

Title: **GENERAL INFORMATION AND
REQUIREMENTS FOR MEDIUM-
VOLTAGE CABLE SYSTEMS**

Unique Identifier: **240-56030635**

Alternative Reference Number: **34-1175**

Area of Applicability: **Engineering**

Documentation Type: **Standard**

Revision: **3**

Total Pages: **69**

Next Review Date: **March 2026**

Disclosure Classification: **Controlled
Disclosure**

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1. Introduction

This cross divisional Standard has been prepared to establish and promote uniform designs for medium-voltage (MV) cable distribution systems. Design Engineers should take cognizance of the constraints regarding system operation, system protection considerations and the design opportunities for effecting further cost savings. Designs should take into consideration proposed future developments and adjacent supply areas. Underground cabling is generally capital intensive, it is therefore important to evaluate the commercial viability of the project over its lifetime.

2. Supporting clauses

2.1 Scope

This standard covers the general requirements for MV (3.3 kV up to and including 33 kV) cable systems as illustrated in figure 1 of annex A. The cable is generally installed underground, but can also be in ducts or in air. A cable system would typically consist of all or part of the following:

- a) a step-down substation usually supplied at voltages of 44 kV, 66 kV, 88 kV or 132 kV, stepping down to either 3.3 kV, 6.6 kV, 11 kV, 22 kV or 33 kV (240-56063710);
- b) a substation switching house with indoor, metal-clad switchgear, or to outdoor arrangement via cable end support;
- c) primary cable feeders distributing power to switching stations;
- d) secondary cable feeders distributing power to sub-switching stations (free standing RMUs) and/or mini-substations;
- e) mini-substation (or sub-ring) cable feeders distributing power exclusively to mini-substations; and
- f) a cable feeder from an overhead line supplying power to a mini-substation or ground-mounted transformer).

2.1.1 Purpose

The document is a standard to be implemented in the designing of MV cable networks.

2.1.2 Applicability

This document shall apply throughout 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] ISO 9001 Quality Management Systems.
- [2] 240-56062745, Planning guideline for medium-voltage underground cable systems.
- [3] 240-56062831, Medium voltage services to large power users.
- [4] 240-56063710, Medium voltage cabling in substations.
- [5] 240-56030406, Specification for ring main units for systems with nominal voltages from 3.3 kV to 33 kV.
- [6] 240-71062174, Generic substation design.

- [7] 240-75661043, Services section 3: Outdoor low-voltage services for small power users and large power users.
- [8] 240-125300846, Distribution standard for feeder operating diagrams
- [9] 240-125300736, Distribution standard for station operating diagrams
- [10] 240-97791005, ABB Safering AND Safeplus RMU range of Types D, C, F and V operating procedures
- [11] 240-70500880, Standard for the control and application of master locks and issue of master keys.
- [12] 240-61227438, Network planning guideline for lines and cables.
- [13] DST 34-820, Distribution Standard – Part 19: Statutory applications to water authorities.
- [14] DST 34-822, Distribution Standard – Part 19: Statutory applications to local authorities.
- [15] DST 34-1812, Distribution Standard – Part 19: Statutory applications to rail authorities.
- [16] DPC 34-82, Distribution Standard – Part 19: Procedure for the approval of work where Eskom's rights may be encroached upon and/or services/assets placed at risk.
- [17] 240-56065032, Distribution Standard – Part 22: Medium-voltage CT-VT metering units for systems with rated voltages from 11 kV to 33 kV.
- [18] 240-97690165, Telecontrol requirements for ring main units
- [19] DPC 34-926, Distribution Standard – Part 21: Procedure for the environmental assessment of reticulation and sub-transmission projects.
- [20] 240-91190294, Distribution Standard – Part 16: Design standard for D.C. & auxiliary supplies.
- [21] 240-130615754, Distribution Standard -Part 2: Earthing Section 1 MV and LV distribution system earthing.
- [22] 240-97791047, Distribution Standard - Part 12: Merlin Gerin RMU Type RM6 operating procedures
- [23] DSP 34-1080, Distribution Standard - Part 22: Specification for fault indicators for MV cables and overhead line networks up to 66kV.
- [24] DST 34-1143, Distribution Standard – Part 12: Standard for identification and spiking of high-voltage power cable.
- [25] DST 34-1157, Distribution Standard - 11Part 7: Distribution group's requirements for 11 kV, 22 kV and 33 kV indoor switchgear manufactured in accordance with NRS 003.
- [26] 240-56030637, Distribution Standard - Part 22: General information and requirements for low-voltage cable systems.
- [27] 240-53114314, Minimum reliability and capacity requirements of essential DC power supplies for various equipment at distribution sites.
- [28] DST 34-1364, Distribution Standard – Part 12: Phasing of equipment.
- [29] DPC 34-1403, Distribution Standard - Part 12: Operating procedure for 11 kV Type A miniature substations
- [30] 240-120804300, Distribution Standard - Part 12: Standard for the labelling of sub-stations and networks.
- [31] 240-61266445, Distribution Standard - Part 15: Distribution specification for a medium voltage cable feeder and busbar arc flash.
- [32] DPC 34-1521, Operating procedure for 22 kV Type A miniature substations.
- [33] DSP 34-1616, Personal protective equipment specification.
- [34] 240-70044736, Arc Flash Protective Clothing and Personal Protective Equipment against the Thermal Hazard of an Electrical Arc Specification.

- [35] 240-56062752, Specification for medium-voltage miniature substations for systems with rated voltages from 3.3 kV, 6.6kV, 11 kV and 22 kV standard.
- [36] 240-56030619, Accessories for medium-voltage power cables with rated voltages from 11 kV to 33 kV.
- [37] 240-56063792, Specification for medium voltage XLPE and impregnated paper insulated cables.
- [38] 240-45395762, Specification requirements distribution pole and ground-mounted transformers up to 33 kV and 1 MVA.
- [39] DSP 34-1692, Distribution Group's specific requirements for the wiring of circuit-breakers and built-in current transformers.
- [40] 240-45683927, Compaction testing of cable trenches.
- [41] IEC 60853-1, Calculation of the cyclic and emergency current rating of cables. Part 1: Cyclic rating factor for cables up to and including 18/30 (36) kV.
- [42] ISO/IEC Guide 51, Safety aspects – Guidelines for their inclusion in standards
- [43] SANS 1332, Cable terminations and live conductors within air-filled enclosures (insulation co-ordination) for rated a.c. voltages from 7,2 kV and up to and including 36 kV
- [44] NRS 040, Operating regulations for high-voltage systems (ORHVS).
- [45] NRS 088-1: Duct and direct buried underground fibre optic cable: Part 1 – Product specification
- [46] NRS 088-2: Duct and direct buried underground fibre optic cable: Part 2 – Installation Guidelines
- [47] Occupation Health and Safety Act (OHS Act) No 85 of 1993
- [48] SANS 97, Electric cables – Impregnated-paper-insulated metal-sheathed cables for rated voltages 3,3/3,3 kV up to 19/33 kV.
- [49] SANS 780, Distribution transformers.
- [50] SANS 876, Cable terminations and live conductors within air filled enclosures (insulation co-ordination) for rated a.c voltage from 7.2 kV and up to 36 kV.
- [51] SANS 0200, Neutral earthing in medium voltage industrial power systems.
- [52] SANS 1019, Standard voltages, currents and insulation levels for electricity supply.
- [53] SANS 1186, Symbolic safety signs.
- [54] SANS 1339: Electric cables – Cross-linked polyethylene (XLPE)- insulated cables for voltages from 3,8/6,6 kV to 19/33 kV
- [55] SANS 1803-1, Lugs and ferrules for insulated electric cables – Part 1 Copper conductors (draft).
- [56] SANS 6281-4, Test methods for impregnated paper-insulated electric cables Part 4: Tests after installation.
- [57] SANS 10198-1, The selection, handling and installation of electric power cables of rating not exceeding 33 kV Part 1 Definitions and statutory requirements.
- [58] SANS 10198-2, The selection, handling and installation of electric power cables of rating not exceeding 33 kV Part 2 Choice of cable type and methods of installation.
- [59] SANS 10198-3, The selection, handling and installation of electric power cables of rating not exceeding 33 kV Part 3 Earthing systems – general provisions.
- [60] SANS 10198-4, The selection, handling and installation of electric power cables of rating not exceeding 33 kV Part 4 Current ratings.
- [61] SANS 10198-5, The selection, handling and installation of electric power cables of rating not exceeding 33 kV Part 5 Determination of thermal and electrical resistivity of soil.

- [62] SANS 10198-6, The selection, handling and installation of electric power cables of rating not exceeding 33 kV - Part 6 Transportation and storage.
- [63] SANS 10198-7, The selection, handling and installation of electric power cables of rating not exceeding 33 kV - Part 7 Safety precautions.
- [64] SANS 10198-8, The selection, handling and installation of electric power cables of rating not exceeding 33 kV Part 8 Cable laying and installation.
- [65] SANS 10198-10, The selection, handling and installation of electric power cables of rating not exceeding 33 kV - Part 10 Jointing and terminating of paper-insulated cables.
- [66] SANS 10198-11, The selection, handling and installation of electric power cables of rating not exceeding 33 kV - Part 11 Jointing and terminating of polymeric-insulated cables.
- [67] SANS 10198-13, The selection, handling and installation of electric power cables of rating not exceeding 33 kV - Part 13 Testing, commissioning and fault location.
- [68] SANS 60076-7, Loading guide for oil-immersed power transformers.
- [69] SANS 61238-1: 1993, Compression and mechanical connectors for power cables with copper or aluminium conductors - Part 1: Test methods and requirements.
- [70] SANS 62271-200, High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV.
- [71] SANS 62271-202, High-voltage switchgear and controlgear – Part 202: High-voltage/low-voltage prefabricated substations.
- [72] VC 8077, Compulsory specification for the safety of medium voltage electric cables.
- [73] D-DT-0291, MV-fuse / cut-out assembly - steel cross-arm.
- [74] D-DT-0292, MV-disconnector assembly - steel cross-arm.
- [75] D-DT-0642, MV and LV earth electrode connection details.
- [76] D-DT-0850 Cable termination from substation onto overhead.
- [77] D-DT-0851, Cable termination onto overhead line with fuse-cut-out assembly general arrangement.
- [78] D-DT-0852, Overhead cable support bracket for station class S.A.'s
- [79] D-DT-0853, 11 kV Air insulated cable junction box detail.
- [80] D-DT-0854, MV power cable trench details (1 off - 3 core).
- [81] D-DT-0855, Mini-substation earthing for MV systems without E.C.C. to source substation.
- [82] D-DT-0856, Standard power and control cable codes.
- [83] D-DT-0857, Example of network operating diagram.
- [84] D-DT-0858, Example of as built medium voltage cable layout.
- [85] D-DT-0859, Type "A" mini-substation plinth (cast on site).
- [86] D-DT-0860, 11 kV mini-substation Type A cable termination detail.
- [87] D-DT-0861, 11 kV & 22 kV CT-VT plinth details (cast on site).
- [88] D-DT-0862, Transformer earthing for MV systems with E.C.C. to source substation.
- [89] D-DT-0862, Earthing for transformer and RMU connected to overhead line.
- [90] D-DT-0863, 11 kV & 22 kV 3-way SF6 ring main unit plinth details (cast on site).
- [91] D-DT-0864, Transformer plinths for 100 kVA to 1000 kVA transformers plans and sections (cast on site).
- [92] D-DT-0864, Transformer plinths for 100 kVA to 1000 kVA transformers plans and sections (pre-cast).

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- [93] D-DT-0865, MV LPU earthing for MV systems with continuous E.C.C. to source substation.
- [94] D-DT-0894 sheet 2 of 4, Manhole details – HV/MV fibre optic cable draw pit.
- [95] D-DT-0895, MV / HV cable under-river crossing details of channel type river crossing for use under small / shallow rivers.
- [96] D-DT-0896, MV under-stream crossing details of cable stream crossing where base of stream is bedrock.
- [97] D-DT-0897, HV cable tunnel details.
- [98] D-DT-1850, Equipment cut-outs (links) or dis-connectors 1.3m steel cross-arm / single pole.
- [99] D-DT-1874, Equipment cut-outs (links) or dis-connectors 2.4m steel cross-arm / H-pole.
- [100] D-DT-5240, Earthing standard – MV 3-core cable termination at metal-clad switchgear
- [101] D-DT-3000, X-arm, steel channel 2400 long.
- [102] D-DT-3015, Rod, threaded galvanized M20x350mm washer + nuts.
- [103] D-DT-3017, Insulator, station post 22kV 1.5kN 31mm/kV.
- [104] D-DT-3049, Plate, blank ALU pole MK 25x150mm
- [105] D-DT-3076, Ferrule, crimp Cu 70 SQ non-butt.
- [106] D-DT-3082, Set screws.
- [107] D-DT-3086, Cut-outs (including brackets, cut-out bases, fuse holders, solid links, contacts).
- [108] D-DT-3087, Disconnectors.
- [109] D-DT-3091, Earth rod Cu 1500LGx16mm DIA thread-less.
- [110] D-DT-3093, Clamp, earth rod 16 ROD.
- [111] D-DT-3100, Surge arresters, distribution class.
- [112] D-DT-3102, Lug, crimp Cu.
- [113] D-DT-3110, Buckle - stainless steel strapping 12 mm.
- [114] D-DT-3129, Staple, galvanized.
- [115] D-DT-3131, Stainless steel strapping 12 mm.
- [116] D-DT-3137, Wire, Cu 16SQ 7/1.79 STR PVC black.
- [117] D-DT-3139, Cond, Cu bare STR 7/1.63 annealed 16mm SQ.
- [118] D-DT-3166, Lug, bi-metallic 9.0 - 15.0 DIA M16 bolt 0 degree indent crimp.
- [119] D-DT-3170, Wire, barbed galvanised.
- [120] D-DT-3202, Sign, danger electrical symbol 150x150x0.6.
- [121] D-DT-3202, Sign, ABC LV 270x120x0.6
- [122] D-DT-3202, Sign, ABC MV 270x120x0.6
- [123] D-DT-3207, Bracket, cable termination support.
- [124] D-DT-3213, Tape, Denso 50mm WD x 10m Roll.
- [125] D-DT-5015, Signs A, B and C.
- [126] D-DT-5016, Signs D and E.
- [127] D-DT-5017, Sign F.
- [128] D-DT- 5238, Building, Switch room.

- [129] D-DT-6072, Sign ABC – unauthorised entry/interference apparatus.
- [130] D-DT-6073, Sign DE – Procedure in case of fire / no H₂O.
- [131] D-DT-6074, Sign F – Prohibitive (various).
- [132] D-DT-6215, Surge arresters, station class 22 kV.
- [133] D-DT-6216, Surge arresters, station class 11 kV.
- [134] D-DT-8000, Cable, 11 kV and 22 kV impregnated paper-insulated.
- [135] D-DT-8001, Cable, 11 kV and 22 kV XLPE-insulated.
- [136] D-DT-8004 MV trifurcating kits with 2,5 m tails
- [137] D-DT-8005, Termination kit, 1-core and 3-core 11 kV and 22 kV PILC.
- [138] D-DT-8006, Termination kit, 1-core and 3-core 11 kV and 22 kV XLPE.
- [139] D-DT-8007, Joint kit, 1-core and 3-core 11 kV and 22 kV PILC.
- [140] D-DT-8008, Joint kit, 3-core 11 kV and 22 kV XLPE.
- [141] D-DT-8010, Surge arrester station class 11 kV and 22 kV polymer – indoor.
- [142] D-DT-8011, Shroud, straight 11 kV and 22 kV 200 mm long.
- [143] D-DT-8012, Cable route marker, concrete.
- [144] D-DT-8013, Cable warning tape.
- [145] D-DT-8015, Cap, cable end seal.
- [146] D-DT-8017, Connectors, separable screened 22 kV.
- [147] D-DT-8018, Pipe, PVC cable.
- [148] D-DT-8019, Clamps, cable.
- [149] D-DT-8020, Ferrules, cable.
- [150] D-DT-8021, Joint kit, transition 3C 11 & 22 kV XLPE to PILC.
- [151] D-DT-8022, Distribution transformer with MV/LV cable boxes.
- [152] D-DT-8023, Pipe, steel 100NBx3.9W/THK 3X2m LG.
- [153] D-DT-8025, Plinths, pre-cast concrete.
- [154] D-DT-8027, Grommet, rubber cable 50-100 dia.
- [155] D-DT-8028, Pin, earthing MV OHL cable term
- [156] D-DT-8029, Sealant strip for mini-sub / RMU
- [157] D-DT-8050, Mini-sub 11 kV Type B.
- [158] D-DT-8051, Mini-sub 22 kV Type B.
- [159] D-DT-8052, Mini-sub 11 kV Type A
- [160] D-DT-8053, Mini-sub 22 kV Type A.
- [161] D-DT-8054, 11 kV Type B Mini-sub Fitted with RTU.
- [162] D-DT-8055, 22 kV Type B Mini-sub Fitted with RTU.
- [163] D-DT-8060, RMU, 11 kV and 22 kV stand alone.
- [164] D-DT-8061, RMU 11 AND 22kV OD AND ID IRTU
- [165] D-DT-8076, Cable trench pre-cast concrete slabs

[166] D-DT-8077, Sleeve, cable repair 60-120 1m LG

[167] D-DT-8080, Pre-cast manholes

[168] D-DT-8081, Fibre optic ducts

2.2.2 Informative

None

2.3 Definitions

2.3.1 General

Definition	Description
Firm	In the event of a single item of equipment failure (N-1), supply to all loads can be restored without having to reconfigure the network (e.g. loads do not need to be transferred onto other sources of supply).
Miniature substation (or mini-substation)	A factory-assembled and tested free-standing unit that is suitable for use in an area accessible to the public, that comprises a transformer, an equipped medium-voltage compartment and an equipped low-voltage compartment and that is suitable for connection to underground cables (SANS 1029).
Mini-substation feeder (or sub-ring feeder)	A feeder that is supplied off a secondary feeder from a sub-switching station and is looped in and out of mini-substations.
Open ring feeder	A ring feeder that is configured with a normally open point.
Primary feeder	A feeder that is supplied from a step-down substation directly to a switching station. A primary feeder does not loop in and out of sub-switching stations or mini-substations.
Radial feeder	A feeder that has only one source of supply (i.e. no alternative source of supply for back-feeding purposes)
Ring feeder	A feeder that has two or more possible sources of supply.
Rock	Rock is a naturally occurring aggregate of minerals and/or mineraloids. This type of material can generally only be excavated after the use of blasting, boulder busting or chemical rock breaking. Pneumatic (compressor operated) or hydraulically operated rock drilling / breaking equipment may also be used.
Secondary feeder	A feeder that is supplied from either a step-down substation or a switching station and is looped in and out of sub-switching stations and/or mini-substations. Other feeders (e.g. mini-substation or sub-ring feeders) may be supplied off secondary feeders.
Shale	Shale (also called mudstone) is a fine-grained sedimentary rock whose original constituents were clay minerals or muds. It is characterized by thin layers breaking with an irregular curving fracture, often splintery. Shale is the most common sedimentary rock. This type of material can be excavated by means of a pick and shovel or a mechanical excavator (back-actor).
Soil	Soil is the naturally occurring, unconsolidated or loose covering of broken rock particles and decaying organic matter (humus) on the surface of the Earth. Soil particles pack loosely, forming a soil structure filled with voids. This type of material can be excavated by means of a pick and shovel or a mechanical excavator (back-actor).

Definition	Description
Step-down substation	A site primarily used to transform large quantities of energy from a high distribution voltage to a medium distribution voltage.
Sub-switching station (RMU)	A metal-enclosed substation for the purpose of switching power between one or two supply feeders to mini-substation feeders or to a customer that takes bulk supply at MV.
Switched firm	In the event of a single item of equipment failure (N-1), supply to all loads can be restored but only by reconfiguring the network (e.g. loads must be transferred onto other sources of supply).
Switching station	A brick-built substation for the purpose of switching power between one or more supply feeders to any number of distribution feeders, without transformation to a different voltage.

2.3.2 Disclosure classification

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

2.4 Abbreviations

Abbreviation	Description
ACSR	Aluminium conductor steel reinforced.
CCRA	Condition criticality and risk assessment
HDPE	High density polyethylene
ID	Inner diameter
IRTU	Integrated remote terminal unit
OD	Outer diameter
RMU	Ring main unit

2.5 Roles and responsibilities

The Employer or his Delegate shall ensure that this standard is implemented and adhered to when dealing with MV cable systems.

2.6 Process for monitoring

The relevant divisional project approval processes and governance structures shall apply.

2.7 Related/supporting documents

Not applicable.

3. Requirements

3.1 Statutory requirements

- a) The requirements of the Occupational Health and Safety Act, Act 85 of 1993, (OHS Act) and all subsequent amendments and regulations shall be observed and adhered to except where exemption has been obtained from the Chief Factories Inspector. If any text or drawings in this standard are in conflict with the OHS Act and no exemption has been obtained, the OHS Act requirements shall take precedence over the standard.
- b) The requirements of SANS 10198-1 shall be observed and adhered to except where exemption has been obtained from the relevant authority.

3.2 Other statutory bodies

- a) Other statutory bodies from which permission may have to be obtained are:
 - 1) National roads agency
 - 2) Provincial and/or metropolitan roads agencies
 - 3) Department of Water and Forestry;
 - 4) Department of Environmental Affairs and Tourism;
 - 5) local metropolitan / municipal town councils; and
 - 6) Any other statutory body that may be considered a stakeholder.
- b) Applications to the water, rail and local authorities shall be made in accordance with DST 34-820, DST 34-1812 and DST 34-822.

3.3 Servitude and wayleave agreements

- a) Primary cable feeders that traverse private property shall have registered servitudes.
- b) Secondary and mini-substation cable feeders that traverse private property shall have registered servitudes or wayleave agreements signed with the property owner.
- c) Servitudes and wayleaves for cables installed within private property shall be registered for a minimum width of 1 m on both sides of the outer most cables in the servitude.
- d) Where a servitude is to be registered within a private property boundary for the installation of a mini-substation or ground-mounted transformer, the minimum servitude dimensions shall be 6 m × 3 m (i.e. with the 6 m dimension parallel to the road reserve boundary).
- e) Where a servitude is to be registered within a private property boundary for the installation of equipment required for an MV bulk supply (i.e. free-standing RMU and CT-VT metering unit), the minimum servitude dimensions shall be 7.5 m × 3 m (i.e. with the 7.5 m dimension parallel to the road reserve boundary).
- f) Where a servitude is to be registered within a private property boundary for the installation of a sub-switching station (i.e. free-standing RMU), the minimum servitude dimensions shall be 4 m × 3 m (i.e. with the 4 m dimension parallel to the road reserve boundary).
- g) Where the property owner chooses to enclose the servitude, it shall be ensured that access is provided for Eskom staff and that an Eskom padlock is installed.
- h) The special requirements of municipal wayleaves shall be considered.
- i) The operating unit Asset Creation Department - Land Development Section shall be consulted for further details regarding registration of servitudes and wayleave agreements.
- j) In the event that Eskom's rights (servitudes / wayleaves) may be encroached upon and / or services / assets placed at risk, the requirements of DST 34-827 shall be followed.

