with other networks. In addition to the obligatory connections, additional connections of the neutral/earth conductor to earth electrodes shall be made at every interim mains straight joint and every mains breeches joint. Drawing C952986 see appendix E shows typical arrangements of LV network earthing

The earthing arrangements at new substation must comply with Section 3.20.

If the HV and LV earth electrodes have been separated at a ground mounted substation the overall resistance to earth of the LV earth electrodes shall not exceed 20 ohms. Measurements of resistance shall be made by an approved method (see appendix C). If the resistance of LV electrode to earth exceeds 20 ohms then additional earth electrodes shall be connected to reduce the resistance. The method of installation of earth electrodes shall be as described in 3.9.

If the HV and LV earth electrodes have been combined at the substation because they meet the conditions in Section 3.20.5 no measurement of neutral-to-earth resistance need be made.

Good load balance along an LV feeder will assist in containing neutral voltage rise in the event of an open circuit neutral conductor.

3.7.2. New Overhead Networks

New overhead networks shall normally use CNE Aerial Bundled Conductor (ABC) in accordance with the code of practice NSP/004/041 - Code of Practice for the Construction of LV ABC Overhead Lines.

It shall be permissible to use separate neutral and earth conductors for services or networks where this is beneficial for safety or economic reasons in such cases the use of 5 core ABC shall be justified at the design stage. However, the practice of making SNE overhead customers dependant on CNE overhead circuits shall be avoided due to possible inadequacy of customer’s internal bonding.

For PME networks, the neutral/earth conductor shall be connected to earth electrodes or to the neutral/earth conductors of other distributors at the final supports of every branch of the distributor. Additional earth electrodes shall be installed at the end of each section of ABC distributor, at junctions between cable and overhead lines and at all service distribution boxes. Additional earths shall be installed at intervals of not more than eight span-lengths along open wire distributors. A multi-service line or undereaves wiring supplying up to four adjacent customers need not normally be considered as a branch of the distributor for this purpose. However, where a single service exceeds three overhead spans in length an additional earth electrode shall be installed either on the overhead service termination, where the connection is made to the undereaves wiring installation or at the final support of the overhead line.

Good load balance along an LV feeder will assist in containing neutral voltage rise in the event of an open circuit neutral conductor.

Drawing C952986 shows typical arrangements of LV network earthing.

3.8. Earthing Arrangements on Existing LV Networks

3.8.1. Underground Networks with Electrically Continuous Sheaths

Existing earthing arrangements of such networks are satisfactory and will not require modification.

Any extensions or modifications, including repairs to these networks, shall employ either CNE or SNE cables. When SNE cable, which has an insulated outer sheath, is used an earth electrode shall be installed at each service joint position.

When repairs or alterations are carried out on SNE networks, SNE cable should be used

The following arrangements may occur in the network:

(i) <u>CNE Cable Supplied via an SNE Cable</u>

The neutral/earth conductor of the CNE cable shall be connected to the neutral conductor and sheath or earth conductor of the SNE cable at the transition joint. Further earth electrodes shall be installed on the CNE cable section in accordance with Section 3.7.1.

Drawing C952994 Sheet 1 and C952997 Sheet 2 show typical arrangements.

The work completed above will result in the CNE cable section and that part of the SNE cable lying between the substation and the CNE cable having been converted to PME. But neither the branches of this SNE cable, nor any other distributors on the network will have been converted unless the neutral conductor has been earthed at an appropriate position on the branch or distributor.

Drawing C953019 shows typical applications of CNE cable

(ii) <u>SNE Cable Supplied via a CNE Cable</u>

The neutral/earth conductor of the CNE cable shall be connected to earth electrodes at the end of every branch. At the transition joint it shall be connected to the neutral conductor and metallic sheath of the SNE cable.

Existing SNE customers' may retain an SNE earth when one off the following conditions are met:

The circuit is interconnected with another or the same substation via SNE cable.

A continuous metallic earth return path exists to the source substation and the SNE cable is 50 metres or more in length, whose metallic sheath is in close contact with earth, as it will normally provide an adequate connection with earth (10 ohm or less) to limit the rise of potential under open circuit neutral. Where the SNE cable is less than 50 metres in length additional earth electrodes should be connected (including at every service joint position) to reduce the values of earth resistance of the metallic sheath to 10 ohm or less

When the above criteria cannot be met the bonding at existing properties shall be checked to ensure that it complies with latest edition of the BS 7671 the IET wiring regulations (summarised in appendix A of this document) and the cable and services shall be converted to PME. Further earth electrodes need be connected only to ensure that the overall resistance to earth of the neutral of the LV network complies with Section 3.7.1.

Drawing C953011 Sheet 1 and C953015 Sheet 2 show typical arrangements.

The work completed above will result in the CNE cable section having been converted to PME. The SNE cable section will not have been converted to PME unless the neutral conductor has been earthed at additional positions.

Drawing C953019 shows typical applications of CNE cable

(iii) <u>Section of CNE Cable Inserted between Two Sections of SNE Cable</u>

The neutral/earth conductor of the CNE shall be connected to the neutral conductor and metallic sheath or earth conductor of the SNE cables at the transition joints.

Existing SNE customers' on the SNE cable most remote from the substation may retain an SNE earth when one of the following conditions are met:

The circuit is interconnected with another or the same substation via SNE cable.

A continuous metallic earth return path exists to the source substation and the SNE cable is 50 metres or more in length, whose metallic sheath is in close contact with earth, as it will normally provide an adequate connection with earth (10 ohm or less) to limit the rise of potential under open circuit neutral. Where the SNE cable is less than 50 metres in length additional earth electrodes should be connected (including at every service joint position) to reduce the values of earth resistance of the metallic sheath to 10 ohm or less

When the above criteria cannot be met the bonding at existing properties shall be checked to ensure that it complies with latest edition of the BS 7671 the IET wiring regulations (summarised in appendix A of this document) and the cable and services shall be converted to PME. Further earth electrodes need be connected only to ensure that the overall resistance to earth of the neutral of the LV network complies with Section 3.7.1.The work completed above will result in the CNE cable section and that part of the SNE cable section lying between the substation and CNE cable section having been converted to PME. Any branches of the SNE cable nearer the substation and all the SNE cable more remote from the substation will not have been converted to PME unless additional neutral to earth connections have been made at appropriate positions.

Drawing C953019 shows typical applications of CNE cable.

(iv) Cable Overlay/Replacement in SNE Cable Network

Where it is necessary to overlay a section of SNE cable in an SNE network 3 core CNE waveform cable shall be used unless it can be shown to be beneficial for safety or economic reasons to use 4 core SNE cable, in such cases the use of SNE cable shall be justified at the design stage Where the SNE cable which is replaced had a metallic sheath which is in close contact with earth the disconnected cable shall be retained and the metallic sheath used as an additional earth electrode to help maintain the network earth. The disconnected cable must be marked up on the cable records as an earth electrode.

Where 3 core CNE waveform or 4 core SNE waveform cable is used the following additional procedure shall be adopted:-

At suitable service joint positions (Approx. every 50m) cross-bond the copper earth screen to the metallic sheath of the disconnected cable with 35mm sq. cu insulated conductor using a substantial earth clamp which complies with the requirements of EREC C93. This will help reduce the overall network earth impedance.

In addition if 4 core SNE waveform cable is used the following procedure shall be adopted:-

The tail end of the 4 core waveform cable shall be fitted with an end joint and an earth electrode installed connected to both the neutral and earth conductors. Both SNE and CNE earth facilities can continue to be made available along the route in accordance with Section 3.8.1 (v).

(v) Provision of Northern Powergrid Earth Terminals on mixed CNE and SNE Cable Networks

Northern Powergrid earth terminals, connected to the neutral/earth conductor, will normally be provided to customers connected to CNE cable sections unless they are precluded under the ESCQ regulations (boats and caravans) or are a “Special Case” as defined in Section 3.15. The customers' installations must comply with the bonding and earthing conditions of Appendix A before connection to the earthing terminal may be made.

Existing services on the SNE cable section may either be provided with, or may retain, Northern Powergrid earth terminals connected to the sheath or earth conductor. When PME has been applied to part of the network, all new services on the SNE sections of the network will be provided by CNE service cables and the customers offered the use of a Northern Powergrid earth terminal connected to the neutral; their installations must then comply with the PME bonding conditions of BS7671 (IET Wiring Regulations). If the metallic sheath of the SNE cable section is in close contact with earth it will be necessary to bond the neutral/earth conductor of the CNE service cable to the neutral and metallic sheath of the SNE cable section only at the service joint. In cases where the SNE sheath is insulated from earth or is less than 9 metres in length then an earth electrode must be installed and connected to the neutral at the service joint, unless a similar connection has previously been made on the branch concerned at a point farther from the supply transformer.

Note -The 9 metres of SNE cable is equivalent to an earth rod which would need to be installed at the most remote point on the network or at the most remote service position to enable PME supplies to be provided from the network.

If CNE cables are used to replace existing lengths of SNE cables and existing SNE service cables are transferred to the CNE cable, any existing Northern Powergrid earth terminals must be replaced by earth terminals connected to the neutral/earth conductor. The metallic sheath of the SNE service cable shall then be bonded to the neutral/earth conductor of the CNE cable at the service joint. Customers' installations must then comply with the requirements of BS7671 (IET Wiring Regulations) summarised in Appendix A of this document.

3.8.2. Underground Networks with Electrically Discontinuous Sheaths

Where it is decided to apply PME to the network the earthing arrangements at the substation will be reviewed to comply with Section 3.20 where practical.

The neutral/earth conductor of the distributor shall be connected to earth electrodes, or to the neutral/earth conductors of other distributors, at the ends of all branches. Alternatively, where it is more convenient, earth connections may be made at points not nearer to the substation than the remote service at which a Northern Powergrid earth terminal is to be provided. The connection may be made either at the most remote PME joint position or at the corresponding service intake.

Where the earth connection is made at the customer’s service intake an earth electrode shall be installed.

The customer's earthed metalwork or gas and water service pipes shall not be used for this purpose.

3.8.3. Overhead Networks with Aerial Earth Wires

The earthing arrangements of such networks are satisfactory in the short term. When, however, the network is reviewed in accordance with Section 3.3.2 additional earth electrodes connected to the earth wire and neutral conductor shall be installed at those positions at which earth electrodes would have been required if the network were being converted to PME and all neutral connections made with compression joints, duplicate split bolt connectors mechanical connectors or ABC insulation piercing connectors.

The work completed above will result in the overhead section having been converted to PME future services should be offered as PME whilst existing SNE services may be retained.

Note- Single bolt insulation piercing connectors are suitable for service neutral connections but distributor neutral connections must utilise double bolt insulation piercing connectors.

3.8.4. Overhead Networks without Aerial Earth Wires and which have not been converted to PME or PNB

Where it is decided to apply PME to the networks and the earthing arrangements at the substation supplying the network shall be made to comply with the requirements of Section 3.20 where practical.

The neutral conductor of the network shall be connected to an earth electrode, or to the neutral/earth conductor of another distributor, at the end of every distributor or branch to which PME is to be applied. These connections shall normally be made at the final support of the distributor in order that all customers may be offered a Northern Powergrid earth terminal.

Group services or under-eaves wiring supplying up to 4 adjacent customers need not be considered as branches of the distributor for this purpose.

Additional earth electrodes shall be installed at intervals of not more than eight span lengths along the route of a long overhead distributor. All neutral connections shall be made using compression joints or duplicate mechanical connectors.

Where LV underground cables are connected in overhead lines the metallic casing of cable boxes and any metallic cable sheaths shall be connected to the neutral conductor at both ends of the underground cable sections. Line tap type neutral connections on tier type cable boxes shall be replaced with compression lugs fitted with double locking nuts.

Where an LV isolator is installed in the run of an overhead line the neutral blade of the isolator shall be removed and replaced by a bolted link or compressed jumper connection.

If the HV and LV earth electrodes have been separated at the substation, the overall resistance to earth of the neutral/earth conductor must not exceed 20 ohms. The measurement of resistance shall be made by an approved method and additional earth electrodes installed at convenient points on the network as necessary to achieve the required value.

If the HV and LV earth electrodes have been combined at the substation no further measurements of neutral to earth resistance need be made.

3.8.5. Overhead and Underground Networks which have been converted to PME

Existing earthing arrangements of such networks are satisfactory and require no modification. Any extensions to these networks shall be made in accordance with the ESQC Regulations (2002), irrespective of the form of approval under which they were initially constructed. Existing Northern Powergrid earth terminals may be retained but new ones will be provided only if a customer's installation complies with the conditions of BS7671 (IET Wiring Regulations) summarised in Appendix A of this document.

3.9. Low Voltage Earth Electrodes

3.9.1. Earth Electrodes on PME Systems

All earthing materials shall be in accordance with Northern Powergrid Electric material specification NPS/002/001 - Technical Specification for Earthing Materials.

When PME is applied to an LV network obligatory earth electrodes must be connected to the neutral/earth conductor of a distributor at points remote from the substation. As a minimum, these electrodes shall consist of a driven rod, 1.2m in length or strip electrode of similar area. The driven rod electrode is preferred and plate electrodes should no longer be used. Where it is not practical to install a driven rod because of the proximity of other services or cables in the footpath the preferred alternative is install a 2 metre length of bare 70mm^2 (32mm^2 for service joints) copper conductor around the base of the joint hole or trench as illustrated in figure 3.9 below. Alternatively if, at the position where the neutral is to be connected to an earth electrode, it is connected to the metallic sheath of a cable or the metallic case of a link box or pillar which is in contact with earth then a separate earth electrode need not be installed providing the overall resistance to earth is less than 20 ohms. The sheaths and armouring of hessian served cables may be assumed to be in contact with earth. The earth resistance of individual earth electrodes need not be determined.

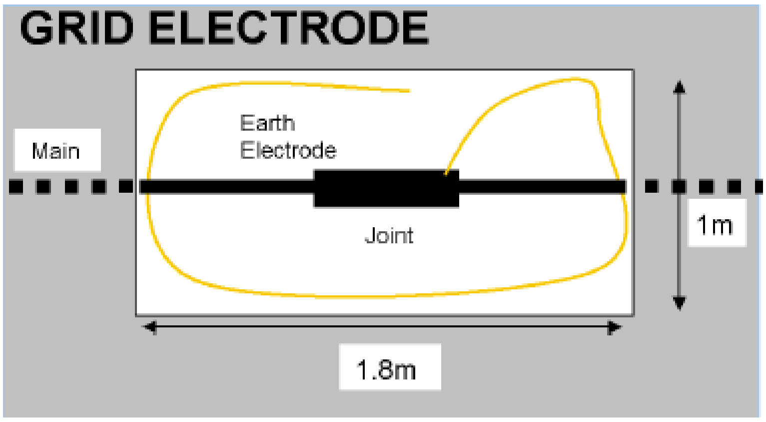


Figure 3.9 earth electrode used as an alternative to an earth rod

3.9.2. Earth Electrodes at Substations

Where earth electrodes are installed at substations they shall consist of driven rods or stranded copper conductor or copper strip, the driven rod is preferred. The earth resistance of these electrodes will normally have to be measured at pole-mounted substations and, in combination with HV cable sheaths etc., at ground mounted substations.

Connections to earth electrodes shall be insulated from earth to a depth of at least 600mm below ground level using the conductors specified in Appendix D. Where 9m separation of earth electrodes is necessary from an HV earth, then the connection cable in the ground should be insulated irrespective of its depth.

Where additional earth electrodes have to be installed, either at the substation or on the LV network, to achieve a required value of resistance it will generally be more effective to use driven rods than plate or strip electrodes.

Where additional driven rods are connected, they should be separated from each other and from any adjacent cables by a distance not less than the depth to which they are driven. Additional rods should be connected using copper tape or bare copper cable of the same cross sectional area as the earth electrode conductor. The additional electrodes should be placed so that any necessary separation of the HV and LV earth electrode systems is maintained.

3.10. Arrangements at Link Boxes and Pillars on PME Networks

Where metal link boxes are installed on CNE cables the metal case of the box must be connected to the neutral/earth conductor of the LV network. New metal link boxes for use on CNE cable networks are provided with suitable facilities for the neutral-to-case bond. If metal link boxes are installed so that the cases are not in close contact with earth or when plastic link boxes are installed then an earth electrode must also be installed and connected to the external earth connection.

On PME networks using SNE cables the metallic case of the link box or pillar will generally be connected to the cable sheaths. Provided that the metallic sheath of at least one cable is electrically continuous and is connected to the neutral conductor of the network at a convenient position, this connection is adequate. If the cable sheaths are not electrically continuous or not connected to the case of the link box or pillar, suitable connections must be provided either by bonding the neutral/earth conductor to the case within the link box or pillar, or by connecting the sheath to the link box or pillar and to the neutral/earth conductor at a convenient position (e.g. a joint or service termination). If the metallic case of a link box or pillar is not in contact with earth, either directly or by connection to a cable sheath which is earthed, then an earth electrode must be installed and connected to it.

All neutral links should be fitted permanently in position by bolting even where the phase links are removed for normal operation.

All metallic link box pits should also be bonded to the metal case of the link box and the neutral/earth conductor however for plastic link boxes with a metal top frame for the footway cover the metal top frame does not require bonding.

Where non-metallic link boxes are used in conjunction with metallic link box pits, there shall be a bond between the metallic link box pit and the neutral/earth conductor.

3.11. Street Lighting, Road Signs and Other Street Furniture with Electrical Load of 500W or Less

3.11.1. The Application of PME

The following paragraphs provide general guidance on the provision of earth electrodes for street lighting supplies Engineering Recommendation G39 (Earthing Arrangements for Street Lighting Furniture) should be consulted for more detailed information.

The application of PME to street furniture was previously governed by an Exemption to the Electricity Supply Regulations. These have now been superseded by the 2002 ESQC regulations which do not differentiate licensed & non licensed operators, but make reference to Street Electrical Fixtures with an expectation to comply with the current edition of “ER G12 Application of PME to LV networks”.

The exemption permits the use of PME on street lighting authority owned CNE cables and permits bonding with 6mm^2 copper equivalent conductor rather than 10mm^2.

Single services to street furniture from a PME distributor do not need an electrode, provided that the distributor neutral is earthed either at or beyond the service joint position.

An earth electrode shall be provided at the end of every service or main supplying more than one street lamp or road sign.

An earth electrode shall be provided at the source pillar or supply point servicing more than one street lamp or road sign. Where the load on the pillar is greater than 500W the earth electrode shall be in accordance with section 3.15.15

Where a street lamp or road sign is installed within an insulated foundation such as a plastic or non-conductive collar an earth electrode shall be installed connected to the earth terminal at each such installation.

It is not permissible to consider metallic street furniture to be earth electrodes, although they will carry neutral current if earthed and within a PME system.

The exemption to the regulations applies to street furniture supplied by DNOs or street lighting authorities when using CNE cable. C953029 shows a street lighting authority CNE distributor fed from a PME service to a street lighting pillar. At the street lighting pillar, the DNO's PME neutral will be connected to the customers' earthing terminal, to the pillar and associated metalwork. Each column will be bonded to the neutral of the street lighting cable. At the last column an earth electrode will be installed.

Private installations are not covered by the exemption. These and local authority installation using SNE cables which are supplied from PME services must be SNE. A typical installation is shown in C953031.

3.11.2. Street Lighting Brackets mounted on Poles or Buildings

The earth terminal and any external metalwork of street lighting fittings mounted on buildings or wooden poles will be connected to the PME earth terminal. The only exception is if the fitting is double insulated. Bond size shall be $6mm^2$.

3.11.3. Roadside and Other Housings Accessible to the Public

Examples are public telephones, pedestrian crossing bollards, and ticket machines. Equipment of this type should be Class II (double insulated) or equivalent construction. No mains derived earthing terminal is required, neither is a residual current device needed for earth fault protection. For installations of class 1 construction (where an earth terminal is provided) see section 3.15.15.

3.11.4. Existing Separate Street-Lighting Mains with Inadequate Earth-Return

The earthing arrangements on these distributors shall be brought to the standard required by the Electricity Safety, Quality and Continuity Regulations 2002. This shall be done either at the request of the Local Authority or as the result of the earthing improvements on the electricity distribution network.

The sheaths of any underground street lighting cables and the metalwork of any link boxes, pillars or pole boxes shall be connected to the neutral/earth conductor.

3.11.5. Street-Lighting Services from Electricity Networks with Inadequate Earth Return

Where individual street-lighting services are provided from distributing mains with inadequate earth-return facilities two courses of action are possible: -

(i) Bring the earthing arrangements of the whole network up to the standard required by this Code of Practice.

(ii) Apply the Electricity Safety, Quality and Continuity Regulations 2002 to those parts of the network from which street-lighting services are fed.

Generally the former course of action will be preferable as the benefit of improved earthing facilities may be offered to all customers. In some cases, however, the latter course of action may be necessary.

On every branch or section of a distributing main to which the relevant street furniture is connected the neutral/earth conductor shall be bonded to the non-current carrying metalwork of the relevant equipment with the exception that metal doors of concrete and plastic columns shall not be so bonded where the supply to the column is derived from a PME network. The neutral/earth conductor of the distributor shall also be connected to earth or to the neutral of another distributor at a point farther from the supply transformer than the most remote street lighting column etc., at which point an earth terminal is to be provided.

In any case where looped services are provided between street lamps an earth electrode shall be installed and connected to the neutral/earth conductor at the final lamp position. It is not permissible to consider metallic street furniture to be earth electrodes.

3.11.6. Street Lighting Columns with Inaccessible Cable Sheaths

The bonding of the non-current carrying metalwork of street lighting columns includes the bonding of the supply cable armouring and metallic sheath to the neutral/earth conductor. Cases will arise where the street lamp service cable will be terminated below the column door opening and therefore inaccessible for the fitting of a bonding clamp. In such cases the armouring and metallic sheath of the service cable need not be bonded to the neutral conductor.

