Eskom	Guideline	Technology

Title: **TRANSMISSION SUBSTATION EARTH FAULT APPLICATION GUIDE**

Unique Identifier:	**240-95773230**
Alternative Reference Number:	**N/A**
Area of Applicability:	**Engineering**
Documentation Type:	**Guideline**
Revision:	**2**
Total Pages:	**18**
Next Review Date:	**July 2025**
Disclosure Classification:	**Controlled Disclosure**

Compiled by	Approved by	Authorized by
Theunus Marais	**Braam Groenewald**	**Bheki Ntshangase**
Chief Engineer – Substation Engineering	**Corporate Specialist – Substation Engineering**	**Senior Manager – Substation Engineering**
Date: 2020/06/25	Date: 2020/06/30	Date: 6/07/2020

PCM Reference: **Substation Design**

SCOT Study Committee Number/Name: **Substation**

Content

Figures

Tables

1. Introduction

In order to do the substation earth grid safety design and to determine the number of earth tails needed per structure it is necessary to know, among other factors, what the expected highest future single-phase earth fault current in the substation is likely to be, also referred to the substation end of life earth fault current. To prevent confusion and inconsistency in Transmission substation earth grid design it was identified that a transmission substation earth fault application guide should be compiled to provide earth fault current design limits to be applied during the substation earth grid design process.

2. Supporting clauses

2.1 Scope

This guide details the methodology to be followed in determining the substation earth fault design limits to be applied during the earth grid design process. This is applicable to new substations, substation additions, substation extensions and substation refurbishments.

2.1.1 Purpose

The purpose of this guide is to provide transmission substation designers with a process to be followed in determining the substation earth fault design limits to be applied when designing transmission substation earthing systems.

2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited Divisions, applicable to transmission substations.

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] 240-79774981, Eskom Transmission System 2013-2014 Annual Fault Level Report

[3] 240-118802871, Eskom Transmission System 2019 Annual Fault Level Report

[4] 240-134369472, Substation Earth Grid Design Standard

2.2.2 Informative

[5] IEEE Std 80-2013, IEEE Guide for Safety in AC Substation Grounding

[6] SANS 725, Guide for Safety in AC Substation Grounding (IEEE Std 80-2000).

[7] SANS 10199:2012, South African National Standard, The design and installation of earth electrodes.

[8] 240-55922824, Substation Layout Design Guideline

2.3 Definitions

2.3.1 General

Definition	Description
CDEGS	Current Distribution, Electromagnetic Fields, Grounding and Soil Structure Analysis software package developed by SES Technologies.
Earth grid	An earth electrode consisting of a large rectangular arrangement of conductors embedded in the ground and divided by longitudinal and transverse conductors into a number of smaller rectangles.
Earth lead/tail	A conductor including any clamp or terminal, by which connection of equipment/structures earth terminal or conductor to an earth electrode is made. Typically the connection between the structures and the earth grid.
Earthing	The electrical connection between an apparatus and the general mass of earth in such a way that it will ensure a safe discharge of electrical energy at all times.
Earthing system	A system intended to provide at all times, by means of one or more earth electrodes, a low impedance path for the immediate discharge of electrical energy, without danger, into the general mass of the earth.
Equipment uprating	Replacing equipment as a result of not meeting technical requirements.
New substation	Greenfields project, typically from nothing to a complete substation.
Potential gradient	Potential difference per unit length (usually expressed in volts per metre, V/m), measured in the direction in which the potential difference is at a maximum
Step potential	Part of the earth electrode potential gradient that could be bridged by a person from foot to foot, normally calculated over a distance of 1m.
Substation addition	Any equipment addition to an existing substation that does not necessitate extending the existing substation yard.
Substation extension	Anything from equipping a single or multiple bays within an existing substation yard, and/or extending the existing substation yard in order to add additional bays.
Substation refurbishment	The replacement of any equipment in the substation as a result of age or being technically underrated, including the earth grid or any part thereof.
Touch potential	Part of the earth electrode potential gradient that could be bridged by a person from a hand in contact with a structure, through the body to the feet.

2.3.2 Disclosure classification

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

2.4 Abbreviations

Abbreviation	Description
EF	Earth fault
kA	Kilo-ampere
kV	Kilo-volt
ms	Milliseconds

Abbreviation	Description
NI	No information
URS	User Requirement Specification
V/m	Volt per meter

2.5 Roles and responsibilities

Substation Engineering shall utilise and implement this guide during the transmission substation earth grid design process.

2.6 Process for monitoring

The following should review the correct application of the guide:

1) Applicable Senior/Chief Engineer.

2) Substation Design Review Team.

2.7 Related/supporting documents

This document must be read in conjunction with the applicable substation earth grid design standard [3].

3. Determining design fault current

3.1 Background

When designing the substation earth grid it is necessary to know what the long term (end of life) expected single-phase (earth fault) current will be. During the design process this is the most challenging parameter to get confirmation of.

