NS116

Design Standards for Distribution Earthing

JUNE 2005

Amendments included from NSA 1360 Sep 2005, NSA 1376 Feb 2006, NSA 1471 May 2008, NSA 1512 Jan 2009

SUMMARY

Network Standard NS116 provides the criteria for earthing of distribution centres, control points, centres for the control of supply to high voltage customers' installations (HVCs), and overhead line equipment; for connection to Ausgrid's network.

ISSUE

Ausgrid staff: for issue to all staff involved with design and installation of earthing systems for distribution centres, control points and overhead line equipment forming part of Ausgrid's network, and for general reference by technical and engineering staff.

Where this standard is issued as a controlled document replacing an earlier edition; remove and destroy the superseded document.

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DISCLAIMER

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 is to 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 ensure that a safe system of work is employed and that statutory requirements are met.

Ausgrid disclaims any and all liability to any person or persons for any procedure, process or any other thing done or not done, as a result of this Network Standard.

This document is **not** intended to address issues that include, but are not limited to:

- Environmental and planning requirements
- Construction, inspection and maintenance safe work practices
- Inspection and maintenance requirements
- Emergency preparedness and response
- Earthing and substation layout design

Note: The use of any steelwork in substations have unique requirements with respect to earthing. All designs involving steelwork are to be reviewed by *Network Engineering*.

INTERPRETATION

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.

Network Standard
NS116
Design Standards for Distribution Earthing
June 2005

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Foreword

Ausgrid is responsible for the management and operation of Ausgrid's electricity supply network. The network is a major infrastructure investment, and is required to operate economically and reliably in all weather and environmental conditions.

The earthing requirements specified in this Network Standard are intended to satisfy electrical performance and economy requirements, and to meet all statutory obligations.

This Network Standard may be amended or updated at any time to reflect improvements in design, technology advances, etc. The Service Provider (Designer) shall ensure that the latest version of this Network Standard is used for distribution system earthing designs.

Scope

This Network Standard:

- applies to nominal 11 kV (and 5 kV) primary voltage systems
- applies to nominal 415 / 240 volt distribution systems
- does not cover all requirements for SWER systems
- does not apply to nominal primary voltage systems higher than 11 kV
- does not apply to zone or sub-transmission substations.

1 INTRODUCTION

This Network Standard specifies Ausgrid's requirements for the design of distribution earthing systems. Information is also included on requirements for installation and testing of earthing systems. It is a revision of the version dated 1 October 1997, as amended, which is now withdrawn.

The primary reason for this revision of NS116 was to eliminate the differences that were specified previously for the ex Sydney and ex Orion areas. It is an interim revision, with some additional information included, pending the outcome of a comprehensive review of earthing performance requirements, design processes and practices, that is currently being undertaken.

Additional requirements for earthing systems within distribution centres, and for earthing of distribution system equipment, are included in the relevant standards including:

- NS109 Design Standards for Overhead Developments
- NS110 Design and Construction Standards for URDs
- NS113 Site Selection and Civil Design Standards for Chamber Type Substations,
- NS114 Electrical Design and Construction Standards for Chamber Type Substations,
- NS117 Design and Construction Standards for Kiosk Type Substations,
- NS118 Specification for Street Lighting Design Standards (Central Coast and Sydney areas),
- NS119 Specification for Street Lighting Design and Installation (Newcastle and Upper Hunter Regions),
- NS122 Pole Mounted Substation Construction,
- NS126 Specification for Design and Construction of High Voltage Overhead Mains,
- NS127 Specification for Low Voltage Cable Joints and Terminations,
- NS128 Specification for Pole Installation and Removal,
- NS129 11 kV Joints and Terminations – Paper Insulated Lead Covered Cables,
- NS130 Specification for Laying of Underground Cables up to 22 kV and
- NS177 11 kV Joints (including Transition Joints) and Terminations – Polymeric Insulated Cables.

2 ASBESTOS

All materials and equipment used for construction of Ausgrid's assets are to be free from Asbestos and or Asbestos related products. Suppliers are expected to comply with the Occupational Health and Safety Act 2000 (NSW) together with the Occupational Health and Safety Regulation 2001 (NSW) and confirm in writing that all products supplied to Ausgrid contain no Asbestos related materials.

3 GENERAL REQUIREMENTS

The integrity of the earthing system is critical in providing a safe electricity supply.

The design and installation of earthing systems must fulfil the following basic requirements:

- Appropriate safety standards must be complied with, so as to minimise the risk to personnel and the general public from step and touch voltages that may appear on or near equipment or structures during fault conditions.
- Equipment must be adequately earthed to ensure that protective devices operate correctly in the event of electrical faults on the system.
- The short-time current carrying capacity of the earthing conductors and electrodes must not be exceeded.

Earthing systems must also be designed with due regard to any special situations in the vicinity. These may include but are not limited to metallic fences, swimming pools, flammable gas or liquid storage tanks, electric railway lines, pipelines, high voltage substations, high voltage transmission lines, operating theatres or similar medical facilities, communication centres, pits, pillars and metallic sheathed communication cable.

3.1 Cases Requiring Detailed Earthing Design

The following are a number of scenarios, which should be referred to Ausgrid for further earthing study prior to any construction being undertaken as they are likely to result in unacceptable earthing.

3.1.1 Case 1 - High soil impedance

Areas where the soil resistivity is known to be high, or areas where the soil has been inspected and identified as a type that is likely to have a high resistivity, often produce a combined earthing resistance that is greater than acceptable.

