

Network Standard

NETWORK

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**NS116 DESIGN STANDARDS FOR DISTRIBUTION EQUIPMENT
 EARTHING**



ISSUE

For issue to all Ausgrid and Accredited Service Providers' staff involved with the design and construction of distribution equipment earthing systems and is for reference by field, technical and engineering staff.

Ausgrid maintains a copy of this and other Network Standards together with updates and amendments on www.ausgrid.com.au.

Where this standard is issued as a controlled document replacing an earlier edition, remove and destroy the superseded document

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As Ausgrid's standards are subject to ongoing review, the information contained in this document may be amended by Ausgrid at any time.

It is possible that conflict may exist between standard documents. In this event, the most recent standard shall prevail.

This document has been developed using information available from field and other sources and is suitable for most situations encountered in Ausgrid. Particular conditions, projects or localities may require special or different practices. It is the responsibility of the local manager, supervisor, assured quality contractor and the individuals involved to make sure that a safe system of work is employed and that statutory requirements are met.

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All design work, and the associated supply of materials and equipment, must be undertaken in accordance with and consideration of relevant legislative and regulatory requirements, latest revision of Ausgrid's Network Standards and specifications and Australian Standards. Designs submitted shall be declared as fit for purpose. Where the designer wishes to include a variation to a network standard or an alternative material or equipment to that currently approved the designer must obtain authorisation from the Network Standard owner before incorporating a variation to a Network Standard in a design.

External designers including those authorised as Accredited Service Providers will seek approval through the approved process as outlined in NS181 Approval of Materials and Equipment and Network Standard Variations. Seeking approval will ensure Network Standards are appropriately updated and that a consistent interpretation of the legislative framework is employed.

Notes: 1. Compliance with this Network Standard does not automatically satisfy the requirements of a Designer Safety Report. The designer must comply with the provisions of the Workplace Health and Safety Regulation 2011 (NSW - Part 6.2 Duties of designer of structure and person who commissions construction work) which requires the designer to provide a written safety report to the person who commissioned the design. This report must be provided to Ausgrid in all instances, including where the design was commissioned by or on behalf of a person who proposes to connect premises to Ausgrid's network, and will form part of the Designer Safety Report which must also be presented to Ausgrid. Further information is provided in Network Standard (NS) 212 Integrated Support Requirements for Ausgrid Network Assets.

2. Where the procedural requirements of this document conflict with contestable project procedures, the contestable project procedures shall take precedent for the whole project or part thereof which is classified as contestable. Any external contact with Ausgrid for contestable works projects is to be made via the Ausgrid officer responsible for facilitating the contestable project. The Contestable Ausgrid officer will liaise with Ausgrid internal departments and specialists as necessary to fulfil the requirements of this standard. All other technical aspects of this document which are not procedural in nature shall apply to contestable works projects.

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In the event that any user of this Standard considers that any of its provisions is uncertain, ambiguous or otherwise in need of interpretation, the user should request Ausgrid to clarify the provision. Ausgrid's interpretation shall then apply as though it was included in the Standard, and is final and binding. No correspondence will be entered into with any person disputing the meaning of the provision published in the Standard or the accuracy of Ausgrid's interpretation.

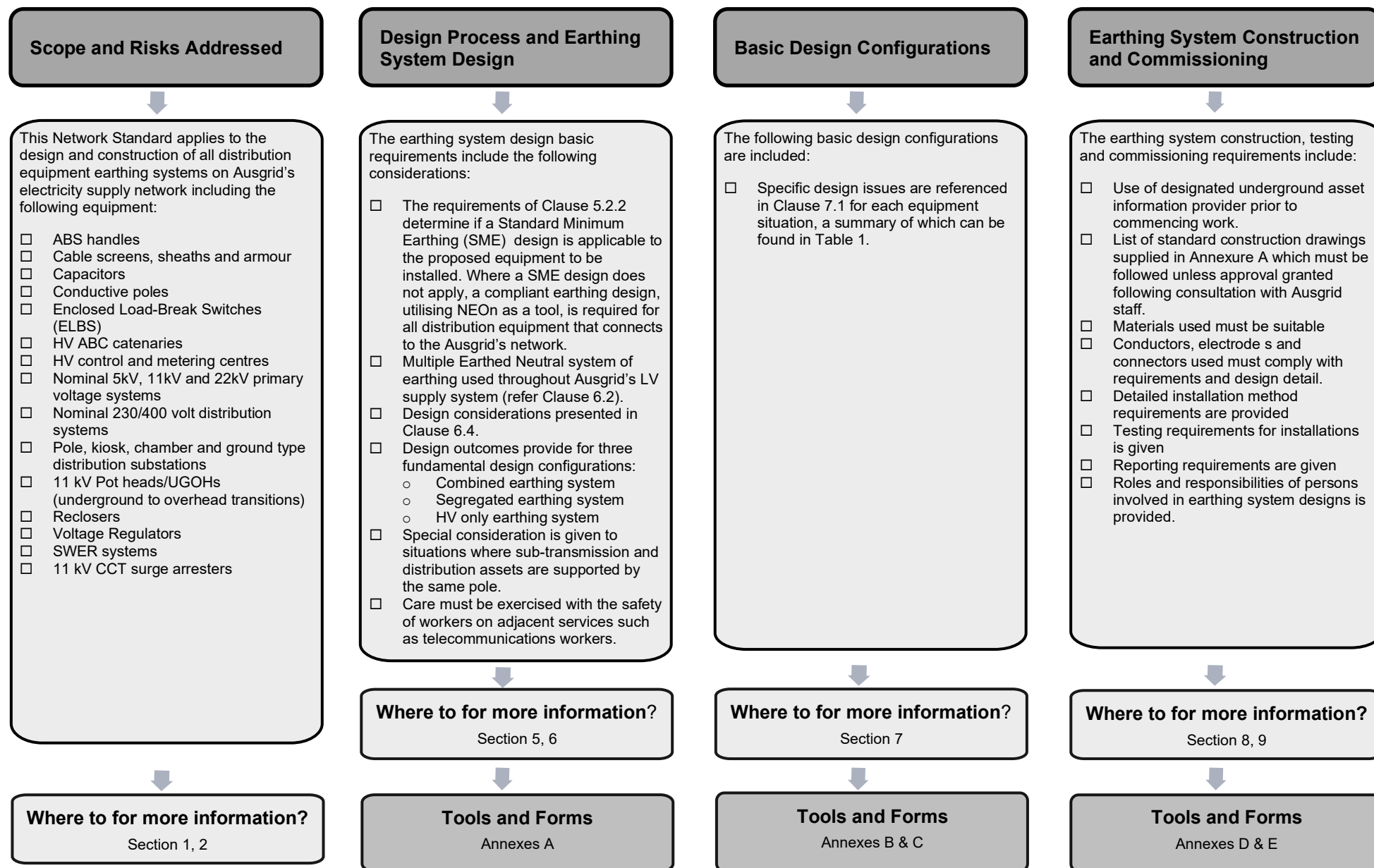
KEYPOINTS

This standard has a summary of content labelled "KEYPOINTS FOR THIS STANDARD". The inclusion or omission of items in this summary does not signify any specific importance or criticality to the items described. It is meant to simply provide the reader with a quick assessment of some of the major issues addressed by the standard. To fully appreciate the content and the requirements of the standard it must be read in its entirety.

AMENDMENTS TO THIS STANDARD

Where there are changes to this standard from the previously approved version, any previous shading is removed and the newly affected paragraphs are shaded with a grey background. Where the document changes exceed 25% of the document content, any grey background in the document is to be removed and the following words should be shown below the title block on the right hand side of the page in bold and italic, for example, Supersedes – document details (for example, "Supersedes Document Type (Category) Document No. Amendment No.").

KEY POINTS OF THIS STANDARD



Network Standard

NS116 Design Standards for Distribution Equipment Earthing

Contents

1.0	PURPOSE	6
2.0	SCOPE	6
3.0	REFERENCES	7
3.1	General	7
3.2	Ausgrid documents	7
3.3	Other standards and documents	7
3.4	Acts and regulations	8
4.0	DEFINITIONS	9
5.0	INTRODUCTION	9
5.1	General requirements	9
5.2	Design process	9
5.2.1	General	9
5.2.2	Standard minimum earthing designs	9
5.2.3	Non-standard minimum earthing designs	10
6.0	EARTHING SYSTEM DESIGN	11
6.1	General requirements	11
6.2	Design context	11
6.3	System components	12
6.4	Design considerations	12
6.5	Design outcomes	13
6.5.1	General	13
6.5.2	Combined earthing system	13
6.5.3	Segregated earthing system	13
6.5.4	HV only earthing system	14
6.6	Sub-transmission and distribution on shared poles.....	14
7.0	BASIC DESIGN CONFIGURATIONS	15
7.1	Configuration fundamentals	15
7.1.1	General	15
7.1.2	Air Break Switch (ABS) handle earthing	15
7.1.3	Capacitors	15
7.1.4	Pole top substations on conductive distribution poles	15
7.1.5	Construction drawings and specifications from NEOn	15
7.1.6	Electrode connections.....	15
7.1.7	Earth electrodes	15
7.1.8	HV cable screen earthing.....	15
7.1.9	HV earth electrode groups in segregated earthing systems	16
7.1.10	Kiosk housings	16
7.1.11	LV neutral interconnections	16
7.1.12	Metallic HV cable covers on wood poles	16
7.1.13	Metallic LV cable covers on wood poles	17
7.1.14	Metallic cable covers on conductive poles	17
7.1.15	Provision for future test	17

7.1.16	Reclosers, regulators and capacitors	17
7.1.17	Sub-transmission voltages on conductive poles or poles with earthed overhead earth wire also carrying distribution equipment	17
7.1.18	Separation required from earthing electrodes	17
7.1.19	Segregated earthing systems	18
7.1.20	Street lighting standards	18
7.1.21	Substations near electrified rail lines	18
7.2	Basic configuration summary	19
8.0	EARTHING SYSTEM CONSTRUCTION	21
8.1	General	21
8.2	Utility services and obstructions	21
8.3	Physical earthing system layout	21
8.4	Earthing materials - general.....	22
8.4.1	Materials - general	22
8.4.2	Earthing conductors	22
8.4.3	Earthing electrodes	22
8.4.4	Above ground earthing conductor connections	23
8.4.5	Earthing backfill compounds	23
8.4.6	Prevention of contact	23
8.5	Installation methods	24
8.5.1	Earthing arrangements	24
8.5.2	Electrodes not to be driven after crimping	24
8.5.3	Earthing not to encroach on other allocations	24
8.5.4	Earth and neutral bar connections	24
8.5.5	Stainless bolts – lubrication of threads	24
8.5.6	Asphalt	25
8.6	If a certified design cannot be achieved	25
9.0	EARTHING SYSTEM COMMISSIONING	25
9.1	General requirements	25
9.2	Earthing resistance commissioning tests	25
9.2.1	Earthing configuration inspection.....	25
9.2.2	Three point / fall of potential - resistance test.....	25
9.2.3	Loop (clip-on tong) - resistance test	25
9.3	Commissioning test data recoding	26
10.0	ROLES AND RESPONSIBILITIES.....	26
11.0	RECORDKEEPING	27
12.0	AUTHORITIES AND RESPONSIBILITIES.....	27
13.0	DOCUMENT CONTROL	27
	ANNEXURE A – STANDARD CONSTRUCTION DRAWINGS	28
	ANNEXURE B – SEPARATION BETWEEN DISTRIBUTION EQUIPMENT EARTHING SYSTEMS AND TELECOMMUNICATIONS PLANT	30
B1	Background.....	30
B2	Separation between HV earthing systems and telecommunications plant	30
B3	References.....	32
	ANNEXURE C – SOIL RESISTIVITIES (INDICATIVE ONLY)	33
	ANNEXURE D – GUIDANCE FOR TESTING	34
D1	Introduction	34

D2	Staged earthing tests	34
D3	Test methods	34
D4	Soil resistivity – Wenner 4 pin method	35
D5	Earthing interconnectivity – 4 terminal continuity	43
D6	Earthing interconnectivity - insulation resistance test.....	45
D7	Local Earthing impedance - loop test	46
D8	Local earthing - three terminal test / fall of potential test.....	48
ANNEXURE E – TEST SHEETS		51
ANNEXURE F – EARTHING SIGNS		56

1.0 PURPOSE

This network standard outlines Ausgrid's design, construction, testing and commissioning requirements for distribution equipment earthing systems and should be considered in conjunction with other standards relating to distribution equipment. Earthing systems are required to manage the transfer of fault energy via a low impedance path to limit the risk to people, equipment and system operation to acceptable levels.

Ausgrid's electricity supply network is a major infrastructure investment, and is required to operate safely, economically and reliably in all environmental conditions and with respect to other metallic systems. The design and construction requirements specified in this document are intended to satisfy electrical performance and economic requirements, and to meet all statutory obligations. The distribution equipment earthing systems specified utilise readily available components that have demonstrated reliability.

2.0 SCOPE

This Network Standard applies to the design, construction testing and commissioning of all distribution equipment earthing systems including but not limited to:

- ABS handles
- Cable screens, sheaths and armour
- Capacitors
- Conductive poles
- Enclosed Load-Break Switches (ELBS)
- HV ABC catenaries
- HV control and metering centres
- Nominal 5kV, 11kV and 22kV primary voltage systems
- Nominal 230/400 volt distribution systems
- Pole, kiosk, chamber and ground type distribution substations
- 11 kV Pot heads/Underground to Overhead (UGOH) transitions
- Reclosers
- Voltage Regulators
- SWER systems
- 11 kV CCT surge arresters

3.0 REFERENCES

3.1 General

All work covered in this document shall conform to all relevant Legislation, Standards, Codes of Practice and Network Standards. Current Network Standards are available on Ausgrid's Internet site at www.ausgrid.com.au.

