

Title: **DISTRIBUTION HIGH VOLTAGE
OVERHEAD POWERLINES
EARTHING STANDARD**

Unique Identifier: **240-75880946**

Alternative Reference Number: **ASABF9**

Area of Applicability: **Engineering**

Documentation Type: **Standard**

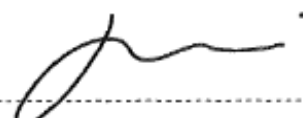
Revision: **3**

Total Pages: **40**

Next Review Date: **September 2031**

Disclosure Classification: **Controlled
Disclosure**

Compiled by



Lucy Sangweni

Chief Engineer, HV Lines
Engineering

Date: 09/09/2026

Approved by



Lerato Lekhema

Senior Manager
Technology & Engineering

Date: 09/09/2026

Authorized by



Al'Louise Van Deventer

General Manager
Technology & Engineering

Date:

Supported by SCOT/SC



Lerato Lekhema
SCOT Chairperson

Date: 09/09/2026

Content

	Page
1. Introduction	4
2. Supporting Clauses	4
2.1 Scope	4
2.1.1 Purpose	4
2.1.2 Applicability	4
2.2 Normative/Informative References.....	4
2.2.1 Normative.....	4
2.2.2 Informative	5
2.3 Definitions.....	5
2.3.1 General	5
2.3.2 Disclosure Classification	6
2.4 Abbreviations.....	6
2.5 Roles and Responsibilities	6
2.6 Process for monitoring	6
2.7 Related/Supporting Documents	6
3. Earthing Standard.....	7
3.1 Requirements	7
3.1.1 Earthing.....	7
3.1.2 Types of Earth Electrodes.....	8
3.1.3 Earthing systems for pad and chimney foundations (self-supporting towers)	8
3.1.4 Earthing system for piled foundations.....	8
3.1.5 Earthing system for single steel pole and grillage (unguyed intermediate tower)	8
3.1.6 Earthing systems drilled foundations and guyed towers	8
3.1.7 Earthing systems for wood poles	9
3.1.8 Additional earthing	9
3.1.9 Shield wire.....	9
3.1.10 Terminal towers	12
3.1.11 Tower footing resistance measurements	13
3.1.12 Soil Resistivity and Resistance of Earth Electrode	14
3.1.13 Fences	15
3.1.14 Allowable step and touch potential limits	15
4. Authorisation.....	17
5. Revisions	17
6. Development team	18
7. Acknowledgements	18
Annex A – Figures showing various earthing installations	19
Annex B – Methods of measuring earth resistance	24
Annex C – Various types of counterpoise installations	25
Annex D – Back flashover rate versus footing resistances	27
Annex E – Earthing system for Steel pole with bolted foundation.....	35
Annex F – Earthing system for Steel pole with planted foundation	36

Annex G – Earthing system for wooden poles	37
Annex H – Typical resistivity of various materials	38
Annex I – Earthing system for a shallow planted single pole structure.	39
Annex J – Earthing system for a pinned single structure	40

Figures

Figure 1: Typical earthing system of an overhead powerline	7
Figure 2: Step and touch potential illustration	16
Figure A.1: Connection between tower steel and reinforcing bar with largest diameter	19
Figure A.2: Terminal tower bonded to substation earthmat	19
Figure A.3: Insulation of shield wires where terminal tower cannot be connected to substation main earth ...	20
Figure A.4: Normal arrangement for termination at distribution substation with low level busbar	20
Figure A.5: Normal termination at traction substations	21
Figure A.6: Insulation of shield wires on first five towers out from substation, with footing resistance less than 10 Ω	21
Figure A.7: Insulation of shield wires on suspension towers crossing railway lines or pipelines	22
Figure A.8: Insulation of shield wires on suspension and strain towers crossing railway lines or pipelines	22
Figure A.9: Insulation of shield wires on routes parallel to railway lines or pipelines	23
Figure B.1: Method of measuring earth resistance on a tower with standard earthing, using a earth resistance tester	24
Figure B.2: Method of measuring earth resistance on a tower with counterpoise earthing, using an earth resistance tester	24
Figure C.1: 4 x 15m Counterpoise earths.....	25
Figure C.2: 4 x 15m Counterpoise earths with 5m drilled hole at each end.....	25
Figure C.3: Method B with additional 15 m counterpoise earths and 5 m drilled hole at each end	26
Figure C.4: 2 x 10m Counterpoise earths.....	26

Tables

Table 1: Typical Constants for various conductor materials.....	10
Table 2: Description of constants and symbols as used in equation (3).....	11
Table 3: Shield Wire Ratings	12
Table 4: Values of k	15

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 Distribution 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 Distribution and its business associates.

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] SANS 10280-1:2017, Overhead powerlines for conditions prevailing in South Africa.
- [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
- [12] Bisnath, S. & et al. (2010). The planning, Design and Construction of Overhead Power Lines of 132kV and above. Power Series Volume 1. Crown Publications cc: Johannesburg, South Africa.
- [13] CIGRE Technical Bulletin 207: Thermal Behaviour of Overhead Conductors.
- [14] 240 -80880493, Fault Current Withstand Calculation for Transmission Line Earthwires.
- [15] 240 -134369472, Substation Earth Grid Design Standard.
- [16] 240 -66418968, Guideline for the electrical co-ordination of pipelines and power lines.
- [17] IEC 60865-1, Short-circuit currents – Calculation of effects –Part 1: Definitions and calculation methods.

ESKOM COPYRIGHT PROTECTED

[18] IEEE Std 80, IEEE Guide for Safety in AC Substation Grounding.

[19] Occupational Health and Safety Act 85 of 1993: Electrical Machinery Regulations.

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
High public exposure areas	An area where members of the public frequently gather, pass through regularly, or have easy access, resulting in a greater likelihood that members of the public could be exposed to a hazard.
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.

Definition	Description
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.
step voltage	The difference in surface potential over a distance of 1m that can be bridged by a person from foot to foot without contacting any other earthed object.
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
touch voltage	the voltage difference between an earthed metallic structure and a person in contact with the earth's surface or another metal structure.
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
ACSR	Aluminium Conductor Steel Reinforced.
BIL	Basic insulation level
IACS	International Annealed Copper Standards
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
RMS	Root Mean Square
TPS	Three-point star electrode

2.5 Roles and Responsibilities

It is the responsibility of the design engineers to completely abide by the principles set out in this standard together with the requirements mentioned in the referenced documentation.

2.6 Process for monitoring

This document will be reviewed once every five years.

2.7 Related/Supporting Documents

See Section 2.2

3. Earthing Standard

3.1 Requirements

The general purpose of earthing overhead powerlines is to create a sufficiently low resistance path for short-circuit and lightning currents to ground/earth, without developing dangerous contact voltages and overvoltage on the network that could damage equipment or give rise to poor quality of supply. Earthing powerlines reduces the overvoltage effects and reduces to within safe limits step and touch voltages to which the public may be exposed.

3.1.1 Earthing

Earthing includes the provision of an electrical connection of a power system to the general body of the earth. This implies connecting, by means of visible conductors, all metal work that may transfer dangerous voltages to equipment or people. This connection serves as a safety measure, as it ensures the safe dissipation to ground of fault currents and static electricity.

Earthing system of an overhead powerline constitutes four components i.e. overhead ground wire, tower body, foundation reinforcement and ground electrodes buried or driven at the base of the tower, all solidly connected to each other, refer to Figure 1.

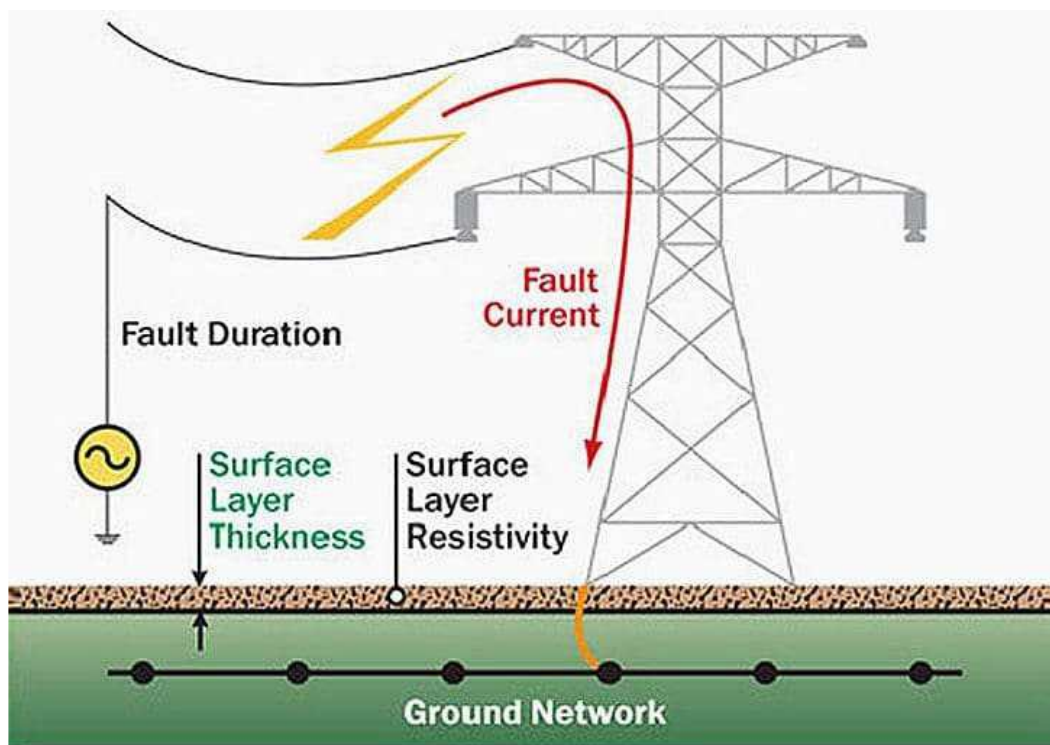


Figure 1: Typical earthing system of an overhead powerline

The following factors influence the magnitude of an overvoltage:

- Tower Footing Resistance.
- The desired nominal tower footing resistance for 44kV to 132 kV lines shall be 20 Ω .
- 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 3.1.10 shall be installed and the footing resistance of the terminal structure shall be less than 10 Ω .

Note 1: 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 Annex D indicate the higher back flashover rate.

ESKOM COPYRIGHT PROTECTED

- d) The footing resistance of the structures up to 1km from the substation, on 44kV to 132 kV lines shall be less than 20 Ω . For footing resistances less than 10 Ω , refer to 3.1.10.
- e) The relevant method, as set out in 3.1.11 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's Network Engineering Manager concerned.

Note 2: Earthing of electrical components does not prevent faults from occurring but reduces the risk of electrical shocks and equipment damage, thus maintaining continuous power supply.

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, if required.

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 $\times$ 3 mm galvanised mild steel strap or suitable earth conductor that has been approved by Eskom in writing (see figure A.1 in Annex 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)

Self-supported steel poles may have a planted foundation or steel reinforced bolted concrete foundation. If additional earth electrode is required to achieve the desired footing resistance, for the bolted concrete foundation, a connection with the anchor bolt shall be made within the concrete foundation and trenched horizontally to the desired length, refer to Annex E. For the planted steel poles, the additional earthing shall be connected on the earthing lug on the steel pole below ground level, and trenched horizontally to the desired length, refer to Annex F. Additional earthing shall only be applied if the required earthing 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.

For pinned foundation towers, a set screw at the top of the pin shall be used to connect a short earth strap (galvanised 40 mm x 3 mm) to the tower and a hole at the bottom of the pin is available to connect an earth strap or cable to the foundation rebar, refer to Annex J.

This connection shall consist of 40 mm x 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 ID-DT-0640 in Annex I, for the earthing method to be used in this case.

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 structure, one on each leg. 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, refer to Annex G.

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 Annex 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 Network 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

Initially, shield wire were for the protection of phase conductors against direct lightning strikes. For the purpose of lightning strikes protection, steel wires 7/3.35 or 19/2.65 were often used as powerline shield wires, since though lightning currents are high but last for a very short time, therefore highly conductive material is not necessary. The minimum cross-sectional area of any conductor in a lightning protection installation shall be about 35mm². The minimum diameter of individual strands of a stranded conductor should be at least 2.5mm.

However, shield wires have become a substantial part of the earthing system and thus important in providing a return path for short-circuit currents. Where single phase fault current level magnitude is large, ACSR or OPGW or similar stranded conductors which offer higher fault current ratings shall be used. The selected conductor shall be able to carry fault currents while retaining its mechanical and electrical properties without degradation. For single phase to ground fault, selection of the fault duration for design purposes must be based on the present protection scheme. Eskom Distribution's practice is to use one-second, which includes backup protection fault clearing times.