High soil resistivity can be defined as anything over 200 Ohm-metres. This normally occurs in dry and/or rocky or sandy areas. Some examples of known high resistivity areas are:

- Kogarah
- Clovelly
- Kariong
- Peats Ridge
- Mangrove Mountain
- Lochinvar
- Windella
- Corlette
- Tanilba Bay
- Williamtown
- Coastal sand dune areas

3.1.2 Case 2 - Little to no MEN present

The Multiple Earthed Neutral (MEN) system provides multiple parallel paths to disperse HV fault currents in combined earthing designs. In situations where there is a small number of MEN connections and associated earth electrodes present, a combined earthing design may actually result in the MEN voltage (earth potential rise (EPR)) rising to unacceptable levels.

- A small MEN network is considered to be anything with less than a hundred neutral interconnected dwellings/services in the circular radius of 1km.

3.1.3 Case 3 - Commercial centres with little MEN or no LV interconnection

Substations designated to solely supply commercial or industrial centres may not have a neutral connection to the rest of the MEN network. The customer may choose to cut costs and opt not to run a LV interconnection to the MEN. This results in a situation similar to Case 2.

- Neutral connectivity to the rest of the MEN network should be checked for commercial developments and the design should be checked in the absence of neutral connectivity to the MEN.
- A small MEN network is considered to be anything less than a hundred neutral interconnected dwellings/services in the circular radius of 1km.

3.1.4 Case 4 - Close proximity of public swimming pools.

Public swimming pools have a different presence probability than other wet areas. This factor combined with lower body impedance due to people being wet means that different safety criteria apply to these locations.

- For the HV earthing system, close proximity is considered to be to be within a 15m distance of the boundary of the swimming complex (including the fence)

3.1.5 Case 5 - Close proximity of Telstra pits

AS 3835.3 required that all access areas to telecommunications lines be separated from electrical earthing systems by a distance that ensures that the earth potential rise (EPR) voltage contour (for distribution) be within allowable limits.

- Refer to NEG SD04 for guidelines

3.1.6 Case 6 - Close proximity of continuous metallic objects for segregated designs

In the event of a segregated earthing design, if a continuous metallic object is near the HV earthing system it may transfer a fault potential to another remote location. Examples include fences and pipelines.

- If a continuous metallic object is greater than 15m in length and located within 15m of the HV earthing system then further earthing design work is to be undertaken.

3.2 Unusual or Special Situations

Where an unusual or special situation is encountered, a specific earthing design must be prepared by a designer with recognised earthing system design expertise. Before installation of the earthing system, the specific design must be provided to Ausgrid's Liaison Officer for the project, who will forward the design to Ausgrid's Network Earthing Group for review. The earthing installation must not proceed before approval is obtained from Ausgrid's Network Earthing Group and any conditions contained in that approval are complied with.

In addition, substations within 20 metres of a rail traction corridor normally require at least a "drainage bond", to mitigate damage to earth rods and cable sheaths caused by long term exposure to electrolysis associated with stray traction currents. Ausgrid will specify the additional earthing requirements for substations near rail traction corridors.

The design and installation of earthing systems must also comply with all of the following requirements:

- The MEN system of earthing is to be installed throughout the low voltage supply network.
- The low voltage neutral connections are to be continuous throughout the low voltage network, ie across open points in the low voltage phase conductors.
- Separation between distribution earthing systems and telecommunications plant shall comply with the requirements of Appendix B.
- Earth installations shall be designed and installed so as to not encroach along the agreed footpath / street allocations of other public utilities. Street allocations are specified in NS130 *Specification for Underground Cable Laying*.
- A soil resistivity test is required, to determine the most efficient depth and spacing for the electrodes. The soil resistivity test method is described in the section of this standard on testing.

4 ELECTRODES AND EARTHING CONNECTIONS

4.1 Electrode Systems

Earthing systems must consist of vertical electrodes interconnected with earthing cable. (Electrodes are the vertical bare conductors, 5 metres or longer, consisting of joined rods, tube or stranded conductors.)

Electrode systems must be one or more of the following:

- **Driven rod system.** This system utilises 15 mm OD copper clad steel rods in 1800 mm lengths. When driven into ground types other than sand or loam, the start rod must be fitted with hardened steel driving point. Rods must be joined with the approved friction joint couplings. The minimum electrode depth is 5 metres.
- **Bore hole / copper tube system**. This system is constructed by boring a 35 mm (diamond bit) or 50 mm (clay bit) clearance hole into the ground to a suitable depth, then inserting a 14.3 mm OD x 1.63 mm wall copper tube and filling the bore hole with a slurry made from an *approved earthing compound. The earthing compound must be pumped down the tube to fill the hole from the bottom up. The minimum electrode depth is 5 metres.
- **Alternative bore hole systems**. Ausgrid may also approve alternative bore hole type electrode systems utilising copper clad steel rods and/or bare stranded minimum 70 mm^2 copper cable, where the bore hole is filled after electrode installation with a slurry made from an *approved earthing compound, where satisfactory operational performance can be demonstrated, and where the minimum electrode depth is 5 metres.

(* Ausgrid approved earthing compounds are “Good Earth” or “Lo-Ohm”.)

Greater electrode depths or additional electrodes will be required in some areas to achieve the required earthing system resistance. Where the minimum values of earth resistance specified in Section 5 for each type of substation cannot be achieved with the minimum number of 5 metre electrodes, additional or longer electrodes must be installed. In some locations with high resistivity soils, it may be necessary to drill to depths exceeding 10 metres to obtain a suitable resistance value.

