Eskom	Standard	Technology

Title: **STANDARD FOR DETERMINING DROPPER CONDUCTOR SHORT-CIRCUIT FORCES ON EQUIPMENT IN OUTDOOR SUBSTATIONS**

Unique Identifier: **240-85524376**

Alternative Reference Number: **<n/a>**

Area of Applicability: **Engineering**

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COE Acceptance

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Date: 2/2/2021

DBOUS Acceptance

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Date:05/02/2021

This document is **STABILISED.** The technical content in this document is not expected to change because the document covers: *(Tick applicable motivation)*

1	A specific plant, project or solution	
2	A mature and stable technical area/technology	
3	Established and accepted practices.	x

This letter is for multiple documents: N/A

PCM Reference: **240-53459042**
SCOT Study Committee Number/Name: **Substations**

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Supported by SCOT/SC

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Content

Figures

1. Introduction

Whenever new substations are designed and constructed, use is made of dropper conductors which often connect overhead bus type conductors to items of primary plant. These droppers can be quite lengthy, and undergo forces of attraction and repulsion when high fault currents flow through them. These forces are transferred to the fixed ends of the dropper conductors and therefore to the items of primary plant. The design engineer needs to ensure that the dropper forces do not exceed the design parameters of the plant it is connected to.

The objective of this document is to provide technical guidelines in calculating the forces exerted on equipment due to the lower fixed point connection of the dropper conductor.

2. Supporting clauses

2.1 Scope

The document only refers to AIS substations where the dropper conductors are realised with stranded flexible conductors.

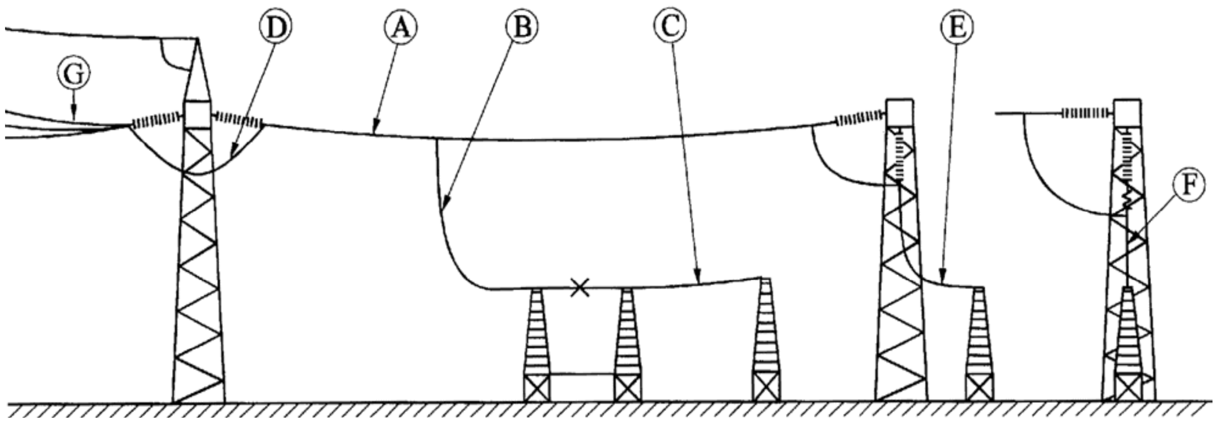

Figure 1: Flexible bus configuration for calculation and tests

- Horizontal strain bus connected by insulator chains to steel structures
- Vertical dropper between strained bus and apparatus
- Horizontal connection between components
- Jumper connecting two strained conductor sections
- E,F) End-span droppers (classical or spring loaded)

This document only discusses the cases labelled B) and E) as illustrated in Figure 1. Auto-reclosing is not considered in this document.

2.1.1 Purpose

The purpose of this document is to provide a method of determining the forces that dropper conductors exert on items of equipment to which they are attached whilst conducting short-circuit current.

