Eskom	Standard	Technology

Title: **STANDARD FOR EARTHING OF SECONDARY PLANT / CONTROL PLANT EQUIPMENT IN SUBSTATIONS**

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Content

Figures

1. Introduction

This standard describes the earthing requirements for secondary plant equipment installed within the Eskom substation environment. In the Distribution, secondary plant is referred to as control plant.

The standard draws heavily from the recommendations of NRS 083 “Electromagnetic Compatibility (EMC) in Electricity Utility Networks”, notably Part 2: “Substation design and equipment installation practices” and Part 3: “Secondary equipment installation sin substation rooms – Illustrations”.

2. Supporting clauses

2.1 Scope

This standard describes the earthing requirements for secondary plant/control plant equipment installed within the Eskom substation environment within Eskom Holdings SOC Limited.

2.1.1 Purpose

This document promotes the application of standard earthing practices to secondary plant/control plant equipment in substations so as ensure safety of personnel and plant, and to minimise the risk of misoperations or damage due to electromagnetic interference with secondary plant equipment within the substation environment.

2.1.2 Applicability

This document shall apply to secondary plant equipment in substations within Eskom Holdings SOC Limited Divisions.

2.2 Normative/informative references

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

2.2.1 Normative

[1] NRS 083 (All Parts), Electromagnetic Compatibility (EMC) in Electricity Utility Networks

[2] IEEE Std C57.13.3, IEEE Guide for Grounding of Instrument Transformer Secondary Circuits and Cases

[3] 240-60725641, Specification for standard (19 inch) equipment cabinets

[4] SANS 474, Code of Practice for Electricity Metering

2.2.2 Informative

[5] SANS 61000-5-2, Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 2: Earthing and cabling

2.3 Definitions

2.3.1 General

Definition	Description
Daisy chain	Connection of components to earth via a series connection. Component earth terminals are connected together via discrete radial connections, with the last device's earth terminal being connected to the enclosure earth bar. A break in one of the connections may result in multiple components losing connection to the earth bar.
Electromagnetic Compatibility	The ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment [IEV 161-01-07]
Parallel Earthing Conductor	A conductor usually laid along the cable route to provide a low-impedance connection between the earthing arrangements at the ends of the cable route [SANS 61000-5-2]

2.3.2 Disclosure classification

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

2.4 Abbreviations

Abbreviation	Description
D.C	Direct Current
ESD	Electrostatic Discharge Point
EMC	Electromagnetic Compatibility
IDF	Intermediate Distribution Frame
IED	Intelligent Electronic Device
IEV	International Electrotechnical Vocabulary (www.electropedia.org)
NRS	National Rationalised Specification
OEM	Original Equipment Manufacturer
PEC	Parallel Earthing Conductor
PTM&C	Protection, Telecommunications, Measurements & Control
RTU	Remote Terminal Unit
SANS	South African National Standard
TC	Technical Committee

2.5 Roles and responsibilities

Design engineers shall implement this standard in their designs of new substations or substation refurbishment projects. Construction, commissioning and maintenance staff shall check for compliance with this standard during their normal duties.

2.6 Process for monitoring

The responsibly parties shall monitor compliance to this standard and shall present deviations to the relevant technical governance committee for support.

2.7 Related/supporting documents

Not applicable.

3. Requirements

3.1 Introduction

Earthing is required for reasons of personal safety and therefore all electronic equipment (other than portable equipment with self-contained power sources) and metallic components not intended to be energised, shall be earthed. The following rules shall apply:

a) All metalwork associated with the structure shall be provided with adequate means for bonding to earth.

b) Reliance shall not be placed upon the metalwork as an earth return. Earth conductors shall be used.

c) Earthing conductors and structural metalwork shall not carry any currents other than fault or interference currents.

d) The size of the earthing conductors shall be such that with the maximum possible value of fault current, no damaging temperature rises occur before the protective device operates.

e) All metal components of the panel, control devices and all relay/device frames shall be effectively connected to the panel earth bar by means of 2.5 mm² green/yellow insulated earthing conductors.

f) All earth connections shall be as short as possible and shall not be coiled.

g) The arrangement and detail of the earth bar and connection terminal shall be to Eskom's approval.