The maximum current carrying capacity of a shield wire can be calculated using equation (1) as per IEC 60865-1.

$$I = \frac{KA}{\sqrt{T_{kr}}} \quad \text{Eq. (1)}$$

Where K is given by:

$$K = \sqrt{\frac{K_{20}cp}{\alpha_{20}} \ln \left[\frac{1+\alpha_{20}(\theta_c-20)}{1+\alpha_{20}(\theta_b-20)} \right]} \quad \text{Eq. (2)}$$

Where:

$I(A)$ = current (rms)

$A(m^2)$ = conductor cross section

$T_{kr}(s)$ = time duration of current (I)

$\theta_c(^{\circ}C)$ = maximum allowable temperature

$\theta_b(^{\circ}C)$ = ambient temperature

$K_{20}(1/\Omega m)$ = specific conductivity at 20 °C

$c(J/kg^{\circ}C)$ = specific thermal capacity

$p(kg/m^3)$ = specific mass density

$\alpha_{20}(1/^{\circ}C)$ = temperature coefficient of resistance

Table 1: Typical Constants for various conductor materials

Symbol	SI - UNIT	Copper	Aluminum Alloy (ACSR)	Steel
c	$J/kg^{\circ}C$	390	910	480
ρ	kg/m^3	8900	2700	7850
K_{20}	$1/\Omega m$	56×10^6	34.8×10^6	7.25×10^6
α_{20}	$1/^{\circ}C$	0.0039	0.004	0.0045
θ_c	$^{\circ}C$	200	200	300
θ_b	$^{\circ}C$	40	40	40

The above method of calculation is based on IEC 60865-1. This method is applicable to monometallic conductors. In the case of an ACSR conductor or bimetallic conductor, only the main current carrying part must be taken into account i.e. the aluminium part of the conductor must only be taken into account. However, this assumption can lead to considerable errors in calculating the conductor temperature rise during a short circuit, especially with bimetallic conductors of a high steel content. For this reason, the Cigre Technical Brochure 207 calculation method shall be used for ACSR or bimetallic conductors. The Cigre Technical Brochure 207 calculation method takes into account the heat capacity of the steel part of a bimetallic (ACSR) conductor but with a conductance of 0% IACS. In order words the heat capacity of the steel has been taken into account but not its conductivity. The Cigre Technical Brochure 207 method of calculation is provided by equation (3) below

$$\frac{1}{\alpha_{20}} \ln \left[\frac{1 + \alpha_{20}(\theta_c - 20^\circ\text{C})}{1 + \alpha_{20}(\theta_b - 20^\circ\text{C})} \right] = \frac{i^2 \rho_a}{A_1 A_2 \gamma_{tot} C_{tot}} t \quad \text{Eq. (3)}$$

Where:

$$\gamma_{tot} = \frac{\gamma_a A_a + \gamma_s A_s}{A_a + A_s} \quad \text{Eq. (4)}$$

$$C_{tot} = \frac{C_a \gamma_a A_a + C_s \gamma_s A_s}{\gamma_a A_a + \gamma_s A_s} \quad \text{Eq. (5)}$$

$$A_2 = A_a + A_s \quad \text{Eq. (6)}$$

$$A_1 = A_a \quad \text{Eq. (7)}$$

This heat capacity of both metals must be taken into account (Aluminium and Steel) in ACSR but not the conductivity of steel.

Table 2: Description of constants and symbols as used in equation (3)

Symbol	Description	Unit
C_{tot}	Total specific heat capacity	$J/kg^\circ\text{C}$
C_a	Aluminium specific heat capacity	$J/kg^\circ\text{C}$
C_s	Steel specific heat capacity	$J/kg^\circ\text{C}$
α_{20}	Aluminium Temperature Coefficient of Resistivity At 20 °C	$1/^\circ\text{C}$
ρ_a	Specific Resistivity of Aluminium at 20 °C	Ωm
γ_{tot}	Total Mass Density	kg/m^3
γ_a	Aluminium Mass Density	kg/m^3
γ_s	Steel Mass Density	kg/m^3
A_1, A_2	Cross-Sectional Area	m^2
A_a	Aluminium Cross-Sectional Area	m^2
A_s	Steel Cross-Sectional Area	m^2
t	Duration of short circuit	s
θ_c	Maximum allowable temperature	$^\circ\text{C}$
θ_b	Ambient temperature	$^\circ\text{C}$
i	Current	A

a) Shield wire insulation

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 1 s. Table 3 provides the 1 s rating of commonly used shield wires.

Table 3: Shield Wire Ratings

1	2	3
Shield wire type	Rated fault current (kA)	Time (s)
Steel wire 3/4	2.5	1
Steel wire 7/3,35	4.1	1
Steel wire 7/3.51	4.5	1
Steel wire 7/4	5.9	1
Steel wire 19/2,65	6.9	1
Steel wire 19/2.7	7.2	1
Mink	7.1	1
Hare	11.7	1
Tiger	15.2	1
Wolf	18.4	1

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 earthmat, shield wire jumpers shall be fitted (see figure 3 in Annex A). Furthermore, terminal tower footing resistance should be reduced to less than 10 Ω .
- At DC 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 Annex A).
- If any of the towers within 1km of the substation has a footing resistance less than 10 Ω , then shield conductor jumper leads shall be fitted on strain structures only (see Figure 6 in Annex A). If the towers within the first 1km all have footing resistances below 10 Ω , then circulating currents due to electromagnetic induction can flow, which will find their way back to the substation earthmat. The shield wire is insulated from these towers to break the circuit so that no circulating current can flow, and no electrolytic corrosion can take place.
- 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 Figures 7, 8 and 9 in Annex A). In the case of an existing line, the party that constructed the pipeline shall comply with the safety requirements for induced voltages stipulated in the Guideline for the electrical co-ordination of pipelines and power lines, 240 -66418968. Shield wire insulators are installed at all towers within 800 metres of electrified railway tracks or metal pipelines to ensure that stray DC current cannot circulate in the overhead powerline earthing system and cause corrosion.

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 Annex 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 at the same depth as the substation's earth mat, usually 1000 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), silbrallo alloy 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 Annex 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 Annex A.
- i) For low profile substation, no shielding wire is strung between substation terminal steelwork and the terminal structure (see figure 4 in Annex A).

3.1.11 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 Annex 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 Annex B. The method set out in Figure B.1 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

ESKOM COPYRIGHT PROTECTED

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 Figure B.1 and Figure B.2 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.

3.1.12 Soil Resistivity and Resistance of Earth Electrode

Soil Resistivity

Designing an effective earthing system requires careful consideration of various factors to ensure its reliability and performance.

The resistivity of the soil in the area where the earthing system will be installed is a critical factor. Lower resistivity soils offer better earthing performance, as they allow for more efficient dissipation of fault currents. The resistivity of most soils rises abruptly whenever the moisture content is less than 15% of the soil weight [12]. The amount of moisture further depends on the grain size, compactness, and variability of the grain sizes. Annex H shows typical resistivity of various soil and rock types, water and metals.

Soil composition and moisture content determine resistivity, and these two factors can vary considerably from place to place. The earth resistance at a particular installation may also vary as a result of seasonal changes to the soil moisture content, consequently, the determination of soil resistivity is an important part of the design of an earthing system. Wenner soil resistivity survey method shall be used to determine the soil resistivity of the different layers of the soil at each pylon position. This information will guide the selection of the type of electrodes that will be used to improve pylon footing resistance, if necessary.

Resistance of Earth Electrode

The resistance of a vertical earth electrode/rod in homogeneous soil is defined by equation (8) and equation (9) as per [12]:

$$R_{rv} = \frac{\rho}{2\pi L} \ln \left[\frac{4L}{d} \right] \Omega \quad \text{Eq. (8)}$$

Where:

ρ = soil resistivity (Ωm)

L = length of the electrode (m)

D = diameter of the electrode (m)

ESKOM COPYRIGHT PROTECTED

When vertical rods are equally spaced in a straight line and connected in parallel, the separation distance between them should be greater than their length. The total resistance R of an array of vertical rods in parallel is described by equation (9):

$$R = R_0 \frac{1+k \times m}{n} \quad \text{Eq. (9)}$$

Where:

R_0 = resistance of one vertical rod

n = total number of vertical rods in parallel

m is defined by equation (10)

$$m = \frac{L}{\left[\ln\left(\frac{8L}{d}\right) \right] \times s} \quad \text{Eq. (10)}$$

Where:

L = the effective length of the rod (m)

d = diameter of the rod (m)

s = separation distance between rods (m)

The value of k in equation (9) is defined in Table 4 below:

Table 4: Values of k

n	k
2	1
3	$\frac{12m - 10}{7m - 6}$
4	$\frac{21m - 26}{10m - 12}$

The material used for the grounding electrodes, such as copper, galvanized steel, or copper clad steel, should be selected based on factors like conductivity, durability, and corrosion resistance.

3.1.13 Fences

Powerlines can induce voltages which may be dangerous on fences during both steady state and fault conditions. It shall be ensured that these induced voltages are safe when contact is made with a fence. Safety measures might involve inclusion of additional earthing or equipotentialization or both.

In the case of existing powerline, the party that constructed the fence shall notify Eskom of the construction in writing. Eskom shall inform the landowner about the safety of fences in close proximity to powerlines and provide technical guidance if necessary.

3.1.14 Allowable step and touch potential limits

Dangerous step and touch potentials can occur around powerline towers and poles under fault conditions. These conditions only exist for a short period until the fault is cleared by a protection system. Where such risks exist in areas of high public exposure, measures to guard against step and touch potentials hazards should be implemented. Due to the costs involved in achieving safe step and touch potentials around a pylon, the safe step and touch potentials requirement is only applicable in high public exposure areas such as parks, schools, sports grounds, townships, rural pathways, farming areas, and similar environments [6].

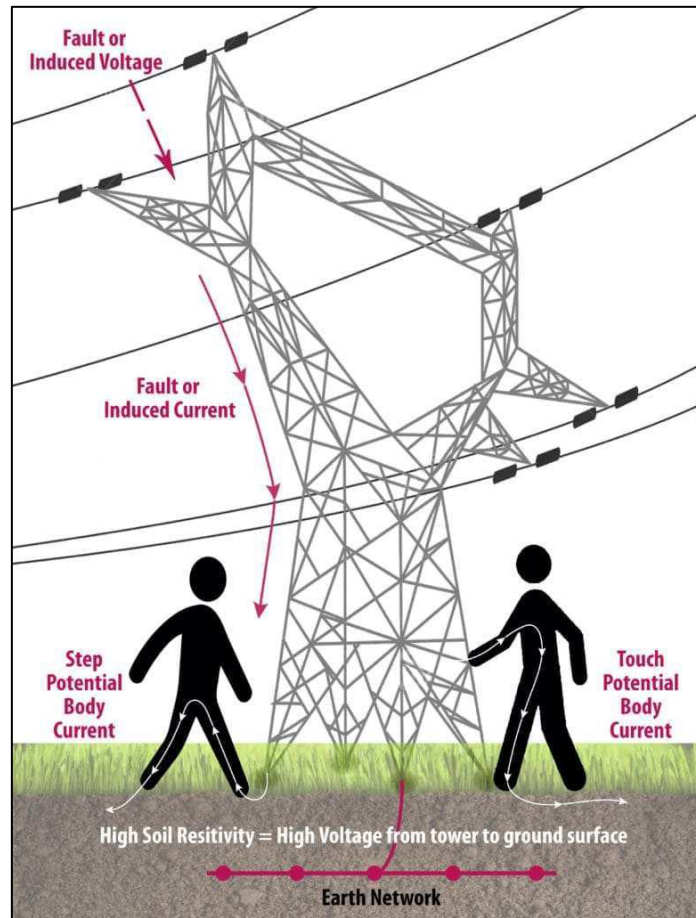


Figure 2: Step and touch potential illustration

Safe limits of step and touch voltages are based on the maximum body current that can be endured by a person without affecting muscular control or causing ventricular fibrillation. IEEE 80 code of practice provides a guideline for calculating the safe step and touch potential exposure limits. Body resistance is taken as a 1000Ω and the body current associated with a person weighing 50kg or more. The following equations are used to calculate the allowable (safe) step and touch potential limits as per **240-134369472**:

$$I_b = \frac{0.116}{\sqrt{t_f}} \quad \text{Eq. (11)}$$

$$C_s = 1 - \frac{0.09 \cdot \left(1 - \frac{\rho}{\rho_s}\right)}{2 \cdot h_s + 0.09} \quad \text{Eq. (12)}$$

$$E_{step} = I_b \cdot (R_b + 6 \cdot \rho_s \cdot C_s) \quad \text{Eq. (13)}$$

$$E_{touch} = I_b \cdot (R_b + 1.5 \cdot \rho_s \cdot C_s) \quad \text{Eq. (14)}$$

Where

E_{step}	-	maximum allowable step voltage	-	V
E_{touch}	-	maximum allowable touch voltage	-	V
I_b	-	maximum expected RMS current in the grid conductor	-	A
R_b	-	body resistance	=	1000Ω
ρ_s	-	resistivity of the surface material	-	Ωm

ESKOM COPYRIGHT PROTECTED

C_s	-	surface layer de-rating factor		
t_f	-	fault clearing time	-	s
ρ	-	soil resistivity in which the earth grid is buried	-	Ωm
h_s	-	thickness of the surface layer	-	m

3.1.15 Backfilling

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

3.1.16 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. All pylon earthing material shall be installed below ground level to prevent theft.

4. Authorisation

This document has been seen and accepted by:

Name and surname	Designation
Al' Louise Van Deventer	General Manager: Technology and Engineering
Lerato Lekhema	Senior Manager: Technology and Engineering
Pravind Orrie	Asset Creation Senior Manager - Limlanga Cluster
Zetu Nciza	Asset Creation Senior Manager - Central East Cluster
Thandiwe Nkambule	Asset Creation Senior Manager - Gauteng Cluster
Dumisani Gumi	Asset Creation Senior Manager - Gemma Cluster (Acting)
Paul Matiwani	Asset Creation Senior Manager - Cape Coastal Cluster

5. Revisions

Date	Rev	Compiler	Remarks
Sept 2026	3	L. Sangweni	Document has been updated with new sections 3.1.11 to 3.1.14 and Annexures E, F, G, H, and J.
March 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

- Lucy Sangweni
- Jayant Raghubir

7. Acknowledgements

Distribution Earthing Care Group, High Voltage Overhead Powerlines Study Committee and Operating Units/Clusters for their contribution in reviewing this document.

