

NRS 116-1:2026

Edition 1

**GUIDE FOR DESIGNING WILDLIFE-
FRIENDLY OVERHEAD DISTRIBUTION
LINES**

**PART 1: MEDIUM VOLTAGE LINES –
NEW CONSTRUCTIONS**

This document is not a South African National Standard



This rationalized user specification is issued by
the Technical Governance Department, Eskom,
on behalf of the
User Group given in the foreword
and is not a standard as contemplated in the Standards Act, 1993 (Act No. 29 of 1993).

Table of changes

Change No.	Date	Text affected

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NRS 116-1:2026

Foreword

This specification was prepared by a Working Group that comprised the following members:

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NRS 116 consists of the following parts under the general title Guide for designing wildlife-friendly overhead distribution lines:

Part 1: Medium voltage lines – New constructions

Part 2: Sub-transmission lines – New constructions (to be developed)

Part 3: Mitigation of existing MV and HV lines (to be developed)

Introduction

South Africa's expanding renewable energy sector, as in many parts of the world, has led to the rapid development of overhead power lines by Independent Power Producers (IPPs). This increases the risk of wildlife interactions with power infrastructure, such as electrocutions and the collisions.

Such incidents pose the following risks:

- a) deteriorated network performance: wildlife incidents cause power interruptions, damage to equipment and diminished quality of supply;
- b) financial impact: loss of income from power interruptions and incurrence of costs to repair or mitigate infrastructure;
- c) damaged reputation: negative publicity due to bird mortalities;
- d) environmental impact: wildlife mortalities, especially those classified as protected in terms of legislation, can negatively affect local and regional bird populations; and
- e) legal liability: a utility may be liable for excessive wildlife mortalities.

Many of these power lines are not governed by Eskom or municipal design standards, e.g. lines from IPPs to collector substations. IPP lines also at times have different applications to Eskom, e.g. higher power transfer requirements and use of shield wires, heavy conductors and conductive poles.

There is currently no local industry-wide document that guides designers with respect to designing overhead lines to be wildlife-friendly. The purpose of this specification is to provide guidance for the design of wildlife-friendly lines for cases not governed by Eskom or municipality requirements. This is targeted at all potential users of this information, e.g. designers and operators of this infrastructure and consultants involved (technical and environmental).

This is a legal requirement, in accordance with Section 28 of the National Environment Management Act. It is also a legal requirement to comply with the Occupational Health and Safety Act, which requires compliance with SANS 10280-1. However, SANS 10280-1 does not contain requirements for wildlife safety.

NRS 116 is divided into the following three parts:

Part 1 (this part) covers the design of new medium voltage (MV) lines, where MV is defined as lines operating at 11-33 kV between phases.

Part 2 (to be developed) covers the design of sub-transmission (HV) lines, where HV is defined as lines operating at above 33 kV and up to 132 kV between phases.

Part 3 (to be developed) covers mitigation of existing MV and HV lines, where these lines were not designed according to part 1 or 2.

Keywords

wildlife friendly distribution line, vulture, bird, elephant, rhinoceros, buffalo, giraffe, electrocution, collision, nesting, mitigation.

Contents

	Page
Foreword	3
Introduction	4
1. Scope	3
2. Normative references	3
3. Terms, definitions and abbreviations	3
3.1 Terms and definitions	3
3.2 Abbreviations	4
4. Mitigation of bird electrocution	4
4.1 Technical principles	4
4.2 Electrical separation distances	8
4.3 Structure selection	11
5. Mitigation of bird collisions	17
6. Mitigation of bird nests	18
7. Other risks due to birds	19
8. Mitigation of large game interactions	19
9. Mitigation of Giraffe electrocutions	20
Annex A – Supporting information for electrical separation distances for minimizing bird electrocution risk.....	21
Bibliography	28

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GUIDE FOR DESIGNING WILDLIFE-FRIENDLY OVERHEAD DISTRIBUTION LINES

Part 1: Medium voltage lines – New constructions

1. Scope

NRS 116 covers overhead power lines rated up to and including 132 kV. This part covers the design of new MV lines, where MV is defined as lines operating at 11-33 kV between phases.

The scope includes mitigation of the following:

- a) bird electrocutions, with a focus on vultures because designing lines for vultures, results in safe structures for other birds as well – due to their large size and gregarious nature;
- b) bird collisions;
- c) bird nesting;
- d) interactions with large game such as Elephant, Rhinoceros and Buffalo; and
- e) electrocution of giraffe, due to their large height.

The following is not within the scope of NRS 116:

- a) geographic locations where the contents of NRS 116 should be applied. Cases where the contents of NRS 116 should be applied should be informed by the relevant specialists;
- b) power apparatus apart from overhead lines, e.g. substations;
- c) power with voltages lower than 11 kV, except where specifically mentioned;
- d) direct current (DC) systems;
- e) traction systems and mining and other industrial power systems, apart from overhead electricity distribution infrastructure; and
- f) extremely high risk (localized) locations, e.g. vulture feeding sites; such situations may require special additional measures to those listed in this specification.

2. Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies. Information on currently valid national and international standards can be obtained from the SABS Standards Division.

Occupational Health and Safety Act 85 of 1993.

Occupational Health and Safety Act 85 of 1993: Electrical Machinery Regulations, 2011, Published under Government Notice R250 in *Government Gazette* 34154 of 25 March 2011.

National Environment Management Act No.107 (Act No. 107 of 1998).

SANS 10280-1: Overhead power lines for conditions prevailing in South Africa Part 1: Safety.

3. Terms, definitions and abbreviations

For the purposes of NRS 116, the following terms, definitions and abbreviations apply.

3.1 Terms and definitions

“conductive” material: material that has substantially low electrical resistance (impedance), e.g. concrete and steel

“non-conductive” material: material that, once seasoned, has substantially high electrical resistance (impedance) unless wetted, e.g. due to rain. The most common example is wood.

shielded line: a power line that has one or more earthed shield wires for the purpose of improving lightning performance

unshielded line: a power line that does not include shield wires, and that is designed accordingly

wildlife-friendly: electrical power infrastructure that is intentionally designed to limit the risk of injury or mortality to wildlife, and the consequences thereof, to a reasonably practicable level

3.2 Abbreviations

AMEU: Association of Municipal Electricity Utilities (Southern Africa)

DC: Direct Current

EWT: Endangered Wildlife Trust

FRP: Fibreglass Reinforced Plastic

HV: Sub-transmission

IPP: Independent Power Producer

ISD: Internal Separation Distance

kV: Kilovolt

LED: Light-emitting diode

MV: Medium Voltage

SABS: South African Bureau of Standards

SANS: South African National Standard

SAWEA: South African Wind Energy Association

USA: United States of America

USAID: United States Agency for International Development

4. Mitigation of bird electrocution

This section explains the technical principles of mitigation, namely isolation, avoidance and insulation. The recommended electrical separation distances associated with the isolation approach are then provided. Guidance on selection of structure configurations is then given.

4.1 Technical principles

The following are important to note (from [4], augmented with South African experiences):

- At-risk birds such as vultures and other raptors¹ are at the highest risk of electrocution on electricity networks in the range covered by this specification because the dimensions of their bodies are comparable with (or greater than) the separation between conductive apparatus such as conductors, jumpers power line structures. The most commonly involved species are listed in table 1.
- This is complicated by the following:
 - Bird feathers provide excellent electrical insulation when dry, bird flesh-to-flesh dimensions are therefore the most important.
 - A living being does not need to be in direct contact with an energised object to be electrocuted. This is because voltage can cause air to electrically break down, and hence for sparks to jump across air gaps – the higher the voltage, the greater the distance that can be bridged. Lightning is an extreme example.
- Far fewer direct electrocutions have historically been recorded on the transmission lines of South African utilities such as Eskom and municipalities – less than 4% [18]. This is due to transmission voltages being higher than distribution voltages and hence require larger separation distances.

