Eskom	**Standard**	**Technology**

Title: **GENERIC SUBSTATION DESIGN**

Unique Identifier:	**240-71062174**
Alternative Reference Number:	**34-304**
Area of Applicability:	**Engineering**
Documentation Type:	**Standard**
Revision:	**2**
Total Pages:	**45**
Next Review Date:	**September 2024**
Disclosure Classification:	**Controlled Disclosure**

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PCM Reference: **Substation Design**

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

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1. Introduction

Of importance is to keep in mind that the substation layout design intent is to satisfy all the "abilities", i.e. constructability, reliability, availability (of supply), accessibility, operability, inspect-ability, maintainability, expandability and scalability to mention a few.

To this end this Distribution Standard has been prepared to promote standardized distribution substation designs, including the use of standardized equipment, materials and practices, thereby reducing design and construction periods, equipment stock levels and costs generally. This document highlights important factors that must be considered during the design process and is applicable to new substation as well as substation strengthening and refurbishment projects where applicable.

This standard does not include control plant designs.

2. Supporting clauses

2.1 Scope

This standard does not cover the detail of each topic discussed, but rather highlights important factors that must be considered during the design process.

2.1.1 Purpose

The purpose of this document is to sensitise mainly substation design engineers on the important factors that must be considered during the substation design process.

2.1.2 Applicability

This document shall apply to the Distribution Division, Eskom Holdings Limited.

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] CIGRE Technical Brochure 740, Contemporary Design of Low Cost Substations in Developing Countries

[2] ISO 9001, Quality Management Systems

[3] IEEE Std 81, Guide for measuring earth resistivity, ground impedance and earth surface potentials of a grounding system

[4] IEEE Std 1119, Guide for fence safety clearances in electric-supply stations

[5] SANS 121, Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods

[6] SANS 282, Bending dimensions of bars for concrete reinforcement

[7] SANS 1019, Standard voltages, currents and insulation levels for electricity supply

[8] SANS 1186, Symbolic safety signs (App)

[9] SANS 1200A, Standardized specifications for civil engineering construction – A General

[10] SANS 1200AA, Standardized specifications for civil engineering construction – AA General (small works)

[11] SANS 1200C, Standardized specifications for civil engineering construction – C Site Clearance

[12] SANS 1200D, Standardized specifications for civil engineering construction – Earthworks

[13] SANS 1200DA, Standardized specifications for civil engineering construction – Earthworks (small works)

[14] SANS 1200DB, Standardized specifications for civil engineering construction – DB Earthworks (pipe trenches)

[15] SANS 1200DK, Standardized specification for civil engineering construction – DK Gabions and pitching

[16] SANS 1200DM, Standardized specifications for civil engineering construction – DM Earthworks (road, subgrade)

[17] SANS 1200G, Standardized specifications for civil engineering construction – G Concrete (structural)

[18] SANS 1200GA, Standardized specifications for civil engineering construction – GA Concrete (small works)

[19] SANS 1200GB, Standardized specifications for civil engineering construction – GB Concrete (ordinary buildings)

[20] SANS 1200H, Standardized specifications for civil engineering construction – H Structural steelwork

[21] SANS 1200HA, Standardized specifications for civil engineering construction – HA Structural steelwork (sundry items)

[22] SANS 1200HC, Standardized specifications for civil engineering construction – HC Corrosion protection of structural steelwork

[23] SANS 1200LB, Standardized specifications for civil engineering construction – LB Bedding (pipes)

[24] SANS 1200LE, Standardized specifications for civil engineering construction – LE Stormwater drainage

[25] SANS 1200M, Standardized specifications for civil engineering construction – M Roads (general)

[26] SANS 1200ME, Standardized specifications for civil engineering construction – ME Subbase

[27] SANS 1200MF, Standardized specifications for civil engineering construction – MF Base

[28] SANS 1200MK, Standardized specifications for civil engineering construction – MK Kerbing and channelling

[29] SANS 1200MM, Standardized specifications for civil engineering construction – MM Ancillary roadworks

[30] SANS 10103, The measurement and rating of environmental noise with respect to annoyance and to speech communication

[31] SANS 10144, Detailing of steel reinforcement for concrete

[32] SANS 10164, The structural use of masonry – All parts

[33] SANS 10199, The design and installation of an earth electrode

[34] SANS 10280-1, Overhead power lines for conditions prevailing in South Africa – Part 1: Safety

[35] SANS 10400-T, The application of the National Building Regulations – Part T: Fire protection

[36] SANS 60060-1, High-voltage test techniques – Part 1: General definitions and test requirements

[37] SANS 60815, Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – All parts

[38] 32-95, Environmental, Occupational Health and Safety Incident Management Procedure

[39] 34-1985, Distribution Standard – Part 2, Earthing Section 1. MV and LV reticulation earthing

[40] 240-47172520, The Standard for the Construction of Overhead Powerlines (TRMSCAAC5.2)

[41] 240-55922824, Substation Layout Design Guide

[42] 240-64720986, Emergency Preparedness Public Address System – For Large Area Deployment

[43] 240-65216546, Standard for Portable Earthing Gear

[44] 240-66917056, Standard for Passive Fire Protection In Distribution Substation Yards

[45] 240-68971854, Standard for Power Frequency Electric and Magnetic Analysis in Substations

[46] 240-68972308, Standard Procedure for Single Line (Station Electric) Diagram Development

[47] 240-72597722, Environmental Impact Assessment for Distribution Activities

[48] 240-75660336, Substation and Network Equipment Label Specification

[49] 240-76368574, High Security Mesh Fencing

[50] 240-76613395, Planning Standard for Distribution Network Reliability to Ensure Distribution Network Code Compliance

[51] 240-78980848, Specification for Nonlethal Energized Perimeter Detection System (NLEPDS) for Protection of Eskom Installations and its Subsidiaries

[52] 240-84854974, Continuity Measurement of Substation Earth Grid Systems

[53] 240-87605434, Quality Checklist for Distribution Substation Primary Plant Prior to Handing Over for Commercial Operation

[54] 240-91190304, Specification for CCTV Surveillance with Intruder Detection

[55] 240-91252315, Standard for Bullet-resistant Guard Facilities

[56] 240-91252455, Lighting for Perimeter Security at Eskom Installations

[57] 240-96393507, Soil Resistivity Testing For Substation Applications

[58] 240-101940513, Substation Earth Electrode Resistance Measurement

[59] 240-102220945, Specification for Integrated Access Control System (IACS) for Eskom Sites

[60] 240-109589380, Direct Lightning Stroke Protection of Substations

[61] 240-113163905, LED Floodlights for Distribution Substation Applications

[62] 240-114967625, Operating Regulations for High Voltage Systems

[63] 240-120804300, Standard for the Labelling of Electrical Equipment within Eskom Wires Networks

[64] 240-122922610, Specification For Substation Tubular Conductors

[65] 240-134369472, Substation Earth Grid Design Standard

2.2.2 Informative

[66] 32-9, Definition of Eskom Documents

[67] 32-644, Eskom Documentation Management Standard

Definitions

2.2.3 General

Definition	Description
Busbar	Low impedance conductor to which several electric circuits can be connected separately.
Corona	Luminous, audible discharge as a result of electrical overstressing in an insulating material, usually air that occurs when there is an excessive localized electric field gradient upon an object or conductor that causes the ionization and possible electrical breakdown of the air adjacent to this point.
High Voltage	The set of nominal voltage levels that are used in power systems for bulk transmission of electricity in the range 44kV < Un ≤ 220kV.
Medium Voltage	The set of nominal voltage levels that lie above low voltage and below high voltage in the range 1kV < Un ≤ 44kV.
Minimum bay separation distance	The minimum distance between the centre lines of two bays next to each other exiting the busbar in the same direction.
Specific Creepage Distance (SCD)	The total creepage distance divided by the phase-to-phase system highest voltage.
Unified Specific Creepage Distance (USCD)	The total creepage distance divided by the phase-to-earth system highest voltage.

2.2.4 Disclosure classification

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

2.3 Abbreviations

Abbreviation	Description
AASHTO	American Association of State Highway and Transportation Officials
AIS	Air Insulated Switchgear
AMSL	Above Mean Sea Level
AV	Abnormal Vehicle (exceeding normal mass and dimensional limits, or both)
CAP	Committee for Accepted Products
CFC	Chlorofluorocarbon
DCP	Dynamic Cone Penetration
EIA	Environmental Impact Assessment
EIMP	Environmental Impact Management Plan
EMF	Electromagnetic Field
EPDM	Ethylene Propylene Diene Monomer
GIS	Gas Insulated Switchgear
GM	General Manager
HV	High Voltage

Abbreviation	Description
IEC	International Electrotechnical Commission
LAP	List of Accepted Products
LV	Low Voltage
MTS	Mixed Technology Switchgear (a combination of AIS and GIS)
MV	Medium Voltage
NED	Network Engineering and Design
n/a	not applicable
OHS	Occupational Health and Safety
RMS	Root Mean Square
RTU	Remote Terminal Unit
RTV	Room Temperature Vulcanizing
SCADA	Supervisory Control and Data Acquisition
SCD	Specific Creepage Distance
TOV	Temporary Overvoltage
UHF	Ultra-high Frequency
USCD	Unified Specific Creepage Distance
UV	Ultraviolet
VHF	Very High Frequency

2.4 Roles and responsibilities

The Operational Unit Network Engineering and Design managers shall ensure that the document is distributed to the relevant people for implementation.

2.5 Process for monitoring

The responsible NED Zone Managers will monitor the implementation and adherence to this standard in the Operating Units.

2.6 Related/supporting documents

This document replaces Distribution Standard 34-304.

3. Requirements

The requirements of the Occupational Health and Safety Act, Act 85 of 1993 (OHS Act) and all subsequent amendments and regulations shall be observed at all times.

3.1 Site selection

The starting point for site selection is the load centre as determined by the planning engineer and captured in the applicable planning report. In most cases it will not be possible to position the substation at exactly this point so it becomes the starting point to determining the actual (final) substation site.

Following are important factors to take into consideration in determining a feasible site for the substation.

3.1.1 Factors to consider in site selection

The following factors have a bearing on the design, and consequently cost of a substation, and shall be considered in the selection of a site for a proposed substation:

a) Site dimensions (refer to paragraph 3.1.2).

b) Environmental factors (refer to paragraph 3.1.3).

c) Proximity to bodies of water, the selected site should preferably be at least 500m above the 50 year flood level.

d) Topography affecting the following (refer to paragraph 3.1.4):

    1) Site grade

    2) Storm water management

    3) Communications

e) Geological and geotechnical characteristics of the soil (refer to paragraph 3.1.5) affecting:

    1) Foundations

    2) Yard platforms

f) Access and access roads (refer to paragraph 3.1.6).

g) Feeder corridors, especially for overhead lines (refer to paragraph 3.1.7).

h) Environmental factors affecting system reliability (refer to paragraph 3.1.8):

    1) Lightning

    2) Pollution

i) Soil resistivity affecting the earthing design (refer to paragraph 3.1.9).

j) Telecommunications (refer to paragraph 3.1.10).

k) The Security risks associated with a proposed site must be considered during site selection based on a Security Threat and Risk Assessment.

3.1.2 Site dimensions

It is critical that the dimensions of the site acquired are as close as possible to the proposed long term (end of life) substation footprint in order to minimize land wastage and costs.

Conversely, if an adequate site cannot be obtained based on the above requirements, a change to more advanced and capital intensive technology will be necessitated, e.g. Mixed Technology Switchgear (MTS) or Gas Insulated Switchgear (GIS). These technologies have many ramifications (impacts and risks) in terms of design and standardization.

As far as possible, the future, or ideally the ultimate configuration (end state) of the substation employing conventional Air Insulated Switchgear (AIS) technology, is to be considered in procuring a site.

3.1.3 Environmental factors

Due to the requirement for an Environmental Impact Assessment (EIA), it is essential that environmental factors are taken into consideration in the early stages of any proposed development in order to ensure that:

a) legal requirements are adhered to;

b) customer requirements are met;

c) environmental, legal and financial risks are minimized; and

d) construction is in line with the Eskom environmental policy and strategy criteria.

