Eskom	Standard	Technology

Title: **EARTHING STANDARD**

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PCM Reference: **240-151017656**

SCOT Study Committee Number/Name: **Earthing Working Group**

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1. Introduction

Sufficient earthing of sub-transmission line structures is of the utmost importance for the earthing of a line. Emphasis must be given to the safety and reliability of a line in order to maintain continuous supply. This Standard has been prepared to promote a common understanding, throughout Eskom for the earthing of sub-transmission line structures.

2. Supporting Clauses

2.1 Scope

2.1.1 Purpose

This standard sets out distribution requirements for the earthing of sub-transmission lines, shielding wire arrangement 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 document shall apply throughout Eskom Holdings Limited Divisions.

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] ISO 9001 Quality Management Systems.

[2] IEC 60050-466:1990, International Electrotechnical Vocabulary – Chapter 466 Overhead lines.

[3] IEC 61089:1991, Round wire concentric lay overhead electrical stranded conductors.

[4] SABS 177-1:1990, Insulators for overhead lines of nominal voltage exceeding 1 000 V – Part 1: Ceramic and glass string insulator units and insulator strings and sets.

[5] SABS 0199:1985, The design and installation of an earth electrode.

[6] SABS 0280:1998, Code of practice for overhead power lines for RSA.

[7] Eskom Specification DCD 3212, Earthwire insulation on transmission lines.

[8] Eskom Drawing No. 0.54/393

[9] Guidelines on the Earthing of the Terminal Structure of the Distribution Line – K Rozmiarek.

[10] Tst 41-321 :Rev.1, Earthing of transmission line towers.

[11] TRMSCAAD6:Rev.0, Specification for overhead ground wire with optical fibre

2.2.2 Informative

None

2.3 Definitions

2.3.1 General

Definition	Description
back flashover	Insulation breakdown caused by the rise in potential when the lightning strikes the shield wire, due to the fact that neither the pole footing resistance nor the surge impedance of the conductor are zero. Also, excessive rise in potential results in a flashover from the shield wire (or earth wire) back to the phase conductors.
backfill	The soil removed during excavation, with or without specific conductive mixture, replaced after the installation of the foundation
basic insulation level	The overall designed insulation level of the system to withstand lightning impulses and switching surges
clamp	Any fitting that is designed to be fixed on to a conductor.
conductor	A wire or combination of wires not insulated from one another, suitable for carrying electric current.
counterpoise	A conductor or system of conductors, buried in the ground and connected to the footings of the line supports.
earth	The conducting mass of earth where the electric potential at any point is conventionally taken as zero.
earth electrode	One or more horizontal and/or earth rods bonded together and embedded in the earth for the purpose of making effective electrical contact with the general mass of the earth and to act as a path for the discharge of either lightning currents or faults currents.
earth resistance	The resistance of the electrode and surrounding earth as measured between the earth lead and the general mass of the earth.
earthed	Connected to the general mass of earth in such a manner to ensure an immediate safe discharge of electrical energy.
footing resistance	The resistance of a structure to earth.
guyed tower	A structure that is provided with additional staywires to stabilize the tower body
insulator	A device intended for electrical insulation and mechanical support of equipment or conductors that are subject to electrical potential differences.
jumper	A short length of conductor, not under mechanical tension, making an electrical connection between two separate sections of a line.
shield wire	A conductor connected to earth at some or all supports, that is suspended above the line conductors to provide a degree of protection against lightning strikes.
structure	A device designed to carry, through the insulators, a set of conductors of the line.
stub	An element used to connect the leg of a support to the foundation
terminal structure	A structure that is designed to terminate the line tension of conductors on one side
tower	A support that may be made of steel, wood, concrete and comprising a body which is normally four-sided, and cross-arm

2.3.2 Disclosure Classification

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

2.4 Abbreviations

Abbreviation	Description
BIL	Basic insulation level
TPS	Three point star electrode

2.5 Roles and Responsibilities

Not applicable.

2.6 Process for monitoring

Not applicable.

2.7 Related/Supporting Documents

Not applicable.

3. Earthing Standard

3.1 Requirements

3.1.1 Earthing

a) Tower Footing Resistance

b) The desired nominal tower footing resistance for 66 kV to 132 kV lines shall be 20 Ω.

c) Where, for any reason, it is not possible to bond a terminal structure to the substation or traction substation earth mat, an earthing system as described in 4.10 shall be installed and the footing resistance of the terminal structure shall be less than 10 Ω.

Note: The specified values of footing resistances in b) to d) are not fixed. Where they cannot be achieved a higher back flashover rate can be expected on the affected sections of the line. Graphs in Appendix D indicate the higher back flashover rate.

d) The footing resistance of the structures up to 1km from the substation, on 66 kV to 132 kV lines shall be less than 20 Ω. For footing resistances less than 10 Ω, refer to 4.9.2.3.

e) The relevant method, as set out in 3.1.13 shall be used to measure footing resistance.

f) Where ground conditions are poor and the specified footing resistance is impossible to achieve using the methods specified in 3.1.8, the matter shall be referred to the relevant Eskom Project Engineering Manager concern.

3.1.2 Types of Earth Electrodes

Following are the types of earth electrodes to choose from:

- Buried horizontal wire
- Three-point star
- Ring of wire
- Buried vertical wire

3.1.3 Earthing systems for pad and chimney foundations (self-supporting towers)

a) Line tower

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

Before the foundation is cast, a proper connection shall be made, at each foundation, between the tower stub steel and the main reinforcing bar (rebar), both connections being within the concrete.

These connections shall consist of a 40 mm × 3 mm galvanised mild steel strap or suitable earth conductor that has been approved by Eskom in writing (see figure A.1 in appendix A).

The earth conductor shall be bolted to the tower leg and shall be connected to the foundation rebar using brazing or a method approved by Eskom in writing.

3.1.4 Earthing system for piled foundations

Each leg shall be effectively connected to the reinforcing bar of the pile cap.

All reinforcing bars are to be connected in a proper mechanical fashion. Pile caps to be properly mechanically connected to the reinforcing bar in piles. Where the described footing resistance is not achieved, additional earth electrode shall be applied. The TPS is preferred.

3.1.5 Earthing system for single steel pole and grillage (unguyed intermediate tower)

This type of foundation obviates the need for a separate (additional) earth electrode unless the desired footing resistance is not achieved.

3.1.6 Earthing systems drilled foundations and guyed towers

a) Line guy type structures

A connection within the concrete shall be made between the main foundation rebar and one of the anchor bolts.

Three anchor bolts shall be bolted onto each ball and socket for the masts. The two masts shall be connected together using 40 mm × 3 mm galvanized mild steel strap, provided no cattle guard is in place.

This connection shall consist of 40 mm × 3 mm galvanised 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 brazing or an alternative method approved by Eskom in writing.

b) Guyed intermediate single pole structure

The four guys act as earth electrodes. As the tower planted at a very shallow depth below ground depth is so shallow, the tower itself cannot be regarded as an adequate earth electrode. (refer to D-DT-0640).

Where three single mast structures are used for each phase, the three bases shall be connected together by means of 40 mm x 3 mm galvanized steel strap, each with an 18 mm diameter hole at each end that is buried 600 mm below ground level. The connection between the bases and the mild steel strap shall be achieved by bolting the strap to the tower leg using a 16 mm (min) diameter bolt.

3.1.7 Earthing systems for wood poles

An earth wire shall be connected with the horizontal shield wire and run straight down to the bottom of the pole. On the butt end of the pole, the earth wire shall be coiled and stapled. Where H-pole and 5 pole structures are used, two earth wires shall be used on each pole. The size of the earthwire can be 7/3.35 or 3/3.35. Additional earthing shall only be applied if the required earthing resistance is not achieved.

3.1.8 Additional earthing

Where the specified tower footing resistance has not been obtained using the methods described in 3.1.3 through to 3.1.10 and where additional earthing is required, the following methods shall be employed.

a) Horizontal earth electrode

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 brazed copper joints.

Various types of counterpoise installations are shown in figures 12, 13, 14 and 15 in Appendix C.

The trench for the counterpoise earth need only be as wide as is necessary to achieve the specified depth.

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

Where counterpoise earthing is to be used in rocky areas, trenches shall be backfilled in such a manner that the counterpoise is encased with 100 mm(min) of an approved mixture, as specified in a).

Should the specified footing resistance not be obtained using these methods, the matter shall be referred to the relevant Eskom Project Engineering Manager responsible.

b) Vertical earth electrode

Where space does not permit, the vertical spike can be connected to the horizontal electrode.

3.1.9 Shield wire

a) Shield wire insulation

The standard shield wire to be used shall be 7/3,35 mm but final selection shall be dependent upon anticipated fault levels, and the number of the shield wires to be used.

Shielding wire on the line side of the steel terminal structure shall be bonded to the structure itself or to an earthing lead in the case of concrete and wood pole structures.

Shielding wire on all intermediate structures on which the shield wire is not insulated shall be bonded to the structure or an earthing lead.

The shield wire shall be able to withstand the rated fault current for 3 s. Table 1 gives the 3 s rating of different size shield wires.

Table 1: Shield Wire Ratings

1	2	3
Shield wire type	**Rated fault current (kA)**	**Time (s)**
7/3,35	7,455	3
19/2,65	12,555	3

b) Shield wire insulators

Shield wire insulators shall be 120 kN (tensile strength) units in accordance with D-DT-7012. Where earth wire insulators are fitted with adjustable spark-gaps, the gap shall be set to 6 mm for all cases.

Shield wire insulators shall be installed in the following circumstances:

At terminal towers not connected to the main substation, earth mat shield wire jumpers shall be fitted (see figure 3 in Appendix A).

At d.c. traction substation terminal towers, the continuity of the shield wire shall be broken. No shield conductor jumper leads shall be fitted (see figure 5 in Appendix A).

If any of the towers within 1km of the substation has a footing resistances less than 10 Ω, then shield conductor jumper leads shall be fitted on strain structures only (see figure 6 in Appendix A).

On all towers within 800 m of electrified railway tracks or metal pipelines where the power line either crosses or runs parallel to the service in question, unless otherwise directed by Eskom's site representative. Shield conductor jumper leads shall be fitted on strain towers only (see figure 7, 8 and 9 in Appendix A).

In 3.1.8a and 3.1.8b the values of 10 Ω and 800 m shall be utilised only as a guide, however, these values must be verified for all new designs.