The substation earth grid design standard [4] refers to the fault levels listed in the Planning Report or URS. The information received from Grid Planning with regard to future fault currents is not always clear with regard to applicability, i.e. are the values provided applicable to the implementation of this project only, is it applicable for 15 years into the future or are the end of life values provided.

The purpose of this document is to give guidance on how to determine the earth grid design fault current based on the information in the URS, Planning Report or Engineering Report. This guide is based on the calculated expected maximum fault currents as reflected in [2], as well as the actual maximum fault currents experienced during transmission line faults for the period 2001 – 2014. In addition, the 2014 values reflected in [2] were compared to the 2019 values reflected in [3] to confirm the applicability of the original assumptions made.

3.2 Calculated maximum fault currents (Eskom Transmission System Operations)

As a guide, the Eskom Transmission annual fault level report [2] was used to determine the expected maximum single-phase fault current per substation, and this was compared to the information in [3]. As stated in the reports, the network model used to determine these values includes future network expansions with a high degree of certainty to be completed before the end of the report calendar year. All available generators at the time of doing the studies were taken into consideration.

Table 1 and Figure 1 reflect the number of stations per single-phase fault current level range, and from this the following can be observed:

- 2014: 60.9% ≤ 25kA, 31.8% between 25kA and 40kA; and 7.3% above 40kA.
- 2019: 55.1% ≤ 25kA, 36.4% between 25kA and 40kA; and 8.6% above 40kA.

It is understood and taken into account that the fault current levels will increase over time as additional generators are connected to the network, and as the network becomes more integrated. That is highlighted

Refer to Annex A for the detail on which this is based. It must be noted that the information reflected in Annex A is only used as input in determining the ranges as reflected in Table 3 and should not be used for design purposes. If fault levels per station are required for whatever reason it must be obtained from Grid Planning or from the latest Eskom Transmission annual fault level report.

Table 1: Fraction of stations per stated earth fault current range

Earth fault current range	Portion of stations (2014 report)	Portion of stations (2019 report)
$I_{1ø} \leq 5kA$	6.1%	4.0%
$5kA \leq I_{1ø} \leq 10kA$	11.2%	12.1%
$10kA \leq I_{1ø} \leq 15kA$	17.9%	15.2%
$15kA \leq I_{1ø} \leq 20kA$	12.8%	14.6%
$20kA \leq I_{1ø} \leq 25kA$	12.8%	9.1%
$25kA \leq I_{1ø} \leq 30kA$	18.4%	16.7%
$30kA \leq I_{1ø} \leq 35kA$	9.5%	9.6%
$35kA \leq I_{1ø} \leq 40kA$	3.9%	10.1%
$40kA \leq I_{1ø} \leq 45kA$	1.7%	3.0%
$45kA \leq I_{1ø} \leq 50kA$	1.7%	2.0%
$50kA \leq I_{1ø} \leq 55kA$	1.1%	0.5%
$55kA \leq I_{1ø} \leq 60kA$	1.1%	1.5%
$I_{1ø} \geq 60kA$	1.7%	1.5%