Eskom's particular documents in this respect are:

- 32-95, Environmental, Occupational Health and Safety Incident Management Procedure
- 240-72597722, Environmental Impact Assessment for Distribution Activities

3.1.3.1 Environmental impact assessment

An EIA shall be performed for every substation development project in accordance with 240-72597722.

The EIA process shall ensure that the following criteria have been met:

a) Have the basic principles of integrated environmental management been applied?

b) Has the broad definition of the 'environment' been adopted in the planning and assessment?

c) Has there been sufficient consultation with interested and affected parties?

d) Is it clear where accountability for the information lies?

e) Is there sufficient information in the report to make a decision?

f) Is the report accurate, unbiased and credible?

g) Have enough alternatives been considered?

h) Does the assessment consider the possibility of cumulative impacts?

i) Are mitigating measures included and defined in specific and practical terms?

j) Are the judgements made around the issue of significance valid?

k) Is the information in the assessment report communicated clearly?

3.1.3.2 Environmental impact management plan

An Environmental Impact Management Plan (EIMP) shall be developed for the substation construction phases, in order to provide management strategies to mitigate any adverse environmental impacts identified during the EIA process. Factors to be considered in the EIMP are detailed in Annex A. These factors shall also be considered during site selection to ensure that the plan requirements are met before final site selection.

3.1.4 Topography

The aim of selecting the optimum site is to minimize construction costs and duration. The following are important points to consider in the choice of a suitable site:

3.1.4.1 Site grade

The ideal site is mildly graded (sloped) such that earthworks ('cut and fill') are minimal. The ideal gradient of the natural ground is 1:150. Furthermore, such a site will permit the entire substation to be constructed on a single platform.

Multi-terraced platforms are to be considered for otherwise unsuitable sites if the following conditions are encountered:

a) The gradient of the natural ground results in cut and fill embankments exceeding 3 m in height.

b) Decomposed rock is present that will result in costly earthworks.

c) There are high precipitation levels that will necessitate a special drainage design.

3.1.4.2 Storm water management

Sites with preferred grade (refer to paragraph 3.1.4.1) will typically not require a special storm water drainage design. The drainage design will result in additional costs that will affect the viability of the site. The following areas are to be avoided where possible:

a) Low-lying areas where flooding could occur.

b) Areas where the water table could be high or even above ground at times of heavy rainfall.

3.1.4.3 Influence of topography on communications

The topography affects the application of certain types of telecommunication media. Line of sight to the nearest suitable high site is applicable for microwave communications, and to a lesser extent area radio.

a) Microwave

Microwave transmission, which utilizes high frequency radios, requires line of sight between antennas. In order to ensure efficiency of transmission, the airspace between the towers needs to be clear of any obstructions that could possibly block signals to the receiver. Topography thus plays a vital role in microwave communications between the Supervisory Control and Data Acquisition (SCADA) master station and the Radio Terminal Units (RTUs) in the field. Microwave transmission is utilized extensively in the backbone of the Eskom Telecommunications network and from the repeater site to the SCADA master station.

b) UHF and VHF area radio

Despite line of site not being a mandatory parameter in area radio application as with microwave transmission, topography does plays a vital role in communications over the air. The signal decays over a finite distance and additional factors such as curvature of the earth, obstructions (hills, mountains, buildings etc.) contribute to the degradation of the signal. In order for Eskom Telecoms to establish an acceptable radio path design, coverage plots need to be developed in order to ascertain if the degraded signal meets the minimum telecommunication requirements. This can be supplemented with field testing in order to authenticate the results of the designed coverage plots.

3.1.5 Geological and geotechnical characteristics of the soil

The following geological and geotechnical characteristics of the soil are to be considered:

3.1.5.1 Soil types

a) The ideal soil is a well-graded mixture of gravel and sand. A site is acceptable if either soil type 1 or 2, as specified in 240-47172520, is present.

b) If soil types 3 or 4 are present, either the foundations will require redesign due to the inferior bearing capacity of the soil, or the in situ soil will have to be excavated to an appropriate depth and replaced with suitable imported material.

1) Areas with moderate to high clay content (type 3 e.g. 'turf`' and type 4) are to be avoided if possible, as this will result in costly foundations due to the poor bearing capacity of the soil. With clay, there also exists the potential for 'heaving' (shrinkage and expansion) with seasonal soil moisture variation.

2) Cohesionless sand (type 3) conditions are also to be avoided, as they result in costly foundations.

c) Rocky conditions (either hard or soft/decomposed rock) also result in costly foundations despite the high bearing capacity, since excavation is difficult and may even require blasting.

3.1.5.2 Test holes

Test holes shall be excavated and the suitability of the subgrade (soil and ground water conditions) evaluated. The following factors are to be considered:

a) The conditions are to be evaluated by a professional civil engineer, prior to a final decision being made on the site selection.

b) If site conditions are homogeneous or moderately homogeneous, test holes are to be excavated in accordance with the following guideline based on the diagonal dimension (D) of the substation:

1) For substations with a diagonal dimension of up to 25 m, a single test excavation shall be made close to the centre of the site, or as determined by the substation designer or a civil engineer.

2) For substations with a diagonal dimension of 25 m < D ≤ 50 m, a minimum of two test excavations are to be made at least 20 m apart on the site diagonal, or as determined by the substation designer or a civil engineer.

3) For substations with a diagonal dimension > 50 m, a minimum of four test excavations are to be made at the corners of a rectangle situated at least 5 m within the site boundary, or as determined by the substation designer or a civil engineer.

c) If site conditions appear to be non-homogeneous or moderately non-homogeneous as defined in b) above, or if the substation grade is > 1:70, a geotechnical survey should be requested, as there could be major impacts for earthworks and foundations.

3.1.5.3 Yard platforms

In cases where soils of type 1 or 2 will allow a firm compacted surface to be achieved, no additional finish is required for the platform. For soil types 3 or 4, additional costs will have to be catered for, and shall be considered in the site suitability evaluation.

3.1.6 Access and access roads

3.1.6.1 Access

Suitable substation access roads are costly and require maintenance. Consequently, the distance from the main road influences the suitability of a site. The Lands and Rights department shall ensure that all restrictions associated to the substation site and access routes are properly communicated to all project team members.

3.1.6.2 Access roads

The manoeuvrability and mass of the abnormal vehicles necessary for the delivery of power transformers are onerous in determining the access road specification.

The following points are to be considered in order to determine the access road details:

a) The width and turning radius, as determined by the manoeuvrability of Abnormal Vehicles (AVs) used in the specific operating unit.

b) The road foundation design as necessitated by the axle loads of AVs (refer to subgrade geotechnical characteristics).

c) The slope, and change in slope of the access road in relation to the wearing surface, as determined by the AV gradient ability (traction).

d) The traffic volume and type, as well as erosion potential, possibly necessitating a wearing surface.

e) The construction of bridges necessitated by natural watercourses.

3.1.6.3 Access for mobile transformers/substations

Access for mobile transformers or substations must be allowed for in the layout design where applicable. This is especially required for single transformer substations. It is important to not only provide the required vehicle access, but also space for both the HV and MV cable routes and connections.

3.1.7 Incoming line corridors

It is less costly to integrate the substation into the network by means of overhead lines. Proximity to existing line corridors greatly affects the suitability of a site. In some cases, particularly in urban areas, where servitudes cannot be obtained for overhead lines, integration via an underground network may be necessary.

The ultimate number, position and terminal tower footprint dimensions of connected lines shall be considered in the site selection and the substation orientation.

3.1.8 Environmental factors affecting system reliability

'Conventional' AIS substations are relatively inexpensive compared with GIS substations, and easy to maintain, but are exposed to environmental factors that have an influence on reliability.

Whilst environmental factors may influence the general suitability of a site, the conditions may prevail throughout the load centre. These factors might not be avoided, but will rather require appropriate mitigation in accordance with the environmental conditions.

3.1.8.1 Lightning

AIS installations are exposed to lightning necessitating due consideration of insulation coordination involving the following areas of the design:

a) Lightning shielding to limit the possibility of direct strikes to the installation

   An effective lightning protection system will prevent penetrations of stroke magnitudes that will result in over voltages which exceed the equipment insulation levels.

b) Application of lightning arresters

   Arresters with the appropriate protective characteristics must be applied and placed in suitable positions in relation to the protective distance.

c) Lightning impulse withstand level of the insulation

   The insulation level must be coordinated with the arrester protective levels.

d) Earthing for transient performance

   The earthing system should be designed for adequate high-frequency performance such that transients are effectively dissipated.

Areas with high lightning flash density and mean peak stroke magnitude will require more stringent designs in respect of the above factors. This will affect the cost.

3.1.8.2 Atmospheric pollution

Ideal insulations exhibit zero leakage current, whereas 'real' insulation always has some 'small' resistive leakage current comprised of components through the insulation material and across the surface of the insulation. The leakage current across the surface insulation is dependent on the presence of a conductive electrolyte formed from certain types of airborne contaminants (generally 'pollution') and moisture. If the resistivity of the surface layer is such that the resulting surface current density is sufficient for 'dry band' formation, a power frequency flashover may result. This flashover represents a phase to earth fault and is cleared through the operation of a circuit-breaker, i.e. a possible outage.

Pollution is related to the steady state (power frequency) performance, and not transient (lightning) performance, of the system.

Various types of atmospheric pollution can be deposited on insulating surfaces; the following are significant for insulation performance:

- 'Coastal pollution' comprised of sea salt.
- Different industrial pollutants with ionic chemical structure that readily dissociate in water to form an electrolyte.
- Conductive particulates such as cement and carbon dust.
- Fires, e.g. sugarcane, may result in flashovers, particularly on overhead lines.

Other atmospheric factors that can influence the risks associated with pollution are:

- The type (thundershower or drizzle etc.) and frequency of rainfall that will influence washing of the insulators.
- Wind direction and intensity, which will affect dispersion of pollution from the source, or carry pollution over considerable distances to an electrical installation. Wind also affects the insulator cleaning.

3.1.8.3 Determination of the risk of pollution-induced flashover

The risk of flashover due to conductive contamination varies with the position of a substation relative to pollution sources.

a) Risk identification process

The process to identify and quantify contamination risk is based on the following techniques:

1) Observation

The observation of signals that indicate the presence of contamination (a visual inspection, refer to paragraph 3.1.8.4).

2) Analysis

The analysis of equipment performance records for installations in the area, in order to gauge the risk (refer to paragraph 3.1.8.5).

3) Pollution maps

Pollution maps of the area may be used to identify risks based on historical information.

4) Dust gauges

Dust gauges may be used to determine the type and level of pollution.

Figure 1 is a flowchart of the pollution risk identification process:

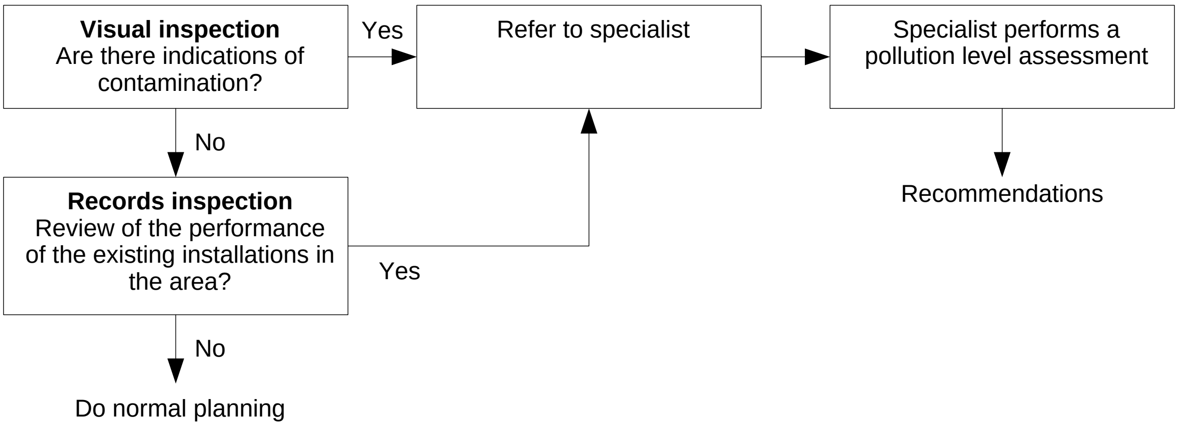


Figure 1: Contamination Risk Identification Process

b) Sources of contamination

As contaminants on the insulating surfaces are not always apparent, it is appropriate to identify potential sources of contamination. These can be:

1) The sea (20km to 50km).