3.2 Ausgrid documents

- Bush Fire Risk Management Plan
- CIA 107 Basic Distribution Equipment Earthing Design Process for Non-Contestable/Capital Work.
- Company Form (Governance) - Network Document Endorsement and Approval
- Company Procedure (Governance) - Network Document Endorsement and Approval
- Company Procedure (Network) – Network Standards Compliance
- Company Procedure (Network) - Production / Review of Engineering Technical Documents within document repository
- Connection Policy - Connection Charges
- Customer Installation Safety Plan
- Customer Connection Contract (NECF) index
- Electrical Safety Rules
- Electricity Network Safety Management System Manual
- ES4 Service Provider Authorisation
- NS100 Field Recording of Network Assets
- NS104 Specification for Electrical Network Project Design Plans
- NS109 Design Standards for Overhead Supply Developments and Distribution Centres
- NS110 Design and Construction Standards for Underground Residential Subdivisions
- NS112 Design Standards for Industrial and Commercial Developments
- NS113 Site Selection and Construction Design Requirements for Chamber Type Substations
- NS114 Electrical Design and Construction Standards for Chamber Type Substations
- NS117 Design and Construction Standards for Kiosk Type Substations
- NS122 Pole Mounted Substation Site Selection and Construction
- NS126 Construction of High Voltage Overhead Mains
- NS127 Low Voltage Cable Joints and Terminations
- NS129 11kV Joints and Terminations – Paper Insulated Lead Covered Cables
- NS130 Laying Underground Cables up to and including 11kV
- NS141 Site Selection and Site Preparation Standards for Kiosk Type Substations
- NS143 Easements, Leases and Rights of Way
- NS156 Working Near or Around Underground Cables
- NS158 Labelling of Mains and Apparatus
- NS174 Environmental Procedures
- NS177 11kV Joints (including Transition Joints) and Terminations – Polymeric Insulated Cables
- NS181 Approval of Materials and Equipment and Network Standard Variations
- NS212 Integrated Support Requirements for Ausgrid Network Assets
- Policy for ASP/1 Premises Connections
- Public Electrical Safety Awareness Plan
- Public Lighting Management Plan
- Tree Safety Management Plan

3.3 Other standards and documents

- AS/NZS 1768:2007 Lightning Protection
- AS/NZS 3835.1:2006 Earth potential rise - Protection of telecommunications network users, personnel and plant - Code of practice
- AS/NZS 3835.2:2006 Earth potential rise - Protection of telecommunications network users, personnel and plant - Application guide
- AS/NZS 4853:2012 Electrical hazards on metallic pipelines

- ENA Doc 001-2019 National Electricity Network Safety Code
- ENA EG-0 Power System Earthing Guide
- ENA EG1 Substation Earthing Guide
- HB 219:2006 Earth potential rise - Protection of telecommunications network users, personnel and plant - Worked examples for the application guide
- WorkCover's Guideline to Work near Underground Assets

3.4 Acts and regulations

- Electricity Supply (General) Regulation 2014 (NSW)
- Electricity Supply (Safety and Network Management) Regulation 2014
- Work Health and Safety Act 2011 and Regulation 2017

4.0 DEFINITIONS

Refer to NS001 Glossary of Terms

5.0 INTRODUCTION

5.1 General requirements

This Network Standard specifies Ausgrid's requirements for the design, installation, testing and commissioning of distribution equipment earthing systems.

A core requirement of this standard is that unless a Standard Minimum Earthing (SME) system can be applied, an earthing design is required specifically for each new equipment item identified. Acceptable application of SME designs for specific equipment is identified in Clause 7.2, Table 1. The underlying requirements for a SME system are identified within Clause 5.2.22.

To manage the design of earthing systems for items of distribution equipment, Ausgrid has developed a design tool, "NEOn" (Network Earthing Online) for use by Ausgrid which is utilised to provide an earthing design that is compliant with this standard.

Some of the advantages of adopting the NEOn design software are:

- Achieving a compliant combined earthing system satisfies the risk requirements for swimming pools and school fences in the vicinity of the distribution equipment earthing system under design.
- The required separation distance from telecommunications provider pits and pillars can be calculated.
- The required segregation distance between HV and LV electrodes (and other services/fences/pools) can be determined if a segregated earthing system is the only practical solution.
- The most cost effective, compliant earthing system design can be determined quickly.
- Earthing designs can be stored for future reference.
- Ausgrid's duty of care with respect to distribution equipment earthing systems is responsibly managed.

The Multiple Earthed Neutral (MEN) system of earthing shall be used throughout Ausgrid's LV supply system.

This Network Standard is to be read in conjunction with the drawings listed in Annexure A and other Ausgrid standards including those listed in Section 3.

5.2 Design process

5.2.1 General

A major objective of this standard is to establish a systematic way of recording and archiving earthing related information for use as part of network operations and maintenance. To realise this aim and recognising the need to systematically gather data for use in the design process, this standard sets out the processes required to be followed.

For non-contestable/capital work, the reference document is CIA 107 – Basic Distribution Equipment Earthing Design Process for Non-Contestable/Capital Work.

For Contestable works contact Ausgrid's Network Connections representative facilitating the contestable project.

5.2.2 Standard minimum earthing designs

Assets deemed to be compliant for a SME arrangement shall be made available:

- Internally: <http://shadowcat/dft/>
- Externally: <http://webgis.ausgrid.com.au/> Navigate to WebGIS and then the Files section found in the top banner. File name: DFT-SME_Results.xlsx

Where an asset has been identified as not SME compliant, any new assets installed downstream shall require a site-specific earthing system (NEOn) design.

Where an asset has been identified as SME compliant, the next new asset installed downstream will also classify as SME applicable where all the following conditions are met:

- the new asset is installed downstream of an asset that is identified as SME compliant
- all new HV supplies, inclusive of alternate HV supply paths to the proposed distribution equipment are via underground cables
- a combined earthing system is implemented
- the earthing system is connected to a MEN interconnected LV street neutral; and
- the separation distance between a telecommunications pit or pillar and the nearest earth electrode for the new asset satisfies the Telco separation distance specified.

Where an SME earthing design is utilised a nominal local earthing system resistance of 200Ω or less is required for each group of earthing electrodes i.e. the maximum total earthing resistance of the combined HV and LV earthing electrodes is less than 100Ω. Where this earthing resistance value has not been achieved, the Earthing Installer/ASP Compliance Officer shall contact Ausgrid Earthing for further direction.

A soil resistivity test is not required for SME area designs.

The date the asset was assessed as SME compliant shall be recorded on the design drawing.

5.2.3 Non-standard minimum earthing designs

NEOn shall be used by the Ausgrid's earthing designers to design earthing systems that are compliant with this standard for all distribution equipment that:

- requires an earthing design (as per Section 7, Table 1); and
- connects to Ausgrid's network.

A soil resistivity test is required where reasonably practical for all new equipment that requires a NEOn earthing system design as per the guidelines within Annexure D4.2. Where it is not reasonably practical to complete a soil resistivity test, i.e. sufficient exposed earth is not within reasonable vicinity that will give accurate local soil resistance results, the Earthing Installer/ASP Compliance Officer shall contact Ausgrid/Earthing & Insulation Coordination group within the Substation Design section for further direction/assistance.

6.0 EARTHING SYSTEM DESIGN

6.1 General requirements

Distribution equipment earthing systems should:

- Reduce the risk to staff and public, to an acceptable level, during the transfer of earth fault energy and load imbalance conditions.
- Allow protection equipment to operate satisfactorily under normal HV fault conditions.
- Be adequately rated to meet stated requirements.
- Help to minimise the risk of voltage stresses in excess of the equipment's BIL.
- Be practical and cost effective to design, install, supervise and maintain.
- Comply with Ausgrid's design requirements and other applicable standards.
- Be captured in designated underground asset information provider and other data systems.

6.2 Design context

Ausgrid's LV distribution network employs the Multiple Earthed Neutral (MEN) system of earthing. This connects the LV distributor neutral conductor to the consumer's neutral and local earth electrode (if present) at each installation. If the water service is metallic it is also bonded to the neutral at this point. This means that the metalwork of electrical appliances, tools and equipment, and the metallic pipes in and around buildings are generally bonded to the local MEN – refer to Figure 1 and Figure 2 below.

As people are frequently in contact with this 'earthed' metalwork they may be exposed to any temporary voltage rises on this metalwork in the event of a local distribution network fault.

Consideration must also be given to the safety of workers on adjacent services, for example telecommunications workers touching remotely earthed cable cores may become a path for returning earth fault current.

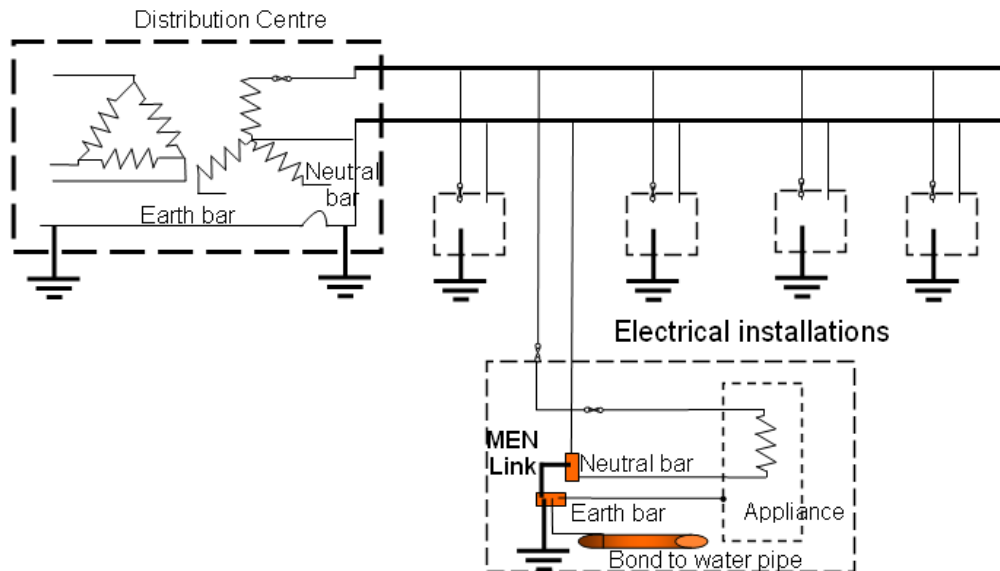


Figure 1: Multiple Earthed Neutral (MEN) System

6.3 System components

The major components of distribution equipment earthing systems (illustrated in Figure 2) are:

- HV cable sheath connections to other substations (distribution or zone);
- MEN network;
- Local earthing system at the item of equipment;
- Earth or ground itself.

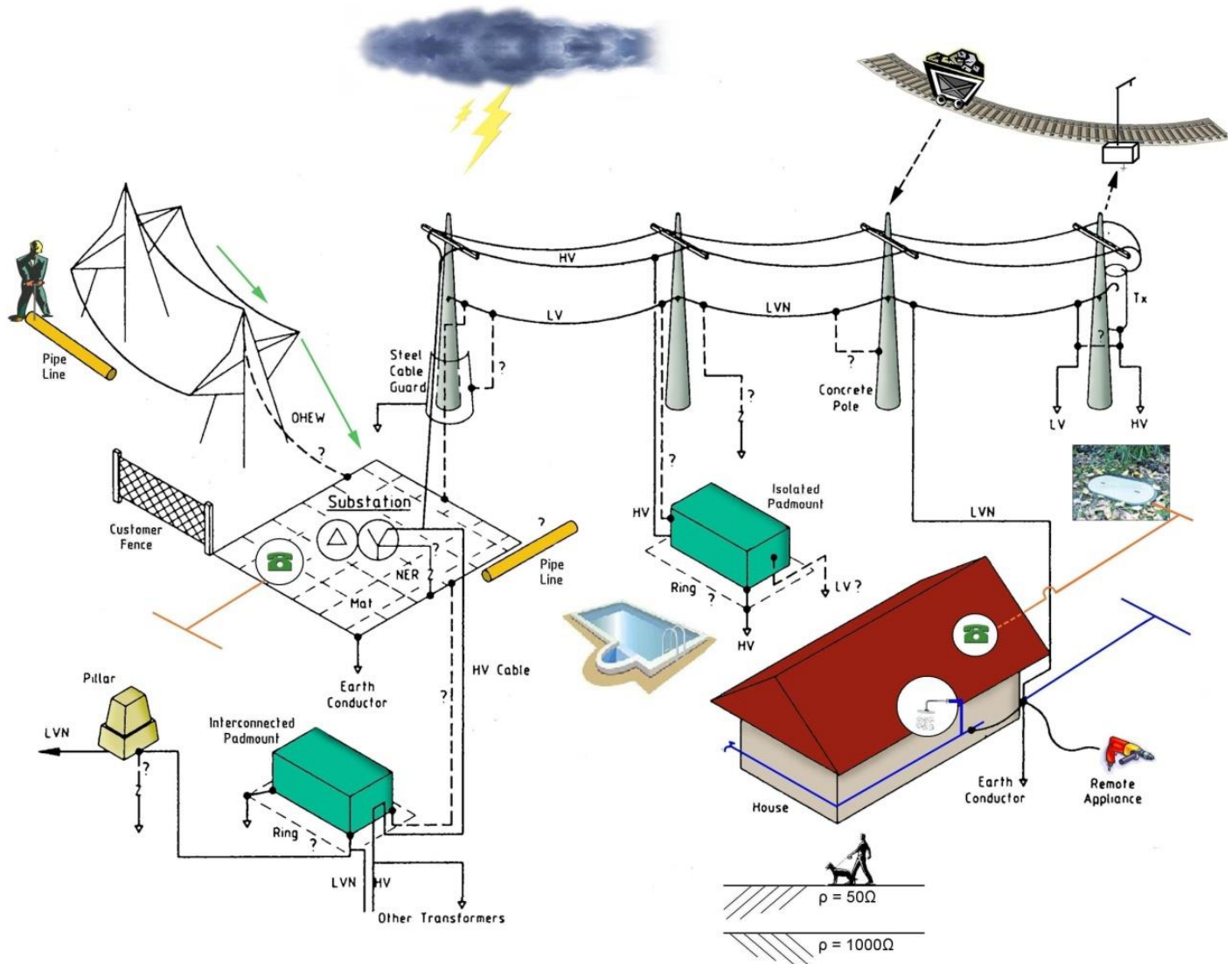


Figure 2: Pictorial representation of the distribution equipment earthing environment

6.4 Design considerations

Earthing systems, when properly designed, will allow earth fault currents to return to their source and protection systems to operate without creating unacceptable risks or exceeding the ratings of earthing components.