Annex A – Figures showing various earthing installations

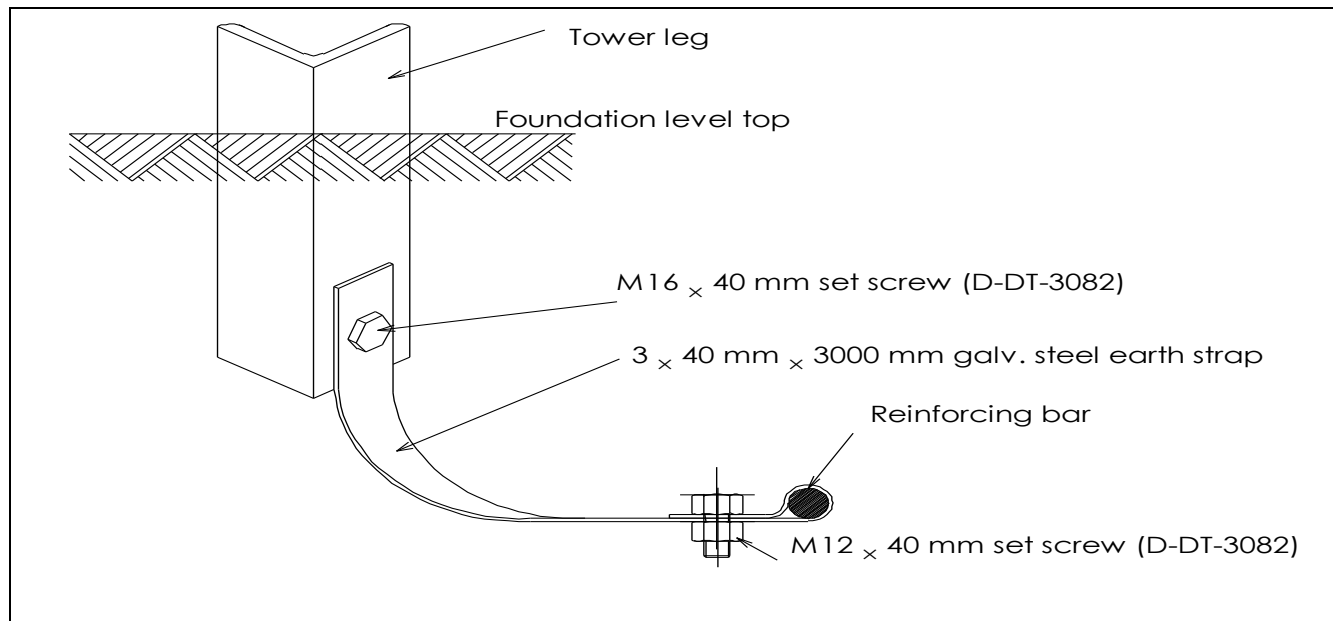


Figure A.1: Connection between tower steel and reinforcing bar with largest diameter

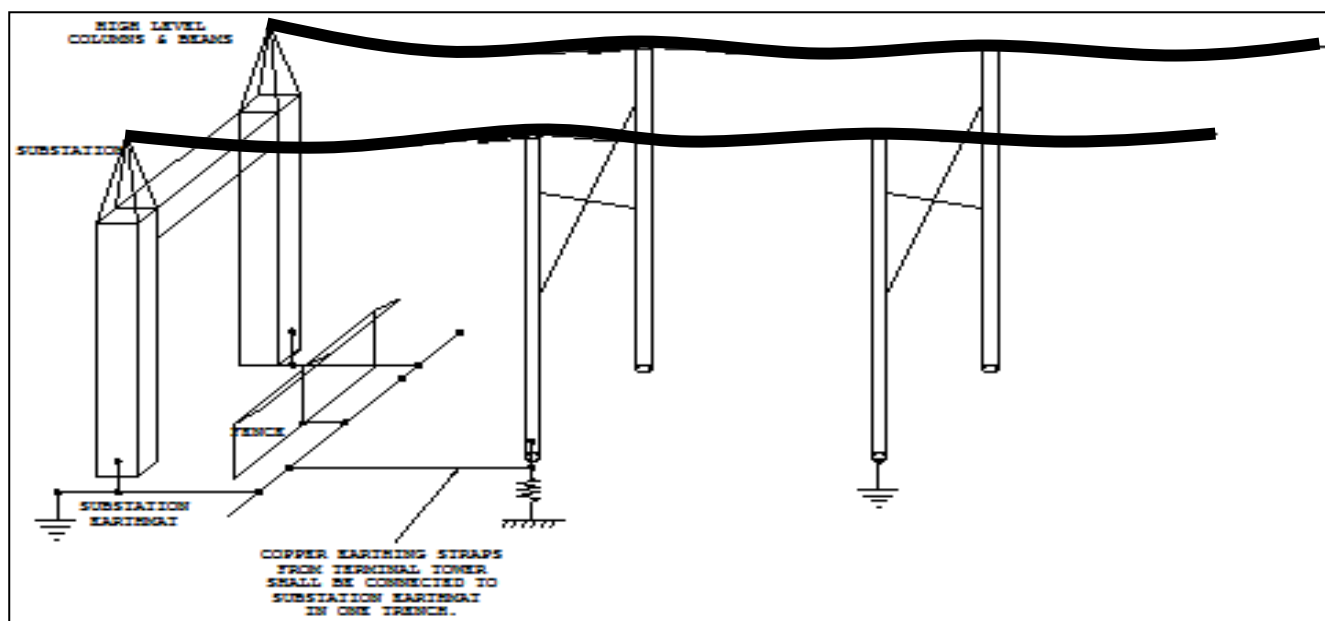


Figure A.2: Terminal tower bonded to substation earthmat

ESKOM COPYRIGHT PROTECTED

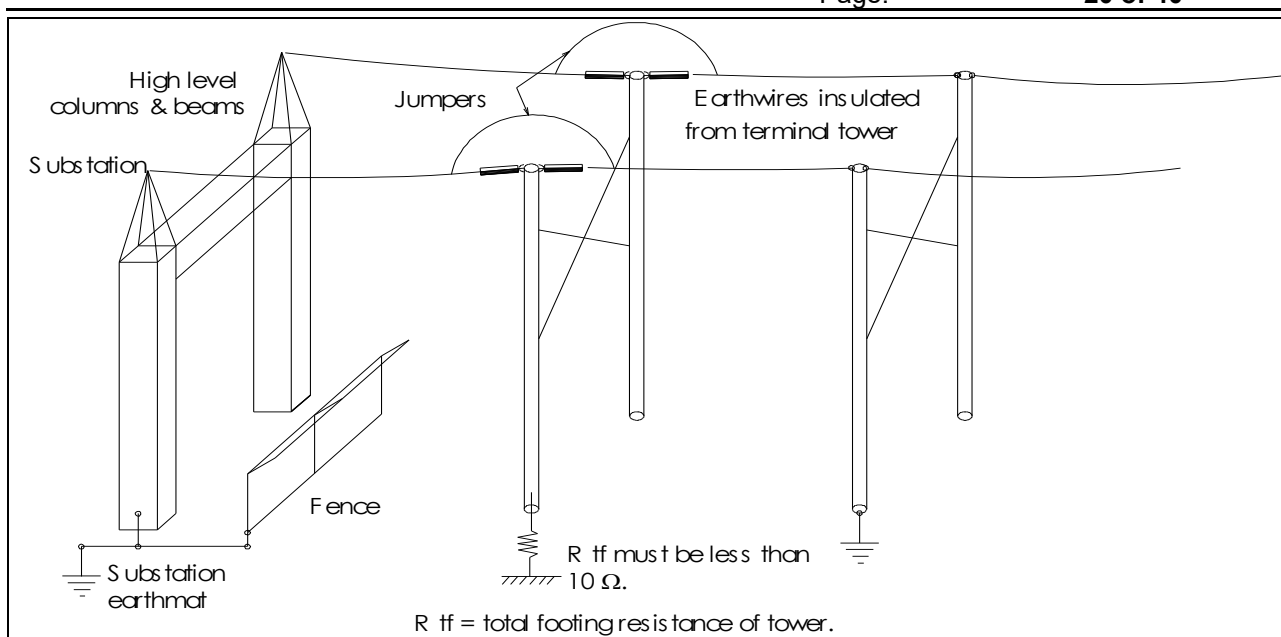


Figure A.3: Insulation of shield wires where terminal tower cannot be connected to substation main earth

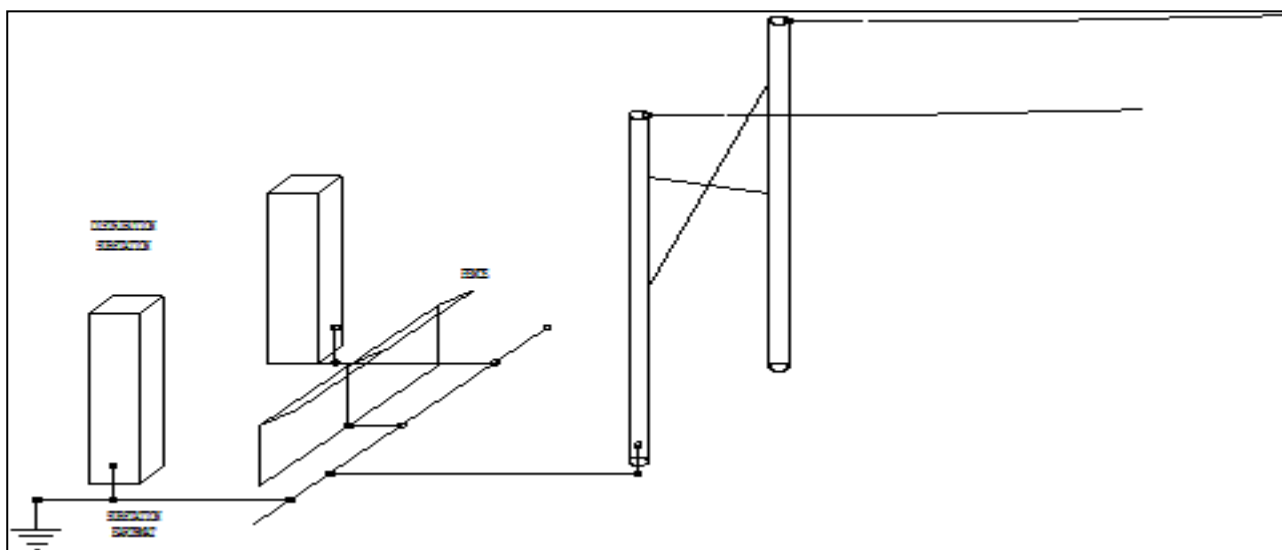


Figure A.4: Normal arrangement for termination at distribution substation with low level busbar

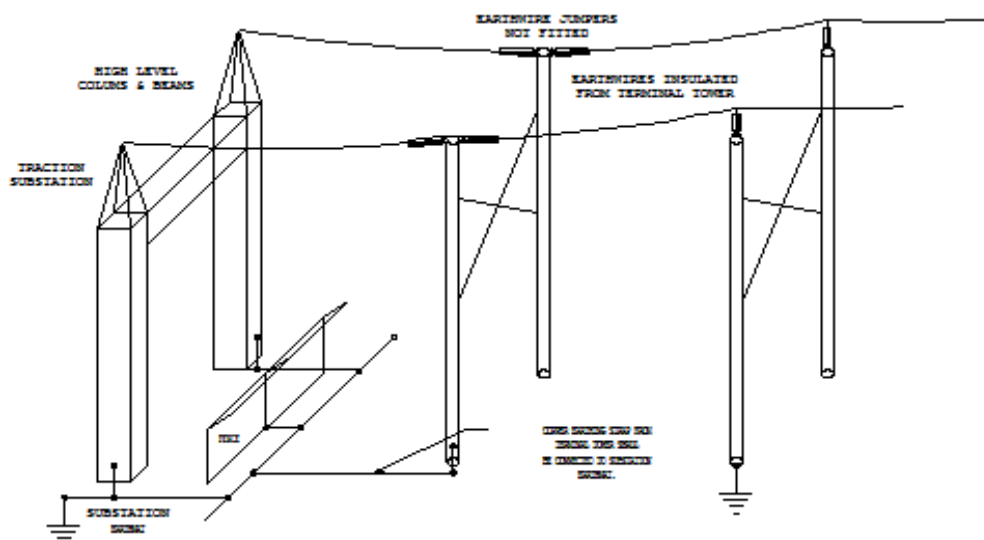


Figure A.5: Normal termination at DC Traction substations

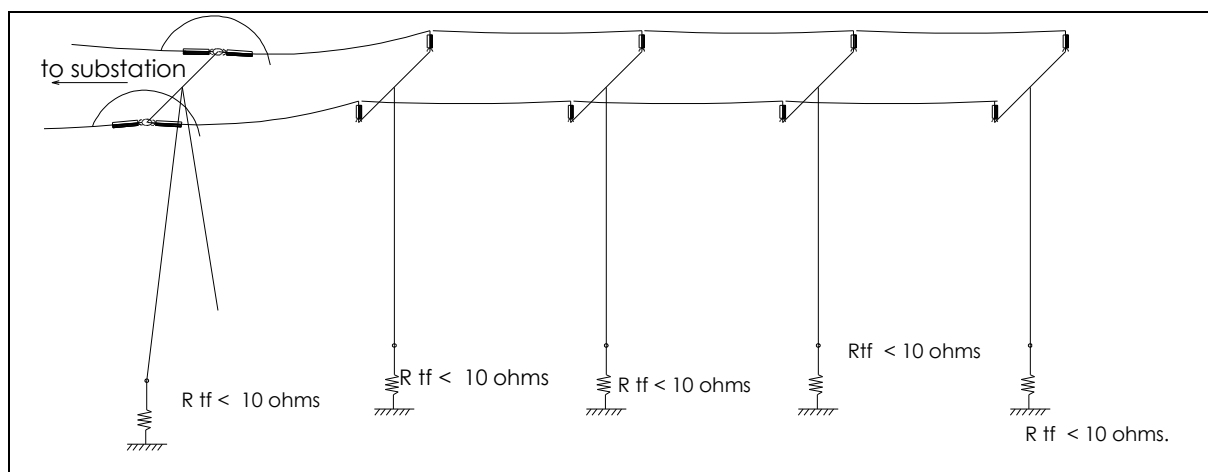


Figure A.6: Insulation of shield wires on first five towers out from substation, with footing resistance less than 10 Ω