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3.4 Environmental considerations

- a) The requirements of the National Environmental Management Act, 1998 (Act 107 of 1998) and Eskom's environmental directives, policies and procedures shall be observed and adhered to except where exemption has been obtained from the relevant authority.
- b) An environmental assessment shall be carried out in accordance with the requirements of DST 34-926.

3.5 Performance and operational requirements

3.5.1 General

- a) Cable systems shall be planned and designed to ensure that the desired network performance is achievable. The provision of locally and remotely controlled switching points may be employed to provide a practical system in support of the performance targets. These include free standing RMUs, Type B mini-substations, the use of earth fault indicators (EFI's), use of IRTU fitted RMUs and the use of Distribution Automation (DA). The Operating Unit Control Plant Departments and any other stakeholders shall be consulted before placement of these devices to ensure optimization of the network. Refer to 240-61227438 and 240-56062745 for further information and guidelines for the planning of MV underground cable systems.
- b) Only material or products that meet Eskom's specifications and requirements shall be used.

3.5.2 Plant location

The location of plant, for example free standing RMUs, mini-substations etc. shall be decided upon considering the following factors:

- a) vehicular and pedestrian traffic;
- b) environmental impact;
- c) water run-off;
- d) pollution;
- e) accessibility for ease of operation and maintenance; and
- f) location of other underground services, for example Telkom, water etc.

3.5.3 Protection philosophy

- a) While the system protection philosophy is intimately related to the specific network design, the general philosophy is as follows:
- b) Primary cable feeders shall have current differential protection utilising a fibre optic communication link between stations or directional over-current and earth fault protection;

Note: Current differential protection may be preferred to avoid unacceptably long tripping times resulting from the grading of series circuit-breakers and switch-fuse combinations.

- c) Secondary cable feeders shall have over-current and earth fault protection;

Note: Generally the use of relays that have "very inverse" characteristic curves will provide suitable grading with downstream HRC fuses. Where customers that take bulk supply at MV are supplied from the same secondary cable feeder care must be taken to ensure that co-ordination is maintained with their protection relays.

- d) Protection, local control and indication schemes for primary and secondary feeders shall comply with the requirements of 240-61266445;
- e) Customers provided with bulk supply at MV that are supplied from secondary cable feeders shall provide over-current and earth fault protection that is capable of isolating their network from the Eskom supply in the event of a customer fault;

Note: Customers provided with bulk supply at MV may be supplied directly from substations or switching stations (MV customers > 6 MVA) or may be supplied from a secondary feeder via a free standing RMUs (MV customers ≤ 6 MVA).

- f) Mini-substations supplied from secondary cable feeders shall be fitted with a circuit breaker; and
- g) Mini-substation cable feeders shall have over-current and earth fault protection.
- h) Because of the influence of fault level, system configuration and equipment short-time current withstand ratings, typical tripping and protection discrimination times are not given in this standard. The actual selection of relay settings and fuse ratings shall be the subject of careful consideration for each specific circuit-breaker and for each specific item of protection equipment.
- i) For primary cable feeder current differential protection, the fibre optic cable shall be in accordance with NRS 088-1 and installed in accordance with NRS 088-2.

3.5.4 System configuration

1 shows all the allowable cable sizes that can be used for primary, secondary and mini-substation feeders. The quantity of cables that can be terminated onto switchgear is determined by the rating of that switchgear. The relevant switchgear standard should be consulted depending on the switchgear type chosen for the design (Withdrawable (240-56065131) or fixed pattern (240-56062704)).

Table 1: Allowable cable sizes for various MV feeders

MV feeder type	Transmission and Distribution				Generation
Cable conductor size (Cu) (mm ²) and type	Cu		Al		Cu
Voltage (kV)	11	22, 33	11	22, 33	11, 22, 33
Primary feeders	185 / 300, 3-core or 630 1-Core	185, 3-core	185 / 300, 3-core	185 / 300, 3-core	185 / 300, 3-core or 630 1-Core
Secondary	50 / 95 / 185 / 300 3-core	50 / 95 / 185 3-core	95 / 185 / 300, 3-core	95 / 185 / 300, 3-core	50 / 95 / 185 / 300 3-core
Mini-substation feeder	50 / 95 or 185, 3-core	50 / 95, 3-core	95 / 185, 3-core	95 / 185, 3-core	N/A
Notes:					
1) 11 kV rated cables and cable accessories will be used for 2.2 kV, 3.3 kV and 6.6 kV voltage ratings.					
2) Where 300 mm ² cable options are used for secondary feeders, special care is required during the design phase to ensure the correct 3 core to single core cable termination options are selected.					

The system configuration may vary depending upon the actual load requirements but shall generally be as indicated in annex A. Refer to 240-56062745 for further planning guidelines for MV cable systems. Considerations are as follows:

- a) Switching stations shall typically have a firm load transfer capacity of 6 MVA to 20 MVA (for switching substation loads < 5 MVA, the load transfer may be switched firm);

Note: Where switching stations are supplied by a group (n) of primary cable feeders, the firm capacity will be determined by the load transfer capacity of (n-1) primary cable feeders;

- b) On secondary feeders, only Type B mini-substations with ring main units will be used;
- c) the use of free standing RMUs supplied directly from secondary cable feeders to provide supplies to mini-substation feeders;
- d) the use of free-standing RMUs supplied directly from secondary cable feeders to provide T-offs to bulk MV consumers;

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- e) bulk MV customers (typically ≥ 6 MVA) fed off primary cable feeders are to be supplied via switching stations (firm supply);
- f) bulk MV customers (typically < 6 MVA) fed off secondary cable feeders are to be supplied via free standing RMUs in accordance with the requirements of 240-56030406 (switched firm supply); and
- g) LV customers on a ring feeder (small power and large power users) are to be supplied via Type B mini-substations
- h) LV customers on a radial feeder can be supplied via type A mini-sub (at the end of radial feeders).

Note: Ground mounted transformers have been used historically in brick-house substations or at the end of radial feeders. Where these cannot be replaced with a mini-substation, these may be replaced. Ground mounted transformers should however not be used on new design if possible.

1000kVA mini-substations are currently only used for supplying a single LV large power user whose notified maximum demand is > 500 kVA. 1000kVA mini-substations are supplied with a built-in LV metering panel in the mini-substation LV compartment.

3.6 Insulation co-ordination

3.6.1 Impulse insulation levels

The following impulse insulation requirements, in accordance with SANS 1019 (see table 2), shall apply to the respective equipment

- a) cable and accessories shall comply with List 3;

Note: Cable and accessories are extensively used to connect directly to overhead lines and are therefore considered to be exposed installations.

- b) mini-substation and ground-mounted transformers shall comply with List 3; and

Note: Type A mini-substations may be used to connect directly to overhead lines by means of a short length of cable and are therefore considered to be exposed installations.

- c) primary switchgear (i.e. indoor metal-clad) and secondary switchgear (i.e. ring main units) for 11 kV and 22 kV shall comply with List 3 and List 2 respectively.

Notes:

- 1) Equipment rated at 24 kV that complies with the requirements of List 3 is not commercially available.
- 2) Where 24 kV rated equipment is supplied from an overhead line by means of a cable that is longer than 50 m screened surge arresters in accordance with 240-56030619 shall be installed at the equipment terminals (see D-DT-8017).

Table 2: Standard voltages and impulse insulation levels

1	2	3	4
Highest voltage for equipment U_m , r.m.s. kV	Nominal system voltage U_n , r.m.s. kV	Rated lightning impulse withstand voltage, peak kV	
		List 2	List 3
12	11	75	95
24	22	125	150

Notes:

- 1) List 2 insulation levels apply in general to equipment in non-exposed installations (such as those connected to cable networks).
- 2) List 3 insulation levels apply in general to equipment in exposed installations.

3.6.2 Insulation requirements for air filled cable termination enclosures

The clearance and creepage within air filled cable termination enclosures shall comply with the requirements of SANS 876. The method of cable termination onto the respective equipment shall be as follows:

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- a) 11 kV and 22 kV indoor metal clad withdrawable switchgear (air-insulated switchgear) – shrouded terminations (see D-DT-8011);
- b) 11 kV ring main units and mini subs – screened separable connectors (see D-DT-8017);
- c) 11 kV extensible fixed pattern switchgear (typically gas-insulated) – screened separable connectors (see D-DT-8017);
- d) 22 kV ring main units, mini subs and extensible fixed pattern switchgear (typically gas-insulated) – screened separable connectors (see D-DT-8017);
- e) 11 kV ground-mounted transformers and CT-VT metering units –or screened separable connectors (see D-DT-8017);
- f) 22 kV ground-mounted transformers and CT-VT metering units – screened separable connectors (“1 CABLE” – see D-DT-8017);

3.6.3 Designed failure mode

The design of all plant within the cable system shall be such that the probability of failure between phases is substantially less than between phase and earth. This requirement is necessary to realise the benefit of limiting earth fault levels through resistive earthing as described in the earthing philosophy (see below).

3.7 Earthing philosophy

The general earthing philosophy for MV cable systems shall be in accordance with SANS 0200 as follows:

- a) the network shall be resistively earthed at the step-down substation by means of a neutral electromagnetic coupler with resistor (NECR) installed per source transformer;

Note: The selection of NECR rated current i.e. 360 A or 960 A is based upon the desired prospective earth fault level and earth fault protection co-ordination requirements between earth fault relays and downstream HRC fuses. The designer must take cognisance of the fact that increasing fault levels to facilitate protection co-ordination comes at the expense of increased damage at the point of fault.

- b) cables and accessories described in this standard are capable of withstanding earth fault current magnitudes in excess of 2 kA for 3 s. It is therefore unnecessary to use a counterpoise earthing conductor where the number of 960 A and 360 A NECRs is restricted to a maximum of two or four respectively;
- c) the connection of the earthing conductor to the cable armouring or lead sheath within a cable accessory (for example joint or termination) shall be by a type tested mechanical arrangement;

Note: Soldered earthing connections of armouring or lead sheath or ECC cannot be used in a national standard due to the lack of suitable skills in certain operating units.

- d) the armouring and lead sheath of the cable shall be continuous back to the step-down substation and shall be used as an earth continuity conductor (ECC);
- e) the bonding and earthing of cables within step-down substations shall comply with the requirements of 240-56063710;
- f) the cable armouring and lead sheath (if applicable) of all primary and secondary feeders within a switching station shall be bonded to the earthing bar of the metal-clad switchgear. The earthing bar of all metal-clad switchgear panels shall be interconnected and bonded to the switching station earth electrode;
- g) the switching station earth electrode shall be designed to meet step and touch potential requirements by ensuring that an equi-potential earth mat is created by:
 - 1) connecting the earth bar of the metal-clad switchgear to the steel re-enforcing used in the concrete flooring; and
 - 2) all other metal-work (steel trench covers, lipped channels door frames, etc.) are connected to the steel re-enforcing used in the concrete floor.

Note: Switching stations are supplied from primary cable feeders and therefore the cable armouring or lead sheath serve as an earth continuity conductor (ECC) back to the step-down substations. Earth fault current magnitudes are limited due to the resistively earthed network.

- h) the bonding and earthing at free standing RMUs (e.g. free-standing RMUs) shall comply with the following requirements:
- 1) if there is a continuous earth continuity conductor (ECC) from the sub-switching station back to the step-down substation earth mat (through the armouring or lead sheath of the supply cable) an equipotential earth electrode shall be installed, below the operator's feet, that ensures safe touch potentials under earth fault conditions (see D-DT-0865 sheet 1), and
 - 2) if no ECC exists then an equipotential earth electrode shall be installed below the operator's feet that ensure safe touch potentials under earth fault conditions. In addition to this an earth electrode shall be provided that ensures that the earth fault protection relay at the step-down or switching station will operate in the event of an earth fault at the sub-switching station (see D-DT-0865 sheet 2). The requirements for the electrode shall be in accordance with the requirements of 240-130615754.
- i) the bonding and earthing at mini-substations shall comply with the following requirements:
- 1) if there is a continuous earth continuity conductor (ECC) from the mini-substation back to the step-down substation earth (through the armouring and lead sheath (if applicable) of the supply cable) an equipotential earth electrode shall be installed below the operator's feet, that ensures safe touch potentials under MV earth fault conditions. In this case the LV neutral busbar of the mini-substation shall be bonded to the mini-substation earth bar (see D-DT-0855 sheet 2), and

Note: Mini-substations in accordance with 240-56062752 are supplied with a 2 X 70 mm² (for mini subs ≤ 500kVA) or 3 X 70 mm² (for 100kVA mini subs) copper link in parallel with a surge arrester that is connected between the LV neutral/earth busbar and the mini-substation earth bar. In this case the copper link and surge arrester arrangement should be left as supplied.

- 2) if no ECC exists then an equipotential earth electrode shall be installed below the operator's feet that ensure safe touch potentials under earth fault conditions. In addition to this an MV and an LV earth electrode shall be installed that ensures that the earth fault protection relay at the step-down or switching station will operate in the event of an MV earth fault at the mini-substation. A surge arrester shall be installed between the LV neutral busbar and the mini-substation earth bar (see D-DT-0855 sheet 1 and 3). The requirements for the MV and LV earth electrodes shall be in accordance with the requirements of 240-130615754.

Note: Mini-substations in accordance with 240-56062752 are supplied with a 2 X 70 mm² (for mini subs ≤ 500kVA) or 3 X 70 mm² (for 100kVA mini subs) copper link in parallel with a surge arrester that is connected between the LV neutral/earth busbar and the mini-substation earth bar. In this case the copper link should be removed.

- j) the bonding and earthing at ground-mounted transformers shall comply with the following requirements:
- 1) if there is a continuous earth continuity conductor (ECC) from the ground-mounted transformer back to the step-down substation earth (through the armouring and lead sheath (if applicable) of the supply cable) an equipotential earth electrode shall be installed below the operator's feet, that ensures safe touch potentials under MV earth fault conditions. In this case the LV neutral terminal of the ground-mounted transformer shall be bonded to the earth boss provided in the LV cable termination enclosure (see D-DT-0862 sheet 2), and

Note: Ground-mounted transformers in accordance with 240-45395762 are supplied with a 2 X 70 mm² (for mini subs ≤ 500kVA) or 3 X 70 mm² (for 100kVA mini subs) copper link in parallel with a surge arrester that is connected between the LV neutral terminal and the earth boss in the LV cable termination enclosure. In this case the copper link and surge arrester arrangement should be left as supplied.

- 2) if no ECC exists then an equipotential earth electrode shall be installed below the operator's feet that ensure safe touch potentials under earth fault conditions. In addition to this an MV and an LV earth electrode shall be installed that ensures that the earth fault protection relay at the step-down or switching station will operate in the event of an MV earth fault at the transformer. A surge arrester shall be installed between the LV neutral terminal and the earth boss provided in the LV cable termination enclosure (see D-DT-0862 sheet 1 and 3). The requirements for the MV and LV earth electrodes shall be in accordance with the requirements of 240-130615754.

Note: Ground-mounted transformers in accordance with 240-45395762 are supplied with a 2 X 70 mm² (for mini subs ≤ 500kVA) or 3 X 70 mm² (for 100kVA mini subs) copper link in parallel with a surge arrester that is connected between the LV neutral terminal and the earth boss in the LV cable termination enclosure. In this case the copper link should be removed.

3.8 Statistical/loss management metering philosophy

The metering strategy set out by the project engineer shall be implemented.

3.9 Medium-voltage cables

3.9.1 Cable selection

- a) Medium-voltage cable (see D-DT-8000 and D-DT 8001) shall comply with the requirements of 240-56063792 and shall have copper or aluminium conductors.

Notes:

- 1) Compulsory safety specification VC 8077 stipulates that all medium-voltage cables in South Africa comply with the requirements of SANS 97 and SANS 1339 for impregnated paper-insulated and XLPE-insulated cables respectively.
- 2) The world market price of copper and aluminium dictates the type of conductor that is most cost effective at any time, however copper conductors have been chosen for the following reasons:
 - the core and outer diameters of a copper conductor cable are smaller for equivalent ampacity than an aluminium conductor cable – facilitating easier working when jointing and terminating;
 - compact gas-insulated secondary switchgear (e.g. ring main units) place restrictions on the maximum size of cable, in particular three-core cable, that can be terminated within the cable termination enclosures. A three-core 185mm² or 300mm² (only on the R module) cable is considered to be the maximum size that can be terminated within a ring main unit cable termination enclosure.
 - compression methods are simple for copper conductors whereas there are numerous differing opinions regarding the crimping requirements for aluminium cables; and
 - copper conductor cables do not require bi-metallic lugs when connecting to equipment fitted with brass stem bushings.
 - compression system and bi-metallic constraints are effectively eliminated with the use of mechanical torque shear lugs and ferrules.
- 3) Aluminium conductor options were re-introduced into Eskom since 2016 for the following reasons:
 - To allow cable options that is of a lower scrap value, to mitigate theft of copper cables,
 - Aluminium conductor cables may also provide Eskom with a cost saving opportunity based on the lower material cost at an equivalent ampacity rating.
- b) XLPE-insulated cable shall be used for all new projects except where there is cut-ins to existing impregnated paper-insulated cable networks.
- c) The rating of all XLPE-insulated cables shall be based upon a maximum conductor temperature of 70 °C in order to prevent drying out of the soil surrounding the cable.

Notes:

- 1) A conductor temperature of 70 °C is specified as it has been shown that sustained operation of XLPE-insulated cable with a conductor temperature of 90 °C leads to drying out of the soil surrounding the cable and potential thermal runaway.
- 2) Operating cables at 70 °C also limits the technical losses (I²R losses).

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- 3) This philosophy also allows greater operational flexibility as it makes provision for additional spare capacity under contingency or unforeseen conditions.
- 4) The protection over-current and thermal replica settings for primary and secondary feeders should however differentiate between impregnated paper and XLPE-insulated cables as the additional capacity of XLPE-insulated cables should be made available under contingencies.
- d) For the purpose of labelling of drawings and purchasing; a method of cable coding has been implemented by Eskom (see D-DT-0856).
- e) The standard cable sizes and typical parameters for use within Eskom are given in table 3 to table 14.

Table 3: 6,35 kV/11 kV 3-core impregnated paper-insulated cables

1	2	3	4	5	6	7	8	9
Conductor size mm ²	Maximum sustained current rating (A)			Fault current rating – 1 s (kA)		Impedance (Ω/km)	A.C. resistance (Ω/km)	Reactance (Ω/km)
	Ground	Pipes	Air	Symm	Earth			
25	115	96	120	2,9	2,9*	0,8788	0,8700	0,124
50	165	135	175	5,8	4,9	0,4769	0,4634	0,113
95	240	200	255	11,0	5,9	0,2517	0,2315	0,099
185	340	285	380	21,5	8,0	0,1503	0,1199	0,091
300	440	370	510	34,8	11,0	0,1129	0,0742	0,085

Table 4: 12,7 kV/ 22 kV 3-core impregnated paper-insulated cables

1	2	3	4	5	6	7	8	9
Conductor size mm ²	Maximum sustained current rating (A)			Fault current rating – 1 s (kA)		A.C. resistance (Ω/km)	A.C. resistance (Ω/km)	Reactance (Ω/km)
	Ground	Pipes	Air	Symm	Earth			
25	115	101	115	3,0	3,0*	0,8821	0,8700	0,146
50	160	140	170	6,0	6,0*	0,4820	0,4633	0,133
95	235	200	260	11,3	10,7	0,2601	0,2315	0,119
185	340	290	385	22,0	12,8	0,1592	0,1197	0,105

Table 5: 19.1 kV/ 33 kV 3-core impregnated paper-insulated cables

1	2	3	4	5	6	7	8	9
Conductor size mm ²	Maximum sustained current rating (A)			Fault current rating – 1 s (kA)		A.C. resistance (Ω/km)	A.C. resistance (Ω/km)	Reactance (Ω/km)
	Ground	Pipes	Air	Symm	Earth			
95	227	197	248	11,0	10,7	0,2316	0,2315	0,115

Table 6: 6,35 kV/11 kV and 12,7 kV/ 22 kV single-core impregnated paper-insulated cables

1	2	3	4	5	6	7	8	9	10
Rated voltage (kV)	Conductor size mm ²	Maximum sustained current rating (A)			Fault current rating – 1 s (kA)		Impedance (Ω/km)	A.C. resistance (Ω/km)	Reactance (Ω/km)
		Ground	Pipes	Air	Symm	Earth			
11	630	696	628	904	94,1	7,4	0,097	0,0386	0,089
22	630	690	622	890	94,1	8,8	0,104	0,0382	0,097

Table 7: 6,35 kV/11 kV 3-core Cu XLPE-insulated cables

1	2	3	4	5	6	7	8	9
Conductor size mm ²	Maximum sustained current rating (A)			Fault current rating – 1 s (kA)		Impedance (Ω/km)	A.C. resistance (Ω/km)	Reactance (Ω/km)
	Ground	Pipes	Air	Symm	Earth			
25	120 (141)	105 (123)	119 (140)	3,6	3,6*	0,8778	0,869	0,124
50	171 (201)	148 (174)	172 (202)	7,1	7,1*	0,4766	0,463	0,113
95	249 (294)	211 (249)	256 (302)	13,5	13,5*	0,2517	0,231	0,100
185	352 (415)	302 (356)	383 (452)	26,5	23,5	0,1506	0,12	0,091
300	447 (527)	387 (456)	513 (605)	42,6	27,2	0,1127	0,074	0,085

Table 8: 6,35 kV/11 kV 3-core Al XLPE-insulated cables

1	2	3	4	5	6	7	8	9
Conductor size mm ²	Maximum sustained current rating (A)			Fault current rating – 1 s (kA)		Impedance (Ω/km)	A.C. resistance (Ω/km)	Reactance (Ω/km)
	Ground	Pipes	Air	Symm	Earth			
95	194 (227)	160 (189)	220 (266)	8.1	8.1	1.034	0.411	0.109
185	274 (319)	255 (265)	316 (383)	15.8	15.8	0.776	0.211	0.095
300	347 (407)	288 (339)	415 (504)	25	25	0.909	0.130	0.0887

