



ESKOM

TRANSMISSION STANDARD

**TITLE: EARTHING OF TRANSMISSION LINE
TOWERS**

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1 Scope

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.

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 Normative references

The following documents contain provisions that, through reference in the text, constitute requirements of this standard. At the time of publication the editions indicated were valid. All standards are subject to revision and parties to purchasing agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the documents listed below. Information on currently valid national and international standards may be obtained from the Information Centre at Megawatt Park and Technology Standardization Department. In cases of conflict, the provisions of this standard shall take precedence:

IEC 60888:1987, *Zinc-coated steelwires for stranded conductors.*

IEC 61089:1991, *Round wire concentric lay overhead electrical stranded conductor.*

SABS 177-1:1990, *Standard specification for insulators for overhead lines of nominal voltage exceeding 1 000 V.*

SABS 0199:1985, *Code of practice for the design and installation of an earth electrode.*

NRS 041:1995, *Code of practice for overhead power lines for conditions prevailing in South Africa.*

TRMASACB2:Rev.0, *Specification for the installation of overhead ground wire with optical fibre (OPGW).*

TRMSCAAD6:Rev.1, *Specification for overhead ground wire with optical fibre.*

Eskom Drawing No. 0.54/393, *Earthing standards.*

3 Definitions and abbreviations

Not applicable.

4 Requirements

4.1 Earthing

4.1.1 Tower footing resistance

4.1.1.1 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 (see annex B). An example demonstrating the use of the backflashover rate as a function of ground flash density is shown in annex C.

4.1.1.2 The terminal tower legs shall be bonded to the main substation earthmat in accordance with 4.2.2.1, 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 .

4.1.1.3 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 .

4.1.1.4 The method to measure footing resistance set out in 4.8 shall be used. Footing resistance shall be measured using an approved earth tester, with the earthing system connected to the tower.

4.1.1.5 Where ground conditions are poor and the specified footing resistances are impossible to achieve using the methods set out in 4.8, the matter shall be referred to Eskom's Project Manager.

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

4.2.1 Line tower

4.2.1.1 The contractor shall supply and install an earth electrode at each individual block of the foundation system of a tower.

4.2.1.2 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.

4.2.1.3 These connections shall consist of a 40 mm \times 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 \times 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.

4.2.1.4 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.

4.2.2 Terminal towers

4.2.2.1 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 see fig.1 in annex A).

4.2.2.2 The contractor shall install, between the two legs of the terminal tower nearest to the substation, a suitable length of 50 mm × 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.

4.2.2.3 Joints between the copper strip and the substation earth mat shall be oxy-acetylene brazed using a minimum 3 mm diameter silbralloys brazing rod or similar brazing rods approved by Eskom in writing.

4.2.2.4 Two 70 mm² solid copper rods shall be used as replacements for each 50 mm × 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.

4.2.2.5 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 4.2.1 shall be installed and the footing resistance of the terminal tower shall be less than 10 Ω.

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

4.3.1 Line guy type towers

4.3.1.1 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 4.2.1.3.

4.3.1.2 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 × 3 mm galvanized mild steel strap, provided no cattle guard is in place.

4.3.1.3 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 × 30 mm galvanized mild steel strap or suitable earth conductor that has been approved by Eskom in writing. The strap on 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.

4.3.2 Single mast guyed towers

Where three single mast structures are used for each circuit, the three bases shall be interconnected using 40 mm × 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 4.7.1.

4.3.3 Cross-rope suspension towers

Line 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 × 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 × 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 4.3.1.3.

4.4 Additional earthing

4.4.1 Where the specified tower footing resistances have not been obtained using the methods described in 4.2 and 4.3 and where additional earthing is required, the following methods shall be used.

4.4.2 Counterpoise earthing

4.4.2.1 Where soil conditions permit, a 15 m radial counterpoise earth shall be added to the two opposite legs of a self supporting tower, or on either side of the base of a guyed tower in the direction of the guys, using 40 mm × 3 mm galvanized strip or a similar material approved by Eskom in writing buried 600 mm below ground level. Where farming activities are likely to take place, the strap shall be buried 1 m below ground level.

4.4.2.2 Should further reduction in the footing resistance be required, another 15 m counterpoise earth shall be added to the other tower legs, or at right angles to those already installed.

4.4.2.3 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, as specified in 4.6.1.

4.4.2.4 If the specified footing resistance is not obtained using these methods, the matter shall be referred to Eskom's Project Manager.

4.5 Earth conductor insulators

4.5.1 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.

4.5.2 Earth conductor insulators shall be installed in the following circumstances:

4.5.2.1 At terminal towers not connected to the main substation earth mat as noted in 4.2.2.5 earth conductor jumpers shall be fitted (see figure 2 of annex A).

4.5.2.2 At traction substation terminal towers, the continuity of the earth conductor shall be broken. No earth conductor jumper leads shall be fitted (see figure 3 of annex A).

4.5.2.3 If any of or all the second, third, fourth and fifth towers from the substation have footing resistances less than $10\ \Omega$, earth conductor jumper leads shall be fitted on strain towers (see figure 4 of annex A).

4.5.2.4 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 (see figures 5A, 5B and 5C of annex A).

4.5.2.5 In 4.5.2.3 and 4.5.2.4 the values of $10\ \Omega$ and 800 m shall be used as a guideline. However, these values shall be verified for new designs.