At any tower indicated by relevant authority.

3.1.10 Terminal towers

a) The leg of the terminal tower shall be bonded to the main substation earth mat using a bonding strap (see figure 1 in appendix A).

b) The bonding strap shall be a suitable length of 50 mm x 3 mm flat copper strap with an 18 mm diameter hole drilled at each end. The strap shall be buried 800 mm below ground level. The strap shall be connected between the tower leg and the substation earth mat.

c) Joints between the copper strip and the substation earth mat shall be oxy-acetylene brazed using a 3 mm diameter (minimum), silbralloy brazing rod or similar brazing rods as approved by relevant authority in writing. The other end of the copper strap should be bolted to the terminal structure. The bolted connection at the terminal structure and the exposed portion of the earth strap shall be painted with a suitable bitumastic compound.

d) A 50 x 3mm length of copper strap shall be replaced by a solid 10mm diameter copper conductor (i.e. where the substation earth mat consists of round copper conductors). Under these circumstances, connections shall be brazed/compression joints in accordance with Eskom drawing number 0.54/393.

e) Should the previous clause apply, bonding to the terminal structure shall be by means of tinned copper crimping lugs.

f) Where for any reason it is not possible to bond the terminal tower to the main substation earthmat, the overhead earth conductors shall be insulated from the terminal tower using earth wire insulators with earth wire jumper leads fitted as in figure 3 in appendix A. An earthing system as described in 3.1.3 shall be installed and the footing resistance of the terminal tower shall be less than 10Ω.

g) The type of terminal structure used will determine the type of earth electrode system. The three-point star electrode is preferred.

h) For a conventional column and beam busbar arrangement, the shielding wire between the terminal tower and the substation terminal earth peak shall be insulated from the terminal tower using earth wire insulator as shown in figure 2 in appendix A.

i) For low profile substation, no shielding wire is strung between substation terminal steelwork and the terminal structure (see figure 4 in appendix A).

3.1.11 Backfilling

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

b) The trench shall be backfilled completely immediately after insertion of the counterpoise earth.

c) The backfill shall be excavated topsoil in normal soil conditions (typically loams, garden soils, soil/gravel mixtures) and conductive concrete mix in rocky, sandstone areas and areas with high resistivity (refer to D-DT 3205).

3.1.12 General

Earth straps or counterpoise earthing shall, in all circumstances, be painted with two coats of bitumastic paint approved by Eskom, in writing, for a length of 450 mm above and 500 mm below finished ground level.

3.1.13 Tower footing resistance measurements

a) The resistance of the installed earth system shall be measured with an approved insulation tester and the relevant results submitted to Eskom without delay.

Resistance shall be measured when foundations and earth straps are all electrically connected: this includes additional counterpoise earthing. Should an earth resistance tester be used, the footing resistance of the tower shall be measured BEFORE the overhead earth conductors are connected to the tower.

b) Methods of testing

- Tower with standard earthing

The circuit diagram is shown in figure 10 in appendix B. The test leads shall be run out in a straight line from the geometric centre of the tower and at right angles to the line. When using an earth resistance tester the distance to the inner (potential) electrode shall be 60 m and the distance to the outer current electrode shall be 100 m.

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

In the case where soil 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.

- Tower with counterpoise earth

The circuit diagram is shown in figure 11 of appendix B. The method set out in □ shall be used, but the distances to the electrodes at 100 m shall be as follows: This is the 61, 8 % method the cross sectional area of the earth electrode shall be less than 100 mm2.

Distance from tower to inner electrode = 61,8 m

Distance from tower to outer electrode = 100 m

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

If a continuous counterpoise earth is run from tower to tower, the methods in □ and □ cannot be used and the earth resistance need not be measured.

c) Measurement of footing resistance with adjacent energized power lines

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

d) Footing resistance meters

- The earth resistance tester is an approved instrument to be used for determining footing resistance measurements. Measurements with an earth resistance tester must be done before the overhead earth conductors are connected to the tower.
- The HW2A high frequency instrument shall be treated as any other meter requiring the Project Engineer’s (Eskom) approval. This meter may be used for future investigations into resistance of the earth electrode where the earth electrode cannot be disconnected from the structure (shielding wire). The meter shall be calibrated to match the surge impedance of the line, otherwise the impact of the other associated towers connected to the shielding wire, will not be excluded from the result.

- Should a contractor wish to use another type of instrument, the details of its intended application and test methodology shall be submitted to Distribution Technology Department for approval.

4. Authorisation

This document has been seen and accepted by:

Name and surname	Designation
Shawn Ramadhin	Eskom Lines Engineering
Arthur Burger	Eskom Lines Engineering
Riaz Vajeth	Eskom Lines Engineering

5. Revisions

Date	Rev	Compiler	Remarks
April 2021	2	B. Mclaren	Document has been updated onto new SCOT template no content changes
March 2016	1	S. Ramadhin	Document reformatted into new document numbering system. No content changed.
Feb 2014	1	S. Ramadhin	Document reformatted, no content changed. This document supersedes ASABF9.
Nov 2012	1	S. Ramadhin	Final Document approved

6. Development team

- Amish Roopnarain

7. Acknowledgements

Not applicable.

Annex A – Figures showing various earthing installations

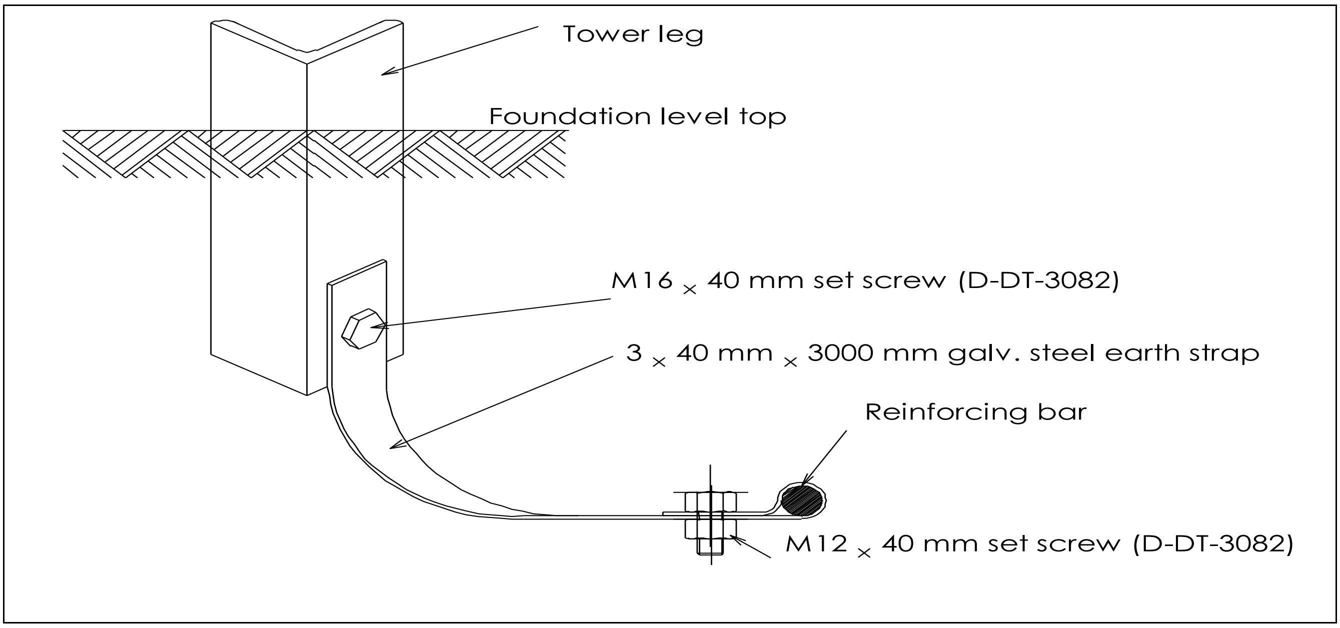


Figure A.1: Connection between tower steel and reinforcing bar with largest diameter