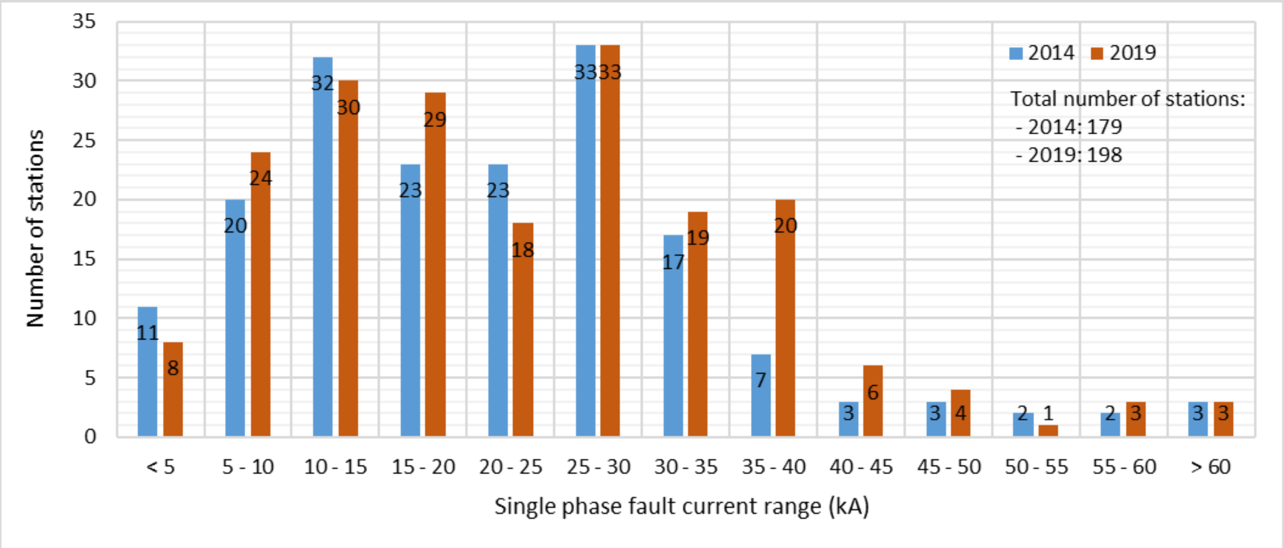

Figure 1: Number of stations per earth fault current range

3.3 Actual fault currents during line faults (Transmission System Operations)

The second aspect considered was the actual fault currents experienced on the transmission system. In the absence of information with regard to substation faults the data used is associated with Transmission line faults for the period 2001 to 2014. It is known that the fault current is naturally limited by the distance to fault and the fault resistance that is always present for line faults. Notwithstanding this fact, the results are still deemed significant and applicable to this study, both in magnitude and fault clearing times.

The neutral current associated with the line faults were analysed and it is significant to note that 89.8% of the faults for this period had a magnitude of less than 10kA and 95.7% of the faults had a magnitude less than 15kA as indicated in Table 2 and Figure 3.

For the period under investigation, only 14 out of a total of 12,667 faults had magnitudes higher than 40kA, with only five of these above 50kA. The maximum fault current was registered during 2006, at 70kA for 127ms. Refer to Figure 2 for an indication of the highest magnitude faults per year with their associated fault clearing times. It is important to observe that the longest fault clearing time is 127ms, with the average for all faults 81ms.

It must also be noted that these listed fault clearing times is a fraction of the standard 500ms normally used for substation earth grid design purposes.

Table 2: Fraction of faults per stated earth fault current range

Earth fault current range	Portion of faults
$I_{1ø} \leq 5kA$	67.62%
$5kA \leq I_{1ø} \leq 10kA$	22.23%
$10kA \leq I_{1ø} \leq 15kA$	5.87%
$15kA \leq I_{1ø} \leq 20kA$	2.15%
$20kA \leq I_{1ø} \leq 25kA$	1.12%
$25kA \leq I_{1ø} \leq 30kA$	0.51%
$30kA \leq I_{1ø} \leq 40kA$	0.39%
$40kA \leq I_{1ø} \leq 50kA$	0.07%
$I_{1ø} \geq 50kA$	0.04%