¹ At-risk birds are defined for the purposes of this specification as species listed on the International Union for Conservation of Nature's Red List of Threatened Species [5].

- Low voltage distribution, such as that to homes (230/400 V), is considered to pose insignificant risk because it is usually insulated².
- Medium voltage networks of below 11 kV are relatively rare in South Africa.
- The principal modes of electrocution are phase-to-phase and phase-to-earth, as illustrated in figure 1. Phase-to-earth mode applies to conductive structures, such as those constructed from materials such as iron or aluminium. This mode also applies in some cases to structures made from an ostensibly non-conductive material. For example, concrete includes iron reinforcing and materials such as fibreglass and wood can become conductive when wet and/or coated in pollution such as sea salt or from industrial sources. Wood is also often more conductive when new [6].
- Complex structures can often pose a greater risk than a simple intermediate or strain structure. Complex structures include those with transformers, reclosing circuit breakers, voltage regulators and t-offs, and usually occur only on medium voltage networks (up to and including 33 kV [3]). Examples of different structure types are shown in figure 2.
- Mitigation may be by one of the following:
 - *Isolation* involves providing sufficient separation distance between conductive objects energised at different voltages to sufficiently limit the risk of a bird being electrocuted.
 - *Avoidance* involves placing some conductive objects out of reach of birds, such as the case in figure 3 where the phase conductors of the two outside phases are suspended below the cross-arm. In this case, birds are not likely to be in the vicinity of the two lower phase conductors because they will in all likelihood perch on the cross-arm.
 - *Insulation*³ of energised parts to prevent a bird from touching an energised object. An example is where the centre phase conductor is covered in figure 3.
- Mitigation by isolation and avoidance are generally preferable at the design stage because this removes the need for additional material that needs to be maintained.
- To effectively apply mitigation by isolation, one must take the following into account:
 - Flesh-to-flesh⁴ dimensions of the largest birds reasonably expected to perch on the infrastructure. This is illustrated in figure 4.
 - The voltage at which the infrastructure will be operated – the higher the voltage, the larger the separation distances need to be.
 - Other mitigating or aggravating factors.

² Additionally, many uninsulated low voltage lines are built in a vertical configuration, which makes it difficult for a bird to simultaneously touch conductors of different voltages.

³ “Insulation” refers to the covering an energized object with non-conductive material of sufficient thickness to permanently prevent contact with the energized object, i.e. it is designed to indefinitely withstand the full voltage at which the object is energized. “Covering” refers to covering an energized object with non-conductive material of sufficient thickness to only protect a bird from momentary contact, e.g. on take-off or landing. Covering is not intended as insulation, i.e. it is not intended to withstand long contact. This notwithstanding, the two terms are used interchangeably in this specification.

⁴ Feathers are usually of high electrical resistance, except when wet. Further information may be found in [Beutel 2019] (refer to the bibliography).

Table 1 — Bird species most commonly electrocuted on electricity distribution infrastructure

Cape Griffon	Spotted Eagle Owl	Southern Ground Hornbill
White-backed Vulture	Barn Owl	Spur-winged Goose
Lappet-faced Vulture	Verreaux's Eagle-owl	Marabou Stork
Martial Eagle	Cape Eagle Owl	Black Crow
African Fish Eagle	Jackal Buzzard	Pied Crow
Verreauxs' Eagle	Steppe Buzzard	Hadedda Ibis
Long-crested Eagle	Pale Chanting Goshawk	African Sacred Ibis
Crowned Eagle	Grey Heron	Egyptian Goose
Black-breasted Snake Eagle	Black-headed Heron	Helmeted Guineafowl
Rock Pigeon	White Stork	Grey Crowned Crane
Speckled Pigeon	Cattle Egret	

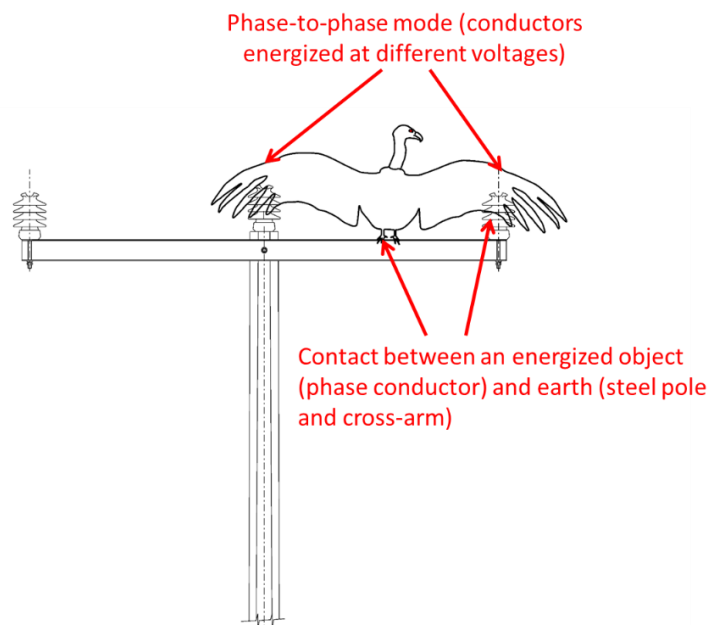


Figure 1: Bird electrocution risks on electrical infrastructure



Intermediate structure



Strain structure



T-off



Recloser structure

Figure 2: Examples of typical structures used on medium voltage distribution networks

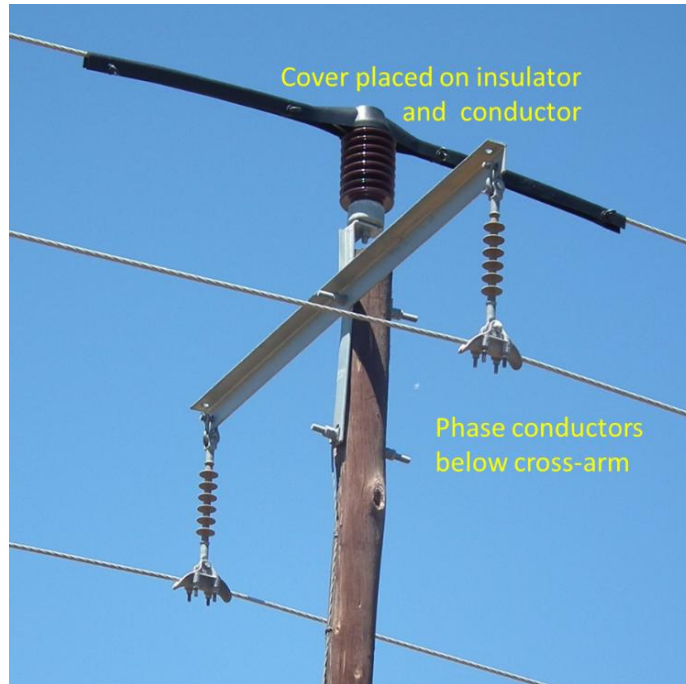


Figure 3: Example of insulation and avoidance principles

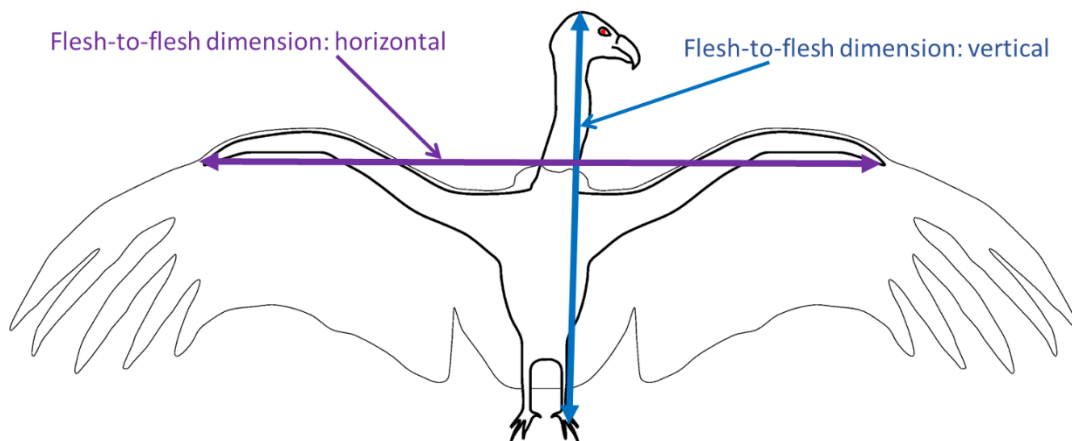


Figure 4: Flesh-flesh bird dimensions (approximation)

4.2 Electrical separation distances

The recommended minimum horizontal separation distances are listed in table 2 and the recommended minimum vertical separation distances are listed in table 3.