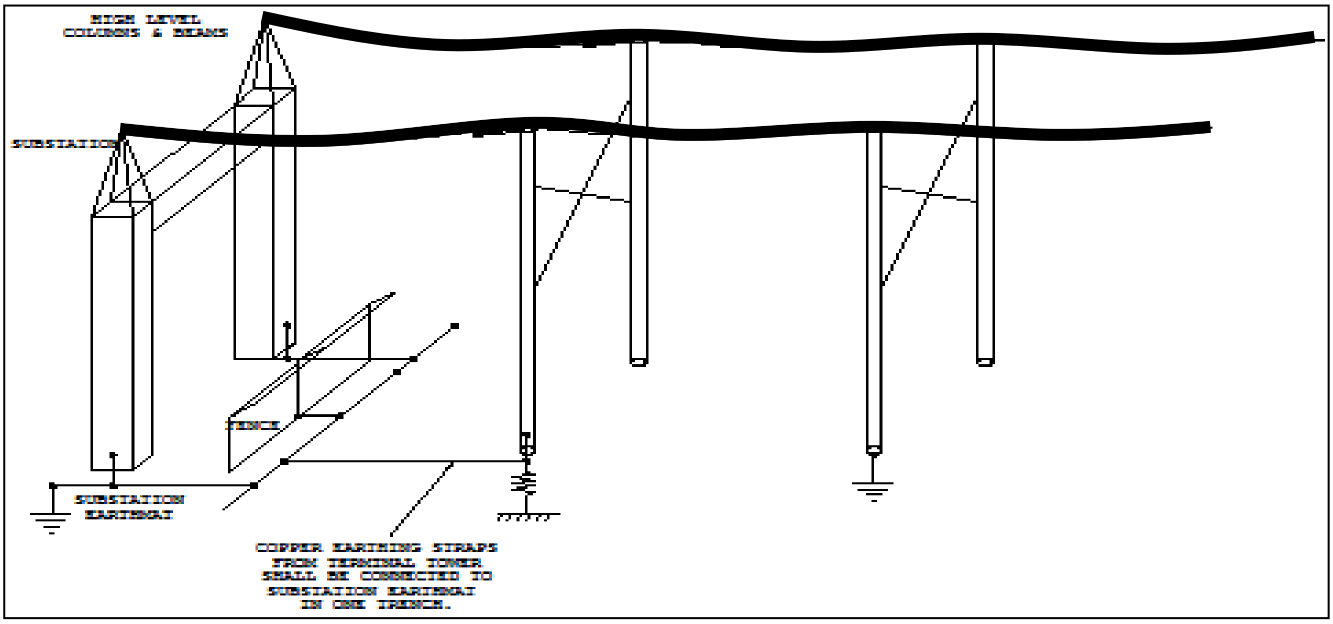


Figure A.2: Terminal tower bonded to substation earthmat

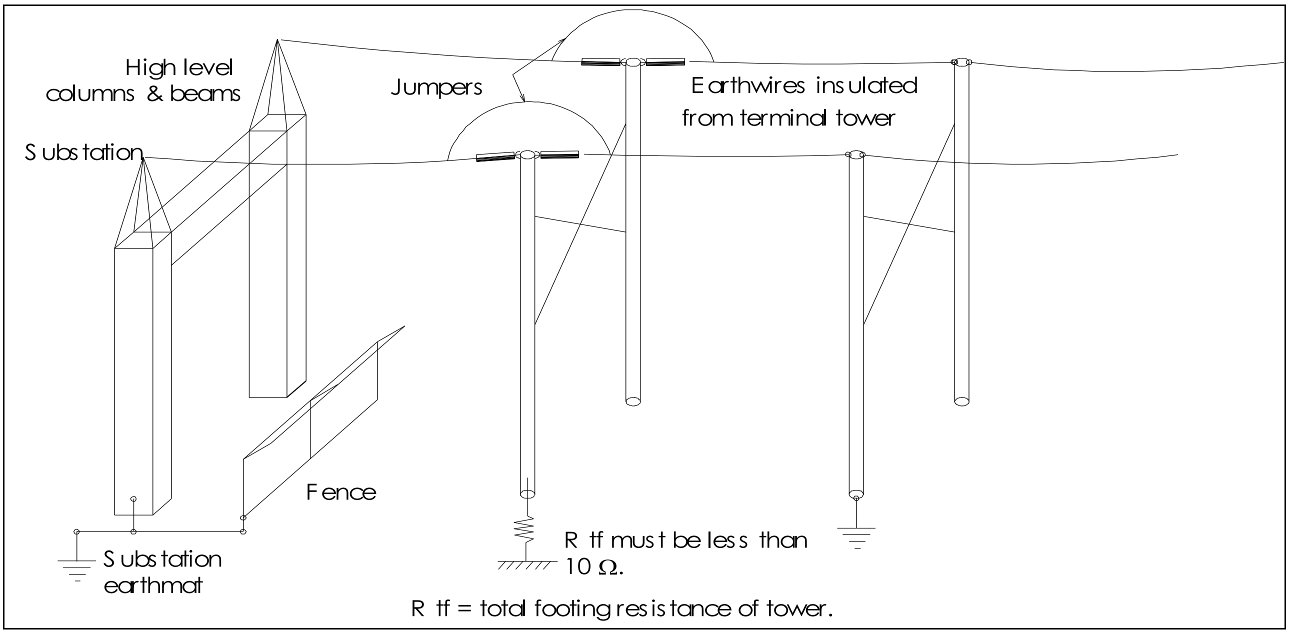


Figure A.3: Insulation of shield wires where terminal tower cannot be connected to substation main earth

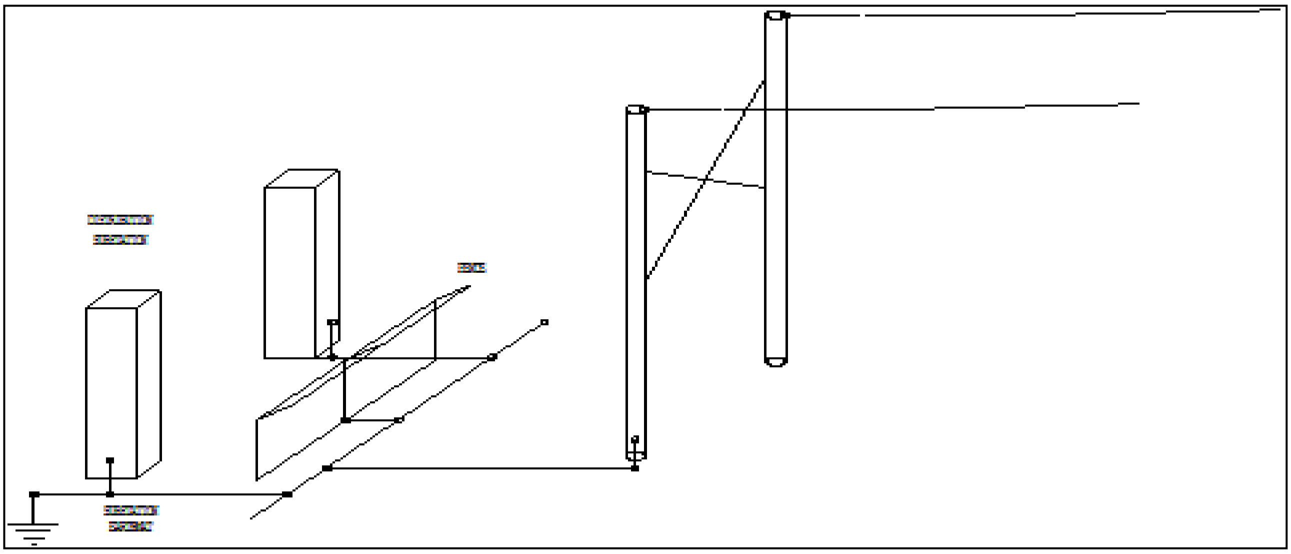


Figure A.4: Normal arrangement for termination at distribution substation with low level busbar

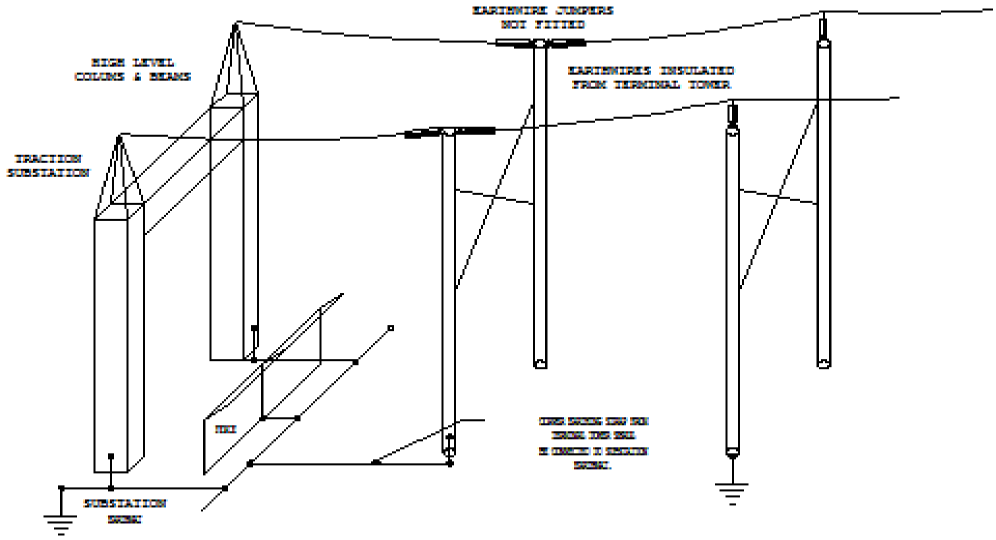


Figure A.5: Normal termination at traction substations

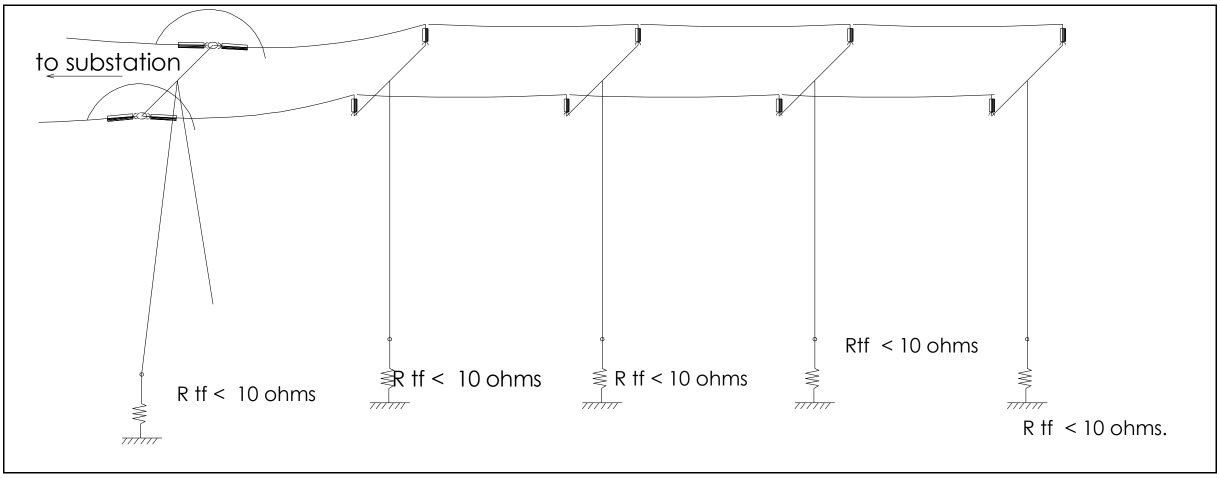


Figure A.6: Insulation of shield wires on first five towers out from substation, with footing resistance less than 10 Ω