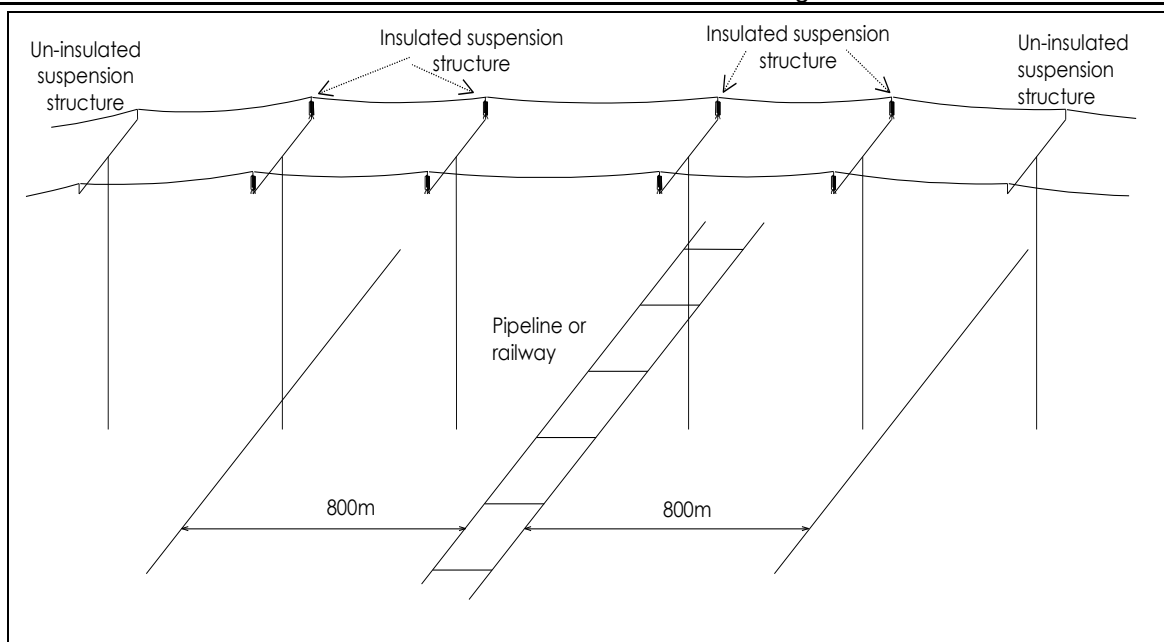


Figure A.7: Insulation of shield wires on suspension towers crossing railway lines or pipelines

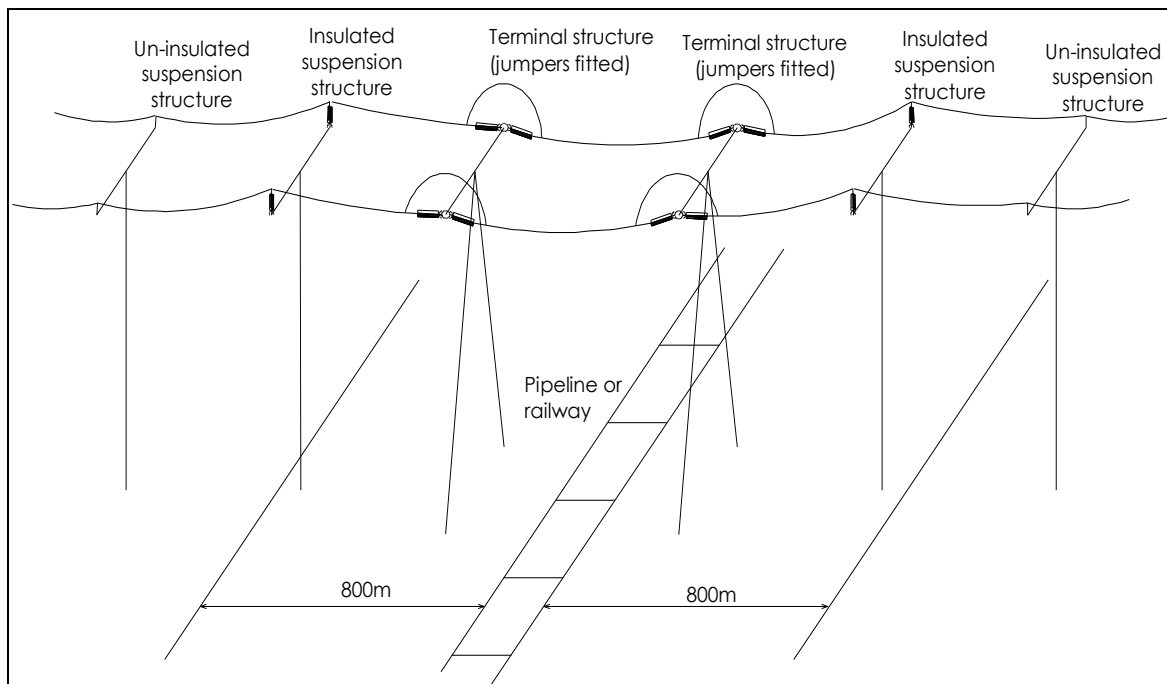


Figure A.8: Insulation of shield wires on suspension and strain towers crossing railway lines or pipelines

ESKOM COPYRIGHT PROTECTED

When downloaded from the WEB, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorized version on the WEB.

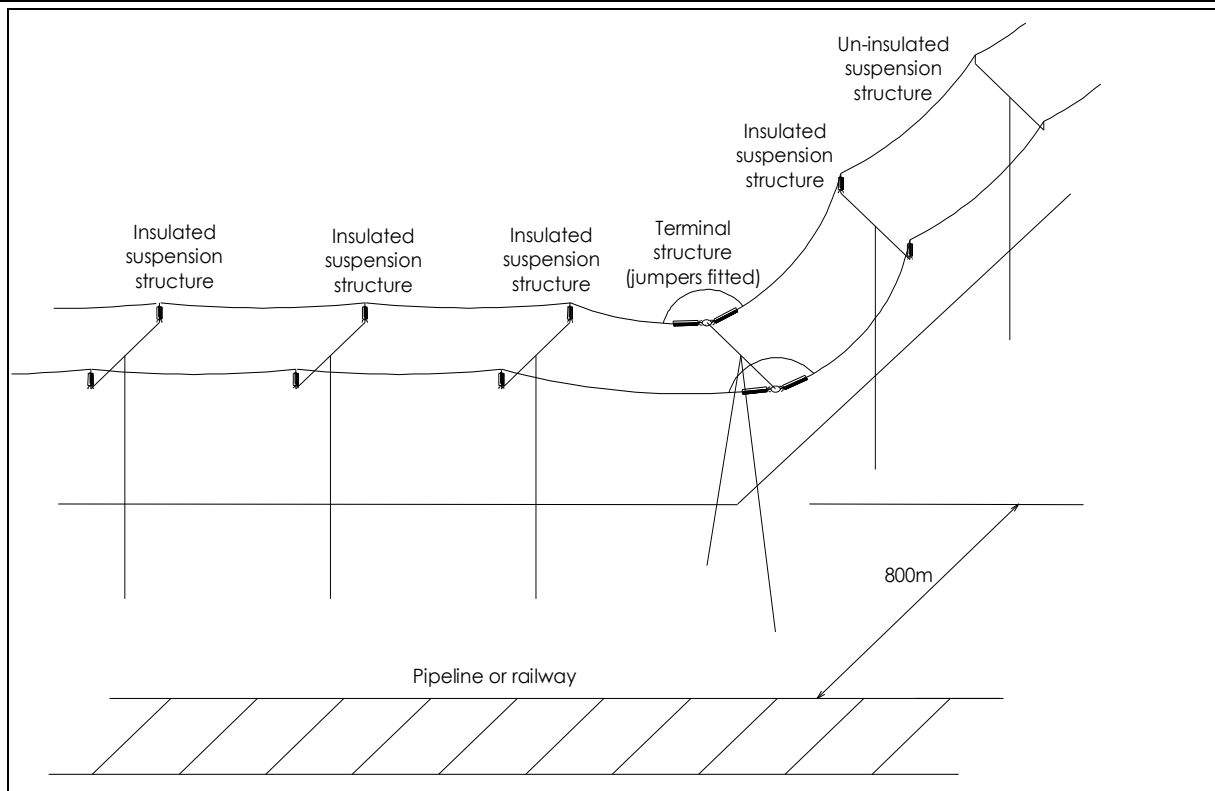


Figure A.9: Insulation of shield wires on routes parallel to railway lines or pipelines

Annex B – Methods of measuring earth resistance

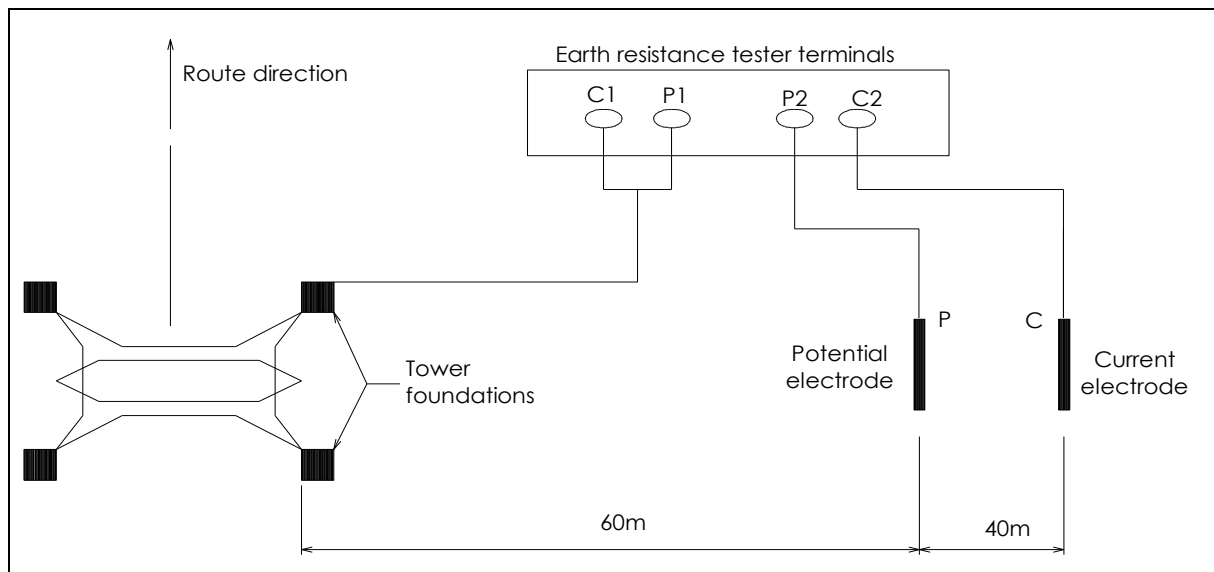


Figure B.1: Method of measuring earth resistance on a tower with standard earthing, using an earth resistance tester

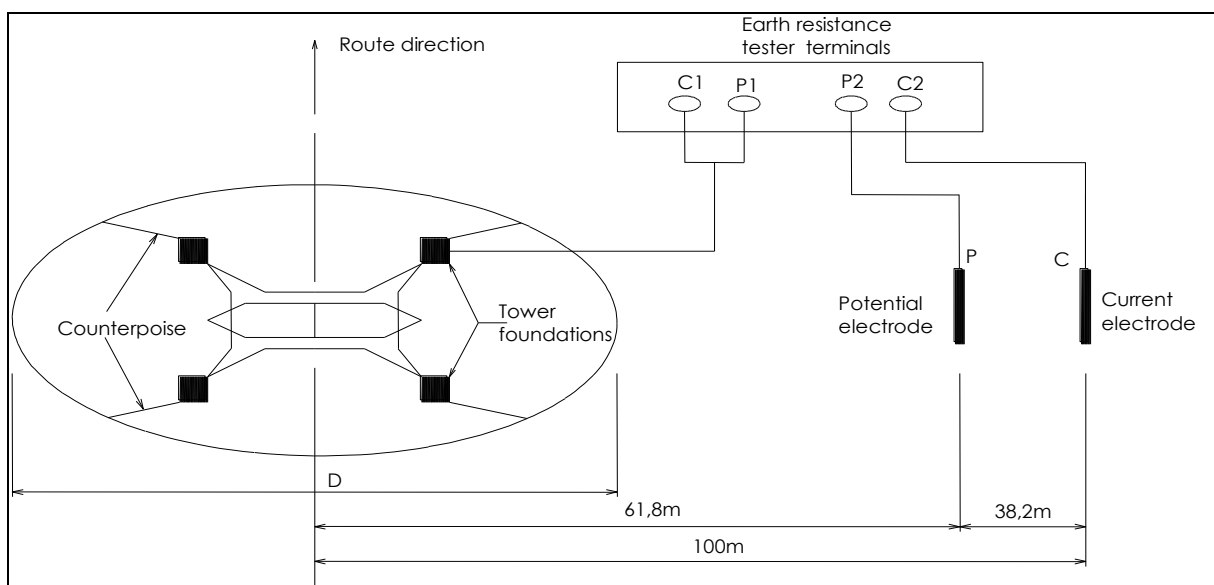


Figure B.2: Method of measuring earth resistance on a tower with counterpoise earthing, using an earth resistance tester

