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1. Introduction

None

2. Supporting clauses

2.1 Scope

2.1.1 Purpose

This standard defines Eskom's requirements for the earthing of transmission line towers and methods to avoid corrosion of tower footings and other buried installations. The standard practices pertaining to earth conductors when crossing or running parallel to railway lines and pipelines are included.

2.1.2 Applicability

This standard is intended for those involved in the specification, design, construction and maintenance of transmission lines. Nothing in this standard shall lessen the obligations of the contractor detailed in any other documents forming part of a contract.

2.2 Normative/informative references

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

- [1] IEC 61089:1991, Round wire concentric lay overhead electrical stranded conductor.
- [2] SABS 0199:1985, Code of practice for the design and installation of an earth electrode.
- [3] SANS 10280 : 2017, Code of practice for overhead power lines for conditions prevailing in South Africa.
- [4] NRS 061-2 : 2015, Specification for the installation of overhead ground wire with optical fibre (OPGW).
- [5] NRS 061-1 : 2019, Specification for overhead ground wire with optical fibre.
- [6] Eskom Drawing No. 0.54/393, *Earthing standards*.

2.2.2 Informative

None

2.3 Definitions

2.3.1 General

None

2.3.2 Disclosure classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

2.4 Abbreviations

None

2.5 Roles and responsibilities

Not applicable.

2.6 Process for monitoring

Not applicable.

2.7 Related/supporting documents

Not applicable.

3. Requirements

3.1 Earthing

3.1.1 Tower footing resistance

3.1.1.1 The nominal footing resistance for:

- a) 132 kV shall be 20 Ω ;
- b) 220 kV shall be 30 Ω ;
- c) 275 kV shall be 30 Ω ;
- d) 400 kV shall be 40 Ω ; and
- e) 765 kV shall be 50 Ω .

Note: These values are not fixed. Where these values cannot be achieved, appropriate values will be given, based on the backflashover rate required for a particular line.

- f) The terminal tower legs shall be bonded to the main substation earthmat in accordance with 3.2.2, however, if that is not possible then the footing resistance at terminal towers on 132 kV to 765 kV lines shall be less than 10 Ω .
- g) The footing resistance on the second, third and fourth towers from a substation on 132 kV to 765 kV lines shall be less than 20 Ω .
- h) The method to measure footing resistance set out in 3.10 shall be used. Footing resistance shall be measured using an approved earth tester with appropriate high frequency filtering, to enable testing with the earthing system connected to the tower.
- i) Where ground conditions are poor and the specified footing resistances are impossible to achieve using the methods set out in 3.4, the matter shall be referred to Eskom's Project Manager.

3.2 Pad and Pier (chimney) foundations for self-supporting towers

3.2.1 Line tower

- a) Before the foundation is cast, a proper connection shall be made at each foundation between the tower stub steel and the main rebar, both connections being within the concrete.
- b) These connections shall consist of a 40 mm x 3 mm galvanized mild steel strap or suitable earth conductor with a minimum diameter of 9 mm which has been approved by Eskom in writing. The choice of a 40 mm x 3 mm strap or minimum 9 mm diameter conductor is based on mechanical reliability. The strap or earth conductor shall be bolted to the tower leg and shall be connected to the foundation rebar using a Crosby clamp or a method approved by Eskom in writing.

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- c) A suitable lug with an 18 mm minimum diameter hole shall be attached to the loose end of the conductor (or the strands). The lug shall then be bolted to a dedicated hole on the tower leg or the cleat. The connection shall be made in the foundation below ground level using a 16 mm minimum diameter bolt.

3.2.2 Terminal towers

- a) The two legs of the terminal tower nearest to the substation shall be bonded to the main substation earth mat and shall be attached at two different points on the earth mat. (Fig.A1 in annex A).
- b) The contractor shall install, between the two legs of the terminal tower nearest to the substation, a suitable length of 50 mm x 3 mm copper strip with an 18 mm diameter hole drilled at each end, or other material and connectors approved by Eskom in writing. The bolted connection at the tower and the exposed portion of the earth strap shall be painted with a suitable bitumastic compound.
- c) Joints between the copper strip and the substation earth mat shall be oxy-acetylene brazed using a minimum 3 mm diameter silbralloy brazing rod or similar brazing rods approved by Eskom in writing.
- d) Two 70 mm² solid copper rods shall be used as replacements for each 50 mm x 3 mm copper strip where more suitable (i.e. where the substation earth mat consists of copper rods). In these circumstances connections shall be crimped joints and earth tail clamps in accordance with Eskom drawing number 0.54/393.
- e) Where for any reason it is not possible to bond the terminal tower to the main substation earth, the earth conductors shall be insulated from the terminal tower using earth conductor insulators with earth conductor jumper leads fitted (see figure 2 of annex A). An earthing connection as described in 3.4 shall be installed and the footing resistance of the terminal tower shall be less than 10Ω.

3.3 Drilled foundations, guyed towers and cross-rope suspension towers

3.3.1 Line guy type towers

- a) A connection within the concrete shall be made between the main foundation rebar and one of the anchor bolts. This connection shall be the same as in 3.2.1.
- b) Three anchor bolts shall be bolted onto each ball and socket for the masts. The two masts shall be connected together using a 40 mm x 3 mm galvanized mild steel strap, provided no cattle guard is in place.
- c) For the guy anchors, a proper connection shall be made at each foundation between the link and the reinforcing steel. This connection shall consist of a 40 mm x 30 mm galvanized mild steel strap or suitable earth conductor that has been approved by Eskom in writing. The strap or earth conductor shall be bolted to the link and shall be connected to the reinforcing using a Crosby clamp or a method approved by Eskom in writing.