2) Industrial facilities emitting contaminants such as SO_2 or NH_3 that can dissolve to form conductive surfaces on insulators during 'acid rain' conditions (5km to 15km).

3) Mining activities that produce dust containing substances such as gypsum or ilmenite (5km to 15km).

4) Agricultural activities such as crop spraying or ploughing (1km to 2km).

Note: In paragraph 3.1.8.3 b)1) to 4), the figures in brackets are the normal to exceptional limits of influence.

3.1.8.4 Visual and audio identification of contamination

Visual inspections of the area surrounding the site and, if present, other substations in relative proximity, can reveal several indicators as to the presence of atmospheric contaminants. These indicators may either be the noticeable presence of contaminants, corrosion of existing infrastructure or unusually high levels of audible corona activity on existing electrical equipment.

Excessive corona could also indicate the presence of pollutants on insulators. However, this must be considered in relation to various other factors that affect corona such as humidity, altitude and the design of the installation with respect to the system voltage, etc. The level of audible corona discharge or Ultraviolet (UV) emission as measured by a UV camera during light to moderate wetting conditions (i.e. fog or light rain) can also be used to evaluate relative contamination levels.

3.1.8.5 Pollution level assessment by equipment performance evaluation

The optimum method to evaluate the level of contamination is to assess the performance of existing equipment in the area under consideration. Within certain limits, there is a linear relationship between the total creepage distance of an insulator and its steady-state pollution performance. Therefore increases in creepage length will result in near proportional improvement in performance under the same conditions. This characteristic can consequently be used as a convenient means to relate the previous performance of the insulation with the prevailing pollution level and washing conditions in the area.

In the area under study, the existing installations will have different insulator string lengths relating to different pollution performance levels. The existing insulator strings are to be inspected for signs of erosion of the insulator or pin corrosion. The maintenance history of the insulators shall also be taken into consideration. The shortest string length that has no significant damage or requires no maintenance can be used to determine the pollution level; refer to Table 1.

Allowance shall be made for the age of the inspected insulators. Some degree of damage should be expected on aged insulators.

Table 1: Relationship between the Minimum Number of Glass, U120, Cap and Pin Insulators giving Satisfactory Performance and the Related Pollution Level

System Nominal Voltage (U_n) (kV)	System Maximum Voltage (U_m) (kV)	Pollution Level, corresponding creepage distances and Minimum Number of Glass, U120, Cap and Pin Insulators			
		Light	Medium	Heavy	Very Heavy
		SCD: 16 mm/kV USCD: 27.8 mm/kV	SCD: 20 mm/kV USCD: 34.7 mm/kV	SCD: 25 mm/kV USCD: 43.3 mm/kV	SCD: 31 mm/kV USCD: 53.7 mm/kV
11	12	1	1	1	2
22	24	1	2	2	3
33	36	2	3	3	4
66	72,5	4	5	6	8
88	100	6	7	9	11
132	145	8	10	13	16

Notes: 1) The specific creepage distance (SCD) is in relation to the system maximum continuous voltage. For AC systems this is the phase to phase voltage.

2) The unified specific creepage distance (USCD) refers to the maximum voltages across the insulator. For AC systems this is the maximum phase to earth voltage ($U_m/\sqrt{3}$).

3) Current standardization practice is to design for a minimum pollution level of Very Heavy (SCD = 31 mm/kV).

4) Further information on the selection of insulators can be obtained from SANS 60815.

3.1.8.6 Mitigation of pollution-induced flashovers

The following possible measures can be considered to reduce the risk of pollution-induced flashovers:

a) Creepage distance selection

The level and type of pollution determine the creepage distance required. Increasing the creepage distance will improve the performance (for a given insulator profile).

b) Insulation material selection

The insulation material also affects the pollution performance under wetting. Hydrophobic insulation materials, e.g. silicone and Ethylene Propylene Diene Monomer (EPDM) rubber, do not form a continuous conductive layer under wetting, thereby strongly suppressing leakage currents. Generally, the use of hydrophilic materials, e.g. glass, porcelain and cycloaliphatic, will normally necessitate additional creepage as compared with the aforementioned hydrophobic materials for equivalent performance.

c) Insulator coating selection

The application of suitable hydrophobic coatings, e.g. Room temperature Vulcanizing (RTV) silicone can be used to improve the insulation performance.

d) Site selection

A more suitable site is to be selected, If possible.

3.1.8.7 Conclusion

Atmospheric pollution resulting in possible insulation flashovers is a critical factor to be considered in the selection of a substation site. If the insulation creepage is not coordinated with the pollution level, the quality of supply will be adversely affected. Additional insulation creepage may result in significant additional equipment insulation costs. The insulating levels shall be selected in accordance with SANS 60815.

A preliminary pollution level assessment shall be conducted for all proposed sites, such that possible contamination problems may be identified at an early stage. Potential pollution problems shall be referred to specialists for further investigation.

3.1.9 Substation earth mat soil resistivity measurement and analysis

The establishment and maintenance of an effective earth electrode is a key factor in the selection of a suitable site. The soil resistivity of the site and surrounding area subgrade greatly affect the efficiency of the substation earth electrode. Adverse soil conditions will render it uneconomical to design an adequate earth electrode at reasonable cost to meet the required performance. The following measurement and interpretation techniques are to be used to determine the resistivity and structure of the soil.

3.1.9.1 Use of existing information

At some prospective substation sites, a geological survey may have been previously performed, e.g. for prospecting purposes. This survey may provide considerable information regarding the resistivities and structure of the soil and may obviate the need for further preliminary investigation (refer to paragraph 3.1.9.2).

3.1.9.2 Soil resistivity determination

The technique for determining soil resistivity is as follows:

a) Method of measurement

The 'Wenner method' of soil resistivity measurement as outlined in 240-96393507, is recommended.

The depth of soil significantly affecting the performance of an earthing system is proportional to the dimensions of the electrode. Since a substation electrode typically occupies a significantly larger area than the electrodes used for Medium Voltage (MV) and Low Voltage (LV) equipment earthing, deeper soil layers will greatly affect the efficiency of the system. Therefore additional readings at wider probe spacings of up to 50m are to be taken, in order to give an indication of the resistivity at deeper levels.

A minimum of two sets of readings shall be taken, preferably in directions at 90^0 displacements or diagonally across the site, whilst maintaining the centre position of the probes (refer to Figure 2).

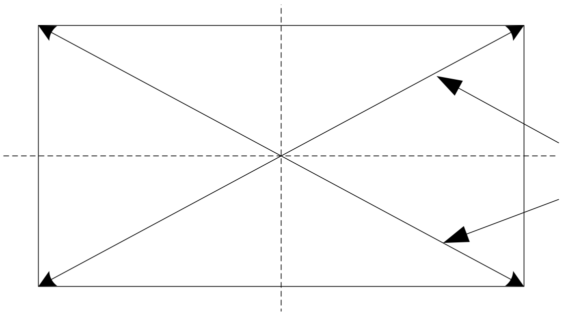


Figure 2: Direction of Soil Resistivity Measurement on a Substation Site

If there is a significant disagreement between the two measurements (> 30%), there is undue influence of existing infrastructure such as power lines, fences or buried pipelines in the vicinity of the measurement site. In the case of visible existing infrastructure such as lines, additional readings should be taken perpendicular to, or as far as possible from, the structure. Buried infrastructure will require additional investigation to determine the nature and position of the object. In this case, additional readings shall be taken until reasonable agreement is achieved. This will provide information as to the possible influence of existing infrastructure. When agreement is achieved between different tests, this can be considered to be representative of the in situ soil. Alternatively, the soil conditions may not be uniform in the horizontal plane.

Emphasis should be placed on the value of meaningful and accurate on-site measurements, as the basis for important decisions regarding site suitability and earthing system design.

The values of the various tests are to be averaged and plotted on bi-logarithmic (‘log-log’) paper. A sample of suitable graph paper, which may be copied, is provided in [62] (240-134369472, Substation Earth Grid Design Standard) Annex A.

Note: A significant difference between the two curves could indicate the presence of a buried object, e.g. a pipeline. In such cases, further investigation is required to determine the nature and depth of the object.

b) Measuring equipment requirements

Details of the measuring equipment requirements are given in 240-96393507.

Note: In areas of high soil resistivity, and especially at wide probe spacings, the current injected by the test set may be extremely low. This introduces the potential for significant measurement errors due to the limitations of the equipment sensitivity. In such cases, the resistance of the current probes should be decreased by wetting the soil in contact with the probes, or by driving the probes deeper into the soil. Alternatively, a better current injection system should be used.

c) Analysis of measurements – soil models

Modern software can generate elaborate soil models. However, for practical purposes, a horizontal two layer stratification model is generally sufficient for a substation electrode design. A two-layer model is often an adequate approximation of the in situ soil structure, even when measurements indicate a more complicated structure.

Figure 3 shows a typical two-layer model:

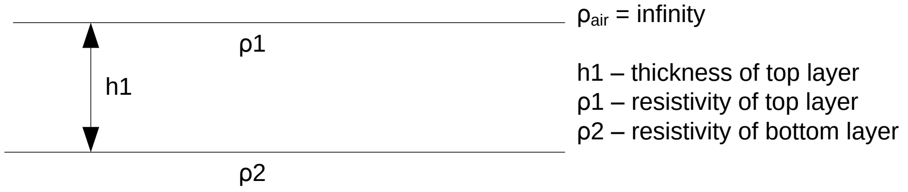
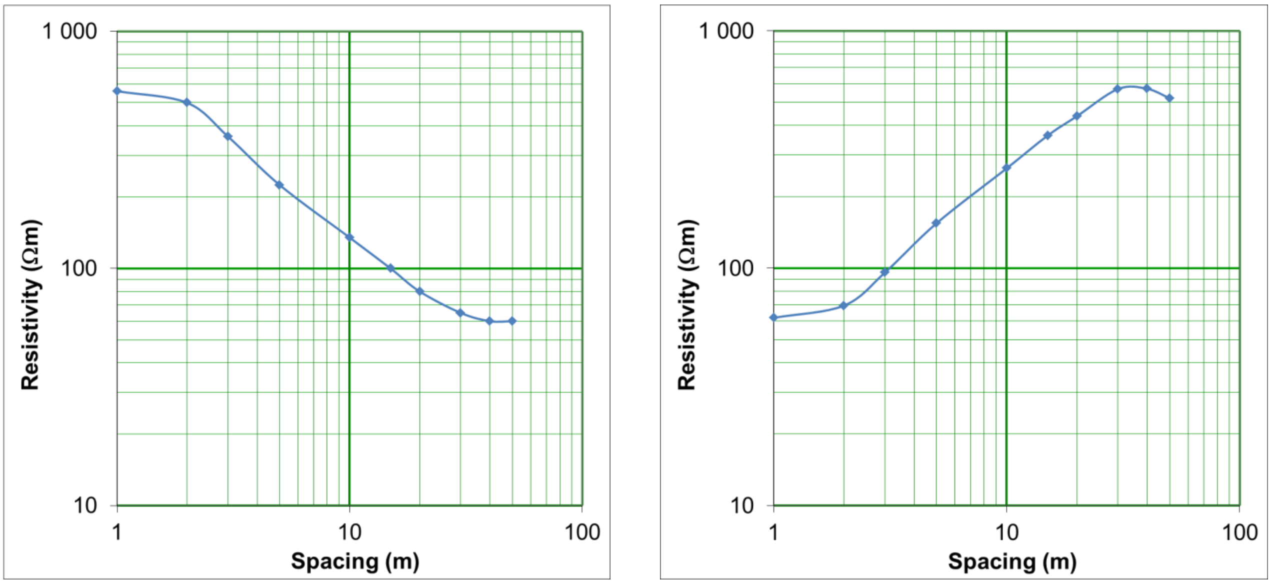


Figure 3: Two-layer soil model

The soil model may be generated by simulation software if available, or developed from first principles as detailed in the following procedure.