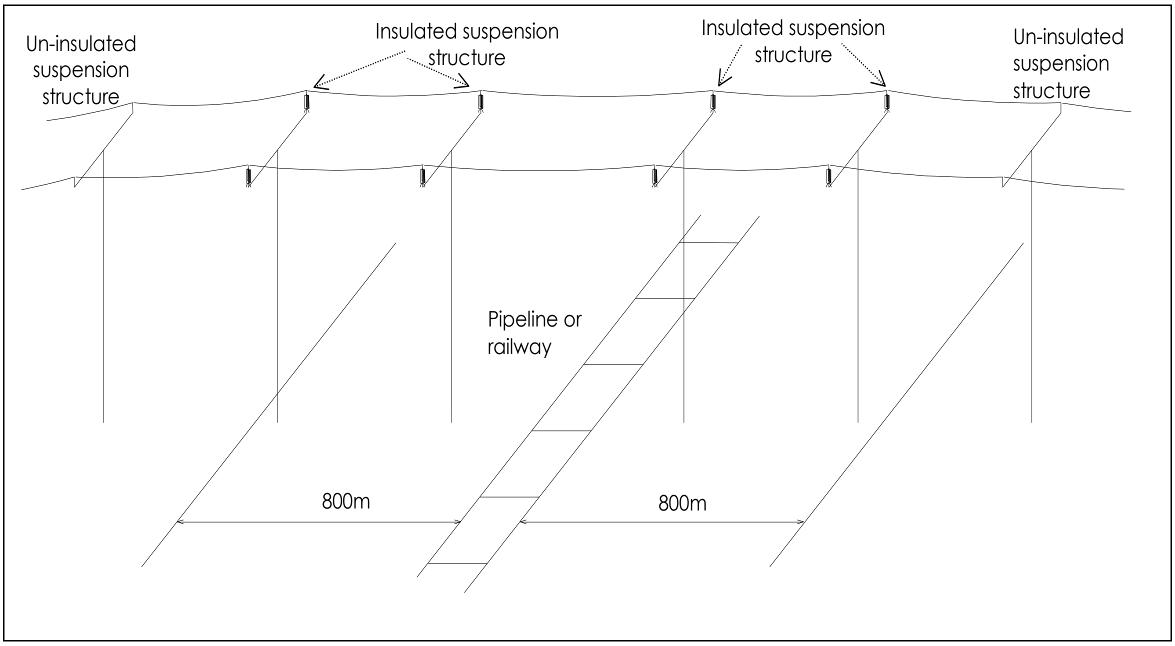


Figure A.7: Insulation of shield wires on suspension towers crossing railway lines or pipelines

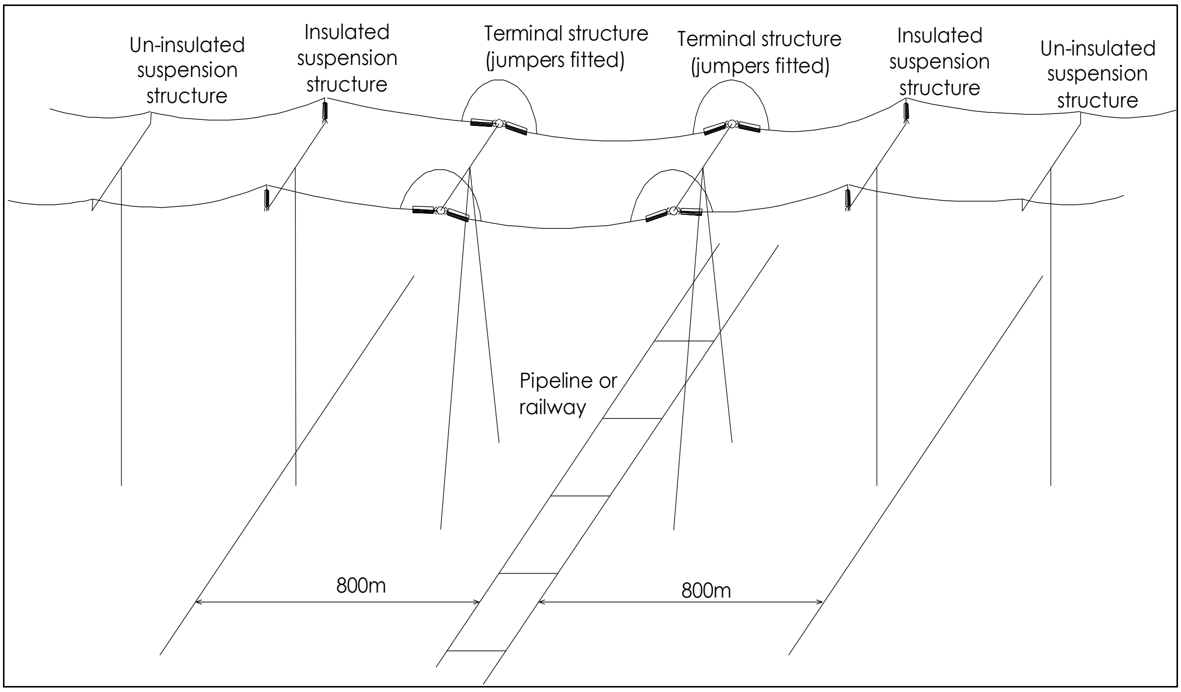


Figure A.8: Insulation of shield wires on suspension and strain towers crossing railway lines or pipelines

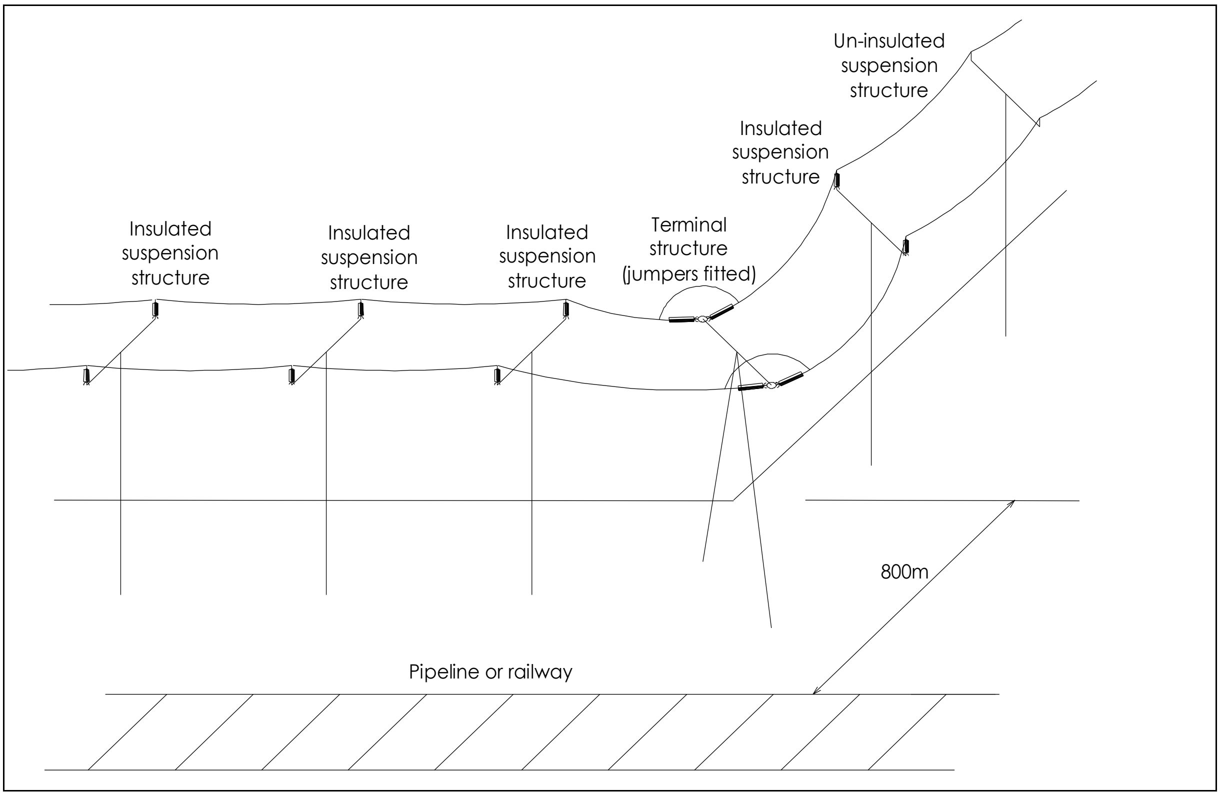


Figure A.9: Insulation of shield wires on routes parallel to railway lines or pipelines

Annex B – Methods of measuring earth resistance

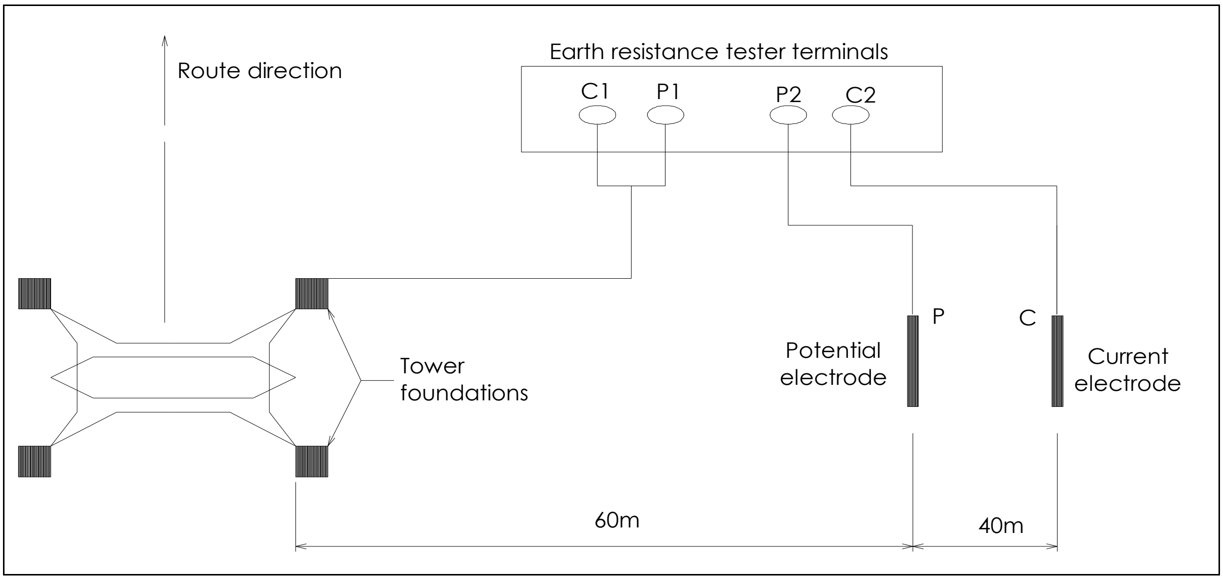


Figure B.1: Method of measuring earth resistance on a tower with standard earthing, using a earth resistance tester