4.5.2.6 At any tower indicated by Eskom, for example, to limit the losses in the earthwire.

4.6 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.

4.7 Optical earth conductor (OPGW)

4.7.1 A post insulator shall be fitted at strain towers where the optical earth conductor is insulated (see figure 8 for details).

4.7.2 Earth conductor jumpers shall be fitted at towers where the optical earth conductor is connected to a junction box (see figure 9 for details).

4.7.3 Earth conductor jumpers, post 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 (see figure 10 for details). For details of the actual fittings to be used, see TRMASACB2.

4.8 General

4.8.1 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 450 mm above finished ground level and 500 mm below finished ground level.

4.8.2 The earth conductor or OPGW with junction box shall, in all circumstances, be bonded to the gantry (see figure 11 for details).

4.9 Tower footing resistance measurements

4.9.1 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.

4.9.2 Method of testing

4.9.2.1 Tower with standard earthing

The circuit diagram for testing is shown in figure 6 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. The leads and distances with the HW2A meter shall be 75 m and 40 m as supplied by the manufacturer.

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.

4.9.2.2 Tower with counterpoise earth

The same method as in 4.9.2.1 shall be used, but the distances to the electrodes shall be as follows:

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

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

4.9.2.3 If a continuous counterpoise earth is run from tower to tower the methods in 4.9.2.1 and 4.9.2.2 cannot be used and the earthing resistance need not be measured.

4.9.3 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.

4.9.4 Footing resistance meters

4.9.4.1 The null balance insulation tester and HW2A high frequency meter from ABB are approved meters to be used to take footing resistance measurements. Measurements with a null balance insulation tester shall be done BEFORE the overhead earth conductors are connected to the tower or the earth conductors can be temporarily isolated.

4.9.4.2 Measurements with the HW2A meter may be done with overhead earth conductors connected to the tower.

4.9.4.3 Should the contractor wish to use another type of meter, the instrument and details of its intended application shall be submitted to Transmission Line Engineering Department for approval prior to implementation.

Annex A
(informative)