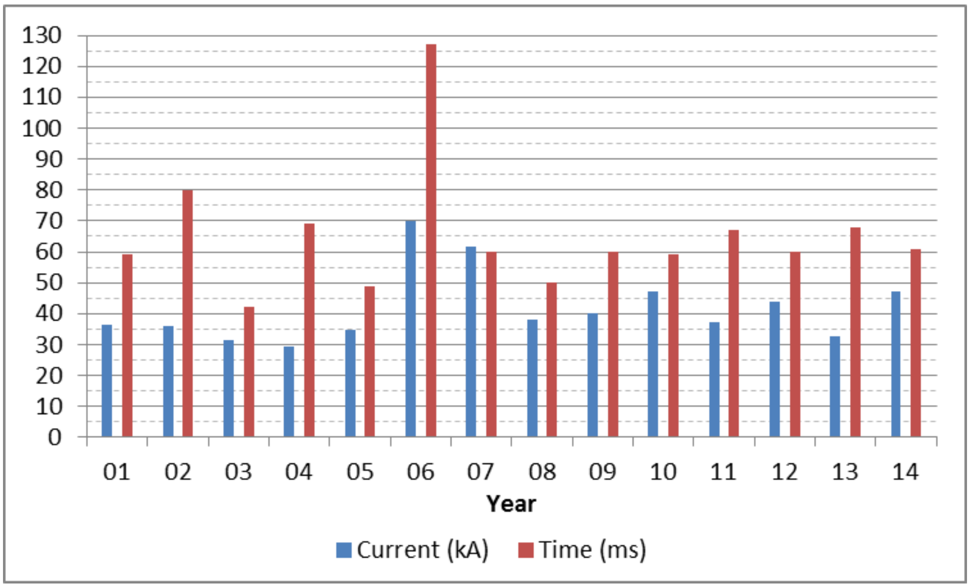

Figure 2: Maximum fault current with associated clearing time per year

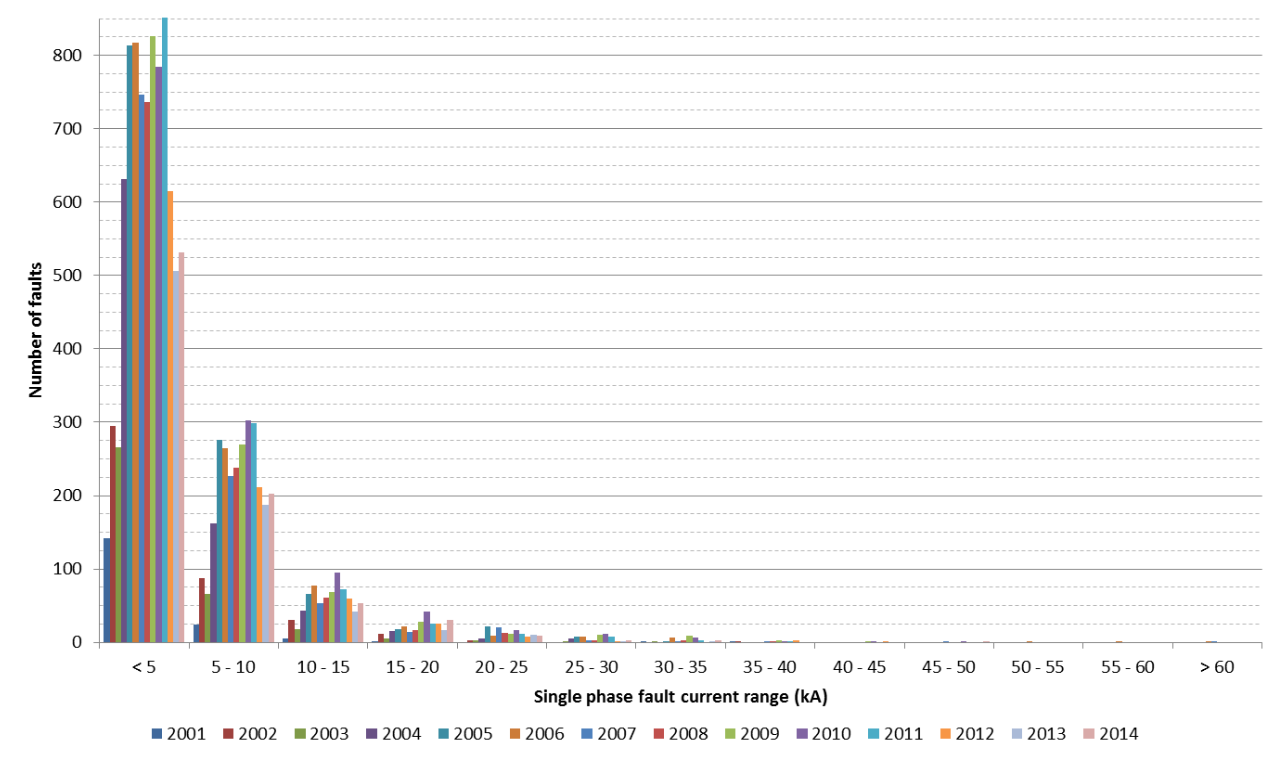

Figure 3: Number of faults per earth fault current range

Refer to Annex B for the detail on which the above is based.

3.4 Planning information needed for earth grid design purposes

The following planning related information is needed for the earth grid design and must be stated in the planning report or URS:

- The maximum calculated single phase-to-earth or phase-phase-to-earth fault current levels associated with all voltage levels in the substation,
- The fault current duration of applicability, i.e. 10 years from the date of the report, 2035, substation expected end of life, etc.
- Network X/R ratio per voltage level,

3.5 Earth grid design fault current guide

The fault current to be used when designing the substation earth grid must be based on the future single-phase fault current stated in the planning report or URS. To ensure that the earth grid will still render the substation safe (with regard to expected step and touch potentials) beyond the stated period refer to Table 3 for the proposed earth fault currents to be used for design purposes. These proposed values take into account the existing low fault current base as well as the fact that the planning proposal indicates a future value already, although the applicable timeframe might be unknown.

These values are applicable in determining the number of earth tails to be applied per structure, as well as for the substation safety design making use of CDEGS. The safety design relates to the dimensions of the blocks forming the earth grid to ensure that step and touch potentials are within safe limits.

Table 3: Earth fault currents for design purposes

	A	*B*	*C*
1	**Future earth fault current (URS of planning report)**	**Design earth fault current (kA)**	**Applicable to**
2	Below 15kA	25	All voltage levels **Maximum for 11kV and 22kV**
3	Between 15kA and 20kA	31.5	All remaining voltage levels **Maximum for 33kV, 44kV and 66kV**
4	Between 20kA and 30kA	40	All remaining voltage levels **Maximum for 88kV and 132kV**
5	Between 30kA and 40kA	50	All remaining voltage levels **Maximum for 275kV and 765kV**
6	Between 40kA and 50kA	60	**Applicable to 400kV only**
7	Between 50kA and 63kA	63	**Applicable to 400kV only** **Maximum for 400kV**

Notes:

1. *If the above limits cannot be met under project specific conditions it must be taken under advisement with the applicable substation earthing specialist.*
2. *Design earth fault current levels at power stations must be determined with care. It is important to keep in mind that these stations are the network current sources.*
3. *Note that the maximum current ratings per voltage levels shall not be exceeded as this exceeds the equipment short-time ratings.*

Refer to section 3.7 for examples on how this guide should be applied.

3.6 Earth tails

As stated in the design standard [4], either 2 x ϕ 10mm round copper rods in parallel or one 50 x 3mm flat copper strap shall be used per earth tail connection. It is important to note that earth tails should run in opposite directions to eliminate common mode failure. Refer to Table 4 for the number of earth tails to be applied based on the applicable design earth fault current from Table 3.

