



TS 109

EARTHING OF THE DISTRIBUTION NETWORK

TECHNICAL STANDARD

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1. PURPOSE

This technical standard describes SA Power Networks general earthing requirements. It provides guidance to all personnel involved in the planning, design, selection, installation and/or testing of permanent earths associated with high voltage (HV) and low voltage (LV) installations on the SA Power Networks electricity distribution network.

This technical standard is also applicable to electricity supply installed to provide a service point for the connection of a customer from existing low voltage mains.

2. SCOPE

This technical standard shall apply to the distribution earthing activities associated with SA Power Networks' electricity distribution network.

For any situation that is not covered in this technical standard, the requirements set out in the relevant Act, Regulation or Australian Standard applies.

For substation earthing and for mobile generation equipment earthing please refer to separate standards.

3. GRACE PERIOD

1. The maximum grace period acceptable for implementation of this technical standard is 3 months from the date of publication.
2. All projects that are not in receipt of "Specification Compliance" at the revised date of issue for this technical standard shall have the latest requirements incorporated. For more information on how to obtain Specification Compliance, and contact details, please refer to SA Power Networks Information Brochure NICC 401 – Information on Network Design Installation by an External Contractor, and in Section 12 – Reporting of this document.
3. This is applicable to both the design and construction phases of the project.
4. The validity period for "Specification Compliance" is 60 days.
5. Any specification change after the validity period (without a documented exemption) shall be incorporated into the design and construction of our infrastructure.

4. INTRODUCTION

Earthing is the intentional connection to ground of a neutral conductor, as well as metal components of a structure not designed to have current flow through them during normal operation. An earthing system is installed as an integral part of an electricity distribution network, to control the magnitude and distribution of short circuit currents in case of a fault.

The following are the fundamental reasons for installing earthing systems:

1. To control touch and step potentials around the base of the structure, thus increasing safety of personnel during faults.
2. To provide a conductive path for fault current, which then ensures protective equipment operates in faulted situations.
3. To meet design requirements for short circuit earth currents.
4. To minimise the potential rise of earthed metallic parts that may become energised due to the passage of fault currents, ie controlling the voltage with respect to earth (or ground) within predictable limits.
5. To provide a reliable path for HV earth return currents without generation of significant standing voltages on the HV earth system for Single Wire Earth Return (SWER) systems.

5. TYPES OF EARTHING SYSTEMS

SA Power Networks uses a direct earthing system, in which the neutral of the HV/LV distribution transformer is solidly earthed and all exposed metallic surfaces of equipment are bonded to the neutral; special conditions apply to Single Wire Earth Return Systems.

Under earth fault conditions, the voltage of the system to earth will not exceed the phase-neutral voltage, but high fault currents will flow necessitating protection to operate as quickly as possible. This requires a low resistance path back to the neutral of the distribution transformer. SA Power Networks uses three basic earthing systems to achieve this, namely:

1. **Multiple Earthed Neutral (MEN) system.** In this system, the neutral conductor is earthed at many points hence the word “multiple”. In an MEN system, the HV and LV system are kept separate. Historically, MEN systems are found in remote locations, where poles are in a location not normally frequented.
2. **Common Multiple Earthed Neutral (CMEN) system.** CMEN is SA Power Networks’ standard earthing system, in which the neutral and earthing are common to both HV and LV networks. In frequented locations, CMEN or a Local CMEN System should be used.
3. **Single Wire Earth Return (SWER).** The transformer earthing in this arrangement is used as the return path for the HV current. Any LV mains supplied by SWER transformer will be either MEN or CMEN.

6. EARTHING SYSTEM - DESIGN

6.1 Multiple Earth Neutral (MEN) system

The standard earthing system for poles in rural areas is MEN (Multiple Earth Neutral).

The neutral is earthed at the transformer and along the length of the mains neutral by bonding to every LV only pole, and at each consumer’s premises.

The effect of having many earth return paths to the transformer neutral produces an earthing system with a low resistance value to earth.

Under fault conditions some of the fault current passes through the various earth connections as well as the neutral, but the neutral is designed to be of adequate size to carry the full amount of current.

Note: In an MEN system the HV and LV earthing systems are separate!

The following three rules apply to MEN networks:

1. Ensure rods are more than 3.5 m away from any structure (fence, pole etc)
2. Allow at least 3 m between rods
3. For MEN systems: a minimum space of 4 m shall be kept between HV and LV earth grids.

For a typical drawing of a pole being earthed using two separate earth grids for HV and LV, please see E-Drawing E 1003, Sheet 2.1.

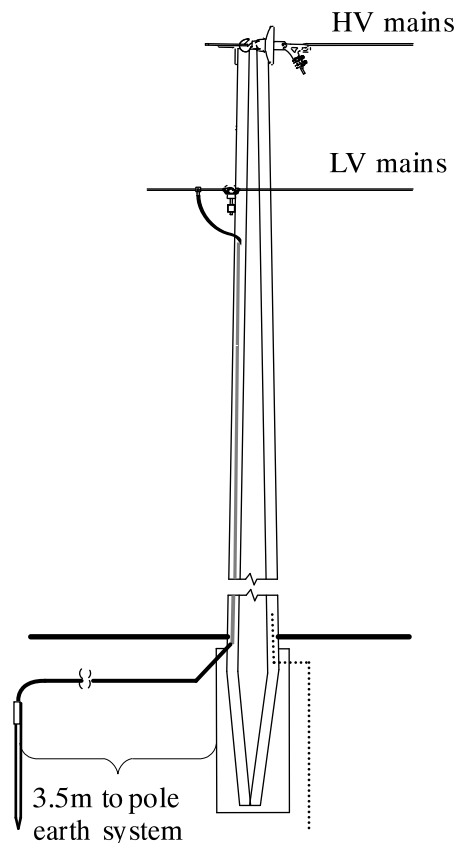


Fig. 1: Typical MEN system as per E-Drawing E 1003, Sheet 2.1

6.1.1 Size of earthing conductors

Conductor between earth stake and any structure (eg a pole) shall be made of copper, and shall have a minimum cross section of 50mm².