3.3.2 Single mast guyed towers

- a) Where three single mast structures are used for each circuit, the three bases shall be interconnected using 40 mm x 3 mm galvanized mild steel strap with an 18 mm diameter hole at each end which is buried 600 mm below ground level. The connection between the bases and the mild steel strap shall be done by bolting the strap to the tower leg using a 16 mm (min) diameter bolt. The strap shall be painted as described in 3.8.
- b) Where the single mast strain tower is used the earthing connections as described in 3.3.1 will apply.

3.3.3 Cross-rope suspension towers

- a) The top of the locating pin protruding from the foundation shall be tapped with a 12 mm hole to a depth of 30 mm. A suitable length of 40 mm x 3 mm galvanized mild steel strap or a method approved by Eskom in writing shall then be used to connect the top of the locating pin to the tower leg. In both cases the strap shall be bolted.
- b) A connection within the concrete between the cast-in locating pin and the main foundation rebar shall then be made. This connection shall consist of either a 40 mm x 3 mm galvanized mild steel strap or a suitable length of earth conductor fixed to the pin with either a lug or Crosby clamp or a method approved by Eskom in writing, and to the rebar with a Crosby clamp or a method approved by Eskom in writing.
- c) For guy anchors, the connection shall be the same as 3.3.1.

3.4 Additional earthing

Where the specified tower footing resistances have not been obtained using the methods described in 3.2 and 3.3 and where additional earthing is required, the following methods can be used.

3.4.1 Counterpoise earthing

- a) For the transmission system a counterpoise arranged in a crow's foot formation must be used. This will consist of wire/s (of appropriate length) running radially out from the center of the tower with an earth rod (designed to an appropriate length) attached to the end of the radial wire.
- b) Where counterpoise earthing is to be used in rocky areas, trenches shall be backfilled in such a manner that the counterpoise is encased by at least 100 mm of an approved mixture.

3.5 Earth conductor insulators

Earth conductor insulators shall be 120 kN units. Where earth conductor insulators are fitted with an adjustable spark-gap, the arcing gap shall be set to 10 mm in most cases. This value is not fixed: in some cases the arcing gap will be set to values ranging from 10 mm to 30 mm as stipulated by the Transmission line engineer.

Earth conductor insulators shall be installed in the following circumstances:

- a) At terminal towers not connected to the main substation earth mat as noted in 3.2.2. earth conductor jumpers shall be fitted (see Figure A2 of Annex A).
- b) At traction substation terminal towers, the continuity of the earth conductor shall be broken. No earth conductor jumper leads shall be fitted (see Figure A3 of Annex A).
- c) If any of the second, third, fourth and fifth towers from the substation have footing resistances less than 10Ω , earth conductor jumper leads shall be fitted on strain towers (Figure A4 of Annex A).
- d) At all towers within 800 m of electrified railway tracks or metal pipe lines where the power line either crosses or runs parallel to the railway or pipe line unless otherwise directed by Eskom's site representative, earth conductor jumper leads shall be fitted on strain towers (Figures A5, A6 and A7 of Annex A).
- e) In 3.5.(a) and 3.5.(b) the values of 10Ω and 800 m shall be used as a guideline. However, these values shall be verified for new designs.
- f) At any tower indicated by Eskom, for example, to limit the losses in the earthwire.

3.6 Backfilling

In rocky areas and areas with high resistivity, a conductive mixture of carbonaceous aggregate, for example, graphite, bentonite or a mixture approved by Eskom in writing, of 4:1 by volume with cement shall be used.

3.7 Optical earth conductor (OPGW)

An insulator shall be fitted at strain towers where the optical earth conductor is insulated (Figure A10 Annex A).

Earth conductor jumpers shall be fitted at towers where the optical earth conductor is connected to a junction box (Figure A11 Annex A).

Earth conductor jumpers, insulators and suitable, approved downlead clamps shall be fitted at towers where the optical earth conductor is insulated as well as connected to a junction box. The optical earth conductor shall be at a minimum distance of 50 mm away from the tower when it is lowered to the junction box (Figure A12)[4].

3.8 Corrosion Protection of guy anchors

The guy anchors shall be painted with two coats of bitumastic paint approved by Eskom in writing.

The guy anchors shall be insulated within 800 m of electrified railway tracks or metal pipe lines where the power line either crosses or runs parallel to the railway or pipe line unless otherwise directed by Eskom's site representative.

3.9 General

Earth straps or counterpoise shall, in all circumstances, be painted with two coats of bitumastic paint approved by Eskom in writing, for a distance of 500 mm above finished ground level and 500 mm below finished ground level.

The earth conductor or OPGW with junction box shall, in all circumstances, be bonded to the gantry (Figure A13 for details).

3.10 Tower footing resistance measurements

The resistance of the installed earth system shall be measured with an approved earth tester. The readings shall be submitted to Eskom without delay.

Resistance shall be measured when foundations and earth straps are all electrically connected: this includes additional counterpoise earthing. Should a null balance insulation tester be used, the footing resistance of the tower shall be measured BEFORE the overhead earth conductors are connected to the tower or the earth conductors can be temporarily isolated.

3.10.1 Method of testing

3.10.1.1 Tower with standard earthing

The circuit diagram for testing is shown in Figure A8 of Annex A. The test leads shall be run out along a straight line from the geometric centre of the tower and at right angles to the line. The distance to the potential (inner) electrode shall be 60 m and to the current (outer) electrode 100 m with the null balance insulation tester.

Measurements shall be taken using the probes supplied with the equipment or alternatively using a stainless steel or copper rod with a minimum 20 mm diameter, driven into the earth to a depth of at least 200 mm.

In the case where resistivity is high, it may be necessary to reduce the resistance of the current and potential electrodes by watering the area immediately around the electrodes or by using additional electrodes and connecting them together.