This exception is permitted because the possibility of being able to touch the cable sheath is extremely remote and for it to be at a potential there would have to be an open-circuit neutral/earth conductor fault in existence at the time.

3.12. Supplies to Customers Direct from Substation

3.12.1. Ground-Mounted Substations

If the customer's earth-continuity conductors (including any cable sheaths employed as such) are marshalled at a point in or near the substation a final earth-continuity conductor shall be provided to connect these conductors to the transformer neutral either directly or via the general substation bonding and earthing conductors.

This conductor shall have a copper equivalent cross-sectional area at least half that of the largest outgoing phase conductor, subject to a minimum value of 16mm^2. If the cable(s) supplying the customer have electrically continuous metallic sheaths these may be used for the final continuity conductor. The earthing arrangements at the substation shall comply with conditions of Sections 3.20.5 and Appendix D.

Where the customer's supply terminals are remote from the substation and a CNE cable has been used to provide the supply it will be inconvenient to install a separate earth-continuity conductor and in such cases PME shall be adopted. The earthing arrangements at the substation shall comply with the conditions of Section 3.20.5. At the customer's supply terminals the neutral conductor shall be connected to an earth electrode and to the customer's earth-continuity conductors. The resistance to earth of the electrode at the customers supply terminals is not specified but the overall resistance to earth of the LV system neutral must not exceed 20 ohms.

3.12.2. Pole- Mounted Substations (PNB)

If a supply is given to a single customer, PNB may be adopted.

The LV neutral conductor shall be earthed at the customer's supply terminals by connections to an earth electrode whose resistance to earth shall not exceed 20 ohms. The metallic sheaths of any LV cables shall also be connected to the neutral conductor at the customer's supply terminals. The transformer tank and associated HV metalwork shall be connected to a HV earth electrode. All uninsulated parts of this electrode shall be at least 9 metres from any part of the LV earth electrode and any earthed metalwork connected to it.

Drawing C953072 shows typical arrangements.

The customer's installation shall comply with the conditions of BS7671 (IET Wiring Regulations) summarised in Appendix A of this document. If the LV network is subsequently extended, PME may be applied without affecting the existing customer, other than changing the PNB warning label.

Although it is preferable that the LV earth electrode is connected to the neutral conductor at the customer's supply terminals, the connection may be made at any other convenient position, for example on the route of under-eaves wiring.

3.13. Customer's Earthed-Sheath-Return Wiring Installation or Customer's Distribution Installation Using Combined Neutral and Earth Conductors

The ESQC Regulations (2002) permit the use of a PME terminal at the supply position provided that the network is suitable and the customer's installation is bonded correctly. It does not provide a mechanism to enable the customer to use PME on an installation connected to the earth terminal.

3.14. Non-Standard Networks With Inadequate Neutrals

The construction of certain existing networks makes it impossible for Protective Multiple Earthing to be applied because in addition to the requirements for earthing at the substation and on the network, there are conditions affecting the integrity and size of the neutral conductor stated in the ESQC regulations and in Engineering Recommendation G12 (Requirements for Application of PME to Low Voltage Networks) which Northern Powergrid have to meet.

The neutral conductor must not include a fusible cut-out, circuit breaker or switch between the supply transformer and any earth terminal connected to the neutral. If such devices exist on a network they shall be removed when multiple earthing is applied. (This does not preclude the provision of links in neutral conductors, but they shall be correctly installed and not removed while the phase conductors are live).

The copper equivalent cross-sectional area of the neutral conductor at any point should not be less than one half that of the phase conductor in a three phase, four wire or single-phase three wire main or service. (Two phase three wire systems include two phases of a three phase system). The copper equivalent cross-sectional area of the neutral conductor shall not be less than that of the phase conductor in a single-phase two wire main or service.

When using larger size three phase LV cables (typically 300mm^2) for single phase applications consideration should be given to them having reduced size neutrals and not meeting the requirement for the neutral to be at least half of the size of the phase conductor. In cases where the larger size cable is installed to overcome volt drop limitations the smaller size neutral may be acceptable.

Where the neutral conductor does not comply with these requirements the network will have to be modified before PME can be applied.

3.15. Customers Installations Requiring Special Attention

A PME earthing terminal provides a very satisfactory means of protection for the majority of customers' installations but there are a number of special situations where the customer should provide an additional or alternative form of earth fault protection. It is not acceptable in these situations to provide an SNE service from a CNE main since any rise of voltage on the neutral of the main will be transferred to the customers' earth terminal.

The following situations fall into this special category:-

3.15.1. Construction Sites

PME earthing terminals shall not be provided on construction sites as it will not be possible to verify the requirements and conditions of BS7671 (IET Wiring Regulations) for bonding of the temporary water, gas and other metallic services including metallic structures which are in or might be expected to come into, electrical contact with earth and which are in easy reach of any exposed non-current-carrying metalwork of the Developer's or Contractor's electrical installation.

Construction site supplies shall be provided through a residual current device (RCD) and associated earth electrode, segregated from any metalwork connected to the PME earthing terminal. The construction site earth continuity conductor should be connected to an independent earth electrode which should be a minimum of 9 metres away from any HV earth electrode or cable sheath which may be on the site. The independent earth electrode should be of such a value that in the event of an earth fault, the maximum sustained voltage between the earth continuity conductor and the general mass of earth should not exceed the values prescribed in the current edition of BS7671.

Alternatively the Developer could install a 1:1 isolating transformer of the appropriate rating enabling a separately earthed neutral LV system to be created within the boundaries of the site.

For large temporary supplies which require their own substation it will usually be possible to provide an earthing terminal connected directly to the transformer neutral and provide an SNE earthing system. For detailed requirements BS 7375 and BS 7671 should be consulted.

Where a Northern Powergrid PME earth terminal is provided for future use the earth terminal block shall be rendered inaccessible so as to prevent unauthorised connection. A notice with inscription "Northern Powergrid EARTH TERMINAL - NOT TO BE USED ON A TEMPORARY SUPPLY" shall be fixed adjacent to the earth terminal block.

3.15.2. Farms, Milking Parlours, Pig Stys etc.

A PME earthing terminal shall be given to farm premises and similar establishments provided that the installation complies with the bonding requirements and conditions of BS7671 (IET Wiring Regulations).

There are areas of special risk where animals could be subjected to a difference in potential between wet floors and bonded metalwork. In these situations the metalwork in the entire area of any farm buildings shall be bonded to the earthing terminal. If the customer wishes he may install a high sensitivity residual current device to provide additional protection in the event of a fault on the installation within the wet area. This is advisable where there is a bare concrete ground floor within the total area of the main buildings. The Northern Powergrid earthing terminal may be used as the circuit breaker earth electrode provided the whole of the metalwork within the main buildings is effectively bonded.

Where in remote buildings all extraneous conductive parts cannot be bonded to the earthing terminal, the pipes and metalwork of isolated buildings, whether or not they have an electricity supply, shall be segregated from metalwork connected to the PME earthing terminal. Any supplies to such buildings should be controlled by a RCD and the associated earth electrode and protective conductor shall be segregated from any metalwork connected to the PME earthing terminal.

Particular care must be taken in areas where livestock are housed as they are sensitive to very small voltages. A suitable metallic mesh shall be installed in the concrete bed of a dairy and bonded in accordance with the PME requirements.

If PME is to be applied to an existing dairy the steel reinforcement in the floor should be bonded. Alternatively, if small voltage differences are unacceptable the area concerned should be protected by an RCD and the associated earthing system segregated electrically from the remainder of the installation.

(a) PNB Installations

Where a dedicated transformer is used to supply a single customer farm premises then PNB should be adopted and shall comply with the conditions of Section 3.12.2 and BS7671 (IET Wiring Regulations)

3.15.3. Swimming Pools

Locations containing swimming pools and other basins are considered to be 'Special locations' within BS 7671 which sets out the requirements and recommendations relating to the use of supplementary equipotential bonding and RCDs in electrical installations in such locations.

BS 7671 recommends that where PME (TN-C-S) earthing is adopted, an earth mat or electrode should be installed for Zone 2.

Safety issues include:

- Wet locations
- Possibility of contact of the body with true earth potential
- Presence of wet barefoot persons

NOTE: In addition to normal electric shock hazards, persons may experience low level shocks or tingles from the out of balance voltages imported via the neutral/earth conductor of the DNO TN-C-S system.

Competent persons enquiring about the suitability of PME for swimming pool supplies should be advised:

- The main service position can be provided with a PME terminal. It is the electrician's decision whether or not to utilise the PME terminal for all or part of the installation.
- Where the pool is in separate building or outdoors the consumer's electrician:
    - may decide to use the PME terminal to earth the house / offices/ shop etc.

Or,

- may decide to segregate the earth conductor / wire armouring of the pool building circuit, install a separate earth electrode for the pool building and apply supplementary equipotential bonding as required by BS 7671 Section 702

Or,

- may decide to use the PME earth if a metallic grid is installed under the poolside areas and bonded to the equipotential bonding.

Where the pool is within the same building the consumer's electrician:

- may decide to use a TT system to earth the entire installation

Or,

- may decide to use a TT system to earth the pool installation, and segregate the metalwork and pipes from the rest of the building and connect them to a separate earth electrode

Or,

- may decide to use the PME earth if a metallic grid is installed under the poolside areas and connected to the equipotential bonding.

3.15.4. Sports Pavilions

Remote sports pavilions having PME supplies may present problems due to out of balance conditions, particularly if the service is of an appreciable length. Low values of voltage may appear on the neutral due to out of balance conditions. No problems will exist if concrete floors have an earth grid bonded to the earthing terminal. However, in the majority of cases the earth grid will not be installed and low levels of voltage could occur between the metalwork which is bonded to the neutral/earth conductor and the general mass of earth (concrete floor) causing unpleasant sensations.

If an earth grid cannot be installed the customer should be advised to install a RCD and associated earth electrode, PME earthing facility should not be provided.

Where a sports pavilion is of timber construction, including the floor, then the difference in potential problem will not exist and a PME earthing terminal can be provided.

3.15.5. 110V Centre-Tapped Supplies via an Isolating Transformer

A number of buildings with bar services have a 2kVA isolating transformer with a 110V centre-tapped secondary winding to give 55V to earth. A supply is given via a flexible armoured cable to delivery tankers which are fitted with 1hp pump motors.

The transformer does not however provide isolation for the centre-tap of the 110V winding if it is connected to the PME earthing terminal. The risk from providing supplies outside the equipotential zone is considered to be slight particularly as the time the tanker will be connected to the supply will be short.

3.15.6. Quarries

A PME earthing terminal may be provided for the part of the installation associated with permanent buildings such as offices provided that the building's electrical installation wiring conforms to BS 7671 and there is no interconnection with the earthing arrangements associated with the plant used in the production work of the quarry.

3.15.7. Fuel Filling Areas

The filling station area should be supplied from a TT system. BS 7671 regulation 331.1 and BS 7671 Appendix 2 give references for the requirement for supplies to fuel filling stations.

Where the filling station is part of a larger site, PME facilities may be provided for permanent buildings such as restaurants and shops, provided the filling station area has an earth system segregated from the PME earth system..

3.15.8. Fairgrounds and Showgrounds

PME earth terminals shall not be made available to such installations. A RCD and the associated earthing electrode must be installed by the customer.

3.15.9. Railway Service Areas of Electrified Railways

A PME service may be provided to station buildings where the track side earthed metal work is segregated electrically from any metal work connected to the PME terminal.

Where connections are made to the track side earth metal work it is recognised that under starting currents or traction fault conditions, a voltage gradient can appear on the traction return rail, which could be impressed on the supply cable. A PME earth terminal will only be provided where the railway operator can confirm that a voltage not in excess of 25V will be impressed on the distribution company earth terminal.

Recent testing carried out by Network Rail, the results of which are published in Appendix 2 of the ENA Engineering Recommendation G12 issue 4, indicates that for a typical installation a voltage not in excess of 25V will be present. However, to satisfy the requirements of this code of practice Network Rail must confirm in writing that a voltage not in excess of 25V will be present at the site where the PME supply is requested.

For connection to other track side facilities such as signals or track side heaters remote from a station area or domestic connections a connection can generally be provided in accordance with section 3.15.15

The requirements for auxiliary LV supplies at traction supply points for ac systems are set out in EREC P24. Because of the traction return currents that will be flowing through earth at these sites PME earth terminals are not permitted at these locations.

Note - Care is necessary with DC traction systems using earth return, as this can cause accelerated corrosion to exposed (i.e. Hessian served) cable sheaths and earth electrodes.

3.15.10. Caravans, Mobile Homes, Temporary Site Offices, Boat Installations and Outside Broadcast Vehicles

The Electricity Safety, Quality and Continuity (ESQC) Regulations 2002 do not permit the provision of PME earthing terminals for caravan and boat installations. This has the following implications:-

(a) A supply may be given without an earth terminal to an individual caravan, caravan site, mobile home or temporary site office, from a PME distribution main.

(b) A PME earthing terminal may be provided for use in permanent buildings on a caravan site such as the site owner's living premises and any bars, shops or wooden built toilet blocks provided that the electrical installation within the buildings meets the bonding requirements of BS7671 (IET Wiring Regulations).

(c) A PME supply shall not be extended to shower blocks due to the higher probability of persons being barefooted at these locations unless a buried bonded metal grid has been installed. This requirement also applies to other locations where toilet or shower blocks have been provided for general public use where people are likely to be barefoot e.g., beachside locations, parks etc. Where outside showers have been provided then provision of PME earthing is not recommended as providing a reliable equipotential cage may prove impractical.

(d) The site wiring shall be two-wire, phase and neutral, supplied through a RCD, the earth conductor should be connected to an independent earth electrode. The residual current devices must be supplied by the customer or site owner. The recommended method of supplying a caravan site should also be used for yacht marinas and other similar installations such as sites with certain types of chalets.

(e) A PME earthing terminal may be provided for use in mobile homes or temporary site offices which are constructed so that a person in contact with the general mass of earth cannot touch any metalwork of the home or site office which would be connected to a PME earthing terminal. Such mobile homes or site offices may be treated in the same manner as permanent premises and provided with a PME earthing terminal if the installation meets the bonding requirements of BS7671 (IET Wiring Regulations).

(f) Where the mobile home or temporary site office has exterior metalwork and cannot comply with the above touch criterion, a PME earthing terminal shall not be provided. Supply should be given through a RCD and an independent earth electrode sited at least 3 metres away from any PME earth electrode should be provided. Both of these items are the responsibility of the customer.

(g) A PME earthing terminal may no longer be provided for use in a vehicle used by the British Broadcasting Corporation, the Independent Broadcasting Authority or others for the purpose of outside broadcasts as the blanket approval is withdrawn. An RCD shall be provided by the customer.

3.15.11. High-Rise Buildings and Multi Occupancy Building Complexes

Engineering Recommendation G87/2 Guidelines for the Provision of Low Voltage Supplies to Multiple Occupancy Buildings should be read in conjunction with the following paragraphs which summaries the earthing requirements.

Networks within multiple occupancy buildings shall be designed on an SNE principle, although incoming service connections from local PME distributors are permissible, as is a PME earth terminal at the Intake Position. The appropriate main equipotential bonding connections to structural steelwork and to metallic services should be made at this point of connection, for details of the size of copper conductor required refer to appendix D. At individual Customer’s Installations the main equipotential bonding between metallic services, extraneous metalwork and the earth terminal shall be carried out in accordance with BS 7671. This will ensure that no harmful potentials appear between earthed and extraneous metalwork within the Customer’s premises under fault conditions. A single Intake Position is the preferred design option for, amongst other reasons, avoiding problems caused by the flow of neutral current through the building steelwork and equipotential bonding between the Intake Positions. Note that a single Intake Position may have more than one incoming service cable and cutout. If it is not possible to design on the basis of a single Intake Position, then a non-PME connection option shall be considered (i.e. shall be of the SNE type or no earth shall be provided from the network the landlord making their own earth provision). All Intake Positions within a single building shall employ the same earthing method. PME connections are not recommended in these situations due to the risks associated with significant neutral current flow through structural steelwork and fixings under fault or other conditions and the difficulty associated with providing an alternative DNO-owned bond between Intake Positions.

In some steel framed multiple occupancy buildings such as a horizontal run of industrial or commercial units where individual services are to be provided from a DNO's PME distribution main it will be more difficult to avoid the problems identified earlier. There are several ways of addressing this which will vary to the extent that they are able to mitigate the problem.

- Provide a single Intake Position to the building with a group metering position at a communal point. A Customer's separate neutral and earth cable could then be supplied to each unit separately.
- Operate all Customers' Installations on the same site as TT systems where practicable (i.e. no DNO earth terminal provided). This solution has the advantage that it eliminates the problem but may not be suitable for all load types.
- Provide a PME connection to a freestanding distribution pillar and then distribute with separate neutral and earth cables in a star formation from this point to each unit. Note that the neutral and earth conductors of the cables MUST NOT be bonded together at any point other than the pillar as this would result in a path for neutral current to be diverted into the building structure.

Individual PME connections are not recommended in these situations due to the risks associated with significant neutral current flow through structural steelwork and fixings under fault or other conditions and the difficulty associated with providing an alternative DNO owned bond between Intake Positions. In the case of multiple PME cutouts at a single Intake Position, all earth terminals shall be bonded together. The size of the bonding conductor shall be not less than that of the smallest associated service cable neutral conductor. Such bonding conductors shall be coloured green-yellow with the addition of blue markers to indicate that they will be carrying current.

Drawing C953070 shows the bonding requirements for an SNE rising main.

Where minor changes or extensions are carried out to existing complexes which have been supplied with CNE mains safeguards have to be taken with regard to the connection of the supply neutral conductor to earth at the extremities of the LV distribution systems in the building complexes. It is essential that the PME earth shall provide a continuous metallic path from the remote end of the distributor to the neutral at the substation.

The connections at the various ends of the neutral conductors shall be made in one or more of the following ways:-

(a) On a ring system the neutrals are made continuous at normally open points.

(b) A bonding lead connecting the neutrals between the remote ends of two distributors.

(c) A separate earth conductor run from the remote ends of the distributors to an earth electrode or the neutral at the substation.

(Note - Potential EMC problems may occur particularly if there is more than one PME supply cable, where neutral return currents could flow through the metal frame of the building appendix B provides guidance on minimising EMC problems).

Incoming gas and water services and structural steel work in contact with the general mass of the earth will be bonded to the earth bar of the incoming distribution panel in accordance with Appendix A.

3.15.12. Supply Terminating in a Separate Building

Occasionally a service will terminate in a position remote from the building it supplies. In this case the size of the PME bonding in the building supplied must be related to the size of the incoming supply cable in accordance with appendix D. If the size of the circuit protective conductor of the cable between the supply intake position and the building is less than that of the PME bonding conductor, a suitable additional conductor shall be installed.

3.15.13. PME and Outside Water Taps

Under an open circuit supply neutral condition, the potential of an outside water tap will rise above earth potential. A person coming into contact with the tap could receive an electric shock and the shock could be severe if that person were barefooted. The probability of these two conditions occurring together is considered to be so small that the use of PME where a metal outside tap exists is not precluded.

An insulating insert may be incorporated in the pipe to the outside water tap. However, care should be taken to ensure that simultaneous contact with metal pipework on each side of the insert is not possible if there is likely to be a potential across the insert under this condition.

3.15.14. Lightning Protection Systems

For the majority of situations, it is acceptable for lightning protection to be connected to the customer's earthing arrangements providing it has been designed and installed in accordance with the latest version of BSEN 62305 "Protection against Lightning".

When periodic testing of the lightning protection system is undertaken, precautions are necessary when breaking the link between the lightning protection electrode and the customer's earth since the customer's earth may be at a potential above true earth.

3.15.15. Roadside Cabinets and Other Fixtures Accessible to the Public with Loads Greater than 500W

Roadside cabinets and other fixtures should preferably be of Class II construction or equivalent as defined in BS 7671. Examples are public telephones, pedestrian crossing bollards, ticket machines. No mains-derived earthing terminal is required, neither is a residual current device needed for earth fault protection.

Where the Roadside cabinets and other fixture is of Class I construction as defined in BS 7671, (examples include cable television distribution cabinets; control cabinets for mobile phone masts; metal enclosures containing pumps, controls, or communications equipment), a PME earth terminal may be provided if the requirements of BS 7671 are met and:

(a) For 3-phase equipment, the load is balanced, or:

(b) For 1-phase equipment and 3-phase equipment with unbalanced load, the maximum load and consumer earth electrode resistance bonded to their main earth terminal fulfil the requirements of Table 3.15.15 below:

Connection	Maximum 1-ph Load or, for 3-phase, maximum overall load unbalance	Maximum consumer earth electrode resistance bonded to main earth terminal (see note)
1-phase or unbalanced 3-phase	500W	100Ω
	1kW	60Ω
	2kW	20Ω
	3kW	14Ω
	4kW	11Ω
	5kW	9Ω

NOTE: By agreement with the Network Operator, it may be permissible to take into account the effect of distributed earths in specific situations.

Table 3.15.15

If the conditions for a Class I installation cannot be met, a PME terminal should not be offered. The earthing system of the installation should form part of a TT system by installing a separate earth electrode and fitting appropriate protection in accordance with BS 7671 (e.g., an RCD).

Electric vehicle charging points located in a street shall always have a TT earthing system by installing a separate earth electrode and fitting appropriate protection in accordance with BS 7671 (e.g., an RCD) unless a neutral fault detection and disconnection device approved by Northern Powergrid is fitted in which case a PME terminal may be provided. At the time of publication, no neutral fault detection and disconnection device had been approved by Northern Powergrid. Appendix F provides details of the requirements which a neutral fault detection and disconnection device must meet before it can be approved.