6.1.2 Size of mains neutral conductor

1. New bare wire low voltage mains shall have a LV neutral conductor of not less than 7/3.75 AAC or equivalent, with the neutral and phase conductors being of the same size and type.
2. The neutral of 50mm² LV ABC is adequate.
3. The LV ABC service mains erected across a road shall be 7/2.75 AAC or equivalent (40mm² in Cu conductor).

6.1.3 Equipment bond size

The minimum bond size on LV only poles in MEN areas is 7/3.75 AAC or 50mm² insulated Cu conductor. For more information on bond sizes, please refer to E-Drawing E1003, Sheet 2.1 and E1009.

6.1.4 Connection of LV neutral to an earth electrode (rod)

6.1.4.1 Overhead areas

Earth electrodes are required when LV neutral earth resistance does not meet resistance values as given in Section 6.1.7 of this document – *Earthing arrangements on poles in MEN area*.

If earth electrodes are required:

1. Connect earth rods to LV poles.
2. Connect earth rods to the neutral conductor using insulated conductor if on a LV/HV poles.
3. The preferred locations for earth rods are at the ends of LV mains and transformer poles.

6.1.4.2 Underground areas

The neutral of LV underground mains shall be connected to an earth electrode at each service pit/service pillar/ junction pit and the transformer LV earthing system.

For an MEN earthing area, the designer shall arrange for soil resistivity/earth resistance tests. The design shall consider these tests in relation to the minimum readings required at the time of installation and factor in earthing standards as stated in E-drawing E1905 series, relevant E-drawing manuals and AS/NZS 3000. The design shall assume worst-case scenario in relation to soil conditions (eg moisture contents), rather than basing the design solely on the soil resistivity values on the day of testing.

For sites with “difficult” earthing conditions, the design shall consider the location of equipment and the installation of additional earthing facilities. Additional earthing facilities can be achieved in a number of ways and there are specialist firms that can provide advice.

6.1.5 Bonding to poles

Poles carrying only low voltage conductors are to be bonded to the low voltage neutral.

6.1.6 Continuity

The low voltage neutral shall be continuous between adjacent low voltage transformer areas.

6.1.7 Earthing arrangements on poles in MEN areas

The decision table below shall be used to determine the earth resistance requirements for MEN areas. For further information, please refer to E-Drawing E1003, Sheet 2.1 and 2.2.

Pole Description	LV Mains Neutral	Neutral earth resistance (Ohms)	Pole earth resistance (Ohms)
LV pole Only	Bonded to pole.	N/A	10
HV pole Only	N/A	N/A	100
Combined HV/LV pole	Insulated from pole.	10	100
Combined HV/LV pole with HV Disconnect Fuses (DF), fuses or ganged air break	Insulated from pole.	10	10
HV Pole with DF, fuses or ganged air break	N/A	N/A	10
Distribution T/F pole	Insulated from pole.	No aerial mains: 30 Overhead or underground mains: 10	10
HV pole with pole top equipment, control box & dedicated T/F	TF/LV neutral bushing bonded to pole.	N/A	10

Table 1: MEN area earthing arrangements for poles

Other earthing considerations on poles in MEN areas include:

1. Customer installations on poles have to be a minimum distance of 3m away from the earth electrodes of the pole.
2. Mechanical protection of customer wiring shall be equipotentially bonded to the pole.

6.2 Common Multiple Earth Neutral (CMEN) system

The standard earthing system for poles in urban areas is CMEN (Common Multiple Earth Neutral). This system of earthing the neutral conductor is similar to the MEN system. The neutral is earthed as per MEN on the poles carrying low voltage only, but is extended to include poles carrying high voltage up to and including 132kV.

The purpose of the CMEN system is to limit the voltage rise from a high voltage fault to acceptable limits. This is achieved by:

1. The common neutral conductor offering low impedance (less than 1 Ohm (one Ohm)) return path for earth fault currents. (Each pole is connected to the CMEN conductor back to the substation.)
2. Greatly reduced current flow through the steel of poles and the earthed neutral of the consumer's installation to ground under fault conditions.

The advantages of using the CMEN system are:

1. It only requires the need for one earthing system to be installed at distribution transformers.
2. Step and touch potentials are reduced.
3. Earth Potential Rise (EPR) problems associated with electrical plant in close proximity to telecommunication plant are reduced.

6.2.1 Earthing of poles

In the overhead network the overall resistance to earth shall be less than 1 Ohm (one Ohm). Install pole earths if necessary to achieve this value.

Poles carrying high voltage lines situated in a CMEN area which have not yet been incorporated into the CMEN system can be connected by following the process for conversion in Section 6.3 of this document. All new poles in a CMEN area are to be bonded to the common neutral.

All poles in CMEN areas (up to and including 66kV) are to be bonded to the LV neutral. In the overhead network the overall resistance to earth shall be less than 1 Ohm (one Ohm). Install pole earths if necessary to achieve this value.