3.10.1.2 Tower with counterpoise earth

The same method as in 3.10.1.1 shall be used, but the distances to the electrodes shall be as follows:

- a) distance from tower to inner electrode = 3 D
- b) distance from tower to outer electrode = 5 D.

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Note: If these distances are impractical, the site representative should be consulted.

If a continuous counterpoise earth is run from tower to tower the earthing resistance need not be measured.

3.10.2 Measurement of footing resistance with adjacent energized powerlines

The electric field produced by an adjacent energized powerline can affect the instrument in close proximity so that a reliable reading is difficult to obtain. Care shall be taken to run the test leads at right angles to the energized line.

3.10.3 Footing resistance meters

- a) The null balance earth testers are approved meters to be used to measure tower footing impedance. Measurements with a null balance earth tester shall be done BEFORE the overhead earth conductors are connected to the tower or the earth conductors can be temporarily isolated.
- b) Measurements with an approved impulse impedance tester or a low frequency meter which is capable of measuring the current flowing through the tower legs as well as the guy anchors may be used with the overhead earth conductors connected to the tower.
- c) The contractor must submit details of the equipment to Lines Engineering Department for approval prior to it being used.

4. Authorization

This document has been seen and accepted by:

Name and surname	Designation
Faith Mokhonoana	Senior Manager LES
Arthur Burger	Chief Engineer

5. Revisions

Date	Rev	Compiler	Remarks
Oct 2022	2	A Nathoo	Added annex b on step and touch potential assessment. Revised section 3.10.3 by including an impulse measurement as a tool and removed reference to a manufacturer specific instrument. Removed annex b-backflashover curves from the annexures and replaced with step and touch potential assessment. Checked content for general grammatical errors, corrected referencing and updated references.
March 2018	1	A. Nathoo	Content copied from old template to current Document number changed.
Nov 2006	0	-	3.2.1.4 amended. 3.3.2.2 and 3.8 added. Graph added for tower type 524A in Annex B. Document replaces TRMASAAJ7.

6. Development team

- A Nathoo

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7. Acknowledgements

Not applicable.