Table 2 — Minimum recommended horizontal separation distances (m)^a

Internal separation distance (ISD) ^b		Add flesh-flesh wingspan of large bird ^c	Total separation distance – full bird ^d		Total separation distance – end of structure ^e	
Phase-to-earth	Phase-to-phase		Phase-to-earth	Phase-to-phase	Phase-to-earth	Phase-to-phase
0,11	0,17	1,77	1,91	1,98	1,02	1,09

Table 3 — Minimum recommended vertical separation distances (m)^a

Internal separation distance (ISD) ^b		Add vertical flesh-flesh bird height ^f	Total separation distance – full bird ^d		Total separation distance – end of structure ^e	
Phase-to-earth	Phase-to-phase		Phase-to-earth	Phase-to-phase	Phase-to-earth	Phase-to-phase
0,11	0,17	1,50	1,63	1,70	0,88	0,95

NOTE:

^a For solitary birds, all dimensions in metres.

^b The internal separation distance is defined as the minimum electrical separation distance internal to a power line tower (structure) required to minimise the probability of electrical flashover (fault), excluding the effect of a bird in the vicinity. This is illustrated in figure 5.

^c Flesh-flesh bird dimensions as illustrated in figure 4, and explained further down.

^d Total separation distance for a full bird is for the case where it is possible for a bird to be electrocuted in more than one mode, as illustrated in figure 6. It is calculated as follows:

$$\text{Total clearance (full bird)} = (\text{Internal clearance} \times \text{Bird movement factor}) + \text{Bird dimension}$$

where:

- the internal separation distance takes into account the ability of electrical flashover through air and hence increases with voltage.
- the bird movement factor is a safety factor used to increase the minimum approach distance to take into account bird movement. A value of 1,2 was selected.
- the bird dimension is the flesh-flesh wingspan for horizontal separation distances and flesh-flesh bird height for vertical separation distances.
- all voltages are steady state power frequency (50 Hz in South Africa).

^e Total separation distance at the end of a structure is for the case where it is possible for a bird to be electrocuted in only one mode, e.g. most likely where the bird is seated at the end of cross-arm. This separation distance is only relevant where a bird can only perch at the end of the gap, and can't realistically get further into the gap, for example as illustrated in figure 7. Otherwise, the full separation distance applies. Total separation distance at the end of a structure is calculated as follows:

$$\text{Total separation distance (end of structure)} = (\text{Internal separation distance} \times \text{Bird movement factor}) + (\text{Bird dimension} / 2)$$

^f Tip of feet to wings stretched out – take-off or landing. Details are included further down.

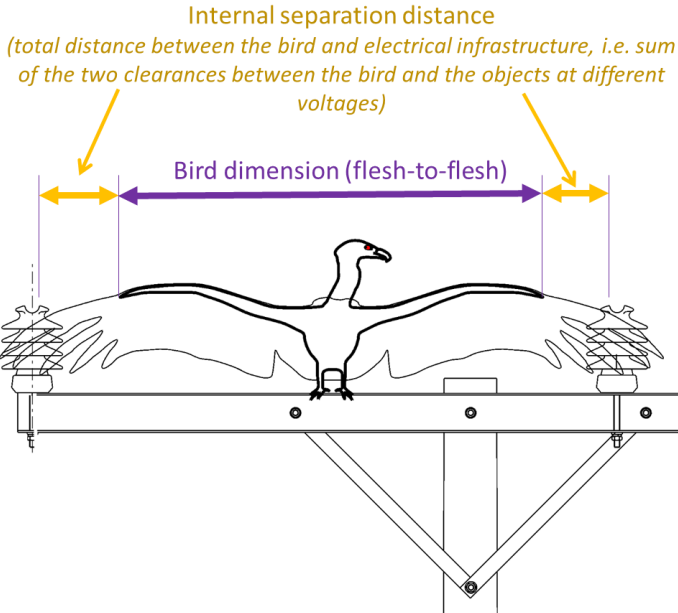


Figure 5: Illustration of internal separation distance by way of example for the horizontal case

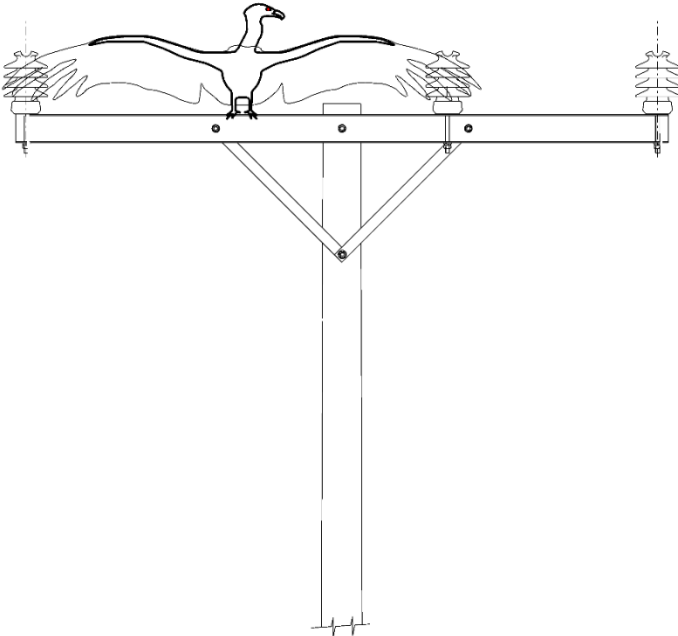


Figure 6: Example of total separation distance for a full bird

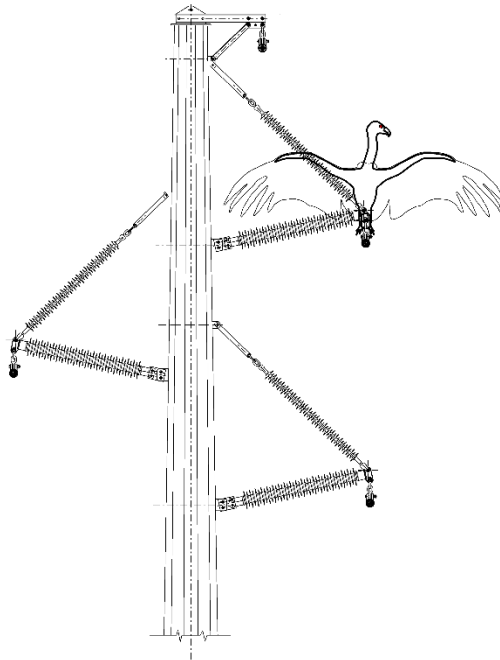


Figure 7: Example of total separation distance for a bird seated at the end of a structure

Traction voltages are also covered by SANS 1019 [3], with the following recommendations for the standard traction voltages falling within the range of Table 2 and table 3:

- Below 11 kV: the values in table 2 and table 3 are recommended, noting that low voltage distribution is considered to pose insignificant risk.
- 25 kV: the values in table 2 and table 3 are recommended.

The reasoning and detail behind the calculations are provided in Appendix A.