6.2.2 Common neutral design considerations

The continued effectiveness of an earth connection is determined by the ability of the electrode to carry fault current without permanent damage. For details of the size of earthing conductors to withstand specific fault levels without burning off and for details of the material, length, size and depth to which rods shall be driven, the spacing and method of connecting rods, refer to the E-Drawings showing SA Power Networks' standard method of earthing (E1453 for SWER Systems, E1003 for MEN and CMEN Systems).

6.2.2.1 CMEN conductor size

Table 2 below shows the minimum CMEN conductor size for 11kV lines:

Fault level (ψ -E)	Distance from substation	Minimum conductor size
Fault level $\leq 12\text{kA}$ (ϕ -E)	N/A	7/3.75 AAC or equivalent
Fault level 12kA-20kA (ϕ -E)	Built up area	
	Up to 400m	19/3.5 AAC or equivalent
	400m to 1500m	7/4.75 AAC or equivalent
	Over 1500m	7/3.75 AAC or equivalent
	Sparsely developed	
	Up to 800m	19/3.5 AAC or equivalent
	Over 800m	7/4.75 AAC or equivalent

Table 2: Minimum CMEN conductor size for 11kV lines

Table 3 below shows the minimum CMEN conductor size for 33kV and 66kV lines, dependent on the distance from the closest substation:

Fault level (ψ -E)	Distance from substation	Minimum conductor size
Fault level $\leq 12\text{kA}$ (ϕ -E)	N/A	7/4.75 AAC or equivalent
Fault level 12kA-20kA (ϕ -E)	Up to 500m	19/3.5 AAC or equivalent
	Over 500m	7/4.75 AAC or equivalent

Note: For meshed networks, use 19/3.5 AAC for the entire line.

Table 3: Minimum CMEN conductor size for 33kV & 66kV lines

6.2.2.2 Pole and equipment bonds

Pole and equipment bond sizes for poles on lines up to 11kV are to be 50mm² Cu XLPE, except for reclosers, where 70mm² Cu XLPE is required. Please refer to E-Drawing E1009 for more information.

6.2.3 CMEN in urban areas

6.2.3.1 Connection to substation transformers

The common neutral conductor shall be electrically connected to the star point of the windings of all substation transformers. For substations with Earth Leakage Zone Protection, the CMEN connects back to the 11kV switchboard earth bar. Refer to E-Drawing E1915 Sheet 8.2 for more details and a diagram.

6.2.3.2 Bonding to substation earth grids

1. Desirably, there should be a minimum of two connections over different routes from each substation.
2. CMEN connections to the substation earth grid and transformer neutral are required.
3. Where possible the common neutral in the street should form a closed loop around the substation.

6.2.3.3 Underground cable exits

The common neutral from a substation where feeder exits are cabled, shall be either the lead sheath of an 11kV or 33kV paper insulated cable, or the earth screen of an 11kV or 33kV XLPE cable, or a separate insulated conductor of 150mm² copper or equivalent.

For 66kV, 240mm² Cu or equivalent shall be used.

6.2.3.4 Overhead feeder exits

The street neutral will follow the route of the line and terminate at a convenient point on the substation structure. It would thus be connected to the substation earth grid.

6.2.3.5 Customer supply point

SA Power Networks will connect to the household supply points, after which it is the owner's responsibility that AS3000 is being adhered to. For more information, please refer to SA Power Networks' Service and Installation Rules.

6.2.3.6 CMEN system for isolated/remote locations

In this type of CMEN, also referred to as "Local CMEN system", the neutral is not continuous back to the substation transformer, instead staying common only within a certain area.

Refer to Section 6.3.1 for details of conversion from MEN to Local CMEN.

6.2.3.7 Determining overall resistance to earth for isolated/remote locations:

1. Select 10 widely separated poles or service pillars within the township.
2. Disconnect the neutral bonds and obtain an average resistance of the poles or service pillars.
3. Divide this figure by the approximate number of poles or service pillars in the township. At the edge of the CMEN area, the last and preferably the third last pole or service pillar shall have an earth resistance of 1 Ohm (one Ohm) or less. The poles or service pillars are to be within one span of the supply line.

6.2.4 Upgrading CMEN conductor for urban 66kV lines

When upgrading CMEN conductor for urban 66kV lines, it is acceptable to:

1. Leave existing LV neutral conductor as is.
2. Use a new dedicated CMEN for the 66kV line, which shall be installed above any existing LV or 11kV lines.

6.2.5 Re-conductoring LV neutral under live HV line

It is essential to keep the common neutral conductor continuous when working under a live HV line.

Example: Re-conductoring LV neutral under a live 11kV radial feeder in a CMEN area. To establish safe working conditions do the following:

1. Pull in the new neutral conductor.
2. Bond the new neutral to the poles.
3. Bridge the new neutral to the section of existing neutral that is to remain.
4. Disconnect the old section of neutral.

6.3 Conversion from MEN to CMEN - general

The decision if and when a conversion from MEN to CMEN system is necessary shall be made on a case-by-case basis, and can be made by the relevant Network Planning Manager (NPM) for your area, as per SA Power Networks Service and Installation Rules.

When implementing the CMEN system at a particular voltage the neutral conductor may be strung in any convenient sequence.

However, it should normally not be bonded to HV poles until either the sequence of actions detailed in 6.3.1 or 6.3.2 have been completed or it has first been connected to the neutral of the supply transformer.

6.3.1 Conversion of MEN to Local CMEN

The following table details the process to convert a MEN location, eg a rural township to CMEN without installing a neutral conductor from the supply substation.