Annex A – Figure showing various earthing installations

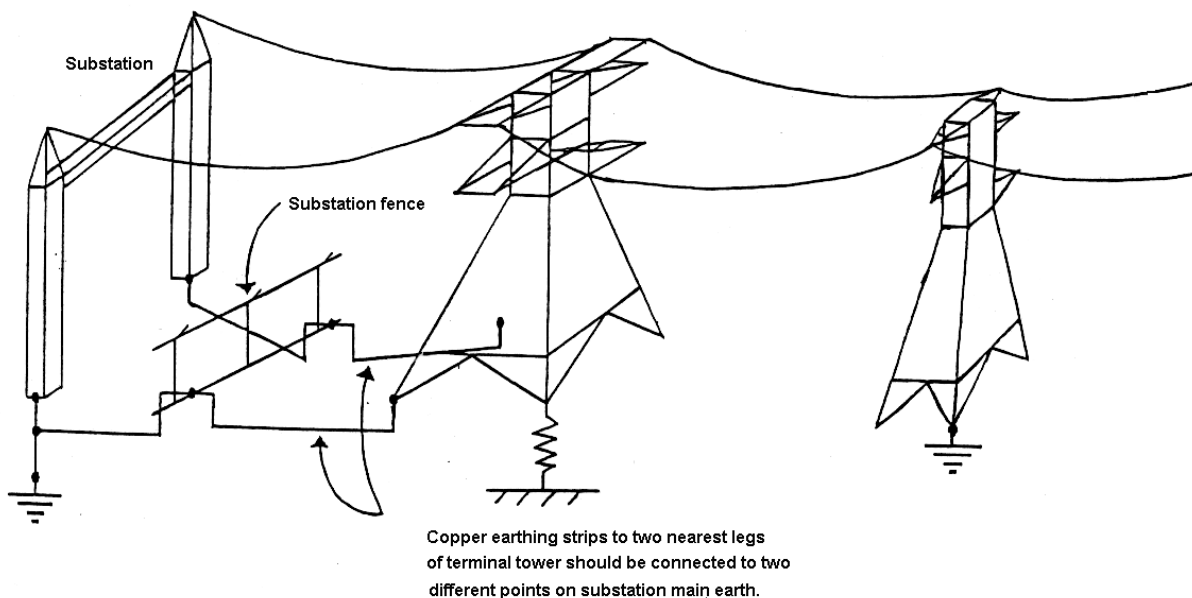


Figure A1: Terminal tower bonded to substation earthmat

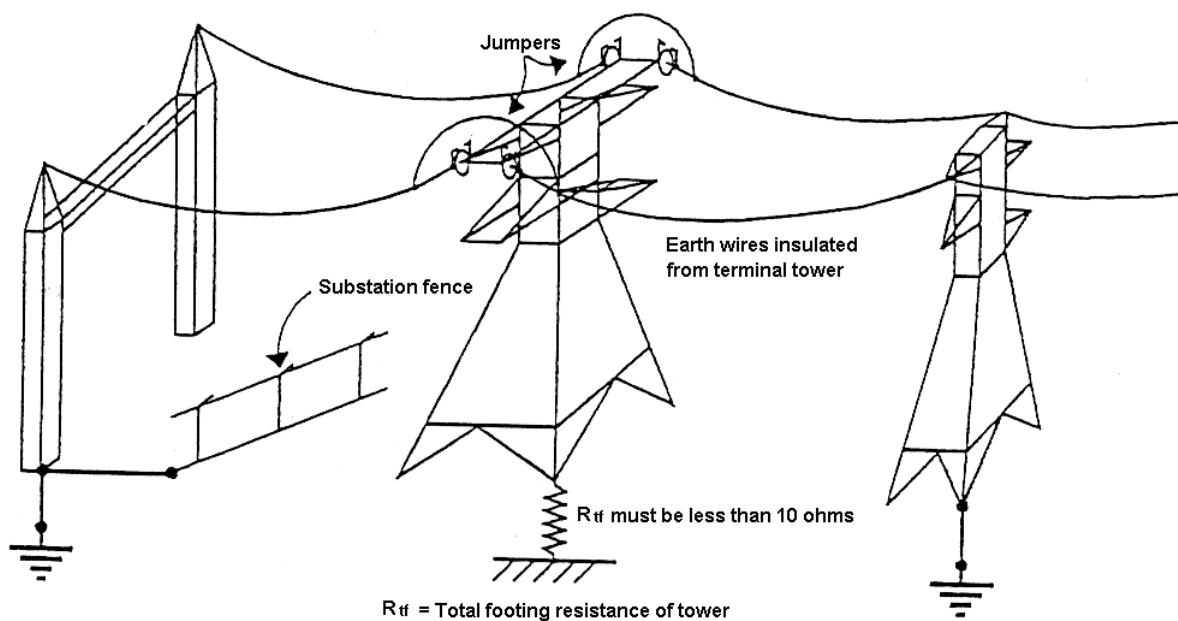


Figure A2: Insulation of earth conductors where terminal tower cannot be connected to substation main earth

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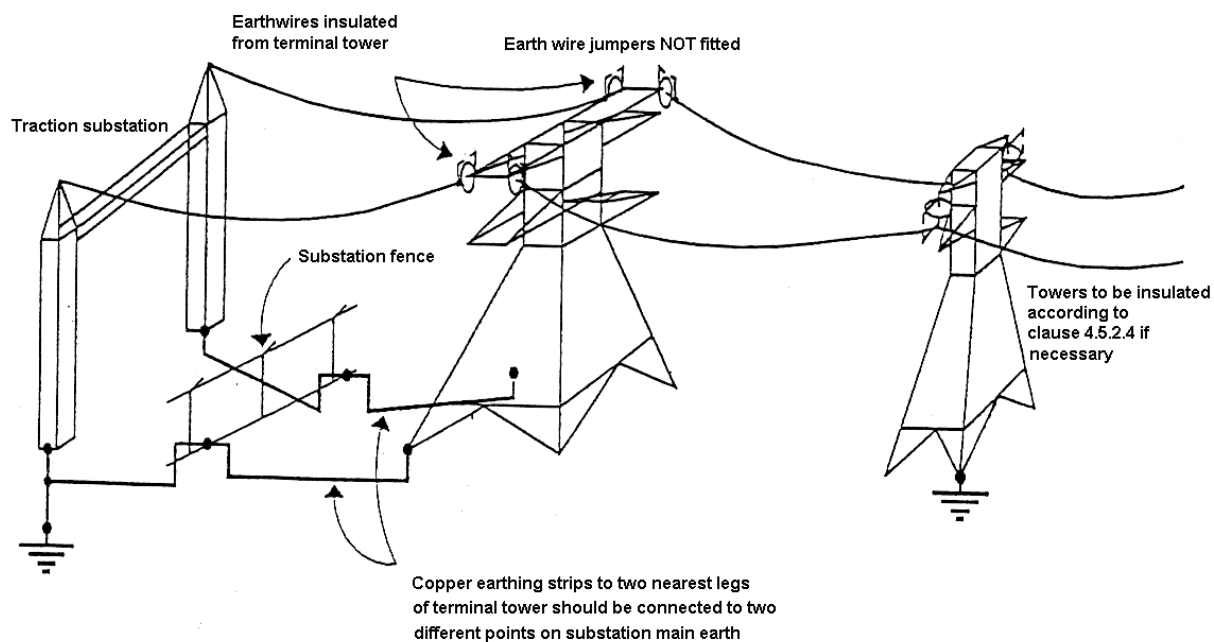
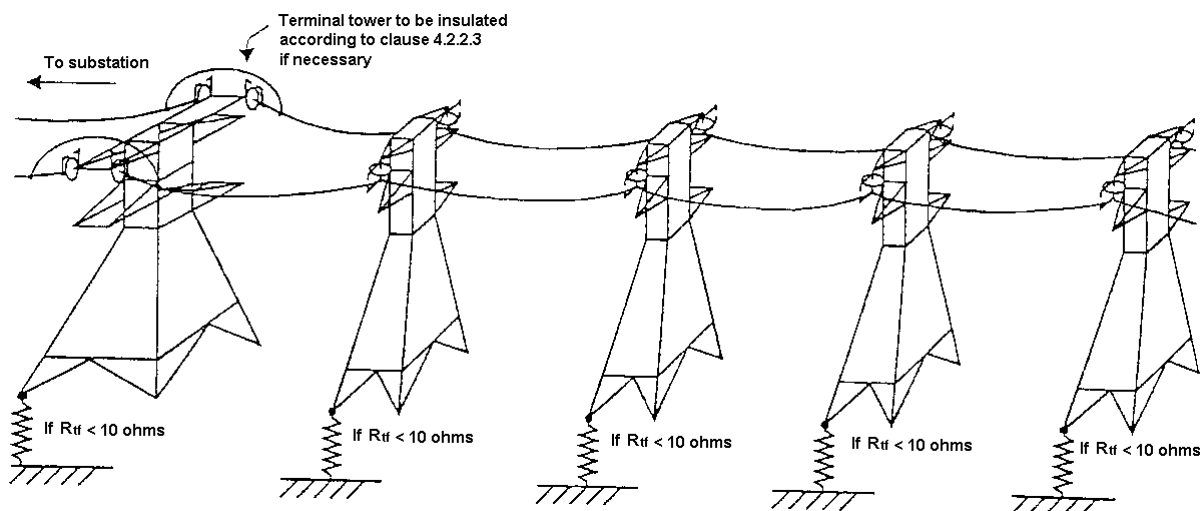