3.2 Indoor cabinet and enclosure earthing

There are two main types of indoor cabinets: Fixed Frame and Swing Frame enclosures. Cabinets come in different sizes, mostly 600 x 600 x 2400 mm or 800 x 600 x 2400 mm. Full specification details are provided in 240-60725641 [3].

The following aspects of the enclosure specification relate to earthing.

3.2.1 Cabinet gland plate and earth bars

a) Provide a non-painted, conductive gland plate at the bottom of the cabinet connected at several points to the enclosure itself. Ensure a high quality, durable metal-to-metal contact with the cabinet (see Figure 1).

b) Provide an earth bar at the bottom of the cabinet. A DIN rail is recommended in the event that surge suppression devices are to be fitted. Where required, provide an additional vertical running bar for cabinets taller than 1 metre.

c) The arrangement highlighted in Figure 1 is mirrored for cables entering from the top of the enclosure. Alternatively, the panel design may be universal, catering for top or bottom entry of cables in which case gland plates and earthing connections are provided on the top and bottom of the enclosure.

3.2.2 Cabinet earthing detail

Cabinets and enclosures provide an effective interference barrier for conducted and radiated interference. The following salient points are applicable to control room cabinets:

a) Gland plates must be provided at cable entry points for the purpose of earthing the shield/armouring. Gland plates must not be painted – plated mild steel (blue passivated), 3CR12 or stainless steel is specified.

b) All cables entering the cabinet must have shields effectively earthed to the gland plate to divert common mode currents away from the cabinet's interior.

c) Cables entering the cabinet should be terminated with a gland near to the cabinet's earthing conductor, to minimize the creation of induction loops.

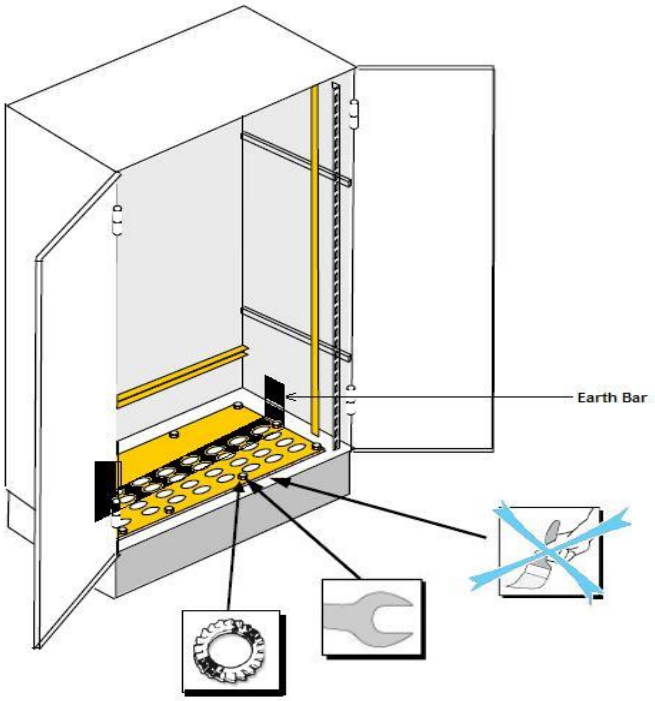


Figure 1: Earthing provisions in a typical indoor enclosure [NRS083-3]