Extraneous-conductive-parts (e.g. safety barriers, pedestrian guard rails) should not be connected to a PME earth terminal.

3.16. Under-Eaves Wiring Installations

3.16.1. New Under-Eaves Wiring Installations

PME shall be adopted on all new under-eaves wiring installations which shall be installed in accordance with NSP/004/043 - Specification for Overhead Services, Surface Wiring and Eaves Wall Mains. Obligatory connections of the neutral/earth conductor to earth electrodes or neutral/earth conductors of other distributors shall be made at the final end joint on underground networks and at the final support on overhead networks of every branch of the distributor.

Under-eaves wiring installations supplying 5 or more adjacent customers will be deemed to be a branch of a distributor and the neutral/earth conductor shall therefore be connected to an earth electrode at or near the last service termination on the branch.

Under-eaves wiring installations supplying up to 4 adjacent customers need not be considered as a branch of the distributor for this purpose. However, the following exceptions will apply:-

i. Where an overhead service exceeds 3 spans in length an additional earth electrode shall be installed either on the overhead-service termination where the connection is made to the under-eaves wiring installation or at the final support of the overhead line.

ii. Where an under-eaves wiring installation includes an overhead interhouse span between customers then an additional earth electrode shall be installed either at the most remote service of the under-eaves wiring or at the termination of that overhead span which is most remote from the substation. If the overhead span consists of a CNE concentric cable or ABC then an additional earth electrode need not be installed.

3.16.2. Existing Under-Eaves Wiring Installations

Earthing arrangements of underground networks with electrically continuous sheaths are satisfactory and those with discontinuous sheaths are unsatisfactory; the latter shall be brought up to the required standard as described in Section 3.8.2.

Earthing arrangements of non PME overhead Northern Powergrid networks without aerial earth-wires are unsatisfactory and must be converted to PME. Overhead networks with aerial earth-wires are acceptable in the short term and can be converted to PME.

Under-eaves wiring installations without an earth conductor shall be either converted to PME or a separate earth conductor will be installed whichever is the more economical. The earth conductor shall be bonded to the sheath of the supply cable of the underground cable network or to the aerial earth wire of the overhead network.

Where the under-eaves wiring installation is connected to an overhead network without an aerial earth wire the customers on that installation shall be converted to PME.

Where the under-eaves wiring installation is converted to PME, 5 or more adjacent customers will be deemed to be a branch of a distributor and the neutral/earth conductor shall therefore be connected to an earth electrode at or near the last service termination on the branch.

Under-eaves wiring installations supplying up to 4 adjacent customers need not be considered as a branch of the distributor for this purpose. However the following exceptions will apply in both the 4 customer case and the case of 5 or more customers.

Where an under-eaves wiring installation is converted to PME or where a separate earth conductor is installed and the under-eaves wiring installation includes an overhead inter-house span between customers then an additional earth electrode shall be installed either at the most remote service of the under-eaves wiring or at the termination of that overhead span which is the most remote from the substation. This additional earth electrode shall be connected to the neutral/earth conductor in the case of PME or the earth conductor where one is installed. If the overhead span consists of a CNE concentric cable then an additional earth electrode need not be installed.

Where an overhead service exceeds 3 spans in length an additional earth electrode shall be installed on the overhead service termination where the connection is made to the under-eaves wiring installation or at the final support of the overhead line.

Drawing C953074 shows typical arrangements of PME earths on under-eaves wiring installations.

3.17. Customers' Private Generator Installations

Recommendations for the connection of small scale embedded generators can be found in Engineering Recommendation G98. For larger embedded generators with a capacity greater than 16A per phase the requirements are covered by Engineering Recommendation G99

3.17.1. PME/PNB Installations

Where private generators are used to provide standby supplies on PME or PNB installations a three-pole (as opposed to a four pole) changeover switch must be used. This is because on a PME or PNB installations the neutral conductor cannot be disconnected simply by the breaking of the neutral conductor in the changeover switch since the earth connection to the generator neutral conductor and the bonding of this same earth to the earth terminal block and neutral at the service position prevent the isolation of the generator neutral from the supply cable.

3.17.2. Non-PME Installations

The connection of a generator to the permanent wiring installation in a customer's premises must include a changeover switch which will completely isolate all phases and neutral of either the permanent or the standby generator supplies. The purpose of the switch is to prevent interconnection of the supplies and the possibility of "feedback" from the generator into the Northern Powergrid supply mains.

The generator neutral terminal shall be bonded to the frame earth terminal and the neutral conductor of the installation.

The earth terminal of the generator shall be connected to an earth electrode which must be provided by the customer as close as practicable to the generator. The resistance to earth of this earth electrode shall not exceed 20 ohms. In addition, the earthing terminal of the generator should be connected to the earthing terminal block at the Northern Powergrid intake unit. In the case of large factory installations, the earth terminal of the generator may be connected to the largest cross section earth conductor at the distribution point, instead of earth terminal at the Northern Powergrid intake unit.

3.18. Connections to Mobile Phone Base Stations associated with Transmission Towers or Primary Substations

Under high voltage fault conditions exceptionally high earth potential rise (EPR) conditions can occur on transmission towers and at some primary substations. Steps must be taken to avoid applying these voltages to the local LV and 11kV systems. Consequently site specific studies and designs are required to ensure the safety of connected customers and network operatives when providing an LV connection. The current edition of Engineering Recommendation G78 gives recommendations for the provision of LV connections to mobile phone base stations with antennae on high voltage structures.

3.19. Cathodic Protection Installations

The usual source of power for cathodic protection installations is mains supplied transformer rectifier unit.

The preferred arrangement is for the customer to provide his own earthing together with an appropriate Residual Current Device. An SNE or PME earth can be given provided there is no electrical connection between the primary and secondary of the transformer rectifier unit.

Where supply is given via a pole-mounted transformer the substation earth electrodes and stay wires should be situated as far as possible from the ground bed.

BS EN 13636 gives more information on cathodic protection.

3.20. Earthing at Distribution Substations

Earthing at all Northern Powergrid 6kV, 11kV and 20kV ground mounted distribution substations shall satisfy the requirements in the following sections.

3.20.1. Earthing Requirements at New Distribution Ground Mounted Substations

3.20.1.1. Introduction

This section summarises the standard arrangements for the earthing and bonding of the most common standard types of 20kV, 11kV and 6kV Ground-Mounted Distribution substations owned and installed by Northern Powergrid.

Where an HV substation is sited within or adjacent to a higher voltage substation (e.g. 132/33kV, 33/11kV, etc.), then the guidance of the Northern Powergrid (NPG) Design Engineer must ALWAYS be sought before proceeding with the construction process.

If there is any overhead line in the HV circuit between a ground mounted HV substation and the source primary substation the HV electrode and the LV earth electrode shall be separated unless the conditions in section 3.20.5 are met.

3.20.1.2. General Earthing Requirements

For a fault directly to earth or between HV and LV transformer windings, a path is required to allow sufficient earth fault current to flow back to its source, operate protection and disconnect the supply. An important part of the path is the earth electrode at the substation. For the majority of ground mounted substations, a combined HV/LV earth will be installed, the electrode will consist of bare conductor and earth rods installed around the HV equipment and bonded to the substation equipment see section 3.20.7.1 for details.

Where the HV and LV earths are combined an electrode will be laid out with incoming and outgoing HV cable routes.

At new ground mounted substations in urban areas supplied from global underground networks, the HV and LV electrode systems will normally be combined, i.e. a separate LV electrode is not necessary.

It is the company’s policy to identify substations where HV and LV electrodes are not combined, by fixing a label to the outside of the LV cabinet.

3.20.2. Bonding and Control of Potential

3.20.2.1. General

During an earth fault, protection must be provided for anyone who could be in contact with exposed earthed metalwork. This applies particularly to those required to carry out fault switching at the substation. This protection can be provided by keeping the operators hands and feet at a similar potential. This is achieved by laying bare HV electrode, which is connected to exposed metalwork and switchgear, in the ground such that it is immediately beneath and just beyond the position where the operator stands

For ground mounted substations, a standard arrangement which provides potential grading and a reasonably low resistance, is always required, the standard earthing arrangements in section 3.20.7.2 should suffice.

3.20.2.2. Bonding

All normally accessible metalwork will be connected together and to the HV earth, via bonding conductors. This is to ensure that all adjacent, exposed metalwork remains at a similar potential during fault conditions. The bonding conductor between main items of plant and the electrode system could carry significant earth fault current and must be fully suitable for this purpose see appendix D.

Exposed metalwork (transformer and switchgear enclosures, metal fencing, metal doors, metal enclosures, LV enclosures) will be bonded together and to the main HV earth electrode (bare electrode in and around the substation).

Doors, metal roofs etc., will not carry appreciable fault current, other than via a secondary wiring fault, so smaller bonding conductors are permitted. In all cases the minimum size is 16mm^2 copper or 35mm^2 aluminium.

3.20.2.3. Substations with Combined HV and LV Earth Electrodes

Where the HV and LV earth electrodes are combined, the neutral-earth connection and LV earth electrode will form part of the return path for HV fault current.

The HV and LV earth electrode systems can be combined only where the following conditions apply:-

i. The conditions in paragraph 3.20.5 are met (the substation is connected to a global earthing system).

And/or

ii. The EPR at the substation is less than 466V during fault conditions lasting 1 second or less. For longer clearance times then a lower EPR must be achieved to permit the HV and LV electrodes to be combined see table 3.20.2.3 below.

Table 3.20.2.3

Fault clearance time in seconds	1	1.1	1.2	1.3	1.4	1.5	2	3
Permissible EPR in Volts	466	438	418	400	386	376	346	324

The conditions can normally be satisfied if the substation is in an urban location, within an all underground cable network and not the first substation on a circuit out from a primary substation.

At new substations bonding of the HV and LV earth electrodes can be achieved using a combined electrode or the fully rated link within the LV distribution cabinet, which connects the LV neutral bar to the HV switchgear earth bar.

Where the HV and LV earth electrodes are combined an electrode will be laid for a minimum of 80m out with incoming and outgoing HV cable routes. Where a new substation is connected into an existing network the additional electrode will be laid the length of the HV trench where this is less than 80m.

Where the HV and LV earth electrodes are not combined because the conditions (i) or (ii) above cannot be met refer to section 3.20.2.4 applies.

3.20.2.4. Substations with Separate HV and LV Earth Electrodes

Where HV and LV earth electrode systems are kept separate at ground mounted substations (for pole-mounted substations see section 3.20.8) the HV earth electrode shall be of sufficiently low value to restrict the rise of earth potential to a maximum of 2000V in the event of an HV fault. Additional earth rods or electrode consisting of bare copper conductor with a minimum cross-sectional area of 70mm^2 may be installed to achieve the sufficiently low HV electrode value. The resistance to earth of the LV earth electrode shall not exceed 20 ohms (This value applies to the main S/S LV electrode only and exclude the benefit of other connections to earth such as cable sheaths, additional PME earth electrodes etc.) Measurements of resistance shall be made by an approved method (see Appendix C).

Separate HV and LV electrode systems are required which are electrically segregated via a 9m separation in the soil, in these situations no additional electrode will be run with the outgoing HV cable routes unless it is installed to achieve the value of HV earth electrode to restrict the rise of earth potential to a maximum of 2000V.

Exposed, earthed metalwork associated with HV plant (transformer, switchgear etc.) shall be connected to the bare electrode in and around the substation. The LV transformer neutral shall be separately earthed via insulated conductor to the LV electrode system situated at least 9m away from the substation HV earth electrode.

Where HV and LV electrode systems are kept separate warning notices shall be fitted with the following wording (black lettering on a yellow background):-

CAUTION

HOT SITE EARTHING – Avoid making simultaneous contact between the high voltage metalwork earthing and low voltage earthing systems.

3.20.3. Distribution Substations Near or Within a Higher Voltage Substation

Such cases are to be referred to the NPG Design Engineer.

3.20.4. Customer Substations Supplied at HV

Wherever possible, one of the standard arrangements having a combined electrode will be used. The HV earth will be installed by Northern Powergrid, whilst the LV electrode will be the responsibility of the customer to design, install and maintain. Where the systems have to be segregated, a nine metre separation is required between the LV electrode and any HV electrode or exposed HV metalwork.

Where the substation forms part of a larger building and it is not possible to install an earth electrode around the full perimeter of the substation, it is permissible to install the electrode in accordance with drawing C1065495 (315 – 1000kVA Slide in UDE - Integral to a building). It is not permissible to install a substation with a high EPR (commonly known as hot) within a larger building.

Should the customer wish to connect the LV electrode to the HV one, the matter is to be referred to the NPG Design Engineer.

The Engineer responsible for site works during construction is required to confirm that the HV and LV electrode (if to be combined) is installed to the company's specifications. Testing of the earth value and, if appropriate, for segregation, should be carried out prior to commissioning, following the approved Northern Powergrid procedure (see appendix C).

Where a standard arrangement is not possible and the customer has HV equipment/plant, then two HV electrode systems will be required. Northern Powergrid will install its own, based on section 3.20.7.1 below. The customer will install a system which, as a minimum, encircles their equipment/plant on all sides, or those sides not covered by the company's electrode. Ideally, the two HV earthing systems will be designed as one entity and be combined to provide a low overall earth impedance. If not designed together, then before a connection between them is permitted, the NPG Design Engineer must ensure that the combined earthing system will be satisfactory and agree the method of connection which will normally be via two connections to a combined earth bar that can be split to segregate the installations for testing purposes.

3.20.5. Installation of HV Substations at Fuel Filling stations

Where a substation at a fuel filling station supplies a small isolated system made up of a single TNS supply or an installation that has a TT earth system for example a rapid charge Electric Vehicle Charging Point (EVCP) installation the F factor mentioned in EREC 41-24 to establish the tolerable voltage should be taken as 1.

For substation where the F factor is 1 the tolerable voltage based on 1 second clearance time will be 233V. If the EPR of the substation is above 233V a specific earthing study will be required to identify the extent of the 233V contour, details of a typical site-specific earthing study provided by an earthing specialist is provided in appendix G. Any TT earth connection for an EVCP installation and any earthed metal work connected to the fuel filling installation should be outside any 233V contour produced by the HV

Where a substation at a fuel filling station site provides a dedicated LV connection for example to a rapid charge EVCP installation the connection should be made by 4 core SNE cable or no earth offered, where the customer installs their own TT earth system.

3.20.6. Global Earth Concept

A global earth system is an equivalent earthing system created by the interconnection of local earthing systems made up of earth electrodes and cables with metallic sheaths in direct contact with earth that ensures, by the proximity of the earthing systems, that there are no dangerous touch voltages. Such systems permit the division of the earth fault current in a way that results in a reduction of the earth potential rise at the local earthing system. An example of a global earth system is one associated with a city centre where the majority of cables have metallic sheaths in direct contact with earth.

In urban situations it is desirable that ground mounted distribution substation HV and LV earths are bonded together to achieve the lowest practical earth value in an environment where installation and effective segregation of earths is often difficult or impossible.

If HV and LV earths are to be combined there is an obligation for Northern Powergrid to ensure the potential on the combined HV/LV earth electrode and in turn customers exposed conductive metalwork does not rise to unacceptable levels under fault conditions. The two main fault scenarios are:

- HV faults at or adjacent to the distribution substation which may or may not be connected to the associated primary substation by a continuous metallic cable sheath.
- EHV faults at the source primary substation causing the primary substation and its HV cable system to become 'Hot'.

The possibility of the earth potential rise (EPR) on the combined HV/LV earth electrode can generally be ignored when:-

a) For distribution substation locations **with NO** continuous metallic sheath connection back to the source primary substation (i.e. there is a section of overhead line in the circuit between the source substation and the distribution substation) where all of the following criteria listed below can be met:

i. The distribution substation concerned is located in an area with a uniform soil resistivity of less than 200Ω m.

ii. A gross source 11kV earth fault current of less than 2500A.

iii. At least 8kM of metallic sheathed cable in direct contact with the soil (Cables sheaths further than 1km from the substation under consideration should not be counted).

iv. The distribution substation concerned will also have metallic interconnection via HV or LV cable sheaths to at least one other distribution substation.

Or

b) For distribution substation locations **with a** continuous metallic sheath connection back to the source primary substation where all of the following criteria listed below can be met :

i. A continuous metallic sheath connection back to the source primary substation bonded effectively at each substation.

ii. The distribution substation concerned is located in an area with a uniform soil resistivity of less than 200Ω m.

iii. A gross source 11kV earth fault current of less than 2500A.

iv. At least 2kM of metallic sheathed cable in direct contact with the soil (Cables sheaths further than 1km from the substation under consideration should not be counted).

v. The distribution substation concerned will also have metallic interconnection via HV or LV cable sheaths to at least one other distribution substation.

c) In addition to the requirements of 2) above the primary substation supplying the distribution substation is classified as cold.

If the above conditions are met the HV and LV earths of urban ground mounted distribution substation may be bonded together.

If any of these criteria cannot be met further investigation will be required:

- If condition 1 or 2 cannot be met the actual earth return current at the proposed distribution substation can be calculated and Tables 1 and 2 consulted using this current in place of the source fault current.
- If the conditions still cannot be met further investigation into the value of return earth current through the electrode and the resistance value of earth the electrode should be carried out including assessing the impact of adding additional electrodes.

If after this further investigation the requirements for combining the HV and LV earth cannot be met the earths shall be separated with reference to the guidance in section 3.20.7.3

Table 1

Calculated Impedance of PILCSWA Cable Networks with Metallic Sheaths in Contact with the Soil - Assumes No Continuous Metallic Sheath Path Back To Source

Resultant EPR's > 466V are shown highlighted in grey

Total* Length of PILCSWA cable - kM	Impedance ohms	EPR for Calculated Site Earth Fault Currents of:					
		3000A	2500A	2000A	1500A	1000A	500A
2	0.431	1293	1077.5	862	646.5	431	215.5
4	0.247	741	617.5	494	370.5	247	123.5
6	0.188	564	470	376	282	188	94
8	0.155	465	387.5	310	232.5	155	77.5
10	0.136	408	340	272	204	136	68

*Metallic cable sheaths must be in direct contact with the soil.(hessian serving allowed), Cables sheaths further than 1km from the substation under consideration should not be counted

Cable in ducts or with plastic sheath do NOT count.

Cables following parallel routes do NOT count.
Metallic sheathed LV cables may only be counted if they are connected to a common HV/LV earthing system

Uniform Soil Structure 200Ωm Cable size used for modelling 0.1 sq in 11kV

Table 2

Calculated Impedance of PILCSWA Cable Networks with Metallic Sheaths in Contact with the Soil - Assumes Continuous Metallic Sheath back to Source Substation (maximum 65% reduction - minimum 35% ground return)

Total* Length of PILCSWA cable - kM	Impedance ohms	EPR for Calculated Site Earth Fault Currents of:					
		3000A	2500A	2000A	1500A	1000A	500A
1	0.82	861	717	574	431	287	144
1.5	0.64	672	560	448	336	224	112
2	0.431	453	377	302	226	151	75
4	0.247	259	216	173	130	86	43
6	0.188	197	165	132	99	66	33

*Metallic cable sheaths must be in direct contact with the soil.(hessian serving allowed) Cables sheaths further than 1km from the substation under consideration should not be counted

Assumes continuous Sheath back to source primary substation.

Cable in ducts or with plastic sheaths do NOT count.

Cables following parallel routes do NOT count.

Metallic sheathed LV cables may only be counted if they are connected to a common HV/LV earthing system

Uniform Soil Structure 200Ωm Cable size used for modelling 0.1 sq in 11kV

Maintaining a Global Earthing System

If the substation is connected to a modern HV cable network with all insulated cable sheaths, e.g. PICAS, XLPE etc. In this case the HV and LV cable sheaths will make no significant contribution to the HV earthing system. (They are generally the most important factor in lowering earthing resistance in older systems with hessian served metallic sheathed cables) Unless carefully managed there is a natural tendency for such systems to have high resistances to earth and a high earth potential rises under fault conditions. The benefits of Global earthing tend to be lost overtime as more insulated sheath HV and LV cable is installed and cables with metallic sheaths in contact with the soil are removed.

In order to maintain a global earthing system the following action will be taken: -

- Often reinforcement schemes involve replacement of lead sheathed, steel armoured 6.6, 11 or 33kV cables. The sheaths of these old cables once disconnected should be connected to the electrode system. Due to the high risk of damage, it is essential that multiple connections are provided to such cables. They should also be marked up on the cable records as supplementary earth electrodes. The remote ends (or intermediate points) must also be connected to the electrode system by connections to the cable sheath at suitable points, such as at joints or distribution substations.
- Where the HV and LV earth electrodes are combined a bare copper stranded earth electrode of 70mm^2 cross-sectional area shall be laid with an out-going group of insulated sheath cables for a minimum distance of 80 metres from the substation. Care should be taken to avoid placing this electrode in areas subject to a rise of earth potential from adjacent towers or EHV substations.
- In newly developing urban areas where a high proportion or possibly all the network has or will be plastic sheathed HV and LV cables and where there is higher than average soil resistivity (>200Ωm) consideration will be given at the network design stage to installing addition earth electrode in excess of the 80m mentioned above at each distribution substation in such cases guidance of the policy manager for earthing will be sort.

3.20.7. Construction Details

3.20.7.1. Materials

The standard materials are:

(i) For the perimeter electrode 25 x 4mm copper earth tape or equivalent (This can cater for up to 8kA fault current for three seconds, as required by ENA TS. 41-24). Where, bare stranded copper conductor is used as an equivalent to provide a similar corrosion resistance to that of tape this shall be of a minimum cross sections area of or 120mm^2.