4.3 Structure selection

Table 4 and table 5 guide the designer in selecting structures to minimize the risk of bird electrocutions, with a focus on vultures because their large size and gregarious nature mean that designing lines for vultures results in safe structures for other birds as well. Options for shielded and unshielded lines are given and structure types that can be used without any additional bird electrocution mitigation and those that require mitigation (with mitigation measures included) are listed. Figures illustrate the various options – these figures are not drawn to scale; their intention is purely to illustrate the principles. Allowable structure families with no mitigation should adhere to the electrical separation distances of Section 4.2.

Table 4 — Mitigation of bird electrocution: intermediates

Allowable structure families – no mitigation – unshielded	Allowable structure families – with mitigation – unshielded	Allowable structure families – no mitigation – shielded	Allowable structure families – with mitigation – shielded
H-pole suspension, “non-conductive” or “conductive” pole and cross-arm (Figure 8)	Delta, “non-conductive” or “conductive” pole and cross-arm, cover centre phase (Figure 9)	Monopole delta suspension (“non-conductive” or “conductive”) (Figure 10)	None
		H-pole suspension, “non-conductive” or “conductive” pole and cross-arm (Figure 11)	
		Double circuit single-pole suspension (Figure 12)	
		Single or double circuit braced post structure (“non-conductive” or “conductive”) (Figure 13)	

Table 5 — Mitigation of bird electrocution: strainers and equipment structures

Allowable structure families – no mitigation – unshielded	Allowable structure families – with mitigation – unshielded	Allowable structure families – no mitigation – shielded	Allowable structure families – with mitigation – shielded
Triple-pole structures, “non-conductive” or “conductive” (Figure 14)	None	H-pole strain, “non-conductive” or “conductive” pole and cross-arm (Figure 15)	None
H-pole strain, “non-conductive” or “conductive” pole and cross-arm (Figure 16)		Single-pole strain (Figure 17) For double circuits, use two single-pole strainers	
Equipment and other complex structures, e.g. T-offs, transformers, reclosers, cable terminations: cover all jumpers (Figure 18)			

The following principles apply to table 4 and table 5:




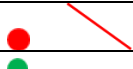


- “Non-conductive” materials refer to those that, once seasoned, have substantially high electrical resistance (impedance) unless wetted, e.g. due to rain. The most common example is wood, but composite poles and cross-arms have been used in other parts of the world⁵. This specification does not preclude the use of composite poles and cross-arms.
- “Conductive” materials refer to materials that have substantially low electrical resistance (impedance), e.g. concrete and steel.
- Wood pole structures may require bonding and/or earthing wires for reasons such as lightning and pollution performance. All down-running earth wires used on unshielded lines must have a gap inserted, to prevent them from transferring earth potential to the pole-top. Two examples of how this gap can be implemented are shown in figure 19.
- Pole-top electrical bonding wires may be required for insulation coordination purposes on “non-conductive” structures. These should be positioned such that they don’t introduce significant additional electrocution risk. Figure 20 shows an example of such bonding. In this case the bonding should be run below (preferably) or along the side of the cross-arm as

⁵ CIGRE Technical Brochure 818, Transmission line structures with Fiber Reinforced Polymer (FRP) composite, Nov 2020.

much as possible to limit the risk of a bird making simultaneous contact with the bonding and the live centre phase conductor. This is achieved in the case of figure 20, but it would not be possible if the cross-arm were conductive, e.g. steel.

- All jumpers that are not suspended must be covered, even for structures listed as not requiring mitigation. Covering is defined as a non-conductive barrier that can withstand the voltage between the energized part that it is covering and earth for a short time, i.e. for a momentary contact by a bird during take-off or landing. Covering is not intended as insulation, i.e. it is not intended to withstand long contact.
- It is understood that in most cases, it is not practical to cover *all* exposed live parts of overhead MV infrastructure. Covering all jumpers reduces the risk as far as reasonably practicable for most situations.

The following key is used for the figures supporting table 4:

	Non-conductive material
	Conductive material
	Applicable to both conductive and non-conductive structures
	Live parts, e.g. conductors and jumpers
	Earthed parts, e.g. shield wires
	Covering