Figures showing various earthing installations

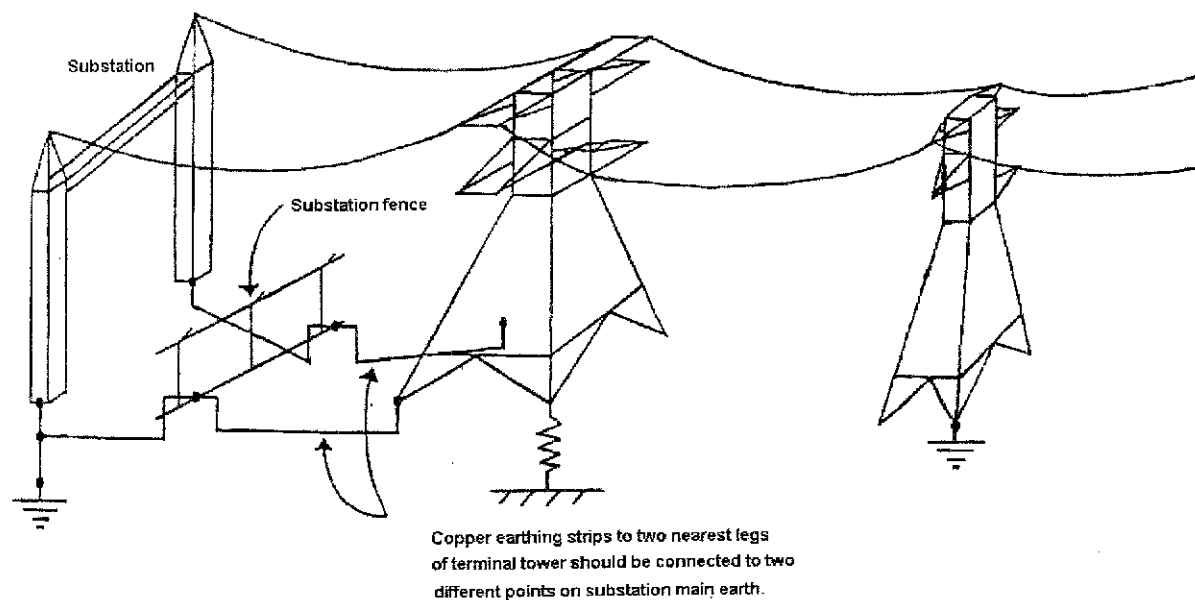


Figure 1 – Terminal tower bonded to substation earthmat

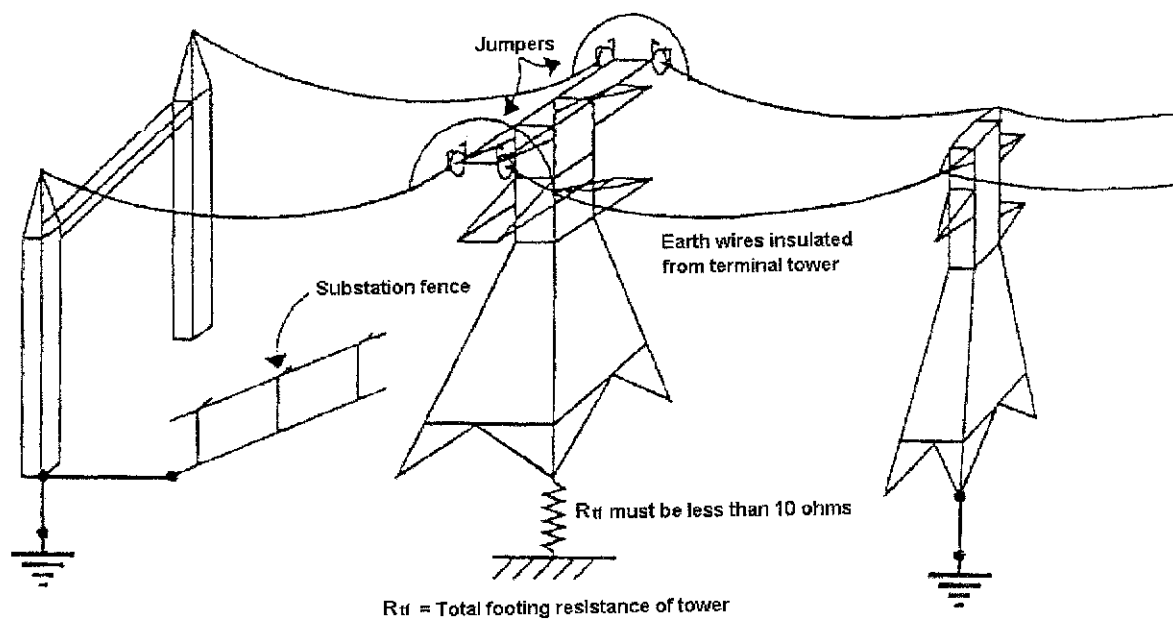


Figure 2 – Insulation of earth conductors where terminal tower cannot be connected to substation main earth

Annex A
(continued)