It is important to note that not all structures in the substation will necessarily have the same quantity of earth tails, but that they are dependent on the proposed fault levels to be applied per voltage level. Refer to the next section for examples on how this should be applied.

Table 4: Number of earth tail connections

	A	*B*
1	**Design earth fault current**	**Number of connections**
2	Up to 25kA	2 connections per support
3	Between 25kA and 40kA	3 connections per support
4	Above 40kA	4 connections per support

3.7 Application examples

Below are a number of examples on how to apply the guidelines given in Tables 3 and 4.

3.7.1 Example 1

Consider a 275/132kV substation with the following as given:

Table 5: Example 1 proposed fault current levels received

	A	*B*	*C*
1	**System Voltage (kV)**	**URS single-phase fault current (kA)**	**URS three-phase fault current (kA)**
2	275	8.2	9.2
3	132	11.9	11.2
4	22 (auxiliary)	0.37	5.1

It is important to remember that the single-phase fault current level is applicable to the earthing design. From Table 3, determine the proposed fault current applicable for each voltage level in the substation and with that and from Table 4 the number of earth tails to be applied per voltage level.

Note that the highest design fault current level must be used when doing the substation safety design with CDEGS to ensure the whole substation is safe with regards to expected step and touch potentials in the substation during fault conditions.

From Table 5, for each voltage level given in column *"A"*, compare the *"URS single-phase fault level"* in column *"B"* with the ranges given in Table 3 column "*A*" to determine the proposed *"Design earth fault current"* as given in Table 3 column "*B*", while taking cognisance of the conditions given in Table 3 column "*C*".

Determine the number of earth tails needed per voltage level by making use of the chosen design fault current levels per voltage level (Table 6 column *"C"*).

The fault current to be used for the substation safety design (safe step & touch voltages) is the highest values in Table 6 column *"C"*. In this example all values are the same at 25kA as reflected in column *"E"*.

Table 6: Example 1 proposed and design fault current levels

	A	*B*	*C*	*D*	*E*
1	**System Voltage (kV)** (from Table 5)	**URS single-phase fault current (kA)** (from Table 5)	**Design fault current (kA)** (from Table 3)	**Earth tails per structure** (from Table 4)	**Safety calculations (step & touch)**
2	275	8.2	25	2	**Whole substation based on 25kA** (Highest value applicable to 275/132/22kV)
3	132	11.9	25	2	
4	22 (auxiliary)	0.37	25	2	

The following is observed from Table 6:

- The total substation earth grid is sized and simulated in CDEGS to be safe for 25kA (column "C").
- Two earth tails to be applied per structure for all voltage levels as indicated in column "D".
- The 275kV fault current level can effectively triple without having to do anything at the substation (comparing Table 6 cell "B2" with cell "C2").
- The 132kV fault current level can more than double without having to do anything at the substation (comparing Table 6 cell "B3" with cell "C3").

3.7.2 Example 2

Consider a 275/88kV substation with the following as given:

Table 7: Example 2 proposed fault current levels received

	A	*B*	*C*
1	**System Voltage (kV)**	**URS single-phase fault current (kA)**	**URS three-phase fault current (kA)**
2	275	10.2	9.2
3	88	15.4	12.2
4	22 (auxiliary)	0.37	5.1

As in the previous example remember that the single-phase fault current level is applicable to earthing design. From Table 3 determine the proposed fault current level applicable for each voltage level in the substation, and with that and from Table 4 the number of earth tails to be applied per voltage level.

Note that the highest design fault current level must be used when doing the substation safety design with CDEGS to ensure the whole substation is safe with regards to expected step and touch potentials in the substation during fault conditions.

From Table 7, for each voltage level given in column *"A"*, compare the *"URS single-phase fault level"* in column *"B"* with the ranges given in Table 3 column "*A*" to determine the proposed *"Design earth fault current"* as given in Table 3 column "*B*", while taking cognisance of the conditions given in Table 3 column "*C*".

Determine the number of earth tails needed per voltage level by making use of the chosen design fault current levels per voltage level (Table 8 column *"C"*).

The fault current to be used for the substation safety design (safe step & touch voltages) is the highest values in Table 8 column *"C"*. In this example the 88kV value is the highest at 31.5kA as reflected in column *"E"*.

Table 8: Example 2 proposed and design fault current levels

	A	*B*	*C*	*D*	*E*
1	**System Voltage (kV)** (from table 7)	**URS single-phase fault current (kA)** (from table 7)	**Design fault current (kA)** (from table 3)	**Earth tails per structure** (from table 4)	**Safety calculations (step & touch)**
2	275	10.2	25	2	**Whole substation based on 31.5kA** (Highest value applicable to 275/88/22kV)
3	88	15.4	31.5	3	
4	22 (auxiliary)	0.37	25	2	

The following is observed from Table 8:

- The total substation earth grid is sized and simulated in CDEGS to be safe for 31.5kA (column "C").
- Two earth tails to be applied per structure at 275kV and 22kV level and three per structure at 88kV level as indicated in column "D".
- The 275kV fault current level can more than double without having to do anything at the substation (comparing Table 8 cell "B2" with cell "C2").
- The 88kV fault current level can double without having to do anything at the substation (comparing Table 6 cell "B3" with cell "C3").