(ii) Extensible earth rods - copper clad to ENA TS 43-94. 1.2m long 16mm diameter.

(iii) Bonding conductor for connecting roof and metal walls of external enclosure - stranded copper, PVC covered, flexible 16mm^2 cross sectional area.

(iv) Inter-plant bonding conductor - stranded, copper conductor of 95mm^2 cross section, PVC covered, to BS EN 60228.

(v) Flexible copper connecting braid of $16mm^2$ minimum.

(vi) Flexible copper power cable gland connections of minimum $50mm^2$.

(vii) Electrode conductor (run 80m with cable)- bare copper conductor of $70mm^2$

3.20.7.2. Installation of Electrodes

Where it can be reasonably assumed that the soil resistivity will be greater than 200Ωm (i.e. in arrears where the soil is made up primarily of slate, shale or rock), prior to, or during the civil works, soil resistivity readings should be taken. Once interpreted, these can be used with table 3.20.7.3 and 3.20.7.4 to provide an estimate of the resistance value. If the calculated resistance is too high, the guidance in the tables should be followed to reduce it. Normally this is by installing longer vertical rods. Alternatively, or in addition, earth electrode can be installed in one of the HV cable trenches, provided this is 9m from any planned LV electrode.

The LV electrode can be laid in an LV cable trench, providing that 9m separation is maintained between this electrode and any HV metalwork, HV hessian served cables and the HV electrode. Guidance is provided in Table 3.20.7.4 concerning the amount of electrode required to achieve the necessary LV resistance value.

Care must be exercised when driving earth rods because of the possibility of puncturing / damaging cables or other services buried below the cable trench level. This is especially important when rods are installed after the completion of cable laying. Cable locating tools and techniques must be used in addition to consulting accurate cable records, to avoid damaging such cables/services.

Where earth conductors are laid adjacent to HV cables, the backfilling medium will be dictated by the cable thermal requirements. Where a site has been classified as cold there is a requirement to install an additional electrode in the form of a bare earth conductor of 70mm square cross-sectional area. Where achievable this electrode will be 80m long and installed on the bottom of the trench, below the cables, in direct contact with the surrounding soil with a clearance of 0.5m from hessian-covered or plain tape-armoured conductors and 0.2m where the cable has an insulated outer sheath. Where this cannot be achieved for technical reasons, the electrode will be installed the length of the excavated trench and installed with a minimum depth of 0.6m, surrounded by non-corrosive soil of fine texture, firmly compacted and with a minimum clearance of 150mm from any cables with an insulated outer sheath.

The horizontal electrode adjacent to a substation door (and any other earth electrodes forming part of measures to reduce the effect of touch voltage) should be bedded in suitable backfill, then covered with a layer of crushed rock or chippings or concrete slabs.

Bare copper conductor can corrode in hostile soil environments causing earthing systems to become ineffective. Soils containing sulphates, sulphides and acids should be avoided.

Under no circumstances are earth electrodes to be installed in coal ash (or similar material), which is normally very corrosive to copper.

The use of land in which bare earth electrodes are placed should be considered. Locations to avoid include sites where people may be expected to walk barefoot such as caravan sites and pathways to beaches etc. Animals have a relatively low step voltage (25V), hence routes where farm animals may be expected to pass or congregate frequently such as gateways and drinking/feeding troughs etc. should be avoided.

3.20.7.3. 20/11/6.6kV Cables

The earth sheaths (and armours, if present) are to be terminated via a flexible connection onto the switchgear earth bar that interconnects the transformer and HV switchgear. The flexible connection shall be sufficiently long to accommodate earth passage fault indicators or automation transmitters and shall be of $50mm^2$ (minimum) copper or for XLPE cables the cables screen shall be used. It is important that these connections are of low resistance and secure against loosening by vibration etc.

The resistance of the connection and joint is to be measured using a micro-ohmmeter and will be below 100$\mu\Omega$.

3.20.8. Standard Arrangements

3.20.8.1. Standard Earthing Arrangements for Ground Mounted Substations

HV Electrode

A perimeter electrode (25 x 4mm copper earth tape or equivalent) shall be installed on the outer edges of the foundation, in direct contact with the soil at a depth of no less than 0.6m and unless there is good technical reasons not to at a depth of 1.2m.

Two connections from the perimeter electrode shall be brought up to the switchgear earth bar and fitted adjacent to one another.

Where reinforcing bar is used in the foundation of the substation, the reinforcing bar that is under the position of an operator during high voltage switching activities will be connected to the main HV earth electrode. If bolted connections are used the connection will be at a minimum of 2 position where the connection is by welded techniques 1 connection will be acceptable.

Where no reinforcing bars are available an additional earth electrode will be installed under the position at which an operator will be stood during high voltage switching activities, the electrode shall be a minimum cross-sectional area of 70mm^2 connected to the main perimeter earth electrode at 2 points and installed at a maximum depth of 600mm.

Four 1.2m earth rods shall be installed 1 on each of the corners (2.4m rods in rural areas) of the perimeter electrode.

If metal doors are used, then additional grading electrode will be required in front of the doors.

If the substation is of a steel kiosk construction a second perimeter electrode shall be installed around the substation, 0.6m deep and 1m away from and bonded to the standard perimeter electrode at two points.

Where the HV and LV earths are combined an electrode will be laid for a minimum of 80m out with incoming and outgoing HV cable routes. Where a new substation is connected into an existing network the additional electrode will be laid the length of the HV trench where this is less than 80m

Bonding

All main items of plant must be bonded to the main switchgear bonding bar with either 25 x 4 mm copper tape, 25 x 6mm aluminium tape, 95mm^2 PVC covered copper or 120m m^2 PVC covered aluminium. The bonding bar and bonds to each main item of plant are normally supplied installed on new plant by the manufacturer. Connections to metalwork must be free from paint, cleaned and a protective coating of grease applied. Where copper theft has occurred on a site the above ground bonding should be replaced with aluminium conductor in line with Note 3, 4 and 6 of appendix D.

LV Electrode

Not required where the HV and LV earths are to be bonded, as the HV earth will fulfil the necessary requirements.

If separate earths are required (see para. 3.20.2.4) a minimum distance of 9m must be maintained between this electrode and any 11kV electrode, the substation compound and any other metalwork connected to the HV earth. The LV electrode will be connected to the LV neutral busbar in the LV cabinet via at least 9m of 95mm^2 PVC covered copper conductor. The PVC conductor must be connected to the LV earth electrode at one end and to the neutral bar of the distribution cabinet at the other, via Northern Powergrid approved connectors.

High Voltage Cables

The outer metal sheath of 11kV cables will be bonded to the switchgear bonding bar via a flexible strip or braid having a current carrying capacity equivalent to at least $50mm^2$ copper. This is to be of sufficient length to accommodate a fault current indicator.

Low Voltage Cables

For modern CNE cables, the outer sheath of the cable will be connected to the neutral bar in the distribution pillar using a Northern Powergrid approved compression or mechanical connector.

For SNE cables the outer sheath and armouring should be bonded together and connected to the earth bar in the distribution pillar. The neutral conductor is then connected to the neutral bar.

3.20.8.2. Standard Arrangement Drawings

Construction layouts have been produced to cover the main types of new HV substation, including kiosk type. The layouts have been designed to meet the following requirements:

(i) HV and LV earthing systems are installed separate or bonded.

(ii) LV electrodes if separated will have a maximum value of 20Ω.

(iii) Full bonding within the substation is provided.

(iv) Additional protection is provided to protect operators, staff and the public against possible excessive voltage rise, where applicable.

3.20.8.3. Standard Arrangement Drawing list

The following arrangement drawings provide details of the construction practice necessary:

Title	Drawing No.
Earth Point Connection Details	C978643
315 – 1000kVA Slide in UDE - Integral to a building (not suitable for a free standing substation) earthing arrangement combined site (cold)	C1065495
315 – 1000kVA Slide in UDE with customer LV MCCB earthing arrangement – combined site (cold)	C1024527
315 – 1000kVA UDE earthing arrangement – combined site (cold)	C1010793
800 – 1000kVA Slide in UDE earthing arrangement – combined site (cold)	C1010820
11kV Extensible HV panel with metering annexe earthing arrangement – combined site (cold)	C1010822
11kV RMU cable connected 1600kVA transformer and 2500A MCCB earthing arrangement – combined site (cold)	C1010824
11kV RMU and metering unit with optional extensible switch earthing arrangement – combined site (cold)	C1010827
20kV RMU cable connected 1600kVA transformer and 2500A MCCB earthing arrangement – combined site (cold)	C1010839
20kV Extensible HV panel with metering annexe arrangement – combined site (cold)	C1010841
20kV Distribution substation earthing arrangement – combined site (cold)	C1010842
315 – 1000kVA Slide in UDE earthing arrangement – separate site (hot)	C1010854
315 – 1000kVA Slide in UDE with customer LV MCCB earthing arrangement – separate site (hot)	C1010607
Title	**Drawing No.**
11kV RMU cable connected 1600kVA transformer and 2500A MCCB earthing arrangement – separate site (hot)	C1010855
20kV RMU cable connected 1600kVA transformer and 2500A MCCB earthing arrangement – separate site (hot)	C1010858
800 – 1000kVA UDE earthing arrangement – separate site (hot)	C1010864
20kV Distribution substation earthing arrangement – separate site (hot)	C1010867
11kV RMU and metering unit with optional extensible switch earthing arrangement – separate site (hot)	C1010868
20kV Extensible HV panel with metering annexe earthing arrangement – separate site (hot)	C1010869
11kV Extensible HV panel with metering annexe earthing arrangement – separate site (hot)	C1010879
Earthing connection point examples for policy IMP/010/011	C1010947
Schedule of drawings earthing arrangements for policy IMP/010/011	C1010944

3.20.8.4. Standard Arrangement Resistance Values

The above standard arrangements produce the resistance values in different soil types illustrated in table 3.20.7.3 below.

Table 3.20.7.3

Soil Type	Typical Soil Resistivity (Ωm)	Resistance of Standard Earthing Designs with 1.2m Earth Rods at S/S
Loam	25 or less	2.2Ω
Chalk	50 or less	4.4Ω
Clay	100 or less	8.7Ω
Sand/Gravel/Clay mix	150 or less	13.0Ω
Sand/Gravel/Clay mix	200 or less	17.3Ω
Slate/Shale/Rock mix	500	43.2Ω

3.20.8.5. Approximate Electrode Earth Values

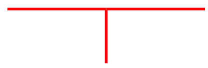
Where it is necessary to install a separate earth with a maximum 20Ω value then the following alternative arrangements shown in the table below may be installed:-

Arrangement 1 gives the required length of horizontally laid bare conductor (A minimum length of 5m is suggested) required to achieve an LV electrode value of less than 20Ω for various soil resistivities

Arrangement 2 is a simple horizontally laid conductor installed in incremental lengths of 5m plus a 3.6m vertical rod at 5m intervals.

Bare LV earth conductor shall be separated by at least 9m of insulated conductor from the nearest part of the HV electrode system. (This includes non-plastic sheathed HV cable such as PILCSWA cables with hessian serving).

Table 3.20.7.4 LV Electrode Arrangements to give 20Ω

Soil Resistivity (Ωm)	LV Electrode Arrangements to give 20Ω	
	Arrangement 1 **Horizontal Electrode Only (Length Required)**	**Arrangement 2** **3.6m Vertical Rods + 3.6m Horizontal Electrode Segments**
25	2.5m	
50	6m	
100	12m	
150	20m	
200	28m	
500	75m	3.6m Rod x 7 plus 7 x 5m Horizontal
Key Key 3.6m Vertical Rod 5m Horizontal Electrode		

3.20.9. Pole-Mounted Substations

The cost of installing earth electrodes at an isolated pole-mounted substation and associated LV network to achieve a resistance to earth value capable of restricting the EPR to less than 466V under HV fault conditions will normally be excessive.

Therefore, the HV earth electrode at the pole-mounted substation shall always be separated from the LV earth electrode.

The HV earth electrode and the LV earth electrode shall each have a resistance to earth of 20 ohms or less; the value will be measured by an approved method.

A minimum distance of 9 metres will be maintained between any uninsulated parts of the HV and LV earth electrodes which are below ground level. The required separation will normally be obtained by earthing the LV neutral conductor one span away from the substation, Drawing C953076 Fig A. (over page) Connections to earth electrodes will be insulated from earth to a depth of at least 500mm below ground level using the conductors specified in Appendix D.

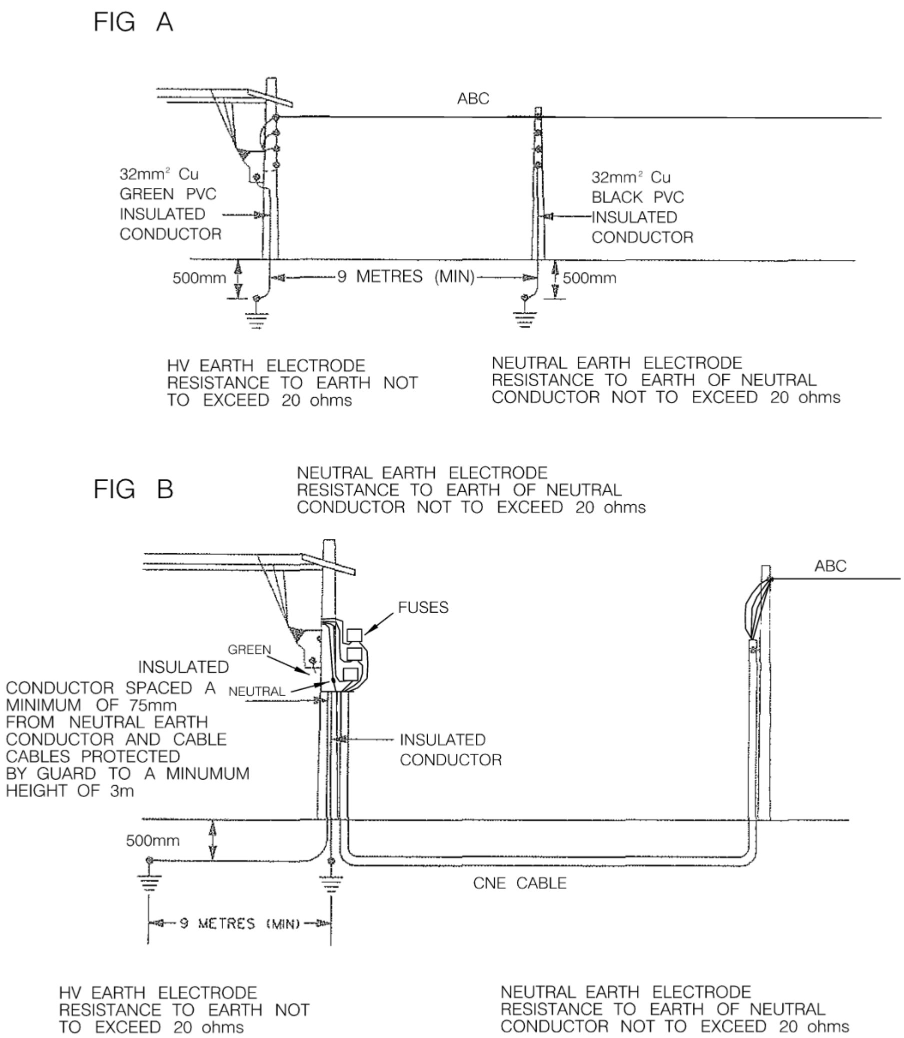
Consideration must be given to maintaining HV/LV earth physical segregation including taking into account the presence of metallic sheathed cables.

If a metallic sheath LV cable is connected at the substation its metallic sheath must be connected to the neutral conductor. Separation of the electrodes in this case may be achieved by connecting the transformer tank to a remote earth electrode 9m away from the base of the pole by a green coloured insulated lead as shown in Drawing C953076 Fig B. The HV earth electrode lead on the pole will be spaced at least 75mm from the LV earth-lead and the sheath of the LV cable.

For structures fitted with surge protection an HV earth value of 10Ω or less will be installed to limit EPR under lightning induced fault conditions. This will reduce the risk of plant insulation failure through back flashover.

Pole mounted substations supplying mobile phone base stations on transmission towers shall be designed and installed in accordance with The Energy Networks Association document G78 (Recommendations for low voltage supplies to mobile phone base stations with antennae on high voltage structures).

Where copper theft has occurred on a site the above ground bonding should be replaced with aluminium conductor in line with Note 3, 4 and 6 of Appendix D.



NORTHERN POWERGRID	Lloyds Court, 78 Grey Street, Newcastle Upon Tyne, NE1 6AF		
Manufacturer Details	EARTHING ARRANGEMENTS AT POLE MOUNTED SUBSTATIONS WITH SEPERATE HV AND NEUTRAL EARTH ELECTRODES		
Sheet No. / Scale N.T.S.			
Prepared By John.Brooke	Document Details PLANT DIAGRAMS GENERAL		
Revised 13/10/2017 / Grid Reference	Ref No. C953076	Historic Drawing No.	
Date Issued 17/10/2007 / Checked By J PAINE	Revision A	Notes DIMENSION CHANGES	A4

File last saved / modified on the 16/10/2017 09:33:53 by John.Brooke.
OS File Name - [C953076.DGN]

3.20.10. HV Substations or LV network adjacent to EHV towers or EHV Substations with a High EPR

Where a new substation or low voltage distribution network is to be located within 100 metres of a tower supporting conductors at 132kV or above an assessment will be made of the voltage contours from the tower to determine if additional measures need to be taken into consideration when designing the earthing. For installations between 100m and 30m a desk top review should be carried out using information and guidance in EREC S41, EREC S34 and EREC 41-24 to understand the likely effect of the contours on the earthing design. For installations within 30m of the tower a specific earthing study should be caried out by an approved earthing specialist. Where it is established that the soil resistivity is above 200 ohm metres at the tower the 100m rule may need to be extended,

Where a new substation or Low voltage distribution network is to be located within 100 metres of an EHV substation with a high EPR the extent of the voltage contours above tolerable voltage limit should be established with refence to the Northern Powergrid substation hot site database; information, and guidance in EREC S41, EREC S34 and EREC 41-24 to understand the likely impact of the contours on the earthing design of the installation Where it is established that the soil resistivity is above 200 ohm metres at the tower the 100m rule may need to be extended.

3.20.11. LV Auxiliary Supplies to EHV Substations with a High EPR (Hot) Site

This section provides guidance on the provision of LV supplies to all EHV sites that are HOT or owned by National Grid. Supplies to these sites require special consideration to avoid the earth potential rise (EPR) during an earth fault being exported onto the HV or LV network and into a customer's premises where it could cause danger to life or damage to property.

Due to the risks of an insulation breakdown / flashover on the LV it is not permitted to provide an auxiliary supply to an EHV substation with a high EPR direct from an LV network. The auxiliary supply shall always be provided from a dedicated HV supply, no other customers shall be connected to the transformer. Special operational procedures apply to jointing on HV cables connected to substations within hot sites these are identified in document RTN/500/410/006 - Approved Procedure for Jointing on High Voltage Interconnecting Cables between Hot and Cold Sites.

3.20.11.1. EHV Substations with a High EPR in Rural Locations

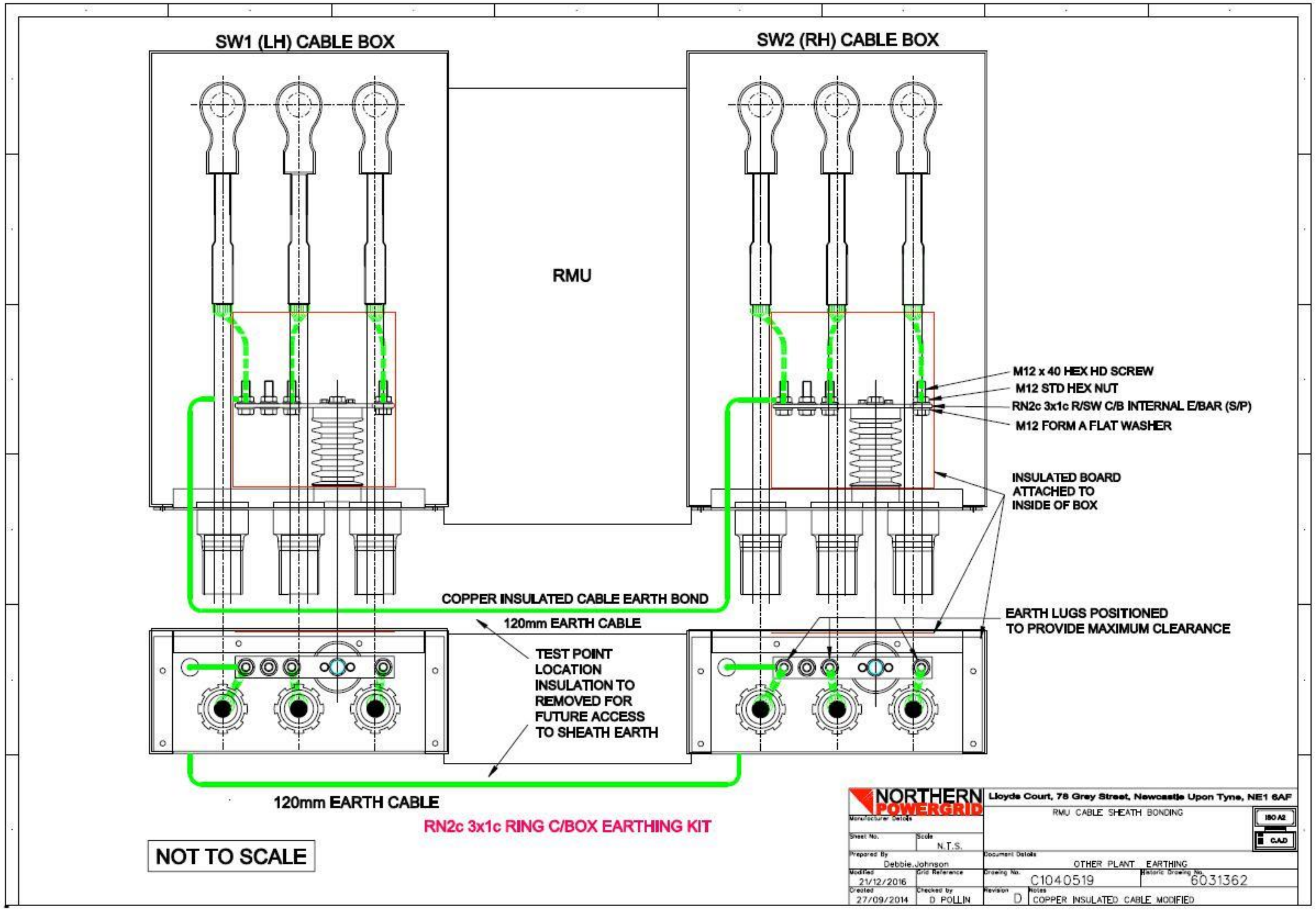
The preferred option for providing auxiliary supplies to EHV substations within rural locations is to provide a pole mounted transformer within the hot sites connected off an overhead line. The pole equipment HV and LV earths shall be bonded together and to the EHV earth electrode of the hot site.