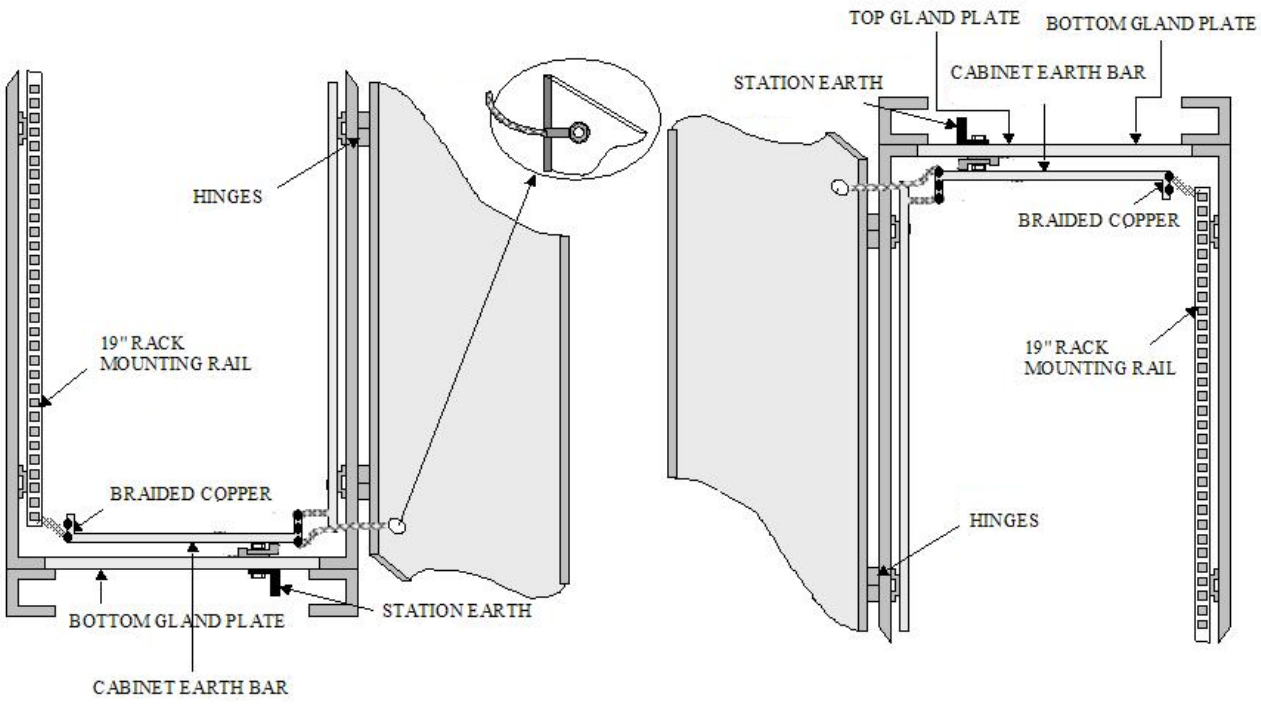


Figure 2: Typical earthing detail of equipment cabinets

3.2.3 Bonding of cabinet metallic components

a) The following components mounted on or inside cabinets shall be connected to the cabinet earth bar using 2.5 mm^2 green/yellow insulated copper conductors.

1) Discrete electronic equipment with metal casings or earthing provisions, including IEDs, meters, transducers, RTUs, auxiliary relays, electronic boards, power supply units etc.

2) IED or RTU cards/modules (as required).

3) Any push buttons or control switches with metal mechanisms or housings.

4) Any metallic component which is not intended to be energised and which is without a continuous metal-to-metal connection to the panel earthing bar, including painted plates, removable plates, and sub-racks. To this end, each such metal component shall include an unpainted earthing stud that has a direct metal-to-metal connection with the component.

b) Earth connections shall be kept as short as possible. Direct connections between the equipment and earthing bar are preferred with daisy-chaining of earth connections being used by exception.

c) Daisy-chain earth connections are not permitted for earthing of EMC screens such as IED casings and cards, nor for critical safety earths such as instrument transformer neutral earths, control switch or push button mechanism earths, earthing of an operating panel or terminal rail earths. Daisy chaining is permitted for the earthing of blanking plates. Where daisy-chaining is used, the earth conductors shall be easily visible for periodic inspection and shall not be obscured within trunking.

d) Daisy-chained earth connections have proven to be satisfactory for safety standards but are not effective for high frequency electromagnetic interference control.

e) Tinned braided copper conductors may be used in place of 2.5 mm^2 stranded copper conductors in certain applications (as prescribed by the Supplier/OEM).

f) Enclosure doors and hinged frames must be bonded to the cabinet using 12 mm^2 braided tinned copper connections. NRS 083-3 recommends that braided straps should be as short and as wide as possible, giving a recommended length to width ratio less than 3.

g) It is preferred that no more than two ring lugs be connected to each side of an earthing bolt on a panel earthing bar.

h) Figure 3 shows best practices for the connection of lugs to plates, and the bonding of plates:

1) Remove insulating coatings and paintwork between surfaces in contact;

2) Ensure adequate tightening by using a nut and bolt and good contact by using bite washers; and

3) Apply paint or grease to ensure high quality contact is maintained over time.