To achieve a satisfactory earthing design the following factors must be considered and successfully managed:

- What is the resistivity of the soil?
- Can a site with lower soil resistivity be chosen for the new equipment?

- Can the new equipment be solidly interconnected to a large neighbouring MEN?
- What is the likely range of earth fault currents?
- How will this current be divided between the earthing system components?
- How quickly will the protection clear the fault?
- What is an appropriate touch voltage design curve (volts versus clearing time)?
- What is the optimum arrangement of local earthing electrodes?
- Will corrosion be an issue in this type of soil? (likely in soil of resistivity less than 10ohm.m)
- Can a combined earthing system be successfully designed?
- If not, how should a segregated earthing system be designed?
- How much separation is required between the distribution equipment earthing system and other exposed metallic services and conductive structures such as: gas mains, water mains, telecommunications plant, metallic fences, swimming pools, electrified rail lines and underground petrol tanks?

6.5 Design outcomes

6.5.1 General

There are three fundamental distribution equipment earthing system design configuration outcomes:

- combined earthing system,
- segregated earthing system, or
- HV only earthing system.

6.5.2 Combined earthing system

A correctly designed combined earthing system is the preferred design outcome. The combined earthing system is configured by connecting the local HV earthing electrodes, and the earthed metalwork on HV mains and equipment, to the LV earthing electrodes and the neutral of the local MEN network.

The advantages of a correctly designed combined earthing system over a segregated earthing system are that:

- HV faults will clear more quickly due to the lower impedance at the point of fault.
- HV faults will not raise the HV earthing system and surrounding soil to thousands of volts with respect to remote earth or the MEN.
- The requirement for specific segregation distances between the HV electrode group and:
 - the LV electrodes/MEN is eliminated;
 - other services or conductive structures is minimised.

6.5.3 Segregated earthing system

If a combined earthing system cannot be achieved at all or at reasonable expense, then a segregated earthing system must be installed to manage the risk of transferring hazardous voltages into the MEN in the event of a HV fault. There are two additional factors to consider with respect to segregated earthing systems:

- Should a LV winding/tapping to tank fault develop in a transformer, a persistent hazardous voltage will be present between the HV earth and the ground and possibly the LV earth and the ground. This means that equipment with segregated earthing systems should be designated by appropriate signs (refer to Annexure F), and that staff should always check for the presence of a hazardous voltage before touching any earthed metalwork on equipment with a segregated

earthing system. If a voltage is present then a suitable safe work method shall be adopted before proceeding.

- It is important to maintain appropriate separation distances between the HV electrodes and other services or structures as the transfer potential risks may be severe. Such structures include but are not limited to metallic fences, swimming pools, flammable gas or liquid storage tanks, electric railway lines, pipelines, transmission or sub-transmission substations, transmission or sub-transmission lines, operating theatres or similar medical facilities, communication centres, pits, pillars and metallic sheathed communication cables.

6.5.4 HV only earthing system

A number of items of distribution equipment may only require a HV earthing system (eg: reclosers, HVCs, regulators) if they have no associated LV network or if their LV supply will not be connected to the MEN network (ie may have a dedicated isolated LV source – eg via a VT).

It is important that the Earthing Designer determine how far these HV only earthing systems should be separated from other surrounding metallic services, structures and MEN earth electrodes to ensure unacceptable voltages are not impressed on them.

6.6 Sub-transmission and distribution on shared poles

Where sub-transmission and distribution feeders are or may be supported by the same pole, serious consideration needs to be given to the questions of insulation coordination and impressed Earth Potential Rise (EPR).

This situation may lead to excessive EPRs exceeding distribution safety criteria being transferred into the MEN network.

If the pole is conductive and/or there is distribution and sub-transmission earthing proposed for the same pole, an earthing design risk assessment must be conducted to ensure safety criteria are not compromised. Please refer designs of this type to Ausgrid/Earthing & Insulation Coordination group within the Substation Design section for approval.

7.0 BASIC DESIGN CONFIGURATIONS

7.1 Configuration fundamentals

7.1.1 General

The following are earthing design fundamentals that shall be used to shape more complex earthing design configurations and standard construction drawings. Some of the typical issues arising are also discussed:

7.1.2 Air Break Switch (ABS) handle earthing

For an ABS with a ground level handle, the operator's hands and feet shall be equipotentially bonded or suitably insulated. The use of fixed or temporary operator mats is allowable for ground level handles. Bonding of the ABS handle to adjacent pole steps may be required if the ABS is elevated and operated from the pole. Arrester earthing or other HV earthing conductors shall not be bonded to the ABS handle. ABSs operated from ground level with insulated portable operating sticks (i.e. no permanent downrod) do not require earthing.

7.1.3 Capacitors

Pole mounted capacitors generally obtain LV controller supply from an external source. If the external LV source is supplied from a compliant combined earthing substation then the capacitor earthing may also be combined. If not, a segregated earthing design for the capacitor will be required.

7.1.4 Pole top substations on conductive distribution poles

Earthing designs for PTs on conductive poles shall be referred to Ausgrid/Earthing & Insulation Coordination group within the Substation Design section.

7.1.5 Construction drawings and specifications from NEOn

Annexure A lists the standard construction drawings applicable to earthing various items of distribution equipment. The appropriate drawings and specifications from NEOn shall form part of the certified earthing design. The design specification from NEOn shall specify whether a combined, segregated or HV only earthing system is required for a particular item of equipment and also the designed depths, spacings and resistances of electrodes.

7.1.6 Electrode connections

Electrode connections shall be made with two approved compression crimps at each connection or by another approved means.

70mm² PVC/XLPE insulated copper conductor shall be used between electrodes and earth or neutral bars. Where specified in installation drawings for certain pole mounted equipment, insulated aluminium conductor of equivalent section shall be used.

7.1.7 Earth electrodes

Unless a site specific NEOn earthing design specifies otherwise, earth electrodes shall have a minimum installed length of 5 metres (e.g. three 1800mm rods produce a 5.4m electrode) and be made of 15mm diameter copper clad steel rods or bare 70mm² copper conductors. Steel reinforced concrete in contact with the ground may also serve as an effective electrode provided the steelwork has adequate concrete cover, and good electrical continuity is ensured through the interconnected steelwork to the earthed equipment. This is often achieved via welding selected reinforcing rods together.

7.1.8 HV cable screen earthing

7.1.8.1 General

The cable screens of HV distribution cables shall be bonded to the associated earthing system at both ends (solidly bonded) unless specified within Clause 7.1.8.2. This ensures that a large proportion of the earth fault current will return through the cable screen rather than through the soil

and earth electrodes. This reduces the magnitude of the EPR. Where this is not possible the Earthing and Insulation Coordination group within the Substation Design section is to be consulted.

In some situations this sheath connection may transfer a hazardous EPR from one substation to another. This possibility should be considered when designing HV cable connections from Zone Substations and from equipment with segregated earthing systems.

Note: The cable sheath may need to be routed through a protection Current Transformer (CT) rather than directly connected to the earthing system. Refer to NS177 11kV Joints (including Transition Joints) & Terminations - Polymeric Insulated Cables to determine the appropriate cable sheath routing details.

7.1.8.2 HV cables between HV switchgear and distribution transformers

The screen of the HV cable between HV switchgear and an associated distribution transformer must be bonded to the earthing system at one end only. Refer to NS177 to determine the appropriate configuration for terminations of this type.

7.1.8.3 Single point bonded cables

Where single core cables are earthed at one end only (single point bonded) Earthing Continuity Conductor/s (ECC) shall be installed to bond the associated earthing systems together and to carry the earth fault return current. The only exemption for this is where segregated earthing systems exist.

Note: Where possible ECC's are to be installed as close as possible to the associated single point bonded HV cable.

7.1.9 HV earth electrode groups in segregated earthing systems

The resistance of the local HV earth electrode group should generally not be greater than 30 ohms to satisfy lightning surge / Lightning Impulse Withstand Voltage (LIWV) stress requirements.

In some segregated earthing designs, a single deeper HV electrode (rather than multiple electrodes) can be used to minimise the extent of the separation required.

It is sometimes possible to satisfy separation requirements by using deep drilled electrodes with a significant portion of the top of the electrode being insulated conductor.

7.1.10 Kiosk housings

Kiosks that have a combined earthing system and metallic outer housings shall have their housings bonded to the earth bar. Kiosks that have a segregated or HV only earthing system shall have fibreglass housings or a suitably designed alternative (which must be approved by Earthing & Insulation Coordination group within the Substation Design section) to manage the touch potential risk. Where asphalt is specified in the design to be installed within the nominal easement area around the perimeter of the kiosk refer to clause 8.5.6.

7.1.11 LV neutral interconnections

Low voltage neutrals shall be interconnected at open points in low voltage phase conductors (e.g. at LV links).

To enhance the safety of the network, LV neutrals shall be extended to interconnect to adjacent LV distributors wherever practical. Multiple neutral return paths provide redundancy and improve consumer safety in the event of a high impedance fault in one neutral conductor. This is of increasing importance as many metallic water mains (which in the past provided a backup neutral connection) are being replaced with mains of non-metallic construction.

7.1.12 Metallic HV cable covers on wood poles

Metallic covers for HV PVC over-sheathed cables on UGOH poles shall not be earthed or bonded to the MEN. The cable's metallic sheath or screen is deemed sufficient to cause the protection to operate should a vehicle collision crush the cable. This eliminates the need to determine if it is safe to earth each cover individually depending upon the particular situation.

Jute served steel wire armoured cables are a special case. If a combined earthing system arrangement can be established by a site specific earthing design for the UGOH then the arrangement is satisfactory. Earthing & Insulation Coordination group within the Substation Design section can assess particular situations where this cannot be achieved and provide recommendations as required.

An earthing design shall be produced in NEOn for the earthing of the cable sheath/screen for each 11 kV UGOH.

7.1.13 Metallic LV cable covers on wood poles

As most LV cables do not have an earthed sheath/screen, their metallic cable covers shall be bonded to a (correctly identified) LV neutral. This is intended to reduce the risk that a phase-to-cover fault will not clear. Simply earthing the cover locally may not ensure sufficient fault current to clear the fault.

Where a LV neutral earthing conductor exists on a pole, eg for an 11kV UGOH common earthing arrangement identified within Annexure A UGOH design, it is acceptable to terminate the LV cable cover to the existing earth bar where possible or to the LV neutral earthing conductor utilising two line clamps.

For new and replacement installations, non-metallic covers are installed on LV UGOHs, refer NS127.

7.1.14 Metallic cable covers on conductive poles

Earthing designs shall be referred to Ausgrid/Earthing & Insulation Coordination group within the Substation Design section.

7.1.15 Provision for future test

Earthing cables shall be arranged to provide a suitable test point with sufficient clearance between the earth cable and the structure to allow a 'clip-on' or 'tong' resistance tester to enclose the cable and check that earthing connections and electrodes remain intact. Annexure D describes the use of these testers.

7.1.16 Reclosers, regulators and capacitors

Pole mounted reclosers, regulators, enclosed load-break switches and capacitors that can obtain LV supply from their own voltage transformers should do so. This arrangement eliminates the need to supply the control equipment from the MEN and is thus a HV only earthing system.

However if this equipment is located in an MEN area, connecting the equipment to a compliant combined MEN earthing system will solve issues with clearance from MEN and other metallic structures.

For single phase to earth equipment the standard construction design for protecting the earthing shall be followed.

7.1.17 Sub-transmission voltages on conductive poles or poles with earthed overhead earth wire also carrying distribution equipment

Without a site specific earthing design it is not permissible to allow distribution and subtransmission earthing systems to be connected together deliberately or inadvertently. Requests for earthing designs shall be referred to Ausgrid/Earthing & Insulation Coordination group within the Substation Design section.

7.1.18 Separation required from earthing electrodes

For SME earthing system installations the minimum separation required from a HV or LV electrode and an item of telecommunications plant or other conductive service or structure shall be at least 1.2m. Where this separation cannot be achieved refer to Clause 8.6. Alternatively for installations other than SME installations the required separation shall be calculated using NEOn.

Annexure B gives indicative separation distances. These should be used only as a guide. They may be inadequate if the soil resistivity in the vicinity is 'high' or 'low on high', or the MEN network is limited.

Wherever it is determined that a separation of less than 15 metres is appropriate, the Telstra Power Co-ordination group should be advised, in writing, of the extent of any hazard zone and the rationale used to determine it.

7.1.19 Segregated earthing systems

In a segregated earthing system design, the HV equipment is earthed to the HV electrode group and is at no point bonded to the earthing conductors connecting the LV equipment, neutrals and LV electrode group.

The required separation between the HV electrode group and the LV electrode group is a function of the EPR on the HV electrode, the soil resistivity, the allowable voltage on the LV electrodes, and the size of the MEN. If the other factors remain constant increasing soil resistivity requires increasing electrode segregation distance.

Where HV and LV earth bars associated with a segregated earthing system are mounted on a conductive structure i.e. within a kiosk housing, additional segregation precautions are required. Under fault conditions a HV earthing system can typically rise to an EPR around 5kV. To avoid impressing this voltage on the local MEN system from the substation the level of insulation between the LV neutral bar, along with the LV earth bar if separate, and the HV earth bar shall be adequately rated.

When a segregated earthing system is used on a pole top transformer, a weatherproof zinc-oxide gapless low voltage arrester must be installed on the transformer LV neutral bushing. The arrester must be connected between the transformer LV neutral and the transformer tank.

No metalwork or conductors connected to the segregated HV earthing system shall be accessible to the public under normal circumstances.

Warning signs shall be attached to advise personnel who may work on or near this earthing system that the earthing of this item of equipment is segregated and that suitable safe work methods must be used. Refer to Annexure F. Within kiosk substations a sign is to be installed on both ends of the kiosk's access panels/doors.