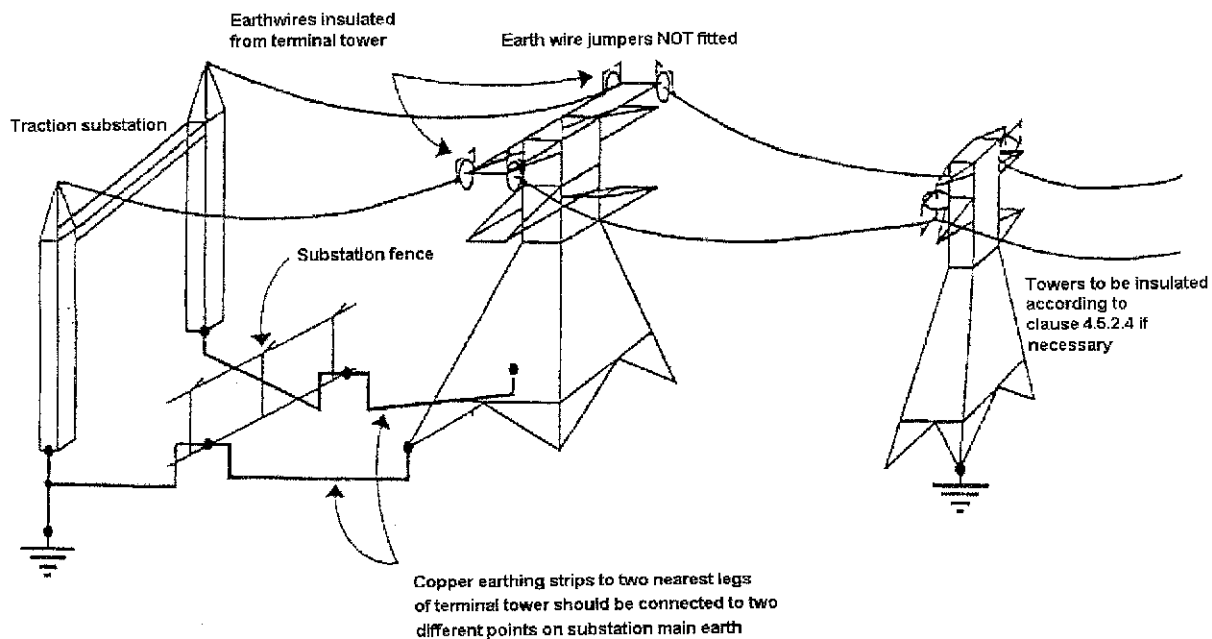


Figure 3 – Normal termination at traction substations

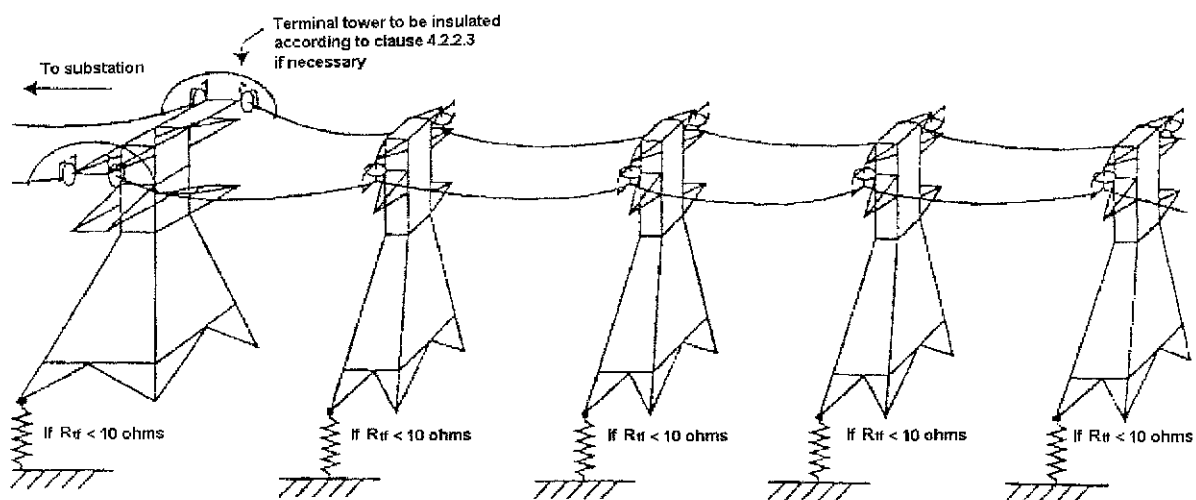


Figure 4 – Insulation of earth conductors on first five towers out from substation, with footing resistance less than 10 Ω

Annex A
(continued)

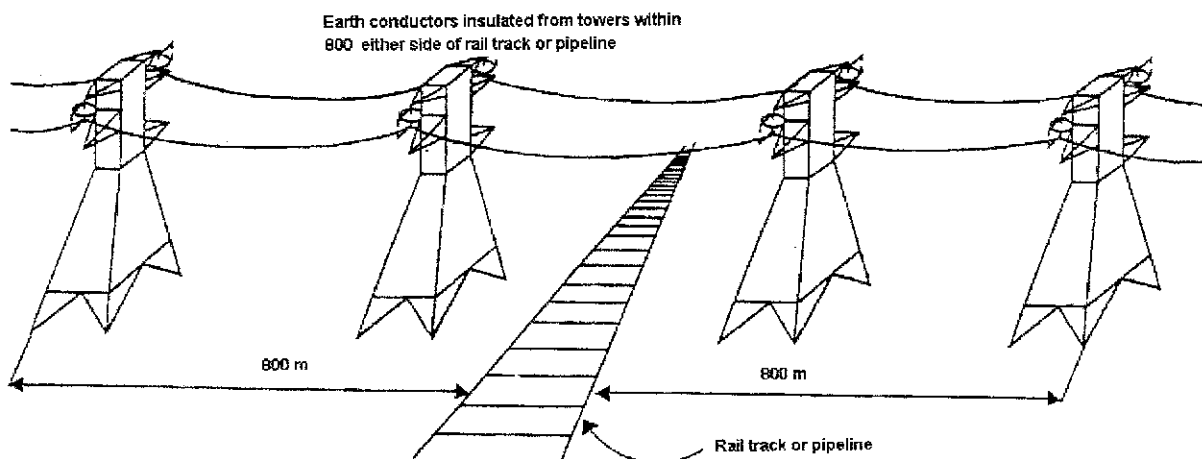


Figure 5A – Insulation of earth conductors on suspension towers crossing rail tracks or pipelines

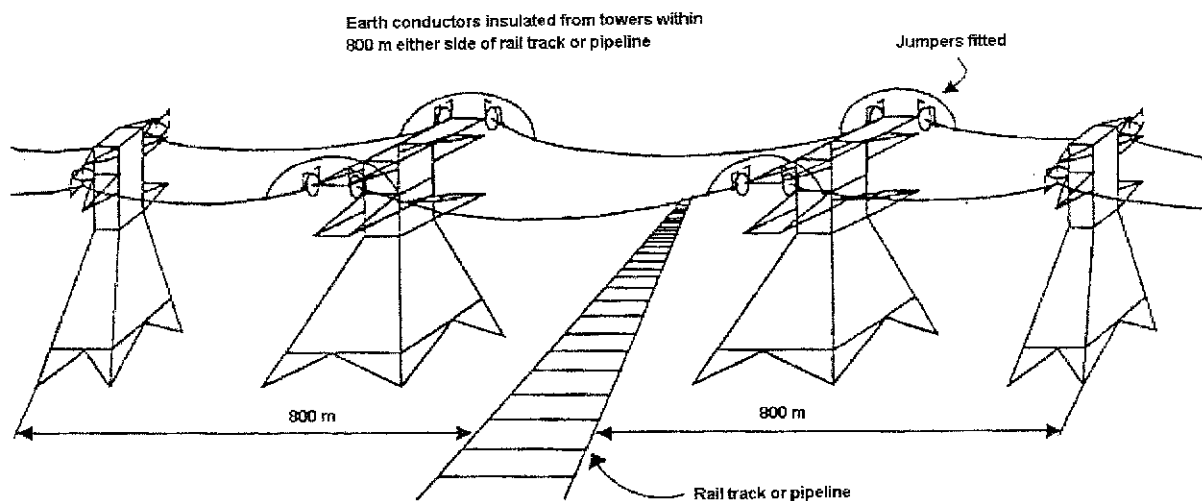


Figure 5B – Insulation of earth conductors on suspension and strain towers crossing rail tracks or pipelines