Figures 4 (a) and (b) illustrate the two basic configurations for a horizontal two-layer soil model. In the high-over-low soil indicated in Figure 4 (a) the top layer of soil has a higher resistivity than the bottom layer, i.e. $\rho 1 > \rho 2$. In the low-over-high soil indicated in Figure 4 (b) the top layer of soil has a lower resistivity than the bottom layer, i.e. $\rho 1 < \rho 2$.



(a) High-over-low soil (b) Low-over-high soil

Figure 4: Typical soil resistivity plots for a horizontal two-layer model

d) Curve matching techniques

The analysis of the field-measured results in order to obtain the soil parameters is critical in determining the suitability of the in situ soil.

Although in most cases the apparent resistivity, plotted as a function of the electrode spacing, shows a large variation of resistivity, the field curve is approximated as a two-layer soil model. The logarithmic curve matching technique outlined in 240-134369472 (Substation Earth Grid Design Standard) Annex A is recommended to obtain h1, $\rho 1$ and $\rho 2$. This method uses the theoretical family of master curves in SANS 10199. The best fitting theoretical curve is used as a reference to calculate the unknown parameters.

3.1.10 Telecommunications

3.1.10.1 Requirements for radio communications link

a) The most important requirement for a radio communications link is clear ‘line of sight’ between the transmitting and receiving antennas.

b) Secondly, line of sight may be necessary to more than one radio site destination. In general, the optimum site from a telecommunications network point of view is the closest site.

c) It is possible that the favourable location of the substation site could eliminate the need for an intermediate radio repeater site.

3.1.10.2 Telecoms position considerations

In determining the ideal telecoms position for the substation, the following points should be considered:

a) The location should generally be at the highest elevation possible, taking into account environmental factors. It may not be necessary to situate the substation on a hilltop. It may be possible to locate the substation below the horizon of a hill by using a mast of moderate height to obtain a clear path past obstructions.

b) The substation should not be situated such that buildings encroach into the proposed radio path. Future developments in this regard should be taken into consideration when establishing a substation in a developing industrial or suburban area.

3.1.10.3 Site selection information for Telecoms Planner

During the site selection phase, the Telecoms Planner must be provided with the following information for each site being considered:

a) Details (line length and destination substation) of all proposed lines to the new substation

This is necessary to determine whether optical fibre is an option.

b) The categorization of and the protection requirements of the substation

This is necessary to determine the type of Telecommunications required and hence the radio path clearance requirements.

c) The coordinates (latitude and longitude) of the site as well as the elevation

This is necessary to enable the generation of path profiles from the proposed site to all existing or planned Telecommunications sites.

d) Bandwidth requirements for security systems at site must be included in the calculation of bandwidth allocation to the site

Given this information, the Telecoms Planner will be able to perform a preliminary Telecoms design for each site, resulting in a budget Telecoms cost. The addition of this cost to each proposed site will facilitate better site selection.

3.2 Earth mat design

The requirements for earth grid design are given in 240-134369472 and shall be adhered to as applicable.

3.3 Site preparation and construction

3.3.1 General

The work associated with the preparation of the substation site shall be performed in accordance with the following specifications as a minimum requirement:

a) SANS 1200AA, SANS 1200A – General.

b) SANS 1200C – Site clearance.

c) SANS 1200D, SANS 1200DA, SANS 1200DM – Earthworks.

d) SANS 1200DB – Pipe trenches.

e) SANS 1200LB – Bedding pipes.

f) SANS 1200DM – Earthworks (road, subgrade).

g) SANS 1200LE – Stormwater drainage.

h) SANS 1200M, SANS 1200ME, SANS 1200MF, SANS 1200MK, SANS 1200MM – Roads/Subbase/Base/Kerbing.

3.3.2 Yard platforms

a) The top 150 mm layer of the in situ soil shall be scraped to remove all vegetation prior to levelling taking place. This can either be used for cut-and-fill embankments, as topsoil for grassing, or spoiled.

b) The cut-to-fill ratio shall be designed to balance with the finished yard having an ideal cross fall of 1:100 to 1:200. The final platform should ideally have a uniform slope in one direction only and preferably at right angles to the busbars.

c) In order to reduce costs for steeply graded sites, a maximum cross fall of 1:70 might be permitted only under exceptional circumstances. Consideration to the following must be given to:

 1) Compensation of busbar support height either by means of foundation or structure modifications,

 2) Possible ponding to be mitigated by the addition of subsurface drains, etc.

d) In cases where type 1 and 2 soils will allow a firm compacted surface to be constructed, no additional finish is required. The platform shall be compacted to a minimum of 93% Mod AASHTO density.

e) Where the natural soil has a high clay content or consists of cohesionless sand, a 150 mm thick layer of subbase (G5 or G4 i.e. type 2 soil) shall be constructed over the levelled platform. This layer shall be compacted to 93% Mod AASHTO density.

f) Compaction tests shall be carried out on the completed platform in critical areas where transformers or building will be erected. (Test method: DCP.)

g) Weed killer shall be applied to the finished platform before stoning.

3.3.3 Storm water drainage

a) If the substation is to be located on a slope with a catchment area up-slope from the site, an earth berm 1,5m wide x 0,75m high shall be constructed from sub-grade material. The sides shall be shaped to a gradient of 45° and compacted to a density of at least 90% of Mod AASHTO maximum density. This berm shall be positioned in order to divert the water to either side of the site.

b) If the substation is to be constructed in a low-lying area with a high water table, then a subsurface drain shall be built to lower the water table in the substation. A civil engineer shall design such subsurface drains.

c) Where a substation warrants surfaced roads with kerbs and channels, all substation levels shall tie in with the road, which shall act as the surface drainage point for major drainage.

3.3.4 Access road

a) Where the in situ soil is either type 1 or type 2 soils, the access road shall consist of a 200mm layer of base course compacted to 98% Mod AASHTO density. Type 1 and 2 soils are soils that are comprised of well graded sand and gravel as described in 240-47172520.

b) In the case of type 3 soils, where the natural soil has a high clay content or consists of cohesionless sand, a 200mm layer subbase course of type 2 soil shall be imported and compacted to 93% Mod AASHTO density. On this, a 200mm layer of base course compacted to 98% Mod AASHTO density shall be constructed.

c) Where poor soil conditions or erosion problems are anticipated, it may become economically justifiable to surface the road with a wearing surface, i.e. asphalt, due to the significant long-term maintenance costs.

d) Consideration should also be given to the opinions of the district official, since the district staff who will be visiting the site on a regular basis will be most affected by access quality.

3.3.5 Embankments and retaining structures

3.3.5.1 Embankments

a) All embankment slopes shall be constructed with a maximum gradient of 45º and finished with one of the following:

 1) A natural slope stabilized with hessian and seeded with an appropriate grass, or

 2) A 100mm layer of subbase material (G2).

b) The two options in (a) are the most cost effective, but the potential for severe erosion may justify the use of more expensive retaining structures, e.g.:

 1) Paving bricks, or

 2) A 100mm 15 MPa concrete layer.

3.3.5.2 Retaining structures

Where space constraints necessitate embankments with steeper grades, the following retaining structures shall be used:

a) Precast concrete terrace blocks, e.g. 'Loffelstein',

b) Geosynthetic fabric reinforced soil with concrete segmental façade,

c) Gabion baskets, or

d) Retaining walls (gravity, cantilever, piling, tie-back, etc.).

3.4 Civil and structural design

3.4.1 Civil design

3.4.1.1 Standards

Concrete works shall be carried out in accordance with the following standards:

a) SANS 1200G – Concrete structural.

b) SANS 1200GB – Concrete buildings.

c) SANS 10164 – Structural use of masonry.

3.4.1.2 Foundation excavations

The following requirements shall apply to foundation excavations:

a) Excavations shall be made as close as possible to the required foundation dimensions.

b) Shoring shall be used where the depth of the foundation excavation exceeds 1.5m.

c) Shoring shall be used for excavations shallower than 1.5m, where the subgrade has the tendency to collapse, e.g. in cohesionless sandy soils.

d) The bottom of all foundation excavations shall be level and cut squarely with the sides of the excavation.

3.4.1.3 Compaction

Compaction is required in the following situations to increase the stability of the foundation and minimize settlement:

a) Disturbed soil in the bottom of the foundation excavation shall be moistened to optimum moisture content, and compacted with a mechanical plate compactor to a minimum of 93% Mod AASHTO.

b) Where compaction is required around an excavation, the fill shall be compacted at optimum moisture content with a mechanical plate compactor in maximum 150mm layers to a density of 93% Mod AASHTO.

3.4.1.4 Shuttering

a) All exposed surfaces of concrete shall have a smooth 'off-shutter' finish and be free of all irregularities and honeycombing.

b) The exposed edges of all concrete work shall have a 25mm chamfer.

3.4.1.5 Reinforcing

a) All reinforcing shall comply with SANS 10144.

b) All bars shall be neatly bent whilst cold, in compliance with SANS 10144.

c) The bars shall be accurately fixed and securely wired in the configuration and position shown on the drawing.

d) The reinforcing shall be free of loose rust and grease.

e) The minimum concrete cover for all reinforcing shall be in accordance with SANS 0100-2 table 3 and is a function of:

   1) The application condition, and

   2) Concrete MPa requirement.

3.4.1.6 Concrete

a) Concrete works are to be carried out in accordance with SANS 1200G.

b) All plinths and foundations shall have a minimum strength of 25 MPa at 28 days or as specified on the drawing, with a nominal stone aggregate dimension of between 19mm and 25mm.

c) All blinding and strip footings shall have a minimum strength of 15 MPa at 28 days.

d) Any non-standard structural concrete applications shall be designed by a civil/structural engineer, e.g. the use of higher strength concrete to expedite projects.

e) Any additives, e.g. accelerants, to the concrete shall be done with the approval of a civil/structural engineer.

f) All building foundations shall have a minimum strength of 20 MPa at 28 days.

g) No concrete is to be placed if the ambient air temperature is < 4°C within 8 hours of pouring the concrete, unless an Eskom-approved additive is used.

3.4.1.7 Testing

a) Samples of all component materials to be used in the concrete shall be tested and approved prior to construction commencing. This is of particular significance where unknown local materials are to be used in order to minimize haul distances.

b) Concrete cube testing shall be done on all substation concrete works in accordance with SANS 1200G.

c) Concrete slump testing shall be performed to ensure consistent water-to-cement ratios throughout the construction. The slump allowed shall be in the range between 50mm and 80mm.

3.4.1.8 Loading of concrete foundations and plinths (installation of equipment)

To ensure the proper curing of the foundations and plinths the following shall be applied as a guide for 25 MPa strength concrete at 28 days:

a) Columns are only to be erected after 28 days.

b) Transformers can only be positioned on plinths after 28 days.

c) All other foundations:

  1) After 7 days steelwork supports can be erected,

  2) After 14 days steelwork supports can be aligned and torqued,

  3) After 18 days equipment can be installed,

  4) After 28 days conductor and clamps can be installed.

3.4.1.9 Fencing

a) Standard fence types

Standard substation fencing details are given in D-DT-5237 and are selected in accordance with the security risk associated with the site. The standard fence types are:

  1) 2.4m diamond mesh,

  2) 2.4m weld mesh,

  3) 2.4m steel palisade,

  4) 2.4m concrete wall and

  5) 3.0m concrete wall.

b) Other fences

The following fences may also be used where warranted:

  1) Concrete palisade may be used in high-risk areas or where high touch potentials exist at the substation perimeter.

  2) Brick or precast concrete walls may be used where aesthetic or noise sensitivity in the area necessitates the use of a solid barrier, or where space constraints infringe on the required safety clearances in the substation.

For detail on high security mesh fences refer to 240-76368574.