Where the HV tee cannot be provided by overhead line a HV cable can be connected to the overhead line and to an inverted pole equipment (Totem Pole) located within the hot zone. The HV cable shall be ducted within the hot zone; the HV and LV earths shall be combined and connected to the EHV earth electrode. The HV cable shall be fitted with a surge diverter at the overhead line tee off position and a 10 ohm earth will be installed at this point. A warning label shall be fitted at the HV tee off position (black lettering on a yellow background) “Warning connection to a hot site – Special Operational Procedures apply”

Where it is uneconomic to connect to an overhead line and a HV cable is available a ground mounted substation will be located within the hot zone. The HV cable shall be ducted within the hot zone; a stand-off insulator will be mounted in each HV cable box, the cable sheath will be terminated to an earth bar mounted on this stand-off insulator (see photograph 3.20.9) there shall be no connection between the HV cable sheath and the switchgear earth. Where the substation is looped in the HV cable sheaths shall be connected together using an insulated bond (see drawing 3.20.9). The substation HV (excluding the HV cable sheath) and LV earths shall be combined and connected to the EHV earth electrode. A warning label shall be fitted to the substation HV switchgear and at the remote end switchgear supplying the substation, the warning label will have black lettering on a yellow background “Warning connection to a hot site – Special Operational Procedures apply”.

3.20.11.2. EHV Substations with a High EPR in Urban Locations

Where EHV substation sites are located in urban areas surrounded by cable networks a ground mounted substation will be located within the hot zone. The HV cable shall be ducted within the hot zone; a stand-off insulator will be mounted in each HV cable box, the cable sheath will be terminated to an earth bar mounted on this stand-off insulator (see photograph 3.20.9) there shall be no connection between the HV cable sheath and the switchgear earth. Where the substation is looped in the HV cable sheaths shall be connected together using an insulated bond (see drawing 3.20.9). The substation HV (excluding the HV cable sheath) and LV earths shall be combined and connected to the EHV earth electrode. A warning label shall be fitted to the substation HV switchgear and at the remote end switchgear supplying the substation the warning label will have black lettering on a yellow background “Warning connection to a hot site – Special Operational Procedures apply”.



3.20.9 Cable Sheath Bonding between HV Cables

<u>3.20.9 Cable Sheath Earthing Arrangement</u>

4. References

4.1. External Documentation

Reference	Title
	The Electricity Safety, Quality and Continuity Regulations 2002.
BS 62305	Code of practice for protection against lightning
BS 7375	Code of practice for Distribution of electricity on construction and building sites
BS EN 13636	Cathodic protection of buried metallic tanks and related piping
BS7671	Requirements for Electrical Installations (IET Wiring Regulations) - Current Edition
ENA Technical Specification 41-24	Guidelines for the design, installation, testing and maintenance of earthing systems in substations
ENA Technical Specification 43-94	Earth rods and their connectors
Engineering Recommendation G12/5	Requirements for the Application of Protective Multiple Earthing to Low Voltage Networks
Engineering Recommendation G14	Protective Multiple Earthing; Recommended Principles for Testing to ensure Correct Polarity
Engineering Recommendation G39/2	Model Code of Practice covering electrical safety in the planning, installation, commissioning and maintenance of public lighting and other street furniture
Engineering Recommendation G59/3-2	Recommendations for the Connection of type tested small scale Embedded Generating Plant to the Public Electricity Suppliers Distribution Systems
Engineering Recommendation G78/3	Recommendations for the provision of LV Connections to Mobile Telephone Base Stations with Antennae on High Voltage Structures.
Engineering Recommendation G87/2	Guidance for the Provision of Low Voltage Supplies to Multi Occupancy Buildings
Engineering Recommendation G98	Requirements for the connection of Fully Type Tested Micro-generators (up to and including 16 A per phase) in parallel with public Low Voltage Distribution Networks on or after 27 April 2019
Engineering Recommendation G99	Requirements for the connection of generation equipment in parallel with public distribution networks on or after 27 April 2019
Engineering Recommendation P04/1	Services to British Telecom public telephone housings
Engineering Recommendation P24	AC traction supplies to British Rail (Addendum No.1 1990)
Engineering Recommendation S34	A guide for assessing the rise of earth potential at electrical installations
Engineering Recommendation S41	Guidance on transferred voltages from earthing systems
EREC C93	Type approval tests for mechanical connections to metallic sheaths of cables
Guidance Note GS 24	Electricity on Construction Sites
Guidance Note HS(G)41	Petrol Filling Stations: Construction and Operation

4.2. Internal Documentation

Reference	Title
NSP/002/001	Technical Specification for Earthing Materials
NSP/004/041	Code of Practice for the Construction of LV ABC Overhead Lines
NSP/004/043	Specification for Overhead Services, Surface Wiring and Eaves Wall Mains
RTN/500/410/006	Approved Procedure for Jointing on High Voltage Interconnecting Cables between Hot and Cold Sites

4.3. Amendments from Previous Version

Reference	Description
Appendix E	Drawing C952986 being updated to show additional earth taken from mains breeches joint
Appendix F	New Appendix F added – Guidance on the approval of neutral detection and disconnection devices
Appendix G	New Appendix G – Example of a site specific earthing study
3.7.1	Wording added to clarify the requirement for a neutral/earth to earth connection at interim mains straight joints and a new requirement for an earth at mains breeches joint to comply with ESQC Reg 9(2)(b)
3.20.7.1 (vii)	Requirement for the earth electrode to be hard drawn copper removed
3.20.2.4	Clarification added that additional electrode may be added to sites with High EPR to reduce the EPR to tolerable levels or to 2kV where the HV and LV electrodes are separated
3.4.1, 3.4.5(i), 3.8.2, 3.8.4, 3.14	Sections updated to reflect current practice and that safety standards have changed over the years and the connection to the external earth was not always required. In older properties it's quite common to find no external earth installed. This does not necessarily make them unsafe; many properties have had no earth for over 50 years.
3.20.5	New guidance on the installation of HV Substations at Fuel Filling stations
3.20.6 table 2	Table 2 extended to 1km PILC
3.15.7	Special situation fuel filling stations updated to align with G12, the option to supply the filling installation using SNE earth removed
3.20.10	New guidance added for HV and LV networks adjacent to EHV towers or EHV Substations with a High EPR (Hot) Site
3.15.15	Additional examples of cable television distribution cabinets; control cabinets for mobile phone masts added for clarity. Section updated to enable future use of neutral detection and disconnection devices when approved for EVCP. Approval process added as appendix F
4.1	External references updated

5. Definitions

Term	Definition
Arial Bunched Conductor (ABC)	Refers to a single bunched LV overhead cable construction
Bonding Lead	Means a conductor by which items of metalwork are connected together electrically, not normally for the purpose of carrying current, but so as to ensure a common potential.
Branch Lines	Means any electric line through which energy may be supplied to 5 or more customers from any distributing main
Business Owner	Means the manager (or his representative) within the business responsible for the business process
Combined Neutral and Earth (CNE)	Refers to a network where the earth return and neutral return are provided by the same conductor
Customer	Means anybody or person supplied or entitled to be supplied with energy by Northern Powergrid and will include those customers on un-metered supplies.
Customer's Installation	Means 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 meter or cutout shall not form part of the customer's installation.
Customer's Premises	Means any area or building in the sole occupation of the customer.
Distributing Main	Means the portion of any main which is used for giving supply to branch lines, service lines and multi-service lines for the purpose of general supply.
Earth Electrode	Means 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 Potential Rise (EPR)	Means the rise in potential from a zero earth reference value during an earth fault on an adjacent HV or EHV circuit.
Earth-Continuity Conductor	Means a conductor including any clamp connecting a part of an installation or other accessible metalwork which is required to be earthed, to another such part or to the supply neutral/earth conductor.
Earthing Lead	Means the final conductor by which the connection to the earth electrode is made.
Earthing Terminal	Means the terminal provided by Northern Powergrid and directly connected to the supply neutral/earth or earth conductor at the supply terminals.
EHV	Means 33kV, 66kV or 132kV
Global Earth	Means an equivalent earthing system created by the interconnection of local earthing systems made up of earth electrodes and cables with metallic sheaths in direct contact with earth that ensures, by the proximity of the earthing systems, that there are no dangerous touch voltages
HV	High Voltage means above 1kV
Multi-service Line	Means any electric line through which energy may be supplied to two, three or four adjacent customers from any distribution main or branch line or substation.
Protective Multiple Earthing (PME)	The technique of using the supply neutral/earth conductor of a LV distribution system for earthing of services to customers and street lights or other street furniture.
Protective Neutral Bonding (PNB)	Refers to the situation where there is only one point in a network at which consumer's installations are connected to a single source of voltage, in such a case the supply neutral conductor connection to earth may be made at that point, or at another point nearer to the source of voltage.
Residual Current Device (RCD)	Means a mechanical switching device or association of devices intended to cause the opening of the contacts when the residual current attains a given value under specified conditions.
Separate Neutral and Earth (SNE)	Refers to a network where the earth return and neutral return are provided by separate conductors.
Service Lines	Means any electric line through which energy may be supplied to a customer from any distributing main on branch line or directly from a substation.
TN-C	Means a system where the neutral and protective functions are combined in a single conductor throughout the system. Earthed concentric wiring or Earthed Sheath Return Wiring is both examples of a TN-C system also known as CNE systems.
TN-C-S	Means a system where the neutral and protective functions are combined in a single conductor but only in a part of a system. Systems with PME applied to them are examples of a TN-C-S system, where the distribution system between the source of energy and the installation is TN-C and the installation itself is TN-S. PNB is also a variant of a TN-C-S system also known as a mixed system.
TN-S	Means a system where there are separate neutral and protective conductors throughout the system. A system where the metallic path between the installation and the source of energy is the sheath and armouring of the supply cable is a TN-S system also known as SNE systems.
TT	Means a system that has one or more points of the source of energy directly earthed and the exposed and extraneous-conductive parts of the installation are connected to a local earth electrode or electrodes that are electrically independent of the source earth(s). An example would be where the customer provides his own independent local earth and provides earth fault protection by use of a RCD
Where Practical	In the context of this document means where it is physically and technically possible to achieve within the budgetary context of the work programme or capital scheme that the activity is taking place under.

6. Authority for Issue

6.1. CDS Assurance

I sign to confirm that I have completed and checked this document and I am satisfied with its content and submit it for approval and authorisation.

		Date
Liz Beat	Governance Administrator	08/03/2023

6.2. Author

I sign to confirm that I have completed and checked this document and I am satisfied with its content and submit it for approval and authorisation.

Review Period - This document should be reviewed within the following time period.

Standard CDS review of 3 years	Non-standard review period & reason	
Yes	Period: n/a	Reason: n/a
Should this document be displayed on the Northern Powergrid external website?		Yes

		Date
Jim Paine	Technical Policy Manager	08/03/2023

6.3. Technical Assurance

I sign to confirm that I am satisfied with all aspects of the content and preparation of this document and submit it for approval and authorisation.

		Date
Andrew Scott	Technical Services Manager	04/04/2023
Phil Jagger	Head of Network Planning and Design	15/03/2023

6.4. Authorisation

Authorisation is given for the content of this document.

		Date
Mark Nicholson	Director of Engineering	06/04/2023

Appendix A - Customers' Installations

Customers installations can only be connected to a PME terminal if the bonding conforms to BS7671 (IET Wiring Regulations)

1. Bonding and Earthing

The customer's water, gas and any other metallic services (except metalwork forming part of a telegraphic, telephone or signalling circuit) shall be bonded to the Northern Powergrid earthing terminal block either separately or by means of a common bonding lead having a minimum cross sectional area as specified in Appendix D. Conductor shall be stranded copper, green/yellow PVC insulated cable. Any other metal structures which might come into electrical contact with earth and which are in easy reach of any exposed non-current-carrying metalwork of the customer's installation shall also be bonded to the earthing terminal.

Where doubts arise on the need for bonding particularly items of extraneous metalwork the criteria to follow are:-

(a) All structural metalwork which is embedded in the earth and is situated such that a person may make simultaneous contact with it and any other exposed metalwork which is to be connected to the earthing terminal must be bonded by a main equipotential bonding lead having a minimum cross-sectional area as specified in Appendix D.

(b) Supplementary local bonding connections may sometimes be required to maintain the equipotential zone but exposed extraneous fixed metalwork within the zone which is not in contact with earth need not be bonded unless it is likely to come into fortuitous contact with other earthed or bonded metalwork. Bonding connections with cross-sectional areas in accordance with the current edition of the IET Wiring Regulations are then required.

Connections to the service pipes shall be by means of clamps suitable for the pipe diameters which will avoid electrolytic action. These should be made as near as possible, with the exception of the gas service, to the point of entry of the service into the customer's premises.

In the case of gas services, the connection shall be made as near as possible to the outlet union on the customer's side of the gas meter, and before any branch pipe, and in any case no further than 600 mm from the meter. If, for actual or possible cathodic protection, a gas distribution company has installed an insulated insert between the incoming service pipe and the gas meter, the incoming service pipe shall not be bonded. Incoming unused gas service pipes should not be bonded but, if such pipes extended well inside the building, the pipe should be insulated in such a way that the insulation cannot easily be removed.

If the electricity service cable is mechanically protected, then any protecting metalwork shall be connected to the earthing terminal block.

The bonding of the customer's water, gas and any other metallic services with the exception of any Northern Powergrid equipment is the responsibility of the customer.

2. Arrangement at Customer's Intake Unit

Typical customer arrangements are shown in drawing C953036

The earth terminal made available to the customer will be by means of an earth terminal block securely bonded to the neutral conductor. This is achieved in the latest design of unit by bonding the neutral external connection to the Northern Powergrid earth terminal block, where provided, or the customer's earth terminal block and, on the older type, by bonding the neutral internal link on the incoming or outgoing side (as convenient) to the Northern Powergrid earth terminal block. The bonding lead shall be $16mm^2$ minimum green/yellow PVC insulated cable or half the size of the neutral meter tail whichever is the larger. Any metallic sheath or armouring of underground service cables shall be bonded to the earth terminal block or neutral terminal as appropriate.

On temporary supplies and in other situations where we are unable to verify that the requirements of bonding and earthing as described in Section 1 above have been complied with, the earthing terminal block shall be rendered inaccessible so as to prevent unauthorised connection.

The size of common bonding lead between the customer's metallic services and the Northern Powergrid earthing terminal block will be a minimum of $10mm^2$ and that between the neutral link and the Northern Powergrid earthing terminal block will be a minimum of $16mm^2$. Where the expected loads of a customer's installation require it, the size of these connections shall be increased in accordance with the appropriate values shown in Appendix D.

3. Installation of Earthing Clamps at Customer's intake unit on existing underground and overhead networks

In existing customer's installations where there is an earth return path to the substation via the underground cable sheath or separate earth conductor then, when the opportunity arises earthing clamps of an approved pattern shall be fixed, one to the cable sheath and one to any armouring. The clamps shall be bonded together and connected to a Northern Powergrid earthing terminal block on the meter board, to which the customer's earth continuity conductor may be connected. If the service cable contains a separate earth conductor, this shall be connected to the earthing terminal block.

The customer shall be informed by a standard letter that the earth terminal has been provided and is available for his use.

It should be noted that private contractors' staff are not permitted to fix the clamps under any circumstances.

4. Warning Notice

A warning notice shall be fixed at the customer's service position indicating that the earth terminal is PME.

When a new PNB earth terminal is installed the appropriate label will be fixed at the service position. If a supply to a single customer employing PNB is later extended to become a PME network feeding a number of customers, then the PNB warning notice at the original customer's premises shall be replaced by the PME type.

5. Customer's Service Polarity Testing

On a PME system the connection of the live conductor of a service to the neutral connector block on the customer's premises creates a dangerous situation where all the customer's metalwork bonded to the Northern Powergrid earth terminal block becomes live at line voltage. Under these circumstances, the earth in the vicinity of the premises also tends to rise to line voltage, and tests intended to establish polarity may be misleading and may indicate correct polarity even though it is reversed.

Polarity tests will be carried out on all new customer installations or when any work has been carried out which could have affected the customer’s polarity.

Appendix B - General Guidance for Minimising Electrical and Magnetic Compatibility (EMC) Problems

This is becoming an important issue due to the proliferation of computers and other IT type business and entertainment equipment within commercial, industrial and domestic premises. Systems should be able to operate without interfering with each other.

Earthing has an important role in EMC, but this must never be allowed to compromise its primary safety role.

The following general principles should be followed to help reduce the impact of EMC problems on an installation:-

Have a combined earthing/electrode system with multiple ground connection points. This will form part of the common bonding system, which will include extraneous metalwork, steel beams, rebar, pipes etc. Wherever possible the company earthing terminal would form part of this. Internal equipment, lightning protection etc., would then be connected to the common bonding system in a manner required by the customers building services engineer.

Wherever possible, the internal power supply should be of the TN-S type as this has the best EMC performance. Avoid providing multiple PME supplies to single buildings particularly where there are paths for neutral current diversion through structural steelwork, bonding etc. Although hard to manage at large, multi-occupancy buildings, this is essential to prevent significant EMC issues.

Incoming and outgoing cables are best grouped at one point, near which the main incoming earthing terminal and connections to a closely located earth electrode exist. The earth sheaths and screens of the incoming power supply cable should be connected directly to the main earth terminal or (if the earths are not to be connected) have a surge protection device fitted.

Inter-building cables should preferably be in shallow metal troughs, which are multiply earthed and bonded to an integrated electrode system at either end.

The following is a list of other precautionary measures, which may be applied to minimise EMC problems:-

Separate control cable routes from those of power cables

Install cables in trefoil rather than flat formation.

Avoid secondary cable runs in parallel with busbars or power cables.

Route control cables to avoid single-phase transformers and inductances.

Avoid cable earth loops.

Ensure that all wires associated with the same circuit are contained in one cable or grouped along one route.

Auxiliary cable routes to have radial rather than ring configuration.

Use screened, twisted pair cables for data transfer.

Suitable shielding of secondary circuit cables.

Group circuits associated with the same function, wherever possible.

Any equipment used should have the appropriate immunity rating and should be selected and grouped according to its working environment. Filters and voltage limiting devices should be used where necessary.

Appendix C - Earth Electrode Testing

1. Method of Checking Adequate Electrical Separation between Two Electrodes

Three tests are carried out (see Drawing C953068). In the first test, the resistance of Electrode A to the general mass of earth is measured by an earth megger or the equivalent, according to the instructions issued with the instrument; let this resistance be Rae. In the second test, the same measurement is carried out on Electrode B; let the result be Rbe. In the third test, the resistance between A and B is measured let this be Rab.

If the resistance areas of the two electrodes are adequately separated then Rab must be equal to or greater than 0.9 (Rae + Rbe).

It is important when measuring Rae and Rbe to ensure that the voltage and current leads are run out to adequate distances.

2. Method of Measuring the Overall Resistance to Earth of a Multiple Earthed Neutral/earth conductor or Other Extensive Earthing Systems

The combined resistance to earth of an extensive earthing system provided by neutral electrodes cannot be conveniently measured. Therefore the resistance to earth of each earth electrode shall be measured and the combined resistance to earth shall be calculated by assuming that the individual resistance values can be regarded as connected in parallel without their resistance areas overlapping.

The combined resistance to earth is given by:

$$\frac{1}{Rc} = \frac{1}{Rae} + \frac{1}{Rbe} + \frac{1}{Rce} + \ldots\ldots$$

Where Rc = Combined resistance to earth of the individual electrodes

Rae)
Rbe) = Resistance to earth of individual electrodes.
Rce)

It is important that when measuring each electrode resistance to earth that voltage and current leads are run out to adequate distances to ensure that there is no overlap between the resistance.

3. Measurement of Resistance of Individual Earth Components using a clip on earth tester

At a distribution substation, the following items are those that, in parallel, provide the earth resistance value.

(i) 20/11/6.6kV electrode at the substation.
(ii) LV electrode just beyond the substation.
(iii) 20/11/6.6kV cable sheaths.
(iv) LV earths beyond substation.