2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited Divisions.

2.2 Normative/informative references

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

2.2.1 Normative

[1] ISO 9001 Quality Management Systems.

[2] The Mechanical Effects of Short-Circuit Currents in Open Air Substations (Part II), A companion book of the CIGRE brochure 105, 2002

[3] The South African Grid Code (Revision 8.0).

2.2.2 Informative

[4] Definition of Eskom documents (32-9).

[5] Eskom documentation management standard (32-644).

2.3 Definitions

2.3.1 General

Definition	Description
Bending force	A force exerted transversely to the axis of orientation of an item of primary plant, i.e. the force at the lower end of the dropper.
Dropper	A section of conductor connecting an overhead bus conductor to an item of primary plant at a lower level.

2.3.2 Disclosure classification

2.4 Abbreviations

Abbreviation	Description
ms	Millisecond

2.5 Roles and responsibilities

Substation engineering shall utilise and implement the busbar selection criteria within this document.

2.6 Process for monitoring

The following design review teams shall evaluate and monitor the design process:

[1] Substation Design Review Team.

[2] Power Delivery Engineering Design Review Team.

2.7 Related/supporting documents

Not applicable.

3. Document content

The results of tests have shown that the influence of the parameters on the bending force at the lower end of the dropper can be summed up as follows:

- The maximum force increases with the square of the short-circuit current.
- The conductor mass is of less influence.
- The short-circuit duration has no influence.
- Short times to maximum displacement lead to higher forces; the times depend on the short-circuit currents.
- The maximum displacement does not depend on the short-circuit current and the short-circuit duration but on the geometry. This follows from the fact that the maximum displacement is reached for all short-circuit currents durations later than 100 ms. Short times to maximum displacement mean higher velocities during the movement and by this higher kinetic energy in contrast to longer times. Therefore the induced kinetic energy is a measure for the bending force.

3.1 Droppers with fixed upper end (case E)

The upper ends of droppers at the end of the span or near to it and therefore does not move with the main conductor in the bus as shown in Figure 2.

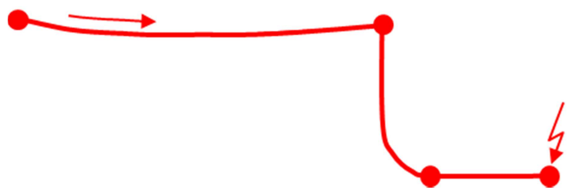

Figure 2: Fixed Upper End Current Path

Figure 3 shows the dropper in its static position and at the moment of maximum displacement. With the given quantities and the assumption that the shape of the dropper at maximum displacement can be described by a parabola it follows for the curve of the displaced dropper:

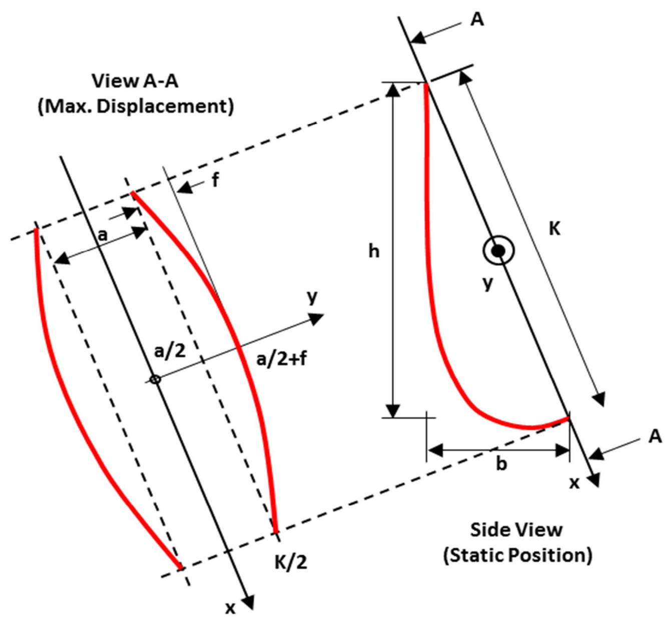

Figure 3: Dropper in static position (right side) and at the moment of maximum displacement (left side)

$$F_d = \frac{5}{3} \cdot \frac{\mu_0}{2\pi} \frac{\left(I_k''\right)^2}{a} \cdot \frac{l_d^2}{b} \qquad \text{eq. (1)}$$