3.4.2 Control buildings/relay buildings/switch buildings

Details of the standard relay room layouts are given in D-DT-5239. The types available are:

a) Type 3A National standard pitch roof relay house.

b) Type 6A National standard flat roof relay house.

All substation building plans, whether to Eskom standard or not, might need to be submitted to the local municipality for approval prior to construction. These plans might need to be signed off by a professionally registered architectural person and may also require support from a professionally registered civil/structural engineering person prior to submission to the municipality. Requirements might differ from OU to OU.

Although the local authority primarily looks at the building plans, certain Metros might query the fire protection systems. The reason for this is based on the fact that they are the ones responding to fires in their areas.

3.4.3 Steel structure design

a) Steelwork shall be in accordance with SANS 1200H, SANS 1200HA and SANS 1200HC.

b) All steelworks, including holding down bolts, shall be galvanized in accordance with SANS 121.

c) In highly corrosive and marine environments, the steelworks shall have a specialized corrosion-proof finish specified. In this situation, all nuts and bolts shall be taped with Denso tape.

3.5 Electrical design

The following are pertinent design factors that must be considered during the design process.

Factors not directly discussed but that also might have an impact and should be considered are:

- Electric and magnetic field exposure levels in and around substations must be kept within safe levels. Refer to 240-68971854.
- The impact of noise generated by the substation must be considered, especially when sited in noise sensitive areas like residential suburbs or game reserves. Refer to SANS 10103.
- Switch houses/buildings shall comply with SANS 10400-T with regards to fire protection as might be applicable.

As part of substation design standardisation the design voltage levels listed in Table 2 shall be designed for, irrespective of the system operating voltage. The implication of this is that the minimum bay separations also listed in Table 2 shall be applied as a minimum for new substations where two or more bays are next to each other on the same side of the busbar. In addition all non-voltage specific equipment associated with the design nominal voltage shall be used.

Table 2: Design voltage levels and bay widths

System nominal voltage (Un) (kV)	Design nominal voltage (Un) (kV)	Minimum transformer bay separation (bay centre to centre) (m)	Minimum feeder bay separation (bay centre to centre) (m)
132	132	12.0	12.0
88	132	12.0	12.0
66	66	9.0	9.0
44	44	8.0	8.0
33	33	8.0	4.2
22	22	6.0	4.2
11	22	6.0	4.2
6.6 and below	22	6.0	4.2

Notes: 1) The layout design must ensure access to all equipment for maintenance and emergency work. It might therefore be necessary to increase these minimum distances depending on the specific application.

2) A number of older 88kV installations employed 10m bay separation distances. When extending these substations care must be taken to allow adequate access to all equipment for maintenance and emergency work if the 10m distances are maintained.

3.5.1 Busbar configuration considerations

The substation busbar configuration shall consider the requirements from Planning as well as the Planning Standard for Distribution Network Reliability to ensure Distribution Network Code compliance.

It must be noted that there is no single optimal configuration that can be applied, but that all decisions impact on cost, reliability, operability and maintainability, and as a result quality of supply as experienced by the customer. The design team has to determine what is required because the chosen configuration does not only impact on the substation primary plant design, but also on the control and protection design.

3.5.1.1 HV busbar

The HV busbar can be a single or double configuration, with or without a coupler and feeder bypasses.

A single busbar station is normally more compact and takes less space because a single busbar section can connect two bays back to back. Normally a line and transformer bay are connected together, in a back-to-back configuration.

If it is a single busbar the design engineer will have to decide if it will be uninterrupted or sectionalised. If configured properly a sectionalised busbar has the advantage that certain sections can be isolated to facilitate maintenance or other work as might be required without affecting all connected services. The sections can be created with isolators only, or with circuit breakers and isolators. There are advantages and disadvantages to both options. An uninterrupted busbar is typically more compact and less cost intensive, but will have a bigger impact on all services connected should it be disconnected for whatever reason.

When a double busbar is chosen it can be with or without a coupler, although there is no advantage to install a double busbar without a bus coupler. Lines connected to it can also be equipped with a feeder bypass, but only if a column and beam configuration is used.

3.5.1.2 MV busbar

Most substations built for dedicated industrial loads do not have an MV busbar but feed the customer directly from the transformer feeder.

Normally a single busbar is installed which can be sectionalised if required. In addition a bypass busbar can be installed which can be energised from any of the connected feeders, or from a dedicated bypass feeder.

3.5.2 Eskom electrical and working clearances

Eskom’s standard electrical and working clearances are listed in Table 3.

3.5.2.1 Electrical clearances

Electrical clearances provide a reliable air gap in order to withstand over-voltages. Generous clearances are required to cater for the high variability of the withstand strength of the air gap, which is related to the air pressure (altitude), humidity and other factors.

The phase to earth clearance is related to the lightning impulse level of the applicable voltage (refer to Table 6). The phase to phase clearance is larger, since this clearance must withstand a lightning impulse imposed on one phase whist a power frequency overvoltage occurs on the other phase.

3.5.2.2 Working clearances

Working clearances prescribe distances that must be adhered to, to allow work to be carried out safely on isolated and earthed equipment whilst adjacent equipment is still live. Working clearances are derived from the ‘reach of a human being’ and the applicable phase-earth electrical clearance. The vertical reach and the horizontal reach are taken to be 2 500mm and 1 200mm respectively. These dimensions take into account the reasonable maximum reach of personnel, but may not be applicable in cases of unusually tall people, where certain areas may now become restricted. Working clearances shall apply at ground level only. Personnel at elevated heights shall take the necessary measures to ensure safe working conditions. Applicable working clearances are given in Table 3.

Table 3: Electrical and Working Clearances

System Nominal Voltage (kV)	System Highest Voltage (kV)	Minimum Electrical Clearance		Working Clearance	
		Phase to Earth (mm)	Phase to Phase (mm)	Vertical (m)	Horizontal (m)
3.3	3.6	80	110	2.5	1.2
6.6	7.2	150	200	2.6	1.2
11	12	200	270	2.7	1.3
22	24	320	430	2.8	1.4
33	36	430	580	2.9	1.5
44	48	450	730	3.0	1.6
66	72	770	1 050	3.2	1.8
88*	100	840	1 150	3.3	1.9
		(1 000)	(1 350)	(3.5)	(2.1)
132	145	1200	1650	3.7	2.3

Note: Bracketed figures for 88 kV clearances are for full insulation and shall be used only if the system is not effectively earthed.

3.5.2.3 Vehicle clearances

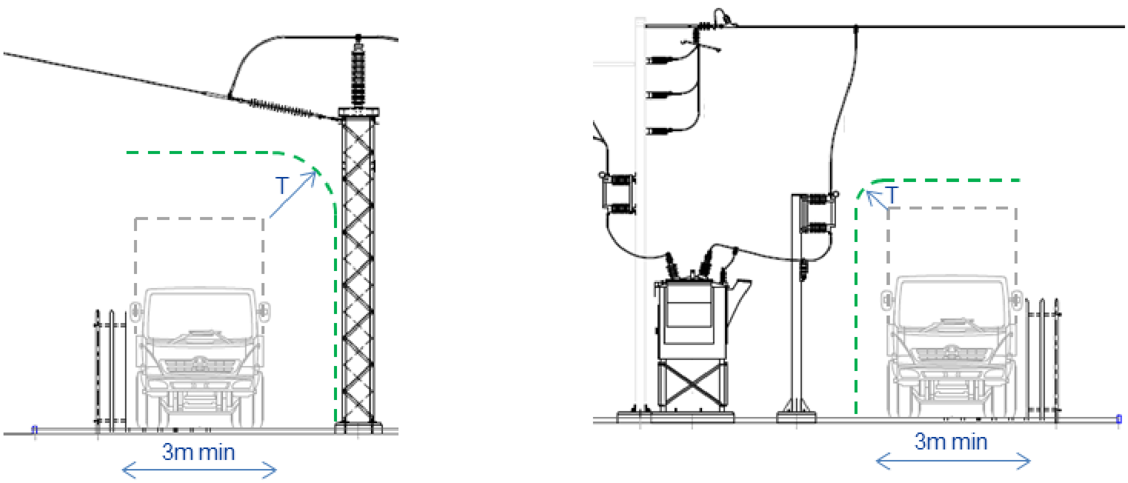
The process to be applied in determining vehicle clearances are described in 240-55922824, section 4-1 paragraph 4.7, Minimum Clearances for Vehicular Access in Power Installations. Vehicles and similar may pass below live parts (without protective devices) or in its vicinity within the enclosed electrical premises of outdoor installations when:

The minimum width of vehicle road or access ways shall be at least 3m, and

The vehicle, even with its doors open, and its load do not come into the danger zone, and

Minimum Transport Clearance (T) = (Minimum Phase to Earth Clearance) + 100mm
with a minimum overall value of 500mm

Figure 5 gives an indication of how this principle should be applied for (a) HV and (b) MV.



(a) Typical HV application (b) Typical MV application

Figure 5: Example of vehicle access clearances

3.5.3 Safety clearances to fences

The substation fence is the interface between the substation (restricted area) and the “outside world” (public). The purpose of this section is to provide a design guide for the location of live equipment with respect to fences within substations. This safety clearance zone is necessary to minimize a possible hazard to anyone on the outside of the substation fence.

The intent of the safety clearances to fences is to provide a reasonable safety clearance zone so that someone inserting an object through the substation fence should not violate the applicable electrical clearance. The same principal is applicable to lines entering or exciting the substation, adequate clearances at these points must be provided for.

3.5.3.1 Horizontal safety-clearances to fences

The distances in Table 4 is a guideline for the minimum horizontal safety clearances required between fences and energized plant in the substation and is based on the principals given in [4]. Figure 6 gives an indication of how these should be applied for (a) 132kV and (b) MV.

These clearances should be adhered to unless the barrier to the public prevents objects or limbs penetrating the barrier, and should be applied to the closest part of the installation, either the life part of the installation as indicated in figure 6 (b), or the equipment/support as indicated in figures 6 (a1) - (a3).

Table 4: Horizontal safety-clearances to fences

System Nominal Voltage (kV)	System Highest Voltage (kV)	Minimum horizontal safety-clearances to fences (m)
3.3	3.6	3.1
6.6	7.2	3.1
11	12	3.1
22	24	3.1
33	36	3.1
44	48	3.7
66	72	3.7
88	100	4.0
132	145	4.3

3.5.3.2 Safety-clearances over fences

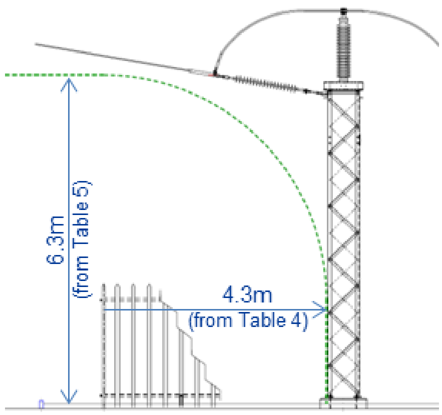
Over the fence and outside the substation clearances as stipulated in SANS 10280-1 (Overhead power lines for conditions prevailing in South Africa, Part 1: Safety) must be adhered to. Table 5 is an extract from Table E.1, SANS 10280-1 indicating the minimum clearances that must be adhered to over and on the outside of fences.

Figures 6 (a1, a2, b) and 7 give an indication of how these should be applied (132kV example).