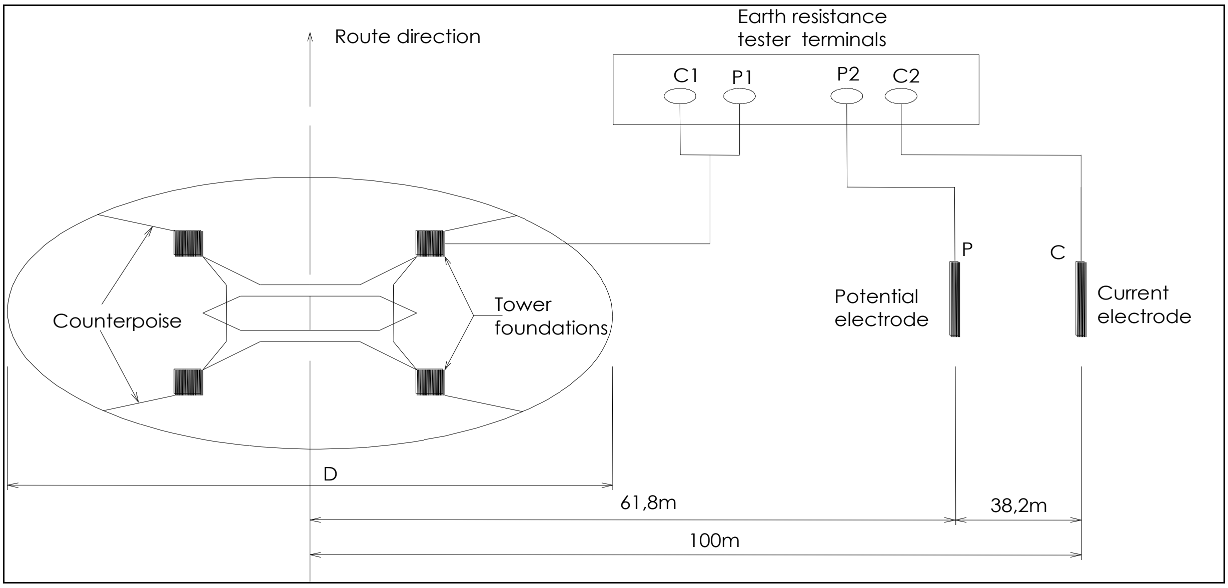


Figure B.2: Method of measuring earth resistance on a tower with counterpoise earthing, using an earth resistance tester

Annex C – Various types of counterpoise installations

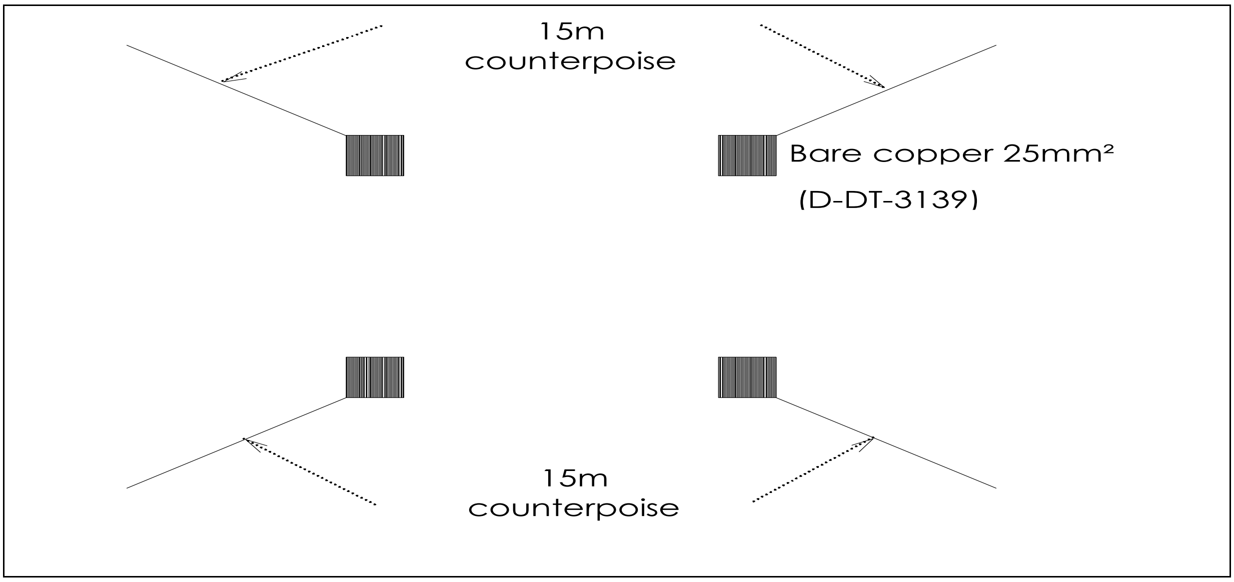


Figure C.1: 4 x 15m Counterpoise earths

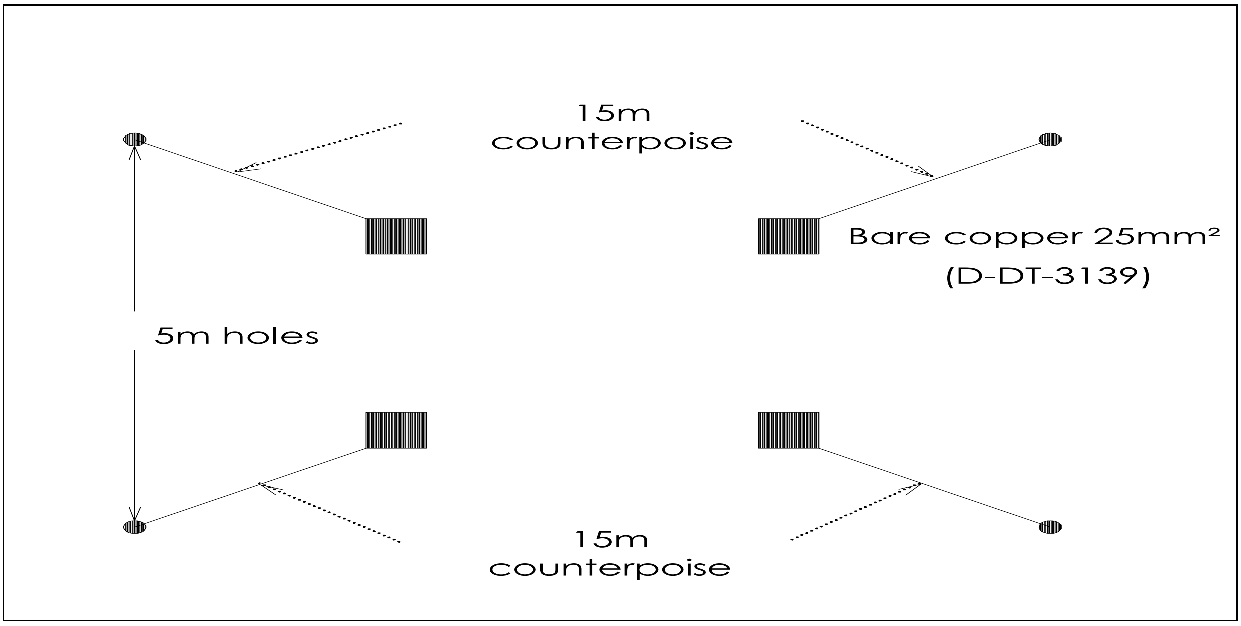


Figure C.2: 4 x 15m Counterpoise earths with 5m drilled hole at each end

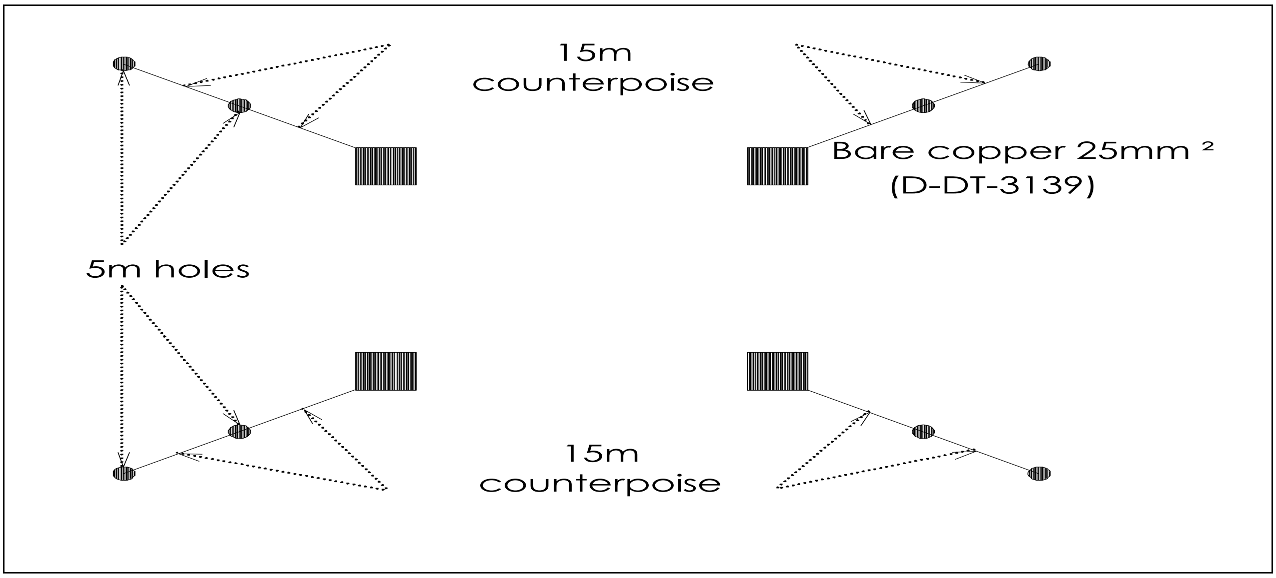


Figure C.3: Method B with additional 15 m counterpoise earths and 5 m drilled hole at each end