The top of each electrode must be not less than 500 mm below ground level. The electrode depth (minimum 5 metres) is to be measured from the top of the electrode and not from ground level.

Copper clad steel rods must comply with Ausgrid’s current specification.

4.2 Electrode Groups – Spacing and Cabling

The electrodes within a group are to be interconnected with insulated stranded copper cable with a cross sectional area of at least 70 mm^2. The cable must be connected to the electrodes with the compression fittings applicable to the type of electrodes used. Welding or brazing must not be used.

Electrode groups must be located so as to minimise the interaction effects between them. For kiosk type substations: electrodes within the substation easement shall be located as shown in drawing no 167433; electrodes outside the substation easement shall be located such that below ground electrodes within an electrode group are separated from electrodes within a different electrode group by a minimum of 3 metres. For chamber type substations, control points and HVCs electrodes within an electrode group must be separated from electrodes within a different electrode group by a minimum of 3 metres. For pole mounted substations and pole mounted HVCs electrodes within an electrode group must be separated from electrodes within a different electrode group by a minimum of 6 metres. Electrodes within an electrode group must also be separated from any street light, low voltage pillar, metallic water mains not bonded to the earthing system in accordance with Section 5.2, or other equipment, by a minimum of 2 metres.

Electrode groups must be connected to the distribution centre earth bar, or control point or HVC earth bar, as applicable, with minimum 0.6 kV black insulated stranded copper cable with a cross sectional area of at least 70 mm^2. The cable must be connected to the electrodes with the compression fittings applicable to the type of electrodes used. Welding or brazing must not be used.

Insulated cables connecting the electrode groups to the distribution centre, control point or HVC, must be separated by a minimum of 40 mm.

Buried earthing conductors connecting electrodes in a group, or connecting a group of electrodes to the substation earth bar or control point or HVC earth bar, shall be not less than 500 mm below ground level, and shall be covered by cable cover slabs or polymeric cable covers. Where earthing conductors are installed in the footpath cable allocation, the installation depth shall be increased so as to comply where feasible with the buried earth conductor detail shown on drawing 167433 and the note that applies to that detail. This requirement applies for all types of substations and control points.

4.3 Connections to Earth Bars and Neutral Bars

In addition to the specific requirements for each type of distribution centre, as referred to in Section 5, earthing conductor connections must comply with the following general requirements:

- Connections to earth bars and neutral bars must be made with a separate bolted connection for each cable, ie two or more terminations per bolt or stud are not permitted.
- Compression lugs must be of an approved type and must not be of a split or slotted type.
- All bolts, nuts and washers must be 316 grade stainless steel, of minimum diameter 12 mm.
- 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 equivalent, Ausgrid stock code 177212.)

5 DISTRIBUTION CENTRE EARTHING

5.1 General

The system of earthing, the number of electrode groups, and the minimum number of electrodes, shall be in accordance with Table 5.1.

Installation requirements for the combined and segregated systems of earthing are contained in Sections 5.2 and 5.3, and additional requirements for earthing of pole mounted substations, kiosks and chamber type substations are included in Sections 5.4, 5.5 and 5.6.

Table 5.1 - System of Earthing, Number of Electrode Groups and Minimum Number of Electrodes for Distribution Centres.

Type of Distribution Centre	*System of Earthing*	*Number of Electrode Groups and Minimum Number of Electrodes*
Chamber substation, control point or HVC, connected to underground high voltage system.	*Combined. Refer also to NS114, as applicable, re special design where necessary.*	*Two groups of electrodes, each with a minimum of two electrodes per group, and labelled as A group and B group.* *Refer also to Sections 5.2 and 5.6.*
Chamber substation, control point or HVC, connected to overhead high voltage system.	*Combined. Refer also to NS114, as applicable, re special design where necessary.*	*Two groups of electrodes, each with a minimum of two electrodes per group, and labelled as A group and B group.* *Refer also to Sections 5.2 and 5.6.*
Kiosk substation, kiosk control point or kiosk HVC, connected to underground high voltage system.	*Combined is preferred Refer also to NS117, as applicable, re special design where necessary.*	***Combined:*** *Two groups of electrodes, each with a minimum of two electrodes per group, and labelled as “Earth Electrodes Group A” or “B”.* *Refer also to Sections 5.2 and 5.5.*
	Segregated may be permitted but only after Ausgrid’s Network Earthing group has examined the project and approved the use of segregated earthing.	***Segregated:*** *The earthing design shall be in accordance with the design report issued by Ausgrid’s Network Earthing Group and may include but not be limited to electrodes, kiosk housing specification, connectivity and surrounding environment.*
Kiosk substation, kiosk control point or kiosk HVC, connected to overhead high voltage system.	*Combined. Refer also to NS117, as applicable, re special design where necessary.*	*Two groups of electrodes, each with a minimum of two electrodes per group, and labelled as “Earth Electrodes group A” or “B”.* *Refer also to Sections 5.2 and 5.5.*
Pole mounted substation or pole mounted HVC. *Rating 50 kVA or greater.*	*Combined is preferred, and must be installed under the conditions specified in Section 5.2.* *Segregated may be permitted under the conditions specified in Section 5.3.*	***Combined:*** *Two groups of electrodes, each with a minimum of two electrodes per group, and labelled as A group (HV) and B group (LV).* *Refer also to Sections 5.2 and 5.4.*
		Segregated: *Two groups of electrodes, each with a minimum of two electrodes per group, and labelled as A group (HV), B group (HV).* *Refer also to Sections 5.3 and 5.4.*
Pole mounted substation or pole mounted HVC. *Rating less than 50 kVA.*	*Combined is preferred, and must be installed under the conditions specified in Section 5.2.* *Segregated may be permitted under the conditions specified in Section 5.3.*	***Combined:*** *Two groups of electrodes, each with a minimum of two electrodes per group, and labelled as A group (HV) and B group (LV).* *Refer also to Sections 5.2 and 5.4.*
		Segregated: *Two groups of electrodes, each with a minimum of two electrodes per group, and labelled as A group (HV), B group (HV).* *Refer also to Section 5.3 and 5.4.*