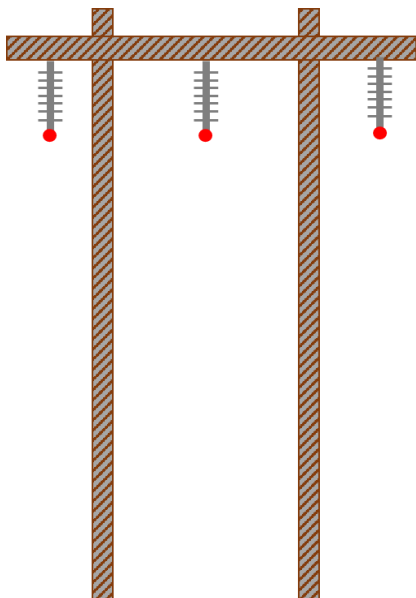


Figure 8: H-pole suspension – unshielded

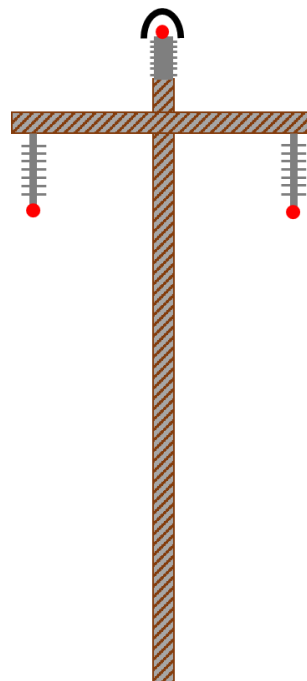


Figure 9: Delta configuration with covered centre phase

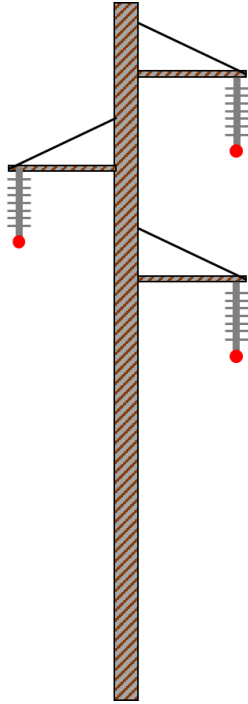


Figure 10: Monopole delta suspension – shielded

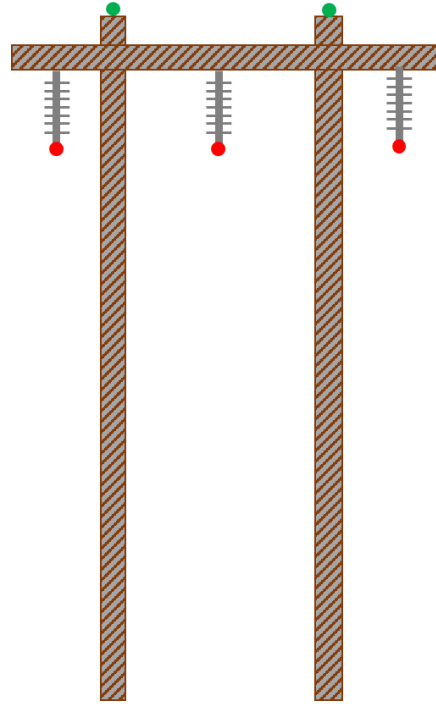


Figure 11: H-pole suspension – shielded

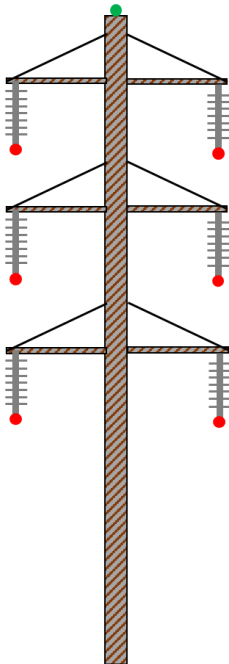


Figure 12: Double circuit single-pole suspension

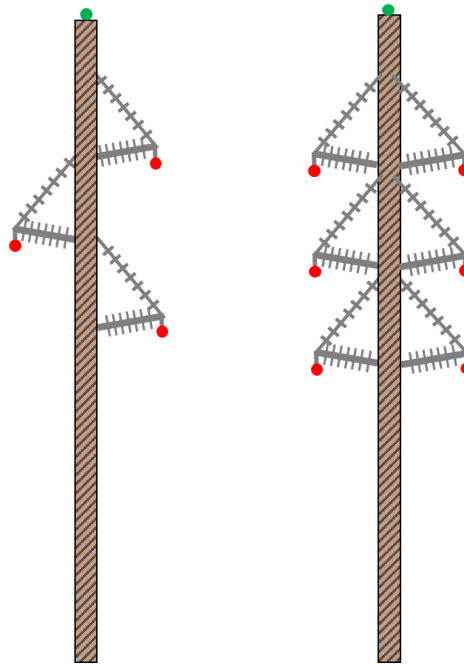


Figure 13: Braced post insulator structure – intermediate shielded⁶

⁶ The entire insulator assembly should be used to achieve an acceptably safe structure, i.e. the post insulator on its own is not acceptable.

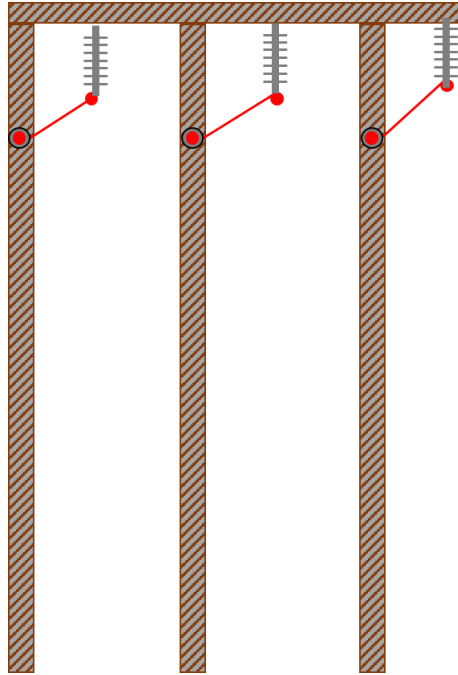


Figure 14: Triple-pole structure – “conductive” or “non-conductive” poles

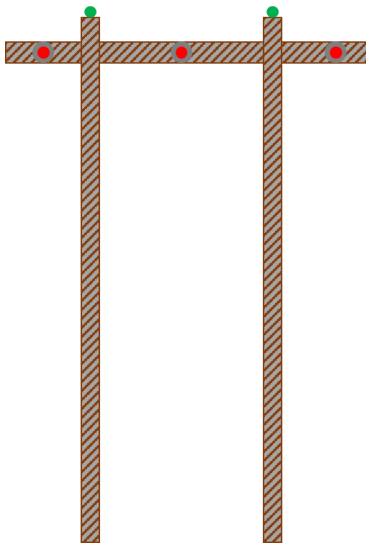


Figure 15: H-pole strain structure – shielded⁷

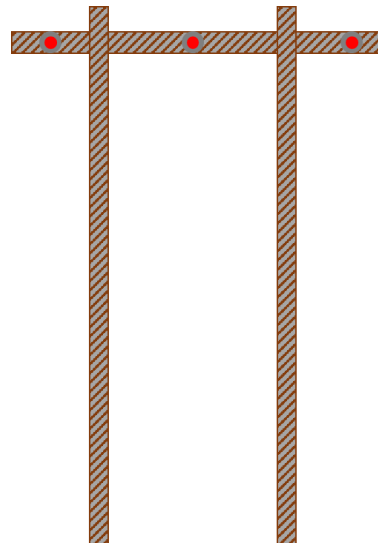


Figure 16: H-pole strain structure – unshielded⁸

⁷ Jumpers should be routed below the cross-arm, not above it.

⁸ Jumpers should be routed below the cross-arm, not above it.

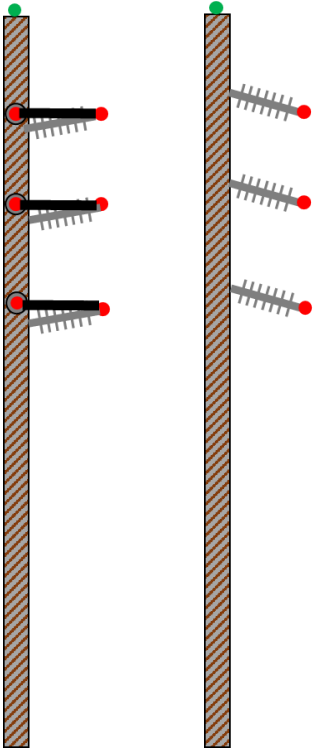


Figure 17: Single-pole strainer (shielded) – with jumpers (left), without jumpers (right)



Figure 18: Example of a complex structure with covered jumpers

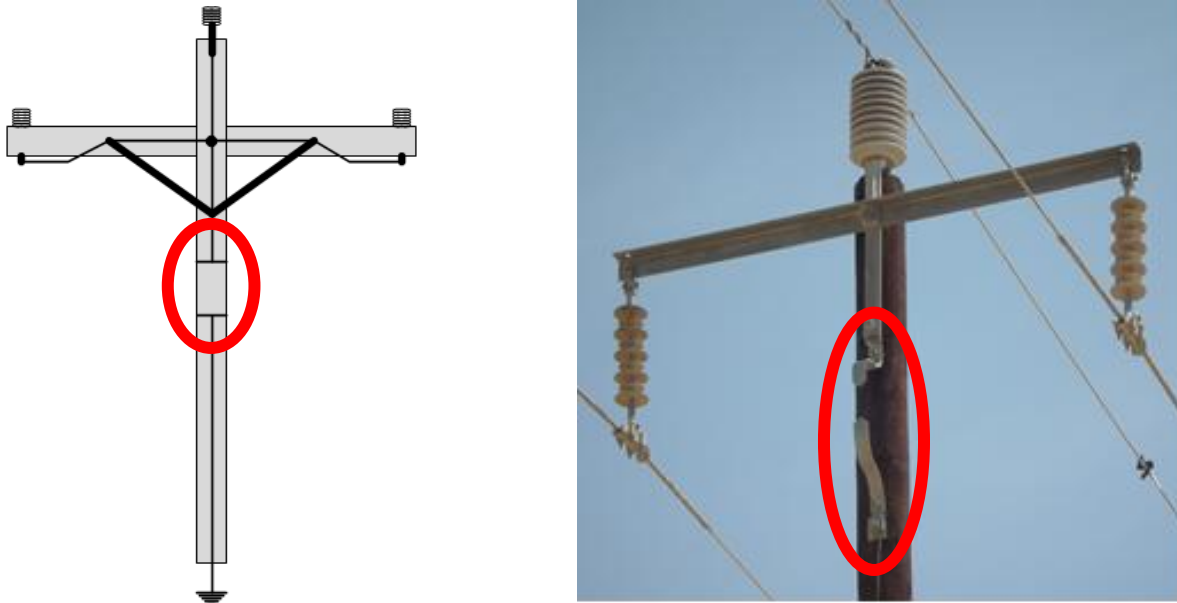


Figure 19: Examples of gap inserted into earth downwire on unshielded line⁹

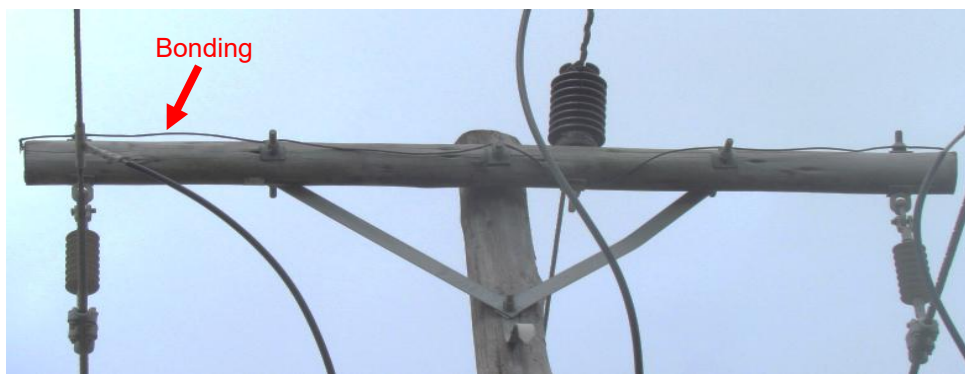


Figure 20: Example of pole-top electrical bonding

5. Mitigation of bird collisions

The following principles apply¹⁰:

1. **Line marking.** Examples of solutions that better highlight or define the sagging of the line against the horizon are flappers, spirals, pigtailed and solar LED devices. Areas of especially high risk are near dams, rivers and wetlands. Cognizance also needs to be taken of the bird species likely to occur in the area, as some species are nocturnal. The type of marking used is therefore very important. Bird flight diverters should have alternating colours, i.e. every alternate should have a different colour.¹¹
2. **Line routing.** In some instances, no amount of technology can effectively and reasonably prevent bird collisions. In these instances, the only long-term solution is to reroute the power.

⁹ A. Beutel, B. McLaren, H. Geldenhuys, W. Dirkse van Schalkwyk, J. Van Coller, "Lightning protection of unshielded overhead medium voltage power lines in South Africa", Proceedings of the 25th International Conference on Electricity Distribution (CIRED), Madrid, Spain, Paper 263, Jun 2019.

¹⁰ Reference for items 1 and 2: A. Beutel, R. Kruger, B. McLaren, D. Hewitt, N. Paus, C. Gomes, "Pro-active approach to mitigating bird mortalities on distribution networks", Proceedings of the 27th International Conference on Electricity Distribution (CIRED), Rome, Italy, Paper 10212, Jun 2023.

¹¹ Note that not all marking products are necessarily effective against all bird species. Research in this regard is ongoing.

line away from such areas, e.g. identified waterbodies which support large number of birds and vulture feeding or breeding sites. This intervention also reduces the risk of electrocution.

6. Mitigation of bird nests¹²

The following methods are available:

- Structures that employ poles, such as those shown in table 4 and table 5, are recommended because they offer minimal substrate for building nests. Lattice structures are not recommended because of the substantial substrate that they offer for nest building.
- Post insulators that are mounted horizontally, or close to horizontally, may also offer opportunities for nesting at unwelcome locations on structures if the insulator base is sufficiently large. The following is recommended where these are used:
 - a. Use insulators with small bases, examples of which are shown in figure 21.
 - b. If insulators with large bases need to be used for other reasons, it is recommended that they are mounted upside down. An example is shown in figure 22. This only applies to insulators supporting jumpers.
- Alternatively, cover all post insulators, as well as the conductors for at least 1 m on both sides of the insulators. This does not prevent nests from being built, but it reduces problems caused by nests.

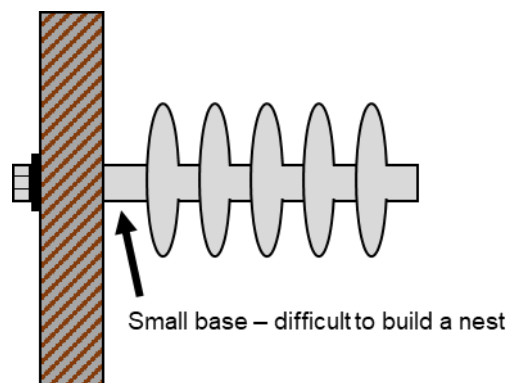


Figure 21: Example of a post insulator with a small base

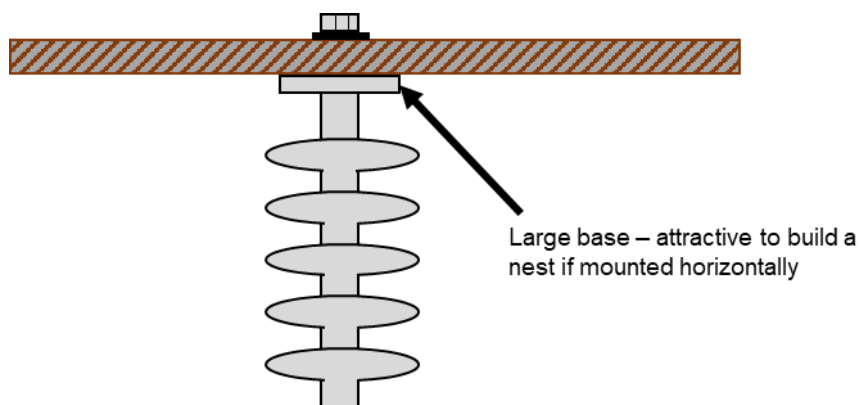


Figure 22: Example of a post insulator with a large base mounted upside down

¹² Parts taken from Eskom Technical Bulletin 11TB-09 (Management of Sociable Weavers on Eskom Networks).

7. Other risks due to birds

A large flock of birds such as doves or guineafowl perching on a span has been known to cause clashing. This is not common and should be treated on a case-by-case basis, e.g. moving the cause of the flocking away from the line.

The contents of this specification were compiled using vultures. In some cases, other large birds are the predominant species that may impact the power network. These cases should also be treated on a case-by-case basis.

8. Mitigation of large game interactions¹³

The mitigation options included in this section are meant to reduce the probability of wood poles breaking due to large game interactions and the subsequent electrocution of large game due to the low-hanging conductors. The following are classified as large game in this context: Elephant, Rhinoceros and Buffalo. Giraffes are not covered in this section; they are covered in the next section.

The following mitigation measures are available:

- Selective placing of line routes.
The routes of new networks should, wherever possible, avoid the portion of the game farms or reserves where there is high probability of wood pole interactions with large game. Where this is not possible, the alternatives are available.
- Installing a rotating rubbing grid.
An example of is specified as follows (Figure 23):
 - Minimum height (H) = 1800 mm, minimum width = 500 mm, thickness = 20 mm.
 - Made of non-conductive material such as Fibreglass Reinforced Plastic (FRP), so that electrical bonding is not required.
 - When an animal pushes against the device, the device rotates around the pole (the device must not be fixed to the pole), thereby limiting the interaction with the pole. This further acts as a deterrent for an animal to rub against it.
- Alternative Maintenance strategy.
This entails an intensive pole inspection programme where poles are replaced sooner than in areas without large game present. This requires frequent wood pole inspection cycles that exceed the minimum requirements of other areas. Also, all pole planting holes should be augured (this ensures minimum natural soil disturbance, which weakens the pole surrounding area).

¹³ Eskom Engineering Instruction 240-142805419, "Mitigation Strategies against Wood Pole Damage due to Large Game interactions with the network".