Figure A3: Normal termination at traction substations

Figure A4: Insulation of earth conductors on first five towers out from substation, with footing resistance less than 10 Ω

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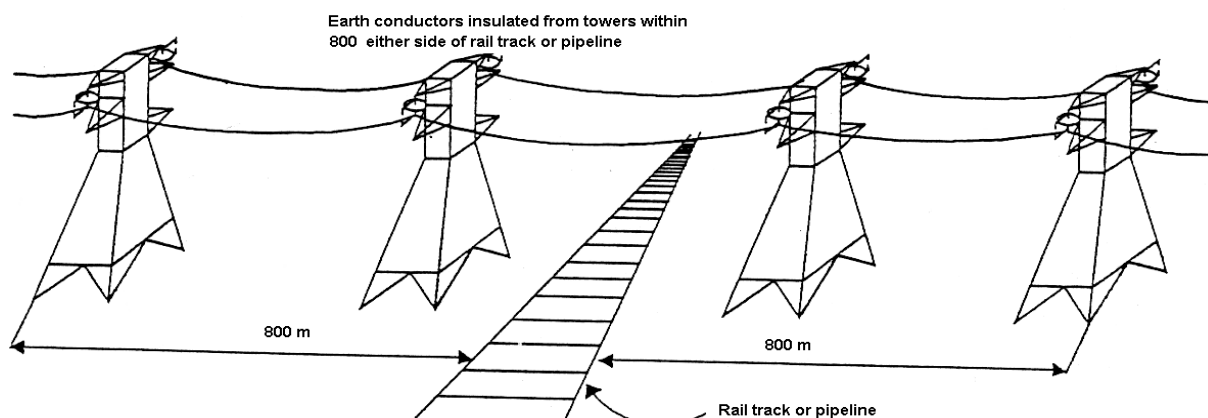


Figure A5: Insulation of earth conductors on suspension towers crossing rail tracks or pipelines

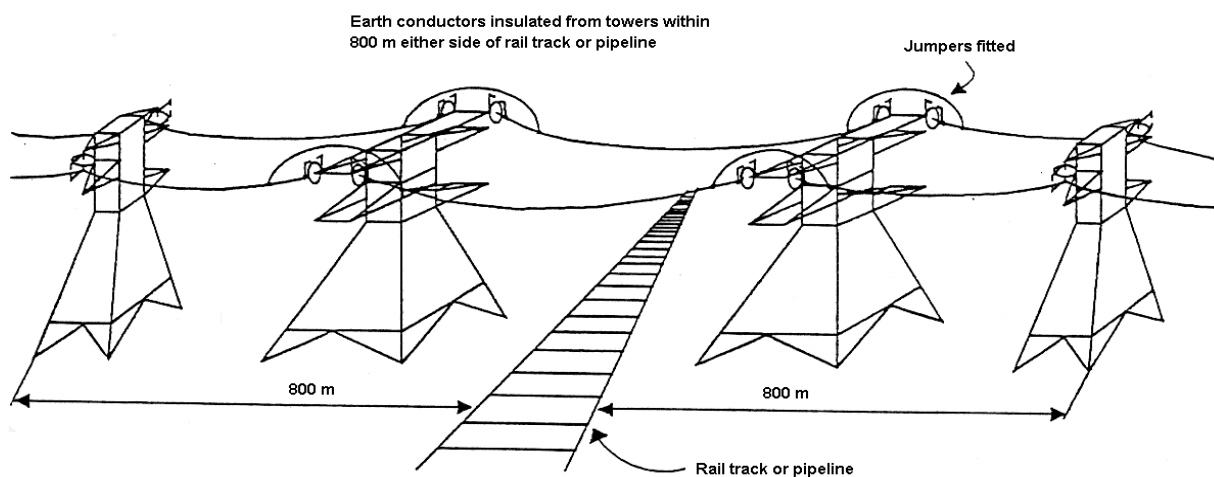


Figure A6: Insulation of earth conductors on suspension and strain towers crossing rail tracks or pipelines

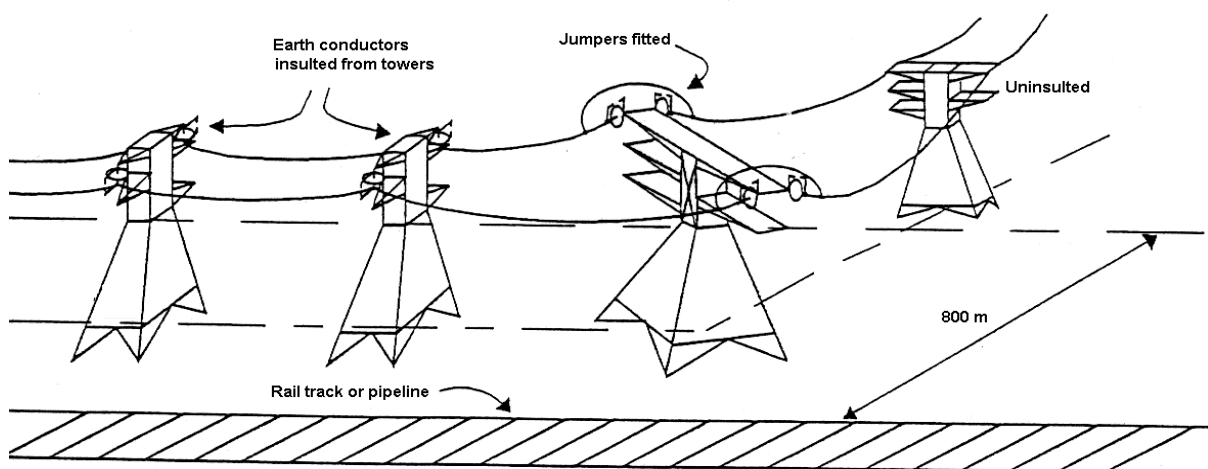


Figure A7: Insulation of earth conductors on routes parallel to rail tracks or pipelines