5.2 Combined Earthing System

The combined earthing system is strongly preferred and every attempt to achieve the required 1 ohm or lower in-service earthing system resistance must be used, even if deeper electrodes and additional electrodes are required.

Where the required 1 ohm in-service earthing system resistance cannot be achieved, a combined earthing system must still be installed when the substation earthing system is connected to the earthing systems of at least two other adjacent distribution centres by:

(a) continuous low voltage neutral conductors, OR

(b) metallic sheathed HV underground cables.

The in-service resistance of each individual electrode group must not exceed 15 ohms.

The standard pole transformer connection to a neutral routed in two different directions towards two adjacent distribution substations is equivalent to two neutral connections as specified above.

It is essential that the two independent neutral connections or HV cable sheath connections have adequate short time fault current carrying capacity.

Connections between electrodes, spacing between electrode groups and connections to electrode groups, must be as specified in Section 4, and must meet any additional requirements for the relevant type of distribution centre, as specified in Section 5.4, 5.5 or 5.6.

Note: The connection of substation earthing systems to nearby metallic water mains should only be made in special circumstances upon approval from Ausgrid and the relevant water authority.

Such connections shall be made using black insulated stranded copper cable with a cross sectional area of at least 70 mm^2 connected to a 20 mm brass plug in the water main. The termination of the water main connection to the neutral earthing bar must be labelled with a 50 mm x 25 mm brass tag inscribed “Water Main Connection”.

The resistance of the water mains must be checked before installation of the earthing connection. The testing method is detailed under the testing sections of this standard.

5.3 Segregated Earthing System

A segregated earthing system may only be used where permitted by Table 5.1, and specific approval is given by Ausgrid’s Network Engineering Section, and:

- where an in-service earth resistance of 1 ohm or lower cannot be achieved by a combined earthing system, or
- where the interconnections to other substations by LV neutrals or cable sheaths, as described in Section 5.2, cannot be provided.

Connections between electrodes, spacing between electrode groups and connections to electrode groups, must be as specified in Section 4, and must meet any additional requirements as specified in Section 5.4.

5.4 Pole Mounted Substation Earthing

The earthing installation must comply with drawing 36377 *Pole Transformer Earth Rod Installation Layout* and the requirements specified in Network Standard NS122 *Pole Mounted Substation Construction*. Drawing 36377 refers to installations in public streets. In other cases, the electrodes shall normally be driven in a direct line between the pole mounted substation and the adjacent line poles. The high voltage and low voltage groups are to be on opposite sides of the substation pole, and the minimum spacing between electrodes of different groups is to comply with Section 4.

The system of earthing, number of electrode groups, and minimum number of electrodes must comply with Table 5.1.

Where the combined system of earthing is used, the in-service resistance must not exceed 1 ohm, and the out-of-service resistance of each individual electrode group must not exceed 30 ohms.

Where a segregated earthing system is permitted in accordance with Table 5.1 and Section 5.3, 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.

For the segregated system of earthing, individual electrode group resistance to earth must not exceed the relevant limit indicated in the following table.

Pole Transformer Rating	Maximum Resistance Value - ohms	
	HV	LV
Single Pole > 50 kVA	30	15
Single Pole ≤ 50 kVA	30	30

Where the segregated system of earthing is used, the pole-mounted substation must have a notice displayed indicating “This substation has the segregated system of earthing”. The notice shall comply with NS158 *Labelling of Mains and Apparatus* and shall be similar to the notice specified for distributors. The notice shall be attached to the pole, below the transformer, but above the danger notice and above the communications crossarm position.

5.5 Kiosk Substation Earthing Arrangement

(For Kiosk Substations Type J, L and K.)

The earthing installations for kiosk type control points, including kiosk type installations for the control of supply to high voltage customer’s installations (HVCs), shall be as for kiosk substations in this Section.

The system of earthing, number of electrode groups, and minimum number of electrodes must comply with Table 5.1. The earthing installation must also comply with the requirements specified in Network Standard NS117 *Design and Construction Standards for Kiosk Type Substations*.

Electrode installations must comply with the requirements of Section 4. For combined systems electrodes shall be located and connected as shown in drawing no. 167433. For segregated systems electrodes shall be located and connected in accordance with the site-specific design report issued by Ausgrid’s Network Earthing group.

The out-of-service resistance of each individual electrode group must not exceed 30 ohms.

The combined system in-service earthing resistance must not normally exceed 1 ohm. Refer also to the requirements of Section 5.2 above, which specify that a combined earthing system must still be installed under the conditions indicated, even if the required 1 ohm earthing system resistance cannot be achieved. Where an in-service earthing system resistance of 1 ohm or lower cannot initially be achieved by the combined earthing system, the requirements of Section 7.1 of Network Standard NS117 *Design and Construction Standards for Kiosk Type Substations* for a special design are to be followed.