CONVERSION OF MEN TO LOCAL CMEN	
STEPS	ACTION
1	The common neutral shall be continuous within a specific area (eg the township).
2	The overall resistance to earth of the common neutral shall be less than 1 Ohm (one Ohm).
3	Notes : <ul style="list-style-type: none"> Shall have a minimum of 10 earthing points. If it is necessary to find better earthing, the CMEN may be extended several spans out along the line from the township until the required resistance value has been achieved. More earth points can first be included within the township area, and then extend outwards from the township area for several spans. Ensure a continuous neutral connection.
4	Difficult and borderline cases should be referred to our Manager Network Standards and Performance.

Table 4: Conversion of MEN to local CMEN Network

6.3.2 Conversion of sub-transmission lines to CMEN (33kV, 66kV)

CONVERSION OF SUB-TRANSMISSION LINES TO CMEN	
STEPS	ACTION
1	Ensure that the neutral conductor is continuous between two substation earth grids.
2	The neutral conductor is to be of the appropriate size as indicated in Section 6.1.2 above.
3	Bond poles not supporting low voltage conductors to the neutral.
4	Bond neutral conductor to poles supporting low voltage conductor. Bond low voltage neutral to high voltage poles.
5	A further test may be required after bonding LV neutral to HV poles to confirm calculations for CMEN system. This test will be conducted at the discretion of the Asset Manager.

Table 5: Conversion of sub-transmission lines to CMEN

When new 66kV or higher voltage cable is installed an insulated Copper conductor will be laid in the same trench as the cable and over the entire route of the cable. Existing installations require detailed investigation. Also refer to SA Power Networks document *TS 110 – 66kV Cable Standard*.

Where there are no low voltage mains along a part of the overhead high voltage line a common neutral shall be installed, preferably at the normal height of low voltage mains.

6.4 Single Wire Earth Return (SWER) transformers earthing arrangements

Earthing of high voltage systems is normally a protective measure and current flows in the earth circuit only for the duration of a fault.

However, in the case of a SWER system, the earthing installation carries the HV load current of the circuit, so a sound earthing installation is essential for the performance of the SWER.

SWER is a good choice when conventional return current wiring would cost more than SWER's isolation transformers and small power losses.

The SWER systems used by SA Power Networks operate on a voltage of 19kV. Isolating Transformers for SWER systems used by SA Power Networks are typically either 33kV/19kV or 11kV/19kV transformers.

6.4.1 HV earthing

The maximum allowable resistance to earth depending on the Transformer Fault Level is shown in Table 6 below:

SWER T/F kVA	Max. HV earth resistance (Ohms)		Pole to earth resistance
	At installation	After one or more year/s	
5	50	80	Less than 100 Ohms (one hundred Ohms)
10	50	80	
20	25	40	
25	20	30	Less than 80 Ohms (eighty Ohms)
50	10	15	Less than 40 Ohms (fourty Ohms)

Table 6: Earthing Resistance Values

6.4.2 LV earthing

The neutral is to have a resistance to earth of 30 Ohms (thirty Ohms) maximum if there are no overhead or underground mains.

If there are overhead or underground mains, the neutral is to have a maximum resistance to earth of 10 Ohms (ten Ohms) at any point along its length.

6.4.3 Size of earthing conductor

In SWER and other similar locations where CMEN is not likely to be adopted connections to earth electrodes from low voltage poles may be made using 50mm² Copper XLPE cable. Refer to E-Drawing E1453 for further details.

6.4.4 Earthing considerations on poles

Similar to the MEN network, other earthing considerations on poles in SWER areas include:

- Customer installations on poles have to be a minimum distance of 3m away from the earth electrodes of the pole.
- Mechanical protection of customer wiring shall be equipotentially bonded to the pole.

6.4.5 Swimming pools in proximity to SWER lines

Special care shall be taken when swimming pools are to be located near to SWER lines. For further information, please contact the Manager Network Standards and Performance (MNSP), SA Power Networks, GPO Box 77, Adelaide SA 5001.

6.5 Other design considerations

6.5.1 Software design aids

All earthing calculations for SA Power Networks are to be conducted using CDEGS Software or an approved equivalent software package. Approval shall be sought in writing from Manager Network Standards and Performance (MNSP), SA Power Networks, GPO Box 77, Adelaide SA 5001.

6.5.2 Bonding of LV steel crossarms

If the concrete surface of the pole prevents contact between the crossarm and the pole then the steel crossarm shall be bonded to the steel of the pole.

6.5.3 Earthing measures against lightning effects

Where an overhead earthwire exists (on towers only), the structure footing resistance values have an influence on the backflashover rate of the line and therefore affect the reliability. A low resistance provides good lightning performance. Design parameters for high reliability lines can be found in Appendix E of AS/NZS7000.

Where the CMEN system is complete, all overhead earth wires will be bonded to the substation earthing systems and the supporting poles. The LV neutral wires may act as the CMEN conductor if necessary.

Where an overhead earth wire protects a HV line that is not part of the CMEN system, the overhead earth wires shall not be bonded to the LV neutral and associated metal work, or any earthing system bonded to it.

For further SA Power Networks requirements on overhead earth wire (OHEW) design, please refer to TS 107 – Overhead line design standard for sub-transmission and distribution networks and SA Power Networks *Manual No. 36 – Insulation coordination and overvoltage protection design principles*.

6.5.4 Earthing and railway lines

Where railway lines are close to the SA Power Networks network, with overhead lines running parallel or over/under railways, earthing systems shall be kept separate.

6.5.5 Cables in metal pipe

Where cables are installed in metal pipe for mechanical protection, eg under bridges or walkways, all three phases shall be installed in the same pipe.

Note: Do not install individual phases in separate metal pipes, as a current will be induced in the pipe.

The metal pipe is to be earthed by connecting it to an earth stake at each end.