Table 9: 6,35 kV/11 kV single-core Cu XLPE-insulated cables

2	3	4	5	6	7	8	9	10
Conductor size mm ²	Maximum sustained current rating (A)			Fault current rating – 1 s (kA)		Impedance (Ω/km)	A.C. resistance (Ω/km)	Reactance (Ω/km)
	Ground	Pipes	Air	Symm	Earth			
50	181 (212)	168 (197)	203 (246)	6.4	6.4	0.767	0.494	0.147
95	261 (304)	241 (283)	303 (367)	7.5	7.5	0.697	0.301	0.131
185	363 (425)	335 (394)	440 (537)	12	12	0.322	0.128	0.118

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300	456 (536)	420 (496)	574 (703)	14	14	0.274	0.079	0.110
630	636 (750)	522 (615)	848 (1052)	26.5	26,5	0,106	0,039	0,100

Table 10: 12,7 kV/ 22 kV 3-core Cu XLPE-insulated cables

1	2	3	4	5	6	7	8	9
Conductor size mm ²	Maximum sustained current rating (A)			Fault current rating – 1 s (kA)		Impedance (Ω /km)	A.C. resistance (Ω /km)	Reactance (Ω /km)
	Ground	Pipes	Air	Symm	Earth			
25	125 (146)	109 (116)	125 (146)	3,6	3,6*	0,8802	0,869	0,14
50	171 (201)	150 (176)	178 (209)	7,1	7,1*	0,4798	0,463	0,126
95	249 (293)	213 (251)	265 (312)	13,5	13,5*	0,2567	0,231	0,112
185	353 (416)	309 (364)	389 (458)	26,5	26,5*	0,1568	0,12	0,101
300	425 (500)	355 (420)	518 (598)	35	35	0.376	0.079	0.104

Table 11: 12,7 kV/ 22 kV 3-core Al XLPE-insulated cables

1	2	3	4	5	6	7	8	9
Conductor size mm ²	Maximum sustained current rating (A)			Fault current rating – 1 s (kA)		Impedance (Ω /km)	A.C. resistance (Ω /km)	Reactance (Ω /km)
	Ground	Pipes	Air	Symm	Earth			
50	134 (156)	111 (130)	147 (177)	4	4	1.279	0.822	0.134
95	194 (226)	161 (188)	220 (267)	8.1	8.1	0.851	0.851	0.117
185	272 (317)	226 (267)	316 (382)	15.8	15.8	0.609	0.211	0.105
300	347 (407)	288 (340)	418 (507)	25.6	25.6	0.489	0.130	0.096

Table 12: 12,7 kV/ 22 kV single-core Cu XLPE-insulated cables

2	3	4	5	6	7	8	9	10
Conductor size mm ²	Maximum sustained current rating (A)			Fault current rating – 1 s (kA)		Impedance (Ω /km)	A.C. resistance (Ω /km)	Reactance (Ω /km)
	Ground	Pipes	Air	Symm	Earth			
50	181 (210)	168 (197)	206 (249)	6.4	6.4	0.717	0.494	0.157
95	260 (303)	240 (282)	305 (370)	11.5	11.5	0.426	0.247	0.140
185	361 (423)	334 (393)	442 (539)	13.2	13.2	0.296	0.128	0.125
300	449 (528)	414 (490)	573 (700)	18.4	18.4	0.228	0.079	0.117
630	636 (750)	561 (586)	851 (1054)	28.8	28.8	0.111	0.038	0.104

Table 13: 19.1 kV/ 33 kV 3-core Cu XLPE-insulated cables

1	2	3	4	5	6	7	8	9
Conductor size mm ²	Maximum sustained current rating (A)			Fault current rating – 1 s (kA)		Impedance (Ω /km)	A.C. resistance (Ω /km)	Reactance (Ω /km)
	Ground	Pipes	Air	Symm	Earth			
50	170 (198)	144 (168)	189 (228)	6.4	6.4	0.900	0.494	0.143
95	245 (286)	205 (242)	279 (337)	12.8	12.8	0.628	0.247	0.128
185	340 (398)	301 (319)	401 (486)	25	25	0.454	0.128	0.114
300	425 (500)	355 (420)	518 (598)	35	35	0.376	0.079	0.104

Table 14: 19.1 kV/ 33 kV 3-core Al XLPE-insulated cables

1	2	3	4	5	6	7	8	9
Conductor size mm ²	Maximum sustained current rating (A)			Fault current rating – 1 s (kA)		Impedance (Ω /km)	A.C. resistance (Ω /km)	Reactance (Ω /km)
	Ground	Pipes	Air	Symm	Earth			
50	133 (155)	112 (131)	148 (178)	4	4	1.111	0.822	0.146
95	192 (224)	158 (189)	219 (258)	8.1	8.1	0.695	0.411	0.128
185	270 (315)	226 (266)	318 (385)	15.8	15.8	0.462	0.211	0.115
300	343 (401)	287 (339)	416 (503)	27.4	27.4	0.362	0.130	0.104

Table 15: 19.1 kV/ 33 kV single-core Cu XLPE-insulated cables

2	3	4	5	6	7	8	9	10
Conductor size mm ²	Maximum sustained current rating (A)			Fault current rating – 1 s (kA)		Impedance (Ω /km)	A.C. resistance (Ω /km)	Reactance (Ω /km)
	Ground	Pipes	Air	Symm	Earth			
50	180 (210)	167 (196)	208 (251)	6.4	6.4	0.617	0.494	0.166
95	259 (303)	240 (283)	308 (374)	12.8	12.8	0.383	0.267	0.180
185	357 (418)	330 (389)	443 (539)	18.4	18.4	0.248	0.127	0.134
300	447 (525)	412 (487)	573 (700)	20.9	20.9	0.201	0.077	0.124
630	570 (677)	545 (647)	795 (991)	25.4	25.4	0.121	0.0405	0.111

Notes:

- 1) The sustained current-carrying capacities calculated in tables 3 to 15 are based upon the standard installation conditions proposed by SANS 10198-4. The above tables have been compiled from data given in SANS 10198 and cable manufacturers catalogues. The standard installation conditions are as follows:
 - maximum sustained conductor temperature for cables laid in ground or single way ducts = 70 °C. For XLPE-insulated cables, the emergency current rating is given in brackets and is based on the 90 °C conductor temperature;
 - soil temperature at depth of burial = 25 °C;
 - ambient air temperature = 30 °C;
 - thermal resistivity of soil = 1,2 Km/W;
 - depth of laying to top surface of cable or single way duct in ground = 0,8 m (see D-DT-0854);
 - load factor = 1;
 - single-core cables are assumed to be in close trefoil and earthed at one end only;
 - each cable is assumed to be thermally independent;
- 2) Notes on fault current ratings:
 - fault current ratings are based on a fault duration of 1 second;
 - fault current ratings are calculated assuming adiabatic conditions with a final conductor temperature of 160 °C for impregnated paper insulated cables and 250 °C for XLPE-insulated cables; and
 - where the earth fault current rating is higher than the symmetrical fault current rating, the symmetrical fault current rating is used.
- f) Where actual installation conditions differ significantly from the standard conditions the sustained current-carrying capacity given in tables 3 to 15 shall be modified by the appropriate rating factors. A quick calculation tool that includes both steady-state rating factors (as given in SANS 10198-4) and a cyclic rating factor (as given in IEC 60853-1) has been developed by Eskom to do this and is available under “Software” on the Distribution Technology website (“Cable Tool”).
- g) Cable networks shall not be planned based upon additional capacity that may be made available due to cyclic load profiles. This is particularly important when considering both primary and secondary feeders under normal and contingency (emergency) conditions.

Notes:

- 1) Additional capacity made available due to cyclic load profiles should only be used for contingencies.
- 2) IEC 60853-1 allows the engineer to capitalise on the fact that cables have a long time constant and thus overloads can be applied for limited periods without the insulating reaching its temperature limit.

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- h) The cable cross-sectional area shall be chosen to suit the network load requirement as well as the prospective symmetrical fault level of the system. The symmetrical and earth fault ratings of the cables are given in tables 3 to 15.

Note: 11 kV and 22 kV secondary cable network symmetrical faults levels are limited to 20 kA and 16 kA respectively (see 240-56062745 for further information).

3.9.2 Route selection

- a) The cable route shall be the most practical and economical route available and where possible cables shall be installed on the northern and western sides of the street.
- b) Electrical services shall be kept on opposite side of road to telecommunication and water services where practically possible.
- c) The cable trench shall be installed within the road reserve at a distance of 1 m from the property boundary.
- d) Provision shall be made for the following:
- e) at joint bays, an additional 1 m of cable shall be provided for each joint;
- f) at ground-mounted equipment terminations, an additional 3 m of cable shall be provided for each cable end; and
- g) at terminations to overhead lines, an additional 12 m of cable shall be provided for each cable end
- h) Generally the majority of cable routes are along roadways and problems of traffic hold-ups caused by trench and joint bay excavations shall be a priority when considering a likely route.
- i) Where space limitations and/or the presence of other underground services within the road reserve prevent the positioning of the trench and joint bays between the road and the adjacent property boundary, consideration may need to be given to the positioning of the trench and joint bays under the road surface.
- j) Where major interruptions to traffic flow in main roads cannot be avoided, open trench excavation may be restricted to shorter lengths (e.g. 100 m) by the local authorities. In such a case, cable pipe ducts (see 3.10 below) shall be installed into which the cable can be pulled at a later stage.
- k) Where severe space limitations exist, consideration may need to be given to the use of underground cable tunnels where multiple feeders / circuits can be installed within a relatively confined space.
- l) The excavation of trial holes shall be used to identify and to establish the positions of existing services on the cable route that may affect the depth of burial or spacing of the cables.
- m) The thermal resistivity of the soil at the proposed cable depth shall be tested in accordance with SANS 10198-5. A minimum of one sample per km shall be tested unless agreed otherwise by the Project Engineer.
- n) The existence of other cables or heat sources along the proposed route shall be ascertained not only from a practical point of view but also because of the possibility of mutual heating, causing de-rating of the cables.
- o) Any bridge crossings shall be designed and approved by a professional civil/structural engineer and shall include precautions to cater for the expansion and vibration of the bridge. The cable bridge crossing shall be designed to ensure the risk of cable theft is mitigated at all costs and that the spare ducts are catered for where required.

3.9.3 Trenches

- a) Where the surface to be excavated will require a permanent re-instatement by a local authority or contractor the surface cut shall be made with an edged tool and shall be cut as cleanly and evenly as possible.

- b) Where the cable route is located parallel to and under the road surface, the edge of the trench and joint bays shall be at least 200 mm from the road kerbing.
- c) MV cable trench details shall be in accordance with D-DT-0854.
- d) Where necessary (i.e. where the excavation is in unstable material), trenches shall be shored with close timber to full depth with a projection of 200 mm above ground level. The shoring shall be suitable for the trench dimensions and the ground conditions and shall only be removed once the cable-surrounding blanket soil has been installed. A professional civil/structural engineer shall design the shoring for excavations that exceed 1,5 m in depth. The design shall take into account the specific ground conditions and details of the trench supports shall be provided.
- e) The Project Engineer shall approve any variations from the depth specified in D-DT-0854. Where the presence of existing services makes it necessary to increase the depth of the trench, the trench shall be returned to nominal depth as soon as is practical. Where the presence of a number of services makes it necessary for deep trenching for a prolonged distance, measures shall be taken to ensure the required cable rating is maintained by back filling with soil having low thermal resistivity (that has been tested in accordance with SANS 10198-5) or by increasing the spacing between circuits.
- f) For road or rail crossings, the depth of cable shall be increased in accordance with D-DT-0854.
- g) Where the cable route is located parallel to and under the road surface, the depth of the cable shall be increased in accordance with D-DT-0854. The cable shall be de-rated accordingly. Unless otherwise specified by the project engineer, concrete slabs (see D-DT-8076) shall be installed above the cable in accordance with D-DT-0854.
- h) Where a change in trench level is necessary, the bottom of the trench shall rise or fall gradually and smoothly.
- i) Trenches shall be kept as straight as possible and the radius of bends shall be tight, however never less than the minimum bending radius of the cable given in table 16.

Table 16: Installation minimum bending radii for MV cables

1	2	3	4
Installation minimum bending radii			
Impregnated paper-insulated cables		XLPE-insulated cables	
Single core	Three-core	Single core	Three-core
20 × D (11 kV) 25 × D (22 kV and 33 kV)	12 × D (11 kV) 15 × D (22 kV and 33 kV)	20 × D	12 × D

Note: D refers to the overall diameter of the cable.

- j) The transport, storage and the use of explosives shall comply with the latest revision of the provision of the Explosives Act No 26 of 1956 and the Explosives Regulations of the Occupational Health and Safety Act No 85 of 1993. A copy of blasting permits issued to workmen and permits issued to the contractor to cover the purchase, storage and transport of explosives shall be given to the project clerk of works.
- k) The material excavated from the trench shall be placed adjacent to the trench leaving a walk-way of at least 500 mm on both sides of the trench. This shall be done in such a manner as to prevent interference or damage to adjacent hedges, trees, drains or other property along the cable route. Where site conditions make this impossible, the excavated materials may, with the approval of the Project Engineer, be removed from the site and returned for re-filling the trench on completion of laying. All surplus material, from whatever source, shall be disposed of by the Contractor.

- l) If steel plates are to be used to allow vehicular access across a trench then they shall be in accordance with a design done by a professional civil/structural engineer. The plates shall be either installed flush with the road and supported on 'I' beams or, if used as a plate across a trench, then the plate shall be pinned to the road surface with suitable spikes to prevent it moving. The plate shall provide a skid-proof surface for motor vehicles.
- m) Excavated trenches that are accessible to the public or that are adjacent to public roads or thoroughfares, or where the safety of persons may be endangered, shall be adequately and effectively protected by a barrier or fence of at least one metre in height and as close to the excavation as is practicable. Warning or danger tapes are not acceptable. Warning illumination or any other clearly visible boundary indicators shall be provided at night or when visibility is poor.
- n) Before installing bedding soil, the trench bottom shall be level, free of loose stones and lightly compacted.
- o) The trench bedding and blanket soil around the cable shall be in accordance with SANS 10198-8 requirements for bedding. A sieve having a mesh size of no larger than 12 mm may be used to sift the excavated soil. Alternatively, suitable bedding and blanket soil having the specified soil thermal resistivity shall be imported. The thermal resistivity of imported soil shall be tested in accordance with SANS 10198-5.
- p) The trench backfilling shall be in accordance with SANS 10198-8.

Note: SANS 10198-5 contains descriptions of the various types of soils and their respective suitability for cable surround soil (bedding and blanket soil) and backfill material.

- q) The bedding soil shall be installed and compacted prior to cable installation. Blanket soil shall be compacted using hand compaction tools. Backfill material shall be compacted in layers of maximum thickness 300 mm. The level of compaction (see D-DT-0854) shall be measured at appropriate intervals using an approved method. The level of compaction shall be measured in accordance with 240-45683927
- r) Warning tape (see D-DT-8013) shall be installed directly above the cable at a depth of 300 mm below natural ground level in accordance with D-DT-0854.
- s) The backfill requirements and required level of compaction for road surface re-instatement shall be in accordance with the relevant road agency specification and shall take precedence over the requirements of D-DT-0854.
- t) All pavements, roads and driveway crossings shall be re-instated to their original state.
- u) Where re-instatement of surfaces cannot be done immediately, a 50 mm compacted crown shall be added above the natural ground level (NGL) to allow for erosion.

3.9.4 Cable pipe ducts

- a) Cable crossing roads or railways shall be installed in PVC/PE pipes (see D-DT-8018). The axial spacing of the pipe ducts shall be at least equal to the cable spacing on the direct-buried sections.

Note: Non-ferrous pipes must be used for single core cables to avoid the effects of magnetic induction.

- b) The internal diameter of the pipe shall be as follows:
- c) For unfilled pipes, a minimum of 30 mm greater than the nominal outside diameter of the cable;
- d) for filled pipes, the internal diameter of the pipe shall be a minimum of 50 mm greater than the nominal outside diameter of the cable for duct runs up to 25 m long;
- e) for longer pipe runs, the internal diameter of the pipe shall be a minimum of 100 mm greater than the nominal outside diameter of the cable.
- f) All pipe ducts shall have a minimum surround of 75 mm of concrete to prevent collapsing or deformation after backfilling. The concrete strength shall be at least 15 MPA. If underground directional drilling has been used to install the pipe ducts, the concrete surround is not required.

Note: Underground directional drilling equipment is used to drill holes that correspond to the pipe diameter being installed and is the Eskom preferred method for trenchless road, river or rail crossings.

- g) The points of cable entry or exit of pipe ducts are susceptible to ground subsidence and therefore where cables enter or exit pipes they shall be supported on rot-proof bags containing a weak sand-cement mix (30:1) for a distance of approximately 0,5 m into the trench.
- h) Generally 110 mm (see D-DT-8018) diameter pipes are suitable for fibre optic cable ducts.
- i) Pipe ducts shall, where possible, project a minimum of 1 m beyond the kerb lines (or other services) so as to completely clear the surface of the carriageway. For dual carriageways and divided highways the pipe ducts shall continue in an unbroken line under the central divider. For railway crossings, the pipe ducts shall project a minimum of 3 m beyond the outermost rails.
- j) PVC/PE pipes may be bent in accordance with the manufacturer's instructions however the radii shall not be less than the cable minimum bending radii given in table 16.
- k) All pipe ducts shall be sealed until the cable is installed.
- l) Before commencing to draw a cable into a pipe duct, a cylindrical wire brush followed by a mop and a close-fitting mandrel shall be drawn through to clean out any dirt and ensure that the pipe duct has not collapsed.
- m) Pipe ducts over 3 m in length shall be filled with a bentonite, water and sand mix. The mixing ratios and procedure shall be as supplied by the supplier. The mix shall be kept in position by sealing the end of the pipe duct where the cable enters and exits. Pipe ducts less than 3 m in length shall be filled with backfill material.
- n) Spare pipe ducts shall be installed for road, railway, river and other service crossings. The number of spare pipe ducts shall be determined by the Project Engineer.
- o) Spare pipe ducts shall always be sealed at the ends to prevent ingress of water, vermin and backfill material.
- p) Cable crossing small/shallow rivers shall be in accordance with D-DT-0895.
- q) Cable crossing streams where the base of the stream consists of bedrock shall be in accordance with D-DT-0896.

3.9.5 Cable tunnels

- a) When direct burial installation in cable trenches is not possible, cable shall be installed in cable tunnels in accordance with D-DT-0897.

3.9.6 Cable installation

- a) Contractors installing cable shall be in possession of all parts of SANS 10198 and shall work according to that code of practice and this standard. Where a situation arises that is not covered by SANS 10198 or this standard, the contractor shall consult the Project Engineer.
- b) The MV cable depth and positioning within the trench shall be in accordance with D-DT-0854.

Notes:

- 1) Where more than one cable is installed in the same trench, a minimum spacing of 300 mm between three-core cables and 450 mm between single-core trefoil circuits should be maintained where possible. De-rating factors are applicable.
- 2) When trenching in rocky ground, a minimum of 150 mm should be kept between the cable and the trench side wall in order to prevent damage to the cable when the trench is back-filled.
- c) Cable laying and installation shall be in accordance with SANS 10198-2 and SANS 10198-8 and, unless otherwise specified, shall be by direct burial in accordance with D-DT-0854.

Note: The key objectives of correct cable installation are the following:

- 1) Cables are not over bent;
- 2) Cables outer sheaths are not damaged or scratched; and

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- 3) Cable kinks or twists are prevented.
- d) MV and LV cable laid in the same trench shall be installed in accordance with D-DT-0854 sheet 5.
- e) Cable crossing roads or railways shall be installed in pipe ducts (see D-DT-8018).
- f) Cables running parallel to or crossing other services shall be installed in accordance with D-DT-0854 sheet 7.
- g) Prior to cable pulling, pipe ducts shall be fitted with bell mouths at both ends to prevent damage to the cable and a suitable lubricant shall be applied to the inside of the pipe.
- h) Prior to cable pulling, the cable shall be inspected for damage and both ends checked to verify that the cable ends were suitably capped. Damaged or uncapped cable shall not be installed.
- i) Prior to cable pulling, the cable inner end shall be cut free from the cable drum flange.
- j) The cable outer end shall be fitted with either a cable pulling sock or a cable pulling eye.

Note: A cable pulling sock applies tension to the cable outer layers, and may sometimes result in stretching or sliding of these layers over the insulated cores. This can happen with impregnated paper-insulated cables. A cable pulling eye applies tension directly to the conductors, and is preferred for larger cables or longer pulling lengths. A combination between both types of pulling system is often used.

- k) A swivel (fitted with a bearing to reduce friction) shall be used between the pulling rope and the cable pulling sock or pulling eye.
- l) When nose-pulling the cable: the pulling tension shall not exceed the manufacturer's recommendations.
- m) Cables shall be pulled either by hand (only where the conditions are suitable and by using a team and leader) or by using a winch.
- n) When a winch is used: it shall be fitted with a reliable and accurate dynamometer whether the cable is nose pulled or bond pulled and it shall be monitored throughout the pull.
- o) Cable rollers shall be carefully positioned in the trench in the line that the cable is to follow. The rollers shall be spaced so that there is no appreciable cable sag between rollers. A spacing of 2 m is normally suitable but this distance shall be reduced if appreciable sagging is seen to occur. Where appropriate; skid plates or corner rollers shall be used.
- p) Where cables are laid in trefoil they shall be tied together with "sisal" string at 1 m intervals to prevent any movement during backfilling.
- q) The design of flexible or rigid cable systems in shafts and tunnels shall be according to the cable manufacturer's specification.
- r) Laid cable that is not immediately jointed or terminated (whether prior to being laid, already laid, still on the cable drum or in transport) shall be sealed by means of cable end caps (see D-DT-8015).

Note: Only in emergency conditions (i.e. only if no end caps or heat shrink equipment is available) may 'DENSO' tape be used to temporarily seal the end of a cable (see D-DT-3213). If DENSO tape has been used, the cable shall be capped within 24 hours.