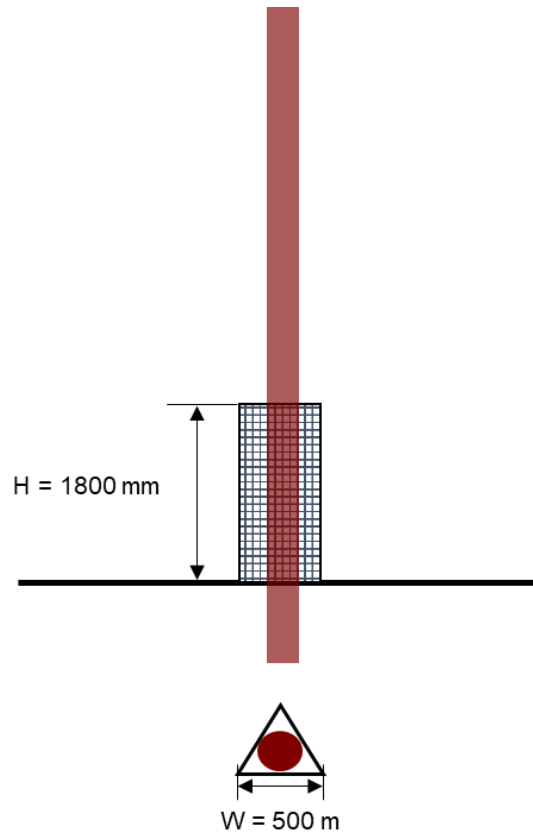


Figure 23: Rotating rubbing grid

9. Mitigation of Giraffe electrocutions¹⁴

All live points and bridging cables on switchgear, transformers, isolating equipment (e.g. cut-outs), T-offs and off-line substations must be in accordance with the minimum safe height from the ground as listed in table 6.

Table 6 — Minimum ground clearance requirements for mitigation of Giraffe electrocution

System Nominal Voltage (kV)	Minimum Clearance for Giraffe (mm)
11	5 700
22	5 820
33	5 930

Aspects such as topography and the type of structure must be taken into account during the design of either a new or refurbishment project.

Design options include:

- a) The use of mini-substations;
- b) Out-of-line transformer assemblies that cater for Giraffe areas with increased clearances; and
- c) Increasing the length of poles used, to cater for topographical undulations and other similar conditions. The purpose is to ensure that the required ground clearances are achieved.

¹⁴ Eskom Engineering Instruction 240-129277839, "Mitigation of giraffe electrocutions".

Annex A – Supporting information for electrical separation distances for minimizing bird electrocution risk

(informative)

A.1 Introduction

This appendix provides the details behind the determination of the acceptable minimum electrical separation distances¹⁵ listed earlier in this specification. These are defined as the air clearances between uncovered (bare) conductive apparatus to reasonably limit the risk of bird electrocutions. Examples are¹⁶:

- Objects energised at different voltages, such as conductors or jumpers of different phases, and
- An energised object and an electrically earthed object such as a power line structure.

This appendix starts by summarising the most important existing local and international documents, and the need for compiling this appendix is clarified. Next, a detailed explanation of the reasoning used to select those separation distances is given. This includes a separate section on how bird dimensions were determined. The appendix then concludes.

A.2 Existing documents

Overhead power lines are governed by the SANS 10280-1 standard [7]. This standard is mandatory because it is referenced in the Electrical Machinery Regulations of the Occupational Health and Safety Act [8]. SANS 10280-1 does not include requirements for wildlife safety.

Utilities have a duty of care in terms of Section 28 of the National Environment Management Act [9] to prevent significant environmental degradation from occurring, continuing or recurring. Directors, managers or employees may be liable if they, unlawfully and intentionally or negligently commit any act or omission which causes significant pollution or degradation of the environment or is likely to cause significant pollution or degradation of the environment. There are no specific requirements for electrical infrastructure.

More detail may be found in documents such as the following:

- Eskom standard 240-115756171 [1] sets out Eskom's requirements for mitigating bird mortalities on medium voltage distribution lines.
- Eskom technical instruction 240-171000057 [2] provides the requirements for structure selection for sub-transmission lines in high vulture risk areas.
- NRS 114 [10], which suggests technical requirements for bird interaction devices for use on overhead electrical infrastructure.

A 2022 regional document produced by USAID, Endangered Wildlife Trust, Power Africa [11] provides much useful guidance on mitigation of bird electrocutions (and other wildlife interactions with electrical infrastructure). However, minimum acceptable separation distances are not included.

CIGRE Technical Brochure 876 [12] provides an international repository of knowledge with respect to mitigating wildlife interactions with electrical infrastructure. No recommended separation distances are provided.

¹⁵ This should not be confused with the legal safety clearance of SANS 10280-1 [7], which is not intended for wildlife safety.

¹⁶ Two points of contact, energized at different voltages, are required for there to be a hazard. Situations such as birds perched on energized conductors away from any other object therefore do not pose an electrocution risk because there is not a second point of contact, e.g. the power line structures.

Annex A (continued)

Other parts of the world also have requirements, the following documents from the USA are included for context:

- Suggested practices for avian protection on power lines [4], which recommends horizontal separation distance of 150 cm and vertical separation distance of 100 cm for North American eagles.
- IEEE guide for reducing bird-related outages [13].
- IEEE guide for wildlife protective devices used on overhead medium voltage distribution systems [14].

A.3 Need for compilation of new separation distances

The contents of the previous section indicate that there is much helpful information available for designers of electrical distribution infrastructure. However, there is no document that advises the specific electrical separation distances to be used when applying isolation, taking into account the typical dimensions of South African bird species.

A.4 Reasoning for recommended separation distances

The *internal separation distance (ISD)* was taken from European Standard EN 50341-1 [15], as referenced in Table 1.1 of CIGRE Technical Brochure 348 [16]. The brochure in question covers mostly transmission voltages, the values selected are the closest to distribution level. The ISD values are for minimisation of flashover risk in different weather conditions, but the brochure does not include bird safety criteria. Separation distances specified in other documents, such as those listed in SANS 10280-1 [7] and used for safety of live workers, are too conservative, and hence result in unrealistically large separation distances.

The *bird movement factor* was selected based on experience, to account for the variability of bird movement. The value of this factor has a relatively small impact on the total separation distance, because the bird flesh-flesh dimensions are an order of magnitude larger. For example, the chosen factor of 1.2 increases the ISD by 20%, i.e. 22 mm for the smallest ISD (0.11 m) and 84 mm for the largest ISD (0.42 m). Doubling the factor to 1.4 (additional 40% instead of 20%) results in total separation distance increases in the region of 5% to 9%. Making this value too large could result in unnecessarily large separation distances, making it too small could result in unacceptable electrocution risk.

In most cases insulators are of lesser length than the total separation distances. In certain cases, it may be feasible to use longer insulators, i.e. insulators for higher voltage systems, to achieve the recommended separation distances. In other cases, covering of live and/or earthed parts may be practical. The use of “non-conductive” structure material such as wood can also reduce the electrocution risk. Whether to employ additional measures such as these or others for the insulators should be informed by the risk of a bird being electrocuted across the insulator gap.

A.5 Determination of bird flesh-flesh dimensions

It is clear that the *bird flesh-flesh dimensions* have the largest impact on the total separation distance. Careful thought was therefore given to their selection, and the process is covered in detail here. The maximum dimensions of vultures recorded in the literature were used. This is because vultures are the largest birds known to frequently perch on electrical energy infrastructure. This is supported by the Endangered Wildlife Trust’s database of reported electrocutions [18].

This allows for a “deterministic” approach for solitary birds, which results in a relatively simple calculation. Factors such as the following change the result to a “probabilistic” one:

- Wet birds increase the risk of electrocution by making the feathers more electrically conductive, but it does not always rain.

Annex A

(continued)

- Birds carrying prey also increases the risk of electrocution because the effective bird dimensions are larger, but birds don't always carry prey.
- Multiple birds perching or roosting on the same structure also increases the risk of electrocution because the group is more likely to bridge an electrical gap than a single bird, but birds don't always congregate in groups.
- Individual birds are expected to usually be smaller in size than the maximum recorded size used for the calculations, this therefore reduces the risk of electrocution.
- The occurrence of a voltage surge, e.g. due to lightning, while a bird is perched on a power system structure would increase the risk of electrocution due to the momentarily larger voltage. This scenario is not considered because the probability is low that a bird is perched at the same time as a surge. Also, impractically large separation distances are required to prevent flashover due to large surges, such as those due to direct lightning strikes, on most distribution lines.
- Wind may force birds to take off or land at angles that increase their probability of electrocution. Strong crosswinds can also increase the probability of electrocution by causing birds to drift sideways during take-off or landing. Specifically including the effect of wind in the calculations shown in this paper is not practicable, it is taken into account by the probabilistic nature of the calculations.
- It is assumed that large birds perch, or attempt to perch, only on the structures of overhead electrical infrastructure, not on other apparatus such as insulators and conductors. This may not be true in all cases but would also be impractical to take into account.
- Structures may be designed with greater separation distances than those recommended in this specification for other reasons, e.g. to ensure adequate electrical clearances at mid span.