ESKOM COPYRIGHT PROTECTED

Annex C – Various types of counterpoise installations

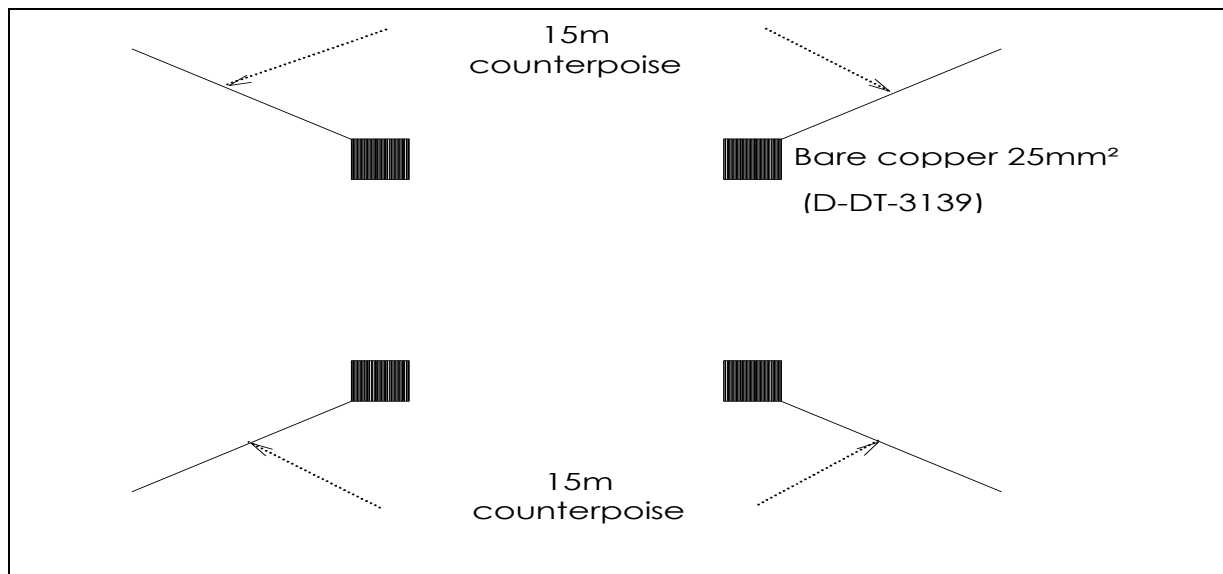


Figure C.1: 4 x 15m Counterpoise earths

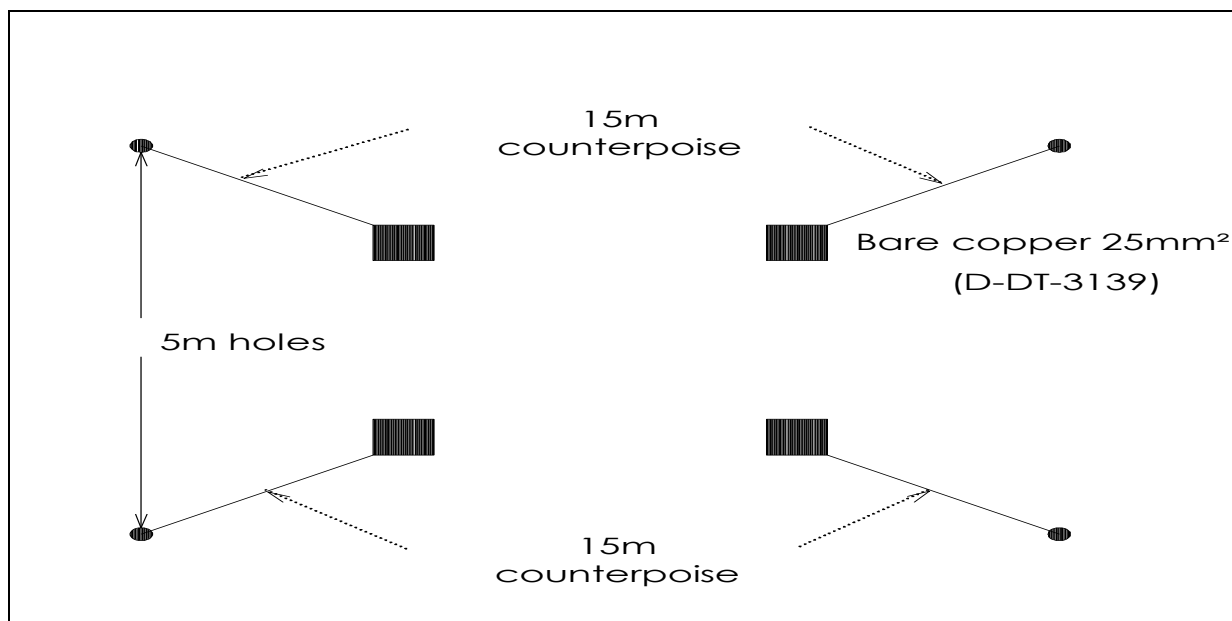


Figure C.2: 4 x 15m Counterpoise earths with 5m drilled hole at each end

ESKOM COPYRIGHT PROTECTED

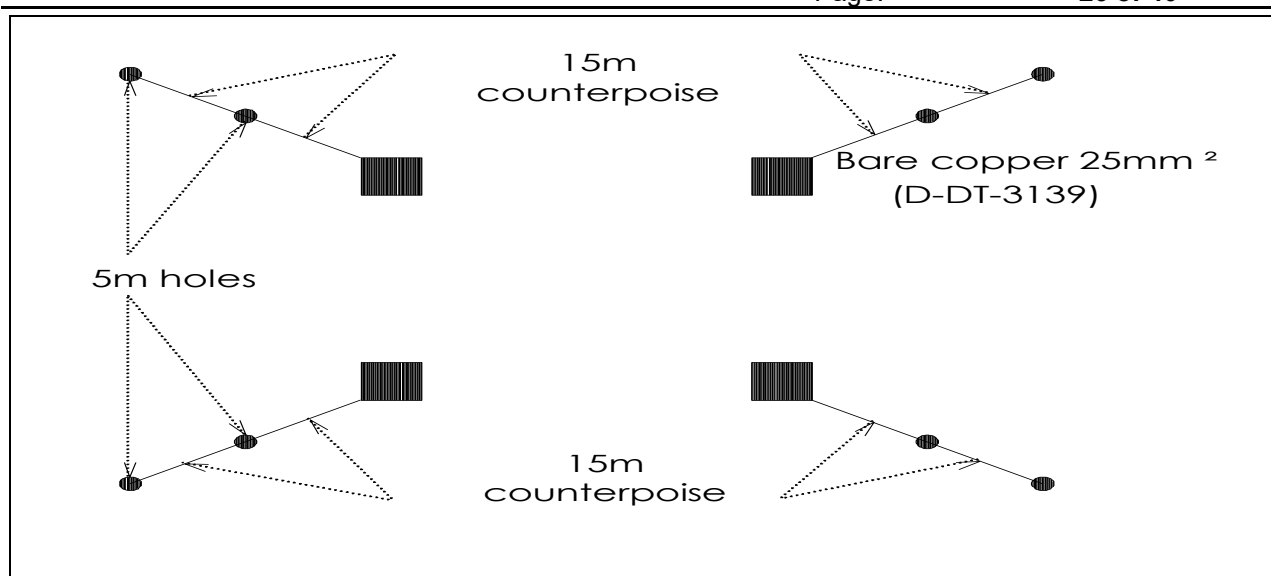


Figure C.3: Method B with additional 15 m counterpoise earths and 5 m drilled hole at each end

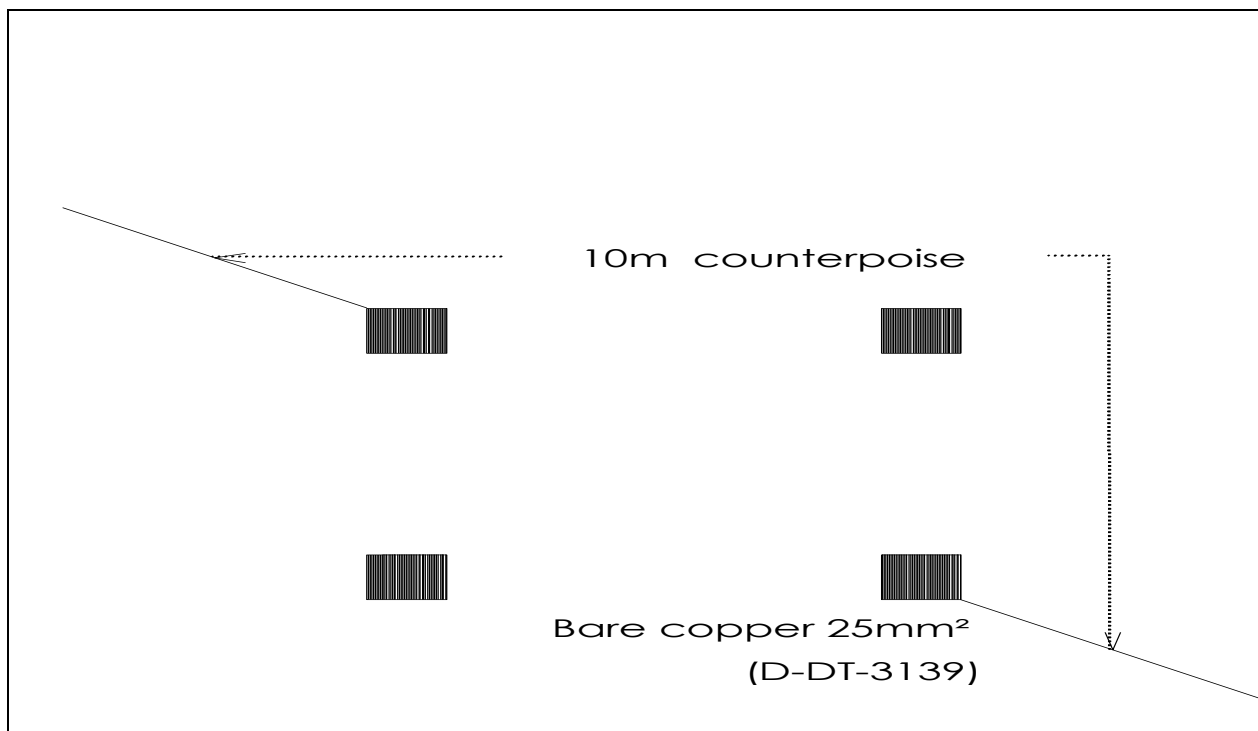
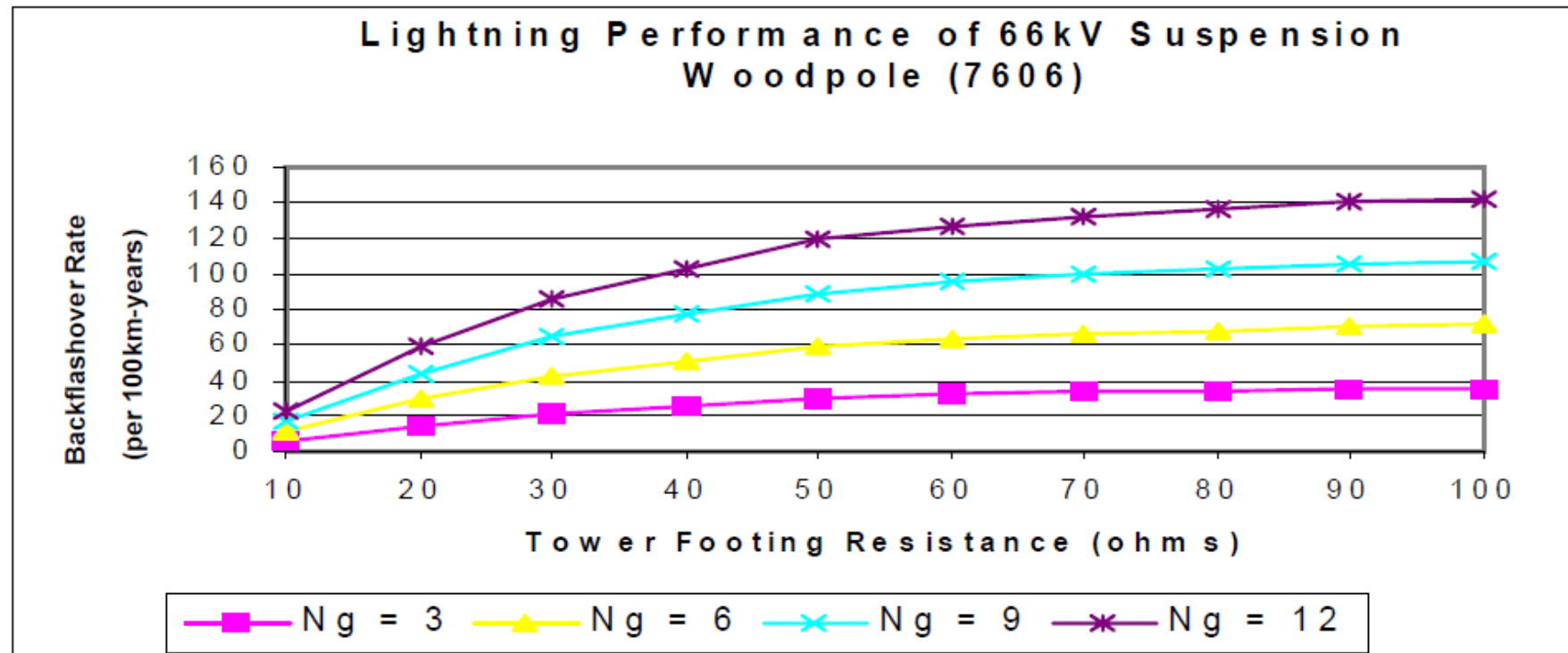


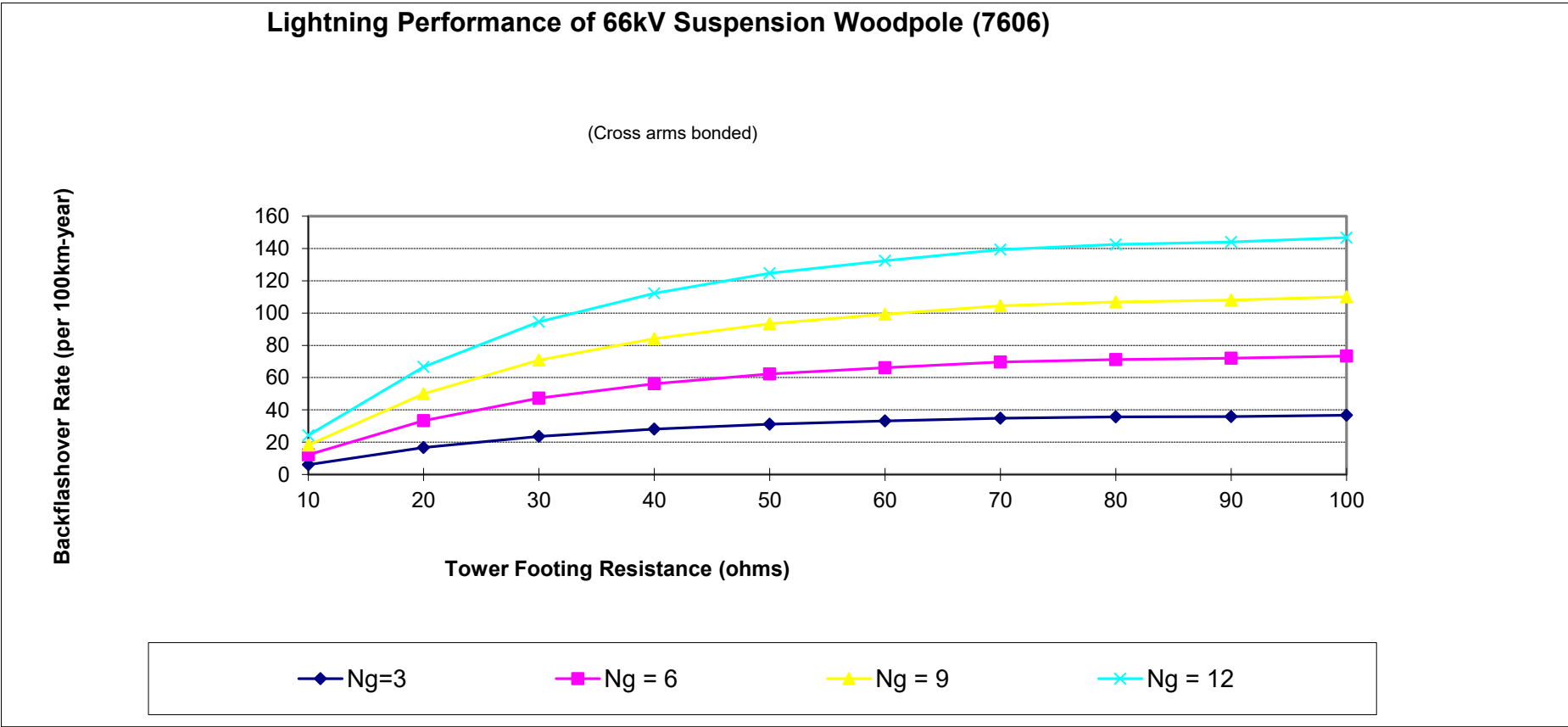
Figure C.4: 2 x 10m Counterpoise earths

ESKOM COPYRIGHT PROTECTED

Annex D – Back flashover rate versus footing resistances**D.1 Lightning performance of 66 kV woodpole suspension tower****ESKOM COPYRIGHT PROTECTED**