- s) Cable end caps shall be inspected for damage prior to and after cable laying. Damaged end caps shall be removed and replaced.
- t) Cable outer sheaths damaged during installation shall immediately be repaired using a cable repair sleeve (see D-DT-8077).

3.9.7 Cable terminations to overhead lines

- a) Outdoor cable terminations (see D-DT-8005/6) shall be used to terminate MV cables onto overhead lines as follows:

Note: Three-core outdoor cable terminations in accordance with 240-56030619 are supplied with 1,6 m tail lengths that can be trimmed back to 1 m if required.

- b) For cables supplied from an overhead line, the cable termination arrangement shall be in accordance with D-DT-0851 and D-DT-0852. The cable shall be protected from lightning surges using distribution class surge arresters (see D-DT-3100). A set of cut-outs (fitted with solid links) or disconnectors (see D-DT-1850 for single pole structures using 1300 mm cross-arms or D-DT-1874 for H-pole structures using 2400 mm cross-arms) shall be installed between the cable termination support structure and the overhead line.

Notes:

- 1) D-DT-0851 includes various sheets for the common types of overhead line structures that may be encountered when terminating a MV cable – including single pole and H-pole structures.
- 2) Cut-outs with solid links (see D-DT-0291 and D-DT-3086) are 200 A rated.
- 3) Disconnectors (see D-DT-0292 and D-DT-3087) are 600 A rated.
- c) For cables feeding an overhead line from a step-down sub-station or switching station, the cable termination arrangement shall be in accordance with D-DT-0850 and D-DT-0852. The cable shall be protected from lightning surges using station class surge arresters (see D-DT-6215/6).

Note: D-DT-0850 includes various sheets for the common types of overhead line structures that may be encountered when terminating a MV cable – including single pole and H-pole structures.

- d) The outdoor cable termination main earthing conductor shall be connected to the steel cable support bracket / cross-arm using an M12 × 65 mm long bolt, nut and washers (see D-DT-3082).
- e) The cable termination crutch (break-out boot) shall be at least 4 m above the ground level.
- f) The cable shall be securely strapped to the pole at 1 m intervals using 12 mm stainless steel strapping (see D-DT-3131) and strap buckles (see D-DT-3110). Additional off-cuts from the cable the outer sheath shall be applied around the cable in order to protect the cable outer sheath from being damaged by the strapping.
- g) An anti-climbing measure / device shall be installed consisting of barbed-wire (see D-DT-3170) wrapped around the pole and secured using galvanised steel staples (see D-DT-3129). The barbed wire shall be installed at least 3 m above ground level. Additional off-cuts from the cable outer sheath shall be applied around the cable in order to protect the cable outer sheath from being punctured by the barbed wire.
- h) An electrical warning / hazard sign (see D-DT-3202) shall be fitted to the pole. The warning sign shall be installed immediately below the barbed wire anti-climbing device.
- i) The cable shall be protected at the base of the pole using a galvanised 3 m steel pipe (see D-DT-8023). The bottom of the pipe shall be buried at a depth of 200 mm.

Note: The galvanised steel 'kicker' pipe is required to protect the cable at the base of the pole from mechanical damage as well as grass-fires. XLPE-insulated cables have a PE outer sheath which is not flame retardant.

- j) At least 2 m of additional cable slack shall be provided at the base of the pole.
- k) The cable termination support structure (see D-DT-0852) shall consist of the following components:
 - 1) Cable support bracket (see D-DT-3207) for single-pole structures (see D-DT-0852 sheets 1 and 2);
 - 2) 2400 mm steel channel cross-arm (see D-DT-3000) for H-pole structures (see D-DT-0852 sheets 3 and 4);
 - 3) M20 x 350 mm threaded rod assemblies (see D-DT-3015) used to secure the cable support bracket or steel cross-arm to the pole(s);
 - 4) 22 kV post insulators (see D-DT-3017) used to support the cable termination tails and conductor jumpers;

Note: Each 22 kV station post-insulator is supplied with a 40 x 6 x 240 mm tinned copper bar, set screws, nuts and washers. The copper bar makes provision for the discreet connection of the M16 cable termination lug, M16 ACSR jumper bi-metallic lug and the M12 surge arrester jumper lug without the need for back-to-back / doubled-up connections.

- l) Earthing pins (see D-DT-8028) for attaching portable earthing equipment when earthing the MV cable terminated onto the overhead line;

Note: The earthing pin has an M12 threaded section for attachment to the M12 stem of the 22 kV station post insulator.

- 1) 11 kV / 22 kV surge arresters (see D-DT-3100 / D-DT-6215/6);
 - 2) 16 mm² copper PVC-insulated wire jumpers (see D-DT-3137) used to connect the cable termination ends to the surge arresters using tinned copper lugs having M12 fixing holes (see D-DT-3102); and
 - 3) Bi-metallic lugs having M16 fixing holes (see D-DT-3166) used to connect the covered ACSR jumpers from the overhead line structure.
- m) Where the MV equipment (e.g. mini-substation or ground-mounted transformer) supplied from the cable terminated to the overhead line is located > 10 m away from the terminal pole, a three point star or trench electrode with 4 earth rods (spikes) earth electrode shall be installed for the surge arresters. The electrode shall be in accordance with the requirements of 240-130615754 (see D-DT-0642) and the following:
- 1) The earth electrode shall comprise bare 16 mm² copper conductors (see D-DT-3139) and 1,5 m copper vertical earth rods (see D-DT-3091). The spacing "L" between the vertical earth rods shall be determined in accordance with the requirements of 240-130615754. The copper conductors shall be buried at least 0,5 m deep. The earth electrode resistance shall not exceed 30Ω.
 - 2) An insulated 16 mm² copper earth conductor (see D-DT-3137) shall be used from the steel support bracket / cross-arm to the earth electrode. The earth conductor shall be secured to the pole using galvanised steel staples (see D-DT-3129) at 0,5 m intervals;
 - 3) The earth conductor shall be connected to the steel cable support bracket / cross-arm using a tinned copper lug having an M12 fixing hole (see D-DT-3102);
 - 4) The bare copper conductors shall be connected together using a non-butt ferrule (see D-DT-3076); and
 - 5) The copper conductors shall be connected to the earth rods using a cable to rod clamp (see D-DT-3093) or an exothermic welded connection.

3.9.8 Joint bays

- a) The trenches on either side of the joint bay shall be properly backfilled prior to jointing for a distance of at least 10 m in both directions.
- b) A 2 m long × 1,5 m wide × 1,2 m deep joint bay shall be provided for each cable joint.
- c) Prior to jointing it shall be ensured that adequate measures have been taken to stop the ingress of water into the joint bay and that adequate measures have been taken around the joint bay to prevent rain or run-off water entering the joint bay. A submersible pump shall be available at all times to pump out any water or seepage that may enter the joint bay.
- d) The joint bay shall be maintained free from dust, dirt and water. Where necessary, the bottom and sides of the joint bay should be draped with appropriate covers.
- e) Cables shall be jointed using water-blocked (i.e. filled) cable joints (see D-DT-8007 for impregnated paper-insulated cable joints and D-DT-8008 for XLPE-insulated cable joints). When an impregnated paper-insulated cable is to be jointed to an XLPE-insulated cable, a water-blocked transition joint shall be used (see D-DT-8021).
- f) Conductors shall be connected using mechanical torque shear ferrules with solid centres in accordance with SANS 61238-1.

- g) Joint bays shall be backfilled in accordance with D-DT-0854. The bedding soil shall be installed and compacted prior to joint installation. Blanket soil shall be compacted using hand compaction tools. Backfill material shall be compacted in layers of maximum thickness 300 mm. The level of compaction (see D-DT-0854) shall be measured at appropriate intervals using an approved method. The level of compaction shall be measured in accordance with 240-45683927.

3.9.9 Fibre-optic cable duct and draw pits for primary cable feeders

- a) If required for primary cable feeders, a Ø32/26 mm OD/ID HDPE duct (see D-DT-8081) shall be installed for the fibre optic cable (protection).
- b) The position of the HDPE fibre optic cable duct (protection) within the trench shall be in accordance with D-DT-0854.
- c) Draw pits in accordance with D-DT-0894 (see D-DT-8080) shall be installed at positions along the cable route determined by the Project Engineer.

Note: Refer to NRS 088-2 for guidelines on underground fibre optic cable installations.

- d) In high-risk areas, draw pits may be installed at least 100 mm below the normal ground level. In this case, the ground shall be re-instated on top of the draw pit cover.

Note: The use of GPS co-ordinates is essential in order to locate draw pits for future access.

- e) No duct couplings or joints shall be used between draw pits.

3.9.10 Cable transportation and storage

- a) Cable shall be transported and stored in accordance with SANS 10198-6.
- b) Cable ends on cable drums shall be sealed by cable end caps (see D-DT-8015).

Notes:

- 1) SANS 97 states that cable shall be sealed "by means of a metal cap plumbed onto the metal sheath or by other acceptable means to prevent the ingress of air or moisture".
- 2) SANS 1339 states that cable shall be sealed "by means of a heat shrink cap or by other acceptable means, to prevent the ingress of moisture".
- c) Cable end caps shall be regularly inspected for damage or cracks that may have occurred after any handling, transport, storage. Damaged end caps shall be removed and replaced.
- d) Cable on damaged drums shall be re-drummed on a drum having a barrel diameter no smaller than the original to avoid over bending.
- e) Drums shall be stored on a hard-surface that has an efficient draining system.
- f) Cable drums shall be so arranged that they are easily identifiable, accessible and that they may be released on a "first in – first out" basis.
- g) Drums shall be rolled only in the direction indicated on the drum.
- h) Drum bolts shall be tight at all times.
- i) Before off-loading, drums shall be checked for damage.

Note: Any defects should be reported to the site supervisor and should include a written statement and photograph. Experience has shown that this is the best method of insuring a successful claim for the damages from the transporters insurance company

- j) Drums shall be lifted by a crane or forklift of suitable size and carrying capacity.

Note: The gross mass is indicated on the cable drum.

- k) If a crane is used, the correct lifting bar (spindle) and slings shall be used and these shall be in good condition. A spreader bar shall be used to prevent the slings from damaging the drum flanges.

- l) If a fork-lift is used, the forks shall extend to both flanges to ensure that the weight of the drum is evenly distributed on both flanges. If necessary, fork extensions shall be used. Care shall be taken in order to prevent the forks from damaging the cable drums (battens and flanges). The forks of the forklift shall not be used to push or pull the cable drum along the ground.
- m) Cable drums shall not be dropped or laid flat.
- n) If rolled off the truck, the maximum ramp slope shall be 1 in 4.
- o) MV cable drums shall be transported using a cable trailer. If this is not possible, drums may be transported by truck.
- p) When transporting by truck, all cable drums shall be secured (e.g. chained) to the truck bed to prevent them from rolling or sliding.

3.9.11 Cable anti-theft measures

In order to assist with cable theft forensic investigations and proof of cable ownership, cable and cable conductor shall be marked in accordance with the requirements of 240-56063792.

For underground cable theft mitigation implementation, the following steps need to be considered:

- a) An investigation needs to be performed for each cable theft case to determine the mode of cable theft
- b) The mode of cable theft categories will be:
 - 1) dig open, cut and remove on cable route;
 - 2) partially open at cable cut position, cut and pull out on cable route;
 - 3) theft at cable outdoor terminations; and
 - 4) theft at cable indoor terminations.
- c) Consider one of the following theft mitigation methods for implementation:
 - 1) Concrete covering slab on top of cable;
 - 2) Cable clamping methods every 2 m to 10 m on cable route;
 - 3) Secure piping at outdoor terminations in combination with concrete slabs;
 - 4) Cable theft alarm technologies in combination with armed/Eskom response notification;
 - 5) Surveillance camera technologies with armed/Eskom response notification; and
 - 6) For MV cable systems only - Aluminium cable options may be considered to investigate and test if the area of concern is less prone to aluminium cable theft.
- d) Once the theft mitigation method or methods have been selected per case, initiate a project to perform a commercial enquiry to evaluate and award a suitable solution.

3.10 Cable accessories, jointing and terminating

- a) Cable accessories shall comply with the requirements of 240-56030619. This specification covers the requirements for the following accessories:
 - 1) cable joints (see D-DT-8007, D-DT-8008 and D-DT-8021);
 - 2) cable terminations (see D-DT-8005 and D-DT-8006);
 - 3) shrouds (see D-DT-8011);
 - 4) screened separable connectors with or without screened surge arresters (see D-DT-8017);
 - 5) trifurcating termination kits (see D-DT-8017 and D-DT-8004);
 - 6) indoor surge arrester (see D-DT-8010);

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- 7) cable repair sleeves (see D-DT-8077); and
- 8) cable sealing end-cap (see D-DT-8015)
- b) All accessories shall be installed according to the manufacturer's installation instructions and SANS 10198-10 and SANS 10198-11. MV cable jointers shall be trained and accredited based upon SANS 10198-10 and SANS 10198-11.
- c) All three-core cable terminations shall be made using the "top-down" method in order to maximise the length of the screened tail to allow for core crossing in the screened section of the termination if necessary.
- d) All MV cables shall be connected to equipment with lugs having M16 fixing holes.
- e) Prior to jointing or terminating of impregnated paper-insulated cable, a moisture test ('crackle test') shall be carried out in accordance with test method SANS 6281-4 on the metallic woven fabric tape and the outermost and innermost papers on each core. If any test shows wet paper (i.e. frothing on the surface of the hot medium together with audible crackling), cut back the cable to where the paper is dry. If moisture is present throughout the cable, it shall be replaced. No joint or termination shall take place using moisture contaminated cable.

Notes:

- 1) It is important that the temperature of the hot medium should be verified before submerging the papers.
- 2) Moisture test kits are available from some suppliers of Eskom accepted cable. Moisture test kits are supplied complete with carry case, paraffin wax, thermometer, burner assembly with container, gas cartridge and instructions. The test can be done using either clean cable impregnating compound or paraffin wax and requires pliers or tweezers to handle the paper.
- 3) Should only a small number of bubbles appear on the surface of the test medium, this is an indication of air bubbles on the impregnated paper and not necessarily moisture. The presence of moisture will result in a series of bubbles rising to the surface of the test medium for a number of seconds (accompanied by a distinctive crackling sound and foaming), until all moisture has been removed.
- f) Each accessory is provided with a labelling system (identification tag) that indicates the manufacturer and part number and allows the date of installation to be indicated. The date of installation shall be indicated on the label and attached to the cable adjacent to the accessory.

3.11 Application for trifurcating kits

There are different installations to be considered when to use trifurcating joints or trifurcating kits. Below are the installations requirements based on the different sizes and types of cables installed.

3.11.1 Three core XLPE up to 185 mm² Cu/ Al screened terminations

This option is applicable to indoor termination where a screened 3C XLPE cable termination is required for all voltage (11 kV, 22 kV and 33 kV). This option is applicable for 3 core cables with conductor size up to and including 185 mm² Cu or Al. In this instance, one would be required to make use of a Trifurcating kit as per DDT 8017 with Screened separable connector.

3.11.2 Three core XLPE up 300 mm² Cu/ Al screened terminations

This option is applicable to indoor termination where a screened 3C XLPE cable termination is required for all voltage (11 kV, 22 kV and 33 kV). This option is applicable for 3 core cables with conductor size of 300 mm² Cu or Al. Due to the physical size and minimum bending radius of a 300mm² cable; it becomes almost impossible to terminate these cables into the cable compartment of an RMU. For this purpose; a Trifurcating joint can be used to join the 3 core cable into 3 x 1 core cables which can be terminated using a screened separable connector.

3.11.3 Single core cables XLPE

This option is applicable to indoor termination where a screened 1C XLPE cable termination is required for all voltage (11 kV, 22 kV and 33 kV). This option is applicable for 1 core cables with conductor size up to 300mm² Cu or Al. A screened separable connector shall be used where the equipment has type C bushings.

3.11.4 Three core PILC terminated using screened separable connector

For the purpose of terminating PILC cables less the following shall be done for three core PILC cables:

- a) A PILC to XLPE transition joint (D-DT 8021) shall be used to transition from 3 core PILC to 3 core XLPE cable.
- b) The steps mentioned in Clause 3.11.1 to clause 3.11.3 shall be followed depending on the size of cable.

3.12 Application for trifurcating joints

There are different installations to be considered when to use trifurcating joints. Below are the installations requirements based on the different sizes and types of cables installed.

3.12.1 Three core XLPE greater than 185 mm² Cu/ Al

This option is applicable to indoor termination where a screened 3C XLPE cable termination is required for all voltage (11 kV, 22 kV and 33 kV). This option is applicable for 3 core cables with conductor size of 300 mm² Cu or Al. Due to the physical size and minimum bending radius of cables greater than 185 mm²; it becomes almost impossible to terminate these cables into the cable compartment of an RMU. For this purpose the following shall be done for three core XLPE cables:

- a) A Trifurcating joint can be used to join the 3 core cable into 3 x 1 core cables which can be terminated using a screened separable connector.
- b) The 1 core XLPE shall be terminated using a screened separable connector to equipment with type C bushing.

3.12.2 Single core cables XLPE

This option is applicable to indoor termination where a screened 1C XLPE cable termination is required for all voltage (11 kV, 22 kV and 33 kV). This option is applicable for 1 core cables with conductor size up to 300 mm² Cu or Al. A screened separable connector shall be used where the equipment has type C bushings.

3.13 Lugs and ferrules

- a) Mechanical torque shear lugs and ferrules that comply with the requirements of SANS 61238-1 shall be used for connecting conductors and are supplied and included with each cable accessory.
- b) Mechanical torque shear lugs and ferrules shall be installed using the correct socket/allen wrench and appropriate holding tool.
- c) Compression lugs and ferrules (see D-DT-3102 and D-DT-8018) shall comply with the requirements of SANS 61238-1.
- d) Compression lugs and ferrules shall be compressed using a hexagonal die crimping system. The crimping dies shall be in accordance with SANS 1803-1.

3.14 Step-down substations

- a) The step-down substation design shall generally be in accordance with 240-71062174.
- b) Medium-voltage cabling within the step-down substations shall comply with the requirements of 240-56063710.

3.15 Switching stations

3.15.1 Civil requirements

- a) The switching station building shall be a type 1 design in accordance with D-DT-5238.
- b) Yard stone may not be required. The installation of a fence will be required in high-risk areas and for protecting servitudes.
- c) The following notices in accordance with SANS 1186 shall be provided in terms of the OHS Act:
- d) to prohibit unauthorised persons from entering the premises (see D-DT-6072);
- e) to prohibit unauthorised persons from handling or interfering with the electrical machinery (see D-DT-6073);
- f) to warn of electric shock hazards (D-DT-6072);
- g) to detail the procedure to follow in case of fire (see D-DT-6073); and
- h) to give directions on how to resuscitate persons suffering from the effects of electric shock (see D-DT-6073).
- i) The notices that shall be used are described in 240-71062174.
- j) Locks shall be fitted to switching stations in accordance with DST 34-616.

3.15.2 MV equipment requirements

- a) Metal-clad switchgear shall comply with the requirements of DSP 34-1157 and DSP 34-1692.
- b) All cables shall be terminated at the switchgear using a shrouded termination comprising an indoor termination kit and shroud (see D-DT-8005/6 and D-DT-8011). The minimum clearances shall be in accordance with the requirements of SANS 876.
- c) The cable termination shall be supported at the switchgear by a cable support clamp (see D-DT-8019) provided with the switchgear (see D-DT-5240 sheet 20).
- d) The cable entry through the gland plate shall be sealed and protected using a rubber grommet (see D-DT-8027) provided with the switchgear (see D-DT-5240 sheet 20).
- e) The armouring and/or lead sheath of the three-core cable shall be bonded to the switching station earth at the switchgear earth terminal provided (see D-DT-5240 sheet 20).

3.15.3 Cabling from indoor switchgear to an overhead line

- a) The cable cross-sectional area shall be chosen to suit the rating of the overhead line conductor as well as the 3 second prospective symmetrical fault level of the system. Table 3 to Table 15 indicates the minimum cable size to be used based upon prospective fault level considerations.
- b) The cable termination to overhead line connection shall be in accordance with D-DT-0850 (see 3.10).
- c) Station class surge arresters (see D-DT-6215 and D-DT-6216) shall protect the cable termination at the overhead line connection.

Notes: Station class surge arresters without disconnecting devices are used for the following reasons:

- 1) Under earth fault conditions temporary over voltages (TOVs) are maximum closest to the source and therefore surge arresters with an MCOV equal to U_m are preferred at switching station riser pole applications.
- 2) A failed surge arrester will result in a permanent line fault requiring immediate replacement of the surge arrester thereby preventing catastrophic failure of the cable or connected switchgear as a result of surges.
- d) Where a cable is used for connecting the switchgear to the overhead line, MV indoor shrouded surge arresters (i.e. Type 2 for withdrawable switchgear) or MV indoor screened separable connector surge arresters (i.e. Type 4 for fixed pattern switchgear) in accordance with 240-56030619 (see D-DT-8010 and D-DT-8017) shall be installed in the switchgear at the cable terminal connection point.

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Note: When specified in schedule A of the switchgear enquiry document by the design engineer, 630 A or 1250 A feeder panels are fitted with MV indoor surge arresters as follows (for further information, refer to 240-56063710):

- 1) surge arresters are in accordance with D-DT-8010 for withdrawable switchgear and D-DT-8017 for fixed pattern switchgear;
- 2) a separate and accessible point of attachment is provided for each surge arrester;
- 3) it is possible to disconnect the surge arresters to facilitate over-voltage testing of the switchgear at the commissioning stage;
- 4) the designed clearance requirements are not reduced by virtue of the fact that the surge arresters are fitted.

3.15.4 Protection, local control and indication requirements

- a) Protection, local control and indication schemes shall comply with the requirements of 240-61266445.
- b) In addition to the local indication requirements of 240-61266445, a white indication lamp (cluster LED type) shall be provided to indicate that the supervisory isolating switch (SIS) is in the OFF position.
- c) Protection, local control and indication schemes shall be mounted onto the metal-clad switchgear front panel.
- d) Primary cable feeders from source substations shall be equipped with current differential protection or directional over-current and earth fault protection.
- e) Secondary cable feeders shall be equipped with over-current and earth fault protection.

3.15.5 Tele-control requirements for switching stations

Switching stations shall be equipped with a remote terminal unit (RTU) that provides the following remote indications, controls and alarms.

- a) Analogue indications:
- b) amperes per feeder;
- c) kilovolt ampere reactance per feeder;
- d) voltage per busbar section; and
- e) two off d.c. voltage and one off d.c. current per battery bank.