**Annex A
(continued)**

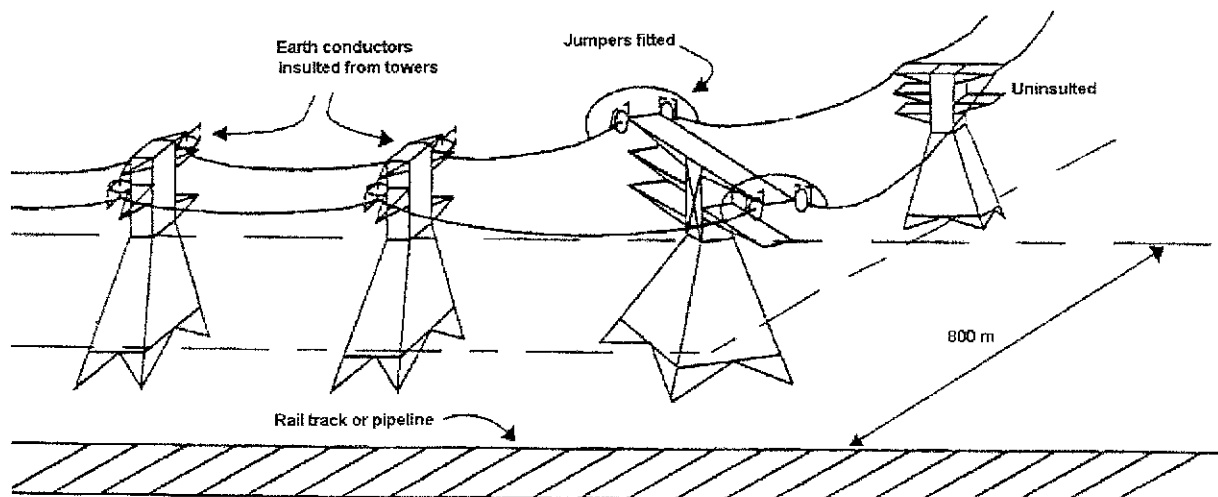


Figure 5C – Insulation of earth conductors on routes parallel to rail tracks or pipelines

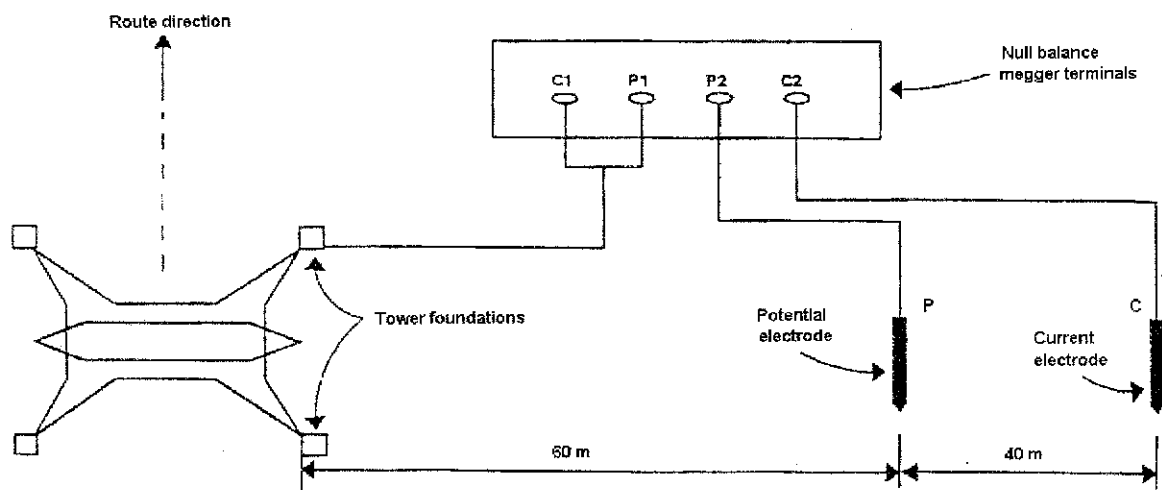


Figure 6 – Method of measuring earth resistance on a tower with standard earthing, using a null balance megger

Annex A
(continued)