Where kiosks are installed on supporting structures, refer to the following drawings for earthing conduit installation requirements:- drawing 151573 for J kiosks, drawing 151572 for L kiosks, and drawing 151190 for K kiosks.

Where kiosks are installed on supporting structures, and earthing cables are to be installed through floors of buildings below the supporting structures, then the arrangements for cabling to electrodes should follow the similar requirements for chamber substations in Network Standard NS113 and in drawing 25121.

Where off-street kiosks are installed on ground, electrodes must be outside the kiosk base area, and approximately but not less than 500 mm from the site boundary, as shown on drawing 167433.

For off-street sites, where the minimum spacing between electrodes cannot be obtained on the kiosk site, the additional electrodes must be installed either in the easement to the kiosk site, or in the footpath area in accordance with drawing 167433.

For kiosks installed in the footpath area, the electrodes may be installed either in the footpath cable allocation in accordance with drawing 167433, or in the pole line allocation as per drawing 36377 for pole mounted substations. The pole line allocation is preferred.

Earthing cable connections within the kiosk must be in accordance with drawings 163539 and 167433.

The 11 kV (and 5 kV) transformer cables are to be bonded and earthed at the switchgear end only.

5.6 Chamber Substation and Chamber Control Point Earthing Arrangement

(includes Chamber Type HVCs)

The earthing installation must comply with drawing 25121 Substation Earthing Typical Installation of Earth Electrodes.

The system of earthing, number of electrode groups, and minimum number of electrodes must comply with Table 5.1. The combined earthing system must be used, and the earthing system must be a stand alone type not connected to building reinforcement bars or grading rings, and must be well clear of the building lightning protection system.

Where the chamber substation does not have an associated control point, the earthing system must be installed under the footprint of the chamber.

Where the chamber substation does have an associated control point, refer to Network Standard NS114 for information on whether an earthing system is required to be installed under the control point chamber or the substation chamber or both chambers.

Refer also to NS114 for information on interconnection of the earthing systems where a chamber substation is located near another chamber substation or near an unassociated control point.

The earthing system must be installed before any waterproof membranes are laid and before the covering floor is constructed. Earth electrodes must be installed at not less than 3 metres apart and in two groups. The connection from the two groups A and B must be up through the floor directly to the position of the chamber earthing bar. The A and B earth electrode groups must be independently connected at the earth bar in the chamber, to form a combined earthing system.

Where the chamber is constructed on a suspended floor slab, the earthing system must be installed at the lowest level of building excavation directly below the chamber footprint. The group A and B electrodes are to be brought up through the building structure to the position of the earth terminal bar in accordance with Network Standard NS113.

The out-of-service resistance of each individual electrode group must not exceed 30 ohms.

The combined system in-service earthing resistance must not normally exceed 1 ohm. Refer also to the requirements of Section 5.2 above, which specify that a combined earthing system must still be installed under the conditions indicated, even if the required 1 ohm earthing system resistance cannot be achieved. Where an in-service earthing system resistance of 1 ohm or lower cannot initially be achieved by the combined earthing system, the requirements of Section 12.2 of Network Standard NS114 *Electrical Design and Construction Standards for Chamber Type Substations* for a special design are to be followed.

Refer to Network Standard NS114 for requirements for earthing of equipment and cable sheaths in substations and control points. Earth cables from equipment must be connected to the earth bar as specified in NS114.

All low voltage neutral terminals of transformers and neutrals of outgoing low voltage cables and busbar supplies must be connected to the neutral busbar. The neutral busbar must comply with Network Standard NS114.

6 OVERHEAD LINE EQUIPMENT

The minimum number of electrodes for each type of overhead equipment is listed in Table 6.1. The electrodes must be installed in accordance with Section 4.

Table 6.1

Equipment	**No. of electrodes**
Pole mounted recloser or sectionaliser.	Two groups, each with two electrodes.
Note: Older air break switch designs (i.e. where the operating handle is directly accessible from ground level) associated with other equipment such as, surge arresters, rod gaps and tanks of OH line reclosers and sectionalisers are to be earthed by a second installation. The two installations must be isolated from each other, and nearest elements of each must be separated in the ground by a distance of not less than 2 metres. The connection from the pole foot to the nearest electrode of the arrester and frame earthing installation must be insulated, and not closer than 2 metres from any element of the air break switch handle earthing installation. For new air break switch designs (i.e. where the operating handle is mid-pole mounted) no separation of earthing systems as discussed above is required..	
HV line surge arrester installation.	Minimum of one electrode or pole butt electrode
HV UG/OH cable sealing ends (cables with continuous metal sheaths or screen) and associated surge arresters.	Pole butt electrode and the earth lead must also be bonded to the sheath of the cable.
LV regulators other than static balancers.	Two electrodes.
Note: The tanks of static balancers must not be earthed. At each static balancer location, a notice must be displayed warning staff that the frame of the equipment must be considered "live”.	
Line air break switchgear with insulated rod extension to handle.	One electrode or pole-butt electrode.
MEN neutral earthing point.	One electrode or pole-butt electrode.
HV ABC catenary (recorded for reference for existing installations).	One electrode or pole-butt electrode.
LV cable end box	Ausgrid to advise.