Notes:

- 1) Transducers are to use spare protection or measurements cores when-ever possible. When transducers are used in protection cores and the fault current exceeds $10 \times I_n$, then interposing current transformers are required.
- 2) Transducers using current inputs from shared protection cores will be terminated at the end of the circuit to RSF1 terminals (or equivalent) for ease of installation and isolation purposes.
- 3) Current and voltage transducer secondary output will be from 0 mA to 5 mA and reactive power transducers will be from -5 mA to + 5 mA.
- a) Battery chargers shall be equipped with the required transducers. The transducers are already fitted within the charger unit and only their outputs shall be taken to the RTU.
- b) Status indications:
- c) busbar section earthed;
- d) circuit-breaker open/closed;
- e) circuit-breaker earthed;
- f) circuit-breaker racked out; and
- g) supervisory isolating (SIS) control switch position.
- h) Alarms:

- i) a.c. fail;
- j) door alarm;
- k) "circuit-breaker not healthy" per feeder;
- l) "protection not healthy" per feeder;
- m) "protection operated" per feeder;
- n) "supervisory isolated" per feeder;
- o) battery charger fail;
- p) battery bank fail.
- q) The alarms shall be grouped within the RTU and not on the protection panels.
- r) The OFF positions of all control switches shall be monitored. A multiplication relay shall be used where no spare contacts are available.
- s) Each fused protection circuit shall have a "d.c. fail" relay. All "d.c. fail" alarms shall be grouped at the RTU on a per bay basis.
- t) The "breaker not healthy" alarm indication shall consist of the following when applicable:
 - 1) "close not healthy";
 - 2) circuit-breaker or spring not charged;
 - 3) low pressure (SF6 gas/oil); and
 - 4) local or remote (LOR) in the "OFF" or "Local" positions.
- u) The "protection not healthy" alarm indication shall consist of the following when applicable:
 - 1) pilot supervision (when available);
 - 2) relay supervision (when available); and
 - 3) d.c. fail.
 - 4) Controls:
 - 5) circuit-breaker "open"; and
 - 6) circuit-breaker "close".

3.15.6 A.C./D.C. supply

The design of the low-voltage a.c./d.c. distribution within the switching station building supply shall comply with the requirements of 240-91190294.

- a) A 2 × 24 distribution board shall be used. The building domestic a.c. supply shall also to be fed from this board, for example, socket-outlet circuits and lights.
- b) The battery charger shall comply with the requirements of 240-53114314.
- c) The d.c. supply voltage shall be 110 V for Distribution and 220 V for Transmission.
- d) The d.c. system shall provide a standby capacity of 12 h taking into account the supply required by the following items:
 - 1) internal arc protection on switchgear panels;
 - 2) protection schemes;
 - 3) supervisory (RTU);
 - 4) emergency lighting (fluorescent lights); and
 - 5) circuit-breaker spring rewind motors.

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3.16 Free standing RMUs

- a) Free standing RMUs shall consist of non-extensible switchgear that is supplied from secondary cable feeders.
- b) Non-extensible RMU (see D-DT-8060) may have one of the following configuration arrangements:
 - 1) 3-way free-standing RMU that consists of two incoming load-break, fault-make isolators and a single outgoing fused load-break, fault-make isolator for supplying smaller customers that take bulk supply at MV. The “2R-1F” RMU shall comply with the requirements of 240-56030406;

Note: The RMU outgoing fused load-break, fault-make isolator (tee-off) provides over-current (short-circuit) protection for the downstream MV customer. The two incoming load-break, fault-make isolators make provision for the RMU to be installed on a ring feeder.

- c) 3-way free-standing RMU that consists of two incoming load-break, fault-make isolators and a single outgoing circuit-breaker for supplying larger customers that take bulk supply at MV or mini-substation feeders. The “2R-1B” RMU shall comply with the requirements of 240-56030406;

Note: The RMU outgoing circuit-breaker (tee-off) and protection relay combination provides over-current and earth-fault protection for the downstream MV customer or mini-substation feeder. The two incoming load-break, fault-make isolators make provision for the RMU to be installed on a ring feeder.

- d) 4-way free-standing RMU that consists of two incoming load-break, fault-make isolators and two outgoing fused load-break, fault-make isolators or two outgoing circuit-breakers for supplying mini-substation feeders. The “2R-2F” or “2R-2B” RMU shall comply with the requirements of 240-56030406; and
- e) 3-way or 4-way free-standing RMU that consists of either three or four load-break, fault-make isolators for network switching points. The “3R” or “4R” RMU shall comply with the requirements of 240-56030406.

Notes:

- 1) The switchgear configuration arrangement is specified using an abbreviation for each function with a hyphen separating each switching device.
- 2) Load-break, fault make isolators are classified as “switch-disconnectors” or “R” functions in accordance with 240-56030406.
- 3) Fused load-break, fault make isolators are classified as “switch-fuse combinations” or “F” functions in accordance with 240-56030406.
- 4) Circuit-breakers are classified as “B” functions in accordance with 240-56030406.
- 5) Example – a RMU that contains two switch-disconnector functions and two circuit-breaker functions would be classified as a 4-way free-standing RMU with a designation of “2R-2B”.
- f) For outdoor applications, free-standing outdoor switchgear (i.e. RMUs within an outdoor kiosk / enclosure) shall be installed.
- g) The supply arrangement for customers that take bulk supply at MV shall comply with the requirements of 240-56062831. Where switchgear is installed within an MV LPU intake chamber (e.g. building basement), indoor switchgear (see D-DT-8060) shall be used.

Note: In general, indoor switchgear is supplied without an outdoor kiosk and is provided with a raising base (pedestal) for the cable support clamps (see D-DT-8019), gland plate fitted with rubber grommets (see D-DT-8027) and an arc venting system to meet the internal arc classification requirements in accordance with 240-56030406.

- h) At 11 kV, cables shall be terminated at the switchgear with an indoor termination kit and screened separable connectors (see D-DT-8017). At 22 kV, cables shall be terminated with an indoor trifurcating kit and screened separable connectors (see D-DT-8017). Refer to clause 3.11 for the installation requirements for trifurcating kits and joints.

Note: Where 22 kV impregnated paper-insulated cables are used, this will require the use of transition joints to XLPE-insulated cable at the sub-switching station (see D-DT-8021).

- i) Cables shall be connected at the switchgear using torque shear lugs with M16 fixing holes (see D-DT-3102).

Note: The torque shear lugs and/or ferrules are supplied as part of the termination and/or joint kit.

- j) When applicable, the protection, local control and indication requirements shall be in accordance with 240-56030406.
- k) When applicable, the load monitoring, tele-control and distribution automation requirements for free standing RMUs shall be in accordance with 240-56030406. The IRTU requirements shall be in accordance with the tele-control requirements specified in 240-97690165.

Notes:

- 1) The Distribution specification 240-56030406 includes the tele-control requirements for remote indications, controls and alarms.
- 2) The RTU fitted Ring main units are specified in D-DT-8061.
- l) Where 24 kV rated equipment is supplied from an overhead line by means of a cable, screened surge arresters in accordance with 240-56030619 shall be installed at the equipment terminals (see D-DT-8017).

3.17 Mini-substations and ground-mounted transformers

The low voltage distribution systems derived from mini-substations and ground-mounted transformers are described in 240-56062752 and 240-56030637.

3.17.1 Type A mini-substations

- a) Type A mini-substations (see D-DT-8052 and D-DT-8053) with ratings of 200 kVA, 315 kVA, 500 kVA and 1000 kVA shall comply with the requirements of 240-56062752.

Note: The use of 500 kVA and 1000 kVA Type A mini-substations is generally limited to applications where the mini-substation is supplied by a short length of cable from an overhead line or is the last mini-substation on a radial cable feeder.

- b) Type A mini-substations shall have a built-in transformer overload protection device that trips the LV main circuit breaker supplying the LV busbars in the event that the transformer top oil temperature exceeds 105 °C.

Note: The transformer overload protection setting device is sealed to prevent unauthorised access.

- c) The MV cables are terminated directly onto the transformer bushings by means of screened separable connectors (see D-DT-0860). Cables shall be terminated with an indoor trifurcating kit and screened separable connectors (see D-DT-8017). Extensible screened connectors shall be used if the Type A mini-substation is supplied by means of a ring feeder.
- d) Where one or more mini-substations are supplied from a length of cable connected to an overhead line, the following shall apply in order to prevent ferro-resonance occurring as described in annex B:
- e) Where the cable length does not exceed the maximum permitted length given in tables 9 and 10 for the respective transformer rating, the cable shall be terminated at the overhead line in accordance with D-DT-0851. In this case isolation of the mini-substation/s is achieved by opening the cut-outs (fitted with solid links) under off-load conditions. The earthing shall be in accordance with D-DT-0855 sheet 3;
- f) Where the cable length exceeds the maximum permitted length given in tables 17 and 18 for the respective transformer rating, the cable shall be terminated at the overhead line in accordance with D-DT-0851 and shall be connected to a ring main unit having a three-phase switch-fuse combination (e.g. "2R-1F" – see D-DT-8060). In this case, isolation of the transformer/s is achieved by opening the three-phase switch of the switch-fuse combination. The earthing shall be in accordance with D-DT-0855 sheet 4.

Note: In situations where there is more than one mini-substation transformer and more than one cable length, the equivalent value of X_m is calculated from the individual values of X_m in parallel. The total cable capacitive reactance must be at least 1.6 times the equivalent value of X_m . The calculation is described in annex B.

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Table 17: Maximum permitted 11 kV cable length for installed transformer kVA

1	2	3	4	5	6
Transformer (kVA)	Cable length (metres)				
	Paper-insulated cable			XLPE-insulated cable	
	25 mm ²	50 mm ²	95 mm ²	50 mm ²	95 mm ²
100	30	26	18	32	26
200	63	52	38	65	52
315	95	80	60	100	80
500	155	130	95	160	130
1000	315	260	190	330	260

Table 18: Maximum permitted 22 kV cable length for installed transformer kVA

1	2	3	4	5	6
Transformer (kVA)	Cable length (metres)				
	Impregnated paper-insulated cable			XLPE-insulated cable	
	25 mm ²	50 mm ²	95 mm ²	50 mm ²	95 mm ²
100	10	8	6	10	9
200	20	16	12	22	18
315	30	25	20	35	28
500	50	40	32	55	45
1000	100	80	65	110	90

- g) Where 24 kV rated equipment is supplied from an overhead line by means of a cable that is longer than 50 m, screened surge arresters in accordance with 240-56030619 shall be installed at the equipment terminals (see D-DT-8017).

3.17.2 Type B mini-substations

- a) Type B mini-substations (see D-DT-8050, D-DT-8051, D-DT 8054 and D-DT - 8055) with ratings of 315 kVA, 500 kVA and 1000 kVA shall comply with the requirements of 240-56062752.
- b) Type B mini-substations shall have a built-in transformer overload protection device that trips the RMU T-off supplying the transformer in the event that the transformer top oil temperature exceeds 105 °C.

Note: The transformer overload protection setting device is sealed to prevent unauthorised access.

- c) The Type B mini-substation is provided with a 3-way RMU having a “2R-1B” configuration.

Note: The RMU outgoing circuit-breaker (tee-off) and protection relay combination provides over-current and earth-fault protection for the downstream mini-substation transformer. The two incoming load-break, fault-make isolators make provision for the mini-substation to be installed on a ring feeder.

- d) At 11 kV, cables shall be terminated at the RMU with an indoor termination kit and screened separable connectors (see D-DT-8017). At 22 kV, cables shall be terminated with an indoor trifurcating kit and screened separable connectors (see D-DT-8017).

Note: Where 22 kV impregnated paper-insulated cables are used this will require the use of transition joints to XLPE-insulated cable at the mini-substation (see D-DT-8021).

- e) The Type B mini-substation RMU self-powered circuit-breaker protection relay shall be supplied fully pre-commissioned (i.e. with relay settings made and a primary current injection test carried out at the factory). No protection relay settings or commissioning tests are required to be made on-site.

Notes:

- 1) The Type B mini-substation RMU circuit-breaker protection relay is sealed to prevent unauthorised access.
- 2) The protection relay over-current function is set using an HRC fuse characteristic or an 'extremely inverse' IDMTL protection element.
- 3) The protection relay over-current parameters are selected to allow for cyclic overloading of the transformer in accordance with the SANS 60076-7 loading guideline applicable to transformers in accordance with SANS 780. In general, this allows the transformer to be overloaded at $1.2 \times$ rated current for 4 hours and $1.6 \times$ rated current for 2 hours.
- 4) The earth fault current protection parameters are selected to prevent spurious earth fault tripping due to a false earth fault detection resulting from the d.c. component of transformer inrush currents when energising the transformer. Certain manufacturer's protection relays have a built-in "inrush current delay" switch for this purpose.
- f) Where 24 kV rated equipment is supplied from an overhead line by means of a cable that is longer than 50 m, screened surge arresters in accordance with 240-56030619 shall be installed at the equipment terminals (see D-DT-8017).

3.17.3 Ground-mounted transformers

- a) Ground-mounted transformers (see D-DT-8022) shall comply with the requirements of 240-45395762.
- b) At 11 kV, cables shall be terminated at the transformer with an indoor termination kit and screened separable connectors (see D-DT-8017). At 22 kV, cables shall be terminated with an indoor trifurcating kit and screened separable connectors (see D-DT-8017).

Note: Where 22 kV impregnated paper-insulated cables are used this will require the use of transition joints to XLPE-insulated cable at the transformer (see D-DT-8021).

- c) **Where a ground-mounted transformer is supplied from a length of cable connected to an overhead line**, the following shall apply in order to prevent ferro-resonance occurring as described in annex B:
- d) Where the cable length does not exceed the maximum permitted length given in tables 17 and 18 for the respective transformer rating, the cable shall be terminated at the overhead line in accordance with D-DT-0851. In this case isolation of the transformer is achieved by opening the cut-outs (fitted with solid links) under off-load conditions. The earthing shall be in accordance with D-DT-0862 sheet 3;
- e) Where the cable length exceeds the maximum permitted length given in tables 17 and 18 for the respective transformer rating, the cable shall be terminated at the overhead line in accordance with D-DT-0851 and shall be connected to a ring main unit having a three-phase switch-fuse combination (e.g. "2R-1F" – see D-DT-8060). In this case, isolation of the transformer/s is achieved by opening the three-phase switch of the switch-fuse combination. The earthing shall be in accordance with D-DT-0862 sheet 4.

Note: In situations where there is more than one transformer and more than one cable length, the equivalent value of X_m is calculated from the individual values of X_m in parallel. The total cable capacitive reactance must be at least 1.6 times the equivalent value of X_m . The calculation is described in annex B.

- f) Where 24 kV rated equipment is supplied from an overhead line by means of a cable that is longer than 50 m, screened surge arresters in accordance with 240-56030619 shall be installed at the equipment terminals (see D-DT-8017).
- g) The tap changer switch of a ground mounted transformer shall be fitted with a padlock.

3.18 Installation of free standing RMUs, mini-substations and ground-mounted transformers

- a) Free standing RMUs, mini-substations and ground-mounted transformers shall be positioned at least 0,7 m from all erf boundaries and at least 1 m from the road kerbing.
- b) Where a RMU and metering equipment, free standing RMU, mini-substation, ground-mounted transformer is installed within a registered servitude as described in clause 3.3 above, the plinth/s shall be positioned 0.7 m from the rear servitude boundary and at least 1 m from the front and side servitude boundaries.

Note: This is to allow sufficient space for the equipment doors to open and provide operator access.

- c) The equipment shall be installed on plinths 100 mm above natural ground level. Plinth designs are available for both pre-cast and cast-on-site options.

Note: Cast-on-site plinths are intended to be used only in areas where the transport to site of pre-cast plinths is not cost effective or where pre-cast plinths are not available.

- d) Before installing the plinth, the ground shall be levelled and compacted to 90 % MODAASHTO. The level of compaction shall be measured in accordance with 240-45683927.
- e) Plinth details for Type A and Type B mini-substations are given in D-DT-0859. The open side of the plinth surrounding the MV cables shall be closed after cable installation using kerbing, brickwork or, in the case of a pre-cast plinth, by using the plinth section provided.

Notes:

- 1) The plinths are designed in conjunction with the removable section of the mini-substation base (MV cable entry). This allows the MV cables to be terminated outside of the mini-substation enclosure and then be moved into position without having to be manoeuvred under the plinth or housing
- 2) For Type A mini-substations with ratings from 200 kVA to 500 kVA, D-DT-0859 sheets 1 or 2 are applicable.
- 3) For Type A mini-substations with a rating of 1000 kVA, D-DT-0859 sheets 3 or 4 are applicable.
- 4) For all Type B mini-substations, D-DT-0859 sheets 6 or 7 are applicable.
- f) Plinth details for free standing RMUs (i.e. free-standing RMUs) are given in D-DT-0863. The open side of the plinth surrounding the MV cables shall be closed after cable installation using kerbing, bricking or in the case of a pre-cast plinth by using the plinth section provided.

Notes:

- 1) The plinths are designed in conjunction with the removable section of the RMU base (MV cable entry). This allows the MV cables to be terminated outside of the RMU enclosure and then be moved into position without having to be manoeuvred under the plinth or housing.
- 2) For 3-way RMUs (e.g. 2R-1B, 2R-1F, 3R), D-DT-0863 sheets 3 or 4 are applicable.
- 3) For 4-way RMUs (e.g. 2R-2B, 2R-2F, 4R), D-DT-0863 sheets 5 or 6 are applicable.
- g) Plinth details for ground-mounted transformers are given in D-DT-0864.
- h) The inside of the plinths for mini-substations and free standing RMUs shall be filled with sifted sand to a level of 50 mm below the top of the plinth. The remaining 50 mm to the top of the plinth shall be filled with a 6:1 ratio of sand to cement mixture that is neatly levelled and compacted.
- i) At Type B mini-substation and free standing RMU installations, the source cable shall be terminated into the left hand side (i.e. when viewed from the point of operation) cable termination enclosure. Similarly, at Type A mini-substation installations, the source cable shall be terminated onto the left hand side of the MV compartment.
- j) Earth fault indicators (EFI's) shall be fitted on mini-substations and free standing RMUs and shall be connected with the current sensor fitted to the source side cable (in order to include the mini-substation and/or RMU as part of the zone covered by the EFI). EFI's shall be in accordance with 34-1080. The EFI current sensor shall be fitted in accordance with guidelines given in Annex C.

Notes:

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- 1) There are essentially two types of EFI's used i.e.:
 - mains powered – where there is a low voltage (230 V) supply available for powering and re-setting the EFI (e.g. mini-substation); and
 - non-mains powered – where there is no low voltage supply available and the EFI is powered by a lithium battery (e.g. free-standing RMU). Resetting of the EFI occurs automatically after a pre-set time.
- 2) A record should be kept of the date of installation of non-mains powered EFI's so that the replacement of the batteries can be scheduled as part of planned maintenance. A lifespan of approximately 10 years is anticipated for Lithium powered EFI's.
- k) The oil temperature sensor pocket on Type B mini-substations shall be checked to ensure that it is filled with oil at the time of commissioning.
- l) In order to maintain the internal arc classification of the RMU (see section 3.28.2 below), the following is required when installing free-standing RMUs and mini-substations:
 - 1) The mini-substation roof (if removable for handling purposes) shall be secured to the mini-substation enclosure using the method provided by the manufacturer;
 - 2) The interface between the RMU / mini-substation base and the concrete plinth top surface shall be sealed using a sealant strip (see D-DT-8029); and
 - 3) The RMU / mini-substation shall be secured to the plinth using 4 × M16×40 mm holding down set screws (see D-DT-3082) – as shown in D-DT-0859.
- m) Locks shall be fitted to free standing RMUs and mini-substations in accordance with 34-616.

Notes:

- 1) The MV door(s) of a mini-substation and the outdoor free standing RMU enclosure door shall be locked using "Operating" locks.
 - 2) The LV doors of a mini-substation shall be locked using a "Prohibited Area" locks.
 - 3) All MV switching devices (of the RMU) shall be locked using "Operating" locks.
 - n) The equipotential earth electrode (see D-DT-0855/0862) shall be installed in accordance with the following:
 - 1) The earth electrode shall comprise a bare 16 mm² copper conductor (see D-DT-3139).
 - 2) The copper conductor shall be buried 0,5 m deep and shall encircle the entire perimeter of the plinth at a distance of 0,5 m from the edge of the plinth.
 - 3) Each end of the earth electrode shall be connected to the MV equipment earth terminal / bar using tinned copper lugs having an M12 fixing hole (see D-DT-3102);
 - o) MV and LV earth electrodes (see D-DT-0855/0862) shall be straight trench electrodes with 5 earth rods (spikes). The electrodes shall be in accordance with the requirements of 240-130615754 and the following:
 - 1) The earth electrodes shall comprise bare 16 mm² copper conductors (see D-DT-3139) and 1,5 m copper vertical earth rods (see D-DT-3091). The spacing "L" between the vertical earth rods shall be determined in accordance with the requirements of 240-130615754;
 - 2) The MV earth electrode shall be connected to the MV equipment earth terminal / bar using a tinned copper lug having an M12 fixing hole (see D-DT-3102);
 - 3) The LV earth electrode shall be connected to the LV equipment earth terminal / bar using a tinned copper lug having an M12 fixing hole (see D-DT-3102);
- Note:** In the case of a mini-substation, the LV equipment earth terminal / bar is the LV neutral-earth busbar for mini-substations of rating up to and including 500 kVA and the LV earth busbar for 1000 kVA mini-substations.
- 4) An insulated 16 mm² copper earth conductor (see D-DT-3137) shall be used from the LV equipment earth terminal / bar to the LV earth electrode. The insulated earth conductor shall extend for at least 5 m from the equipotential earth in order to create a 5 m separation between the MV/equipotential and LV earth electrodes;

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- 5) The electrode bare copper conductors shall be connected together using a non-butt ferrule (see D-DT-3076); and
- 6) The copper conductors shall be connected to the earth rods using a cable to rod clamp (see D-DT-3093) or an exothermic welded connection.