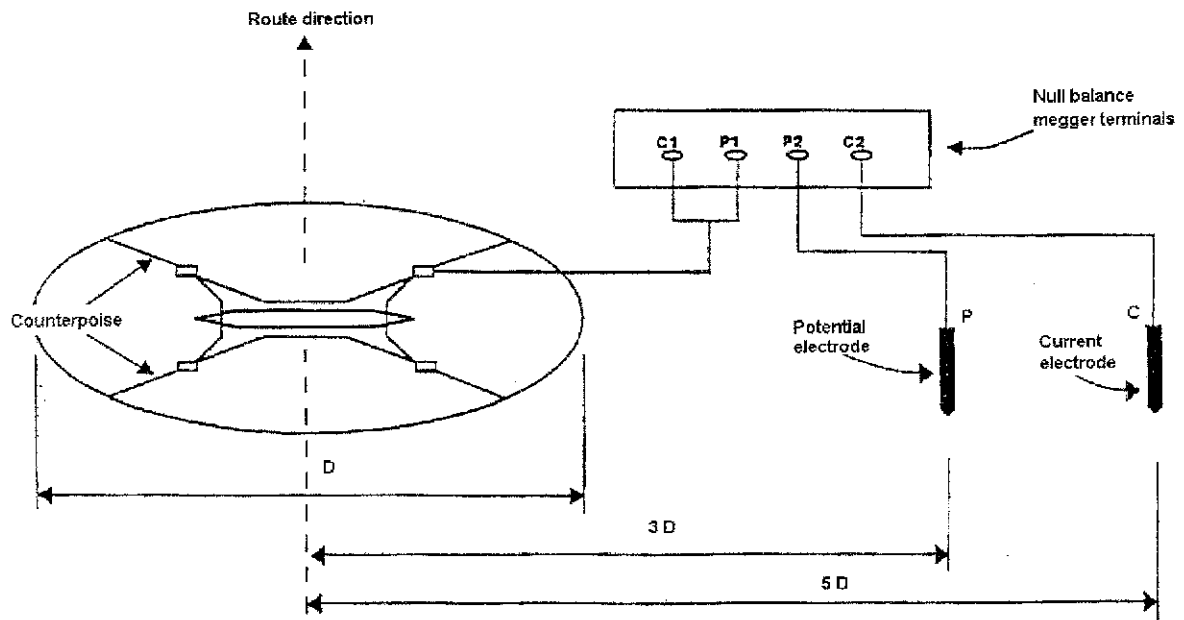


Figure 7 – Method of measuring earth resistance on a tower with counterpoise earthing, using a null balance megger

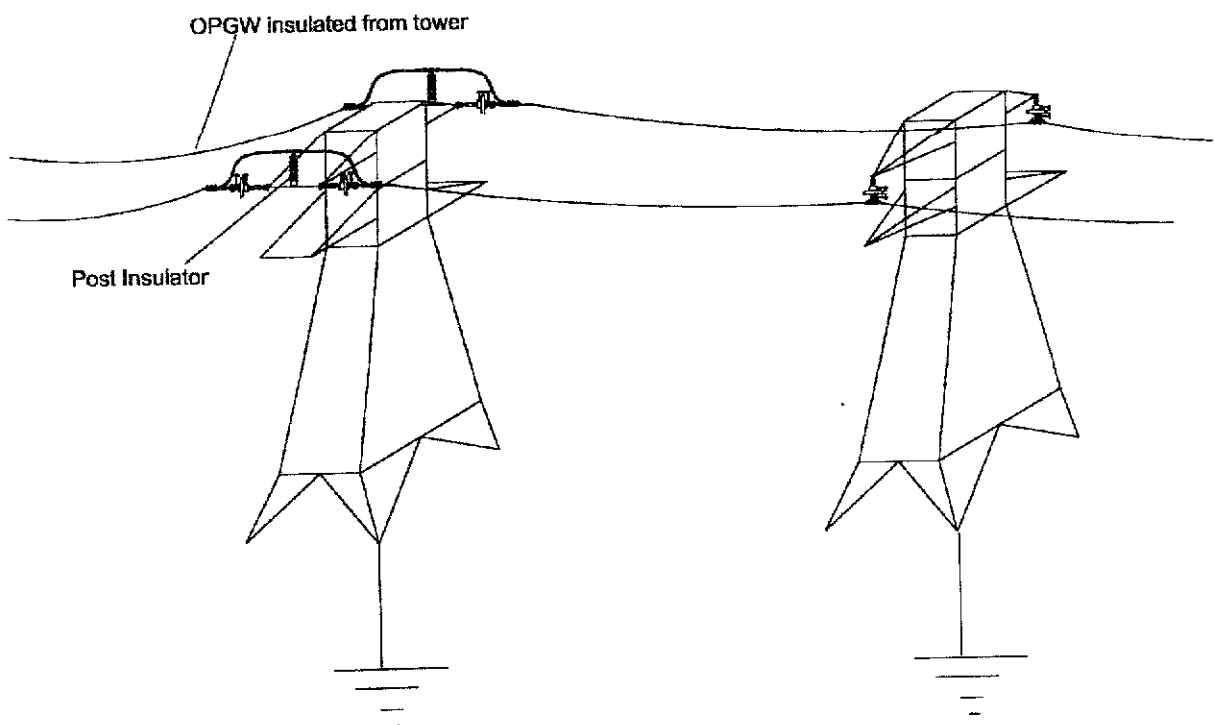


Figure 8 – Use of Post insulator at strain towers where OPGW is insulated

Annex A
(continued)