7.1.20 Street lighting standards

Street lighting standards shall be designed in such a way as to avoid the possibility of reversed polarity connections creating a hazardous standing voltage on the metallic standard.

These may be either:

- double insulated and NOT earthed/bonded to the MEN; or
- bonded to an earth conductor run from the neutral link in the nearest pillar and the active conductor suitably fused at this pillar.

All new or replacement installations utilise a double insulated system, refer NS119.

7.1.21 Substations near electrified rail lines

Substations near electrified rail lines may require a drainage bond, to mitigate corrosion damage to earth rods and cable sheaths caused by long term exposure to electrolysis associated with stray traction currents.

When the installation is within 10m of a rail corridor; electrodes shall be bare 70mm² copper conductors to manage the risk of pitting corrosion due to stray DC traction current.

The need for drainage bonds for substations within 100 metres of electrified rail lines will be assessed and required works specified by Ausgrid's Earthing & Insulation Coordination group within the Substation Design section.

7.2 Basic configuration summary

The local earthing arrangements detailed in Table 1 shall be adopted. Occasionally circumstances warrant a different design. In such cases any change to these configurations must be approved by Ausgrid/Earthing & Insulation Coordination group within the Substation Design section or designed using NEOn as per Section 5.

Table 1: Earthing Design – Basic Configuration Summary

Item of Equipment	Approved Configuration	Details
ABS Handle	Equipotential bond	Bond handle to metallic or reinforced concrete mat if at ground level or adjacent pole steps if operated from an elevated position on the pole. DO NOT CONNECT TO OTHER HV EQUIPMENT EARTHING CONNECTIONS.
Substation (kiosk, chamber)	As per SME design if SME compliant, otherwise as per NEOn design.	As specified by NEOn design and/or approved construction drawing.
Substation (PT, outdoor)	As per NEOn design.	As specified by NEOn design and approved construction drawing.
Pole Mounted Plant (recloser, regulator, capacitor)	As per NEOn design.	As specified by NEOn design & approved construction drawing.
HV cable sheath/screens on UGOH poles:		
- 11kV (on wood poles)	As per NEOn design.	As specified by NEOn design & approved construction drawing.
UGOH Steel Cable Cover protecting:		
- 11kV (on wood poles)	Earthing not required.	DO NOT CONNECT TO EARTH CONDUCTORS.
- LV (on wood poles)	LV neutral bond.	Bond cable cover to local LV neutral.
- 11kV & LV (on conductive poles)	Consult Ausgrid/Earthing & Insulation Coordination group within the Substation Design section for design specifications.	
PT on Conductive Poles	Consult Ausgrid/Earthing & Insulation Coordination group within the Substation Design section for design specifications.	
Surge Arrester at:		
- HV UGOH	As per NEOn design.	As specified by NEOn design & approved construction drawing.
- HV CCT	< 50 ohms.	Local HV only electrode group or pole butt earth
MEN neutral earthing point	Minimum 5m electrode or pole-butt electrode	Used at the last pole of any radial LV distributor
Sub-transmission voltages on: Conductive poles, or Poles with earthed Overhead Earth Wire (OHEW) also carrying distribution equipment.	Consult Ausgrid/Earthing & Insulation Coordination group within the Substation Design section for design specifications.	

Pole Stay Wires	Isolate.	Install a stay wire insulator a minimum of 3m above ground. DO NOT CONNECT TO EARTH CONDUCTORS.
Single Wire Earth Return (SWER) (limit continuous earth rise – ie: under normal conditions to 20V).	Consult Ausgrid/Earthing & Insulation Coordination group within the Substation Design section for design specifications.	
Other distribution equipment including that supplied at other primary distribution voltages – 5kV, 22kV and 33kV.	Consult Ausgrid/Earthing & Insulation Coordination group within the Substation Design section for design specifications.	

8.0 EARTHING SYSTEM CONSTRUCTION

8.1 General

When working near underground assets comply with WorkCover's Guideline to Work near Underground Assets and all Ausgrid requirements (Refer to NS156 Working Near or Around Underground Cables).

Maximum use should be made of the mechanical plant available for installing earthing systems. However, hand excavation must be used where utility services or obstructions exist, at least until it is clear that mechanical equipment can be safely employed.

8.2 Utility services and obstructions

Be aware of the possibility of underground pipes, cables etc, belonging not only to Ausgrid but also to other utilities. Before digging, boring or driving electrodes into unknown ground it is essential to check on the location of any underground services in the vicinity.

To determine if underground service assets exist in a particular location, contact the designated underground asset information provider. This is a free service, providing information on which utility has an interest in a particular location and the relevant contact details.

In all locations in Ausgrid's network franchise area the requirements of NS156 apply for routine/urgent/emergency earthing installation. When plans are not sourced via a designated underground asset information provider enquiry, they are to be obtained directly from the asset owner, or other precautions taken to determine the presence of underground assets.

Where doubt exists as to the presence and location of obstructions, pipes, or cables, excavation should be carried out by hand to a depth of at least 900mm, or until rock or shale is encountered.

Check all the necessary utilities' underground construction plans, to identify where the underground construction is located, before earthing installation begins.

Earthing electrodes and associated crimp joints under driveways, roads or carriageways should be avoided where possible.

8.3 Physical earthing system layout

The physical layout of earthing systems shall comply with the appropriate standard construction drawings for the equipment in question (refer Annexure A) and where required with the detailed design specifications from NEOn (where a SME arrangement does not apply). Unless a site specific earthing system design specifies otherwise, the minimum spacing between earthing

electrodes shall be 3 metres. Where this cannot be achieved the responsible Ausgrid representative shall be contacted as per Clause 8.6.

This will ensure that the earthing system shall:

- comply with step, touch and transfer voltage requirements,
- provide adequate separation from other utility's systems, and
- provide suitable protection against mechanical damage.

Where compliance is impractical, alternatives may be sought in consultation with Ausgrid/Earthing & Insulation Coordination group within the Substation Design section.

8.4 Earthing materials - general

8.4.1 Materials - general

Materials utilised in the installation of an earthing system shall:

- have minimal environmental impact,
- be resistant to and/or minimise corrosion,
- be physically robust,
- be suitable for their design purpose and design life,
- be of a type-tested design as appropriate, and
- be of an approved type.

8.4.2 Earthing conductors

Earthing conductors utilised in the installation of an earthing system have the following requirements:

- 70mm² PVC/XLPE insulated stranded copper conductor shall be used both above and below ground.
- Insulation shall be 0.6/1kV rated, UV stabilised, black PVC/XLPE for exposed situations (e.g. pole downleads).
- Insulation may be 0.6/1kV rated, non UV stabilised, green and yellow PVC for unexposed situations (e.g. below ground, chamber substations, etc).
- Aluminium shall not be used as a buried earthing conductor. 95mm² PVC/XLPE insulated aluminium conductor shall be used above ground where specified in standard construction drawings.
- Stainless steel bolts shall not form part of a current carrying circuit. They will only be used to clamp current carrying components together.

8.4.3 Earthing electrodes

Earthing electrodes utilised in the installation of an earthing system have the following requirements:

- Driven electrodes shall be an assembly of 15mm diameter copper coated (clad or electroplated) steel rods.
- Earthing conductors shall be connected to each electrode by two approved compression P crimps installed in compliance with the manufacturer's guidelines. Bolted, welded or brazed connections shall not be used.
- Earthing conductors shall be connected together by two approved compression C crimps installed in compliance with the manufacturer's guidelines. Bolted, welded or brazed connections shall not be used.
- The electrodes within a group are to be interconnected with continuous PVC insulated stranded copper conductor.

- Where it is not possible to drive copper-coated steel rod electrodes, boreholes shall be drilled which shall accommodate a 70mm² bare stranded copper conductor to act as an electrode. A copper-coated steel electrode may be attached to the end of the conductor to assist in lowering the conductor into the hole.
- Boreholes shall be backfilled as described in Clause 8.4.5.
- Reinforced concrete footings, slabs and piers may be used as earthing electrodes in specific cases if a site specific earthing system design has been completed and approved by Ausgrid.

8.4.4 Above ground earthing conductor connections

Above ground earthing conductor connections utilised in the installation of an earthing system have the following requirements:

- Shall be of an approved type.
- Appropriate bi-metal terminations shall be used where required.
- Aluminium conductors where jointed to copper conductors shall be installed above the copper conductor to prevent galvanic action and pitting from copper salts washing over the aluminium bodied connector.

8.4.5 Earthing backfill compounds

Drilled electrode holes shall be backfilled with an appropriate earthing backfill compound (i.e. a mixture of bentonite and gypsum such as 'Good Earth' or another approved equivalent product). Bentonite expands as it absorbs and retains water. This ensures good contact between the installed earthing electrode and the surrounding soil, and lowers the electrode's resistance. The compound should be installed as follows and in keeping with any instructions from the manufacturer:

- The earthing compound slurry shall be mixed in compliance with the manufacturer's recommendations and poured into the drilled hole around the installed electrode. The electrode shall be agitated to eliminate voids remaining in the slurry.
- The compound shall not be installed dry.
- Neither salt enriched earthing compounds nor 'rock salt' treatment of the electrode installation shall be used as a method of (temporarily) lowering the electrode's resistance.

8.4.6 Prevention of contact

The following requirements should help to prevent contact:

- On wood poles, an appropriate cover strip shall be utilised to prevent contact with above-ground earthing conductors. The cover strips are to be installed as per standard construction drawings.
- Below ground, PVC cover strip or conduit shall be used to protect and identify earthing conductors that are not installed within Ausgrid's distribution substation easements or beneath other cables in Ausgrid's cable allocations.
- Use aluminium cable to 2.4m of ground as an earthing conductor to deter theft of copper cables. For pole mounted substation equipment with single phase VTs use an earthed metallic cover for increased level of mechanical protection. For specific equipment requirements refer to the standard construction drawings.
- Isolation sections in metallic fencing. Refer standard construction drawings for typical fence details.

8.5 Installation methods

8.5.1 Earthing arrangements

Local earthing for distribution equipment is generally one or more vertically driven or drilled electrodes interconnected with associated earthing cable. The earthing cable is to be installed as per the requirements of NS130 for standard backfill and cable cover arrangements for direct buried cables. Typical arrangements for earthing electrodes are as follows:

- **Driven rod electrodes** – shall be 15mm diameter copper coated (clad or electroplated) steel rods. The first rod of each electrode shall be fitted with a hardened steel driving point. Rods must be joined with the approved friction joint couplings. Unless a site specific NEOn earthing design specifies otherwise, the minimum electrode length is 5 metres (e.g. three 1800mm rods produce a 5.4m electrode).
- **Bored electrodes** – shall be bare 70mm² stranded copper cables. They are installed by boring a clearance hole to a suitable depth. Minimum hole diameters are 35 mm in solid rock, and 50mm in loose rock or clay. Crimping an earth rod or a short length of copper tube to the end of the electrode cable allows easier installation of the electrode to the bottom of the hole. Slurry made from an approved earthing compound is then poured into the hole. During the pour, the electrode should be agitated and/or the slurry tamped to expel any trapped air pockets. Once the slurry has set it may be necessary to top up the hole. Unless a site specific NEOn earthing design specifies otherwise, the minimum electrode length is 5 metres.

Note: In some areas greater electrode depths or additional electrodes will be required to achieve the required earthing system resistance. In some locations with high resistivity soils, it may be necessary to drill to depths exceeding 10 metres to obtain a suitable resistance value.

- **Electrode Groups** – shall be arranged as shown on the appropriate approved drawings.

8.5.2 Electrodes not to be driven after crimping

Compression crimp connections to driven electrodes shall not be made before the electrode is driven to its final depth as this may result in a substandard connection and is not permitted. The crimp connections to the electrode shall be made within the excavated trench with the top of the electrode 500mm below finished ground level.

8.5.3 Earthing not to encroach on other allocations

Earth installations shall be designed and installed to ensure they do not encroach on the footpath / street allocations of other public utilities. Street allocations are specified in NS130 Specification for Laying Underground Cables up to and including 11kV.

8.5.4 Earth and neutral bar connections

Cable connections to the substation earth bar must be made with bolts, washers and nuts of the sizes specified in the drawings. Where the bolt size is not specified the bolt and bar hole must be of an appropriate size consistent with the diameter of the hole in the lug being attached. Each cable lug must be separately connected under its own bolt or bolts. Cable lugs must be connected directly to the bar. It may be necessary for additional holes to be drilled in the bar. Connection extension pieces, such as bar stubs or flags must not be used for cable connections. Slotted lugs are not permitted. Full hole compression lugs must be used. Bolts, washers and nuts must be stainless steel grade 316. Lug holes must not be enlarged to accommodate larger bolts. Brass bolts must not be used.

8.5.5 Stainless bolts – lubrication of threads

Before installation of each stainless steel bolt or set-screw, the thread shall be lubricated with specially formulated anti-seize grease containing nickel (eg Loctite Nickel Anti-Seize, or approved equivalent). Ausgrid stockcode is 177212.

8.5.6 Asphalt

Where the earthing design requires the use of asphalt to manage touch / step voltage hazards:

- Preparation: Use of compacted road base (and possibly plastic underlay for weed control)
- Material: Well compacted hot mix at least 50mm thickness compacted (as cold mix electrical properties are compromised in wet conditions)
- Typically, timber edging is provided to protect the edges.

8.6 If a certified design cannot be achieved

If, for some reason, the certified design earthing requirements (as specified in this Network Standard or the relevant drawings and specifications) cannot be achieved, the Earthing Installer/ASP Compliance Officer shall contact Ausgrid/Earthing & Insulation Coordination group within the Substation Design section. Adequate time must be allowed to enable an alternative design arrangement to be developed. In such cases the Earthing Installer will be required to obtain Ausgrid's approval for any design changes. The reasons for these changes to design requirements shall be recorded in NEOn.

9.0 EARTHING SYSTEM COMMISSIONING

9.1 General requirements

The Earthing Installer shall carry out tests as necessary to demonstrate compliance with the requirements of this Network Standard. 'Tests' shall include all checks, measurements and tests necessary to prove compliance.