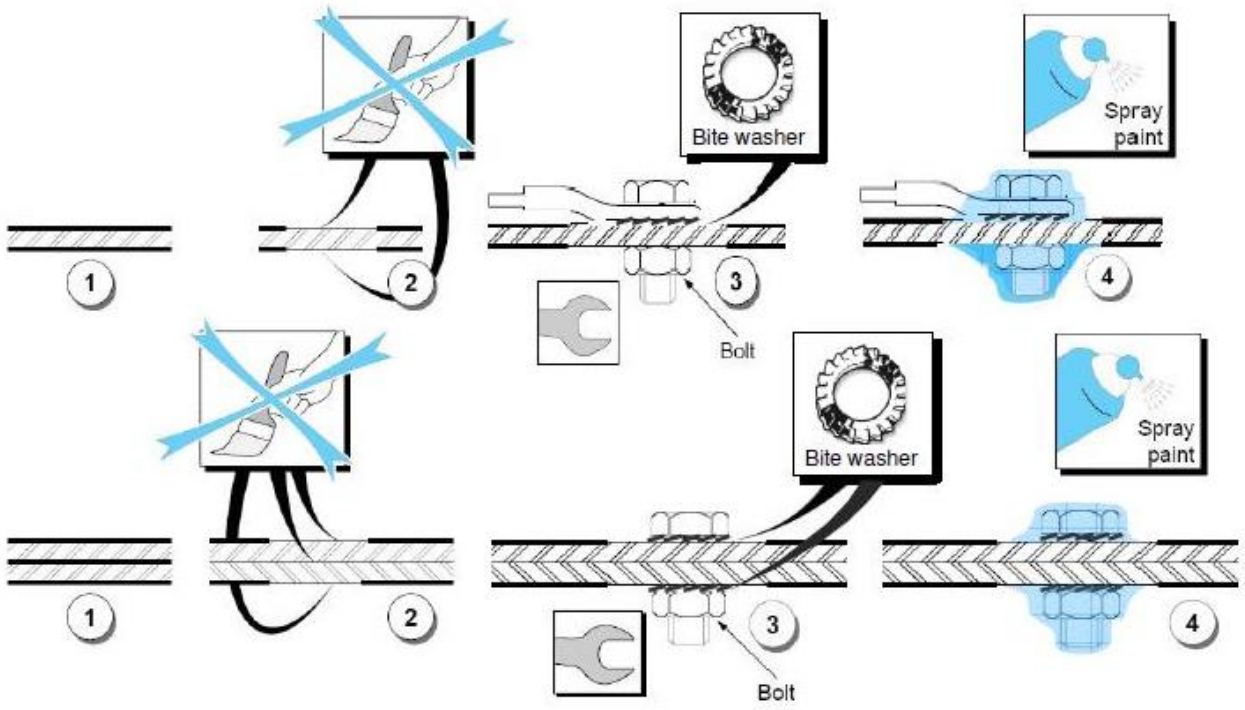


Figure 3: Illustration of good bonding connections [NRS083-3]

3.2.4 Connections to the trench or tray earth conductor

The substation control room earthing point is either the substation overhead cable rack or a 50mm x 3mm copper conductor located in the cable trench. Traditionally, a copper conductor is also fitted to overhead cable racking though the rack is itself an excellent conductor. Care must be taken that the cable rack is bonded to the substation earth by means of a 50mm x 3mm copper conductor. As cable racks are constructed from modular sections, the sections shall overlap and shall be bonded together with either the standard rack connectors of the same material or sections of 50mm x 3mm copper conductor with a suitable number of fixing bolts to ensure a good electrical contact between the connector and the rack at both ends.

For proper EMC shielding each cabinet shall be connected to the station earth bar using an earthing conductor of at least 75 mm^2. Connections between the panel and a trench earth bar are typically made with 50mm x 3mm copper flat bar. If the distance from the panel to the trench earth exceeds 5 metres, then two parallel straps separated by the width of the cabinet must be used.