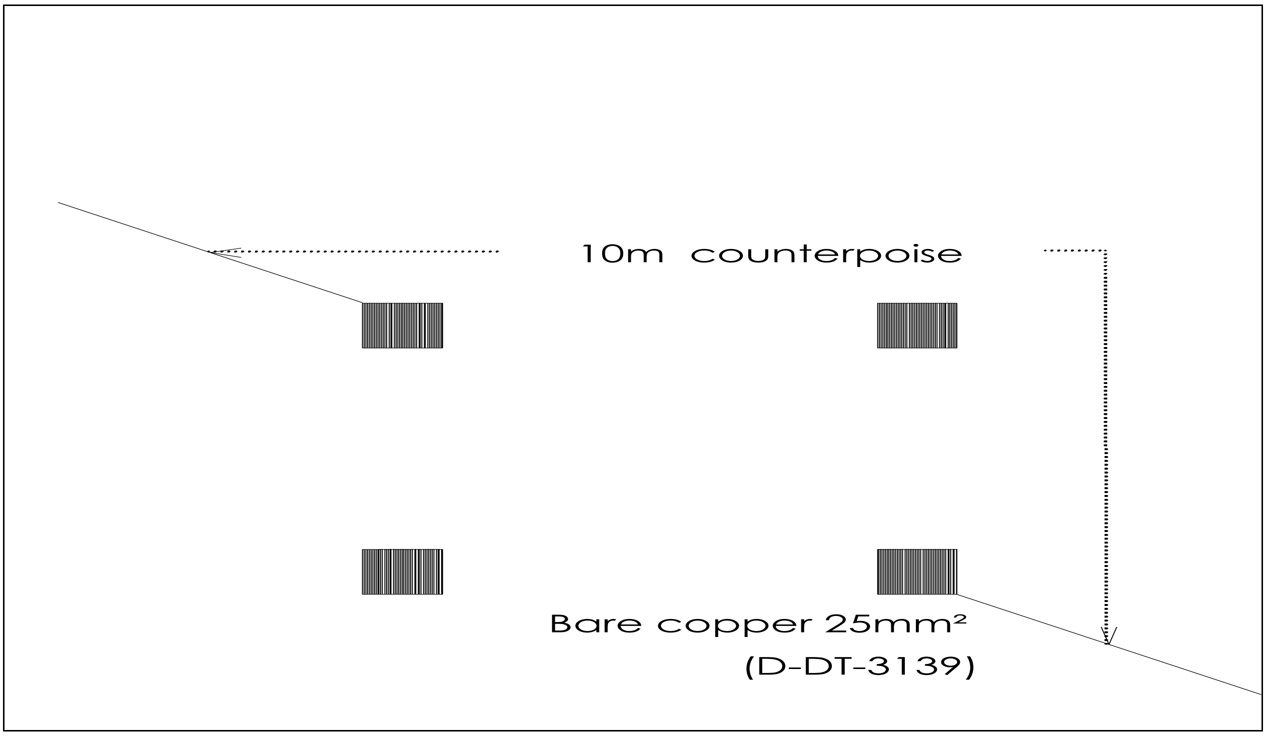
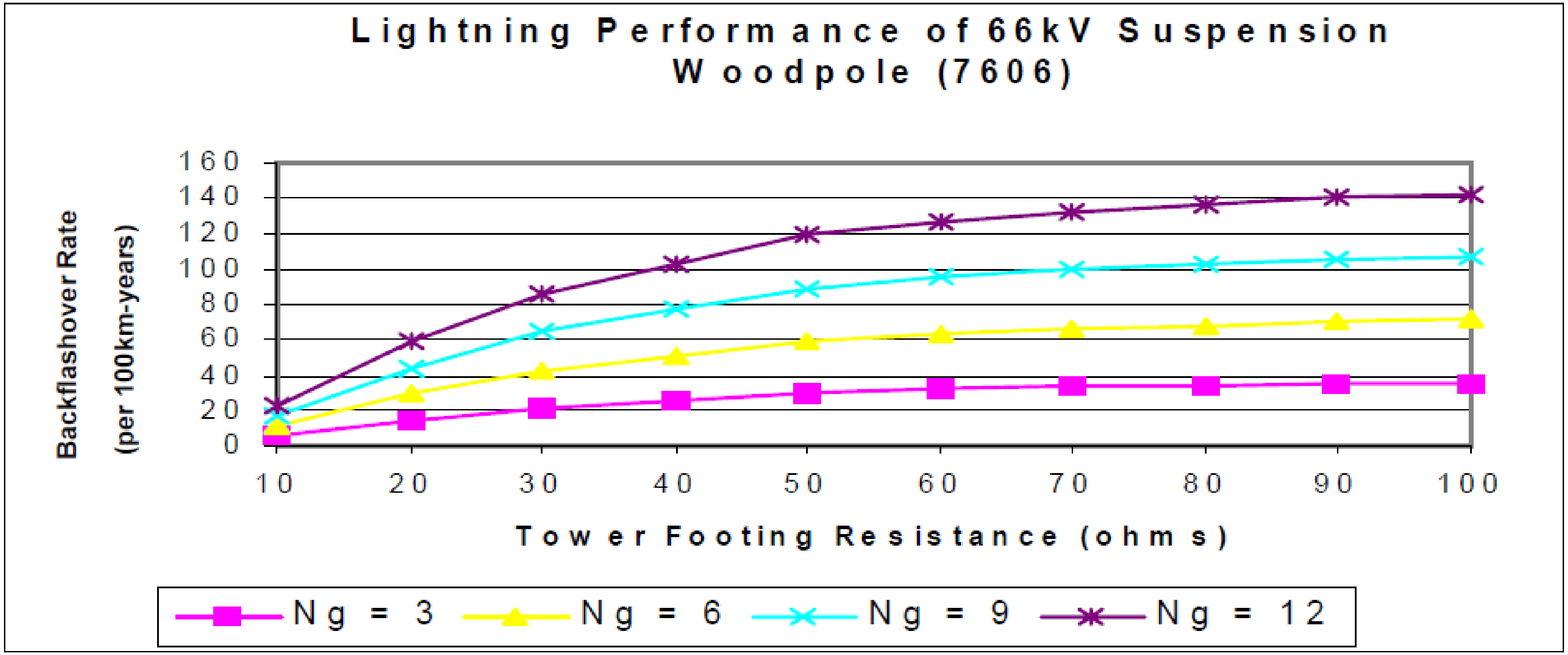