3.7.3 Example 3

Consider a 400/275/132kV substation with the following as give:

Table 9: Example 3 proposed fault current levels received

	A	*B*
1	**System Voltage (kV)**	**URS single-phase fault current (kA)**
2	400	45.6
3	275	38.3
4	132	34.5

As in the previous examples, remember that the single-phase fault level is applicable to earthing design. From Table 3 determine the proposed fault level applicable for each voltage level in the substation, and with that and from Table 4 the number of earth tails to be applied per voltage level.

Note that the highest design fault current level must be used when doing the substation safety design with CDEGS to ensure the whole substation is safe with regards to expected step and touch potentials in the substation during fault conditions.

From Table 9, for each voltage level given in column *"A"*, compare the *"URS single-phase fault current level"* in column *"B"* with the ranges given in Table 3 column "*A*" to determine the proposed *"Design earth fault current"* as given in Table 3 column "*B*", while taking cognisance of the conditions given in Table 3 column "*C*".

Determine the number of earth tails needed per voltage level by making use of the chosen design fault levels per voltage level (Table 10 column *"C"*).

The fault current to be used for the substation safety design (safe step & touch voltages) is the highest values in Table 10 column *"C"*. In this example the 400kV value is the highest at 60kA as reflected in column *"E"*.

Table 10: Example 3 proposed and design fault levels

	A	*B*	*C*	*D*	*E*
1	**System Voltage (kV)** (from table 9)	**URS single-phase fault current (kA)** (from table 9)	**Design fault current (kA)** (from table 3)	**Earth tails per structure** (from table 4)	**Safety calculations (step & touch)**
2	400	45.6	60	4	**Whole substation based on 60kA** (Highest value applicable to 400/275/3132kV)
3	275	38.3	50 (maximum for 275kV)	4	
4	132	34.5	40 (maximum for 132kV)	3	

The following is observed from Table 10:

- The total substation earth grid is sized and simulated in CDEGS to be safe for 60kA.
- There is a substantial margin for fault current levels to increase at 400kV and 275kV.
- The 132kV fault level is close to the 132kV equipment limit, and fault current limiting devices will have to be applied should it increase beyond 40kA. (The limiting factor here is obviously the maximum equipment short time ratings.)
- Four earth tails to be applied per structure at 400kV and 275kV levels and three per structure at 132kV level.

4. Authorization

This document has been seen and accepted by:

Name and surname	Designation
Braam Groenewald	Corporate Consultant – Substation Engineering
Christy Thomas	Senior Engineer – Substation Engineering
Derrick Delly	Chief Engineer – Substation Engineering
Enderani Naicker	Chief Engineer – Substation Engineering
Krishna Naidoo	Senior Engineer – Substation Engineering
Mark Peffer	Chief Engineer – Substation Engineering
Nkululeko Mazibuko	Engineer – Substation Engineering
Rukesh Ramnarain	Chief Engineer – Substation Engineering
Sipho Zulu	Chief Engineer – Substation Engineering

5. Revisions

Date	Rev	Compiler	Remarks
June 2020	2	TJ Marais	Updated 2.2.1 (Normative references) Updated 2.4 (Abbreviations) Updated 3.1 (Background) with reference to the latest substation earth grid design standard. Updated 3.2 (Calculated maximum fault currents (Eskom Transmission System Operations)), added analysis of data from [3]. Updated Annex A (Maximum single-phase fault current per station), added 2019 data
Dec 2015	1	TJ Marais	First issue

6. Development team

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

- TJ Marais

7. Acknowledgements

Everybody that took the time to comment on the draft document.

Annex A – Maximum single-phase fault current per station

This is an extract from references [2] and [3]. Only the maximum single phase EF per station is listed.

Station	Max 2014 EF (kA)	Max 2019 EF (kA)
Acacia	25.793	28.22
Acornhoek	9.102	9.76
Aggeneis	5.835	12.80
Alpha	54.26	56.38
Ankerlig	32.42	36.84
Apollo	34.047	36.15
Ararat	31.168	32.10
Ariadne	24.47	25.67
Aries	5.755	12.66
Arnot	37.744	38.06
Athene	61.582	36.18
Aurora	17.201	21.76
Avon	15.417	22.49
Bacchus	22.97	25.82
Bayside	14.269	NI
Benburg	17.97	14.73
Bernina	23.781	21.36
Beta	25.834	29.95
Bighorn	37.915	36.89
Bloedrivier	9.084	15.37
Bloukrans	16.607	17.18
Bokpoort	NI	37.60
Bolobedu	NI	0.31
Borutho	NI	18.80
Boundary	10.321	16.08
Brakrivier	7.841	NI
Brenner	29.719	31.23
Buffalo	14.37	15.36
Camden	37.573	38.52
Carmel	NI	25.56
Chivelston	17.07	16.94
Cookhouse	NI	10.89
Craighall	35.427	29.32
Croydon	28.535	25.07