All test equipment and instrumentation used for testing shall be traceable to a National Association of Testing Authorities (NATA) Registered Laboratory and have a current test sticker affixed. The Earthing Installer is responsible for ensuring that test equipment and instrumentation used is traceable.

9.2 Earthing resistance commissioning tests

In addition to an inspection of the earthing configuration, two local earthing system resistance tests shall be performed as outlined in this section. The results will be recorded and compared with the specified design requirements. Refer to Annexure D regarding testing details.

9.2.1 Earthing configuration inspection

This inspection shall confirm that the earthing configuration complies with the design specification from NEOn that accompanied the authorised electrical design or when an SME design is used that the criteria identified within Clause 5.2.2 is satisfied. In particular this inspection shall confirm that the earthing has been constructed as per the standard construction drawing specified and that all the earthing systems components have been configured and connected as specified.

9.2.2 Three point / fall of potential - resistance test

The Three Point test (or Two Point test if a Three Point test cannot be achieved) shall be conducted on the installed electrode groups before other earthing system elements are connected (e.g. HV cable sheaths or the MEN). The resistance test results shall be recorded as per the requirements of Clause 9.3.

This test shall confirm that the local earthing complies with the acceptable range of design values within Clause 5.2.2 for SME design electrode earthing resistances or as provided by the Earthing Design Specification and the As Built Installation Report from NEOn.

9.2.3 Loop (clip-on tong) - resistance test

A clip-on tong test shall also be conducted once the earthing system is in its final 'in-service' configuration. The resistance test results shall be recorded as per the requirements of Clause 9.3.

This test shall follow the connection to the HV electrode group and then the connection to the LV electrode group.

If the substation has a segregated earthing arrangement this test shall only be conducted after checking that no hazardous standing voltage exists between the HV and LV earth bars (should a hazardous voltage exist it must be immediately reported to Ausgrid/Earthing & Insulation Coordination group within the Substation Design section). To perform this test on a segregated earthing system a temporary jumper lead must be installed between the HV and LV groups. This test assumes that the impedance of the MEN is small compared to that of the local electrodes.

9.3 Commissioning test data recoding

Following commissioning of the earthing installation, certain procedures are to be followed in order to record and archive earthing related information for use in operations and maintenance. All earthing resistance commissioning test results, both the three point and the loop resistance test results, shall be recorded in Ausgrid's Integrated Asset Management System. As a result commissioning and future maintenance resistance measurements will be available should a simple in-service diagnostic check of the earthing system be required. Comparing subsequent earthing resistance test results with the 'as commissioned' test results should indicate if the resistance of the local earthing has changed significantly.

For non-contestable/capital work, the reference document is CIA 107 Basic Distribution Equipment Earthing Design Process for Non-Contestable/Capital Work.

For Contestable works contact Ausgrid's representative facilitating the contestable project.

10.0 ROLES AND RESPONSIBILITIES

In addition to the roles and responsibilities defined by other applicable Ausgrid standards, the following roles are important for the successful completion of earthing systems:

Electrical Designer

The Electrical Designer will provide specific information on the requirements for each particular project to the Earthing Designer.

Earthing Designer

The Earthing Designer will generally obtain information related to designing earthing systems from the Electrical Designer. When required the Earthing Designer will incorporate this information in NEOn and they must understand the principles by which earthing systems perform, in particular the interactions between various energy sources and systems and the full range of fault current paths.

It would be advantageous if the Earthing Designer is conversant with a range of analysis methods and tools available, and to understand the physical constraints involved in the installation and inspection processes in order to specify robust, practical designs that are appropriate for different situations.

11.0 RECORDKEEPING

The table below identifies the types of records relating to the process, their storage location and retention period.

Table 2 – Recordkeeping

Type of Record	Storage Location	Retention Period*
Approved copy of the network standard	Document repository Network sub process Standard – Company	Unlimited
Draft Copies of the network standard during amendment/creation	Records management system Work Folder for Network Standards (Trim ref. 2014/21250/221)	Unlimited
Working documents (emails, memos, impact assessment reports, etc.)	Records management system Work Folder for Network Standards (Trim ref. 2014/21250/221)	Unlimited
NEOn distribution equipment earthing design	NEOn	Unlimited
Distribution equipment earthing system commissioning test data	Ausgrid's Integrated Asset Management System	Unlimited

* The following retention periods are subject to change eg if the records are required for legal matters or legislative changes. Before disposal, retention periods should be checked and authorised by the Records Manager.

12.0 AUTHORITIES AND RESPONSIBILITIES

For this network standard the authorities and responsibilities of Ausgrid employees and managers in relation to content, management and document control of this network standard can be obtained from the Company Procedure (Network) – Production / Review of Engineering Technical Documents within the documents repository. The responsibilities of persons for the design or construction work detailed in this network standard are identified throughout this standard in the context of the requirements to which they apply.

13.0 DOCUMENT CONTROL

Document Owner : Head of Asset Risk & Performance

Distribution Coordinator : Manager Asset Standards

Annexure A – Standard Construction Drawings

Equipment Type/ Drawing No	Drawing Title
Capacitor	
162475 Sheet 1	Standard construction 11kV pole top capacitors construction detail
162475 Sheet 2	Standard construction 11kV pole top capacitors modification to EDO pole construction detail
Enclosed Switch	
170234	Standard construction 11 kV Nulec RL Series Pole Mounted Enclosed Switch General Arrangement
Recloser	
220041	Standard construction 11 kV S&C Intellirupter PulseCloser Without bypass ABS General Arrangement
220251	Standard construction 11 kV S&C Intellirupter PulseCloser With bypass ABS General Arrangement
224228	Standard construction 11 kV S&C Intellirupter PulseCloser Controlling Pole Mounted Regulators General Arrangement
255677	Standard Construction 11kV Noja Type OSM15 Recloser with bypass ABS General Arrangement
Regulator	
224227	Standard construction 11 kV pole mounted voltage regulator with controlling Intellirupter General Arrangement
224401	Standard construction 2 unit pole mounted regulator with ground mounted control panel
224402	Standard construction 2 unit pole mounted regulator with pole mounted control panel
224229	Standard construction 3 unit pole mounted regulator with ground mounted control panel
Substation – Chamber	
25121	Chamber substation earthing typical installation of electrodes
242607	Standard Construction HVC Kiosk and Chamber Substations Earthing Schematic
Substation – Kiosk	
167433	Standard construction kiosk substation – combined HV/LV typical earthing details
167434	Standard construction multiple kiosk substation – combined HV/LV typical earthing details
173990	Standard construction multiple kiosk substation – segregated HV/LV typical earthing details
151572	Type L kiosk Layout option plan
151190	Type K kiosk Layout option plan
224403	Danger Sign Distribution Substation With Segregated Earth
Substation – Pole	
228821	Standard Construction 3 phase – 11 kV Pole mounted Distribution substation 0-400 kVA General Arrangement
228822	Three Phase PT combined and segregated earthing
228831	Standard Construction 1 phase – 11 kV Pole mounted Distribution substation 0-63 kVA General Arrangement
228832	Single Phase PT combined and segregated earthing
224403	Danger Sign Distribution Substation With Segregated Earth

Equipment Type/ Drawing No	Drawing Title
UGOH	
160354	11kV underground to overhead (UG/OH) construction – combined earthing or HV only
Typical Fence Isolation Detail	
255306	Ausgrid Boundary Fences Isolating Post Details
Timber Pole Butt Earth	
508786	Standard construction timber pole structure earthing arrangement type SE-M5

Annexure B – Separation between Distribution Equipment Earthing Systems and Telecommunications Plant

B1 Background

To protect telecommunication workers, and to prevent damage to telecommunication equipment, the prospective touch voltage, in the vicinity of any telecommunication plant (eg pit, pillar, cabinet, public telephone, exchange), caused by HV power distribution system earth faults, needs to be limited to 430 volts (or 1000 volts depending upon the situation). This particularly applies to faults associated with HV earthing systems.

The voltage rise on an earth grid (and surrounding soil) is a product of the (fault) current that actually enters the soil at that point, and the resistance of the earth grid. Generally only a fraction of the fault current actually flows through the soil. The bulk of the fault current usually returns to its source via metallic circuits such as LV neutrals and cable sheaths. The proportion of the fault current that flows through the earth is dependent on the impedance of the return path via LV neutrals, cable sheaths, etc, and the resistance of the earth grid. The soil voltage rise decreases rapidly as the distance from the earth grid increases, however the rate at which it decreases depends on the soil resistivity.

Thus the distance between any telecommunication plant and any adjacent earthing system, associated with Ausgrid's HV network, needs to be carefully considered when earthing design parameters change. This applies to all accessible telecommunications plant including jointing pits, service pits, manholes, pillars and cabinets containing cables with metallic conductors. Buried telecommunications cables with conductive sheaths also need to be considered.

B2 Separation between HV earthing systems and telecommunications plant

B2.1 Approximate radial extent of 430 V hazard zone

Table B1 defines the separations that are useful as an initial guide to the required separation between the HV system earth grids associated with Ausgrid HV earthing systems and telecommunication plant, unless reduced separations can be justified in accordance with Clause B2.2.

Note: These values do not consider the effect of soil resistivity layering and are not conservative in certain circumstances.

Table B1: Indicative Radial Extent of 430 Volt Hazard Zone

Type of HV Earthing System	Approximate Radial Extent of 430V Hazard Zone (m)
1. 66 kV and 132 kV transmission and distribution system towers, conductive poles and wooden poles with associated earth electrodes.	40
(a) If HV system structures are fitted with a continuous and regularly earthed OHEW.	15
(b) If HV wooden poles are fitted with OHEW with insulated down leads and deep-buried earth electrodes insulated to a depth of 4m.	2.5
2. Distribution systems less than 66 kV - conductive poles and wooden poles with associated earth electrode (including pole-mounted transformers).	15
(a) If HV system structures are fitted with a continuous and regularly earthed OHEW.	5
(b) If HV system structure supporting a distribution substation has: (i) Combined earthing system, and (ii) Interconnected LV neutral conductor, and (iii) MEN earthing system.	5 (refer also to Clause B2.2 below)
3. Kiosk distribution transformers, and pad-mounted RMU switchgear.	15
(a) If fed by a HV cable with cable sheath continuity from zone substation earth grid to kiosk substation earth.	5
(b) If substation has: (i) Combined earthing system, and (ii) Interconnected LV neutral conductor, and (iii) MEN earthing system.	5 (refer also to Clause B2.2 below)
4. Direct buried HV cables with uninsulated sheath.	0.5
5. Zone and transmission substations.	Refer Ausgrid/ Earthing & Insulation Coordination group within the Substation Design section.

B2.2 Reduced hazard zones associated with MEN installations

For SME earthing system installations a reduction of the hazard zone can be applied and hence a minimum nominal separation of 1.2m can be applied as per Clause 7.1.18. Alternatively for installations other than SME installations a reduction in the hazard zone may be appropriate. Therefore where there is:

- a continuous and extensive LV neutral grid forming a return path to the HV earthing system, and
- the HV and LV earthing systems are combined at the distribution substation,

it is likely that the maximum earth potential rise may not exceed 430V and no hazard would exist. However, this must be demonstrated on a case-by-case basis.

Where, after considering the specific characteristics of individual cases, it can be shown that no hazard zone exists, the separations shown in 2(b) and 3(b) in Table B1 above, may be reduced to the minimum nominal separation of 0.5 m.

B2.3 Deep/insulated earthing

Insulated earth conductors may be utilised to achieve suitable separations. For example, where horizontal separation is not practicable, a suitable separation may be achieved by installing deep earthing (e.g. 20 m) and insulating the earthing system to within the hazard zone (e.g. to a depth of 15 m).

B2.4 Detailed calculation or site specific testing

Where the conditions are such (e.g. low on very high soil resistivity) that the separations stated in the above table are inappropriate, detailed calculation or site-specific testing may be carried out to accurately determine the actual location of the 430 volt contour relative to the earthing system. Agreement shall be sought from the relevant telecommunication company that this shall be the minimum separation for that specific installation.

B3 References

- AS/NZS 3835.1:2006 Earth potential rise - Protection of telecommunications network users, personnel and plant - Code of practice
- AS/NZS 3835.2:2006 Earth potential rise - Protection of telecommunications network users, personnel and plant - Application guide
- Code of Practice for the Protection of Personnel and Equipment Against Earth Potential Rises Caused by High Voltage Power System Faults (EPR CODE) 1984
- HB 219:2006 Earth potential rise - Protection of telecommunications network users, personnel and plant - Worked examples for the application guide

Annexure C – Soil resistivities (indicative only)

Soil resistivity (ρ) is a measure of the resistance of the soil across a theoretical cubic metre with electrodes of one square metre on either side.

Note: Soil resistivity is expressed in ohm metres, not ohms per metre. It is sometimes wrongly described as specific resistance.

Soil resistivity varies depending upon the physical nature of the soil, its chemical composition, dissolved salts and moisture content. Soil resistivity is often layered (e.g. 'high-on-low' or 'low-on-high'). Table C1 below gives an idea of the types of soils and typical ranges of resistivity.

Table C1 Soil Resistivity Ranges

Soil	ρ (ohm metres)
Swampy earth	10
Clays	8 to 50
Clay, sand and gravel mix	40 to 250
Sand and gravel	60 to 100
Broken slate, shale and sandstone	10 to 500
Rock	200 to 10 000

When the resistivity is not known, a value of 100 ohm metres is often taken to be representative of an average soil with a moisture content of around 25%. Lowering the moisture content to 5% can raise the resistivity to 500 ohm metres. Completely dry soil can have a resistivity of thousands of ohm metres. An indication of variation of resistivity with moisture is given in Table C2 below.

Table C2 Effect of Moisture on Soil Resistivity

Soil	ρ (ohm metres)
Mud or coal	1
Wet soil	10
Moist soil	100
Dry soil	1 000
Rock	10 000

Annexure D – Guidance for testing

D1 Introduction

Earthing systems are tested to ensure they comply with safety and protection design requirements, and earthing tests are applicable at design, commissioning and maintenance stages. This section addresses the requirements and procedures for design and commissioning tests only.