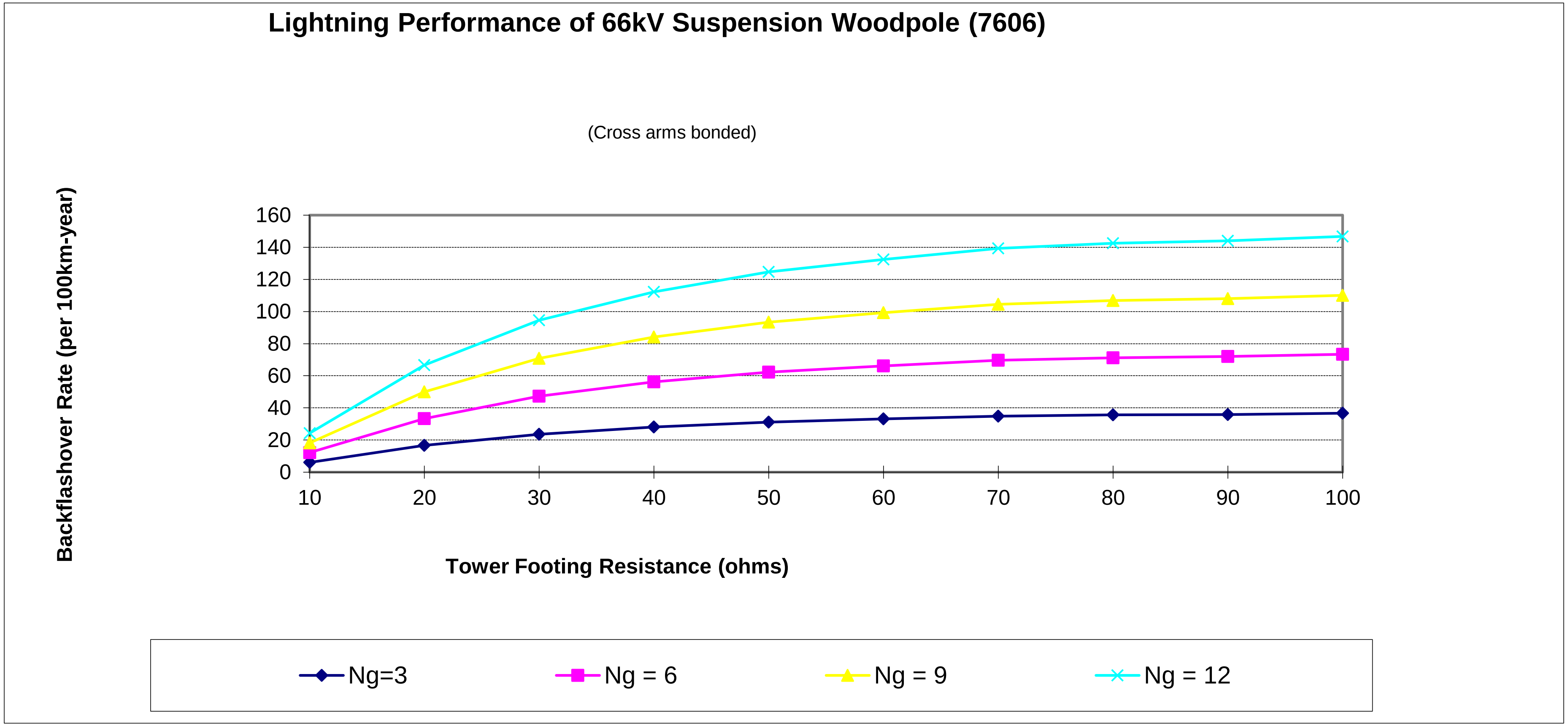
Figure C.4: 2 x 10m Counterpoise earths

Annex D – Back flashover rate verus footing resistances

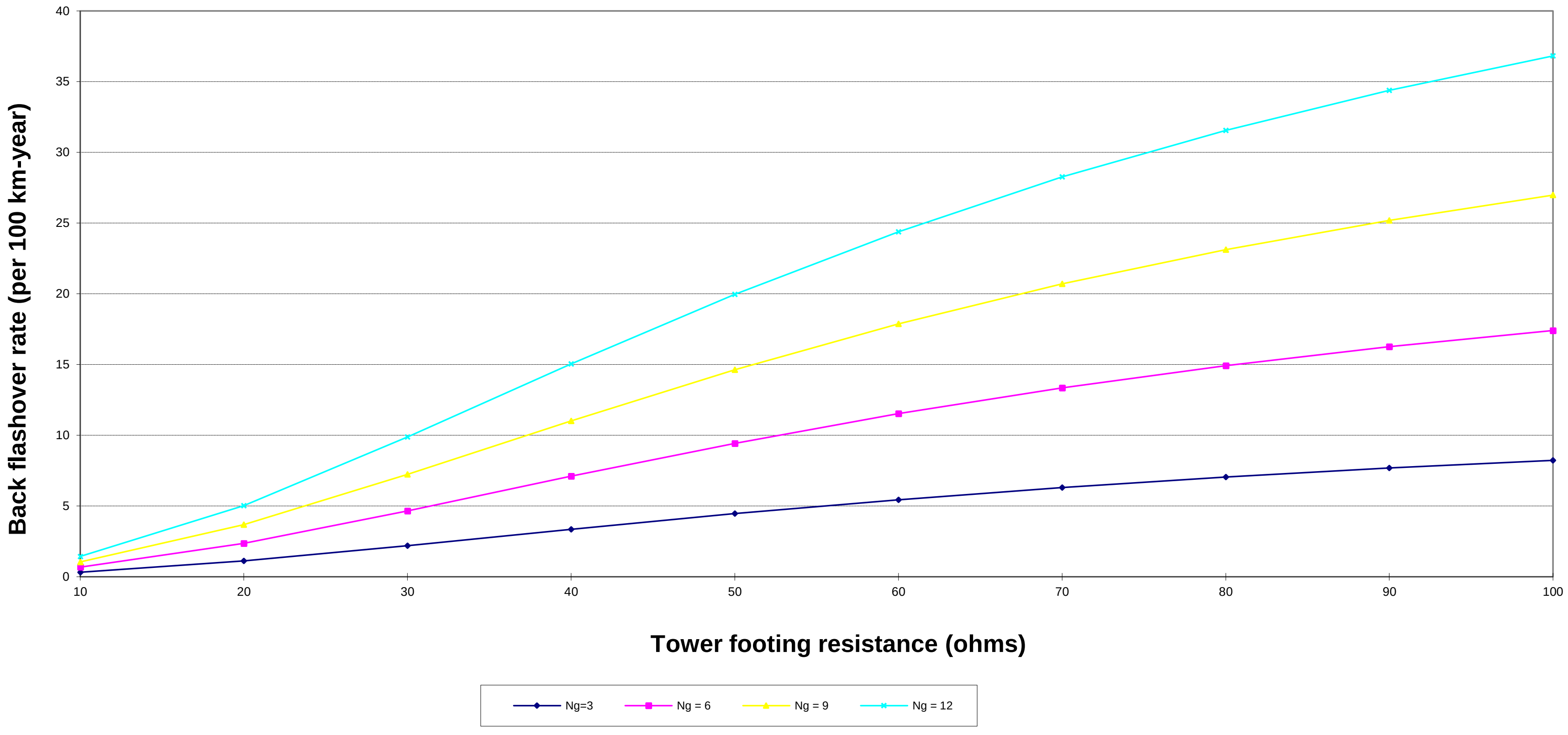
D.1 Lightning performance of 66 kV woodpole suspension tower



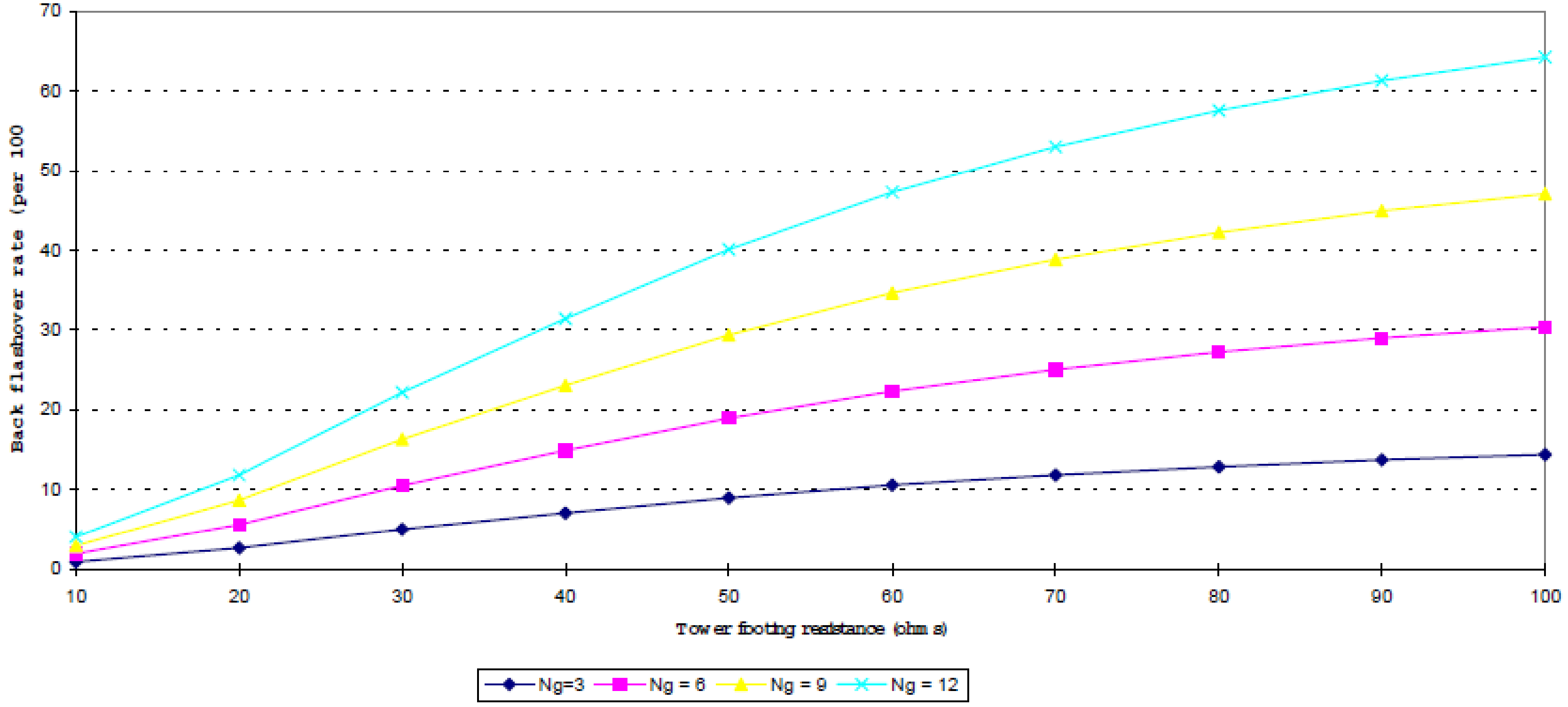
D.2 Lightning performance of 66 kV woodpole suspension tower



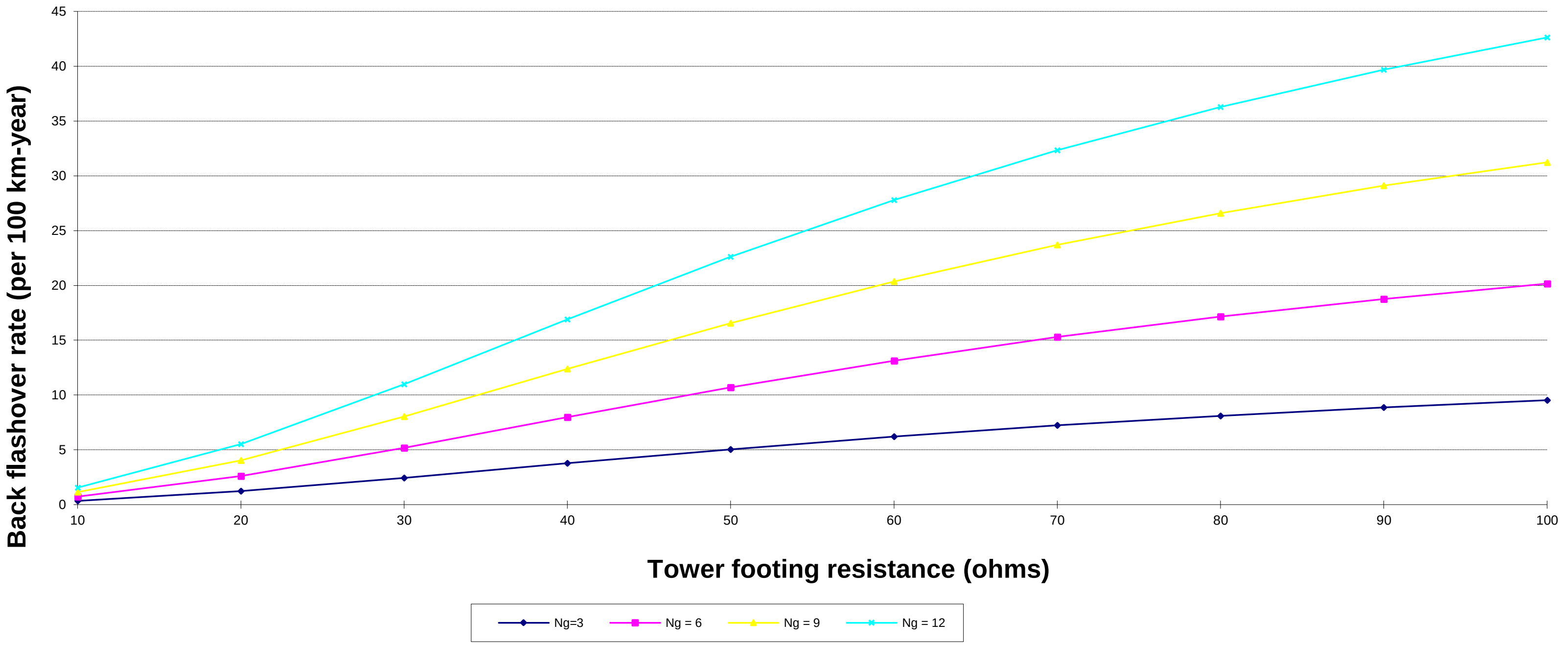
D.3 Lightning performance of 132 kV five pole wooden suspension tower