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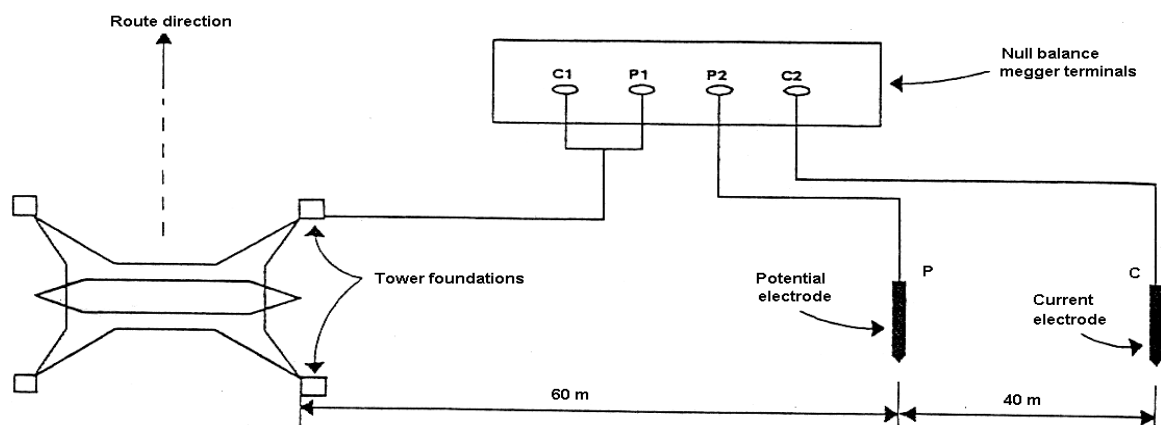


Figure A8: Method of measuring earth resistance on a tower with standard earthing, using a null balance megger

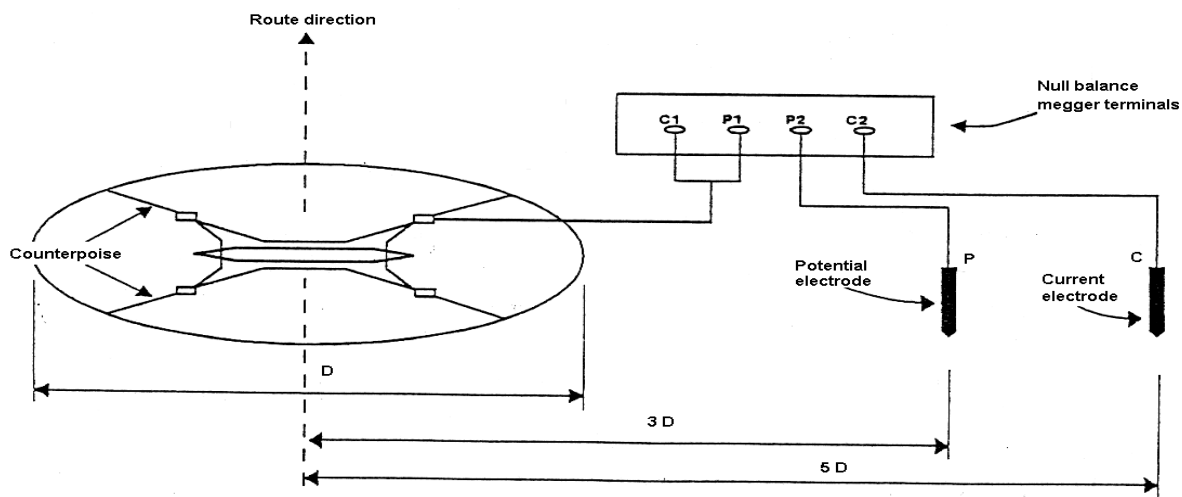


Figure A9: Method of measuring earth resistance on a tower with counterpoise earthing, using a null balance megger