Eskom Distribution uses a lower cross-sectional area limit of 50 mm^2 for panel connections to overhead racks, with earth connections comprising 50mm x 3mm copper flat bar or 4 x 16 mm^2 or 2 x 25 mm^2 multi-strand copper conductors with green/yellow insulation (see Figure 4).

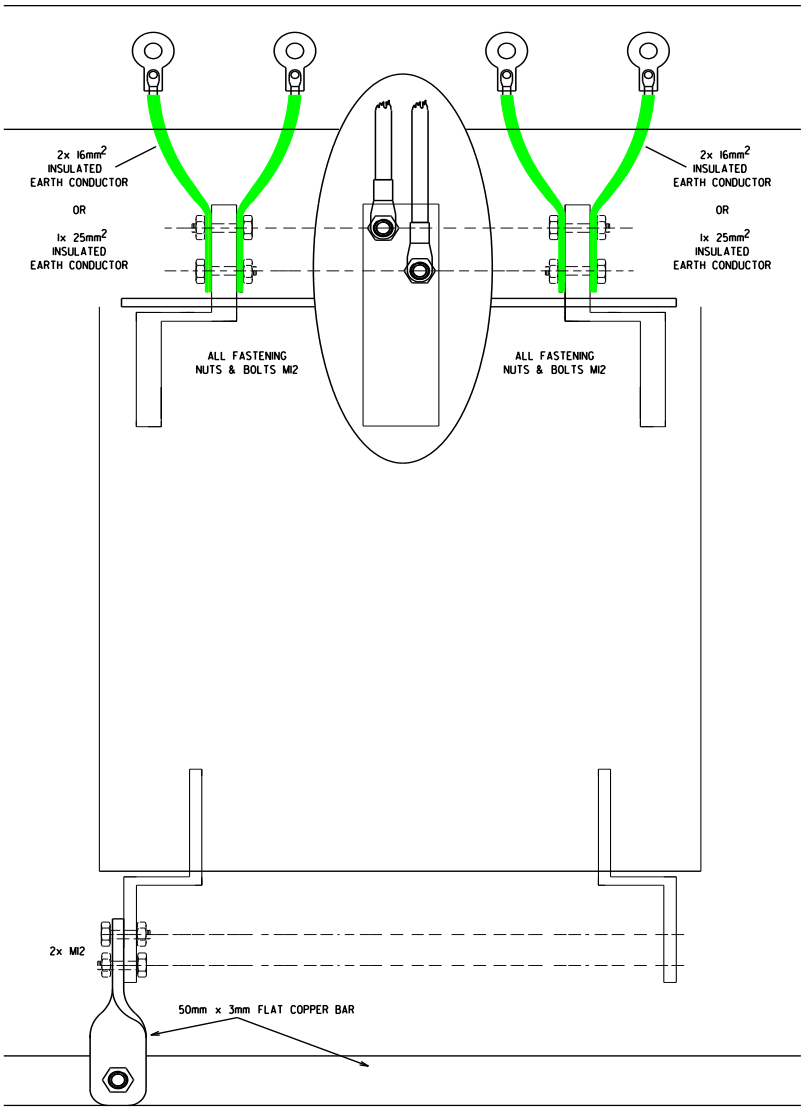


Figure 4: External earthing of Distribution swing frame panels (top or bottom-entry)