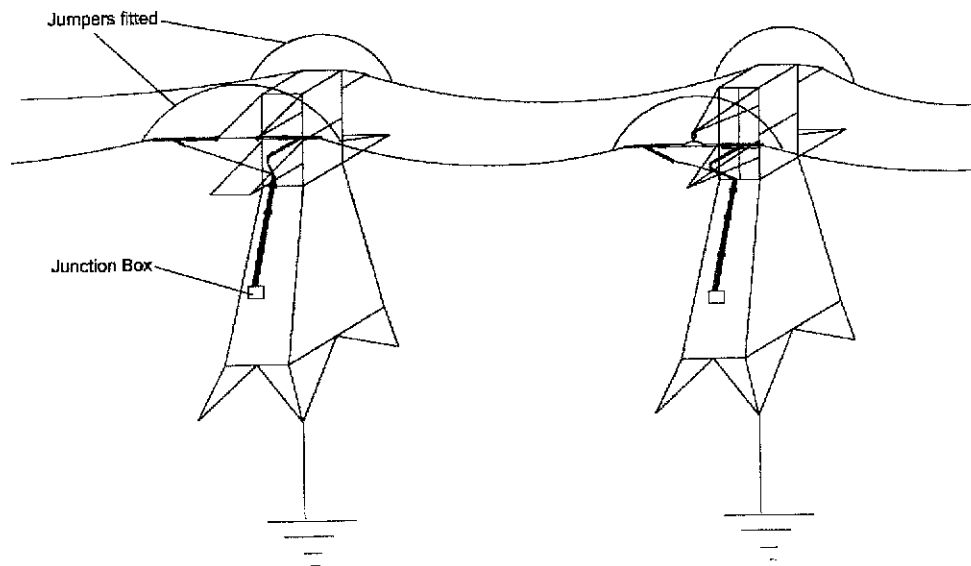


Figure 9 – Jumpers fitted where OPGW is connected to a junction box

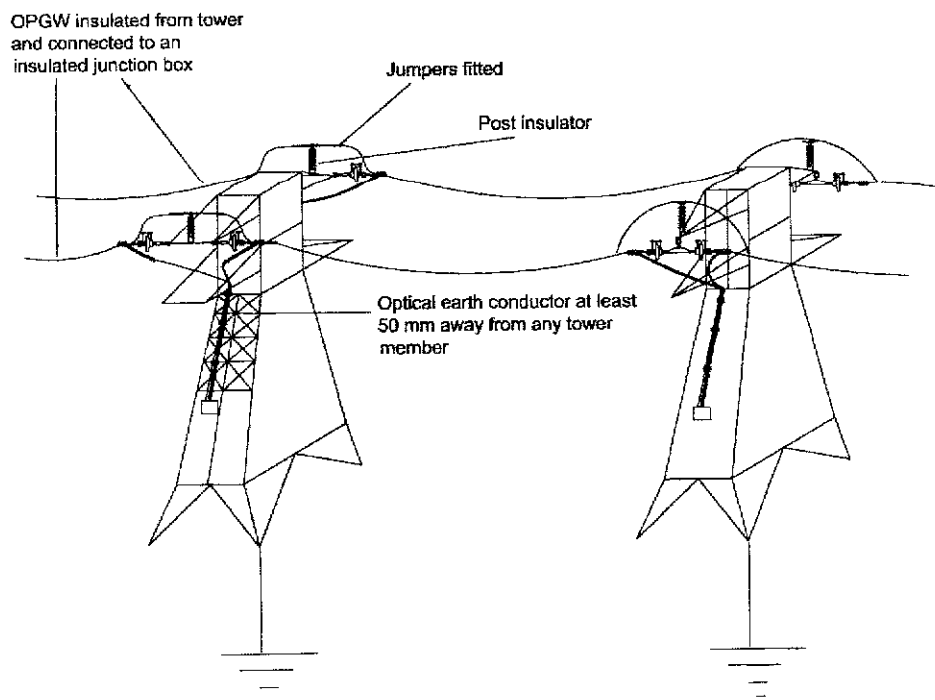


Figure 10 – Jumpers and post insulator fitted where OPGW is connected to a insulated junction box

Annex A
(concluded)