Note: When performing resistance measurements of earthing systems of installations in service, it is very important that no earth connections are broken. Opening earth connections of installations in service constitute a safety hazard.

If there is a need to disconnect earths while performing resistance measurements in service, Ausgrid/Earthing & Insulation Coordination group within the Substation Design section should be consulted before proceeding.

D2 Staged earthing tests

The information needed during the design and commissioning stages is shown in Table D1.

Table D1: Staged Tests

Information	Stage	
	Design	Commissioning
Soil resistivity	√	
Earthing Interconnectivity	√	√
Local Earthing impedance		√

An adequate set of tests to determine this information is outlined in Clause D3.

D3 Test methods

The test methods shown in Table D2 are sufficient to design and assess most distribution equipment earthing installations. Installations which cannot be satisfactorily tested using these methods shall be identified and alternative testing or assessment methods documented in the earthing design report.

Table D2: Test Methods

Test	Test Method	Reference	Earthing Configuration:	
			Combined	Segregated
Soil Resistivity	4 pin Wenner	Clause D4	√	√
Earthing Interconnectivity	4 terminal continuity	Clause D5	√	√
	Insulation resistance	Clause D6	√	√
Local earthing impedance	Loop	Clause D7	√	√
	Three terminal / Fall of Potential	Clause D8	√	√

Testing responsibilities are shown in Table D3.

Table D3: Testing Responsibilities

Test	Responsible	
	Earthing Designer	Earthing installer
Soil Resistivity	√	
Earthing Interconnectivity	√	√
Local earthing impedance		√

D4 Soil resistivity – Wenner 4 pin method

D4.1 Introduction

The accuracy of soil resistivity data has a direct impact upon the accuracy of the earthing design and the performance of the resulting installation.

The 4 pin Wenner method is generally the most direct means of determining soil resistivity to the required level of accuracy. Clause D4.8 discusses solutions to difficulties with the Wenner method.

NEOn provides a Wenner soil resistivity training video and a test sheet which can be used to record field measurements. The following sections outline the information which must be collected.

Each test instrument has capabilities and limitations. Clause D4.9 outlines a procedure to assess whether a test instrument will be suitable to measure the majority of soil types encountered across the Ausgrid region.

There are three main stages when undertaking a soil resistivity test: preparation, test execution and data storage.

D4.2 When and where to test

Where an SME design applies a soil resistivity is not required. However where an SME design does not apply and a NEOn design is required a soil resistivity test shall be completed where reasonably practical as per Clause 5.2.2. The requirement for soil resistivity testing is to assist in the earthing design of a particular distribution asset. Staff undertaking the test will determine the exact test location based on the advice in the following sections.

D4.3 Preparation

Gathering the following information about a proposed test location in advance will reduce the risk of any unexpected results.

D4.3.1 Geological issues

Awareness of the rocks and soil types particular to the site enables the technician to tailor the test to encompass any geological features which may aid or cause problems with the earthing system. Features like rivers, causeways, rocks and the basic soil type should be noted as part of the testing.

D4.3.2 Meteorological issues

Soil resistivity is particularly affected by soil moisture. If the test is undertaken during unusual seasonal conditions then this should be noted. It is generally not ideal to test immediately after heavy rain as the test results will invariably be an optimistic representation of the resistivity during normal dry conditions. In any case, it is important to note the date and amount of the most recent rain so that this information can be considered when analysing the results.

D4.3.3 Site infrastructure and test locations

Any metallic infrastructure in the vicinity of the test site will affect resistivity measurements as the test current will tend to follow the metal rather than flow through the earth. Electrically energised systems can also introduce interference to the test measurements through inductive and capacitive coupling. Examples of metalwork that may pose problems include:

- existing earthing systems
- pipes: gas, water, sewage
- tanks: water, fuel, other storage
- railway lines
- metal fences
- concrete reinforced slabs
- electrical services
- telecommunication services

Test locations should be chosen to avoid traverses parallel to existing metallic infrastructure.

The designated underground asset information provider can assist in determining the presence of existing buried structures.

For new installations, where there is no existing metalwork, the location of each test traverse is simply determined by the position of the planned earthing system.

In many cases, testing the exact site of the new work is not feasible as existing metalwork will interfere with the results. The approach in these situations is to undertake test traverses close enough to the site, so as to get a useful indication of its soil resistivity model, yet far enough away to avoid interference from existing metalwork. In most cases a separation distance of at least 50m between the test electrodes and any existing metalwork will suffice. It is important that the location of any existing conductive structures in contact with the soil is noted in relation to each test traverse so that this information can be considered when analysing results. Doing multiple test traverses at different locations surrounding the site of interest will allow the Earthing Designer to better assess what the soil resistivity is likely to be at the site itself.

Figure D1 suggests two test points that might be considered for an industrial type subdivision.

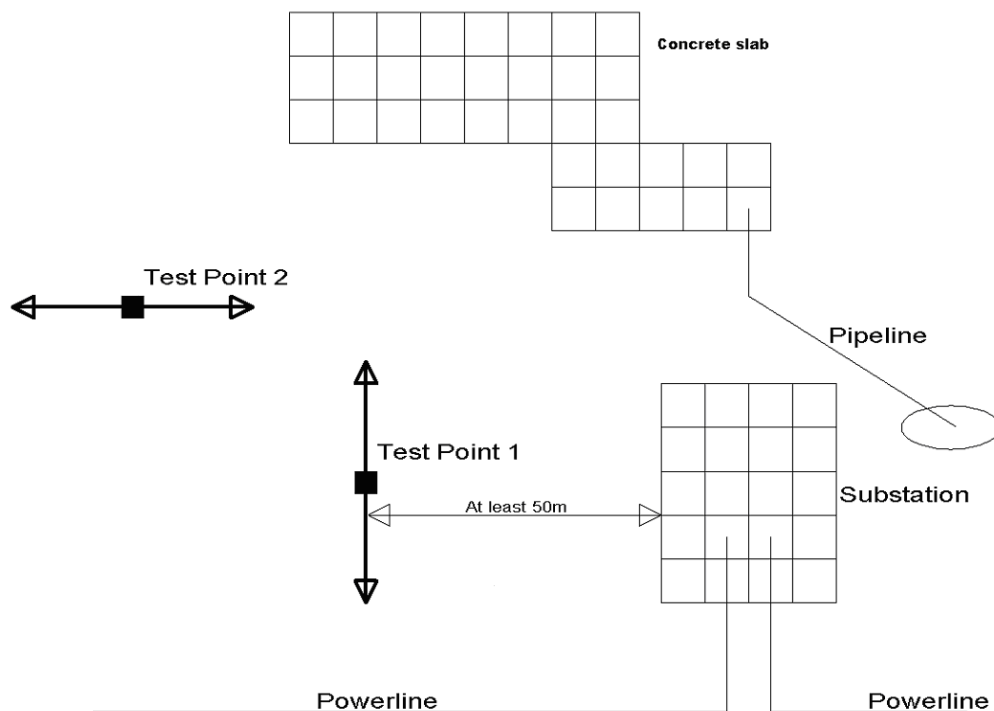


Figure D1. Example Test Points for Typical Industrial Type Subdivision

D4.4 Test equipment

The following list of test equipment is adequate for most sites.

- A 4 terminal tester (refer to Clause D4.9 for further information about the selection of a suitable tester).
- Minimum four electrodes. More electrodes may be required to form a system of interconnected probes in high resistivity locations.
- Minimum four lengths of conductor, insulated to the output rating of the test instrument and of sufficient length to undertake a 32m spacing test. A colour coded arrangement can ease onsite testing. (eg: One reel with a 48m red lead followed by a 16m blue lead and a second reel with a 48m white lead followed by a 16m green lead).
- Assorted short leads and plugs/clips used to make the connections between the electrodes and the meter.
- Two 30m measuring tapes.
- Hammers for driving electrodes.
- 20 litres of water to improve the contact resistance of the test electrodes in dry, high resistivity locations.
- A set of two-way radios can be advantageous in areas where the technician's line of site is impaired by obstacles or rough terrain.

D4.5 Test execution

D4.5.1 Test configuration

The Wenner 4 pin test configuration is shown in Figure D2.

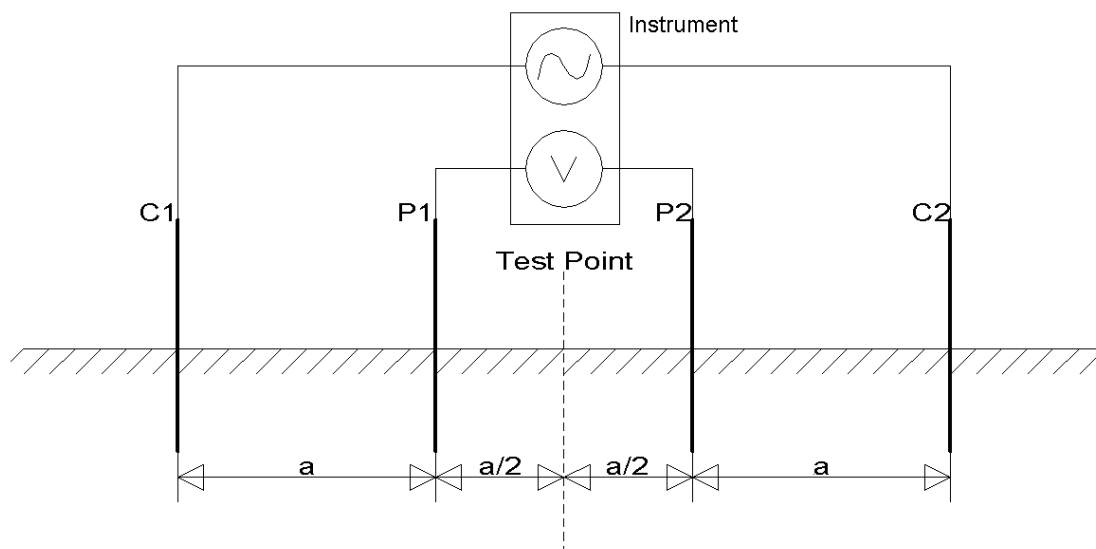


Figure D2. Wenner Test Configuration

Four copper clad steel electrodes are uniformly spaced along a straight line through the Test Point.

The test is performed by injecting a current through electrodes C1 and C2. The soil resistivity meter is then able to determine a soil resistance 'R', using the injected current and the voltage between electrodes P1 and P2. The apparent resistivity ' ρ ' of the test point can then be calculated as follows:

$$\rho = 2\pi aR$$

The test is repeated for a wide range of electrode spacings 'a', to obtain an apparent soil resistivity profile of the site.

A feature of the Wenner test is its reciprocity. This means interchanging the connection of electrodes C1 with P1 and C2 with P2 should not change the result. This is a useful error checking tool when used as part of the testing.

D4.5.2 Test Electrode Depth and Spacing

There are two competing issues when determining electrode depth. Point source assumptions require shallow electrode depths whereas electrode resistance and finite instrument drive capabilities require deeper electrode depths. On balance, the following rules are adequate for instruments meeting the assessment process of Clause D4.9.

- For electrode spacings of up to 8m, the electrode depth should be just enough for the soil to support the weight of the electrode.
- For electrode spacings greater than 8m, increase electrode depth whilst keeping the force required to remove the electrode within reasonable limits and considering other possible buried assets.

Test results are obtained at various electrode spacings to enable the Earthing Designer to determine a model of the soil resistivity as a function of depth.

For distribution assets, electrode spacings of 1, 2, 4, 8, 16 and 32 metres are adequate for the majority of installations. Intermediate spacings or greater spacings may be required by the Earthing Designer if issues arise during testing such as those in Clause D4.8.

D4.5.3 Apparent Resistivity

It is important to plot the apparent resistivity versus the electrode spacing as the test is undertaken. This allows interference or errors to be identified and rectified with minimal effort during the test.

When plotted on log-log paper, the curve should be smooth and tend to flatten out at very small and very large spacings. Wild variations in results normally suggest something has gone wrong. In these cases, different electrode spacings or a different test location should be considered. Clause D4.8 contains more details on issues and solutions.

Figure D3 illustrates the apparent resistivity curve of a two-layer soil structure.

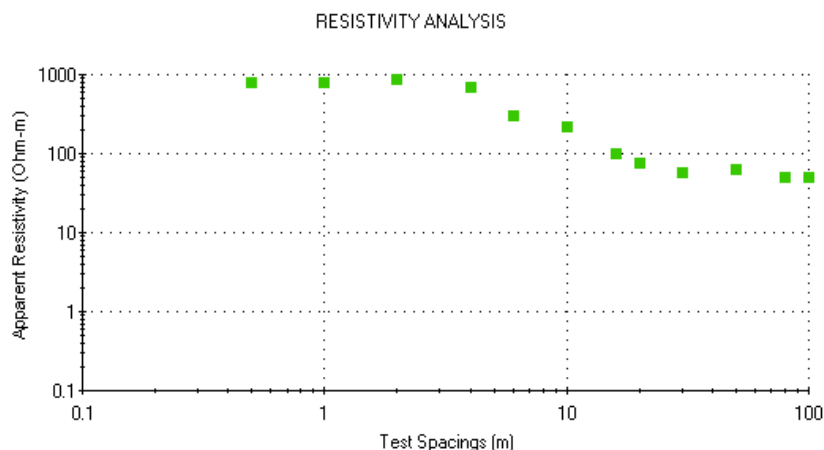


Figure D3. Typical Apparent Resistivity Curve - Two Layer Soil Structure

D4.6 Test procedure steps

This step-by-step procedure should be read in conjunction with a test sheet template. The test sheet template can be found in Annexure E.