With validity range of $1{,}4 \le \frac{l_d}{b} \le 3{,}3$

where:-

F_d	=	Force on the fixing ends in N
I_k''	=	Current in the bundle conductor: Maximum value from I_{k1}'', I_{k2}'' or I_{k3}'' in A
a	=	Spacing between droppers in m
b	=	Width of dropper in m
h	=	Height of dropper in m
l_d	=	Length of dropper in m
K	=	Distance between fixing points in m

In equation (1), $\mathbf{F_d}$ only depends on the geometry and the short-circuit current but, not the conductor mass and the short-circuit duration, as was demonstrated from the tests. The calculation of $\mathbf{F_d}$ according to equation (1) is compared with tests. Most of the values lie within a range of ±25 %, some are slightly more than 25 % on the safe side. This result allows the application of the simplified method given above.

3.2 Droppers with flexible upper ends (case B)

The upper ends of droppers in the middle of the span or near to it move with the main conductor in the bus. If the droppers are not stretched, there will be no significant bending force on the apparatus or insulators at the lower end caused by the movement of the busbar. If the droppers are stretched, a high loading can occur. Until now a simplified method for the calculation of this force is not available. Therefore it is recommended to make the droppers longer to avoid stretching. If this is not possible, advanced methods should be used.

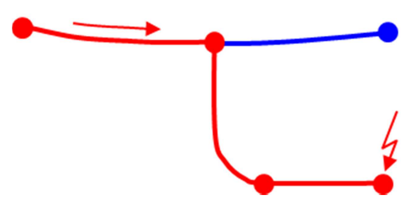

Figure 4: Flexible Upper End Current Path

The droppers with current path in Figure 4 swing out due to the electromagnetic forces between the droppers. The maximum force at the lower end takes place during swing-out of the busbar. A good estimation of the loading at the apparatus and insulators can be determined assuming fixed upper ends of the droppers and using the simplified method stated above by employing equation 1.

Sample Calculation

To determine the short-circuit force exerted by a 2xBull dropper on a 132kV transformer bushing (static rating = 2kN and dynamic rating of 4kN) as illustrated in Figure 5.

a = ½.(5,4+2,2) = 3,8m

b = 16-9,5 = 6,5m

h = 15,344-6 = 9,344m

l_d = 10,5m (estimated)