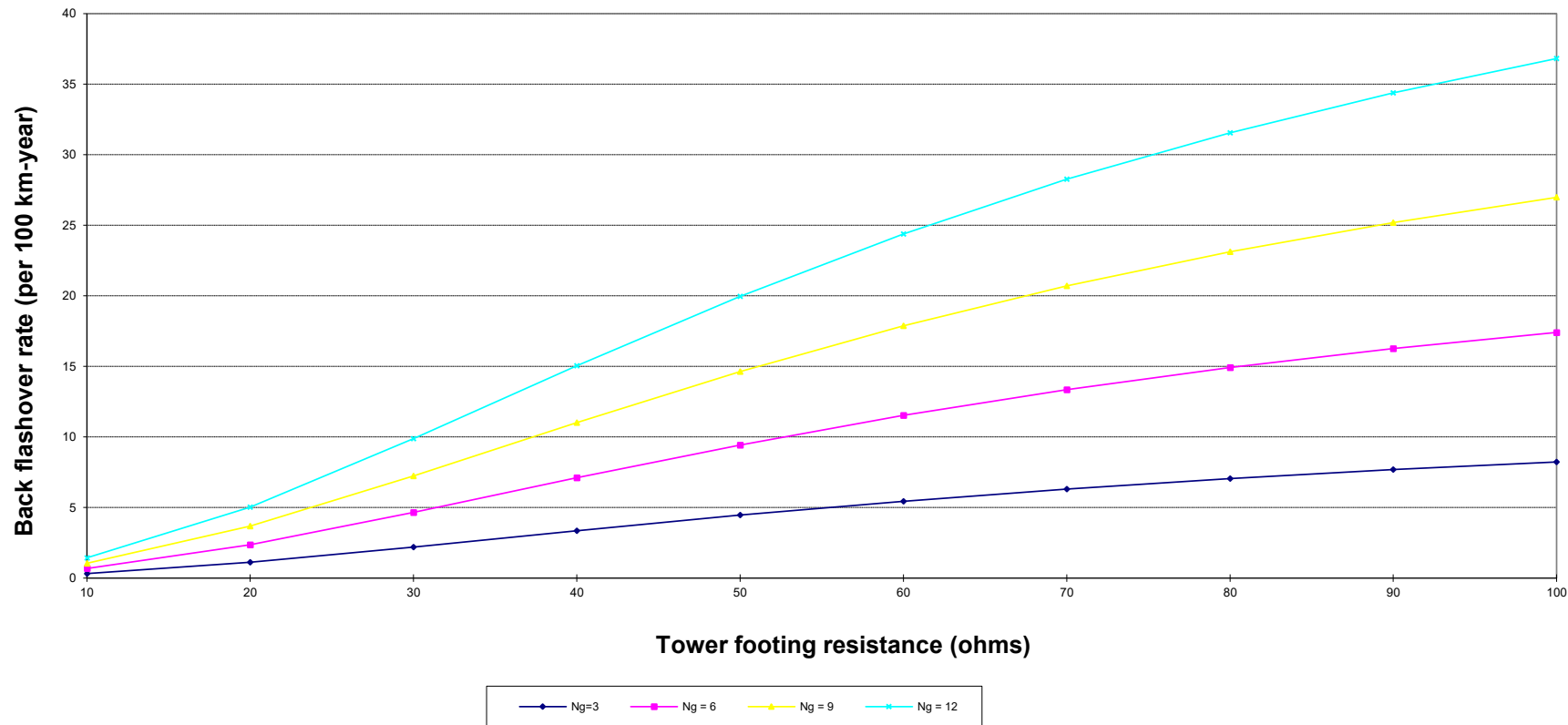
When downloaded from the WEB, this document is uncontrolled and the responsibility rests with the user
to ensure it is in line with the authorized version on the WEB.

D.2 Lightning performance of 66 kV woodpole suspension tower



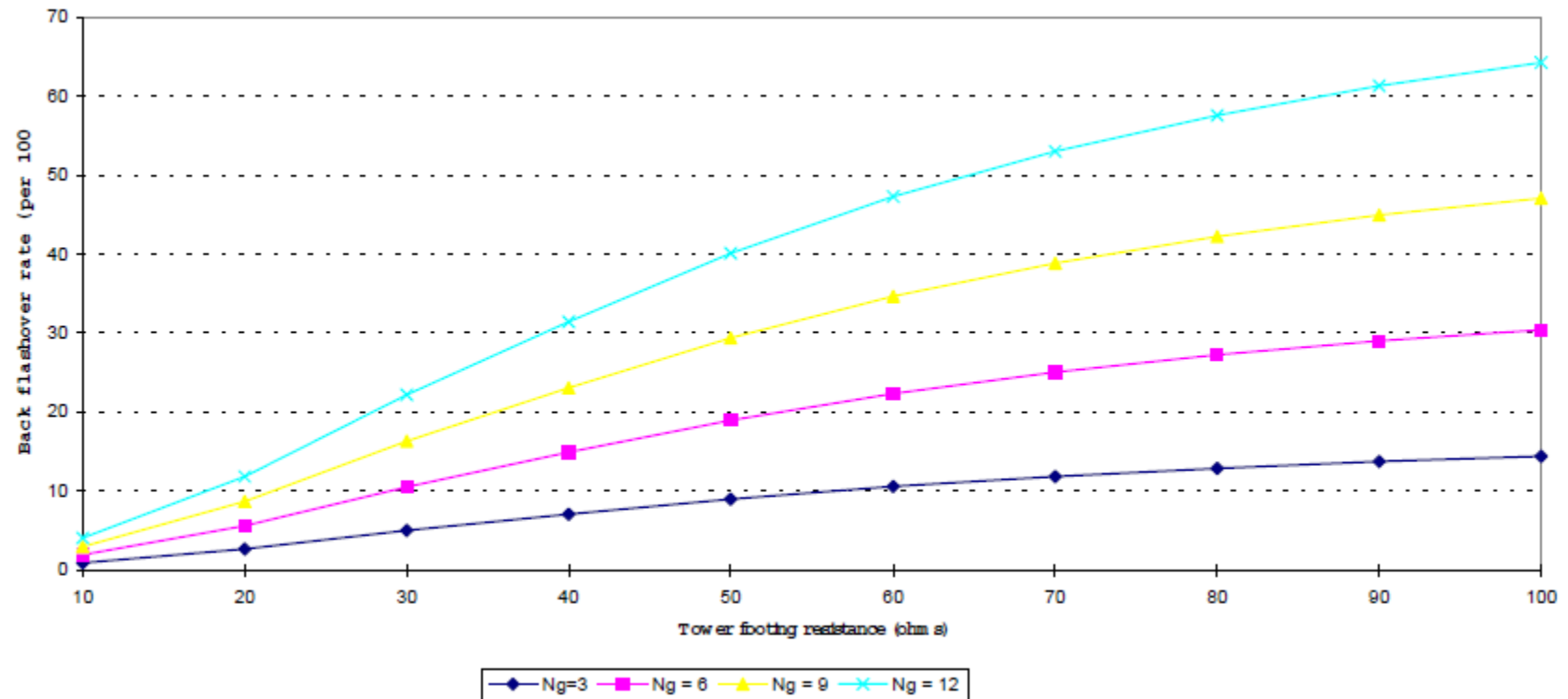
ESKOM COPYRIGHT PROTECTED

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



ESKOM COPYRIGHT PROTECTED

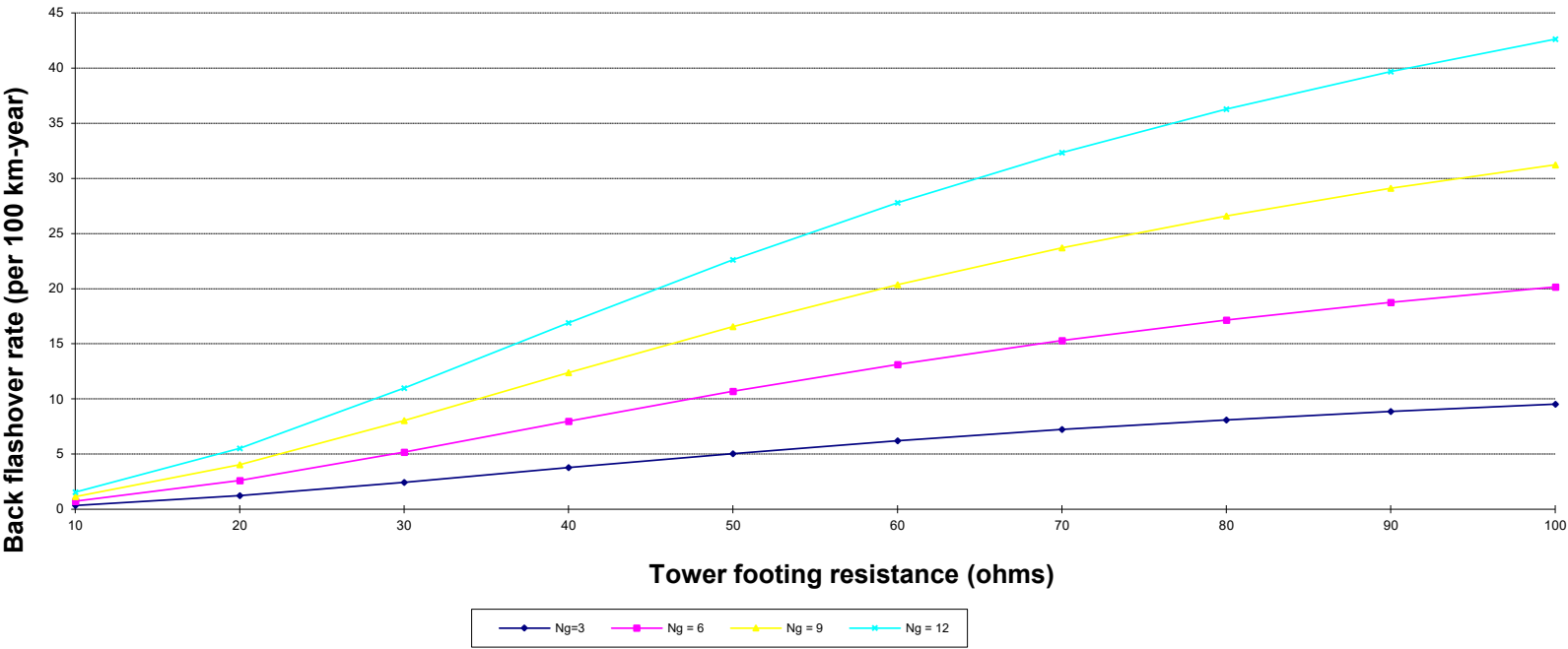
D.4 Lightning performance of 132 kv double circuit tower 253ad



ESKOM COPYRIGHT PROTECTED

When downloaded from the WEB, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorized version on the WEB.