1. Record the project particulars in the space provided at the top of the test sheet. Particular attention should be paid to recording the amount and timing of recent rain as well as a brief description of the geology (eg. sandy top soil on clay base).
2. GPS coordinates or other location information should be recorded which will allow the specific test to be located precisely on a map.
3. Sketch the test location and the position of any metalwork or geographical features (eg. water courses, large rocks etc). Record approximate distances between all metalwork and the test electrodes. Note that the electrodes will extend to almost 100m for 32m electrode spacings.
4. Run out two cables in opposite directions to connect to the outer electrodes. Note that up to 48m of cable will be required in each direction for the 32m electrode spacings. Run out the other cables to connect to the inner electrodes.
5. Measure the probe spacings for the first measurement (1m). Note that the middle probe spacing is split either side of the test point as shown in Figure D2. Drive each probe to the specified depth according to the rules of Annexure E4.5.2.
6. Connect the probes to the test meter as shown in Figure D2 (C1,P1,P2,C2) and record the resistance value. Swap the potential and current leads (P1,C1,C2,P2) and record the resistance value again. Both values should be within twenty percent. Check the electrodes if there is a significant difference in the two readings.
7. Calculate the apparent resistivity for this electrode spacing and plot the results on the log-log paper. The curve should be smooth and tend to flatten out for very small and very large spacings.
8. Reconnect the test in the original configuration (C1,P1,P2,C2) and move the electrodes to the next spacing. Continue for each electrode spacing specified in Annexure D4.5.2.

D4.7 Test recording and filing

After completing a soil resistivity test, soil resistivity results must be entered into the soil resistivity section of NEOn. Each measurement is to be entered. The test sheet, including any sketches is to be scanned in and attached.

D4.8 Testing issues

Generally any difficulty that may be experienced while undertaking a soil resistivity test can be simplified to three primary causes.

- High electrode impedance compared to instrument voltage/current capability and instrument detection sensitivity.
- Interference from nearby infrastructure.
- Test configuration problems.

D4.8.1 Problems and their solutions

While most test instruments offer a range of diagnostic output which should be checked during each measurement, the test instrument cannot detect every condition that may cause an error. Table D4 lists a number of possible issues which should be kept in mind when a test is undertaken.

Consult the test instrument instructions for the interpretation and resolution of instrument diagnostic output.

Table D4: Test Trouble-shooting Guide

Problem	Category of problem	Solutions
Test instrument displays high impedance electrode or current too low.	High electrode impedance.	Install electrodes further into soil. Wet soil about electrodes. Install additional electrodes in parallel.
Measurement is unstable or fluctuates.	High electrode impedance, Interference.	Try solutions above. Rotate test ninety degrees. Relocate test.
Measurement difference when reversing lead configuration.	High electrode impedance, Test configuration problem.	Try solutions above. Check that electrodes are in line. Check that electrodes are connected to the instrument properly. Check that electrodes and connections are in serviceable condition and that instrument is functioning properly.
Sudden changes in resistivity on resistivity Vs spacing plot.	High electrode impedance, Test configuration problem, Interference.	Check solutions above. Re-check for buried metal work. Take additional measurements either side of disturbance and see if it is localised. Relocate test.

D4.8.2 Electrode impedance

If electrode impedance is suspected to be too high, an approximate measurement of electrode impedance can be made by simply making minor configuration changes as shown in Table D5. No electrodes need be moved for this check.

For instruments that have been assessed using Annexure D4.9 the ratio of electrode impedance to the measured resistance can be checked. This ratio should be less than 1000.

For example, if a measurement is made where the instrument displays 0.7 Ohms then each probe impedance can be up to $0.7 \times 1000 = 700$ Ohms.

All test instruments have an upper limit on the ratio rule due to the maximum voltage available at the instrument's output. This limit varies from instrument to instrument, however a maximum electrode impedance of 20kOhms is reasonable.

Electrode impedance ratio rule
Electrode impedance can be up to the smaller value of: • 1000 x measured resistance. • 20k Ohms.

Table D5: Approximate method for finding electrode impedances

Test configuration	Electrode impedance
	Instrument will display the approximate impedance of the C1 electrode.
	Instrument will display the approximate impedance of the P1 electrode.
	Instrument will display the approximate impedance of the C2 electrode.
	Instrument will display the approximate impedance of the P2 electrode.

Occasionally using the Wenner 4 pin test and trying the techniques shown in Table D4 will not work for a particular installation. The process to follow for these sites is shown in Figure D4.

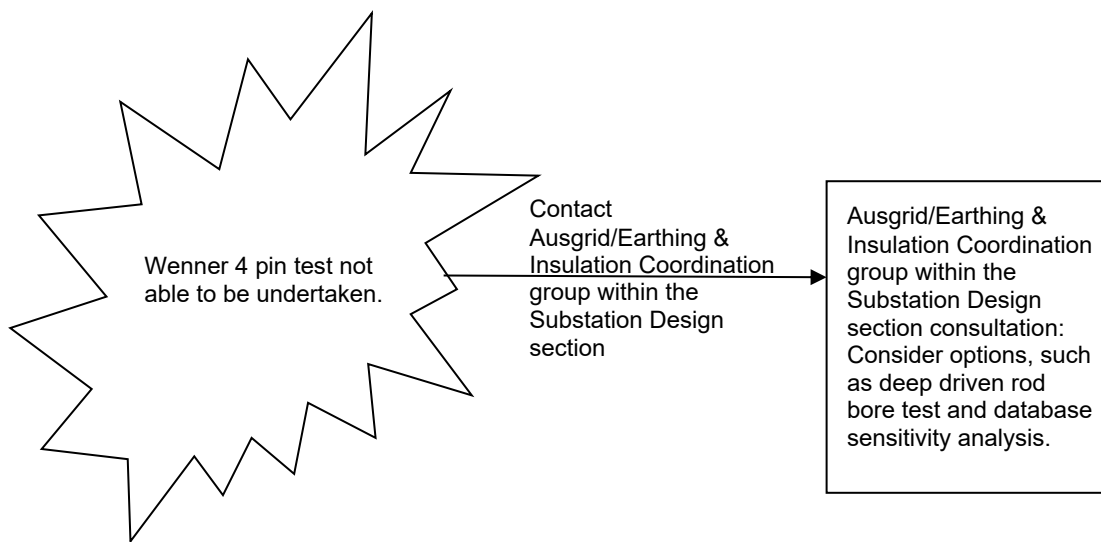


Figure D4. Process where the Wenner 4 pin test has failed.

D4.9 Test instrument assessment

D4.9.1 General

A range of instruments are available which are suitable for Wenner 4 pin soil resistivity testing. Whilst ease of use, robustness and cost are important considerations for the purchaser of the instrument, the following instrument assessment criterion is essential to ensure the instrument has the required drive capability and measurement sensitivity for compatibility with the majority of soil types across the Ausgrid network.

This instrument assessment is an acceptable minimum. Compliance with the assessment does not guarantee that an instrument will perform acceptably under every possible circumstance. An operator must always consider if any of the issues listed in Clause D4.8 are applicable.

D4.9.2 Assessment circuit

The assessment circuit consists of five resistors connected as shown in Figure D5. The assessment circuit approximates test conditions consisting of 32m electrode spacings, 3000Ohm.m surface soil resistivity and a minimum electrode depth of 150mm.

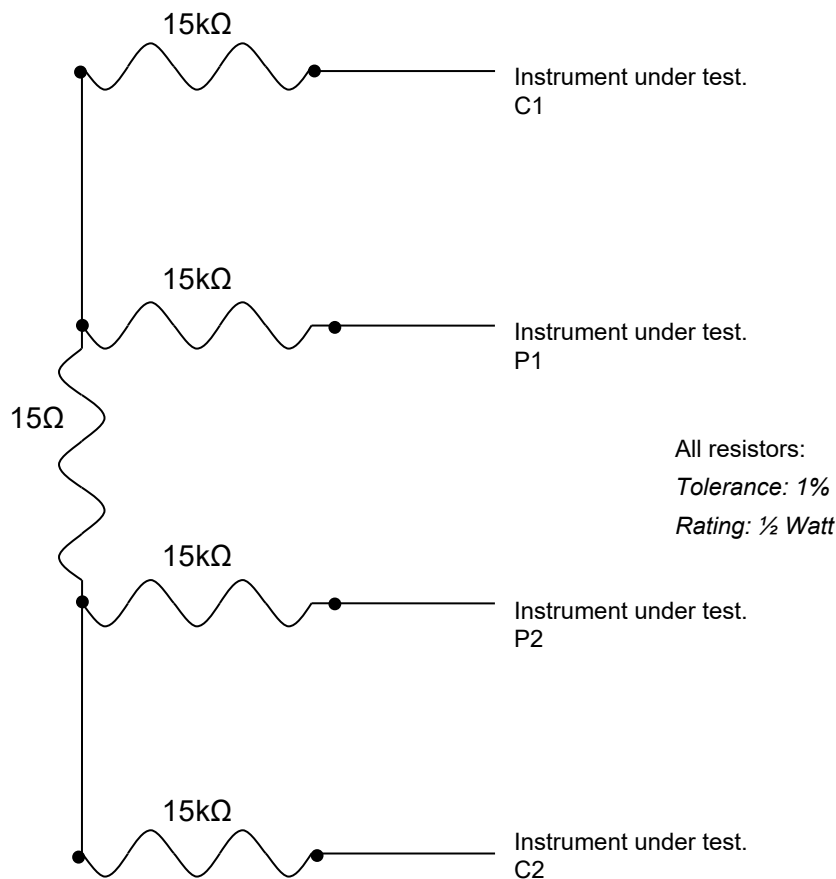


Figure D5. Instrument assessment circuit diagram

When the instrument is connected to the test circuit it should read within 20% of 15 Ohms.

Different instruments will alert the user to possible accuracy issues at different trigger points. For example, two different instruments may measure the assessment circuit with the same acceptable level of accuracy, however one instrument may alert the user to a possible accuracy issue and the other instrument may not.

An instrument that is capable of measuring the assessment circuit to the required accuracy is acceptable irrespective of any alerts. However when using the instrument in the field any alert must be noted and assessed.

D5 Earthing interconnectivity – 4 terminal continuity

D5.1 Introduction

Earthing systems often depend on connections in ways which can be unfamiliar to many electrical workers. These connections carry current in the event of an earth fault and are critical to the safe performance of the earthing system. Continuity testing can help in verifying that the connections will perform as required and when needed.

D5.2 When and where to test

The requirement for a continuity test will be identified by the Earthing Designer and will appear as special instructions in the earthing specification report for a particular installation. The report will also contain guidance on the specific connection to test and the allowed range of resistance values.

D5.3 Test equipment

The following test equipment is required:

- A 4 terminal tester (Refer to Clause D5.7 for further information about the selection of a suitable tester).
- Clips and leads.

D5.4 Test Execution

To measure the continuity (resistance) between two points (Refer to Figure D6):

- Place a current clip (C1) and potential clip (P1) one side of the connection to measure. Note that the current and potential probes must have their own lead and clip.
- Place current clip (C2) and potential clip (P2) at the second point. (Note: The current and potential probes must have their own lead and clip).
- Activate the instrument to measure the result.

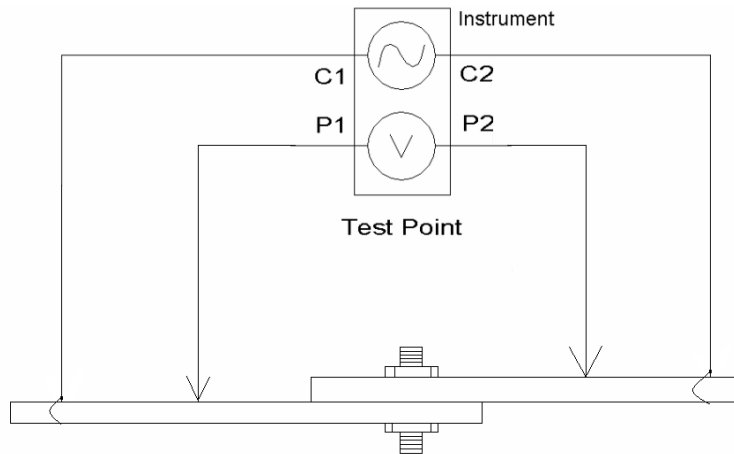


Figure D6. Continuity measurement

D5.5 Test recording and filing

After completing a continuity test, the test sheet and any sketches are to be scanned in and attached to the related job in NEOn.

A test sheet template can be found in Annexure **E**.

D5.6 Testing issues

The following points should be checked to make sure that continuity measurements are valid especially when higher than expected resistance readings are obtained:

- Inadequate current flow – Current probes may not be in contact with a conductive surface, try cleaning the contact surface.
- Noisy measurement - Potential probes or current probes may not be in contact with a conductive surface, try cleaning the surface.

D5.7 Test instrument assessment

A 4 terminal test instrument suitable for measuring continuity shall have a minimum measurement range of 5milliOhms through to 50Ohms with 10% accuracy.

D6 Earthing interconnectivity - insulation resistance test

D6.1 Introduction

Some distribution equipment earthing installations require that particular components to be isolated from each other to meet safety requirements. Common examples include segregated earthing systems for pole mounted and kiosk substations. Elements such as metering, frames and concrete reinforcement can connect components which appear to be disconnected. An insulation resistance (IR) test can be used to make sure there is an adequate insulation level between disconnected components. This form of IR test is also referred to as a Hi-Pot test.

D6.2 When and where to test

The requirement for an IR test will be identified by the Earthing Designer and will appear as special instructions in the earthing report for a particular installation. The report will also contain guidance on the specific connection to test and the allowed range of resistance values.

D6.3 Test equipment

The following test equipment is required:

- A two or three terminal high voltage tester (Refer to Clause D6.6 for further information about the selection of a suitable tester).
- Clips and leads.

D6.4 Test Execution

To measure the insulation resistance between two points:

- Place one probe on each of the two points to measure between.
- Unless specified in the earthing report, there is generally no need to use the guard terminal if a guard terminal is available.
- Make sure that all personnel are clear of the equipment under test, activate the instrument to measure the result.

D6.5 Testing issues

The following points should be checked to make sure that IR measurements are valid and testing is undertaken safely:

- Make sure that probes have good contact with equipment under test.

Maintain safe operation practices including:

- Following manufacturers' instructions and safety guidance.
- Maintain clearance from equipment under test.
- Make sure instrument is off whenever probes are being connected or disconnected.
- Documenting your safety procedures as part of your Hazard assessment.