3.19 Transportation and storage of mini-substations and ring main units

- a) All mini-substations shall at all times be supported by a minimum of three dedicated support blocks. The blocks shall be positioned with one support block in the centre so as to ensure that the mini-substation base and enclosure does not bend due to the mass of the transformer. The support blocks shall all be of the same thickness.
- b) RMUs shall at all times be supported by under-base supports (e.g. wooden pallet or similar).
- c) Mini-substations and RMUs shall be properly secured so that they cannot shift when in transit. Special care shall be taken when securing the equipment to ensure that the equipment is not damaged or paintwork scratched by the securing devices used. Suitable non-metallic strapping shall be used where contact is made with the steel enclosure or roof of the mini-substation or RMU. Metallic chains shall not come in contact with the equipment being transported as they can scratch and damage the steel enclosure. Special attention shall be paid to the roof of the mini-substation to ensure that it cannot become dislodged and possibly fall off the vehicle.
- d) If the mini-substation roof is designed to be removable, the mini-substation shall be lifted using the transformer lifting lugs and not the roof lugs, radiator fins or the ring main unit lugs (in the case of Type B mini-subs). The following procedure shall be followed when lifting mini-subs:
- e) If the mini-substation roof is not designed to be removable, the mini-substation shall be lifted using the external lifting lugs provided on the mini-substation enclosure.
- f) Outdoor free-standing RMUs shall be lifted using the lifting lugs (eyes) provided on the kiosk.

Note: Ensure that lifting slings and lifting equipment (e.g. crane) are adequately rated for the mass of the mini-substation / RMU – which is stencilled onto the side of the equipment enclosure.

- g) Alternatively, mini-substations and RMUs shall be carefully lifted using a fork-lift where the forks are positioned between the support blocks used to support the mini-substation / RMU during transport and storage.

3.20 Installation of cable networks

General installation of cable networks shall be carried out in accordance with the new works production work instructions under Part 24 of the Distribution Standard.

3.21 Marking and labelling

3.21.1 General

It is a requirement of the OHS Act that all controlling apparatus is permanently marked or labelled so as to identify the system or part of the system on the electrical machinery that it controls. Where the control apparatus is accessible from the front and back, these markings shall be on both the front and the back.

3.21.2 Labelling of equipment

- a) Labelling of metal-clad switchgear within step-down substations and switching stations shall be in accordance with 240-120804300 and regional requirements.
- b) All free standing RMUs and mini-substation enclosures shall be externally labelled with an electrical symbolic warning sign (warning flash, see D-DT-3202, SIGN ABC LV AND MV) permanently attached to each door. If pop-rivets are used to attach the signs to the doors, only aircraft or blind rivets shall be used.

- c) All ground-mounted transformers shall have both MV and LV cable termination enclosures externally labelled with an electrical symbolic warning sign (warning flash, see D-DT-3202, SIGN ABC LV AND MV) permanently attached to each cable termination enclosure cover. If pop-rivets are used to attach the signs to the covers, only aircraft or blind rivets shall be used.

Notes:

- 1) The relevant RMU, mini-substation and ground-mounted transformer specifications require that they be supplied fitted with all notices, signs and, where possible, labels.
- 2) Contact incidents have occurred where wire has been pushed through a pop rivet into live components.
- d) All free standing RMUs, mini-substations and ground-mounted transformers shall be labelled in accordance with the requirements of 240-120804300 and regional requirements.

Note: In general, this includes the equipment electrical address (unique name) and the relevant cable feeder information.

3.21.3 Labelling of cables

- a) All MV cables shall be labelled at both ends. The label shall be a flat aluminium plate of dimensions 150 mm × 25 mm × 0,9 mm (see D-DT-3049) tied to the cable with tinned copper binding wire onto which the information is scribed/punched in a font size of 7 mm. The information on the cable label shall include the following:
- 1) cable voltage (e.g. '11 kV', '22 kV');
 - 2) cable size (e.g. '185') in mm²;
 - 3) conductor material ('Cu' for copper and 'Al' for aluminium); and
 - 4) the cable type (i.e. 'PILC' or 'XLPE').
- b) Cable route markers (see D-DT-8012) shall be installed directly above the cable as follows:
- 1) at each bend;
 - 2) at each joint;
- c) at both sides of each road, railway or river crossing; and
- d) along straight sections at intervals of not greater than 150 m.
- e) The marker shall be installed at a depth of 250 mm below natural ground level.
- f) Where a cable route marker is installed on a paved or concrete surface area (e.g. a formal sidewalk); the top of the cable route marker shall be flush with the surface of the paving. In this way, the aluminium plate will remain visible and the cable route marker will not create an obstruction.
- g) The following shall be punched or scribed onto the aluminium plate:
- 1) an arrow indicating the cable route;
 - 2) the cable descriptor referenced to the source equipment, with a font size of 7 mm; and
 - 3) if applicable, a "J" to indicate the position of a joint. Table 19 below shows the different letters used;
 - 4) Table 19: Abbreviated labels for joints

Type of Joint	Abbreviated label
Transition from PILC to XLPE	TJ: PILC-XLPE
Trifurcating joint	TRIF J
Normal Joint (PILC to PILC or XLPE to XLPE)	J

Note: For theft mitigation: OUs to investigate if it is necessary to include the material of the conductor on the cable route markers.

3.21.4 Labelling of cables terminated onto overhead lines

- a) All MV cables that are terminated onto an overhead line shall be labelled at the corresponding pole using an overhead line equipment label. The label is required in order to identify the electrical address of the equipment or pole connected at the other end of the cable.
- b) The information on the label shall include the following:
 - 1) the unique pole number; followed by
 - 2) cable voltage (e.g. '11 kV'); followed by
 - 3) the words "CABLE TO"; followed by
 - 4) the unique pole number or name of the equipment at the other end of the cable.
- c) The information shall be stencilled using black lettering on a yellow background with a minimum font height of 50 mm. The label shall be visible from the ground and shall be installed on the pole below the cable termination.

3.22 Documentation

- a) As-built drawings that show all joints and the position of the cable, relative to boundaries, shall be produced for all cable routes. An example of the required drawing is shown in D-DT-0858.
- b) A network operating diagram that clearly indicates all of the information required, as well as the type and size of the cable, shall be produced. An example of the required drawing is shown in D-DT-0857. Station and feeder operating diagrams shall be in accordance with 240-125300736 and 240-125300846 respectively.
- c) The completed cable installation and test certificate (see Annex D), cable accessory installation instructions and quality control check sheets shall be kept for quality control purposes and stored with the project file.

3.23 Inspection and testing

3.23.1 General

To ensure the safe and reliable operation of a cable system, visual inspections shall be made and electrical tests performed before energizing. The results of the inspections and tests shall be recorded.

3.23.2 Visual inspections

A visual inspection checklist shall be compiled from the requirements of this standard and shall be used by the Clerk of Works (COW) for routine inspections made during construction. A checklist of the items to be inspected is provided on the Distribution Technology (PDE) website. The list is in the form of questions and the answer to these questions shall be in the affirmative before the system may be energised.

3.24 Electrical tests

- a) Earth resistance tests at free standing RMUs and mini-substations shall be carried out as described in 240-130615754.
- b) Prior to energising a newly installed cable, the following commissioning tests shall be carried out. The contractor and person appointed to carry out the tests shall certify the new cable installation by completing a test certificate in accordance with Annex D.
- c) MV XLPE-insulated cable feeders longer than 300 m shall be subjected to an a.c. over-voltage test in accordance with one of the options given in table 20 (extracted from table 3 of SANS 10198 – Part 13).

Table 20: Over-voltage test requirements for newly installed XLPE-insulated cables

1	2	3	4	5
		11 kV	22 kV	33 kV
Test wave-form	Duration [min]	Test Voltage [kV]		
50 Hz a.c.	60	13	25	38
VLF (0.1 Hz) a.c.	60	19	38	57

- d) MV impregnated paper-insulated cable feeders longer than 300 m shall be subjected to an a.c. or d.c. over-voltage test in accordance with one of the options given in table 20 (extracted from table A.2 of SANS 97).

Table 21: Over-voltage test requirements for newly installed impregnated paper-insulated cables

1	2	3	4
		11 kV	22 kV
Test wave-form	Duration [min]	Test Voltage [kV]	
50 Hz a.c.	15	13	25
VLF (0.1 Hz) a.c.	15	13	25
d.c.	15	19	36

- e) For MV cable installations less than 300 m, the cable circuit shall be tested and verified clear by means of at least a 5 kV insulation tester. This test is used for the quick identification of gross faults only.

Note: that if a 10 kV d.c. insulation tester is used on XLPE-insulated cables, the duration of the test shall be limited to 10 seconds.

Notes:

- 1) The test voltage (subject to the power limitation of the test set) shall be applied between all three phase conductors in parallel and the armour (for XLPE-insulated cables) or lead sheath (for impregnated paper-insulated cables). Alternatively, the test voltage shall be applied between each individual phase conductor and the armour/lead sheath.
- 2) The cable armour or lead sheath shall be earthed during the over-voltage test.
- 3) All cable earthing switches in the circuit being tested (e.g. RMU integral cable earthing switches) shall be open. All other earthing switches shall be closed (e.g. mini-substation RMU earthing switches for the t-off supply to the mini-sub transformer).
- 4) All switches shall be open (excluding those required to complete the circuit being tested).
- 5) Where applicable, surge arresters (e.g. installed in metal-clad switchgear or 24 kV RMUs supplied from overhead lines) will need to be disconnected.
- 6) During the test, minimum clearance distances in air for bare live metal shall be checked to avoid flash-over. As a rule of thumb, at least 3 mm/kV is required for d.c. and 5 mm/kV for a.c.
- 7) After using a d.c. insulation tester on an XLPE-insulated cable installation < 300m, the cable shall be solidly earthed for at least 5 minutes (or 8 hours if the cable is not subsequently energised – primarily for safety purposes). Ideally, an insulation tester with a built-in soft-discharge facility shall be used.
- 8) When testing XLPE cables using a VLF test set, the charging (capacitive) current can be calculated and verified using the formula $I=V/Z$, where V = applied test voltage, $Z = 1 / (2 \times \pi \times f \times C)$, $f = 0.1$ Hz and C is measured by the test equipment used or can be calculated from the manufacturers cable parameters.
- 9) When d.c. testing impregnated paper-insulated cables, the phase conductors are tested with a negative polarity with respect to earth.
- 10) When XLPE-insulated cables are tested for maintenance or repair purposes, they should be tested at reduced voltage levels and for shorter durations as given in Table 4 of SANS 10198 – Part 13 (Amendment 2).
- 11) The above XLPE-insulated cable test requirements are also applicable for MV ABC (aerial bundle conductor) cable.

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- f) All new sections of MV cable longer than 300 m shall be subjected to an outer sheath test (serving test). A d.c. sheath test voltage of 5 kV shall be applied for 2 minutes with a leakage current of 1 mA/km being regarded as acceptable. The test voltage shall be applied between the armour (for XLPE-insulated cables) or lead sheath (for impregnated paper-insulated cables) and earth.

Notes:

- 1) The armour/lead sheath cannot be earthed during this test. Therefore, all earth connections (e.g. main earth braids at terminations) shall be disconnected during this test.
- 2) A symptom of a cable outer sheath failure is where the d.c. ammeter on the d.c. test set suddenly becomes unstable, the current rises and the voltage drops. This test is not applicable to MV ABC cable.
- g) Cable fault location shall be done in accordance with SANS 10198-13.
- h) Where a VLF is used for diagnostic testing of XLPE cables the minimum frequency shall be 0.1 Hz. Frequency less than 0.1 Hz are not acceptable as they accelerate the aging of the XLPE due to the introduction of trapped charges in the dielectric.

3.25 Condition Criticality and Risk Assessment

This condition, criticality and risk assessment strategy standard provides the requirements to the Operating Units for establishing and monitoring plant health indices to plan refurbishment and replacement strategies for the medium voltage cable systems. The following shall apply:

- a) The MV Cable CCRA shall be done in accordance with standard 240-52552946.
- b) The MV free standing ring main units CCRA shall be done in accordance with standard 240-56997489
- c) The mini-substation CCRA shall be done in accordance with standard 240- 59033165
- d) The transformer CCRA shall be done in accordance with the relevant standard once published.
- e) The indoor metal-clad CCRA shall be done in accordance with standard 240-56997043

3.26 Operation

All MV network operating shall be carried out in accordance with NRS 040.

3.26.1 Operating procedures for Free standing RMUs and Type B mini-substations

Free standing RMUs and Type B mini-substation RMUs shall be operated in accordance with relevant operating procedures and OEM operating procedures (e.g 240-97791005 and 240-97791047).

3.26.2 Operating procedures for Type A mini-substations

11 kV and 22 kV Type A mini-substations shall be operated in accordance with DST 34-1403 and 240-56062752 respectively.

3.27 Phasing requirements for MV cable networks

3.27.1 Introduction

This section describes the preferred phasing requirements and procedures for MV underground cable networks. It is essential that the methods used to achieve the correct phasing of MV cable networks minimises potential risks associated with phase core crossings of 3-core cables.

Where possible, crossing of phase cores to achieve the correct phasing is to be done at cable joints as opposed to the terminations.

The risks associated with a termination failure (e.g. flashover due to inadequate clearances as a result of the poor crossing of phase cores) are higher when compared to a joint failure as a termination flashover will result in an internal arc fault in the cable termination enclosure – with associated damage to the equipment and venting of gases into the surroundings. Although every effort has been made in the specification and design of indoor cable terminations (see 240-56030619) to ensure that flashovers do not occur at cable terminations, there are always factors (such as quality of workmanship) that could result in insulation failures.

NOTE The Eskom specification for MV cable accessories (see DSP 34-162) requires that all cable terminations be made using the “top-down” method to maximise the length of the screened tail (see figure 1). With the screened section of the phase cores maximised, the risk of a flashover between cores is minimised as the electric field between the cores is eliminated (up to the end of the core screen). The top-down method is not applicable to tri-furcating termination kits used with screened separable connectors (SSCs) for 22 kV 3-core XLPE-insulated cables.

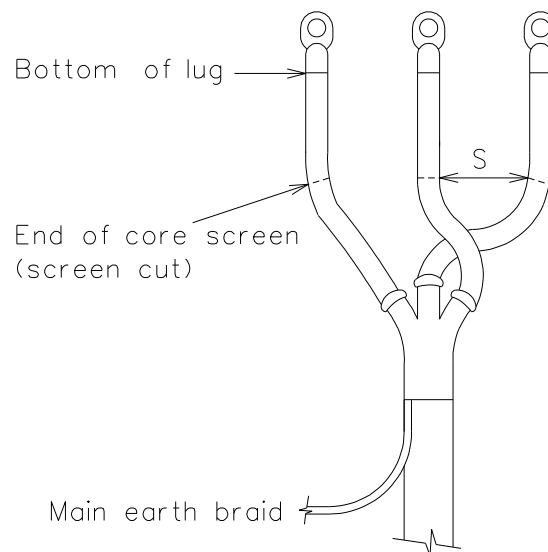


Figure 1: Example of a completed cable termination where the core crossing is made below the end of core screen cut

3.27.2 General requirements when carrying out phasing

The requirements of DST 34-1364 shall apply at all times. In addition, the following general requirements are applicable for MV cable networks:

- a) Where possible, the crossing of phase cores in 3-core cables shall be done at cable joints.
- b) Where possible, cable terminations at equipment (e.g. switchgear) shall be made off straight as follows:
 - 1) The terminations should be made off ensuring that the phase cores do not cross and that the clearances between the cores are maximised.
 - 2) For RMUs, Type A mini-substations and ground-mounted transformers, the phase order is RED, WHITE and BLUE from left to right when facing the front (operating side) of the equipment.
 - 3) For indoor metal-clad switchgear, where access to the cable terminations is from the rear, the phase order is BLUE, WHITE and RED from left to right when facing the rear of the panel.

3.27.2.1 If the phase cores have to be crossed at a cable termination (i.e. where it is not possible to do the phase crossing at a joint), the crossing shall be done in the screened section of the cable termination only (i.e. below the end of the core screen shown in figure 1) – ensuring that the minimum clearances between each core above the end of the core screen (dimension 'S') are maintained (SANS 876).

- c) When provided (e.g. on all RMU 'R' ring switch-disconnector panels), cable test facilities shall be used when carrying out phasing procedures. This prevents the need to remove the separable connectors or shrouds covering the lugs.
- d) When phasing is 'given' from one end of a section of cable to the other, each individual phase is earthed (in turn) at the one end of the cable and an approved insulation tester applied at the other to 'identify' the phase. This is known as 'insulation tester phasing' (e.g. using 2 kV – 5 kV d.c.).
- e) NOTE: Alternatively, an approved electrical phase (core) identification device may be used. Devices are commercially available that do not require the cable to be disconnected, the earthing switch to be opened or portable earthing leads to be removed.
- f) Once the individual phase cores have been identified, the cores shall be identified using suitable temporary colour-coded adhesive tape. All identification tapes shall be removed after the cable cores have been joined or terminated as they will compromise the performance of the insulating material (e.g. anti-track tubing) over time.
- g) If separable connectors have to be removed for the purposes of carrying out a phasing procedure (i.e. in the event that there is no cable test facility or suitable phase identification device available), special care shall be taken to ensure that they are correctly re-installed. Silicone lubricating grease shall be applied onto the bushing in order to ensure that the separable connector is fully pushed onto the bushing as shown in figure 2.

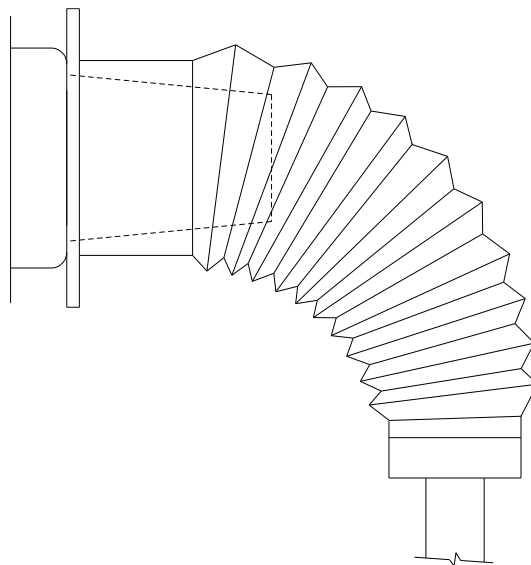


Figure 2: Diagram showing the correct installation of USC on a Type C bushing

- h) The "top-down" method shall be used for all MV cable terminations (see figure 1).
- i) Individual cable core marking (i.e. if the cores are identified by the numbers 1, 2 and 3) is not considered to be relevant when carrying out phasing procedures. It is therefore not necessary to ensure that the continuity of cores is maintained by virtue of the cable core marking.
- j) Approved electrical phasing devices are available that utilise VDS (Voltage Detection System) provided on the 'R' ring switch-disconnector panels of all new RMUs (Type B mini-substations and free standing RMUs).

Note: Some old installations are still using the VPIS (Voltage Present Indicating System) instead of the VDS however all new equipment will be installed with the VDS only.

3.27.3 Phasing procedure when installing a new cable feeder – with no cable joints

- If no joints are required in a new cable feeder (e.g. if the length of cable is taken off a single drum), the phase core crossing (if required) shall be done at one of the terminations. The individual cable core marking (i.e. if the cores are identified by the numbers 1, 2 and 3) can then be used to assist with phase identification. If applicable, the phase core crossing (if required) should be done at the end of the cable terminated into primary metal-clad switchgear where there is adequate space – rather than at equipment such as compact secondary switchgear (e.g. RMUs). Note however that it is possible to avoid phase core crossing if the cable terminations are made off at the same time.
- The optimum positioning of the phase cores shall be obtained in order to ensure that phase core crossing is eliminated at both terminations. This can be achieved if the two terminations are made off simultaneously. For example, it might be that core '1' becomes the WHITE phase, core '2' the RED phase and core '3' the BLUE phase.
- Once the terminations have been completed, all earthing shall be removed (if applicable - depending on the equipment used) and the phasing shall then be checked from one end of the cable to the other.
- The cable shall then be energised from the 'normal' source end.
- If applicable, an approved electrical phasing device shall be used to prove that the phasing is correct before paralleling the MV feeders (e.g. before closing the 'R' ring switch-disconnectors at a RMU).

Note: For type A mini-substations, where there are no MV on-load switching devices, the phasing shall be proved at the nearest available switchgear (e.g. feeder breakers) prior to re-energising the feeder.

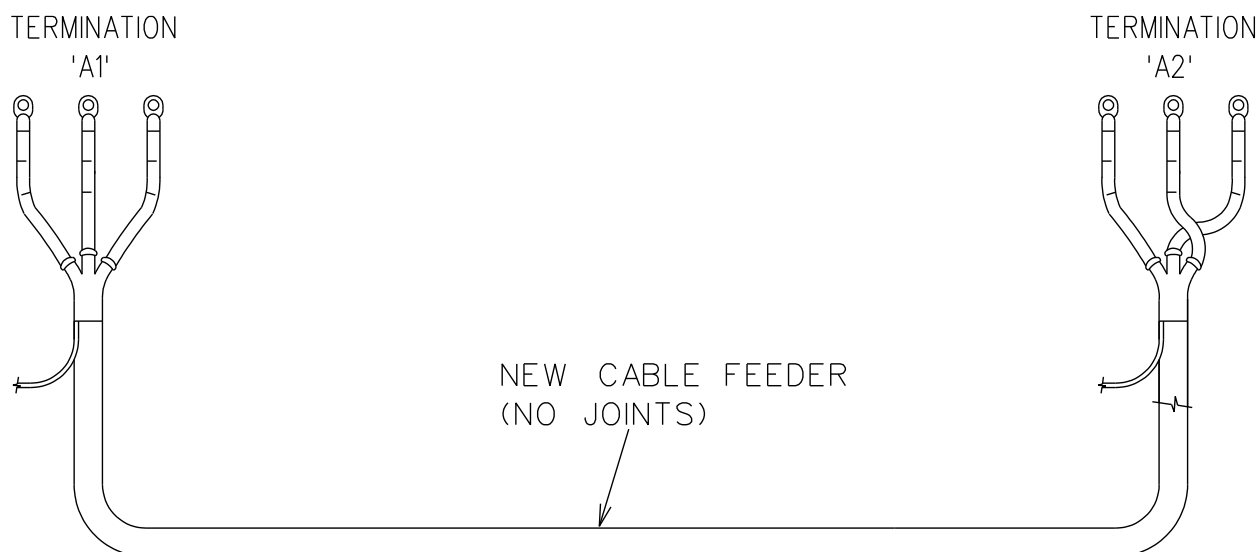


Figure 3: Diagram showing the relevant configuration when installing a new cable feeder – with no cable joints

3.27.4 Phasing procedure when installing a new cable feeder – with cable joint(s)

- All cable terminations shall be made off straight, i.e. RED, WHITE and BLUE from left to right when facing the front of the equipment (e.g. RMU) or as shown in figure 2 for 11kV Type A mini-substations. The terminations shall be made off ensuring that the phase cores do not cross and that the minimum clearances between each core are maintained as shown in figure 1.