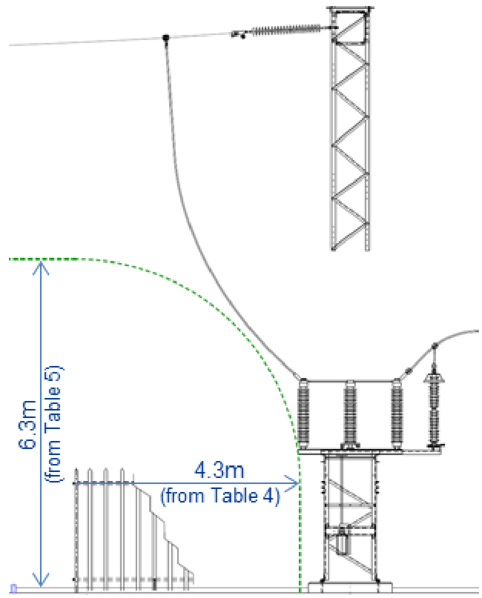
Table 5: Minimum vertical clearances over and on the outside (public side) of fences

System Nominal Voltage (kV)	System Highest Voltage (kV)	Ground clearance, all areas (m)	To buildings, poles, structures not part of power lines and vegetation (m)
3.3	3.6	4.9	3.0
6.6	7.2	5.5	3.0
11	12	5.5	3.0

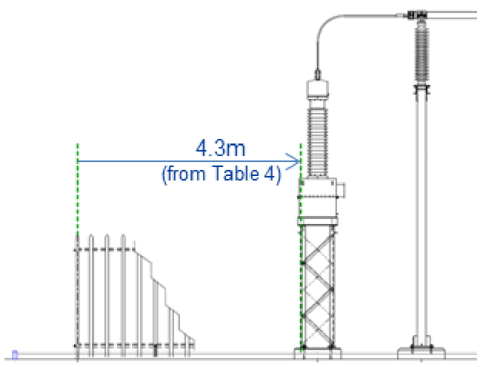
System Nominal Voltage (kV)	System Highest Voltage (kV)	Ground clearance, all areas (m)	To buildings, poles, structures not part of power lines and vegetation (m)
22	24	5.5	3.0
33	36	5.5	3.0
44	48	5.5	3.0
66	72	5.7	3.2
88	100	5.9	3.4
132	145	6.3	3.8



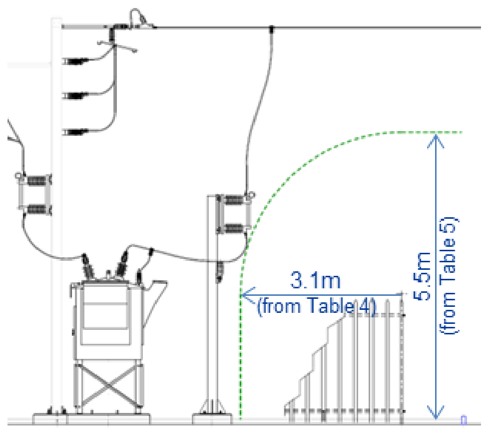
(a1) Typical 132kV application (line terminal)



(a2) Typical 132kV application (line terminal)

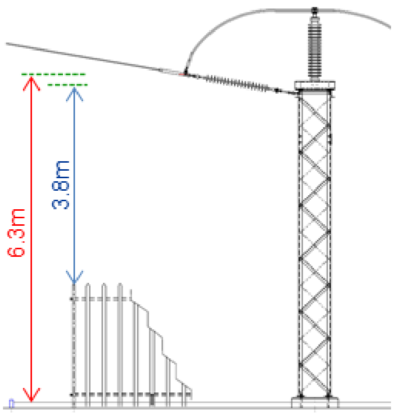


(a3) Typical 132kV application (Busbar VT)

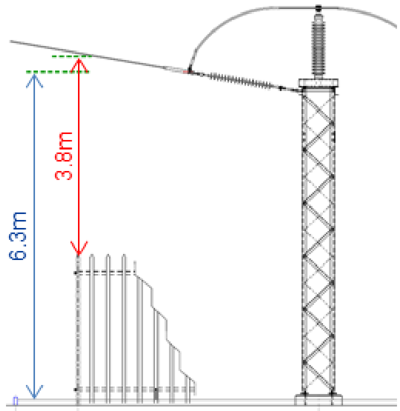


(b) Typical MV application (line bay)

Figure 6: Examples of minimum clearances to fences



(a) Vertical ground clearance dominant



(b) Vertical clearance to fence dominant

Figure 7: Example of determining clearances over fences (132kV example)

3.5.4 Insulation levels

There are two insulation levels applicable to equipment in the range up to 145kV:

a) Power frequency withstand level – related to Temporary Over voltages (TOVs).

b) Lightning impulse withstand level – related to lightning-induced over voltages.

3.5.4.1 Altitude considerations

The service conditions for South Africa are rationalized for altitudes up to 1 800m. Although the insulation levels in Table 6 are specified at an altitude of 0m to 1 000m, the values have been selected for appropriate insulation coordination for altitudes up to 1 800m and need not be corrected for altitude. Equipment with external insulation should be specified with standard values as per Table 6. Test values must, however, be corrected for deviations from the standard reference atmospheric conditions in accordance with SANS 60060-1.

Table 6: Standard Voltages and Rated Equipment Insulation Levels at 1 000m AMSL

Nominal System rms Voltage U_n (kV)	Highest rms Voltage for Equipment U_m (kV)	Rated Short Duration Power-Frequency rms Withstand Voltage (kV)	Rated Peak Lightning Impulse Withstand Voltage (kV)
11	12	28	95
22*	24	50	150
33*	36	70	200
66	72,5	140	350
88	100	185	450
132*	145	275	550

Note: The preferred voltages for industrial substations are those, marked with an asterisk (*).

3.5.5 Insulation pollution performance – Creepage distances

Several pollution levels are defined by IEC. However, due to the benefits of standardization, the standard minimum pollution level for substation equipment is ‘medium’. The medium pollution level corresponds to a specific creepage of 20mm/kV in relation to the system voltage and 35mm/kV in relation to the phase voltage. Due to the different ways of specifying specific creepage, in order to avoid confusion, it is preferable to specify the total creepage distance (in millimetres) required for the particular equipment.

Certain areas such as coastal areas (especially the Cape West Coast and the Natal North Coast) and areas affected by industrial pollution require equipment designed for very heavy pollution level (31 mm/kV). The site selection investigation (refer to paragraph 3.1.8.5) will indicate if other areas require a similar classification.

There are also extreme cases such as proximity to cement plants, where even the creepage for the ‘very heavy’ pollution class will be insufficient. In such cases, an indoor substation may be required or GIS technology may be appropriate.

For equipment rated up to 145kV, there is often very little difference in cost between equipment with creepage for medium and very heavy pollution classes, therefore many types of equipment have been rationalized to the ‘extra heavy’ pollution class.

3.5.6 Standardized conductors and connectors

Table 7 specifies the standardized conductors and connectors to be used in new substations. For extension work done in existing substations the conductor standard originally applied can be followed, except for connectors. Connectors shall be applied as stipulated in Table 7.

Table 7: Standardized conductors and connectors

Item	Description
Connectors	• All current carrying clamps shall be of the compression type. • All voltage connections can be of the bolted type.
Flexible conductor	All busbars, droppers and stringers shall be as follows: • 450A – Hornet (16.3mm diameter gives 157mm^2 cross sectional area) • 800A – Centipede (26.5mm diameter gives 415mm^2 cross sectional area) • 1 250A – Bull (38.3mm diameter gives 865mm^2 cross sectional area) • 2 500A – Twin Bull (2 × 38.3 mm diameter gives 2 × 865mm^2 cross sectional area)
Tubular conductor	• For 132kV busbar applications: Ø120mm x 4mm wall thickness aluminium tube in accordance with 240-122922610 shall be used. • For voltages < 132kV, where the runs between supports are > 10 m, Ø120 mm x 4 mm shall also be used. • For extensions at existing 88kV (and below) substations: Where Ø80 mm x 8 mm wall thickness aluminium tube is used, extensions may be done with the same conductor where the runs between supports are ≤ 10 m. • Centipede conductor shall be installed inside the tube for at least 80% of its length, but preferably for its entire length, to suppress Aeolian vibrations. • The conductor shall be fixed to the end cap on one side only. One side of the bar shall have a sliding type clamp for expansion.
Surge arrester and VT connections	Centipede for HV and Hornet for MV connected as a ‘Tee-off’ from the main conductor run.
MV bypass conductor	450A – Hornet (157mm^2) or as required.
Power cables	To be rated as required based on Buyers’ Guide items.

3.5.7 Standardized equipment

Although Eskom enter into 4 – 5 year equipment contracts with suppliers that limit the design engineer's choices, there are still a number of parameters to verify/consider when choosing equipment. The most important are:

- Voltage rating: Effectively any equipment with voltage rating equal to or higher than the applicable system voltage can be used, except for voltage specific equipment. As a rule 22kV equipment is used for both 11kV and 22kV applications, and similarly 132kV equipment is used for both 88kV and 132kV applications. Voltage specific equipment includes power and auxiliary transformers, NECRT's, VTs and surge arresters.
- Continuous current rating: This is the permanent rated current carrying capacity of the equipment within the system operating parameters. The maximum load connected to the equipment
- Short time current rating: This is the maximum current which the equipment can safely carry for a specified time, normally 3 seconds. This value must be higher than both the substation single phase and three phase fault currents applicable to the specific voltage level.
- Equipment insulation level: Based on the identified pollution level a corresponding creepage level has to be chosen. Most of the equipment standardised on for Distribution substations has an SCD of 31mm/kV which corresponds to a Very Heavy pollution level.
- Backward compatibility: New equipment must be backwards compatible specifically with regards to the basic application, the support it must fit on (including all applicable clearances to be observed), basic dimensions (maximum height and width to ensure it will fit in the space available) and terminal compatibility (stem/pad configuration as the case may be). New equipment will be used to replace failed units during emergencies as well as during refurbishments in addition to new future installations. The bigger challenges are encountered during emergencies when there is a time pressure and a unit for unit swap-out is required with minimal additional work other than commissioning testing.

3.5.8 Standardized rated current levels

Table 8 gives the standardized maximum rated current levels. These are the maximum current ratings per voltage level, and not the standard current ratings per voltage level. Per voltage level equipment with different current ratings will be available, so the ratings of the equipment to be used must be verified against what is required.

Table 8: Standard maximum current ratings per voltage level

Nominal System rms Voltage U_n (kV)	**Highest rms Voltage for Equipment U_m (kV)**	**Rated Continuous Current (A)**	**Rated Short-Time Withstand rms Current (kA)**	**Rated Peak Withstand Current (kA)**
11	12	2 500	31.5	78.75
22	24	2 500	31.5	78.75
33	36	1 600	31.5	78.75
66	72.5	1 600	31.5	78.75
132	145	2 500	40	100

Note: The standard short-time withstand current duration is 3 seconds.

3.5.9 Standardized transformer details

Table 9 gives details of the standardized range of transformers:

Table 9: Full Load Ratings and MV Fault Level Ratings for Standardized Transformers

Vector Group	Nominal Secondary Voltage (kV)	Rating (MVA)	MV Full Load Current (A)	MV Fault Current Rating (kA)
YNd1	11	2.5	131	1.31
YNd1	11	5	263	2.63
YNd1	11	10	525	5.2
YNd1	11	20	1 050	10.5
YNd1	11	40	2 100	21
YNd1	22	2.5	65.5	0.65
YNd1	22	5	131	1.31
YNd1	22	10	263	2.63
YNd1	22	20	525	5.2
YNd1	22	40	1 050	10.5
YNd1	33	40	700	7.0
YNd1	33	80	1 400	13.9

Notes: 1) A transformer impedance of Z = 10% has been used for calculation purposes. Therefore the calculated current for some of the smaller ratings will be higher than tabulated.

2) All prospective fault levels are based on three-phase (symmetrical) faults.

3) The customer involved shall be informed of the full load and prospective MV fault currents in accordance with Table 8, in order for the correct switchgear to be provided.

4) It must be noted that the current values indicated are for standard impedance transformers, which will differ from those for high impedance transformers.

5) This list reflects standard voltage levels for new network development. Transformers for historic networks with different nominal voltages (i.e. 6.6kV or 3.3kV) still have to be procured as required until such time that the applicable networks are decommissioned or uprated.

Where transformers will be installed inside buildings or in areas where it poses a secondary fire hazard the use of active fire protection systems shall be investigated, or as an alternative the use of transformers with type K or L insulating oils with a fire point greater than 300^{o}C.