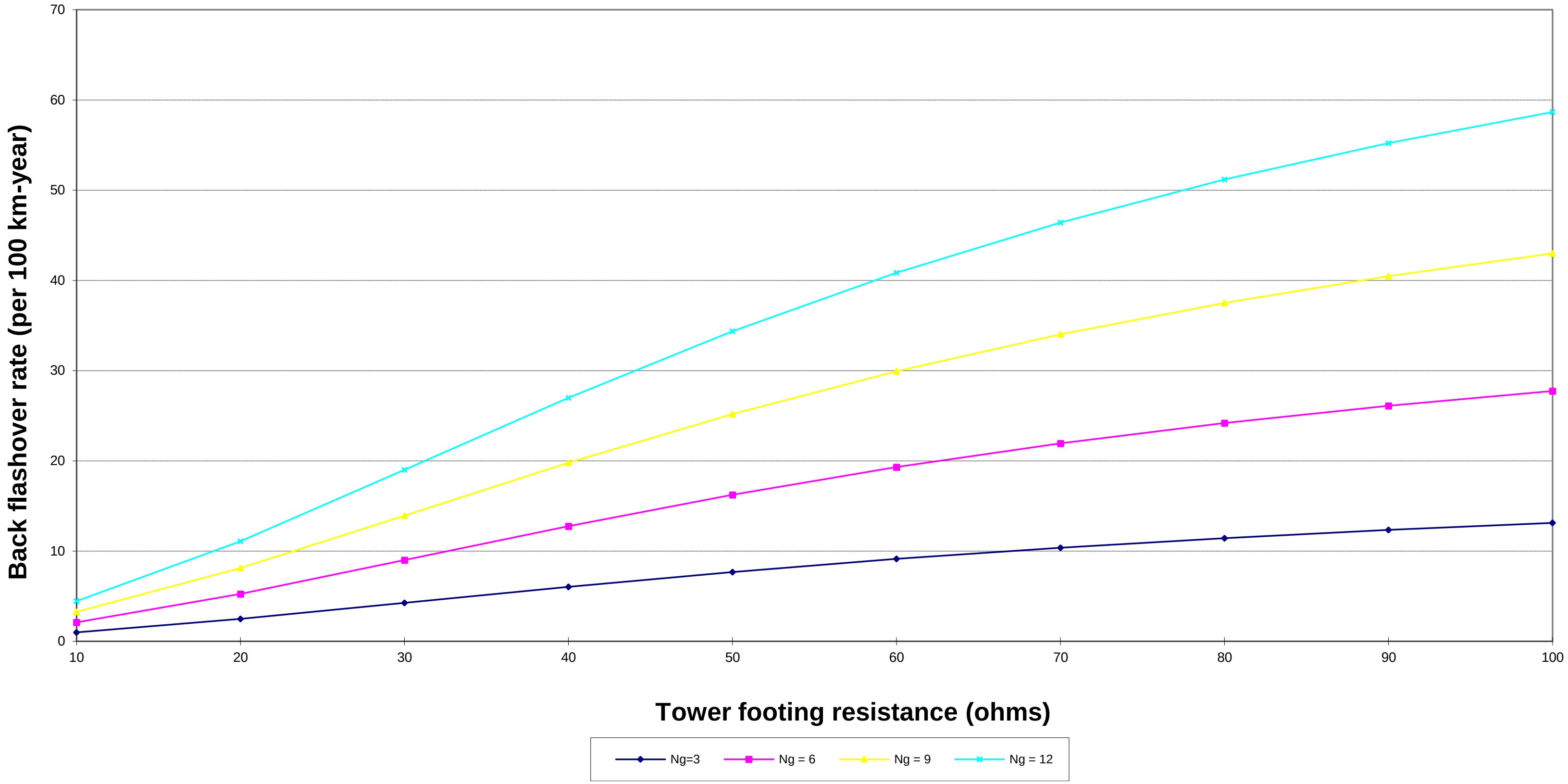
D.4 Lightning performance of 132 kv double circuit tower 253ad



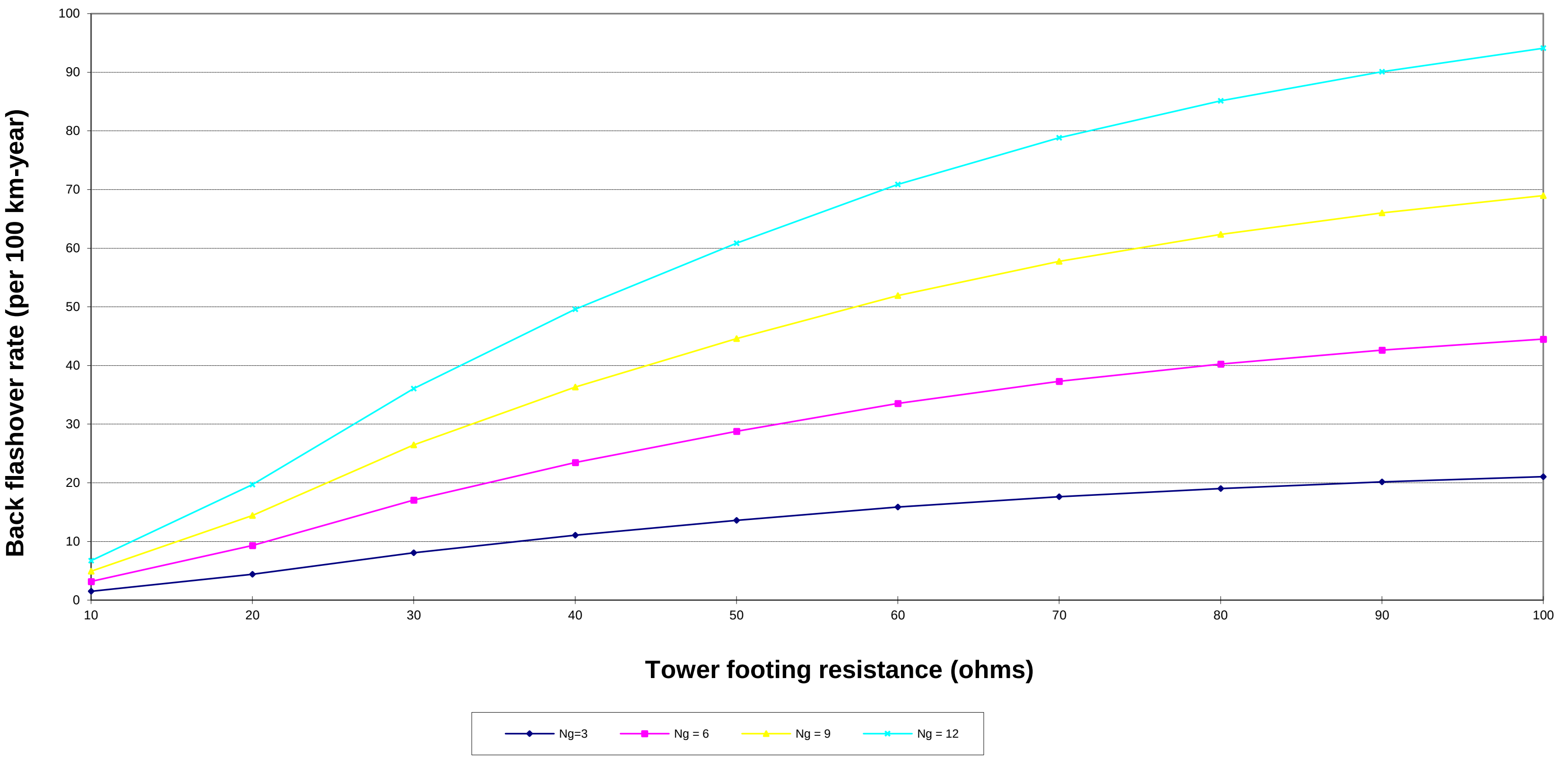
D.5 Lightning performance of 132 kV tower 226 A



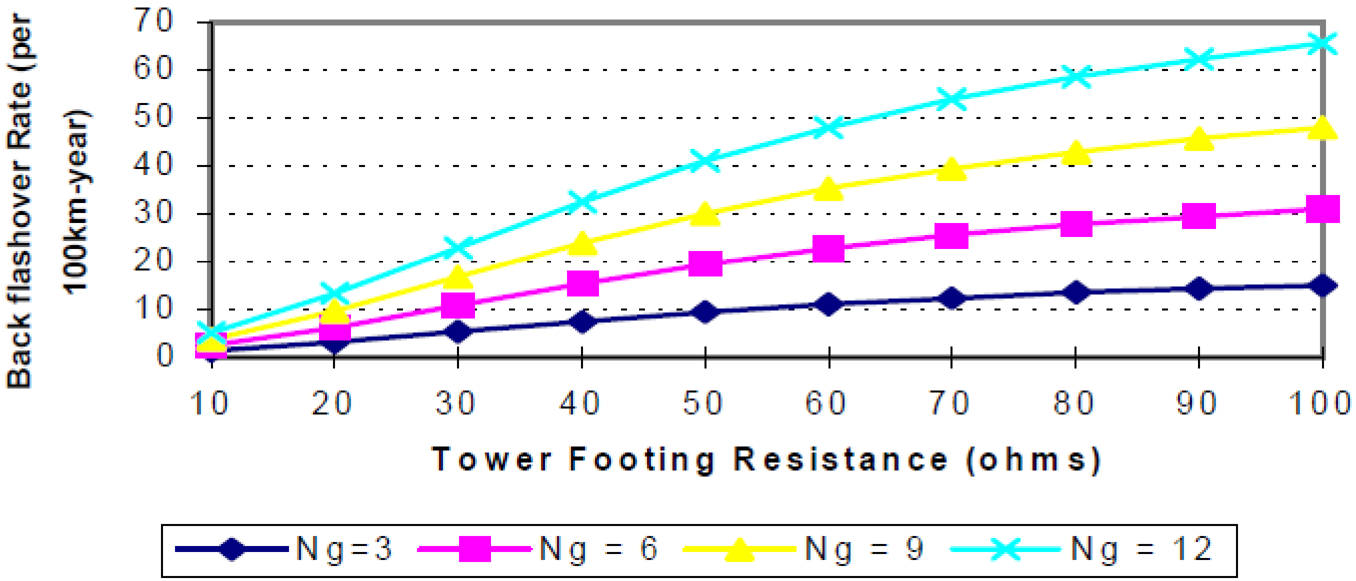
D.6 Lightning performance of 132 kV tower 248 A



D.7 Lightning performance of 132 kV tower 255 A



D.8 Lightning performance of 132 kV stayed steel tower



Annex E – List of drawings

The following drawings form part of this appendix:

Number	Title
D-DT-0640	Footing earth electrode details for concrete pole structures.