7. EARTHING SYSTEM – CONSTRUCTION

7.1 Earth electrodes

Earth electrodes/rods shall meet (but not limited to) the following requirements:

1. The resistance of an earth rod to the general body of earth shall be low enough under fault conditions for the operation of protection equipment.
2. The earth rods and conductors shall be capable of carrying the maximum earth fault current without overheating or mechanical damage.
3. There shall be no deterioration of the electrode system by the action of moisture, corrosion or electrolysis, below a safe level to satisfy 1 and 2 above. Testing shall be carried out as per Section 11 – Earthing System Testing.

Typically, earth electrodes in SA Power Networks have a minimum length of 3m, which is most practically achieved by coupling 2x1.8m rods together. For more information of how to couple two electrodes together, please refer to E-Drawing E1012.

7.1.1 Driven rod electrodes

Driven rod electrodes typically achieve earth resistance values by coupling and driving rods end to end (Refer to E-Drawing E1012). If required, additional earth rods as per Figure 2 below are to be driven and connected up. Using several shorter earth rods (spread apart with insulated cables connecting them) is preferable to driving one rod deeper into the ground. The created earth grid can have any shape, as long as the three rules as per Section 6.1 – Multiple Earth Neutral (MEN) system are being followed.

Please note that no effective benefit is achieved beyond a depth of 6 m.

The top of the rod shall be a minimum of 300mm below ground level in built up areas, and 450 mm below ground level in rural areas. In cable pits, the rod shall not protrude more than 100 mm above the soil surrounding it. See E-Drawing E1011, Sheet 2 for further details.

Figure 2 below shows the preferred method for interconnecting earth rods, where multiple rods are required:

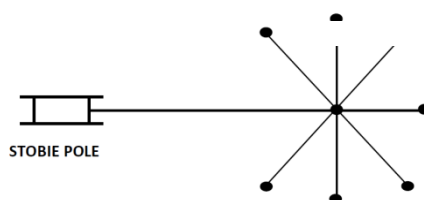


Figure 2: Example of Earth Grid Layout

Minimum distance between earth rods of the same network is 3 metres, but where additional rods are coupled and driven end to end, the minimum distance between rods shall be extended to at least equal the total depth of the rod.

Driven Electrodes shall be stainless steel clad rods. The first rod of each electrode shall be fitted with a hardened steel driving point. The total length can be made up of multiple rods, which shall be connected together with insulated copper conductor. Rods shall be joined with a coupling sleeve if a greater depth is required.

7.1.2 Drilled electrodes

Drilled electrodes shall be installed where driving of electrodes is not possible. In some areas greater electrode depths or additional rods will be required to achieve the required earthing system resistance.

Drilled electrodes are to be bare 70 mm² stranded copper cables. They are installed by boring a clearance hole to a suitable depth.

Crimping an earth rod or a short length of copper tube to the end of the electrode cable allows easier installation at 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. Approved earthing compounds are:

1. Slurry prepared from the excavated soil
2. Ground Enhancement Material (GEM)
3. Bentonite/Earthrite

The preference for one earthing compound over another shall depend on the respective soil resistivity. South Australian soils tend to have lower resistivity than purchased products, so slurry prepared from the excavated soil is preferable in these cases.

7.1.3 Parallel electrodes

If a sufficiently low resistance is not obtainable by means of a single electrode, a number of electrodes may be connected in parallel. However, since the resistance is not concentrated at one point, but is distributed over the soil in the vicinity of the electrode, it follows that if electrodes are installed too closely together their resistance area will overlap and the net resistance of the electrodes in parallel will not be as low as it would be if the electrodes were well separated.

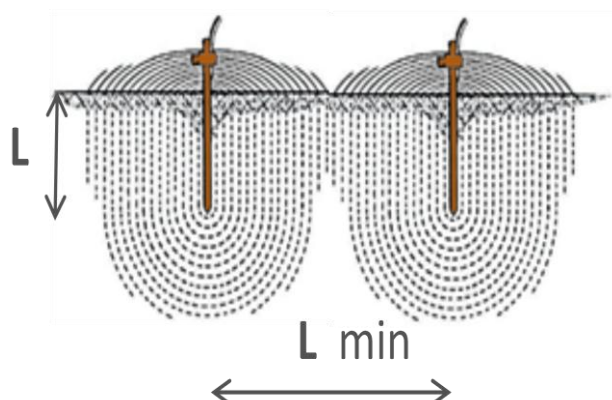


Figure 3: Typical Parallel Electrodes

If electrodes are well spaced the resistance of the electrodes in parallel may be calculated from the resistance of the individual electrodes by using the formula for resistances in parallel.

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

In difficult earthing conditions better results are usually obtained by deep drilling of earth rods rather than using a number of standard length rods in parallel. Where additional rods are coupled and driven end to end the maximum distance between rods shall be extended to at least equal the total depth of the rod.

7.1.4 Location of earth electrodes

7.1.4.1 Overhead areas

Earth electrodes are generally not required in the metropolitan CMEN area. (Due to the large number of steel poles connected to the common neutral resulting in a low value of overall system resistance.)

In areas known to have generally bad earthing characteristics, field tests are required to determine earth electrode requirement.

Examples include the Adelaide Hills and Mount Gambier. Where required, earth electrodes should be driven over two or three spans of mains in good earthing locations.

7.1.4.2 Underground areas

In underground residential development (URD) areas, the common neutral shall be connected to earth rods at transformer locations, and at service pits/ pillars/ junction pits.