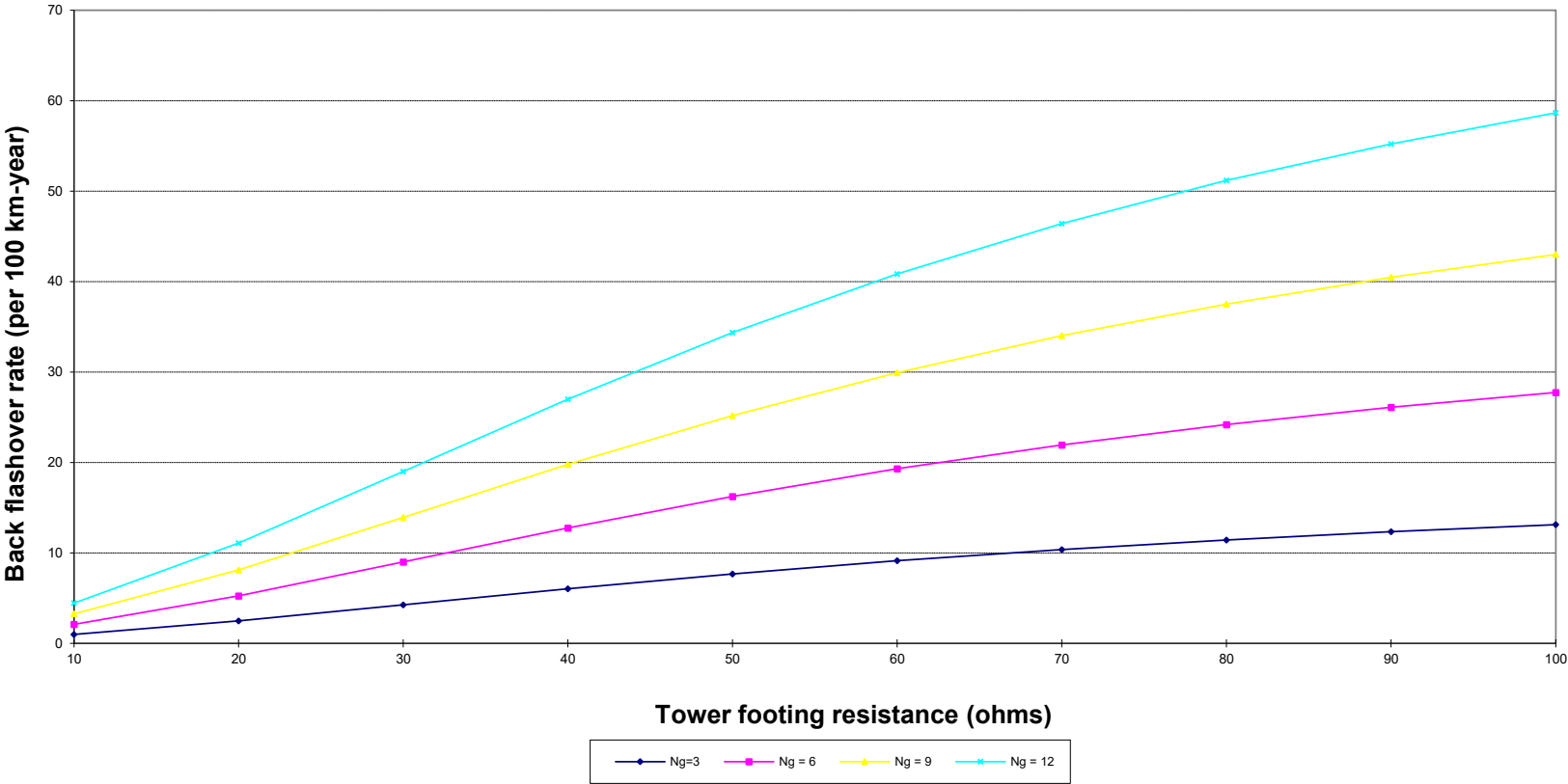
D.5 Lightning performance of 132 kV tower 226 A



ESKOM COPYRIGHT PROTECTED

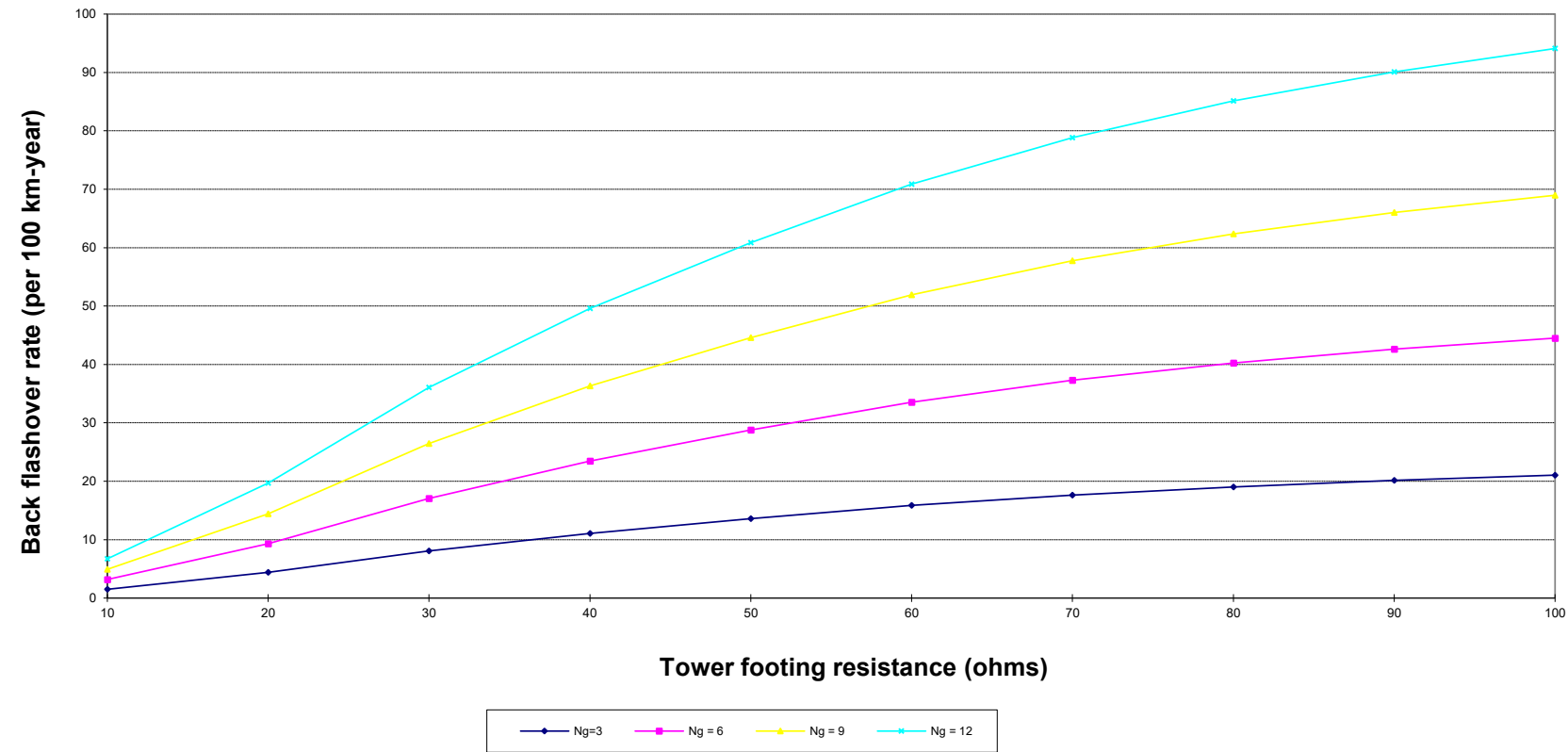
When downloaded from the WEB, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorized version on the WEB.

D.6 Lightning performance of 132 kV tower 248 A



ESKOM COPYRIGHT PROTECTED

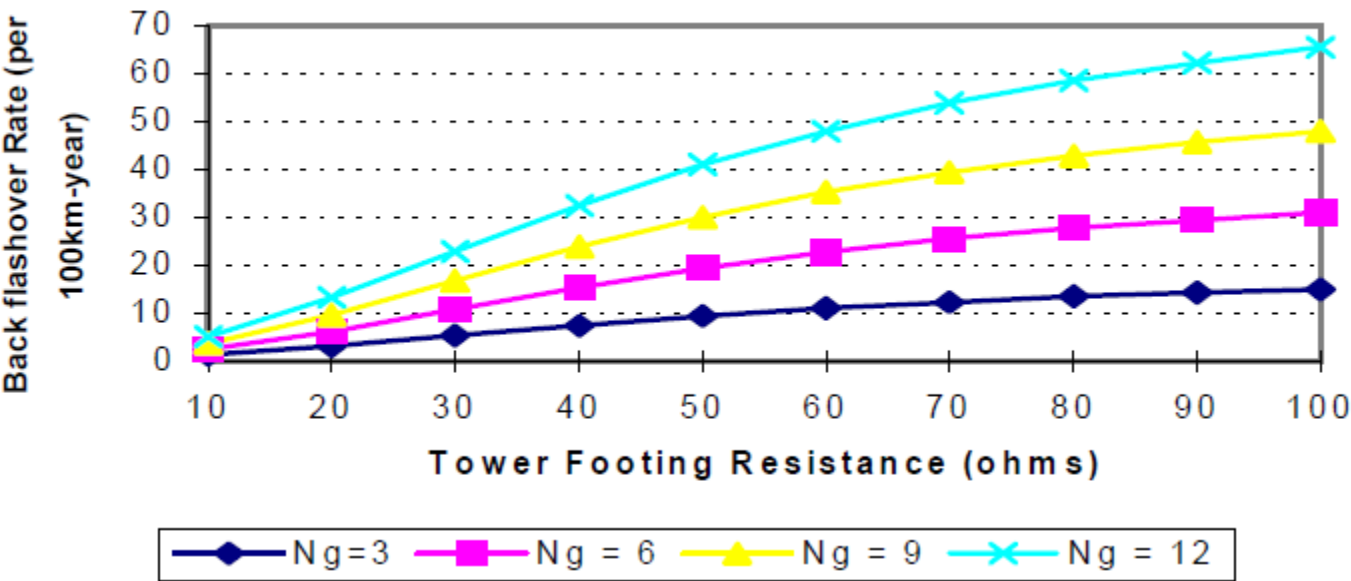
D.7 Lightning performance of 132 kV tower 255 A



ESKOM COPYRIGHT PROTECTED

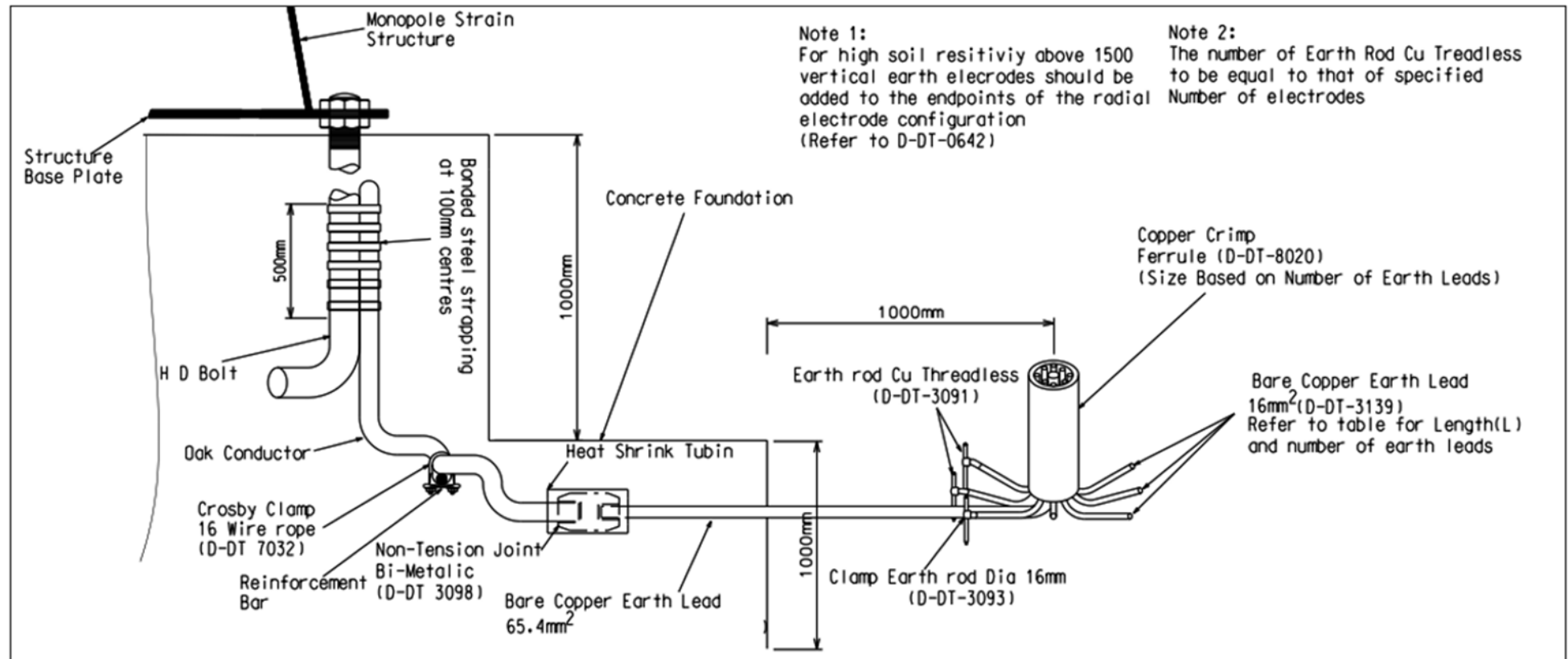
When downloaded from the WEB, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorized version on the WEB.