The maximum resistance value of each installation, or group of electrodes with the other electrode group out-of-service, is listed in Table 6.2.

Table 6.2

Equipment	**Maximum resistance of each earthing installation or group of electrodes, and other requirements**
Pole mounted recloser or sectionaliser.	10 ohms.
HV line surge arrester installation.	50 ohms.
HV UG/OH cable sealing ends (cables with continuous metal sheaths or screen) and associated surge arresters.	All earthing cables shall be a minimum of 70 mm^2 insulated conductor and shall be clamped to electrode. Cable box to earth resistance not to exceed 30 ohms.
LV regulators other than static balancers.	Ausgrid to advise.
Line air break switchgear with insulated rod extension to handle.	An earth installation must be used for earthing the metallic operating handle. The earth electrode shall be driven 1 metre from the pole base on a direct line between the pole and adjacent poles. The electrode shall be installed on the same side as the ABS handle. The earth resistance shall not exceed 30 ohms. All earthing cables shall be a minimum of 70 mm^2 insulated conductor and shall be clamped to electrode.
MEN neutral earthing point.	30 ohms.
HV ABC catenary (recorded for reference for existing installations).	Earthed only where electrodes are installed for other equipment. The maximum catenary resistance must be 10 ohms.
LV cable end box.	All earthing cables shall be a minimum of 70 mm^2 insulated conductor and shall be clamped to electrode. Cable box to earth resistance not to exceed 15 ohms. The cable cover is to be bonded to the LV neutral.

7 ENVIRONMENTAL

The Service Provider must comply with Ausgrid's Network Standard NUS174 *Environmental Procedures*, and all EPA regulations regarding the prevention of silt and or other spoil resulting from earth electrode hole boring, from entering any drain, creek, river or natural watercourse.

8 TESTING

8.1 Methods of Measuring Resistance

8.1.1 General

There are two methods for measuring the resistance of an electrode or a group of electrodes:

- the Two-Spike (Fall-of-Potential) Method, and
- the Two-Point Method.

Both use a null-reading bridge earth resistance tester.

The Two-Spike Method can be influenced by the proximity of buried metallic objects such as water or gas pipes. Therefore, if readings taken by this method are found to be too high, the Two-Point Method is to be used as a check.

WARNING: Before using these testing methods and before driving of spikes into the ground refer to and comply with Network Standard NS156 *Working Near or Around Underground Cables*.

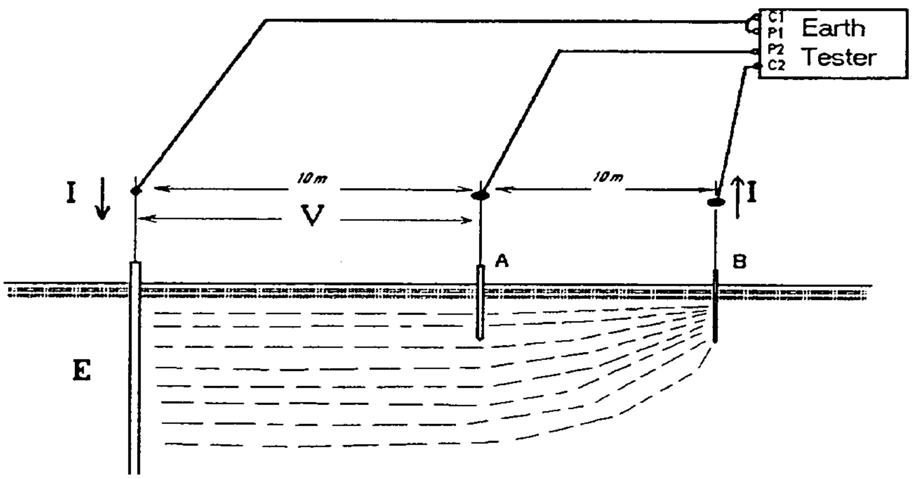
Underground installations such as cables or pipes near underground to overhead connections, street lighting underground cables, traffic light cables, gas, water and telephone services must all be avoided.

Refer also to the relevant street allocations in Network Standard NS130 *Specification for Underground Cable Laying* but do not rely on services being within their indicated allocations.

8.1.2 Two-Spike Method

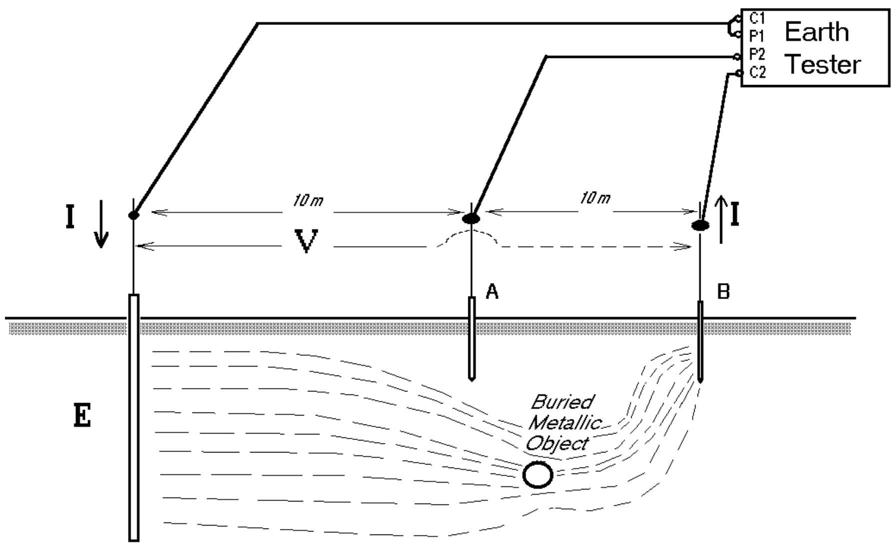
The Two-Spike Method is the most commonly used (see below). Two auxiliary electrodes (A and B) are put in a straight line with the electrode E (or group of electrodes) under test. The normal separation between E and A, and between A and B, is 10 metres.