An individual measurement of each of the first three can be made by connecting a clip on, (contact-less) earth tester around the earth connection between it and the switchgear earth bar. The individual values obtained should be noted and compared to the overall value obtained by measurement. The clip on meter measures the value of the electrode under test in series with the rest of the connected electrodes. The measured value will only be accurate if the other electrodes in parallel have a low value compared to the one under test. Figures D.1 and D.2 show the arrangement for a pole type substation and the electrical equivalent circuit.

Figure D.13: Current Flows for a Loop Resistance Measurement of the LV Earth

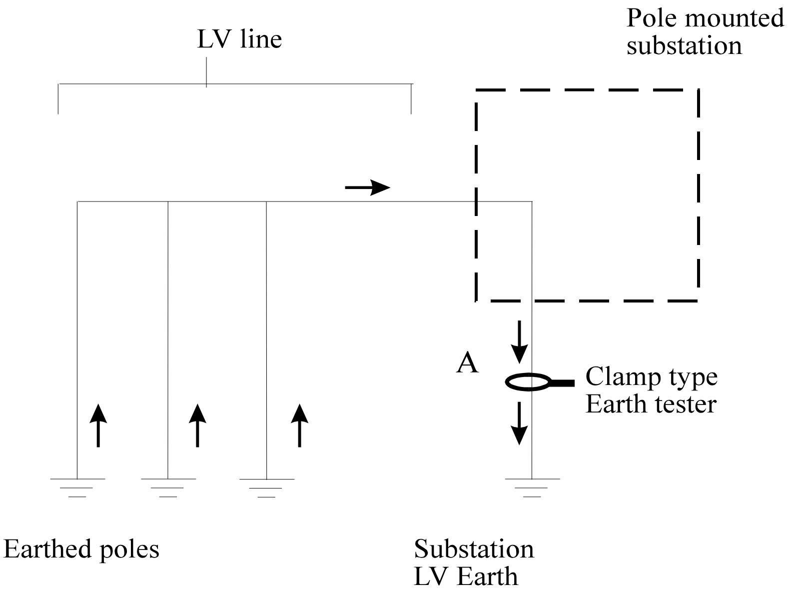
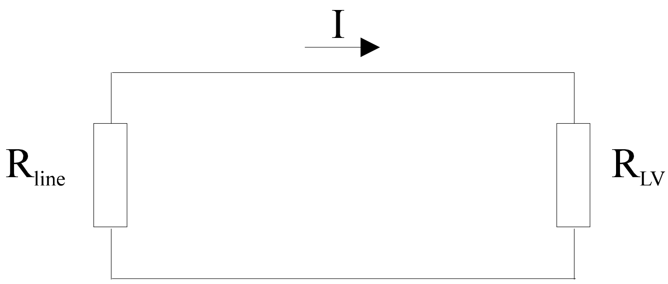


Figure 1.2.4: Equivalent Circuit of a Loop Resistance Measurement



R_{line} is the resistance of the LV overhead earth wire and pole earths, in parallel.
R_{LV} is the earth resistance of the substation LV earth.

The resistance measured by the clamp-on earth tester (R_{total}) will be the sum of the resistance in the loop, i.e. (R_{LV} + R_{line}). It is assumed that the resistance of the return path (R_{line}) is small enough to be considered negligible against the larger R_{LV} value, so that R_{total} is approximately equal to R_{LV}. If a relatively low resistance return path is not available, then this type of measurement cannot be made accurately.

4. At locations where it is not technically possible to carry out an earth electrode measurement to earth

Where it is not possible to carry out an electrode earth resistance measurement for example in a dense urban area where there are multiple interconnected earth electrodes, following approval from the Design Team Leader a documented calculation of the electrode resistance can be accepted.

Appendix D - Type and Size of Earth Connections

The types and size of earthing and bonding connections shall be as detailed in the tables below

LOCATION	EARTHING AND BONDING CONNECTIONS
Overhead HV bonding	$32mm^2$ stranded copper, green PVC (2mm radial thickness) insulated conductor
Overhead LV side and Neutral bond	$32mm^2$ stranded copper, black PVC (2mm radial thickness) insulated conductor
Between LV Overhead line and cable	$32mm^2$ stranded copper, Black PVC insulated
Undergound substation between high voltage equipment	$95mm^2$ stranded copper, PVC insulated conductor or insulated copper strip 3mmx25mm
Underground substation main LV neutral to earth electrode	$95mm^2$ stranded copper, green/yellow PVC insulated conductor
Connection between sheath of SNE cable and Neutral/Earth of CNE cable	$70mm^2$ stranded copper (2 x 35 mm^2), green/yellow PVC insulated conductor for cable sizes above $70mm^2$ for smaller size cable at least equivelant to the phase conductor with a minimum size of $16mm^2$
Bonding and Earth connection to LV earth electrodes on underground cable networks	$25mm^2$, stranded copper, green/yellow PVC insulated conductor

Table 1 Earthing and bonding connections for different locations

Main bonding at customers' premises (See table below)

Connection location	Copper equivalent cross-sectional area
At customer's premises, connection between service neutral and company's earthing terminal	Green/yellow $16mm^2$ or half the size of the Company's neutral meter tail, whichever is the larger
At customer's premises connection between the company's earthing terminal and the earth bar of the consumer unit.	Green/yellow $16mm^2$ or half the size of the Company's neutral meter tail, whichever is the larger

Table 2 Main bonding at customer's premises

Main bonding equipotential connections between earthing terminal and all metallic structures (See table below).

Copper equivalent cross-sectional area of Supply neutral conductor	Minimum copper cross-sectional area of bonding conductor (or continuously rated equivalent)
$35mm^2$or less	$10mm^2$
over $35mm^2$ but not more than $50mm^2$	$16mm^2$
over $50mm^2$ but not more than $95mm^2$	$25mm^2$
over $95mm^2$ but not more than $150mm^2$	$35mm^2$
over $150mm^2$	$70mm^2$

Table 3 Size of Main Equipotential Bonding Copper Conductors

Notes:

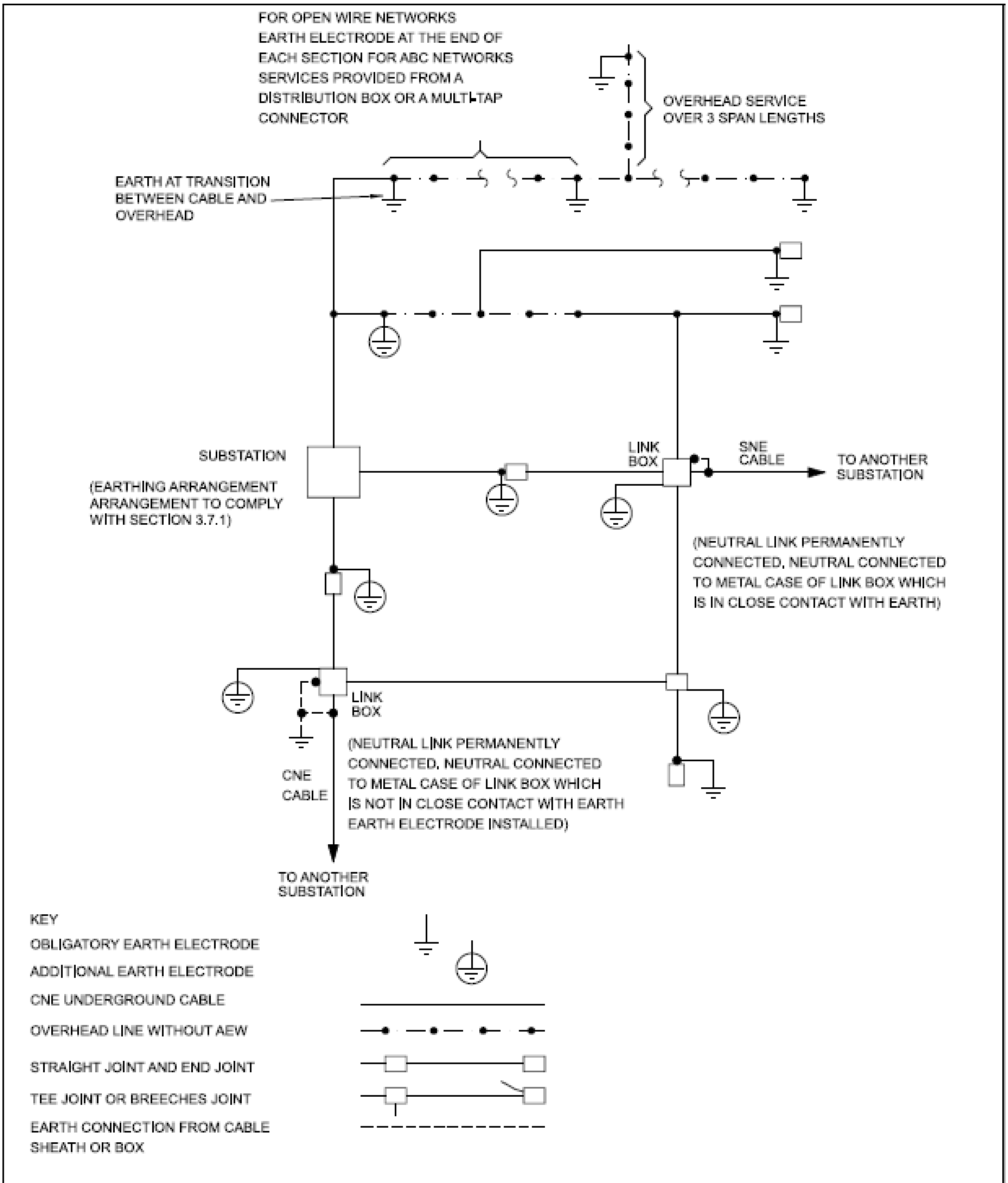
1) Supplementary local bonding conductors and circuit protective conductors in the customer's installation should be of the size specified in the current edition of BS7671 (IET Wiring Regulations)
2) Conductors on poles above 3m need not be insulated
3) Where copper theft has occurred on a site the above ground bonding should be replaced with aluminium conductor (see note 6), with suitable bi-metallic joints at the interface between the aluminium and the copper in the ground.
4) All earthing and bonding connections where buried direct in the ground shall be of copper conductor.
5) The copper equivalent cross-sectional areas of Supply neutral conductors for typical DNO cables are as follows:

   35mm^2 Al CNE – 22mm^2
   95mm^2 Al CNE – 60mm^2
   185mm^{2}Al CNE – 116mm^2
   300mm^2 Al CNE – 116mm^2
   300mm^2 Cu CNE – 150mm^2
   4mmx25mm Cu tape – 6mmx25mm Al tape
   4mmx40mm Cu tape – 6mmx40mm Al tape

6) The aluminium equivalent for copper earth conductors and bonds are listed below:

   4mmx25mm Cu tape – 6mmx25mm Al tape
   4mmx40mm Cu tape – 6mmx40mm Al tape
   70mm^2 or 95mm^2 PVC covered copper - 120mm^2 PVC covered aluminium
   32mm^2 PVC covered copper – 50mm^2 PVC covered aluminium

Appendix E – General Drawings



NORTHERN POWERGRID

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POSITIONS OF PROTECTIVE MULTIPLE EARTHING ELECTRODES ON NEW CNE UNDERGROUND CABLE NETWORKS AND NEW OVERHEAD LINES NETWORKS

Manufacturer Details

Sheet No. 1 | Scale N.T.S.

Prepared By Caralyn.Palmer

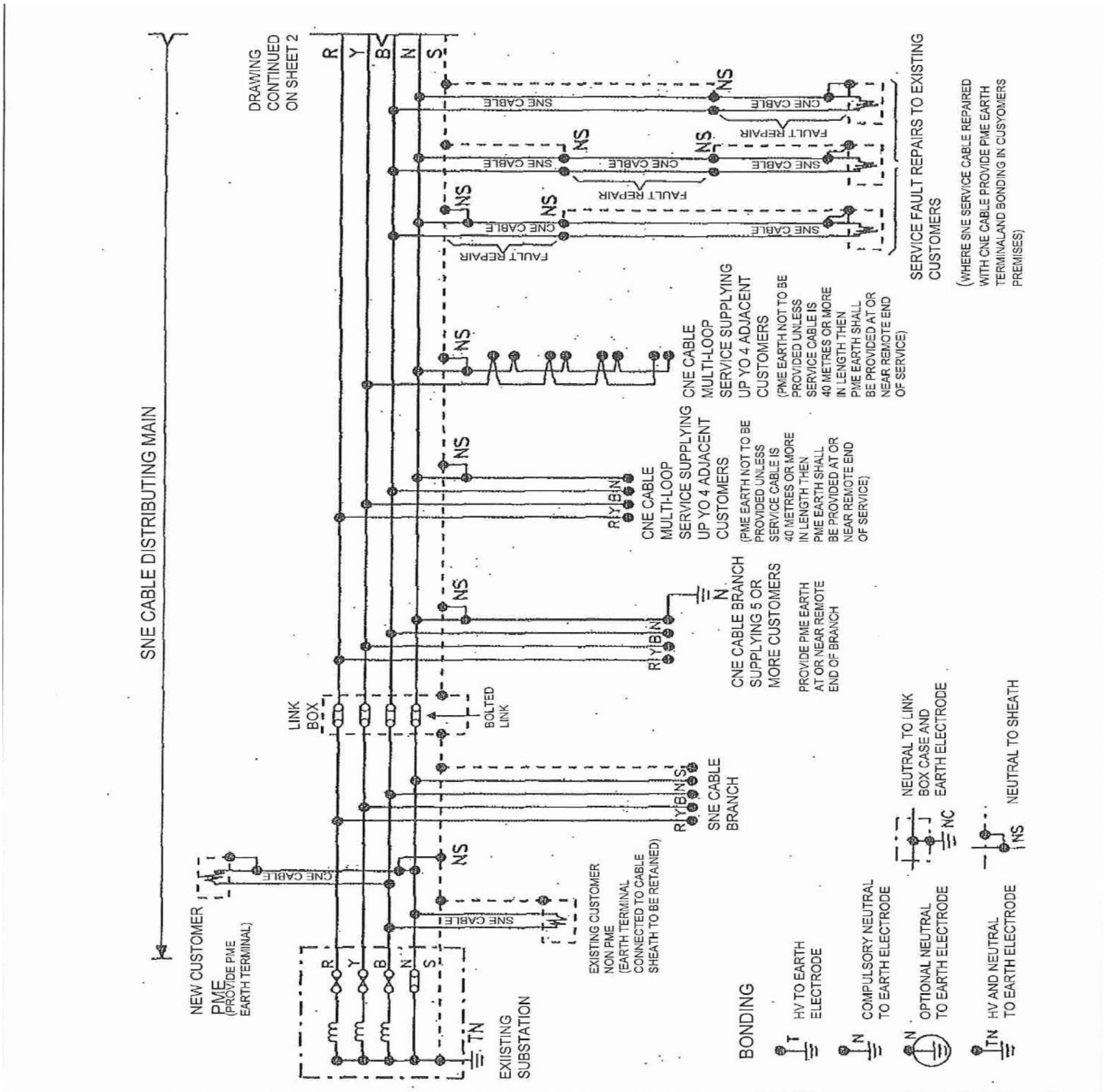
Type PLANT DIAGRAMS GENERAL

Revised 16/10/17 | Grid Reference

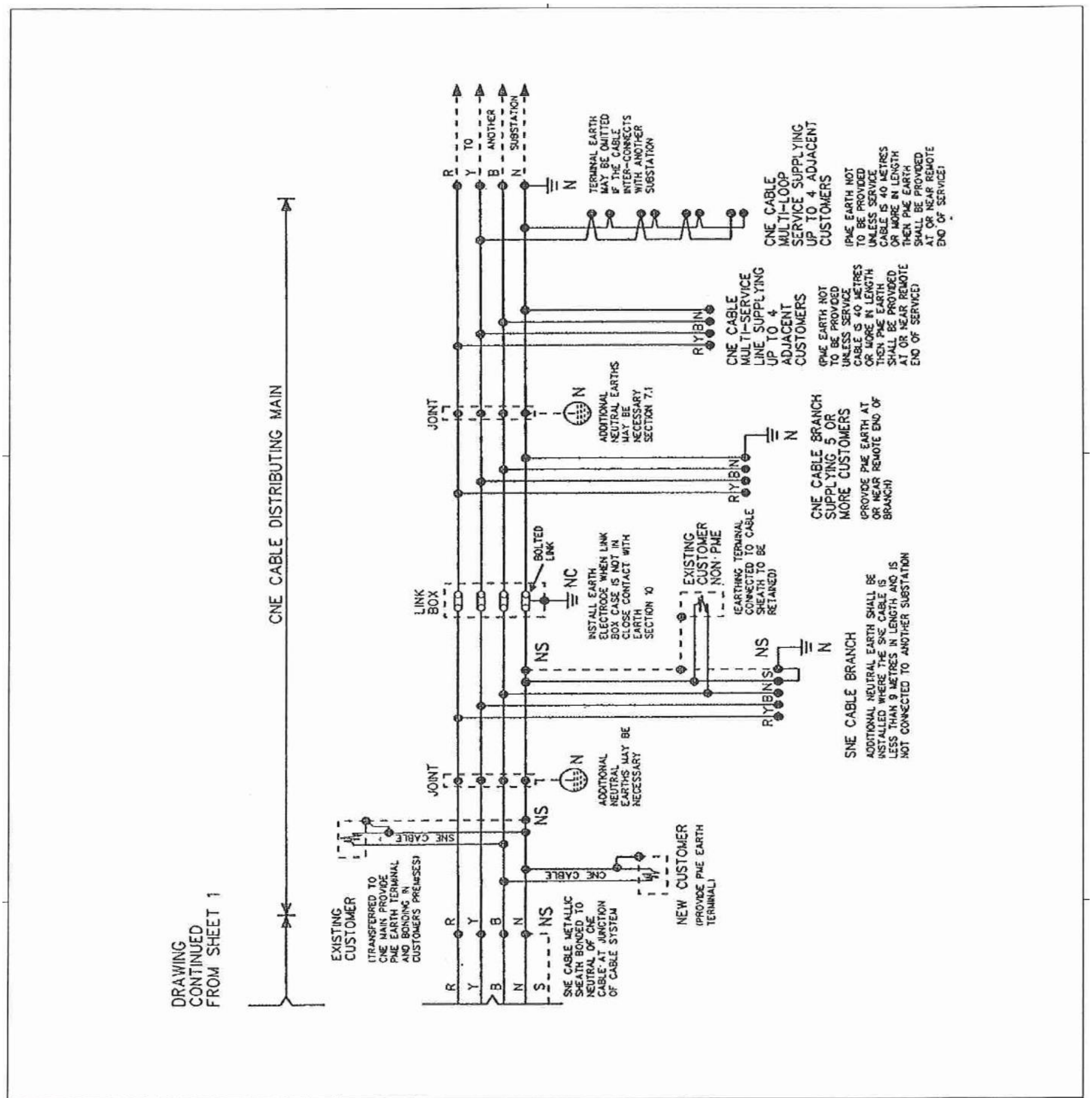
Ref No. C952986 | Historic Drg.No. C952986

Date Issued 16/10/07 | Checked By J PAINE

Revision B | Notes



NORTHERN POWERGRID		Lloyds Court, 78 Grey Street, Newcastle Upon Tyne, NE1 6AF		
Manufacturer Details		EXTENSION OF EXISTING SNE CABLE BY CNE CABLE SHEET 1		
Sheet No. 1	Scale N.T.S.			
Prepared By Joan.Oakley		Type PLANT DIAGRAMS	GENERAL	
Revised 11/11/2014	Grid Reference	Ref No. C952994	Historic Drg.No.	C952994
Date Issued 16/10/2007	Checked By J PAINE	Revision	Notes	