D.8 Lightning performance of 132 kV stayed steel tower



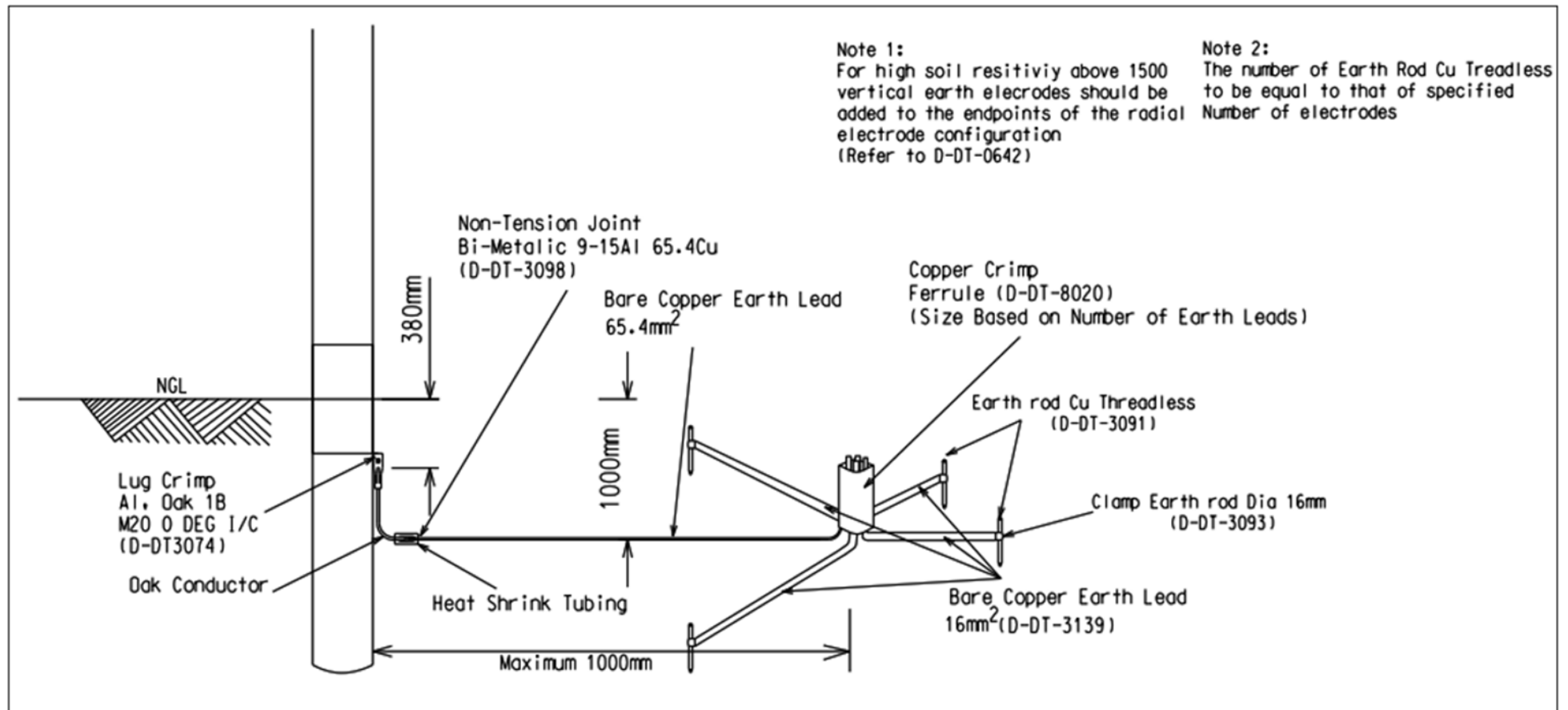
ESKOM COPYRIGHT PROTECTED

Annex E– Earthing system for Steel pole with bolted foundation



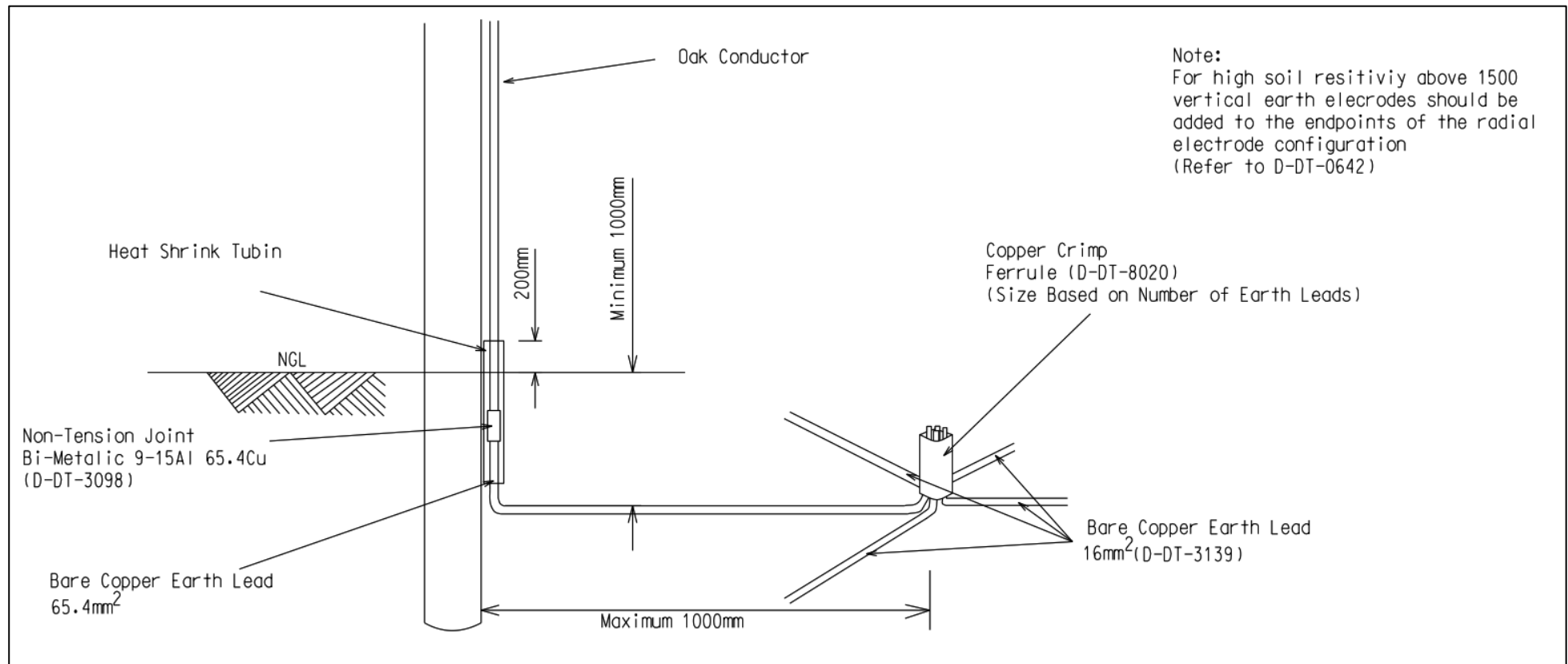
ESKOM COPYRIGHT PROTECTED

Annex F– Earthing system for Steel pole with planted foundation



ESKOM COPYRIGHT PROTECTED

Annex G– Earthing system for wooden poles

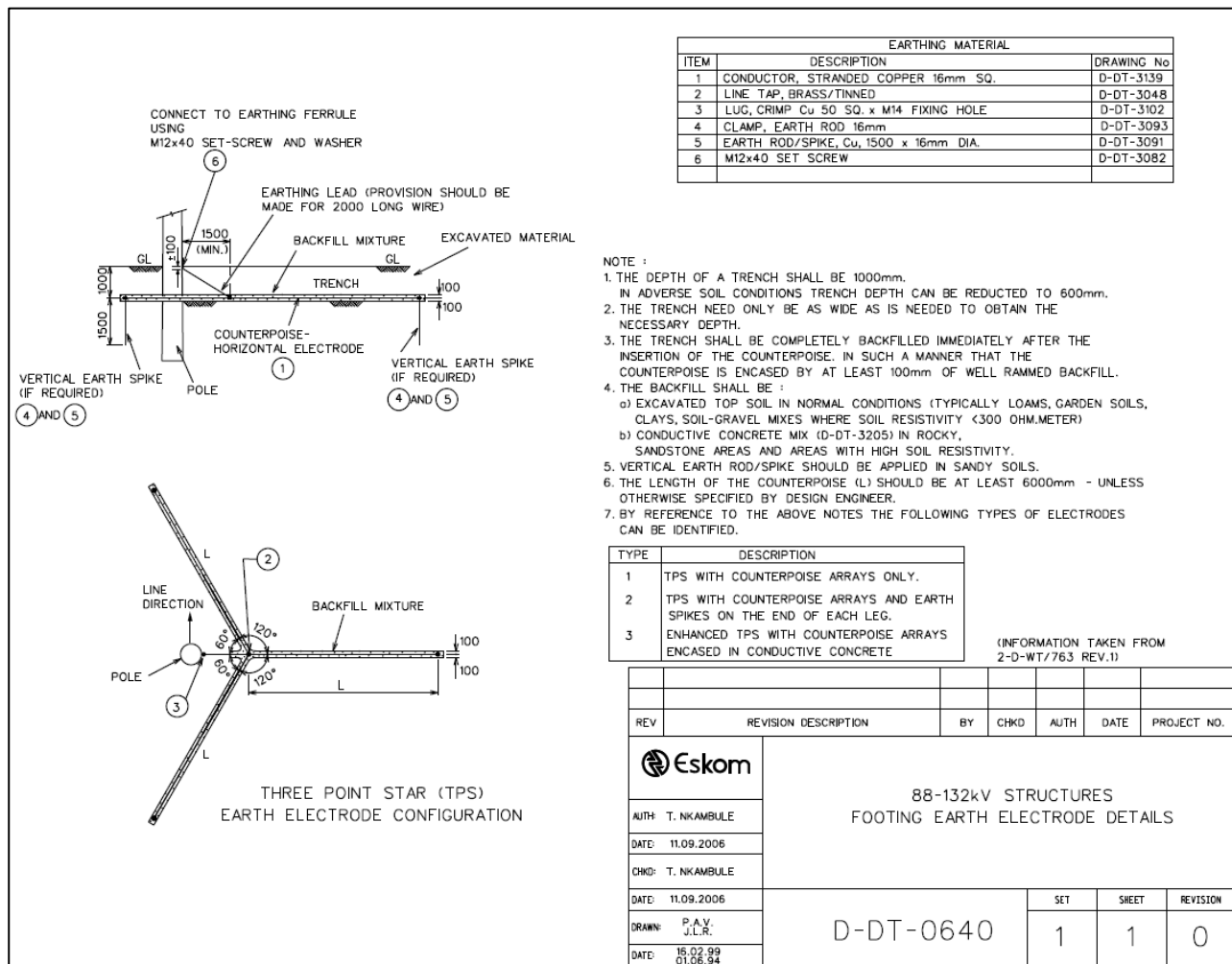


ESKOM COPYRIGHT PROTECTED

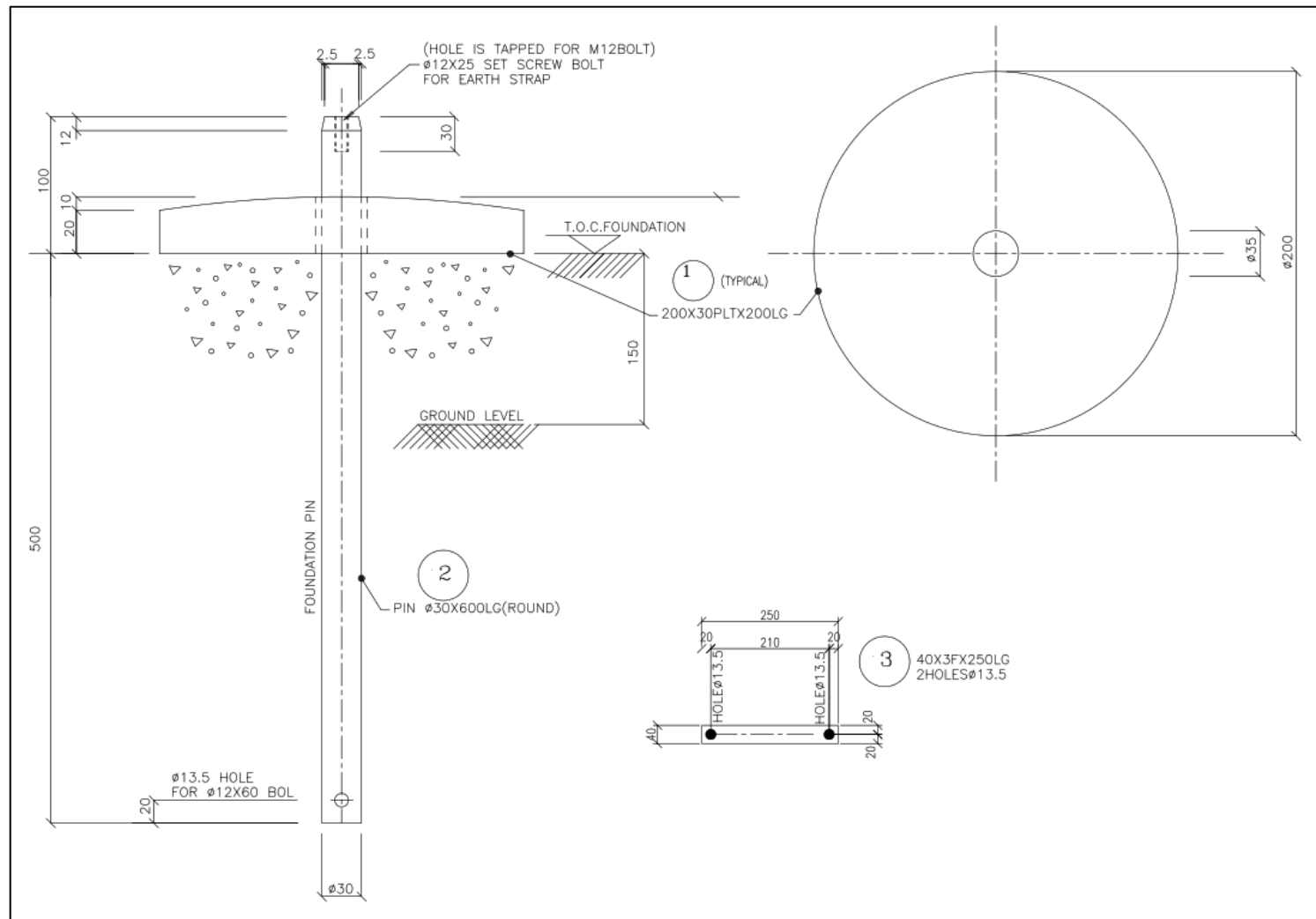
Annex H– Typical resistivity of various materials

Materials	Resistivity (Ωm)
Types of rock	
Compact granite, gneiss	$10^6 - 10^7$
Compact rock, ordinary concrete	10^6
Coal	$10^5 - 10^6$
Master rocks, basalt, diabase	10 000
Dry and fine sand	1000
Water	
Chemically clean water	25×10^4
Distilled water	1000 - 4000
Rainwater	100-1000
Surface water (lakes, rivers)	100 – 500
Ground water, well water, spring water	10 – 150
Sea water	0.1 -0.5
Soils	
Loams, garden soil	5 - 50
Clay, chalk	25 – 70
Clay, sand and gravel mixture	40 -250
Peat, marsh soil and cultivated soil	50 – 250
Diabase, shale, limestone and sandstone	100 – 500
Wet concrete	50 - 100
Dry concrete	2000 - 10000
Minerals and Metals	
Copper	$1.2 \times 10^{-8} - 1.8 \times 10^{-8}$
Refined copper	1.6×10^{-8}
Refined aluminium	2.5×10^{-8}
Graphite	$2.8 \times 10^{-7} - 9.9 \times 10^{-3}$

Annex I – Earthing system for a shallow planted single pole structure.



Annex J – Earthing system for a pinned single structure



ESKOM COPYRIGHT PROTECTED

When downloaded from the WEB, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorized version on the WEB.