When current is passed from the earth tester through electrodes E and B, the voltage drop between electrodes E and A is measured. The resistance of the auxiliary electrodes A and B has no direct influence on the result.



Two-Spike (Fall-of-Potential) Method

WARNING: A buried metallic object such as a water pipe has the effect of nullifying electrode A with the result that the voltage V is that measured between electrodes E and B. This results in an incorrect excessive reading (see figure below) and hence the Two-Point Method must be used as a check.



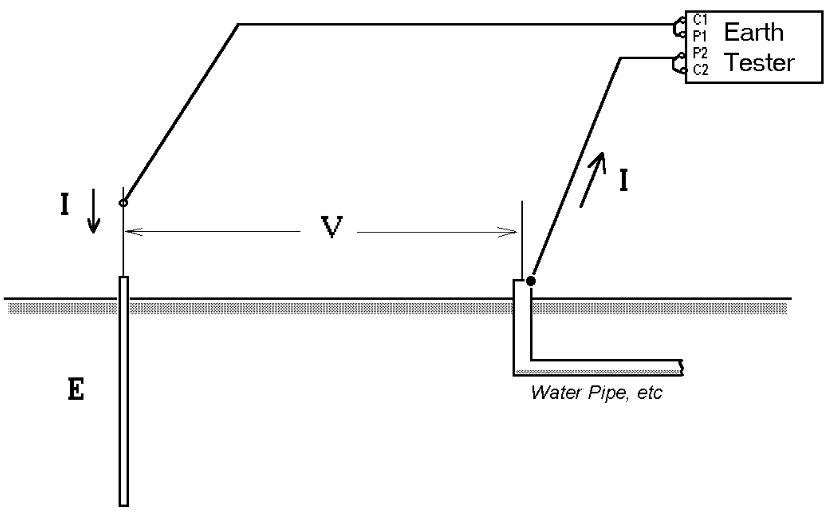
Nullifying effect on electrode A of a buried metallic object such as a pipe.

8.1.3 Two-Point Method

The Two-Point Method is used where the result of the Two-Spike Method is in question (owing to a buried metallic object) or where space limitations or ground covering make the Two-Spike Method impossible to use.

Current from the earth tester is passed from electrode E under test to the buried metallic object (eg water pipe) and the voltage between them is measured (see figure below).

Both the resistance of the water pipe and that of the electrode or group under test is measured but since the resistance of the buried object (eg water pipe) is very low, the reading obtained is assumed to be that of electrode or group E.



Two-Point Method

8.2 Soil Resistivity

The purpose of measuring the soil resistivity (ρ) is to establish the resistance represented by the soil between the electrodes. It is measured using test electrodes and a null-reading bridge. Known as the Wenner 4-Point Method, the procedure is set out below.

When determining soil resistivity on site, a number of readings are taken for various values of test-electrode spacing and depth. From values obtained, either a curve is drawn or the value of soil resistivity calculated. Calculation requires that the ratio of test-electrode spacing to depth is maintained at a maximum value of 20:1. For accurate results, electrode spacing should not be less than 1.5 metres.

The following is the Wenner 4-Point Method:

(a) Set out four test electrodes in a straight line and space them at equal intervals of *a* metres (eg 10 metres).

(b) Drive the electrodes into the ground to a depth of *a*/20 metres or to as close to that depth as possible. **Do not exceed that depth.**

(c) Connect the electrodes and earth tester as shown in the figure below.

(d) Operate the earth tester and obtain a null balance. Note the reading *(R)*.

(e) Calculate the soil resistivity from:

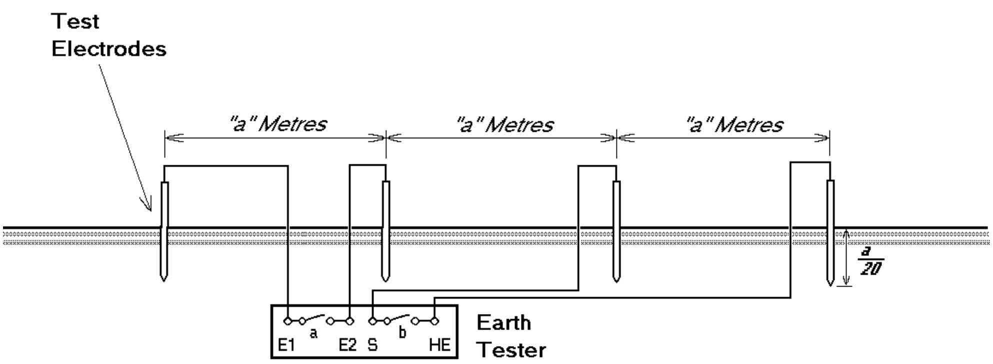
$\rho = 2\pi a R$

where ρ = soil resistivity, in ohm metres (Ω.m)

a = distance between electrodes, in metres (m)

R = reading of null meter, in ohms (Ω)

(f) Calculate the average value of ρ (ρ_{av}) from the values obtained from the calculation.