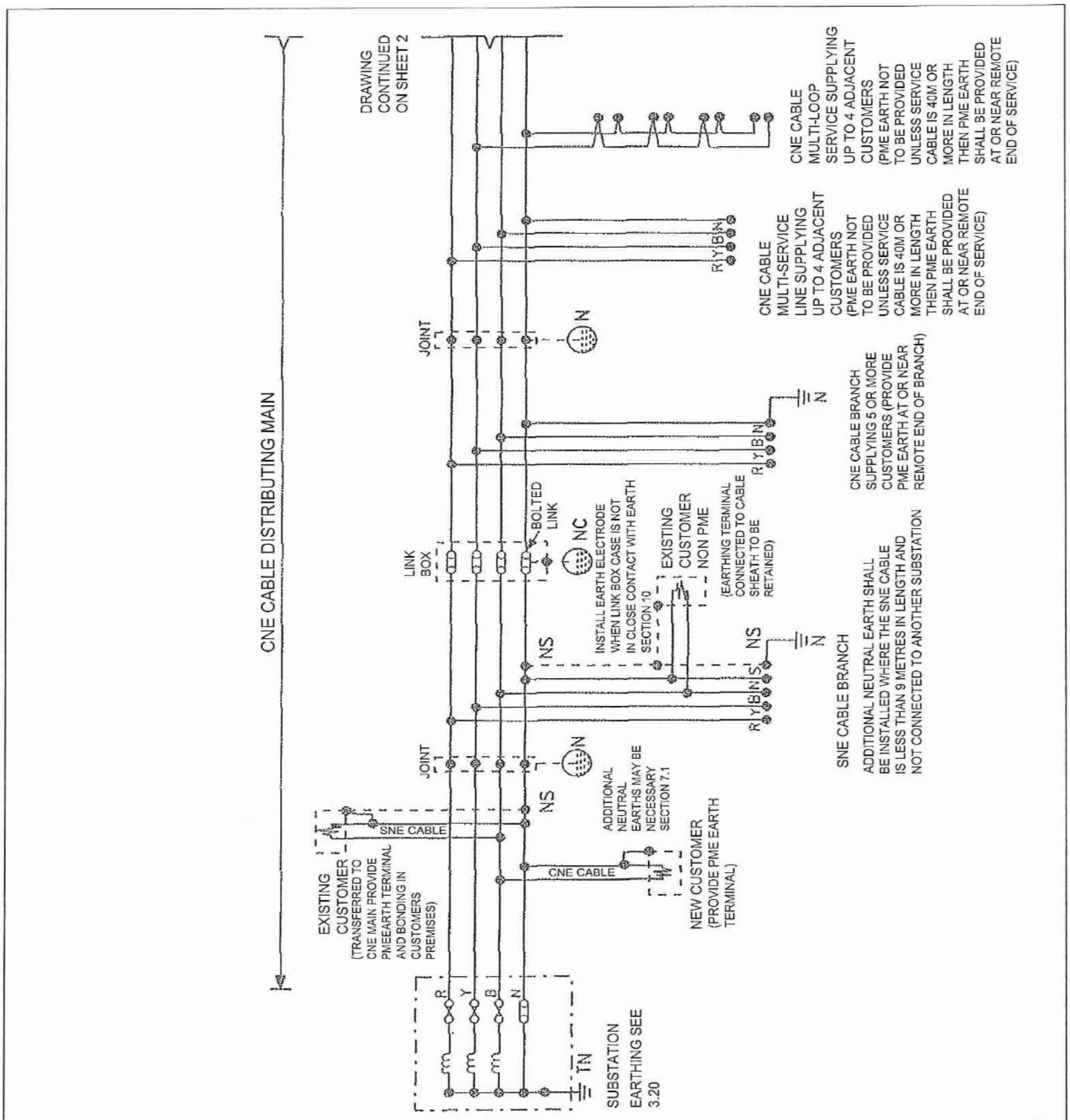


Lloyds Court, 78 Grey Street, Newcastle Upon Tyne, NE1 6AF

Manufacturer Details

EXTENSION OF EXISTING SNE CABLE BY CNE CABLE SHEET 2

Sheet No.	Scale	Document Details		
2 OF 2	N.T.S.	PLANT DIAGRAMS	GENERAL	
Prepared By: XPEmma.Wheeler-Osman		Ref No. C952997	Historic Drawing No. C952997	
Revised	Grid Reference	Revision A	Notes	A4
Date Issued 16/10/2007	Checked By J PAINE			

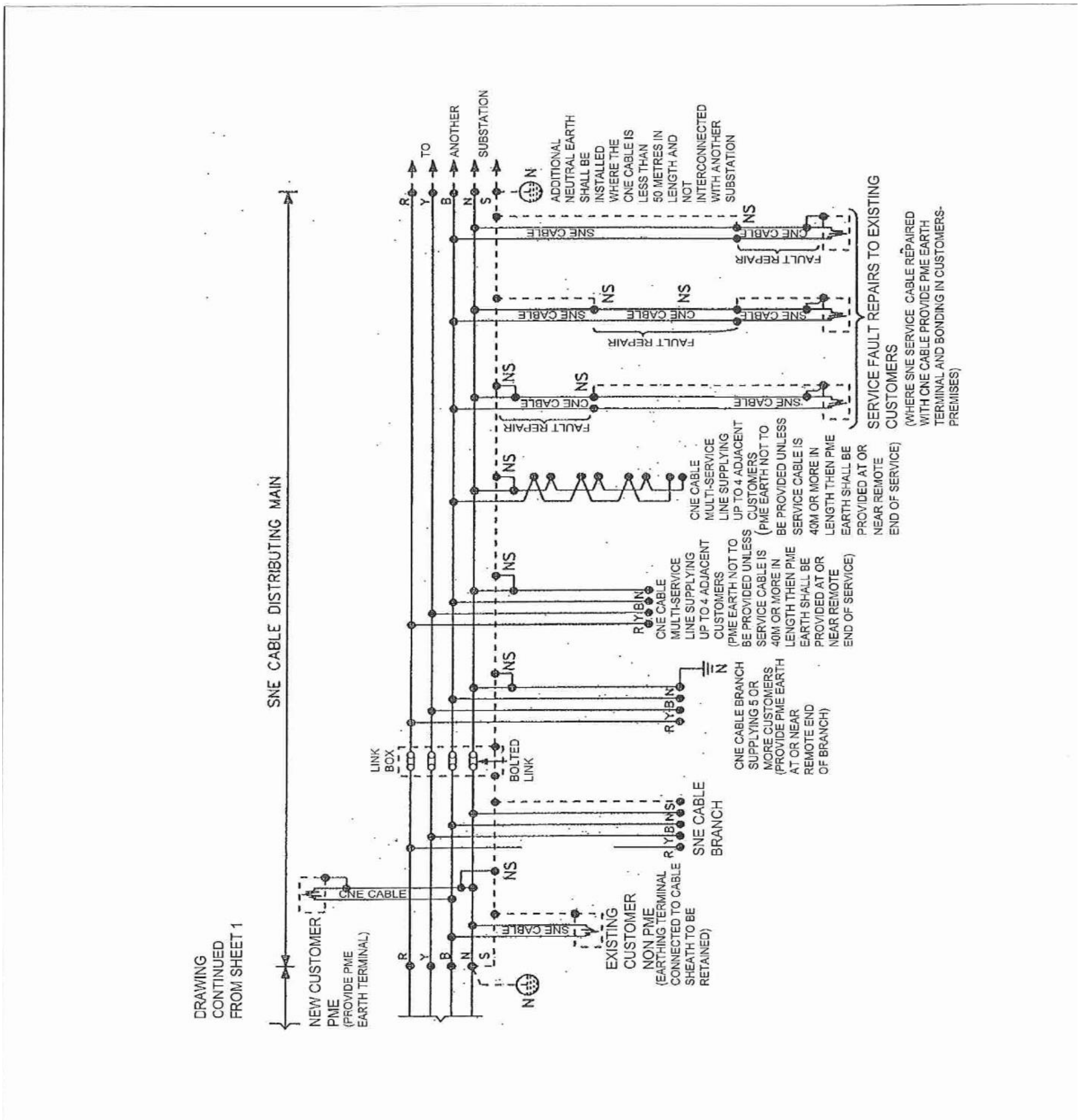


NORTHERN POWERGRID

Lloyds Court, 78 Grey Street, Newcastle Upon Tyne, NE1 6AF

INSERTION OF CNE CABLE BETWEEN SUBSTATION AND EXISTING SNE CABLE SHEET 1

Manufacturer Details			
Sheet No. 1	Scale N.T.S.	Type PLANT DIAGRAMS	GENERAL
Prepared By Barbara.Gordon			
Revised 05/11/07	Grid Reference	Ref No. C953011	Historic Drg.No. C953011
Date Issued 17/10/07	Checked By J PAINE	Revision	Notes

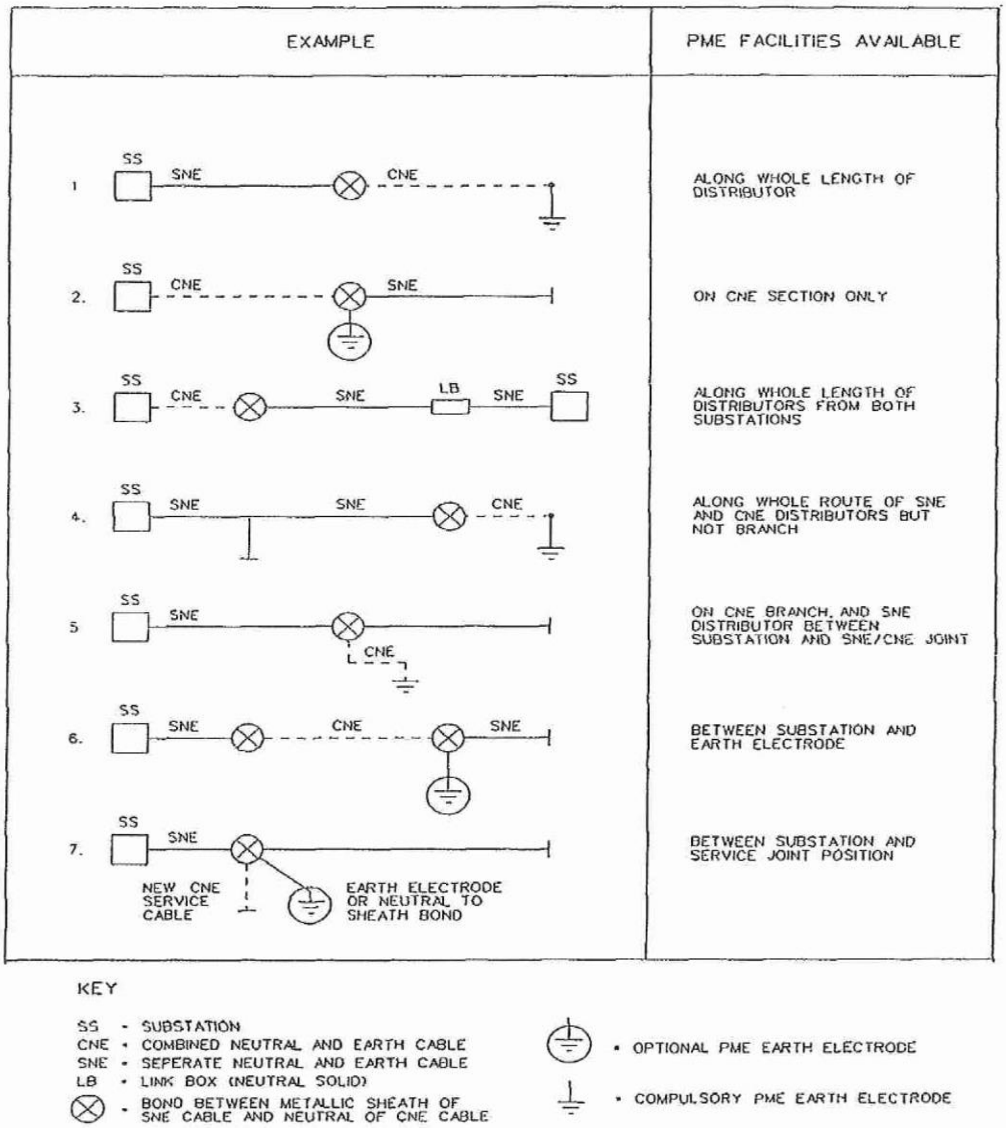


NORTHERN POWERGRID

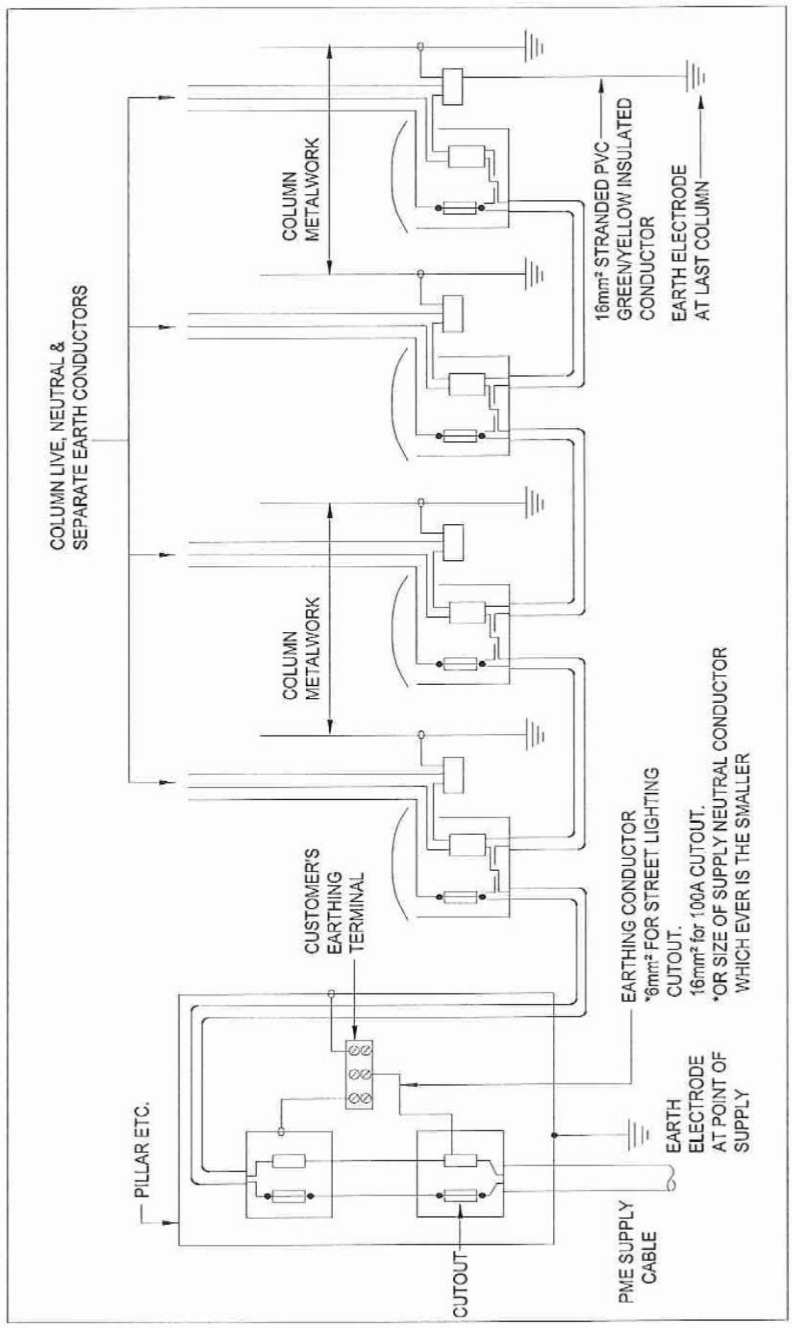
Lloyds Court, 78 Grey Street, Newcastle Upon Tyne, NE1 6AF

INSERTION OF CNE CABLE BETWEEN SUBSTATION AND EXISTING SNE CABLE SHEET 2

Manufacturer Details		Type: PLANT DIAGRAMS	GENERAL
Sheet No. 2	Scale N.T.S.		
Prepared By Barbara.Gordon			
Revised 21/11/07	Grid Reference	Ref No. C953015	Historic Drg.No. C953015
Date Issued 17/10/07	Checked By J PAINE	Revision A	Notes



NORTHERN POWERGRID	Lloyds Court, 78 Grey Street, Newcastle Upon Tyne, NE1 6AF	
Manufacturer Details	TYPICAL APPLICATIONS OF CNE CABLES	
Sheet No. 1 / Scale N.T.S.		
Prepared By XPEmma.Wheeler-Osman	Document Details PLANT DIAGRAMS	GENERAL
Revised / Grid Reference	Ref No. C953019	Historic Drawing No. C953019
Date Issued 17/10/2007 / Checked By J PAINE	Revision 00	Notes A4



NORTHERN POWERGRID

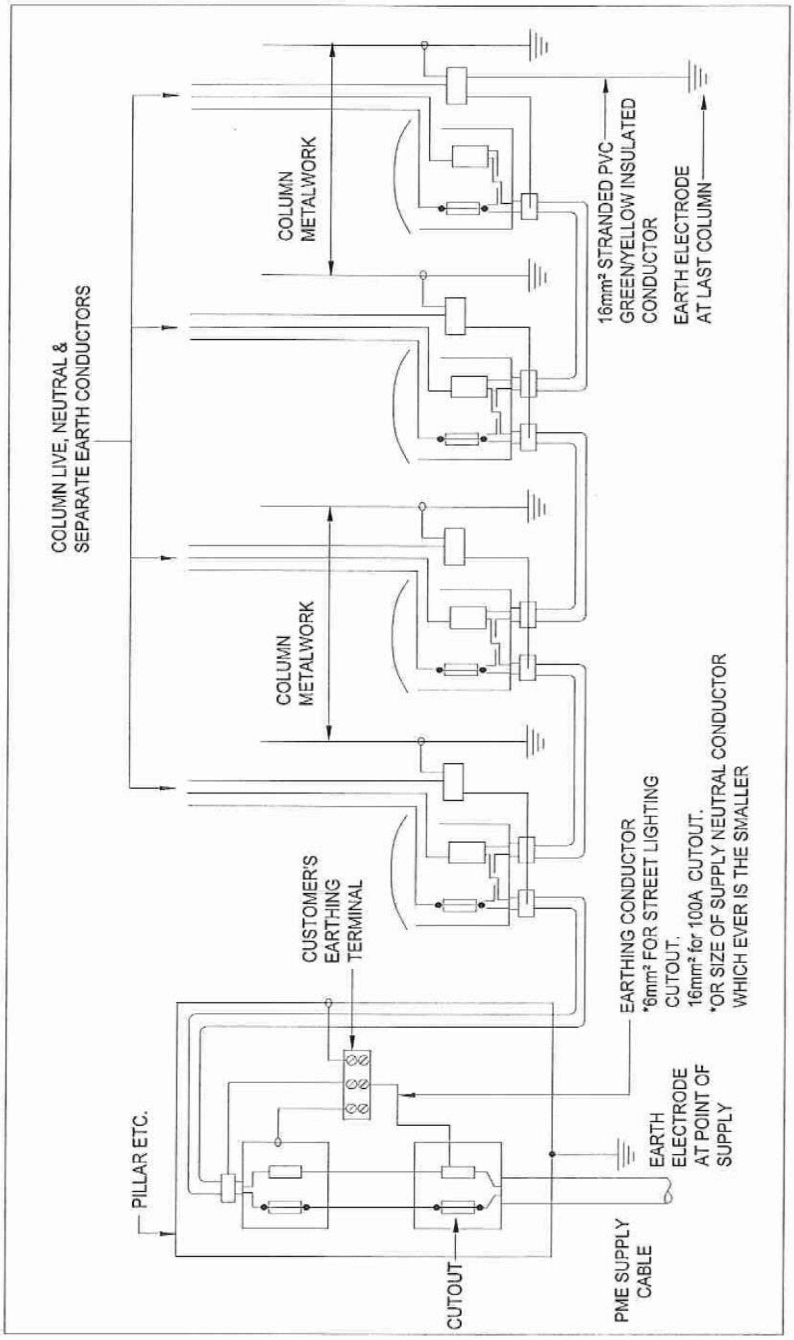
Lloyds Court, 78 Grey Street, Newcastle Upon Tyne, NE1 6AF

Manufacturer Details

STREET LIGHTING AUTHORITY
CNE DISTRIBUTOR FED FROM PME SERVICE

Sheet No.	Scale	Document Details	
1	N.T.S.	PLANT DIAGRAMS	GENERAL
Prepared By: XPEmma.Wheeler-Osman			
Revised: 19/01/2017	Grid Reference	Ref No.: C953029	Historic Drawing No.: C953029
Date Issued: 17/10/2007	Checked By: J PAINE	Revision: B	Notes: ADDED EARTH ELECTRODE AT SUPPLY POINT PILLAR AND TEXT MODS

A4



NORTHERN POWERGRID Manufacturer Details		Lloyds Court, 78 Grey Street, Newcastle Upon Tyne, NE1 6AF		
Sheet No. 1	Scale N.T.S.	STREET LIGHTING AUTHORITY SNE DISTRIBUTOR FED FROM PME SERVICE		
Prepared By XPEmma.Wheeler-Osman		Document Details PLANT DIAGRAMS GENERAL		
Revised 19/01/2017	Grid Reference	Ref No. C953031	Historic Drawing No. C953031	
Date Issued 17/10/2007	Checked By J PAINE	Revision B	Notes ADDED EARTH ELECTRODE, SHEATH BOND & TEXT MODS	A4