- b) Before the last cable joint is completed (i.e. before the conductors are connected), phasing shall be given from both ends to the cable joint. If required, the phase core crossing shall then be made at the cable joint.
- c) Once the last cable joint has been completed, all earthing shall be removed (if applicable - depending on the equipment used) and the phasing shall then be checked from one end of the cable to the other through the joint(s).
- d) The cable shall then be energised from the 'normal' source end.
- e) If applicable, an approved electrical phasing device shall be used to prove that the phasing is correct before paralleling the MV feeders (e.g. before closing the 'R' ring switch-disconnectors at a RMU).

Note: For type A mini-sub, where there are no MV on-load switching devices, the phasing shall be proved at the nearest available switchgear (e.g. feeder breakers) prior to re-energising the feeder.

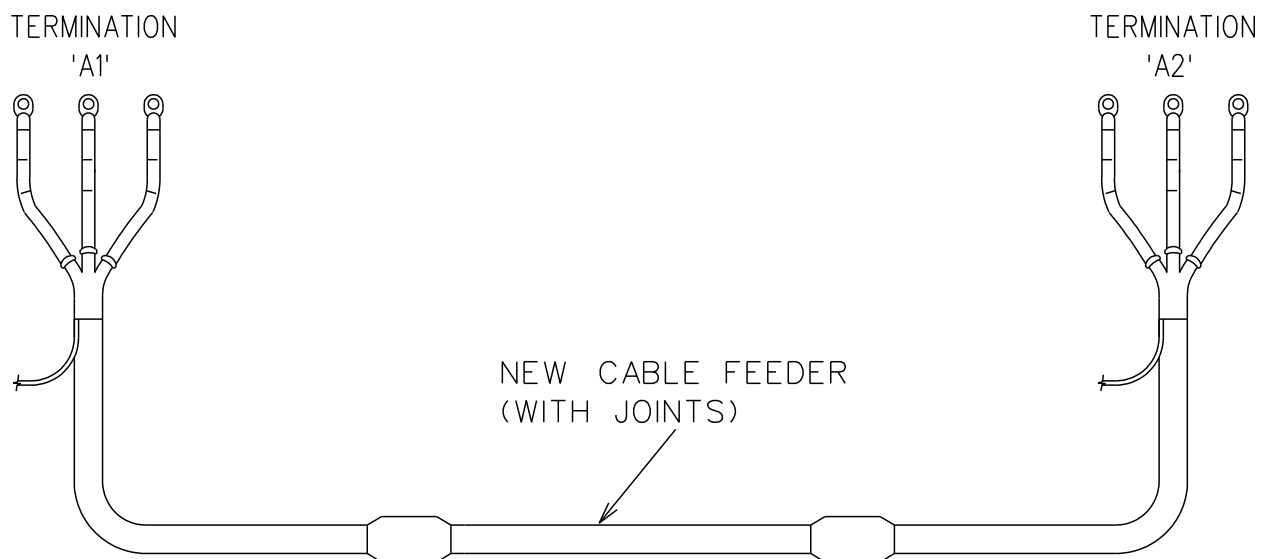


Figure 4: Diagram showing the relevant configuration when installing a new cable feeder – with cable joint(s)

3.27.5 Phasing procedure when 'cutting in' new equipment (e.g. mini-substation) into a feeder

- a) The cable terminations at the newly installed equipment (e.g. Type B mini-substation or sub-switching station) shall be made off straight, i.e. RED, WHITE and BLUE from left to right when facing the front of the equipment (e.g. RMU). The terminations shall be made off ensuring that the phase cores do not cross and that the minimum clearances between each core are maintained as shown in figure 1.
- b) After the applicable section of cable (into which the new equipment is intended to be 'cut-in') has been isolated and earthed at both ends, the phasing shall be checked from the one end to the other to ensure that the phasing is indeed correct.
- c) The cable shall then be identified and spiked in accordance with DST 34-1143.
- d) Once the existing cable has been cut and the two new cable joints are being made-off, the phasing shall be given from both ends of each new cable section (i.e. cables 'A' and 'B') to the respective joints 'A' and 'B' in the joint bay. Referring to figure 6, phasing shall thus be given from cable termination at A1 to joint A, from termination A2 to joint A, from termination B1 to joint B and from termination B2 to joint B. If required, the phase core crossings shall then be made at the respective cable joints.

- e) For Type B mini-substations / free standing RMUs, once the two cable joints have been completed, all earthing shall be removed (if applicable - depending on the equipment used) and the phasing shall then be checked through the new joints (i.e. from A1 to A2 and from B1 to B2).
- f) For Type A mini-substations, once the two joints have been completed, the phasing shall be checked through the two new joints (i.e. from A1 to B1) with the MV cable junction box jumpers connected at the new Type A mini-substation.
- g) For Type B mini-substations / free standing RMUs, the new equipment shall then be energised from each remote end (i.e. from A1 to A2 and from B1 to B2).

Note: The 'R' ring switch-disconnectors at the new equipment (i.e. at A2 and B2) shall still be open at this stage.

- h) For Type A mini-substations, after the relevant section of the cable feeder has been de-energised (i.e. between the nearest adjacent switchgear), the broken MV cable shall be restored and all earthing disconnected at the Type A mini-substations adjacent (if applicable) to the newly installed mini-substation (i.e. at A1 and B1). If the ring feeder normally open point is a Type A mini-substation, the normally open point shall then be re-instated) and the ring shall then be energised to both sides of the normally open point. If the normally open point is an on-load switching device (e.g. RMU); then the relevant section of the feeder shall be re-energised from the source up to the normally open point (which remains open).
- i) For Type B mini-substations / free standing RMUs, an approved electrical phasing device shall be used to prove that the phasing is correct at the newly installed equipment before paralleling the MV feeders (i.e. before closing the 'R' ring switch-disconnectors at the new equipment). The ring feeder normally open point shall then be re-instated (i.e. by opening the ring switch-disconnector forming the normally open point).
- j) For Type A mini-substations, if the feeder normally open point is a Type A mini-sub, approved phasing sticks shall be used to prove the phasing across the Type A mini-substation normally open point). If the normally open point is an on-load switching device (e.g. RMU); then an approved electrical phasing device shall be used to prove the phasing across the normally open point (i.e. between adjacent terminations of the normally open point).

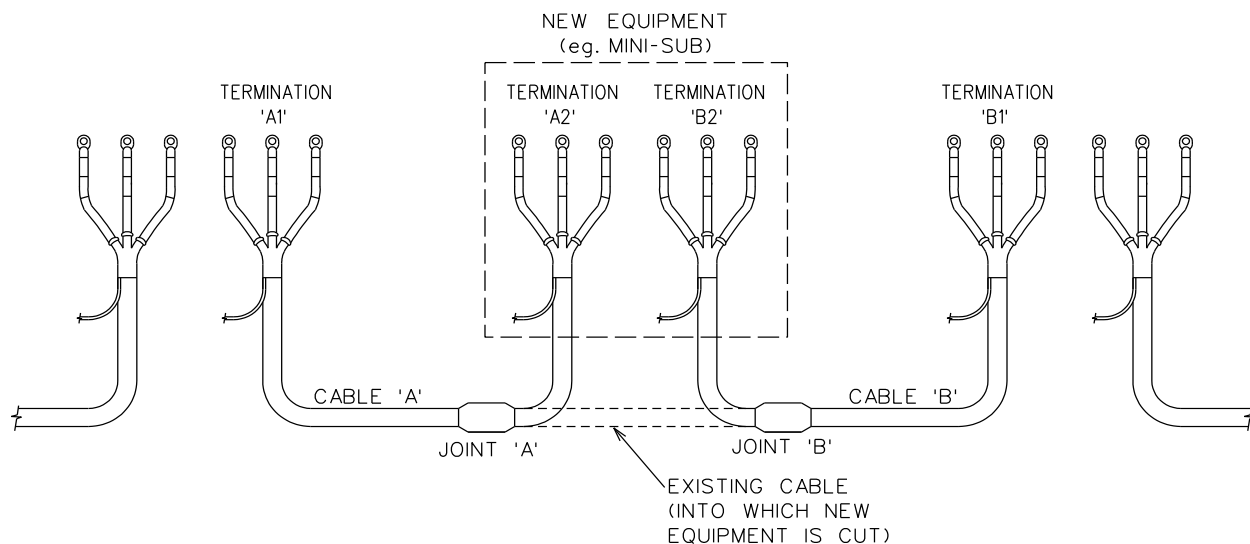


Figure 5: Diagram showing the relevant configuration when 'cutting in' new equipment

3.27.6 Phasing procedure when repairing a cable fault on a feeder

- a) Once the cable fault has been located and the relevant section of cable has been isolated and earthed at both ends, the faulty cable shall then be identified and spiked in accordance with 34-1143. Once the faulty section of cable has been cut out, the cable is then prepared for the installation of two new cable joints and a new short length of cable.

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- b) The first cable joint shall then be completed.
- c) Before the second cable joint is completed (i.e. before the conductors are connected), phasing shall be given from both ends to the second cable joint (i.e. from A1 and A2 to joint 2). If required, the phase core crossing shall then be made at the second cable joint.
- d) Once the second cable joint has been completed, all earthing shall be removed (if applicable - depending on the equipment used) and the phasing shall then be checked from one end of the cable to the other through the new joints (i.e. from A1 to A2).
- e) For Type B mini-substation / free standing RMUs, the repaired cable shall then be energised from the 'normal' source end (i.e. A1).

Note: The 'R' ring switch-disconnector at A2 shall still be open at this stage.

- f) For Type A mini-substations, after the relevant section of the feeder has been de-energised (i.e. between the nearest adjacent switchgear), all screen separable connectors shall be re-connected and all earthing disconnected at the Type A mini-substations adjacent (if applicable) to the repaired cable (i.e. at A1 and A2). If the ring feeder normally open point is a Type A mini-sub, the normally open point shall then be re-instated and the ring shall then be energised to both sides of the normally open point. If the normally open point is an on-load switching device (e.g. RMU); then the relevant section of the feeder shall be re-energised from the source up to the normally open point (which remains open).
- g) For Type B mini-substation / free standing RMUs, an approved electrical phasing device shall be used to prove that the phasing is correct before paralleling the MV feeders (i.e. before closing the 'R' ring switch-disconnectors at A2). The ring feeder normally open point shall then be re-instated (i.e. by opening the ring switch-disconnector forming the normally open point).
- h) For Type A mini-substations, if the feeder normally open point is a Type A mini-substation, approved phasing sticks shall be used to prove the phasing across the Type A mini-substation normally open point (broken MV cable junction box jumpers). If the normally open point is an on-load switching device (e.g. RMU); then an approved electrical phasing device shall be used to prove the phasing across the normally open point (i.e. between adjacent terminations of the normally open point).

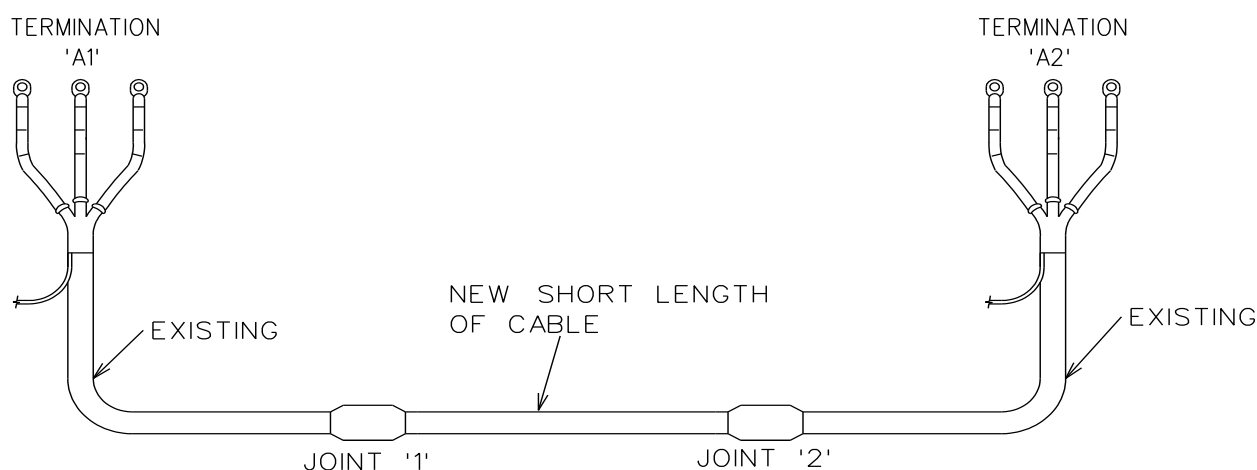


Figure 6: Diagram showing the relevant configuration when repairing a cable fault on a feeder

3.28 Safety

3.28.1 Medium voltage switchgear

- a) Users in South Africa have a duty, in terms of safety legislation (most notably the Occupational Health and Safety Act 85 of 1993) to their employees and the public to provide an acceptably safe environment and to take reasonable measures to mitigate against possible dangers.
- b) According to the ISO/IEC Guide 51, safety is achieved by reducing risk to a tolerable level. Tolerable risk is determined by the search for an optimal balance between the ideal of absolute safety and the demands to be met by a product, process or service, and factors such as benefit to the user, suitability for purpose, cost effectiveness, and conventions of the society concerned.
- c) 'Risk' is considered to be the combination of the probability of occurrence of a harm and the severity of the harm. It follows that there is a need to continually review the tolerable level of risk – in particular when developments in both technology and knowledge can lead to economically feasible improvements – in order to greatly reduce the risk associated with the use of a product, process or service.

3.28.2 Eskom internal arc specification for switchgear

- a) Developments in distribution switchgear technologies have presented end users with a compelling argument for the use of equipment that is not only safer, but is more reliable and has a relatively low total cost of ownership. This includes switchgear having an insulating/interrupting medium of gas, air, vacuum and/or solid dielectric. In addition, modern compact switchgear is available that is 'sealed for life' – requiring minimal maintenance and intervention over its lifetime. With developments in both technology and knowledge, it is now possible to use switchgear that is fully tested not only to withstand the effects of, but to safely 'vent' the emissions generated by, an internal (arc) fault.
- b) The applicable Eskom specifications for distribution switchgear require that they be type tested to give them an internal arc classification (IAC) in accordance with the relevant IEC specifications. This has been made possible due to the specification and purchasing of switchgear with air and gas-insulated switchgear. The SANS (IEC) specifications for internal arc testing (detailed in annex A of IEC/SANS 62271-200 for metal enclosed switchgear and annex A of IEC/SANS 62271-202 for mini-substations and free-standing RMUs) cater for two relevant categories of internal arc classification – based on the type of accessibility required by the user. Type A accessibility is restricted to authorised personnel only and Type B accessibility caters for unrestricted accessibility – including that of the general public. According to IEC/SANS 62271-200, different types of accessibility may be applied to the various sides of the switchgear – i.e. front [F], lateral [L], and rear [R].
- c) For indoor primary switchgear (i.e. metal-clad switchgear), the following is specified in accordance with DSP 34-1157:
 - 1) Classification IAC AFLR (SANS 62271-200)
 - 2) Internal arc 25 kA 1 s (for 12 kV); 20 kA 1 s (for 24 kV)
- d) For outdoor secondary switchgear (i.e. free standing RMUs and in Type B mini-substations), the following is specified in accordance with 240-56030406 and 240-56062752:
 - 1) Classification IAC AB (SANS 62271-202)
 - 2) Internal arc 20 kA 0,5 s (for 12 kV); 16 kA 0,5 s (for 24 kV)

- e) Outdoor secondary switchgear is normally installed in areas of general public accessibility – requiring type B accessibility on all sides (with all doors closed). In addition, with the front MV doors open (front access only), type A accessibility is required for the operator. The 0,5 s arc duration is based on the upstream protection settings typically applied for grading considerations. As this type of switchgear is installed on solid concrete plinths with cable trenches that are backfilled and sealed (using a concrete screed), venting of the switchgear can only be directed upwards – requiring a 2 m high arc venting duct. The duct/venting system is designed and tested to vent emissions resulting from an internal arc fault in any of the gas and/or air-filled enclosures within the switchgear (i.e. a common venting system for the gas-insulated busbar enclosure/s and the air-filled cable termination enclosures).

3.28.3 Operating switchgear and personal protective equipment (PPE)

- a) In general, according to IEC 62271-200, internal arc classification of equipment is intended to offer a tested level of protection to persons in the vicinity of the equipment in normal operating conditions and with the switchgear in normal service position in the event of internal arc. Normal operating conditions are defined as “the conditions of metal enclosed switchgear and controlgear required to carry out operations such as opening or closing HV [including MV] switching devices, connecting and disconnecting withdrawable parts [if applicable], reading of measuring instruments and monitoring equipment, etc”.
- b) For mini-substations and free-standing RMUs in particular, according to IEC 62271-202, internal arc classification is intended to offer a tested level of protection in the event of internal arcs to personnel operating the substation in normal operating conditions and with its MV switchgear and controlgear in normal service position, as defined in the relevant standard (Class IAC-A) and to persons in the vicinity of the substation with its doors closed (Class IAC-B).
- c) The following personal protective equipment in accordance with 240-70044736 must always be worn when operating switchgear:
- 1) protective overalls (cotton fabric of at least 150 g/m²),
 - 2) safety boots,
 - 3) operating gloves,
 - 4) hard-hats; and
 - 5) face shields.
- d) Mini-substations shall be operated with the LV compartment doors closed.
- e) In the event that the equipment is fitted with remote operating facilities (i.e. SCADA or an umbilical cord remote control), as a means to further limit exposure to risk, such a remote control facility shall be used to carry out switching operations.

Note: that the provision of such remote control operating facilities is mandatory for internal arc classified switchgear supplied to Eskom from 2014. Switchgear supplied to Eskom before 2014 might not have the such remote control operating facilities.

3.29 Road safety precautions

- a) When working within road reserves; the road safety precautions and requirements of the local road agency / authority shall be complied with at all times.
- b) Where applicable, the guidelines as set out in the site manuals entitled “Safety at road works in urban areas” and “Safety at road works in rural areas” issued by the Department of Transport.

3.30 Safety of foundations, buildings and structures

- a) Care shall be taken to ensure that excavations do not endanger the foundations of adjacent buildings. All the necessary precautions shall be taken so as to prevent subsidence of soil which could result in damage to foundations.

- b) Where excavations may unavoidably endanger the stability of fences or other structures, such structures shall be removed and replaced to the satisfaction of the owner(s).

3.31 Safety of other services

- a) Where excavations may unavoidably endanger the stability of above ground services, such services shall be adequately and suitably supported and / or stayed.
- b) Where excavations expose any underground services, such services will be adequately and suitably supported to avoid their subsidence and suitable protected against damage.

3.32 Barricading and lighting

In terms of the Construction Regulations of the Occupational Health and Safety Act 85 of 1993, every excavation which is accessible to the public or which is adjacent to public roads or thoroughfares, or whereby the safety of persons may be endangered, shall be:

- a) Adequately protected by a barrier or fence of at least one metre in height and as close to the excavation as is practicable; and
- b) Provided with warning lights or any other clearly visible boundary indicators at night or when visibility is poor.

3.33 Accommodation of traffic and access to properties

- a) In addition to complying with the relevant requirements as applicable, where the work affects the operation or safety of public traffic, the following shall be applicable:
 - 1) by-pass(es), as may be required to deviate traffic from portions of the road that are to be affected by the construction, shall be constructed and put in order; and
 - 2) access ways, as may be required by persons requiring access to properties that fall within or adjoining the area where construction work is taking place, shall be provided. If, for any reason, such access has to be closed for certain periods during the construction period, the persons affected shall be given reasonable notice in writing of each construction period.
- b) Official communication shall be issued by the relevant Communications Office to advise the affected public of all details regarding any traffic deviations and/or access restrictions that may be put in place during the construction period.

3.34 Working on and in the vicinity of live cables

- a) Prior to working on a cable, it shall be positively identified and spiked in accordance with DST 34-1143.
- b) When external damage to a cable has been located and exposed following a cable feeder protection operation (e.g. due to cable damage / theft), the damaged cable shall be visually identified and spiked in accordance with DST 34-1143 before any work is carried out on the cable. This will ensure that a permanent fault is created and the possibility of the cable being incorrectly identified eliminated.

Note: An incident occurred in Eskom Distribution whereby the incorrect identification and isolation of a damaged cable resulted in the faulty cable being re-energised temporarily. The faulty cable, which was thought to have been isolated and earthed, then faulted for a second time when it was disturbed prior to being worked on.

- c) When working in close proximity to other live cables, it is recommended that the other cables be temporarily covered using a "cable flash blanket". This will greatly reduce the risk of an injury in the event of a flash due to a cable fault on one of the nearby cables.

Note: The requirements for a "cable flash blanket" are currently being investigated.

3.35 Unscreened conductors and cable terminations

- a) There is a common misconception regarding high voltage insulation and screening. It is often believed that because equipment is insulated; it was safe to touch. A clear distinction must be made between equipment that is only insulated (i.e. covered) versus equipment that are insulated and screened (i.e. with an electrostatic screen that is earthed).

Note: Type 2 and Type 3 terminations (or conductor arrangements) in accordance with SANS 1332 are classified as insulated (but unscreened) and Type 4 and Type 5 terminations (or conductor arrangement) in accordance with SANS 1332 are classified, by definition, as screened.

- b) For the purpose of explanation, a pre-moulded unscreened elbow connector is shown in figure 7. However, in some applications, high voltage insulating tape and a heat-shrink boot may be used or even only high voltage tape. In this type of cable termination the stress control is performed by means of a cable termination located below the insulated elbow connector. Despite the fact that the termination has controlled the electric field, some of the field remains external to the insulation and therefore all parts of the termination above the stress control region must be considered as live. With most cable terminations it is difficult to determine exactly where the stress control cone/tube ends and therefore any part of a cable termination above the break-out/crutch should be considered as live.
- c) A pre-moulded, insulated and screened elbow connector is shown in figure 7. The elbow connector controls the electric field and also contains it within the insulation of the connector. This is accomplished by continuing the insulation screen of the cable to the surface of the equipment that is being connected to. The fact that the electric field does not exist outside of the insulation and that the surface is at zero potential and earthed means that it can be considered as dead.
- d) However, it is not always easy for the layman to determine whether a conductor or cable termination is only insulated or insulated, screened and earthed. When there is any doubt, an installation should be treated as live.