7.1.5 Stobie poles as earth electrodes

Most Stobie poles and metal towers can be regarded as earth electrodes and should be used wherever possible, as long as the required resistance values can be achieved. Even the smallest steel section used for Stobie poles has sufficient sectional area to perform satisfactorily as earthing conductor. Earth resistance of the earth rods shall be such that protective equipment (such as fuses, circuit breakers and reclosers etc) will operate and clear a fault should a live conductor come in contact with the neutral or other earthed structures.

If the pole itself is not sufficient as earth electrode, there are two options for attaching the earth electrode to the pole (please refer to E1009 and E1011 for further details):

1. Bolting the lug on the earthing cable onto a hole drilled into the flange of the steel section of the pole. For sub-transmission poles use WB1510 or larger.
2. Bolting an earth bracket onto the pole and bolting the lug on the earthing cable to the bracket. Please note: Earthing brackets come with either two M16 pre drilled holes, or one M16 and one M20 hole. Depending on the required pole size, the correct bracket is to be chosen. For more information, please refer to E-Drawing E1011.

7.1.6 Over to under arrangements

For 66kV over to under arrangements, the earth plate is attached to the top of the cable guard as per E1511 Sheet 1. The cable guard arrives pre assembled with the earth plate on top from the manufacturer.

8. EARTHING SYSTEM - RESISTANCE

The principal factors which affect the resistance between the earthing system and the general mass of earth are:

1. The specific resistance (Resistivity) of the soil. (This will depend on the composition, temperature and moisture content of the soil.)
2. The size, shape, number and spacing of earthing electrodes.
3. The depth of electrodes.

The resistivity of the soil is not uniform. It may vary over wide limits even in places a few feet apart, but resistivity generally decreases with depth. The normal range of soil resistivity is between 10 and 1,000 ohm metres. However, values as high as 6,000 ohm metres have been found in some areas of South Australia, where glacial sand with high silica content is present. Values from 1,000 to 10,000 ohm metres are considered exceptional.

In the strata under the surface, loam and clay usually have a low resistivity, while sandy and rocky materials have a higher resistivity.

The depth to which an electrode is driven is probably the most important factor affecting earth resistance, firstly because the volume of soil affected increases directly with the length of electrode below the surface, and secondly because the soil resistivity usually decreases with depth due to the moisture content.

Frequently, owing to lower soil resistivity further down, the resistance will decrease with depth. A typical example of this correlation can be seen in Figure 4 below:

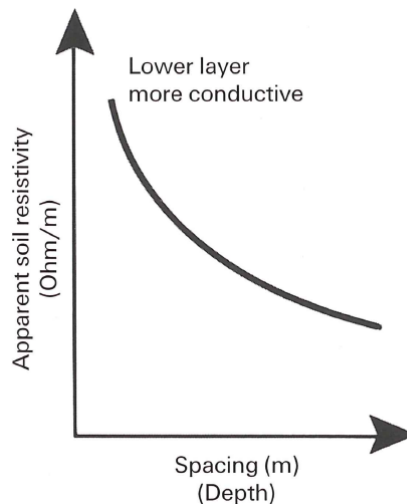


Figure 4: Typical curve of apparent soil resistivity for two layer soils.

9. EARTHING INTERFACE BETWEEN SA POWER NETWORKS AND 11kV CUSTOMERS

Refer to SA Power Networks Service and Installation Rules for detailed earthing requirements.

This section is relevant to 11kV High Voltage customers only. For 33kV or 66kV high voltage customers, the requirements will be determined by Manager Network Standards and Performance (MNSP), SA Power Networks, GPO Box 77, Adelaide SA 5001.

In urban areas, 11kV customer supply is typically via either a single switching cubicle or a pair of switching cubicles in the case of duplicate supply. In these situations, the earth bar of each cubicle is to be bonded to the customer's HV main earth bar using 120mm² Cu cable. In situations where this arrangement does not seem suitable, please contact the Manager Network Standards and Performance (MNSP) to have your situation assessed on a case-by-case basis.

10. SEPARATION FROM TELECOMMUNICATIONS ASSETS

10.1 Background

The distance between telecommunications assets and any adjacent earthing system associated with SA Power Networks' HV network shall be carefully considered, as it may cause injury, damage to equipment or quality issues (noise). This applies to all accessible telecommunications assets including jointing pits, service pits, manholes, pillars and cabinets containing cables with metallic conductors. Buried telecommunications cables with conductive sheaths shall also be considered.

10.2 Separation between HV earthing and telecommunications assets

In CMEN areas, no separation distances are required between telecommunications assets and HV earthing (< 66kV).

In MEN areas, the minimum separation distance between telecommunications assets and HV earthing (< 66kV) is 15m.

11. EARTHING SYSTEM – TESTING

The earthing installer shall carry out tests as necessary to demonstrate compliance with the requirements of this technical standard. 'Tests' shall include all checks, measurements and inspections necessary to prove compliance.

11.1 Soil resistivity test

Specific resistance or resistivity is defined as the resistance across opposite faces of a theoretical cube of one metre in dimension. Soil resistivity is expressed in ohm metres. The resistivity will vary with moisture content, physical nature of the soil and its chemical composition. As the earth is not likely to be homogeneous, strata of different resistivity materials such as rock will occur at varying depths.

Generally the resistivity of soil is determined by the quantity of water held in the soil and on the resistivity of the water itself, since most soils are non-conductors when completely dry. Conduction through soil therefore becomes conduction through the water held in the soil and so the conduction is mainly electrolytic. The main factors which determine the resistivity of soil are:

1. Type of soil
2. Salts dissolved in the contained water
3. Moisture content
4. Temperature
5. Grain size and Closeness of packing and pressure

Type of earth	Typical resistivity ($\Omega.m$)
Wet organic soil	10
Clay silt	50
Typical soil	100
Clay, sand and gravel mix	150
Moist sand and gravel	200
Loam and broken stone	300
Slate, shale and sandstone	500
Very dry soil	1000
Dry sand	2000
Stony/Rocky ground	2000
Dry gravel	3000
Bed Rock	10,000

Table 7: Soil resistivity for different types of earth.