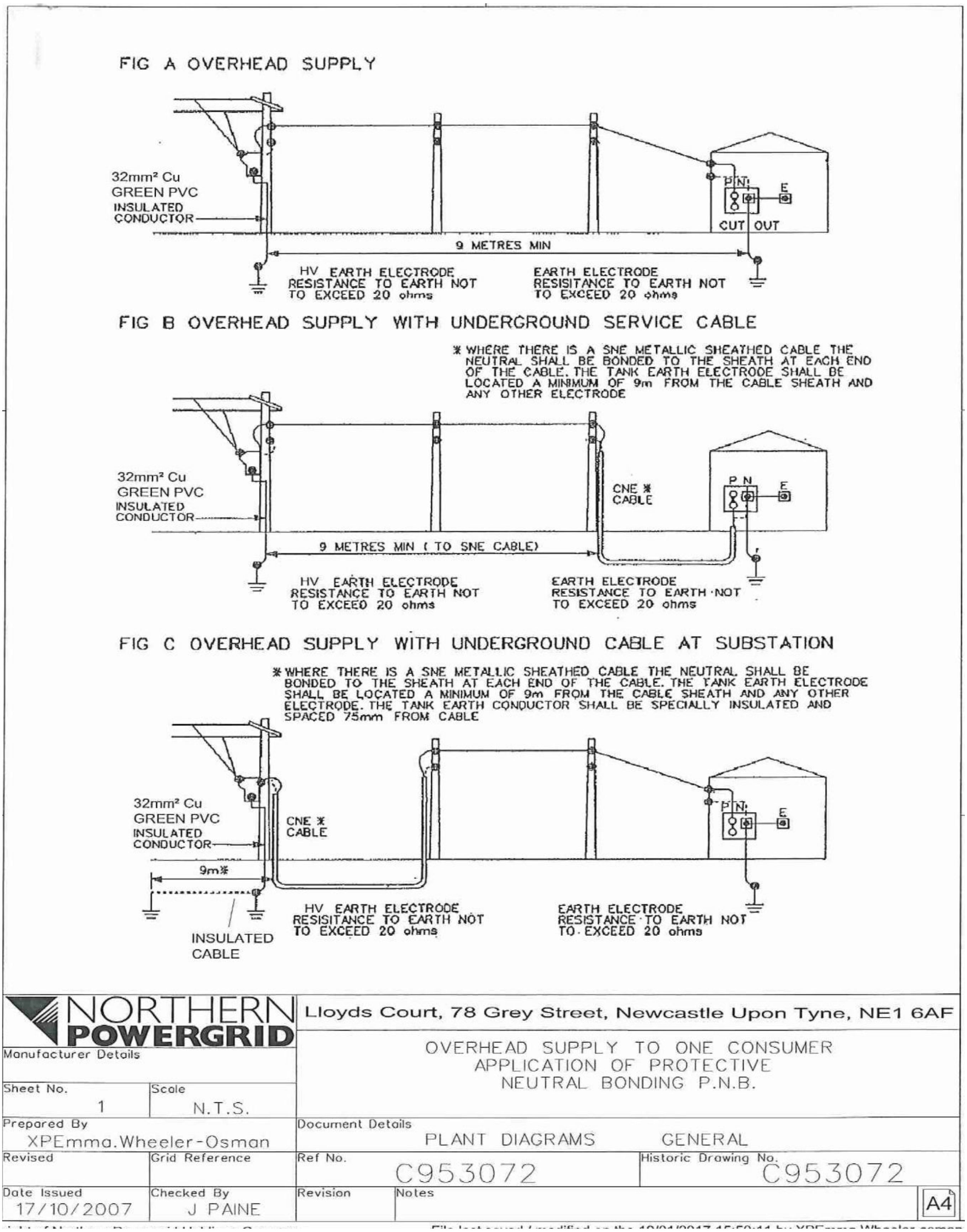
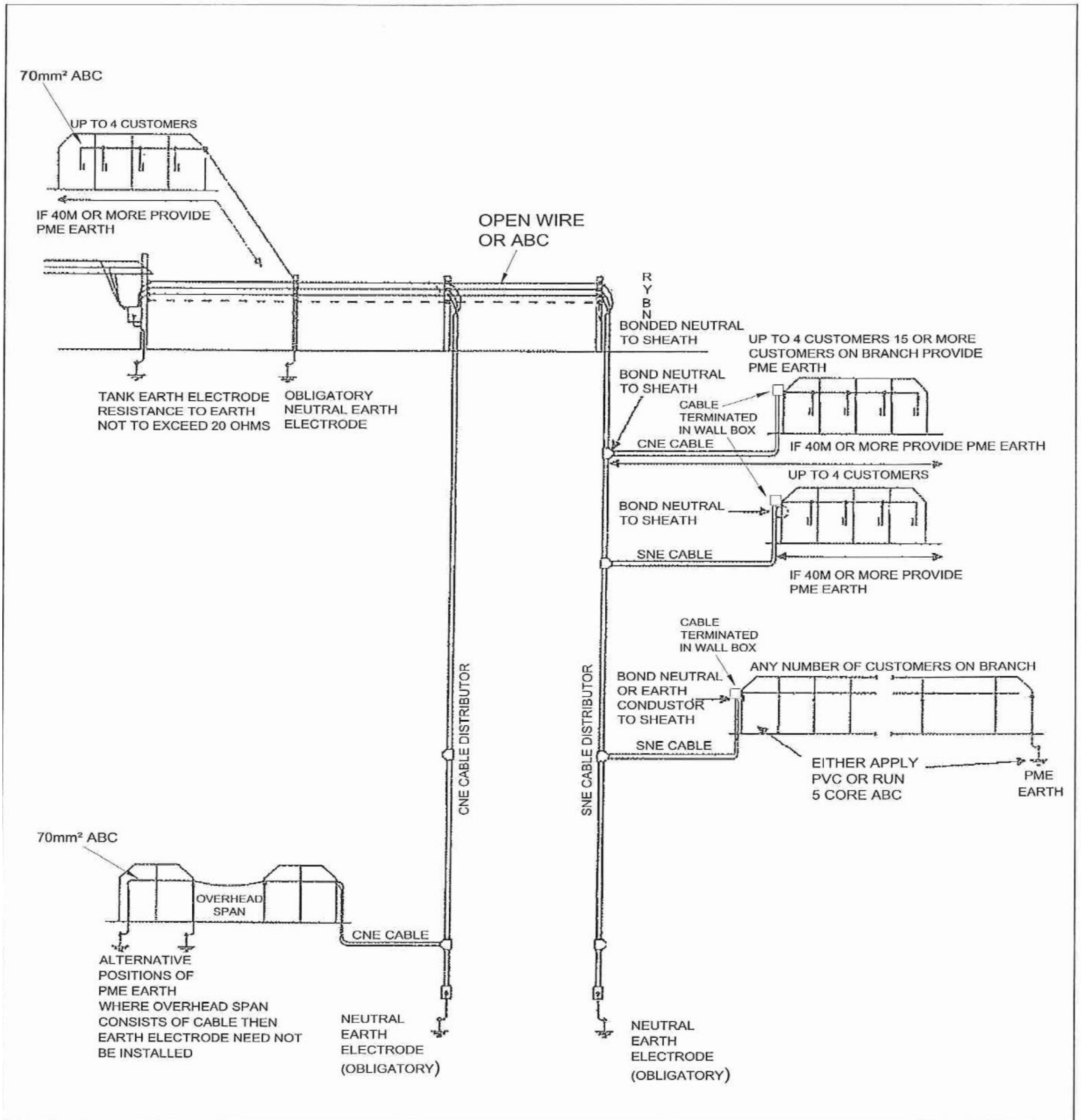
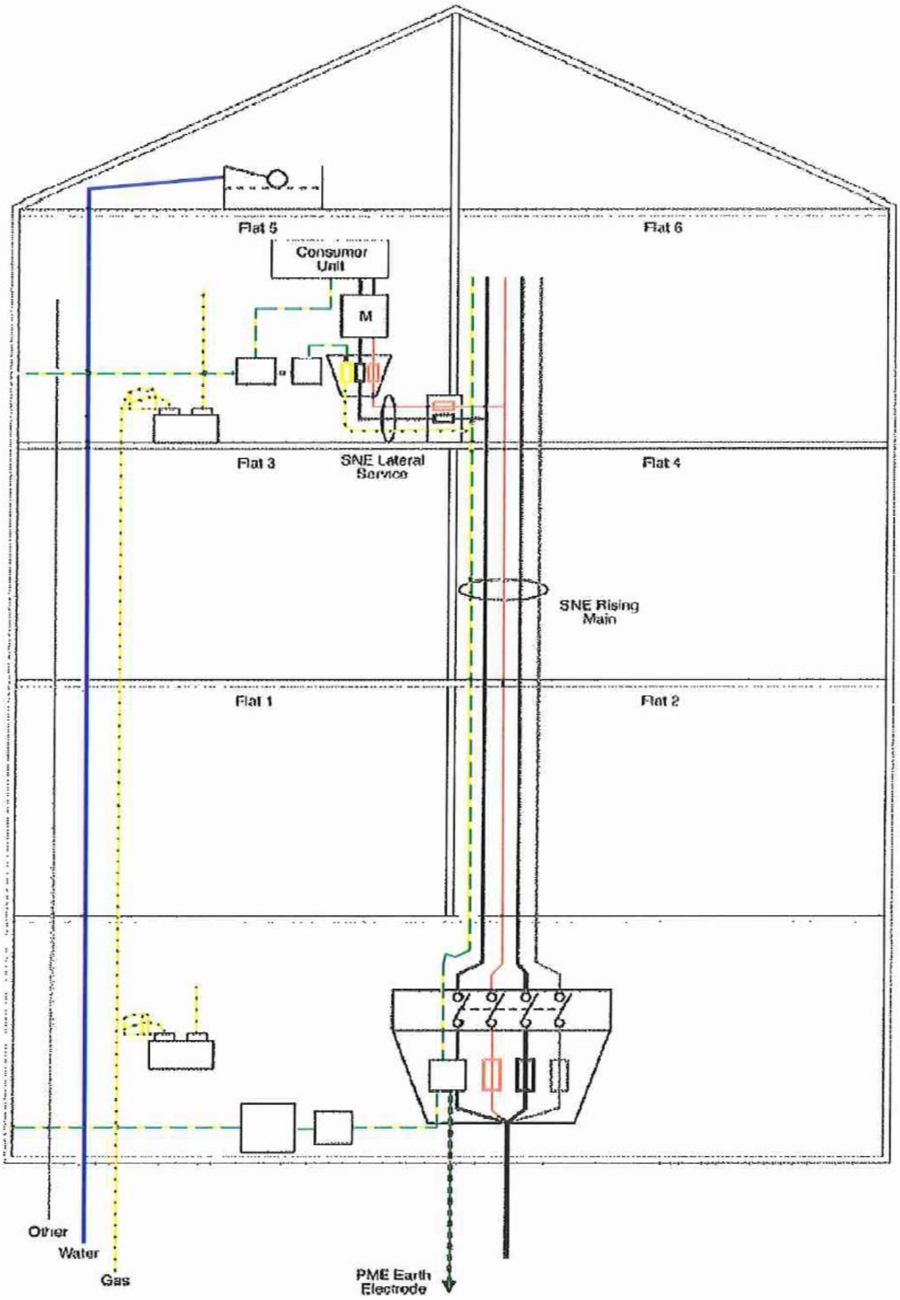


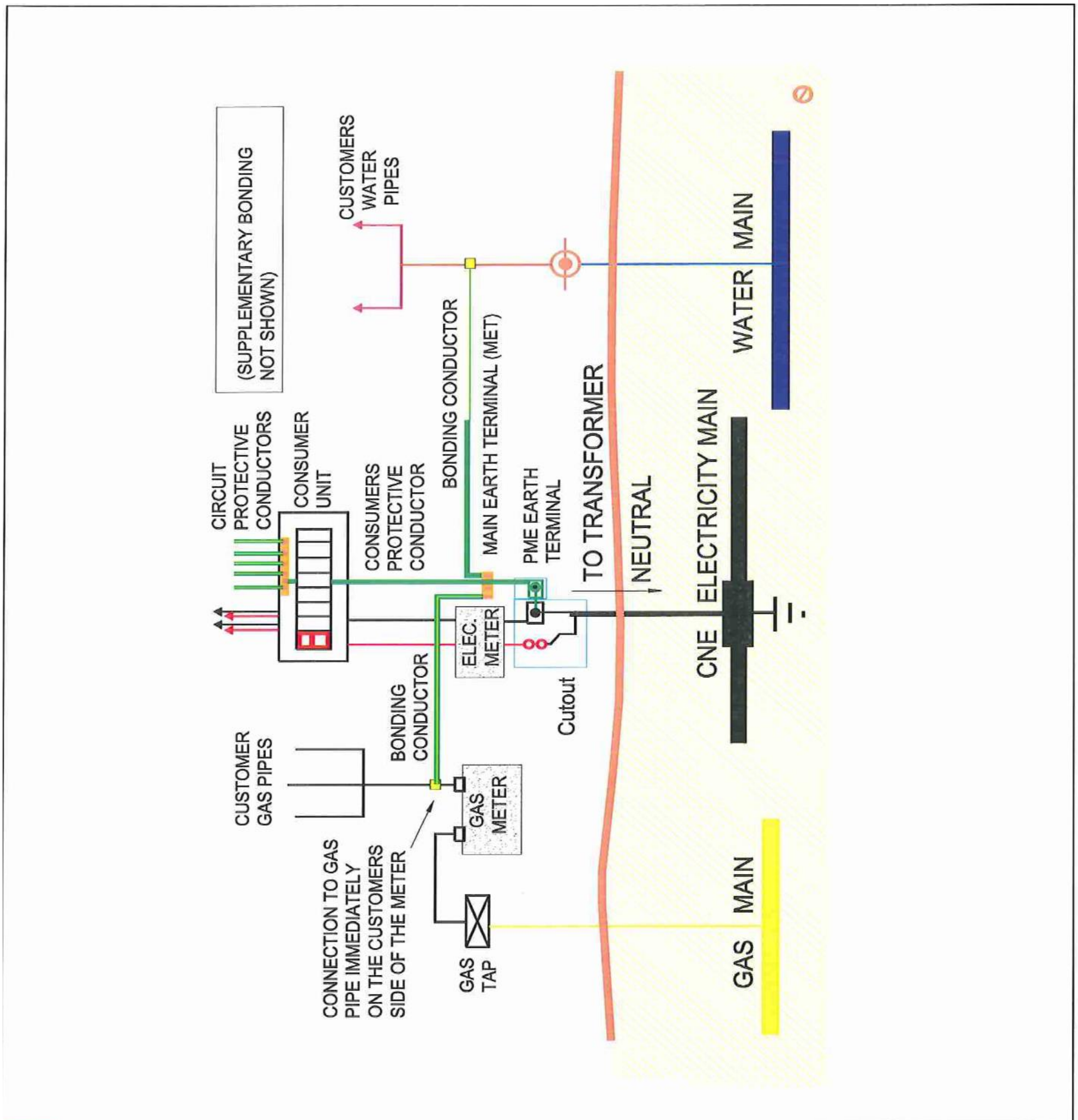
FIG A OVERHEAD SUPPLY
32mm² Cu GREEN PVC INSULATED CONDUCTOR
CUT OUT
P N E
9 METRES MIN
HV EARTH ELECTRODE RESISTANCE TO EARTH NOT TO EXCEED 20 ohms
EARTH ELECTRODE RESISTANCE TO EARTH NOT TO EXCEED 20 ohms
FIG B OVERHEAD SUPPLY WITH UNDERGROUND SERVICE CABLE
* WHERE THERE IS A SNE METALLIC SHEATHED CABLE THE NEUTRAL SHALL BE BONDED TO THE SHEATH AT EACH END OF THE CABLE. THE TANK EARTH ELECTRODE SHALL BE LOCATED A MINIMUM OF 9m FROM THE CABLE SHEATH AND ANY OTHER ELECTRODE
32mm² Cu GREEN PVC INSULATED CONDUCTOR
CNE * CABLE
P N E
9 METRES MIN (TO SNE CABLE)
HV EARTH ELECTRODE RESISTANCE TO EARTH NOT TO EXCEED 20 ohms
EARTH ELECTRODE RESISTANCE TO EARTH NOT TO EXCEED 20 ohms
FIG C OVERHEAD SUPPLY WITH UNDERGROUND CABLE AT SUBSTATION
* WHERE THERE IS A SNE METALLIC SHEATHED CABLE THE NEUTRAL SHALL BE BONDED TO THE SHEATH AT EACH END OF THE CABLE. THE TANK EARTH ELECTRODE SHALL BE LOCATED A MINIMUM OF 9m FROM THE CABLE SHEATH AND ANY OTHER ELECTRODE. THE TANK EARTH CONDUCTOR SHALL BE SPECIALLY INSULATED AND SPACED 75mm FROM CABLE
32mm² Cu GREEN PVC INSULATED CONDUCTOR
CNE * CABLE
9m*
P N E
INSULATED CABLE
HV EARTH ELECTRODE RESISTANCE TO EARTH NOT TO EXCEED 20 ohms
EARTH ELECTRODE RESISTANCE TO EARTH NOT TO EXCEED 20 ohms
NORTHERN POWERGRID
Lloyds Court, 78 Grey Street, Newcastle Upon Tyne, NE1 6AF
Manufacturer Details
OVERHEAD SUPPLY TO ONE CONSUMER
APPLICATION OF PROTECTIVE
NEUTRAL BONDING P.N.B.
Sheet No. 1
Scale N.T.S.
Prepared By XPEmma.Wheeler-Osman
Document Details PLANT DIAGRAMS GENERAL
Revised
Grid Reference
Ref No. C953072
Historic Drawing No. C953072
Date Issued 17/10/2007
Checked By J PAINE
Revision
Notes
A4



NORTHERN POWERGRID	Lloyds Court, 78 Grey Street, Newcastle Upon Tyne, NE1 6AF		
Manufacturer Details	PME EARTHS ON UNDER-EAVES WIRING INSTALLATION		
Sheet No. 1 / Scale N.T.S.			
Prepared By Barbara.Gordon	Type PLANT DIAGRAMS	GENERAL	
Revised 05/11/07 / Grid Reference	Ref No. C953074	Historic Drg.No.	C953074
Date Issued 17/10/07 / Checked By J PAINE	Revision	Notes	



NORTHERN POWERGRID	Lloyds Court, 78 Grey Street, Newcastle Upon Tyne, NE1 6AF		
Manufacturer Details	BONDING REQUIREMENT FOR SNE RISING MAIN		
Sheet No. 1 / Scale N.T.S.			
Prepared By Barbara.Gordon	Type PLANT DIAGRAMS	GENERAL	
Revised 17/10/07 / Grid Reference	Ref No. C953070	Historic Drg.No.	C953070
Date Issued 17/10/07 / Checked By J PAINE	Revision	Notes	



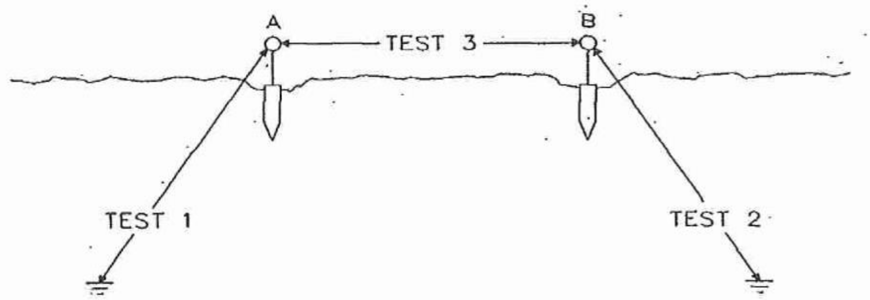
NORTHERN POWERGRID

Lloyds Court, 78 Grey Street, Newcastle Upon Tyne, NE1 6AF

EXAMPLE OF DOMESTIC
MAIN BONDING

Manufacturer Details			
Sheet No. 1	Scale N.T.S.		
Prepared By Barbara.Gordon		Type PLANT DIAGRAMS	CIRCUIT
Revised 17/10/07	Grid Reference	Ref No. C953036	Historic Drg.No. C953036
Date Issued 17/10/07	Checked By J PAINE	Revision	Notes

CHECKING SEPARATION OF TWO EARTH ELECTRODES



NORTHERN POWERGRID Manufacturer Details		Lloyds Court, 78 Grey Street, Newcastle Upon Tyne, NE1 6AF EARTH ELECTRODE TESTING		
Sheet No. 1	Scale N.T.S.			
Prepared By XPEmma.Wheeler-Osman		Document Details PLANT DIAGRAMS GENERAL		
Revised	Grid Reference	Ref No. C953068		Historic Drawing No. C953068
Date Issued 17/10/2007	Checked By J PAINE	Revision	Notes	A4

Appendix F – Guidance on the approval of neutral detection and disconnection devices

Open neutral detection and disconnection device assessment requirements

It is the responsibility of the device owner or installer on behalf of the owner to demonstrate that the device is fit for purpose and that it protects members of the public from the risks associated with the rise of voltage on a Street Electrical Fixture in the event of an open neutral condition.

Whilst currently there are no construction standards for such a device, the device should demonstrate compliance with some standards specifically in the areas below:

- Physical construction of the unit
- Isolation mechanism
- Environmental compatibility

Information must also be provided on the method of detection and disconnection of a neutral fault with some theory on how this works

The device should have the following characteristics which should be demonstrated by performance testing at a recognised independent test facility

1. It detects all types of neutral fault conditions likely to be encountered on low voltage distribution network, under typical system and environmental conditions.
2. On detection of a neutral fault condition the device makes the circuits safe by isolating the phase, neutral and earth conductors and locks out.
3. The device does not falsely operate under expected network operating conditions.
4. The unit should be fail-safe to prevent the operation of the charger if any major or significant component in the device fails.

Appendix G – Example of a site specific earthing study

A typical site-specific earthing study provided by an earthing specialist is detailed below.

A.1 Soil Resistivity Measurements

a) Using geographical drawings of the surrounding area, determine suitable measurement routes and notify the Client in order that they can obtain permission to enter these areas, where applicable, from any third-party landowners.

b) Carry out soil resistivity measurements using the Wenner Array at up to three locations near to the substation location using Wenner Spacings of up to 54m if practicable.

c) Analyse the soil resistivity to provide a representative soil resistivity model for the site using suitable analysis software.

d) Where there is an existing substation that is being upgraded carry out a fall-of-potential measurement to establish the existing HV and LV earth resistance.

e) Produce a report including the measurement results and interpreted soil model.

A.2 Earthing Design and Calculations

a) Analyse the fault current data provided by Northern Powergrid to determine the amount that would flow through the proposed substation electrode during earth fault conditions.

b) Model the proposed earth electrode using CDEGS software and calculate its earth resistance using the soil resistivity model. Optimise as needed to achieve the target earth resistance by adjusting the length / routing of the radial horizontal earth electrode.

c) Calculate the site earth potential rise (EPR) from the calculated ground return current and earth resistance.

d) Calculate the touch and step voltages at the substation, and compare against the tolerable limits. Amend the electrode design in those areas where necessary and repeat the study until acceptable values are achieved.

e) Produce contour plots showing touch and step voltages across the substation for the proposed final earthing arrangement.

f) Model the proposed LV earth electrodes and calculate their earth resistance. Include any existing earths.

g) Calculate the potentials transferred onto the LV earth electrode during an HV earth fault and compare this to the acceptable levels from EREC 41-24. Produce a plot of the relevant voltage contour based on the HV electrode and check if this impinges on any of the LV electrodes or metalwork.

h) Produce a report including a summary of calculations, the above plots and main findings. Provide drawings of the proposed substation earth electrode arrangement.