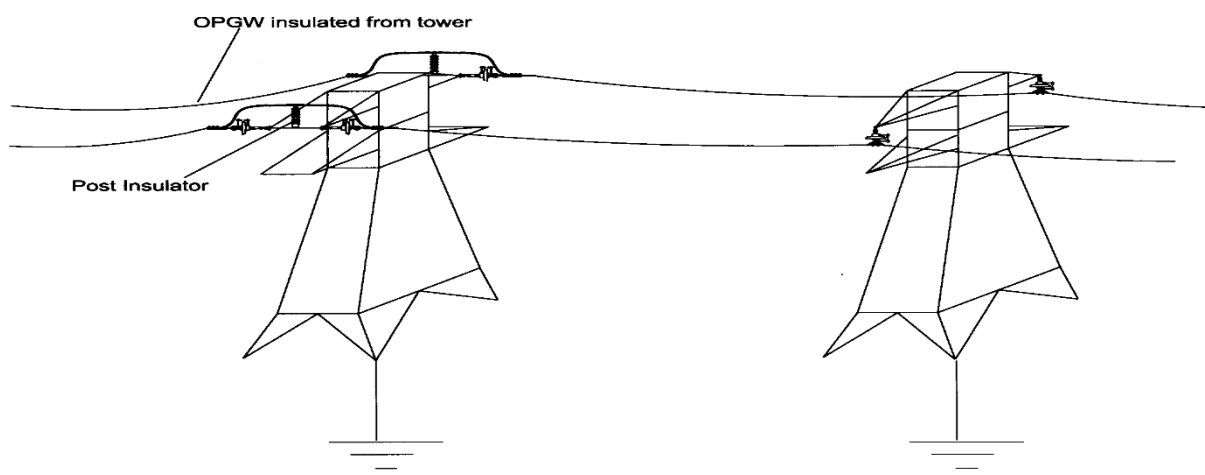


Figure A10: Use of Post insulator at strain towers where OPGW is insulated

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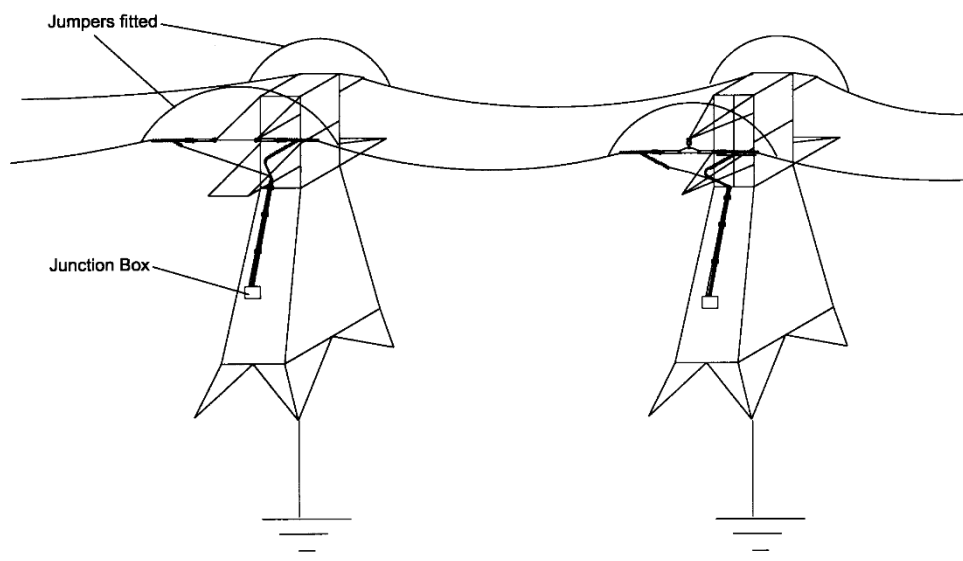


Figure A11: Jumpers fitted where OPGW is connected to a junction box

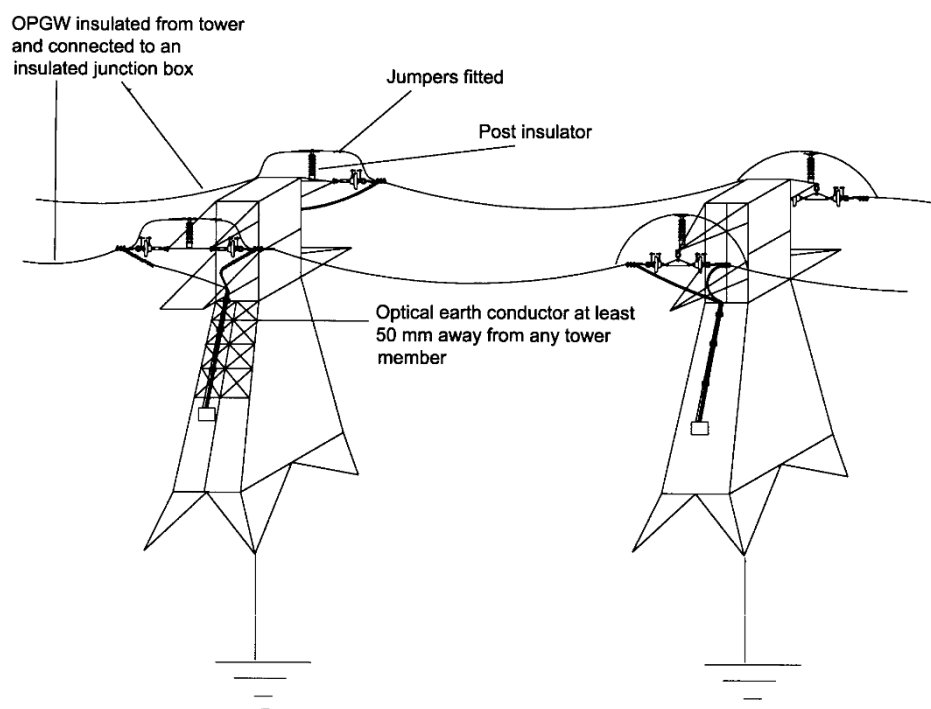


Figure A12: Jumpers and post insulator fitted where OPGW is connected to an insulated junction box