3.5.10 Earthing for maintenance

In substations mainly two types of earths are used for maintenance purposes, i.e. control earths and induction (also referred to as working) earths. Control earths must be capable of withstanding the full expected earth fault current for a specified period of time whereas induction earths are applied as close as possible to the point of work in such a manner that an equipotential zone is created around the work area.

In Distribution, portable earths are mainly used for control earths as opposed to earthing switches.

3.5.10.1 Positioning of control earths

[62] stipulates that except for busbars all isolated sections shall be earthed at all points of supply. Busbar sections shall be earthed at one point as a minimum. Refer to Figure 10 for the positioning of control earths.

Line feeder bay control earthing points shall be provided as follows:

- Line isolators: both line and substation sides,
- Busbar isolators: line bay side only.

Busbars control earth points shall be provided as follows:

- One per busbar section,
- The connection between two busbar section isolators is considered a busbar section and must therefore also get a control earth point.

Transformer bay control earthing points shall be provided as follows:

- HV Busbar isolators: transformer bay side only.
- MV Busbar isolators: transformer bay side only.

3.5.10.2 Provision of connection points for portable control earths

All substations shall provide for the application of portable control earths for maintenance purposes by the installation of fixed earthing ball joints on the steel support structures as follows:

a) Fixed earthing ball joints for control earths shall be installed approximately 1.5m above ground level at disconnectors (isolators) in the positions on the structures shown in Figures 8 and 9. The type of fixed earthing ball joint to be used is specified in D-DT-6081. Due to the risk of theft, the ball joints are to be galvanized steel and shall be rated for 20 kA each.

b) Connection points on the flexible conductors for control earths are to be provided for by means of earthing peg (‘cigar’) connectors to clearly indicate the control earth connection points and to prevent damage to the conductor. Refer to D-DT-6115 for earth pegs to be used on conductors and D-DT-6080 for earth pegs to be used on tubes.

c) The quantity of fixed earthing ball joints and earth pegs to be fitted will depend on the quantity and types of bays in a substation as well as the expected maximum earth fault current. Refer to Table 10 for typical quantities of earthing balls and pegs required per bay type and Figure 10 as an example of where these should be applied in a substation.

Table 10: Quantity of Fixed Ball Joints and Earth Pegs for Portable Control Earths per bay type

Bay Type	**Quantity of Ball Joints and Earth Pegs to be fitted**	
	≤ 18.5kA	**> 18.5kA**
Feeder bay	9	18
Busbar section	3	6
Transformer bay	6	12

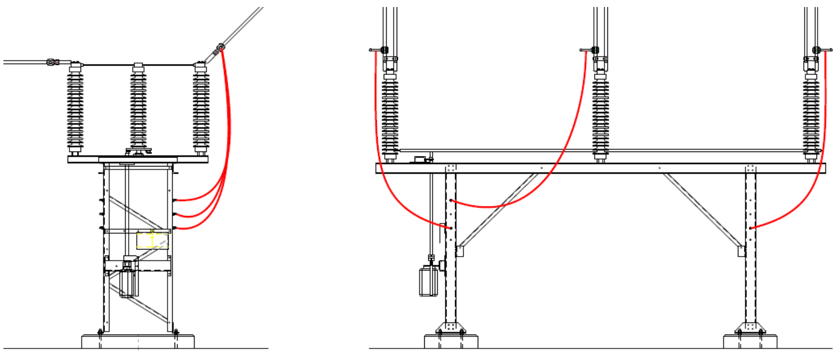


Figure 8: Application of portable earths in a substation with a maximum fault level < 18.5kA for 1s

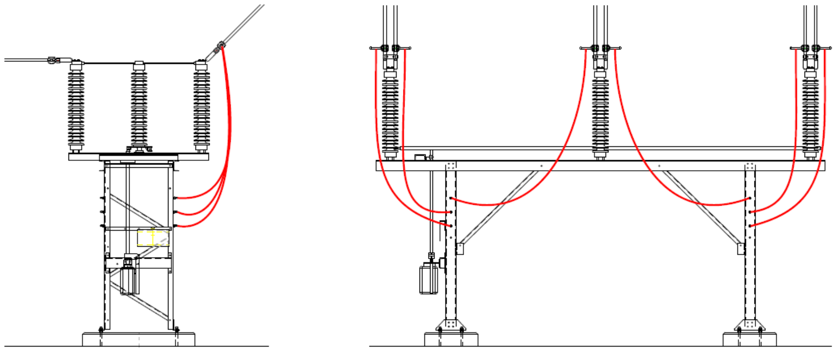


Figure 9: Application of portable earths in a substation with a maximum fault level > 18.5kA for 1s

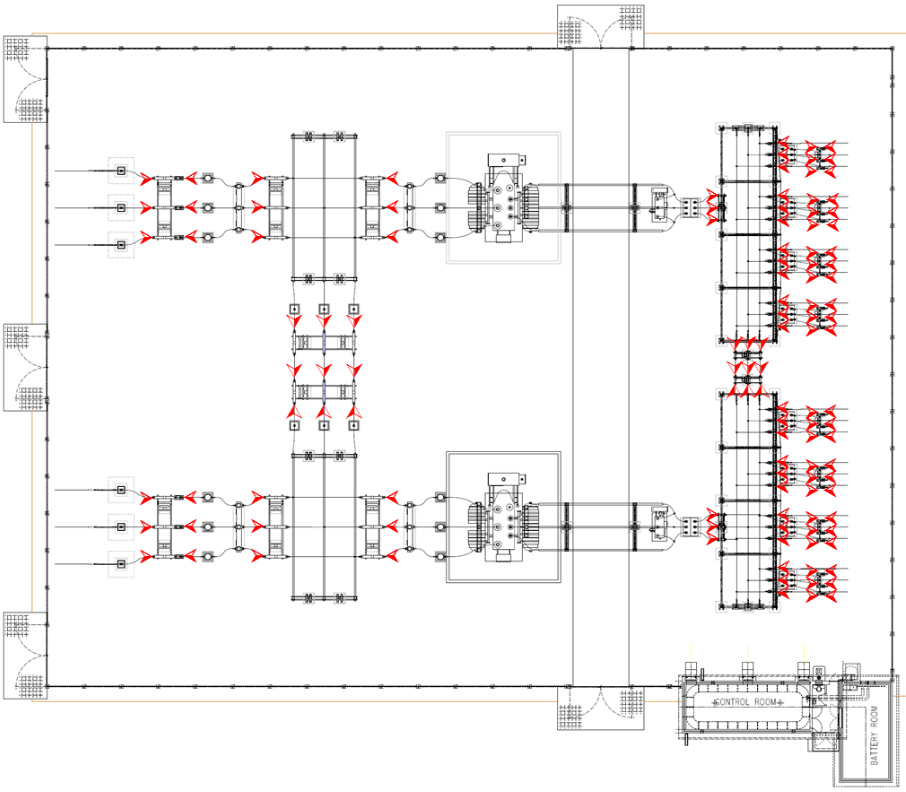


Figure 10: Positions of Fixed Ball Joints on Substation Structures for Connection of Portable Earths

3.5.10.3 Portable control earths (refer to D-DT-6082)

a) Portable earths shall always be supplied in sets of three identical items. Each complete item shall be rated in accordance with 240-65216546 at 18.5kA and comprise:

1) one 4 m length of covered flexible multi-strand copper conductor;

2) one earth end clamp for bolting to the earthing ball on the steel support structure; and

3) one line end clamp for connection to the earthing peg fixed to the conductor.

b) For those applications requiring a fault rating > 18.5kA but ≤ 40kA, two portable earths shall be used in parallel.

c) The quantity of portable earths to be fitted will depend on the quantity and types of bays in a substation and the earth fault level at the substation. Refer to Table 10 for a guideline.

d) Figures 8 and 9 illustrate the fitting of portable earth assemblies as required.

3.5.10.4 Earthing switches

There are some cases where the use of earthing switches as control earths may be justified:

- Due to induction from parallel lines making it dangerous to apply portable earths.
- Where fault levels exceed 30kA, earthing switches shall be installed and may be used in parallel with portable earths depending on the relative ratings and fault level.

In the case where the fault levels in an existing substation without earthing switches increase to beyond this point the respective business unit shall decide on the philosophy to be applied:

a) Do not install earth switches, but ensure number of earth balls and pegs comply with Table 10, or

b) Install earth switches the next time major work is done at the substation, or

c) Install earth switches at any time it is deemed necessary.

3.5.10.5 Positioning of induction earths

Induction earths shall be installed in addition to control earths where required to create an equipotential zone around the area where work must be done.

[62] also stipulates that Transformer windings shall be earthed at each primary, secondary and tertiary winding when required.

3.5.11 Station electric diagrams

These requirements are covered in 240-68972308.

3.5.12 Lighting/Lightning

Lighting and Lightning share the same infrastructure (masts) in most low level substation designs. Details of the standard lighting/lightning mast are given in D-DT-5217.

The optimal design of the two systems is an iterative process because of the shared infrastructure. If the lighting layout is optimised first it will be necessary to test that it satisfies the lightning requirements. Should the position of any infrastructure be changed in any way both lighting as well as lightning compliance will have to be rechecked.

3.5.12.1 Lightning design

For lightning protection the rolling sphere method shall be applied in accordance with 240-109589380.

3.5.12.2 Lighting design

At present two flood light options are available, i.e. HPS luminaires as per D-DT-6104 and the HPS lamps as per D-DT-6105. LED floodlights are available and shall comply with 240-113163905 and D-DT-6009.

The following requirements must be adhered to in accordance with the OHS Act inside the HV yard:

- Average of 10 lux must be maintained,
- Average of 20 lux must be maintained within 5m of critical equipment,
- Uniformity of 1:5 (minimum : average) must be maintained at least 5m around critical equipment.

Note that critical equipment is defined as power transformers, capacitor banks and reactor banks.

Provisioning for security lighting as per the Security Lighting Standard and CCTV Standard illumination requirements must be considered in the design of the illumination for the site. If LED floodlights are used the floodlights can also do duty as security lighting if properly designed and integrated with the alarm control circuits.

The practice is that only one floodlight luminaire per mast will be switched on at night, all the others shall stay off until required for night time operating. The one luminaire per mast shall be switched through a day/night switch and the remaining luminaires through a mechanical timer situated in the control room.

3.5.13 Fire protection

Passive fire protection requirements are covered by 240-66917056 Passive Fire Protection Standard for Oil Filled Equipment In Eskom HV and MV Yards.

Where transformers will be installed inside buildings or in areas where it poses a secondary fire hazard the use of active fire protection systems shall be investigated, or as an alternative the use of transformers with type K or L insulating oils with a fire point greater than 300^{0}C.

The required safety factors must be incorporated when designing switch buildings/rooms to ensure metal clad switchgear failures shall be contained satisfactorily.

3.5.14 Signs and notices

3.5.14.1 OHS ACT minimum requirements

The following are the minimum requirements for ‘Notices’ in terms of the OHS Act, Electrical Machinery Regulation 4 (refer to part 0). The purpose of these notices is to:

a) prohibit unauthorized persons from entering the premises;

b) prohibit unauthorized persons from handling or interfering with electrical machinery;

c) warn of electric shock hazard;

d) contain procedures in case of fire; and

e) contain directions on how to resuscitate persons suffering from the effects of electric shock.

Notes:

1) In terms of the OHS Act, the word ’Notice’ includes both signs and notices. For ease of reference in this standard:
   - a notice is an inscription in English and/or any other language; and
   - a sign is a standard symbolic safety sign.
2) Bolted removable panels are not considered to be entrances in terms of this regulation, as they are normally only removed under supervision of authorized persons to carry out specific tasks.
3) On the distribution system, the substation High Voltage (HV) yard fence may also be the external perimeter fence and is referred to as such in this standard. In other cases there could be an additional secured fence or wall.
4) All signs and notices shall be in accordance with SANS 1186.