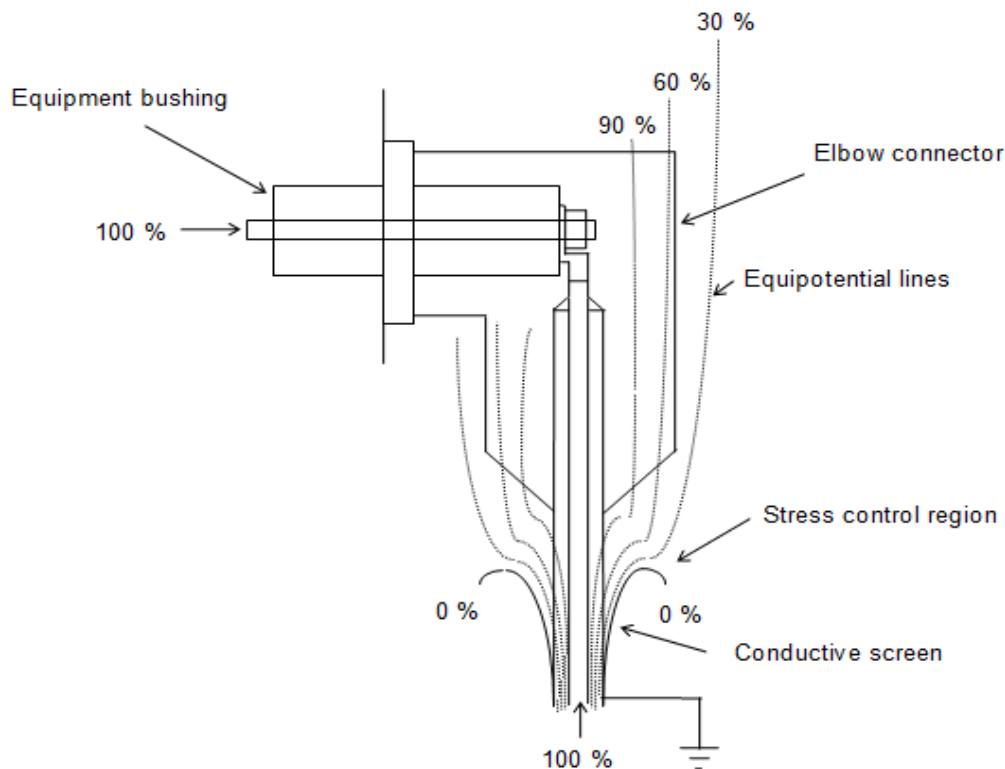


Figure 7: Insulated elbow connector onto equipment bushing

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- e) The fundamental rules that should be applied with electrical installations to ensure personal safety are:
- 1) Low voltage (≤ 1000 V) equipment that is fully insulated may be considered safe to touch.
 - 2) High voltage (> 1000 V) equipment that is fully insulated but not screened must be considered as live.
 - 3) High voltage (> 1000 V) equipment that is fully insulated and screened may be considered safe to touch.

4. Authorization

This document has been seen and accepted by:

Name and surname	Designation
Alex Ndlela	Senior Manager: Dx Ops Support HV Plant
Vinod Singh	Middle Manager: DBOUS

5. Revisions

Date	Rev	Compiler	Remarks
March 2021	3	Q. Khumalo	Clause 3.3e) Servitude requirements for MV bulk supply have been added (7.5 m x 3 m).
March 2020	2	Q. Khumalo	Current rating for single core copper XLPE cables added. Current rating for three core copper XLPE cables added. Labelling of cables revises to include the type of joints and conductor material type. Application for trifurcating kits added. Application for trifurcating joints added
Dec 2013	1	Q. Khumalo, J. Paulse and T. Du Plessis	Document revised to incorporate the new artefact document format for document DST 34-1175.

6. Development team

The following people were involved in the revision of the standard:

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- Queeneth Khumalo: PDE HV Plant
- David Ntombela: DBOUS
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- Kagiso Senosi: Dx GOU SI
- Pieter Vink: Dx FSOU SI
- Barto Olivier: Dx WCOU SI

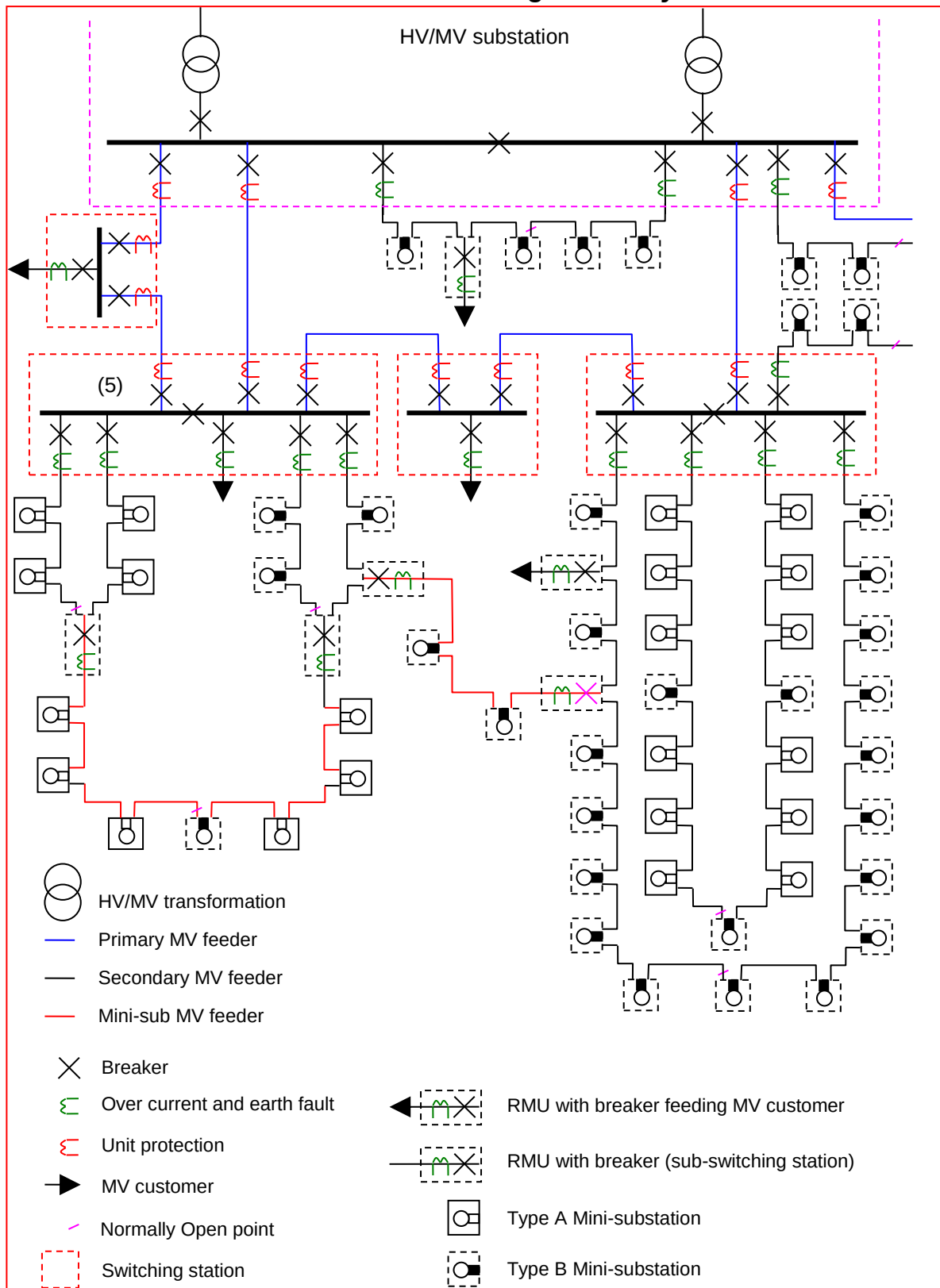
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- Malusi Mathonsi: Dx GOU SI
- Sandisiwe Mtshaulana: Dx MOU SI

7. Acknowledgements

Not applicable.

Annex A – Medium voltage cable system



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Annex B – Recommendations for the Avoidance of Ferro-Resonance arising from Single-Phase Switching of Unearthed Transformer Windings in MV Networks

(Informative)

Introduction

The phenomenon of ferro-resonance may be encountered in power systems in a number of situations, most of which are easy to eliminate.

However, situations conducive to ferro-resonance are occurring increasingly frequently in modern MV networks due to environmental constraints leading to the use of underground cable on short spurs supplying MV/LV distribution transformers in the range 100 kVA to 1000 kVA. It is standard practice that MV networks are earthed at source and that the MV windings of distribution transformers must be unearthed and, in most cases, connected Dyn.

Accepted practice has been to protect spurs off overhead feeders by means of fuses that are naturally single-phase devices. The fuses serve also as switching devices, resulting in short periods of a few seconds during switching operations when one or two of the phases are disconnected from the source. Single-phasing results also when one or two of the fuses blow leaving the other(s) intact. The latter situation could persist for a much longer period, until an operator arrives to restore the circuit.

During single-phasing conditions, the phase(s) open at the fuse position are kept alive from the sound phase(s) through the transformer windings. The phase-to-ground capacitance of an open phase is then effectively in series with the exciting inductance of the associated transformer winding. In many situations, the values of capacitive and inductive reactances obtained result in ferro-resonance, either transient or steady state. The typical range of overvoltage experienced during the ferro-resonant conditions, is in the order of 2 per unit. In some more severe cases, 3 or 4 per unit voltages are experienced.

Because the standard practice on Intermediate Voltage systems is to install 4-core cable and YNyn transformers, ferro-resonance is not a problem except in the extremely unlikely event of a blown fuse accompanied by a broken neutral connection.

Extent of overvoltage effects

There are four broad categories of overvoltage arising from ferro-resonance situations.

- a) When the phase-to-earth capacitive reactance of the cable is greater than the normal (i.e. at system operating voltage) inductive reactance of an MV winding, ferro-resonance can give rise to over-voltages between the cable cores, including the transformer terminals, and earth.
- b) When the phase-to-earth capacitive reactance of the cable is less than the normal inductive reactance of an MV winding, ferro-resonance can give rise to over-voltages across the MV winding. By transformer action, the overvoltage appears across the associated LV winding and affects any consumers' connected appliances.
- c) When the phase-to-earth capacitive reactance of the cable and the normal inductive reactance of an MV winding are of similar magnitude, ferro-resonance will give rise to over-voltages both from phase to earth and across the MV winding.
- d) When the phase-to-earth capacitive reactance of the cable is very much less than the normal inductive reactance of an MV winding such that resonance in the ordinary sense seems not to be expected, ferro-resonance can still occur if triggered by a single-phase switching condition that, due to residual flux, causes total saturation of the affected core. The resonance may be of a steady state or a transient nature.

Proposed measures to avoid over-voltages detrimental to consumers' appliances

In situations where the capacitive reactance of the cable is greater than 1.6 times the normal transformer inductive reactance, ferro-resonance will not occur. In these cases, special measures are unnecessary. The limiting cable lengths that inherently avoid resonance are given in the tables below for a range of cable and transformer sizes. The lengths are based on standard values of capacitance published for screened cables. If belted cables were used, the limits would not be correct.

N.B. Although resonance is avoided when the limiting cable lengths are not exceeded, and transformer LV voltage will not exceed 1.06 per unit, overvoltage will still occur on the cables connected to the open phase(s) and on the end(s) of the winding(s). However, the maximum MV voltage that occurs, with the full limiting length of cable, is less than 1.65 per unit. It is considered that transformer and cable insulation will not be significantly affected by such voltages because of the limited durations likely to occur. Of course, if other more vulnerable apparatus such as surge arresters were connected, 1.65 per unit could not be permitted.

Maximum permitted cable lengths:**1) ON 11 kV SYSTEMS**

Transformer (kVA)	Cable length (metres)				
	Impregnated paper-insulated cable			XLPE-insulated cable	
	25 mm ²	50 mm ²	95 mm ²	50 mm ²	95 mm ²
100	30	26	18	32	26
200	63	52	38	65	52
315	95	80	60	100	80
500	155	130	95	160	130
1000	315	260	190	330	260

2) ON 22 kV SYSTEMS

Transformer (kVA)	Cable length (metres)				
	Impregnated paper-insulated cable			XLPE-insulated cable	
	25 mm ²	50 mm ²	95 mm ²	50 mm ²	95 mm ²
100	10	8	6	10	9
200	20	16	12	22	18
315	30	25	20	35	28
500	50	40	32	55	45
1000	100	80	65	110	90

To calculate the permitted cable length, the capacitive reactance must be at least 1.6 times the winding reactance (X_m) of the transformer. For a delta connected winding,

$$X_m = \frac{3 \times \text{kV}^2 \times 1000}{\text{kVA} \times I_m\%} \times 100$$

For example, the magnetizing current of a 200 kVA 11 kV/400 V Dyn transformer is 1.48%, resulting in:

$$X_m = 123 \text{ k}\Omega.$$

$$1.6 \times X_m = 197 \text{ k}\Omega.$$

In situations where there is more than one transformer and more than one cable length, the equivalent value of X_m is calculated from the individual values of X_m in parallel. The total cable capacitive reactance must be at least 1.6 times the equivalent value of X_m .

Policy when cable lengths exceed the permitted length

In cases where the limiting lengths of cable are exceeded, other steps must be taken to prevent single-phasing as far as possible. Single-phase fuses and switching devices must not be used at the tee-off position. Of course, unforeseen events such as broken jumpers cannot be entirely eliminated.

A three-phase switching device such as a circuit breaker is necessary, if single-phasing during switching operations is to be effectively avoided. Even with a good quality circuit breaker, for which the maximum difference in operating times of the individual phases is only 5 ms, it is possible for a single 5 ms impulse of overvoltage to be generated in a resonant situation. Use of ganged single-phase switches or fuse-switches is likely to allow ferro-resonance to persist for up to a second, perhaps even longer. The CBEMA curve for electronic equipment sensitivity to overvoltage shows voltage tolerance of 1.4 per unit for only 3 ms and 2 per unit for only 1 ms. Clearly, the application of switch-fuses will not achieve the desired result of safeguarding sensitive appliances.

Consideration should be given to the possibility of mounting a manually closed circuit breaker at the tee-off position. Such a device, if available, would surely be significantly cheaper than a recloser.

Alternatively, protection, in the form of fuses or some other device, could be provided at the transformer position instead of at the tee-off. As long as single-phase interruption occurs only downstream of the cable capacitance, ferro-resonance will not occur. Single-phase or ganged disconnects could then be located at the tee-off to enable isolation of the cable after first isolating the transformer by withdrawing its local MV fuses. Restoration would be by first energising the cable, then replacing the transformer fuses. Fault current indicators on the main line, before and after the tee-off, would be necessary to assist in identifying a cable as the faulty network component in the rare instance of a cable fault.

A. H. Ware

30 October, 2001

Annex C – Earth fault indicator current sensor installation

(Informative)

In order to ensure that the EFI operates correctly under earth fault conditions, it is important to ensure that the current sensor (C.T.) is correctly installed. Figure C.1 illustrates the correct positioning of the current sensor relative to the cable termination and main earthing conductor of the cable termination. It is important to note that the current sensor measures residual current and therefore as a general rule its position must be such that an “odd” number of earth fault current paths exist through the current sensor. This is best explained as follows:

- 1) POSITION 1 – there are three earth fault current paths through the sensor i.e. in the phase conductor (1), lead sheath and/or armour (2) and termination main earthing conductor (3);
- 2) POSITION 2 – there is one earth fault current path through the sensor i.e. in the phase conductor (1).

The current sensor should not be positioned any higher than the top of the break-out boot of the termination as there is a risk that it may be too close to the unscreened insulation of the cable termination tails.

When the indicating unit signals an earth fault, it implies that the earth fault location is downstream (i.e. away from the source) from the indicator.

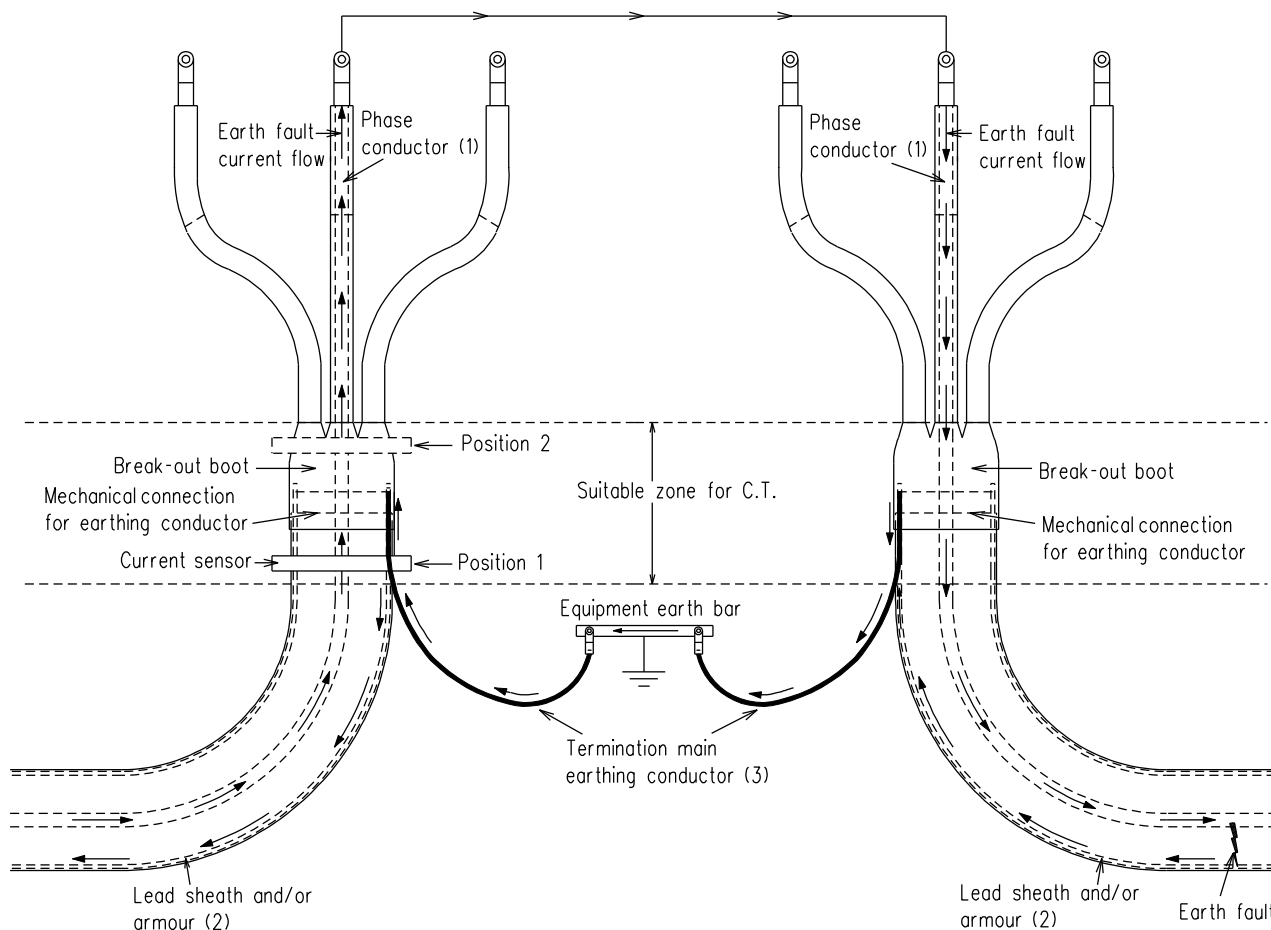


Figure C.1: Correct positioning of EFI current sensor (C.T.)

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Annex D – - Cable Installation and Test Certificate

(normative)

PROJECT NAME:

PROJECT ID:

PROJECT LOCATION:

NAME OF INSTALLATION CONTRACTOR:

NAME AND ORGANISATION OF PERSON PERFORMING TESTS:

NAME AND ORGANISATION OF PERSON COMPLETING QUALITY CHECKLISTS.....

CABLE DATA

MANUFACTURER:

SPECIFICATION: (SANS 1339 / SANS 97):

VOLTAGE (11 kV / 22 kV / 33 kV):
.....

CABLE INSULATION (XLPE / PILC):

NUMBER OF CORES (1-CORE / 3-CORE):

CONDUCTOR SIZE (mm²):

CONDUCTOR TYPE (CU/AL):

SERIAL / ORDER / DRUM NUMBER:

DATE OF INSTALLATION:

AS-BUILT DRAWING NUMBER:

NETWORK OPERATING DIAGRAM NUMBER:

CABLE ACCESSORY INSTALLATION INSTRUCTIONS ATTACHED (YES / NO):

ALL RELEVANT QUALITY CHECKLISTS COMPLETED AND ATTACHED (YES / NO):

CABLE JOINT DATA

JOINT MANUFACTURER:

TYPE OF JOINT (TRANSITION/ TRIFURCATING/ STRAIGHT):

SAP NUMBER:

VOLTAGE (11 kV/ 22 kV/ 33 kV):

LOCATION/ COORDINATES OF THE JOINT:

NAME OF JOINER:

NAME AND ORGANISATION OF PERSON PERFORMING TESTS:

NAME AND ORGANISATION OF PERSON COMPLETING QUALITY CHECKLISTS.....

CABLE TERMINATION DATA

JOINT MANUFACTURER:

TYPE OF TERMINATION (TRIFURCATING/ SSC/USSC/INDOOR/OUTDOOR):

SAP NUMBER:

VOLTAGE (11 kV/ 22 kV/ 33 kV):

LOCATION/ COORDINATES OF THE JOINT:

NAME OF JOINTER:

NAME AND ORGANISATION OF PERSON PERFORMING TESTS:

NAME AND ORGANISATION OF PERSON COMPLETING QUALITY CHECKLISTS.....

TEST EQUIPMENT USED

BRAND:

TYPE:

AC / DC / VLF:

TEST VOLTAGE AND RESULTS

FEEDER NAME	TEST VOLTAGE (kV)	DURATION (minutes)	RESULT (pass/fail)	LEAKAGE CURRENT (OUTER SHEATH TEST)

PERFORMED BY:

.....

NAME, SIGNATURE AND DATE

WITNESSED BY (CLERK OF WORKS / PROJECT CO-ORDINATOR):

.....

NAME, SIGNATURE AND DATE