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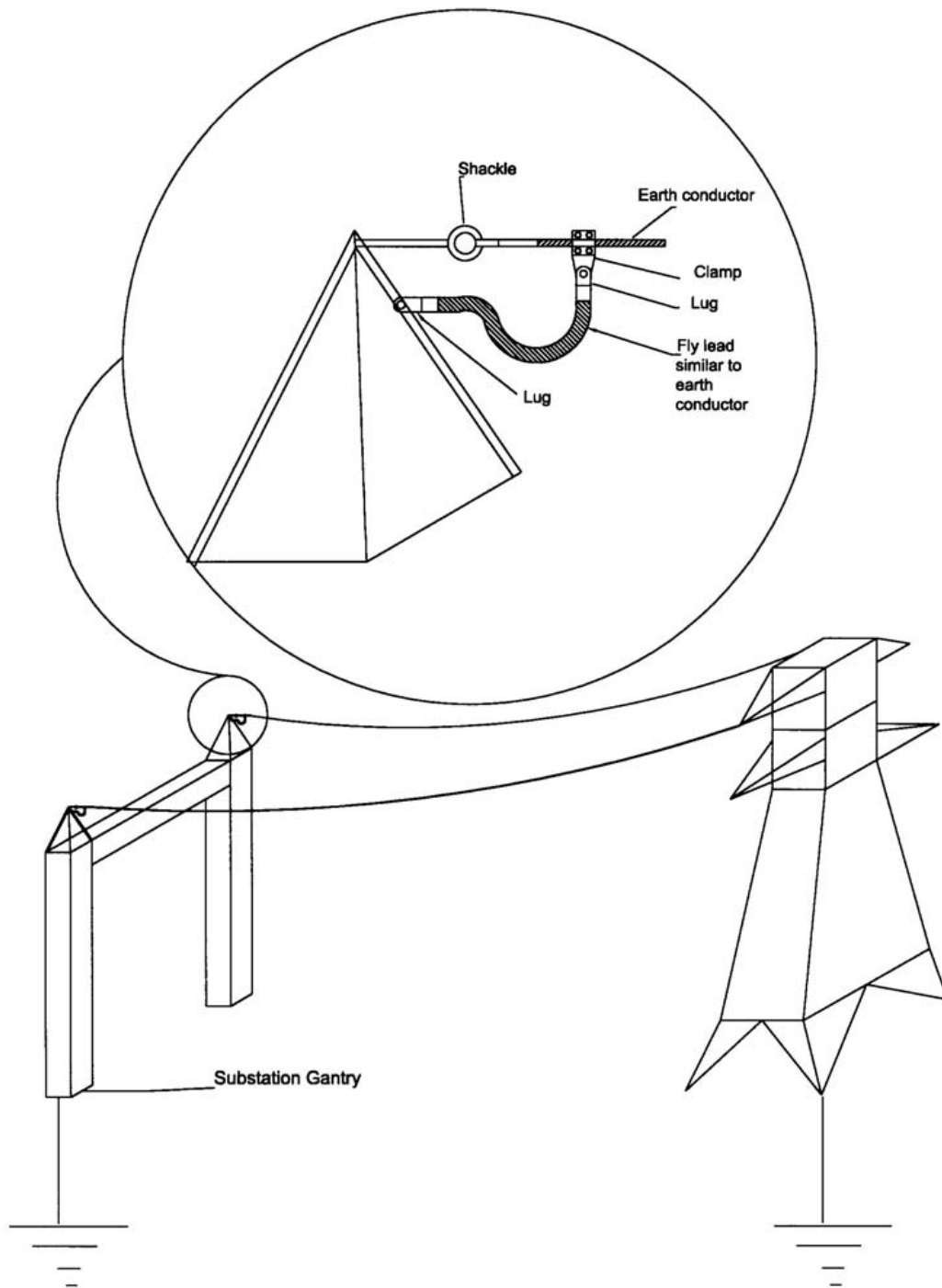


Figure A13: Connection of earth conductor to substation gantry

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Annex B – Assessment Of Step and Touch Potentials On Overhead Powerlines

1) Introduction

The assessment of step and touch potentials must be performed in high public exposure areas.

Examples of these high public exposure areas are :

- Farmlands-dependent on type of farming. If farming is largely labour intensive then this would be classified as high public exposure.
- Busy public areas-jogging trails, schools, urban areas, playgrounds, carpark.
- Encroachments or high possibility of encroachment-shacks.

2) Assessment

The assessment of step and touch potentials must be done using a deterministic approach. The approach to be followed is as detailed in IEEE80.

3) Mitigation

Grading rings in various forms may be used to mitigate for the step and touch potential hazards. In exceptional circumstances continuous counterpoises may be required. Examples of grading rings are shown below:

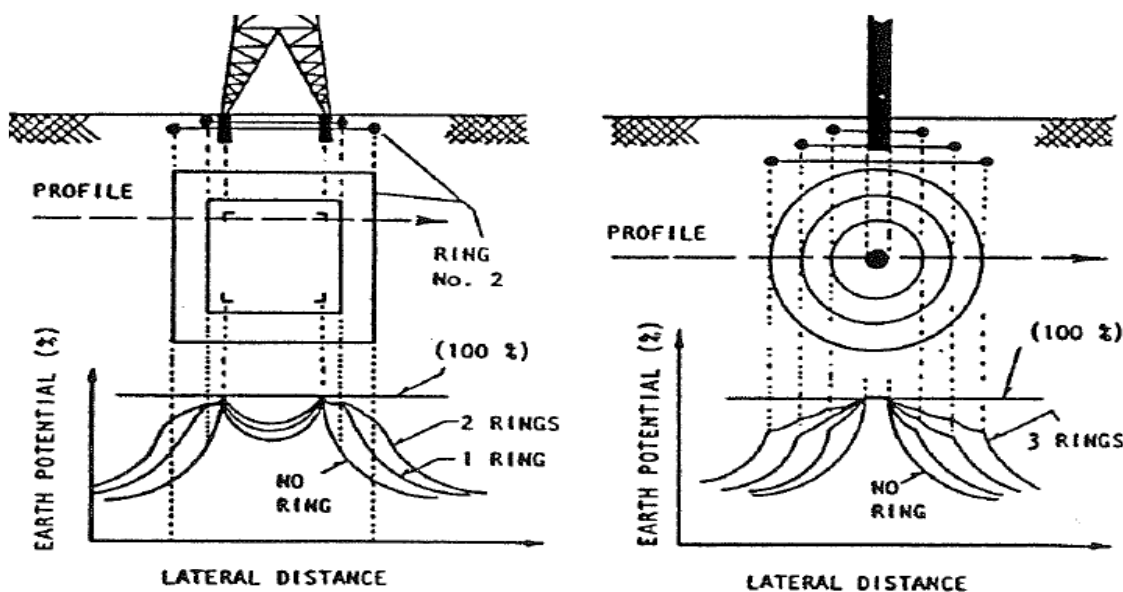


Figure B1: Grading Rings To Limit Touch And Step Potentials