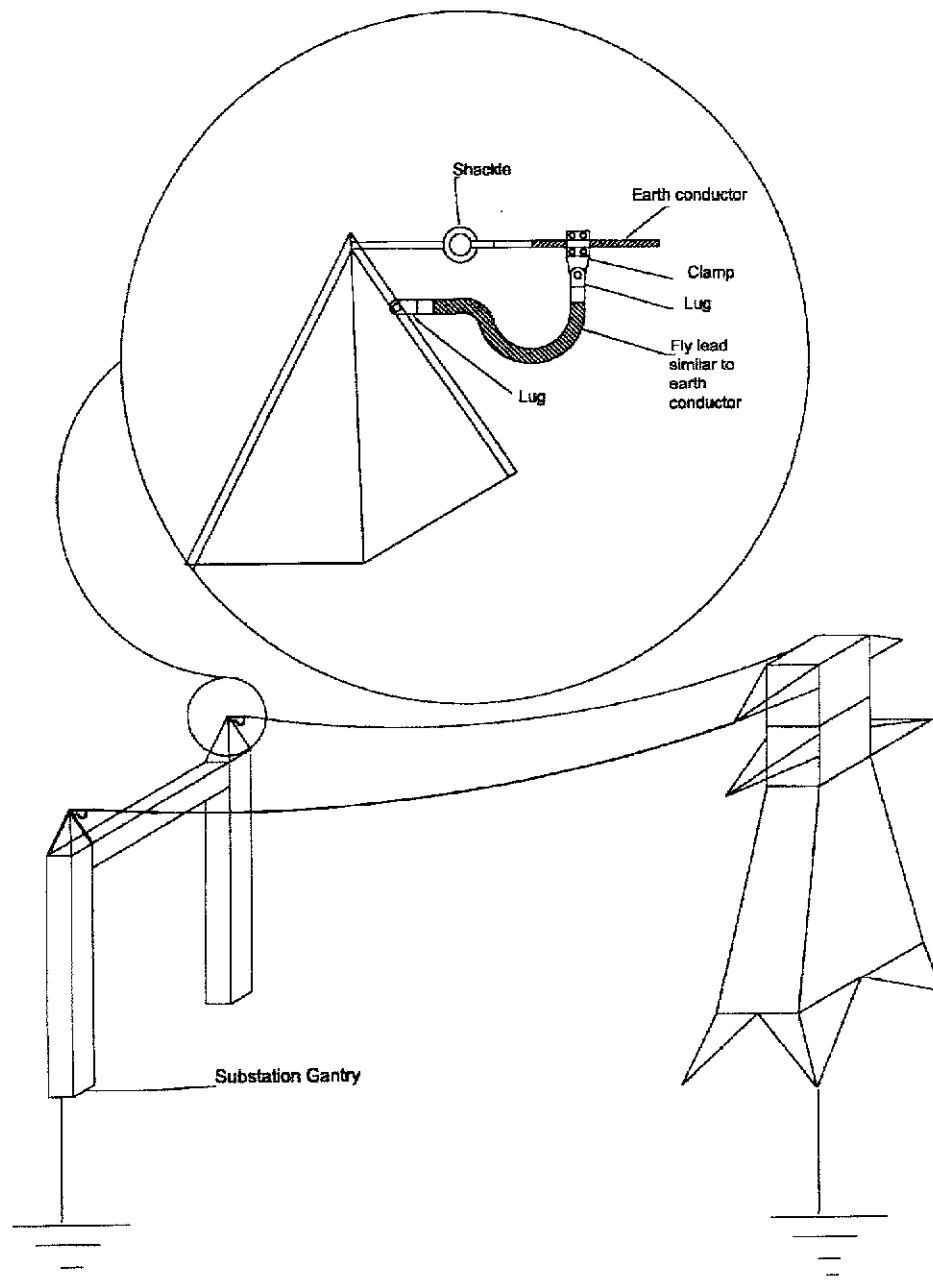
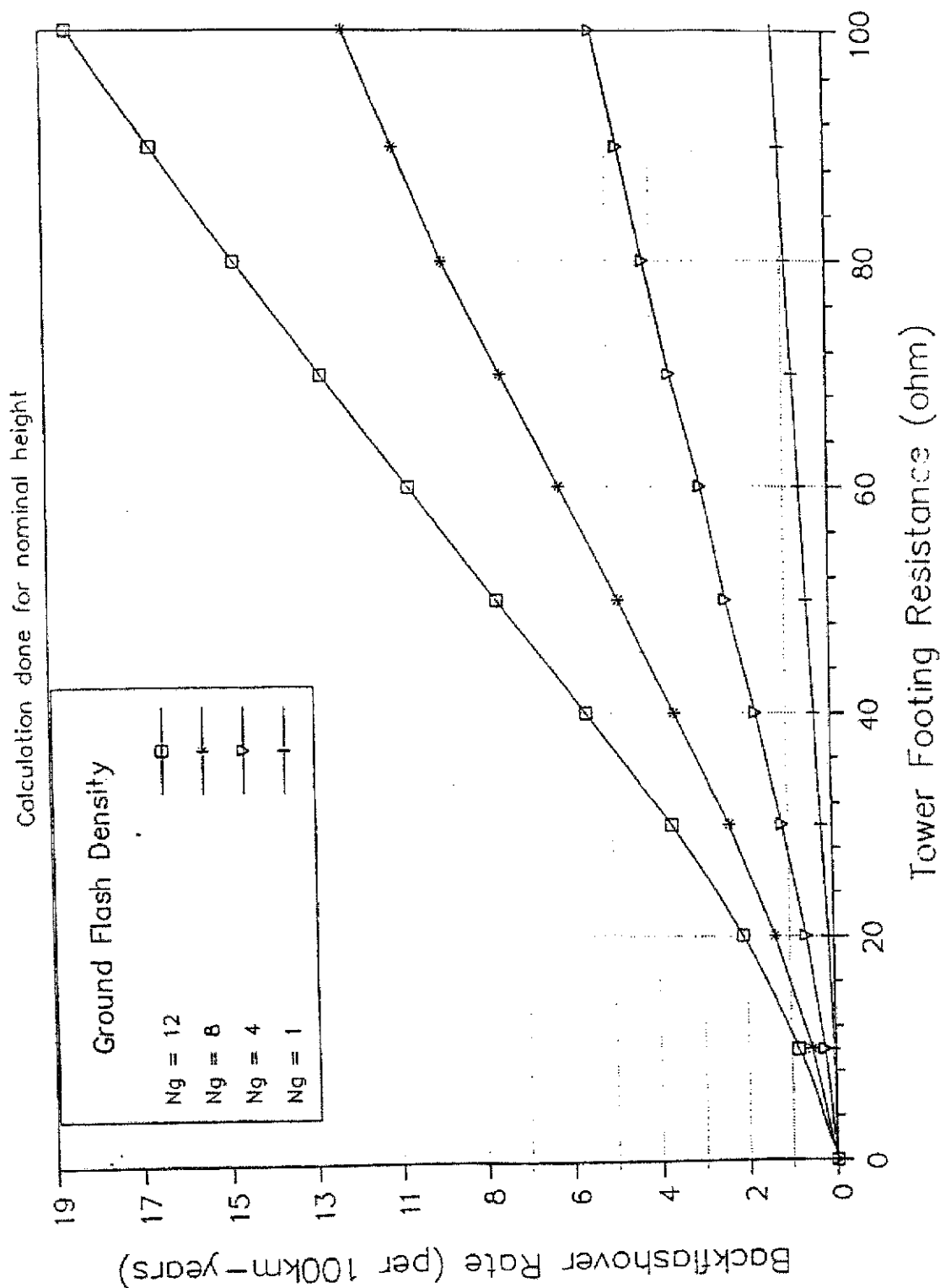


Figure 11 – Connection of earth conductor to substation gantry

Annex B
(continued)

400kV Suspension Tower Type 520A



400kV Guy Suspension Tower Type 520B