The most common method of measuring the resistivity of large volumes of undisturbed earth is the Wenner four probe method.

Refer to AS1289 set for more details on “Methods of Testing Soils for Engineering Purposes”.

It should also be recognised that soil resistivity varies with the seasons. In wetter months the soil resistivity will be lower, while in the dryer months it will be higher. Adequate earthing should be installed to ensure the target resistances are achieved in the drier months.

11.2 Earth resistance - test

11.2.1 Testing in MEN areas

In any overhead or underground network the earth resistance at any point along the length of a LV feeder is to have a maximum resistance of 10 Ohms (ten Ohms) prior to connection to the existing network. If additional earth stakes are required, test the earth system as a whole. It is not necessary to test individual earth points.

In difficult earthing locations alternative configurations, such as overhead earth wire to a more suitable earthing point, may be utilised with agreement from SA Power Networks.

11.2.2 Testing in CMEN areas

In any overhead or underground network the overall resistance to earth shall be less than 1 Ohm (one Ohm). For additions to the network such as new URD, test to confirm the resistance is less than 1 Ohm (one Ohm) prior to connection to the existing network. Test the earth system as a whole. It is not necessary to test individual earth points.

11.2.3 Testing in Local CMEN areas

Testing in Local CMEN areas shall be as per CMEN areas.

11.2.4 Testing in SWER areas

Testing the LV network of a SWER transformer is as per MEN areas.

Each SWER distribution transformer has its own dedicated HV earthing system. Test prior to connecting to the HV neutral bushing for the required resistance value specified in E-Drawing E 1453, Sheet 3.

SWER isolating transformers have two HV earthing networks connected via an earth isolation/test box. Test in accordance with procedure detailed on E-Drawing E 1450 Sheet 5.

11.2.5 Regular testing of earthing arrangements

SA Power Networks shall routinely test all earthing arrangements to see if resistance values are still within acceptable limits. For more information on the frequency of earthing system testing, please refer to Network Maintenance Manual No. 12, Section 6.9.

12. REPORTING

A part of SA Power Networks' acceptance is the sign off on SA Power Networks' **Certificate of Electrical Compliance** and issuing of the **Authority to Proceed-Connection & Energise**. The contractor/constructor is required to supply all relevant test sheets as per TS105 Appendix A – (Forms) completed and in full. In the case of earthing of the distribution network, this may include provision of the following, in addition to the **Electrical Works Compliance Forms** (Forms 1-4):

Form Number	Form Name
TS 105-F-35	Form 35: Certificate of test – earth stake test - transformer
TS 105-F-36	Form 36: Certificate of test – additional earth stake
TS 105-F-37	Form 37: Certificate of test – earth stake test for cut rods - pits
TS 105-F-38	Form 38: Certificate of test – earth stake
TS 105-F-73	Form 73: Certificate of test – earth stake - poles
TS 105-F-74	Form 74: Certificate of test – earth stake – for cut rods - poles

Table 8: Report form names and numbers

APPENDICES

Appendix-A: Definitions

AS/NZS:	Australia and New Zealand Standards published by Standards Australia.
Bonding:	See: Equipotential Bonding.
CMEN:	Common Multiple Earth Neutral – has a neutral that is common to the HV (high voltage) and LV (low voltage) systems and is continuous back to the substation earth.
Conductor:	A wire or other form of conducting material suitable for carrying current, other than wires, cables or other metallic parts directly used in converting electrical energy into another form of energy.
Connection Point:	Has the meaning given to that term in the Electricity (General) Regulations 1997, namely a connection point to a transmission or distribution network. For the purpose of this document connection point also has the same meaning as Point of Supply as defined in AS/NZS 3000.
Distribution Network:	Has the meaning given to that term in the Electricity Act 1996, namely the whole or part of a system for the distribution of electricity, but does not include anything declared by regulation not to be a distribution network or part of a distribution network. For the purposes of these rules, references to distribution network means the network poles, wires, underground cables, transformers, substations etc operated by SA Power Networks which transports electricity from the transmission system to a customer's connection point.
Distribution Transformer:	A distribution transformer which forms a part of the distribution network, typically with a secondary voltage of less than 1,000V a.c.
DF:	Disconnect Fuse.
Earth:	The general mass of earth and electrodes connected to it.
Earthing (Grounding):	The bonding together and to earth of all metallic parts or objects which may become live under fault conditions.
Earthing Point:	An Earthing Point can be a pole or an earth stake, or any other point where current is deliberately being discharged into soil.
Electricity Distribution Code:	Means the Electricity Distribution Code administered by the Essential Services Commission of SA.
EPR:	Earth potential rise is the voltage between an earthing system and reference or remote earth. Under normal operating conditions this value will be zero, but during times when fault currents flow in the earthing system, significant local voltages can be generated. If large voltages gradients are produced there will be a danger of touch and step voltages also being produced.
Equipotential	The practice of intentionally electrically connecting all exposed metallic items not