3.5.14.2 Signs and notices on substations and mini-substations

Requirements for signs and notices on substations and mini-substations are as follows:

a) Any building or enclosure housing electrical plant such as generating, transforming, switching or linking apparatus shall have the following notices and signs displayed at each entrance:

   1) a notice prohibiting unauthorized persons from entering;

   2) a notice prohibiting unauthorized persons from handling or interfering with electrical machinery;

   3) a warning of electric shock hazard sign;

   4) any other mandatory signs only when they are applicable, e.g.:
      - head protection (hard hat),
      - eye protection, and

- hearing protection.

b) Mini-substations and distribution boxes do not require any signs or notices. However, it is advisable to display the following combination:

1) a notice prohibiting unauthorized persons from entering;

2) a notice prohibiting unauthorized persons from handling or interfering with electrical machinery; and

3) a warning of electric shock 'Hazard' sign.

3.5.14.3 Signs and notices at perimeter fences and entrances to substations

Requirements for signs and notices at perimeter fences and entrances to substations are as follows:

a) All entrances (locked gates) in perimeter fences shall have the following notices and signs exhibited:

1) a notice prohibiting unauthorized persons from entering;

2) a notice prohibiting unauthorized persons from handling or interfering with electrical machinery; and

3) a warning of electric shock 'Hazard' sign.

b) On the perimeter fences between the entrances, all that is required is a single combination of the notices described in (1), (2) and (3) in paragraph 3.5.14.3 (a).

c) Where there is only one entrance to the yard, a single combination sign per side is required.

3.5.14.4 Combined emergency notices

At each substation, be it indoor, outdoor or a combination, the following combined notices shall be displayed in a conspicuous position, such as on the wall of the building facing the normal direction of approach, so that they may be referred to when required:

a) a notice of procedure in case of fire; and

b) a notice on how to resuscitate persons suffering from the effects of electric shock.

3.5.14.5 Quantity of signs, notices and positions to be fitted

Table 11 gives details of where which signs and notices should be fitted at substations.

Table 11: Where to install signs and notices at a Substation

OHSA requirement	D-DT	Additional D-DT	SAP	SAP description	Where to install
a, b, c	6072	5015	0172497	SIGN, A B C - UNAUTH. ENTRY/INTERF. APP.	- Control building entrance - First fence panel next to each gate, - First fence panel at each corner, - Intervals not exceeding 20m along the fence
d, e	6073	5016	0172495	SIGN DE - FIRST AID	Each gate
	6074	5017	0172496	SIGN F - PROHIBITIVE (VARIOUS)	Each gate
	6075	5018	0172498	SIGN G - HARD HAT AREA	Each gate

3.5.15 Marking and labelling

These requirements are covered by 240-120804300. Labels must be manufactured according to 240-75660336.

3.5.16 Test and commissioning

These requirements are covered by 240-87605434.

3.6 Substation security

Specific minimum physical security measures and systems as prescribed and approved by the Security Division must be implemented. Site and asset protection should not be compromised as this may inadvertently lead to a security of supply risk. The Security Solutions – Physical department shall be contacted to ascertain the physical security design requirements applicable per substation site.

The approved security standards to be complied with are:

- 240-64720986, Emergency Preparedness Public Address System – For Large Area Deployment
- 240-76368574, High Security Mesh Fencing
- 240-78980848, Specification for Nonlethal Energized Perimeter Detection System (NLEPDS) for Protection of Eskom Installations and its Subsidiaries
- 240-91190304, Specification for CCTV Surveillance with Intruder Detection
- 240-91252315, Standard for Bullet-resistant Guard Facilities
- 240-91252455, Lighting for Perimeter Security at Eskom Installations
- 240-102220945, Specification for Integrated Access Control System (IACS) for Eskom Sites

For each substation project it is necessary to consider the security requirements, irrespective if it is a new substation, substation strengthening or substation refurbishment. Based on the security risk assessment report compiled by the responsible security manager the following should be considered:

a) Boundary perimeter considerations:
    - Fence: Diamond mesh, palisade, welded mesh, concrete wall or three tiers, anti-crawling and/or anti-climbing and non-lethal electric fence.
    - Gates: Gate type, automation requirements, locking mechanism and detection mechanisms.
    - Exterior perimeter barrier detection system: Electronic video surveillance monitoring systems, CCTV cameras, alarms.
    - Patrol roads: Vehicle patrol roads on the outside and foot patrol on the inside of the external perimeter barrier.
    - Guard hut and facilities: Bullet resistant guard hut consisting of kitchenette, bathroom and security control room.

b) Installation considerations:
    - Use of theft deterring equipment supports, i.e. tubular supports with cables routed on the inside.
    - Control room: Roof type, door type, and parking area.
    - Delay measurements: Lock mechanisms, fence anti-crawling and/or anti-climbing and non-lethal electric fence.
    - Security lighting: Floodlight operating considerations, additional perimeter lights.

c) Power cable installations:

- Consider aluminium cables as an alternative.
- Steel or concrete enclosures at cable end supports.

d) Control cable installations:

- Make use of “non-visible” cable trenches.
- Cover cables with a concrete layer.
- Move control room cable entries to below ground level with cable ladders on the inside of the control room.
- Use spare cores for alarms.

4. Authorization

This document has been seen and accepted by:

Name and surname	Designation
Anton Kotzé	Senior Manager Asset Creation – Distribution Division, Mpumalanga OU
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5. Revisions

Date	Rev	Compiler	Remarks
Sept 2019	2	TJ Marais	1. Introduction: second and third paragraphs added. 2.2.1 Normative references updated with [1], [4], [7] and [62]. 2.3.1 General definitions updated. 2.4 Abbreviations updated. 3.1.1 Factors to consider in site selection item (c) added. 3.1.6.2 Access roads items (a) and (c) updated. 3.1.6.3 Access for mobile transformers/substations added. 3.1.7 Incoming line corridors paragraph two updated. 3.1.9 Substation earth mat soil resistivity measurement and analysis revised to reference applicable earthing standards, removed duplications from this document, updated drawings.

Date	Rev	Compiler	Remarks
			3.3.2 Yard platforms item (b) updated. 3.4.1.8 Loading of concrete foundations and plinths (installation of equipment) added. 3.4.1.9 Fencing item (b) (2) updated. 3.4.2 paragraph heading updated and two paragraphs added. 3.5 Electrical design updated and Table 2 added. 3.5.1 Busbar configuration considerations first paragraph updated. 3.5.2.4 Clearances over fences repositioned to 3.5.3.2. 3.5.3 Insulation levels repositioned to 3.5.4 3.5.3 Safety clearances to fences: section added, including Figures 6 and 7 and Table 4. 3.5.4 Insulation pollution performance – Creepage distances repositioned to 3.5.5 3.5.5 Standardized conductors and connectors repositioned to 3.5.6 and updated including Table 7. 3.5.6 Standardized equipment repositioned to 3.5.7 and bullet 5 added. 3.5.7 Standardized rated current levels repositioned to 3.5.8 and Table 8 current ratings for 11kV and 22kV updated. 3.5.8 Standardized transformer details repositioned to 3.5.9 and Table 9 notes 4 and 5 added. 3.5.9 Earthing for maintenance repositioned to 3.5.10 and updated extensively, including Figure 10. Figure 9 (fixed earth ball) removed. 3.5.10 Signs and notices repositioned to 3.5.14. 3.5.12 Lighting/Lightning updated extensively. 3.5.13 Marking and labelling repositioned to 3.5.15. 3.5.14 Fire protection repositioned to 3.5.13. 3.5.15 Substation security repositioned to 3.6. Annex B removed (duplication of 240-134369472 Annex A).
March 2018	1	TJ Marais	Document converted to latest document format. Document renumbered to 240-71062174. References updated as applicable (2.2 Normative/informative references), as well as throughout the document. Definition for Corona added (2.3.1) 3.1 Site selection: general comment added. 3.1.1 Security risk requirements added. 3.1.4.1 Ideal gradient updated. 3.1.8.4 Removed “(refer to the approximate distances in Table 1)”. 3.1.8.5 Table 1: Added USCD values and note 2. 3.1.10 Security system requirements added.

Date	Rev	Compiler	Remarks
			3.3.2 Terrace gradient requirements aligned with 240-55922824, 14-2 Earthworks Design of a Substation Terrace. Compaction test method changed to DCP. 3.4.1.7 Reinforcing point e) updated to be in line with SANS 0100-2 table 3. 3.4.1.8 a) standard fence types updated. 3.4.2 Control buildings updated with current approved drawing numbers. 3.5.1 Busbar configuration considerations added. 3.5.2.3 Vehicle clearances added. 3.5.2.4 Clearances over fences added. Reference to Eskom KIPTS natural ageing and pollution performance test removed 3.5.9.3 Portable earths updated including drawings. 3.5.10.5 Quantity of signs and notices: drawings removed and table added. 3.5.12 Lighting/lightning section updated. 3.5.14 Section renamed to “Fire protection” and detail added. 3.5.15 Substation security section added. Annex A removed, Annex B drawings updated.
March 2012	1	G Strelec	Extensive general revision and reformatting. Additional information on telecoms requirements in terms of site selection. Revised civil requirements in consultation with Barry Hill. Standard electrical ratings updated. Document number changed to DST 34-304.
Aug 1999	0	C Clark	Original document issued – SCSASABK3.

6. Development team

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

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7. Acknowledgements

Johan Ackerman and George Jordaan for inputs and advice on the substation security requirements.

Everybody that gave inputs and commented on this revision of the document.

Annex A – Environmental Impact Management Plan

An Environmental Impact Management Plan (EIMP) shall be developed for the substation construction phases so as to mitigate the environmental impacts identified during the Environmental Impact Assessment (EIA) process. The EIMP shall be included into the project tender document and ultimately in the contract for the construction/project management phase of the substation. The EIMP shall consider but not be limited to the following points:

A.1 Water Management

a) The water drainage system in and around the substation terrace shall be effective in preventing flooding or soil erosion, especially with regard to neighbouring property.

b) The contamination of drainage water by pollutants (e.g. transformer oils, domestic waste, herbicides) shall be prevented

A.2 Transformer Oil Containment

a) Appropriate containment facilities shall be designed to prevent spilled or leaked transformer oil from contaminating surface and groundwater.

b) Adequate facilities shall be provided for the temporary safe storage of used or spilled transformer oil to ensure safe disposal later.

c) Bund walls of transformers.

A.3 Waste Management

a) Adequate and suitable containers shall be provided for the collection of domestic waste.

b) Equipment provided for firefighting and air conditioning shall not contain Chlorofluorocarbons (CFCs).

c) Provision shall be made for the treatment and safe disposal of all sewage effluent to prevent soil and water pollution of the surrounding environment.

A.4 Plants and Animals

a) The design of the substation shall avoid unnecessary removal of trees and plants.

b) Containment dams shall be adequately covered to prevent animals and birds from entering.

c) Electrified security fences shall be designed to prevent the killing of wildlife.

A.5 Aesthetics

Substation design shall ensure that the substation will ‘blend in’ as best as practically possible with the surrounding environment. The following criteria shall be considered with regard to the visual aspect of a substation:

a) Height

The substation shall be located or designed to ensure that the heights of the substation structures are equal to or less than the surrounding buildings/trees/horizon.

b) Surface area

The total surface area of the substation, including access road, shall be kept to a minimum.

c) Arrangement of construction

The design shall comprise a few, clearly arranged buildings, low foundations and tower heights that match the height of surrounding buildings.

d) Arrangement of colours

The colours of the outdoor structures and buildings shall blend in with the surrounding environment (a dark grey is a good neutral colour).

e) Boundary with environment

The substation shall be located and designed so as to ensure that it does not significantly change the appearance of the area in which it is located. This can be enhanced by landscaping, construction of walls and the planting of vegetation that will help to conceal the substation.

A.6 Electromagnetic Field (EMF)

The siting and design of a substation in a residential area or future residential area shall take the perceived risk of electric and magnetic fields into consideration. Substations shall not border directly onto a residential dwelling and, if necessary, screening shall be constructed in the form of vegetation and walls.

The requirements of 240-68971854 shall be adhered to in this regard.

A.7 Noise

The impact of noise generated by the substation shall be considered when the site is located near residential dwellings. Walls and vegetation can help to reduce the level of noise and shall be provided in relevant cases.

The requirements of SANS 10103 shall be adhered to in this regard.