Station	Max 2014 EF (kA)	Max 2019 EF (kA)
Curomane	NI	2.35
Danskraal	9.683	10.35
Dedisa	20.801	27.14
Delphi	8.083	9.77
Delta	23.512	21.24
Dinaledi	26.729	31.48
Drakensberg	17.795	18.59
Droerivier	12.836	13.70
Durban South	NI	27.74
Duvha	61.942	62.56
Edwaleni	11.833	11.37
Eiger	31.995	31.24
Eros	16.723	17.12
Esselen	30.635	30.79
Etna	18.016	24.78
Everest	16.475	32.63
Ferrum	13.97	30.13
Fordsburg	24.117	25.37
Foskor	11.792	12.79
Gabarone South	NI	4.55
Gamma	7.456	8.11
Gariep	12.202	NI
Garona	2.918	9.19
Georgedale	19.321	19.76
Gigawatt	NI	87.50
Glockner	34.226	35.19
Golden Valley	7.365	NI
Gourikwa	15.284	15.98
Grassridge	27.394	28.53
Gromis	3.442	5.42
Grootvlei	28.339	31.91
Gugulethu	NI	19.46
Gumeni	25.037	25.73
Harib	2.665	4.40

Station	Max 2014 EF (kA)	Max 2019 EF (kA)
Harvard	15.709	17.93
Hector	17.954	18.94
Helios	4.845	16.74
Hendrina	38.022	40.64
Hera	20.556	21.53
Hermes	27.642	30.42
Hydra	33.094	39.33
Ilovo	46.685	47.84
Impala	23.752	33.46
Incandu	20.118	19.68
Infulene	6.01	6.59
Ingagane	16.699	14.55
Ingula	11.932	22.05
Insakumini	1.787	1.85
Invubu	15.801	17.66
Juno	7.326	10.94
Jupiter	26.695	27.08
Kappa	14.356	15.60
KaXu	NI	8.82
Kendal	56.992	59.97
Khanyazwe	10.539	12.01
Kingsburgh	NI	9.84
Klaarwater	30.166	26.49
Koeberg	34.842	37.49
Kokerboom	NI	4.10
Komati	27.099	30.00
Komatipoort	10.273	10.31
Kookfontein	31.846	28.86
Kopleegte	NI	9.21
Kriel	46.263	49.49
Kronos	4.707	14.77
Kruispunt	32.292	31.48
Kudu	25.535	20.27
Kusile	25.973	41.60
Kwagga	16.734	17.43
Leaches Bay	11.779	11.96

Station	Max 2014 EF (kA)	Max 2019 EF (kA)
Leander	22.419	29.34
Lepini	29.107	44.16
Leseding	24.796	25.78
Lethabo	42.893	42.20
Lewensaar	2.906	5.60
Lomond	28.981	27.87
Lotus Park	25.058	24.09
Luckhoff	NI	10.51
Lulamisa	29.723	36.92
Majuba	50.756	53.92
Makalu	41.581	27.47
Maputo	24.044	9.39
Marang	45.552	33.08
Marathon	20.72	21.34
Matimba	38.417	43.70
Matla	56.303	57.65
Matola	6.493	NI
Medupi	21.564	37.06
Merapi	6.33	10.54
Mercury	24.703	28.57
Merensky	28.675	27.43
Mersey	18.741	21.16
Midas	32.76	36.16
Minerva	25.315	27.54
Mookodi	7.593	11.84
Mozal	20.243	NI
Mplain	NI	17.32
Muldersvlei	34.141	35.95
Nama	5.579	8.85
Ndlovho	NI	8.69
Neptune	17.535	18.78
Nevis	17.218	18.92
Ngwedi	NI	22.82
Nieuwehoop	NI	13.36
Njala	22.019	24.94
Normandie	12.446	12.08

Station	Max 2014 EF (kA)	Max 2019 EF (kA)
Nxuba	NI	18.18
Obib	NI	1.72
Olien	10.032	17.78
Olympus	40.719	26.45
Oranjemond	3.208	5.95
Ottawa	14.14	14.88
Palmiet	13.455	8.83
Paulputs	4.573	9.40
Pegasus	16.768	18.53
Pelly	13.003	10.31
Pembroke	11.242	13.52
Perseus	31.905	36.18
Philippi	25.468	29.83
Phiri	NI	10.82
Phokoje	9.504	9.66
Pieterboth	14.237	15.01
Pinotage	NI	21.00
Pluto	24.069	25.97
Port Rex	12.21	12.87
Poseidon	28.777	33.71
Prairie	25.594	26.16
Princess	30.451	31.03
Prospect	25.688	26.23
Proteus	23.418	24.54
Rabbit	14.46	NI
Ressano Garcia	11.579	10.06
Rigi	29.866	37.05
Rockdale	32.371	25.03
Roodekuil	6.451	7.32
Ruigtevallei	13.441	15.66
Sasol 2	31.394	42.13
Sasol 3	23.74	46.21
Sasol OCGT	NI	39.11
Scafell	14.648	14.96