Bonding:	designed to carry electricity as protection from electric shock.
Fault Current:	Any abnormal electric current, in high voltage commonly between one or more phases and ground, or between phases.
Fault Level:	The maximum fault current which would be dissipated by a fault at a point in the system.
Frequented Location:	Any urban area associated with a city or town other than a special location.
Ground:	See: Earth.
High Voltage (HV):	For the purposes of this document, shall mean a voltage exceeding 1,000V a.c. up to and including 132,000V a.c.
Local CMEN:	A CMEN system in an isolated (=remote) location, as defined below. It differs from CMEN only in that the neutral is not connected back to the substation earth.
Low Voltage (LV):	For the purposes of this document shall mean a nominal voltage exceeding 50V a.c. but not exceeding 1,000V a.c.
Manager NSP:	SA Power Networks Manager Network Standard & Performance.
MEN:	Multiple earthed neutral is also known in IEC 60364 as a TN-S earthing system. Part of the system used a combined PEN (protective earth – neutral) conductor, which is at some point split up into separate PE and N lines. The combined PEN conductor typically runs between the transformer/supply neutral and the entry point into the building and may be earthed at numerous points. The PEN conductor is only separated into distinct PE and N conductor at the installation switchboard. In the SA Power Networks MEN system, this LV earthing/neutral system is kept distinctly separate from the HV earthing systems.
Must:	Is to be understood as mandatory.
Neutral Conductor:	The wire conducting the power in an electrical circuit back to the source.
Non-frequented location:	A rural area or an area which is not normally frequented.
Phase Conductor:	The current-carrying conductor (as opposed to neutral and ground wires).
Protection:	A term given to various devices, eg fuses, reclosers or circuit breakers, used to detect and initiate the isolation of faulty electrical equipment or installation overload.
Remote Location:	An area not defined as either special or frequented location.

TS 109: Technical Standard for Earthing of the Distribution Network

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Service Point:	Refer to Connection Point.
Shall:	Is to be understood as mandatory.
Should:	Is to be understood as non-mandatory, ie advisory or recommended.
Sparsely Developed:	An area where there is not the multiplicity of parallel paths for the dispersion of fault current through the common neutral as there is in built-up areas.
Special Location:	Within a school's grounds or within a children's playground, or within a public swimming pool area, or at a popular used beach or water recreation area, or in a public thoroughfare within 100m of any of the above-named locations.
Specification Compliance:	Adherence to a set of requirements.
Step Voltage:	Voltage between two points on the earth's surface. A nominal value used is one metre, which is considered to be the stride length of a person. Generally if touch voltages are controlled to safe levels, step voltages will also be safe.
Suitable (or suitably):	To the satisfaction of the relevant SA Power Networks manager.
SWER:	Single wire earth return. The voltage is normally 19kV.
T/F:	Abbreviation for Transformer.
Touch Voltage:	Voltage between conductive parts when touched simultaneously. Normally the voltage is considered to act between the feet and hand(s) as this is the most dangerous situation giving a current path which includes a person's heart.
URD:	Underground residential distribution.
Voltage Stress:	Damage caused to conductors or insulation by side effects of current passing through it. This may include heat, vibration and audible noise.

Appendix-B: References

The following listed documents are for additional information but may not be a conclusive list and other documentation may be required on a project specific basis. Refer to the following SA legislative acts and regulations, SA Electricity Code, SA Power Networks' publications, relevant AS/NZS and ENA standards for more detail.

Please note: It is your responsibility to ensure you have complied with all relevant standards and that you have used the latest version.

South Australian Legislation:

This technical standard does not necessarily align with AS/NZS Standards Australia Publications.

- [SA Electricity Act 1996](#)
- [Electricity \(General\) Regulations 2012](#)
- WH&S Regulations 2012

Energy Networks Association (AUS) Publications:

- [ENA NENS 03 - 2006 - National Guidelines for Safe Access to Electrical and Mechanical Apparatus](#)
- [ENA NENS 04 - 2006 - National Guidelines for Safe Approach Distances to Electrical and Mechanical Apparatus](#)

Standards Australia Publications:

- [AS1289.0:2000 – Methods of testing soils for engineering purposes](#)
- [AS/NZS 3000:2007 - Electrical Installations \(known as the AS/NZ Wiring Rules\)](#)
- [AS/NZS 7000:2010 – Overhead Line Design – Detailed procedures](#)

SA Power Networks Documents:

The construction shall comply with the latest issue of the following SA Power Networks publications current at the time of commencement of the Works and the following publications as determined by SA Power Networks from time to time will be considered to be incorporated in, and form part of, this technical standard.

- [Network information for Contractors and Customers \(NICC Brochures\)](#), in particular:
 - NICC 401 - Information on Network Design Installation by an External Contractor
- [Service and Installation Rules](#)
- [Technical Standards:](#)
 - TS 101 – Public Lighting Standard for Overhead and Underground Networks
 - TS 105 – Testing standard for underground and overhead cable networks
 - TS 107 – Overhead line design for sub-transmission and distribution networks
 - TS 110 – 66kV Cable Standard

Appendix-B: References (continued)

SA Power Networks E-Drawing Series, and the following drawings in particular:

Drawing Title	Drawing Number
Earthing of poles and LV neutral CMEN Areas	E1003, Sheet 1 - 2
Bonding to Stobie Poles	E1009
Earthing Methods	E1011
Earth Rods – Coupling and Driving	E1012
Mounting Bracket – Stobie Poles	E1040
Earthing Arrangement of SWER Isolating T/F	E1451
Arrangement of SWER Distribution T/F	E1452
Earthing Arrangement of SWER Distribution T/F	E1453
66kV Cable Guards	E1511, Sheet 1
Earthing of Underground Equipment CMEN & MEN	E1905
11kV Feeder Termination	E1915, Sheet 8.2
Telecommunications Earthing	E4605