D6.6 Test instrument assessment

An IR tester suitable for testing distribution equipment earthing assets will have the following minimum characteristics:

- Voltage range: 50V – 5kV
- 50Hz Noise rejection
- 20% accuracy
- Resistance range: 10k Ohm to 10M Ohm

The following maximum current is recommended for safety:

- Maximum short circuit output current 10mA peak, 7mA RMS.

D7 Local Earthing impedance - loop test

D7.1 Introduction

All earthing systems present some value of impedance to fault current. One part of an earthing system is the local earthing electrodes installed at a particular installation, an earthing design will specify a required resistance range which the local electrodes must comply with to meet the designed targets.

A loop test is one of the fastest methods for assessing the resistance of the local earthing installation where the configuration allows for a valid loop test.

D7.2 When and where to test

All distribution equipment earthing installations with an earthing design will require a measurement to determine the resistance of the locally installed earthing electrodes.

Local earthing installations which can be satisfactorily tested using the clip on loop style test must have a low impedance to earth in parallel with the local earthing electrodes. Distribution systems which meet this criteria are generally combined earthing systems which have been constructed to an earthing design and have been fully interconnected via a neutral connection or cable sheath.

When required to be done on segregated earthing systems which do have low MEN resistance relative to the local electrodes, the procedure specified in Clause E8 should be followed.

Table D6: Loop test applicability summary

When to use the loop test
- To find the impedance of the local electrodes. - If the installation has a combined earthing system and a NEOn earthing report. - If the installation has a segregated earthing system with low MEN resistance relative to the local electrodes, and a NEOn earthing report. - If connections to neutral / cable sheaths are made.

D7.3 Test equipment

A clamp (tong) style tester with either integrated drive and measurement coils or separate coils. Refer to Clause D7.6 for further information about the selection of a suitable tester.



Figure D7. Loop testers

D7.4 Test execution

Execute the test as follows:

- Check the distribution asset is a combined earthing system constructed to an earthing design report.
- Check neutrals/sheaths are connected.
- Locate the conductor going to an electrode group.
- Clip the loop tester around the identified conductor at a location where all earth bar/link style connections to the conductor are on one side of the tester and the other side of the tester has connections only to the electrodes in the electrode group. Refer to Figure D8.
- Activate test instrument and record the resistance measurement for the electrode group.
- A test sheet template can be found in Annexure E.

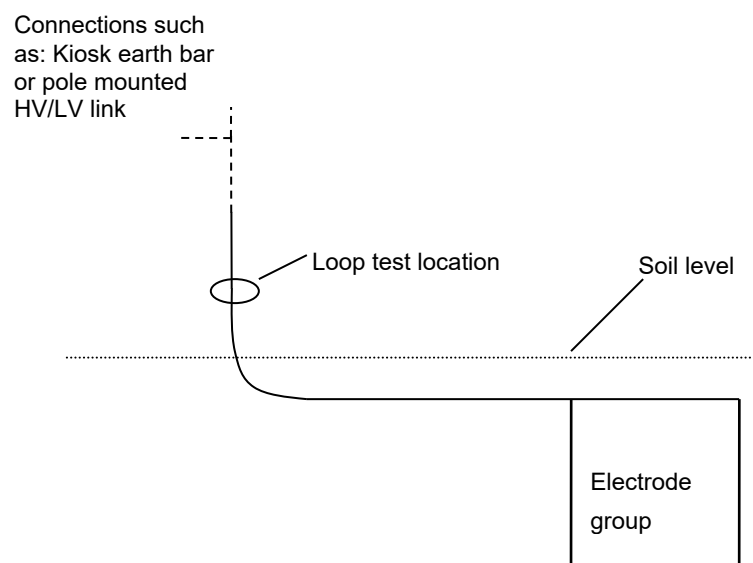


Figure D8. Loop test location schematic

D7.5 Testing issues

The following points should be checked to make sure that loop test measurements are valid:

- If the test instrument displays noisy current or other errors, another test method may be required.
- Make sure that the jaws of the test instrument can fully close.
- Make sure that there is no dirt or other obstruction within the jaws.
- An extremely low impedance ($< 0.5\text{ Ohms}$) on an individual electrode group is likely to be a measurement of a fully metallic loop. Recheck the location of the loop tester and the construction of the earthing system.

D7.6 Test instrument assessment

A loop tester suitable for testing distribution equipment earthing assets will have the following minimum characteristics:

- Resistance range: 0.3 Ohms to 150 Ohms
- 50Hz Noise rejection
- 20% accuracy
- Current measurement 50mA to 15A
- Comfortably fit over straight insulated 120mmSq conductor 75mm long.

D8 Local earthing - three terminal test / fall of potential test

D8.1 Introduction

The three terminal resistance test (sometimes referred to as the fall of potential test) is another method for determining the resistance of an earthing system. For distribution assets the earthing system under test are the local earthing electrode groups.

D8.2 When and where to test

All distribution equipment earthing installations with an earthing design will require a measurement to determine the resistance of the locally installed earthing electrodes.

Unless otherwise specified in the earthing report, a three terminal test will be used to measure the resistance of the local earthing electrode groups.

Each electrode group is to be tested by itself. It is not to be connected to any other earthing system such as the neutral, cable sheath or the other local electrode group for the purposes of the test.

For combined earthing installations an additional three terminal test is to be undertaken where both electrode groups are connected together. The combined electrode group is not to be connected to any other earthing system such as the neutral or cable sheath for the purposes of the test.

D8.3 Test equipment

The following test equipment is required:

- A three or four terminal tester may be used. Refer to Clause D8.7 for further information about the selection of a suitable tester.
- Minimum of two electrodes. More electrodes may be required to form a system of interconnected electrodes in high resistivity locations.
- Minimum of two lengths of covered conductor. Insulated to the rating of the test instrument and a minimum length to undertake the test. Suggested lengths to cover the majority of sites are 100m and 62m leads. Colour coded leads can reduce onsite testing mistakes.
- Assorted short leads and plugs/clips used to make the connections between the electrodes and the meter.
- Hammers for driving electrodes.
- Water to improve the contact resistance of the test electrodes in dry, high resistivity locations.

D8.4 Test Execution

Configuration of the three-terminal resistance test is shown in Figure D9. Lead length requirements to obtain an accurate measurement of electrode resistance are determined by the electrode group under test, the soil resistivity and surrounding infrastructure. The following procedure includes a method for determining if sufficient distance from the electrode group under test has been achieved. A test sheet template can be found in Annexure E.

Survey the site for surrounding metallic infrastructure – designated underground asset information provider can help.

- Select a direction from the electrode group under test with minimal interaction with other buried conductive equipment.
- Connect the current lead to the test unit and run it out 20m from the electrode group under test ('total distance' in Figure D9) and install the current electrode as deep as practical while considering subsequent electrode removal and impacting other possible buried assets.
- Connect the potential lead to the test unit and run it out 60% of the total distance, 12m in this case, and install the potential electrode.

- Connect the other current terminal of the test unit to the electrode group under test. If it is a four terminal instrument also connect the potential terminal to the electrode group. Keep these two leads less than 5m.
- Activate the test unit and note the resistance measurement.
- Move the potential probe so that it is now 50% of the total distance, 10m in this case and activate the test instrument. If the two measurements are within 20% of each other the test is complete.
- If the measurements do not agree within 20%, double the distances for the probe placements. The current electrode would now be at 40m and the potential electrode is 60% (24m). Take a measurement and then move the potential probe to 50% (20m) and take the measurement again.
- If the measurements agree within 20% the test is complete, otherwise increase the distances again.
- If the current electrode has been moved to 100m and the measurements with the potential electrode is at 60m and 50m don't agree within 20% and the testing issues, Clause D8.5, has been consulted then advice should be sought from Ausgrid/Earthing & Insulation Coordination group within the Substation Design section.

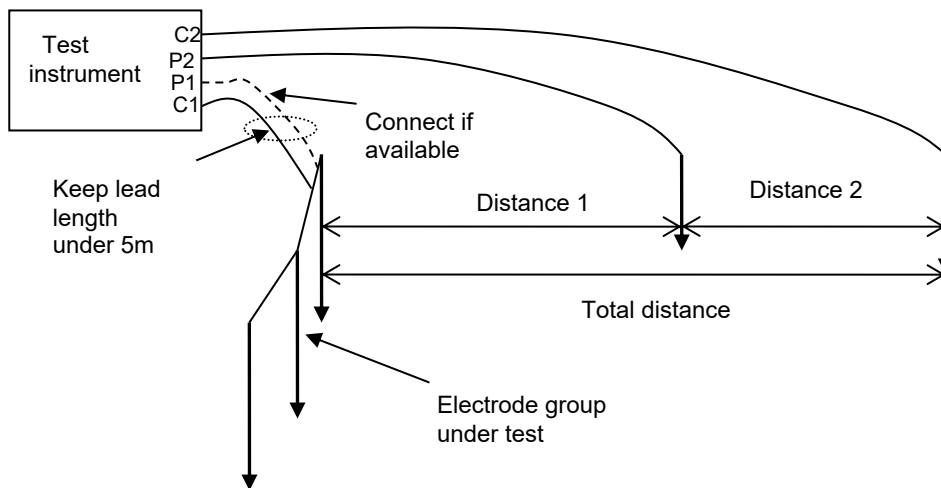


Figure D9. Three terminal resistance test

D8.5 Testing issues

Generally any difficulty that may be experienced while undertaking a three terminal test can be simplified to three primary causes.

- High electrode impedance compared to instrument voltage/current capability and instrument detection sensitivity.
- Interference from nearby infrastructure.
- Test configuration problems.

D8.6 Problems and their solutions

While most test instruments offer a range of diagnostic output which should be checked during each measurement, the test instrument cannot detect every condition that may cause an error. Table D7 lists a number of possible issues which should be kept in mind when a test is undertaken.

Consult the test instrument instructions for the interpretation and resolution of instrument diagnostic output.

Table D7: Test Trouble-shooting Guide

Problem	Category of problem	Solutions
Test instrument displays high impedance electrode or current too low.	High probe impedance	Install probes further into soil Wet soil about probes Install additional probes in parallel.
Measurement is unstable or fluctuates	High probe impedance, Interference	Try solutions above. Try relocating test. Investigate sources of electrical noise

D8.7 Test instrument assessment

A three terminal tester suitable for testing distribution equipment earthing assets will have the following minimum characteristics:

- Resistance range: 0.3 Ohms to 1000 Ohms
- 50Hz Noise rejection
- 20% accuracy

Annexure E – Test sheets

This section contains test sheets for the various testing methods described in this Network Standard. These are:

- Wenner Resistivity Traverse Measurements Sheet
- Earthing Interconnectivity Measurements Sheet
- Loop Impedance Measurements Sheet
- Three Point/Fall of Potential Measurements Sheet

	Wenner Resistivity Traverse Measurements Sheet	
	Project: _____	Date: _____
	Job Site/Location: _____	Time: _____
	Tested By: _____	

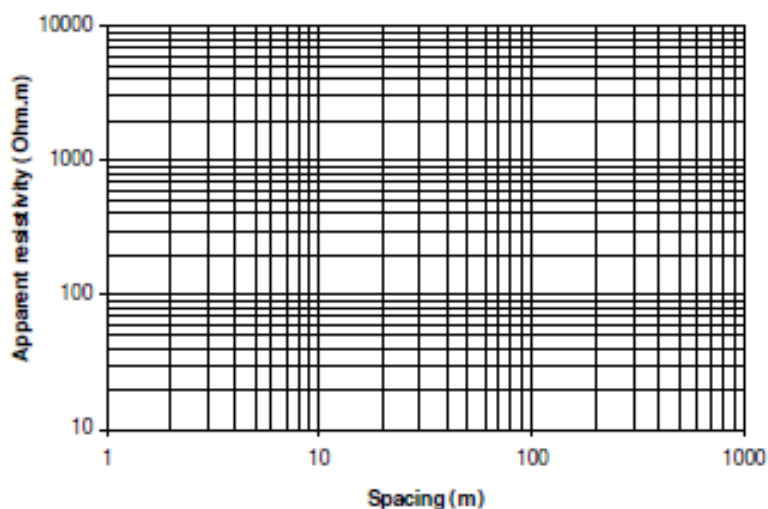
Test Unit Type: _____ Serial Number _____ Last Calibrated: ____/____/____

Switch Unit Used: Y / N Model: _____ Serial Number _____

GPS Location (UTM AUS/GDA/MGA 94): Easting: _____ Northing: _____

Site Photos Taken: ☐ Test Site ☐ General Area Soil Samples Taken: Y / N

Probe Spacing (a) (m)	Resistance Reading (R) (Ω)				C Spike Hi Y/N	Electrode R's (k Ω)				Apparent Resistivity $\rho_s = 2\pi a R$ (Ωm)	Notes (Eg depth, watered etc)
	CPPC		PCCP			C ₂	P ₂	P ₁	C ₁		



Sketch traverse number and location diagram on back of sheet if required

SITE OBSERVATIONS	
Topography:	_____
Geology:	_____
Soil Moisture:	_____
Conductive Infrastructure:	_____
Recent Rainfall:	_____

	Form Id: NS116-WENNER Date: 29 April 2010 Revision: 1
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Earthing Interconnectivity Measurements Sheet



Project: _____ **Date:** _____

Ausgrid Job Site/Location: _____ **Time:** _____

Tested By: _____

4 Terminal Test Unit Type: _____ **Serial Number:** _____ **Last Calibrated:** _____

Hi-Pot Test Unit Type: _____ **Serial Number:** _____ **Last Calibrated:** _____

[illegible]



Ausgrid

Project: _____

Job Site/Location: _____

Tested By: _____

Date: _____

Time: _____

Test Unit Type: _____ Serial Number _____ Last Calibrated: _____

Test Point Description	Does Asset Have a Combined Earthing System?	Are LV Neutrals / HV Cable Screens Connected?	Resistance Reading (ohms)
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	
	☐	☐	

Three Point / Fall of Potential Measurements Sheet



Project: _____ **Date:** _____

Job Site/Location: _____ **Time:** _____

Tested By: _____

Test Unit Type: _____ **Serial Number** _____ **Last Calibrated:** _____

[illegible]

Annexure F – Earthing Signs