Station	Max 2014 EF (kA)	Max 2019 EF (kA)
Segoditshane	NI	3.79
Senakangwedi	11.318	9.17
Simplon	13.592	13.26
Sisimuka	NI	16.23
Snowdon	24.017	21.56
Soetwater	NI	7.14
Sol	35.503	48.28
Sorata	3.465	5.43
Spencer	8.796	9.06
Spitskop	26.625	36.16
Sterrekus	26.528	33.77
Stikland	28.521	32.66
Tabor	14.884	15.04
Taunus	29.155	30.27
Theseus	17.036	28.78
Thuso	24.1	27.65
Trident	25.606	27.22
Tugela	11.405	NI
Tutuka	64.368	68.20
Uitkoms	19.21	20.56
Umfolozi	14.546	14.49
Upington	NI	35.10
Van der Kloof	6.282	NI
Venus	18.016	19.54
Verby	3.556	NI
Verdun	28.378	28.90
Vulcan	29.678	32.91
Vuyani	12.536	12.18
Warmbad	7.338	7.41
Watershed	13.691	13.70
Westgate	20.342	20.01
Witkop	26.546	27.03
Xina	NI	8.82
Zeus	26.481	37.45

Annex B – Number of line faults per fault current range

		Fault current range (kA)													
		<5	**5 to 7.5**	**7.5 to 10**	**10 to 15**	**15 to 20**	**20 to 25**	**25 to 30**	**30 to 35**	**35 to 40**	**40 to 45**	**45 to 50**	**50 to 55**	**55 to 60**	**>60**
2001	**Qty**	142	16	8	5	1	0	0	1	1	0	0	0	0	0
	%	81.6	9.2	4.6	2.9	0.6	0.0	0.0	0.6	0.6	0.0	0.0	0.0	0.0	0.0
2002	**Qty**	295	52	35	30	12	3	0	0	1	0	0	0	0	0
	%	68.9	12.1	8.2	7.0	2.8	0.7	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
2003	**Qty**	266	44	22	18	5	3	2	1	0	0	0	0	0	0
	%	73.7	12.2	6.1	5.0	1.4	0.8	0.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0
2004	**Qty**	631	107	55	43	15	5	5	0	0	0	0	0	0	0
	%	73.3	12.4	6.4	5.0	1.7	0.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2005	**Qty**	814	173	103	66	18	22	8	2	0	0	0	0	0	0
	%	67.5	14.3	8.5	5.5	1.5	1.8	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0
2006	**Qty**	817	166	99	77	22	9	8	6	0	0	0	2	1	1
	%	67.6	13.7	8.2	6.4	1.8	0.7	0.7	0.5	0.0	0.0	0.0	0.2	0.1	0.1
2007	**Qty**	746	158	69	53	14	20	3	1	1	0	1	0	0	1
	%	69.9	14.8	6.5	5.0	1.3	1.9	0.3	0.1	0.1	0.0	0.1	0.0	0.0	0.1
2008	**Qty**	736	166	72	61	16	13	3	3	1	0	0	0	0	0
	%	68.7	15.5	6.7	5.7	1.5	1.2	0.3	0.3	0.1	0.0	0.0	0.0	0.0	0.0
2009	**Qty**	826	167	102	69	28	12	10	9	3	1	0	0	0	0
	%	67.3	13.6	8.3	5.6	2.3	1.0	0.8	0.7	0.2	0.1	0.0	0.0	0.0	0.0
2010	**Qty**	785	214	89	95	42	17	11	6	1	2	2	0	0	0
	%	62.1	16.9	7.0	7.5	3.3	1.3	0.9	0.5	0.1	0.2	0.2	0.0	0.0	0.0
2011	**Qty**	855	209	90	72	26	11	8	3	1	0	0	0	0	0
	%	67.1	16.4	7.1	5.6	2.0	0.9	0.6	0.2	0.1	0.0	0.0	0.0	0.0	0.0
2012	**Qty**	615	127	84	60	26	8	1	0	3	2	0	0	0	0
	%	66.4	13.7	9.1	6.5	2.8	0.9	0.1	0.0	0.3	0.2	0.0	0.0	0.0	0.0
2013	**Qty**	506	137	50	42	16	10	2	2	0	0	0	0	0	0
	%	66.1	17.9	6.5	5.5	2.1	1.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0
2014	**Qty**	532	121	81	53	31	9	3	3	0	0	1	0	0	0
	%	63.8	14.5	9.7	6.4	3.7	1.1	0.4	0.4	0.0	0.0	0.1	0.0	0.0	0.0
Total	**Qty**	8566	1857	959	744	272	142	64	37	12	5	4	2	1	2
	%	67.6	14.7	7.6	5.9	2.1	1.1	0.5	0.3	0.1	0.0	0.0	0.0	0.0	0.0