However, the calculation was repeated for Marabou Storks, for which slightly larger maximum dimensions have been recorded but which are seldomly electrocuted, as a form of sensitivity analysis. The calculation was also repeated for Martial Eagles, which are smaller than vultures, for the same reason. The value for vultures (1,77 m) is recommended because Marabou Storks are seldomly electrocuted.

Determination of horizontal bird dimensions is detailed in table 7 and determination of vertical dimensions is covered in table 8.

Annex A
(continued)

Table 7— Determination of (horizontal) flesh-flesh wingspan

Family/ species	Dimension	Value	Details
Vultures	Largest recorded total tip-tip wingspan (mm) [16]	2830	Lappet-faced Vulture (<i>Torgos tracheliotos</i>): 2800 mm Bearded Vulture (<i>Gypaetus barbatus</i>): 2830 mm Cape Vulture (<i>Gyps coprotheres</i>): 2550 mm
	Flesh-flesh portion of total wingspan (%)	63%	Refer to Figure 24
	Flesh-flesh distance (m)	1,77	Largest recorded wingspan x flesh portion
Martial Eagle (<i>Polemaetus bellicosus</i>)	Largest recorded total tip-tip wingspan (mm) [16]	2270	
	Flesh-flesh portion of total wingspan (%)	65%	Refer to Figure 25
	Flesh-flesh distance (m)	1,47	Largest recorded wingspan x flesh portion
Marabou Stork (<i>Leptoptilos crumenifer</i>)	Largest recorded total tip-tip wingspan (mm) [16]	2870	
	Flesh-flesh portion of total wingspan (%)	67%	Refer to Figure 26
	Flesh-flesh distance (m)	1,91	Largest recorded wingspan x flesh portion

Annex A
(continued)

Table 8 — Determination of (vertical) flesh-flesh height

Family/species	Dimension	Value	Details
Vultures	Vertical flesh-flesh bird height: tip of feet to wings stretched out - take-off or landing (m)	1,50	Refer to Figure 27 ¹⁷
Marabou Stork	Tail tip to beak tip (m)	1,50	Refer to Figure 28
	Vertical flesh-flesh height (m)	1,37	

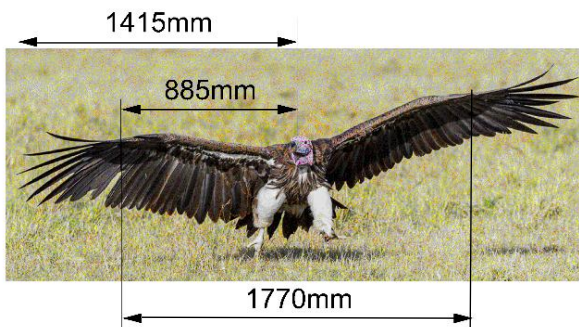


Figure 24: Estimation of vulture flesh-flesh wingspan

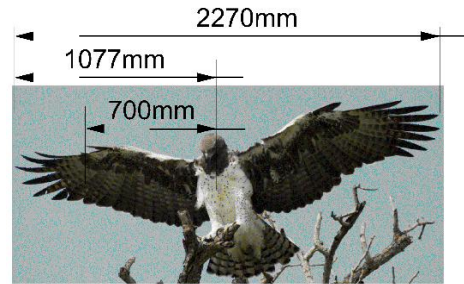


Figure 25: Estimation of Martial Eagle flesh-flesh wingspan

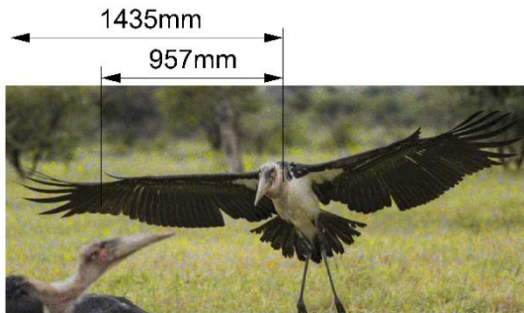


Figure 26: Estimation of Marabou Stork flesh-flesh wingspan

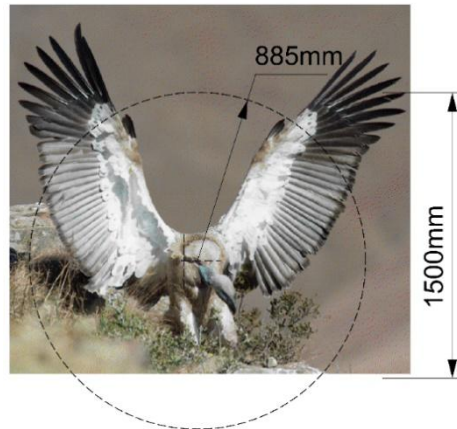


Figure 27: Estimation of vulture flesh-flesh height

¹⁷ A photo of a Cape Vulture was used with dimensions used for the Lappet-faced Vulture.

Annex A (continued)

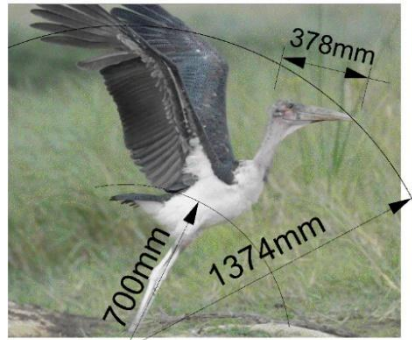


Figure 28: Estimation of Marabou Stork flesh-flesh height¹⁸

A.6 Discussion

The content of this appendix was informed by ecological, biological and engineering standards, guidelines and best practices, as well as the accumulated specialist experience of the members. The resulting recommended separation distances are therefore expected to be reasonable and practical. It is, however, important to note that only electrical separation distances between uncovered (bare) conductive apparatus is dealt with. Therefore, should an unacceptable number of electrocutions still be recorded, despite adhering to the recommended separation distances, measures such as increasing the separation distance and use of insulation should be considered¹⁹. Also, the recommended separation distances do not apply to extremely high risk (localized) locations, e.g. vulture feeding sites; such situations may require special additional mitigation.

A.7 References

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- [6] A. Beutel, B. McLaren, H. Geldenhuys, M. Murison, C. Hoogstad, N. Khoza, M. Mathebula, J. Van Coller, R. Branfield, R. Kruger, "Electrical Model of Phase-to-Woodpole Bird Electrocution", Africa Research Journal, South African Institute of Electrical Engineers, Vol.110 (3), Sep 2019, pp. 125-135.
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- [9] South African National Environment Management Act, Act No. 107 of 1998.
- [10] NRS 114, Material and test requirements for bird interaction devices for use on overhead electrical infrastructure.
- [11] USAID, Endangered Wildlife Trust, Power Africa, "Mainstreaming wildlife incident management into utilities in Southern Africa", 2022.
- [12] CIGRE Technical Brochure 876, Interactions between Electrical Infrastructure and Wildlife, 2022.
- [13] IEEE Std 1651-2010, IEEE Guide for Reducing Bird-Related Outages.

¹⁸ Based on a 378 mm head-bill mean measurements from 5 birds in the collections of Durban and Ditsong Museums, provided by these museums, which is gratefully acknowledged.

¹⁹ One way of increasing separation distance is by introducing or extending insulation.

Annex A
(concluded)

- [14] IEEE Std 1656-2010, IEEE Guide for Testing the Electrical, Mechanical, and Durability Performance of Wildlife Protective Devices on Overhead Power Distribution Systems Rated up to 38 kV.
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