I_k'' = 40000A

With validity range of $1{,}4 \leq \frac{l_d}{b} \leq 3{,}3$

$$\frac{l_d}{b} = \frac{10{,}5}{6{,}5}$$

$$= 1{,}62$$

∴Valid

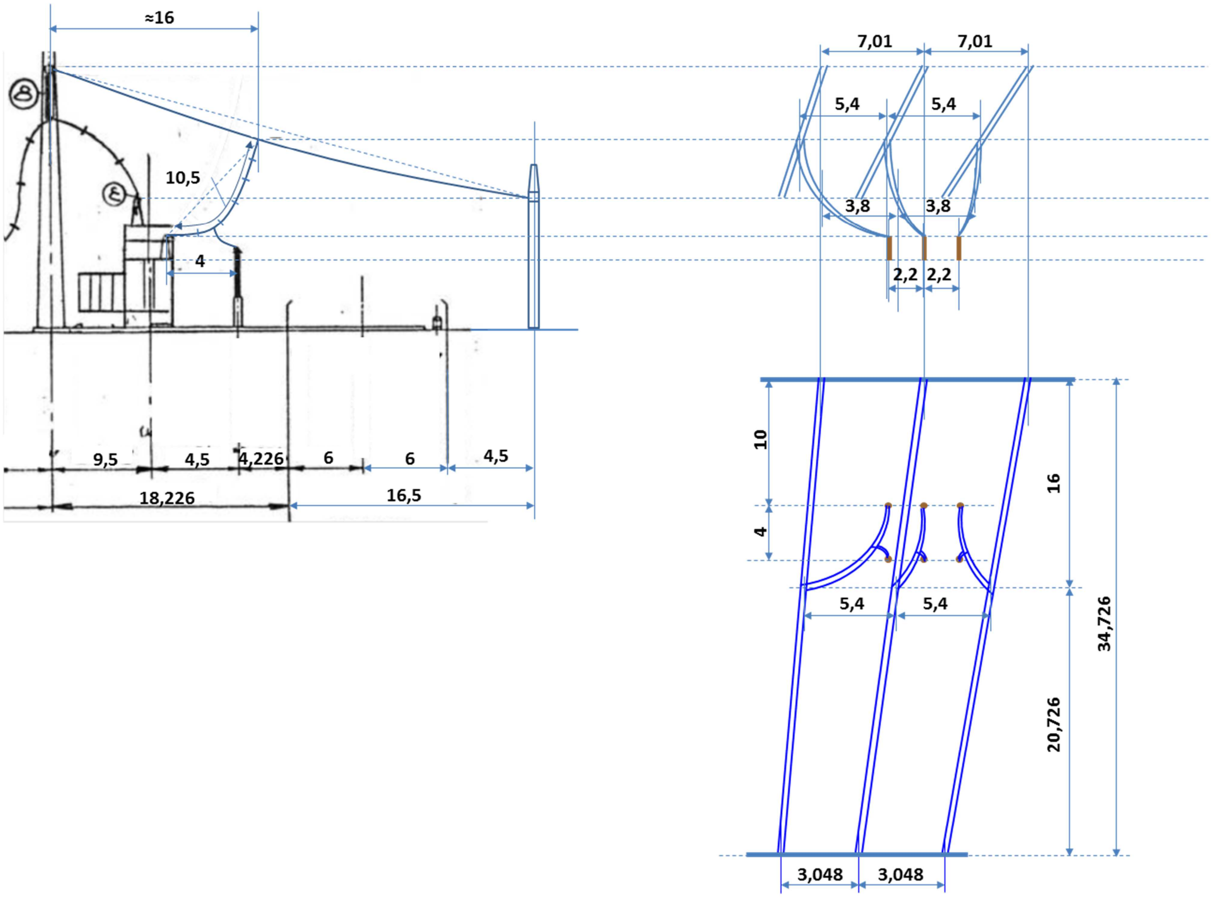

Figure 5: Transformer Droppers - 132kV Side

Force on dropper

$$F_d = \frac{5}{3} \cdot \frac{\mu_0}{2\pi} \frac{\left(I_k''\right)^2}{a} \cdot \frac{l_d^2}{b}$$

$$= \frac{5}{3} \cdot \frac{4\pi.10^{-7}}{2\pi} \frac{(40000)^2}{3{,}8} \cdot \frac{(9{,}344)^2}{6{,}5}$$

$$= 1885\text{N}$$

Assuming and error of +25%,

$\mathbf{F_d}$ = 1885.1,25

= 2356 N

The short-circuit force exerted by a 2xBull dropper on the 132kV transformer bushing is 2,356kV<4kN dynamic rating,

∴Safe

4. Authorization

This document has been seen and accepted by:

Name and surname	Designation
Phineas Tlhatlhetji	Senior Manager-Substation Design
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5. Revisions

Date	Rev.	Compiler	Remarks
Feb 2015	1	AJS Groenewald	First issue

6. Development team

The following people were involved in the development of this document:

- Braam Groenewald

7. Acknowledgements

None