Circuit for the measurement of soil resistivity

8.3 Electrode Resistance

Electrode resistance can be calculated from the length and diameter of the electrode and the average soil resistivity (ρ_{av}), as follows:

(a) Measure the length of an electrode (*L*), in metres, and its diameter (*D*), in millimetres.

(b) Calculate the resistance of the electrode from:

$$R_e = \frac{\rho_{av}}{2\pi L}\left(2.3\log_{10}\frac{1000L}{D} + 1.1\right)$$

where

R_e = resistance of electrode, in ohms (Ω)

ρ_{av} = average soil resistivity, in ohm metres (Ω.m)

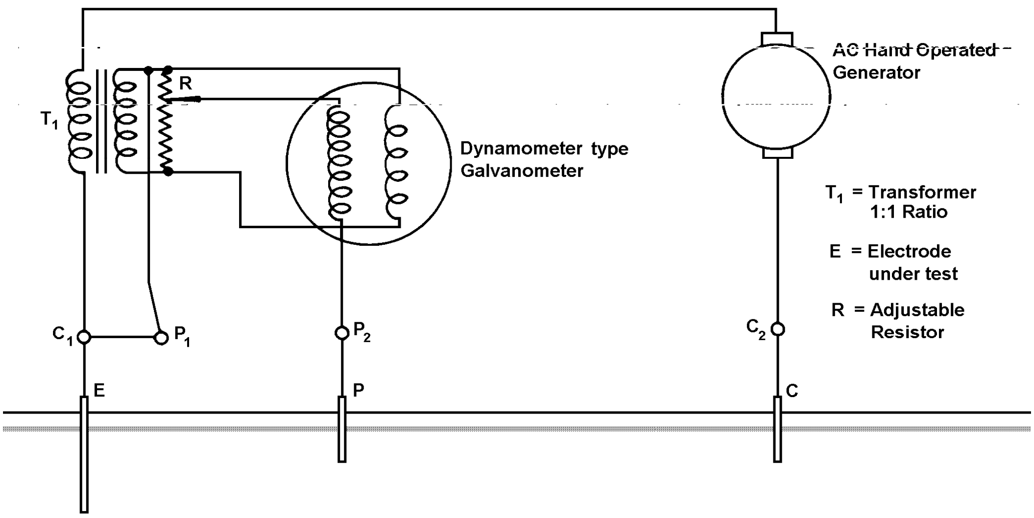
L = length of electrode, in metres (m)

D = diameter of electrode, in millimetres (mm)

Conversely, the length of an electrode of known diameter can be determined from the above.

8.4 Earthing Resistance Testers

Three types of earth-resistance testers all of which are of the null-reading type are being used.



Circuit diagram of a typical a commercial earth-resistance tester of the null-reading bridge type using a hand-operated generator and dynamometer type galvanometer.

The two older testers differ only in the method of voltage generation. One uses a hand-operated generator while the other a replaceable battery with push-button operation. The newer 'Geohm' tester is an electronic instrument and is push-button operated. With these instruments the correct reading is that obtained when the meter reads centre scale.

Typical hand-operated earth resistance tester

'Geohm' push-button type of earth resistance tester

8.5 Test Hints

To minimise induction effects:

- Set the test cable reels at right-angles when they are in close proximity.
- Keep current and voltage leads separate. A separation of between 5 to 10 metres is sufficient.
- If the test instrument has two or more ranges, note the results for each voltage/current combination. Variations in results may indicate that insufficient current is being injected.

Where there is insufficient test current due to high contact resistance, try one or more of the following:

- Without exceeding the depth-to-spacing ratio, drive the current electrodes deeper.
- Drive additional electrodes. Install them near each other and connect them together so that they form a common electrode.
- To reduce contact resistance, pour water (or salt-water) around the current electrodes.

9 DEFINITIONS

Electrode	*The vertical bare conductor, 5 m or longer, consisting of joined rods, tube, or stranded conductor.*
Group OR **Group of electrodes**	*Two or more electrodes mutually connected which may be disconnected from service together.*
in-service	*In-service earthing systems are electrically connected to the earth bus, LV neutrals, HV cable sheaths, etc, (and the water main where the water main connection is installed), ie as normally operated, but not necessarily with the substation commissioned.*
out-of-service	*Out-of-service earthing systems are electrically disconnected from the earth bus (and from any water main connection).*

Appendix A - Soil Resistivities

General

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.

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. Below is a list of typical soil resistivities.

Soil	ρ (ohm metres) at 20^{o}C
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 taken to the 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 resistivities of thousands of ohm metres. A simple guide for resistivity values is given below.

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

Appendix B – Separation Between Distribution Earthing Systems and Telecommunications Plant

This Appendix is currently under review and will be included later by an amendment to the Standard.

In the meantime, if a planned distribution system high voltage earthing installation (including a distribution substation combined earthing system installation) would result in an electrode, or bare earthing cable, or associated earthed item, within *15 metres from telecommunications plant (eg pit, pillar, cabinet, public telephone, etc.), then advice and approval must be obtained from Ausgrid before proceeding with the installation.

(*Note: Although in the large majority of locations in built-up areas, network conditions will be suitable to enable Ausgrid to approve reduction of the clearance limitation to 5 metres, or less in some cases, Service Providers must at this stage obtain approval from Ausgrid before proceeding with designs that would result in clearance of less than 15 metres.)

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