3.2.5 Electrostatic discharge precautions

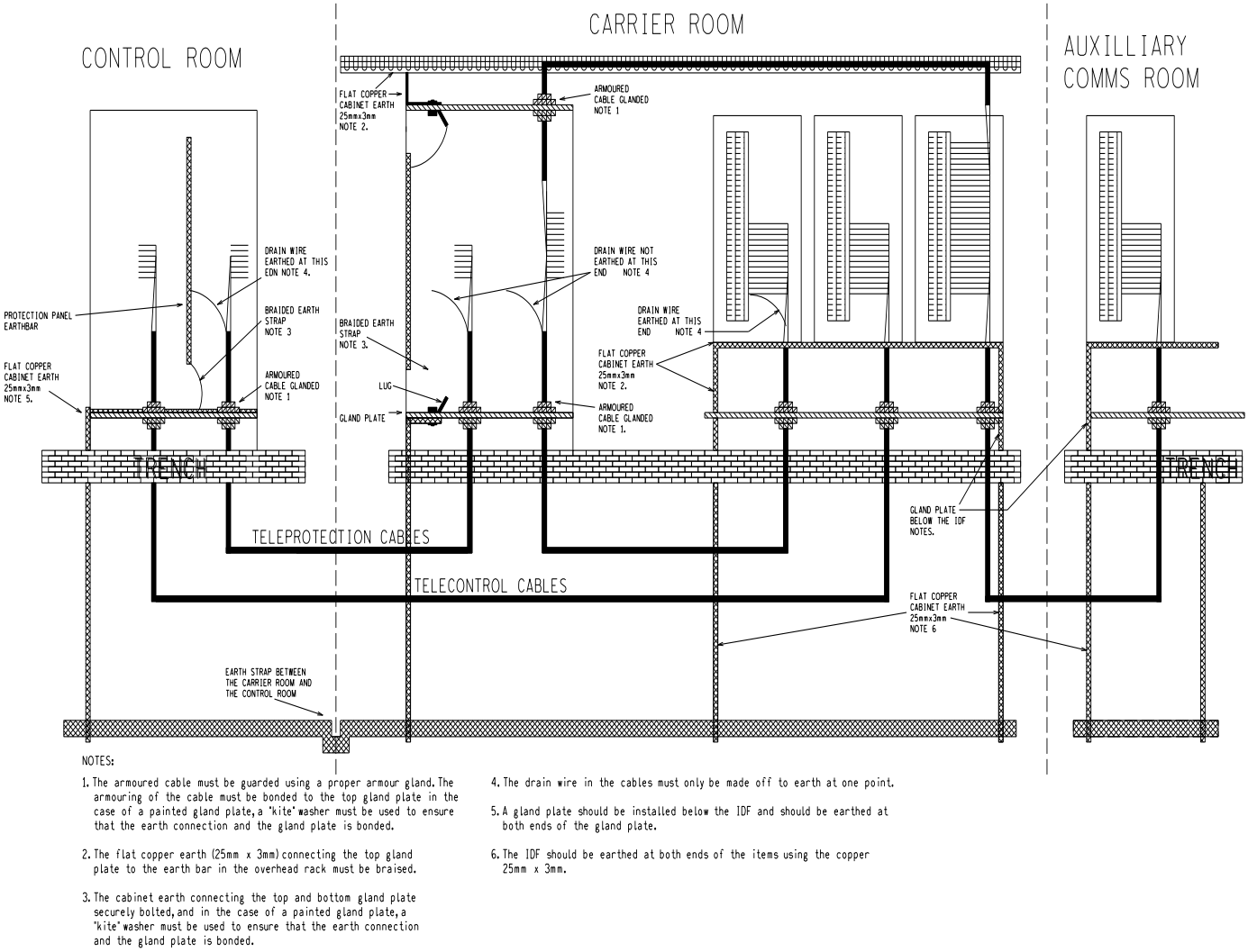
In substation rooms where maintenance of electronic equipment is performed at card or at component level, it is essential to have certain minimum measures in place to prevent damage to electronic equipment by static charges. It is possible for people in a normal working environment to produce electrostatic body charges of up to 30 kV which can damage electronic components whilst handling them.

While working on electronic equipment in substation control rooms (e.g. inserting or removing printed circuit boards from within IEDs) it is mandatory for field personnel to wear static control wrist straps with earthing cords. Such wrist straps need to be in direct contact with the skin. Earthing sockets are to be provided on all cabinets that house devices with removable electronic cards. The ESD earth connection of the cabinet shall include a 1 MΩ resistor to protect the wearer of the ESD wrist strap from high-current electric shock via the card being removed (e.g. should the card be inadvertently energised).

Any card that is removed from a device shall immediately be inserted into an anti-static bag for transport or transferred to an earthed work mat for local repairs.

3.3 Earthing of Intermediate Distribution Frames

The method for Earthing the Intermediate Distribution Frame (IDF) is shown in Figure 5.



NOTES:

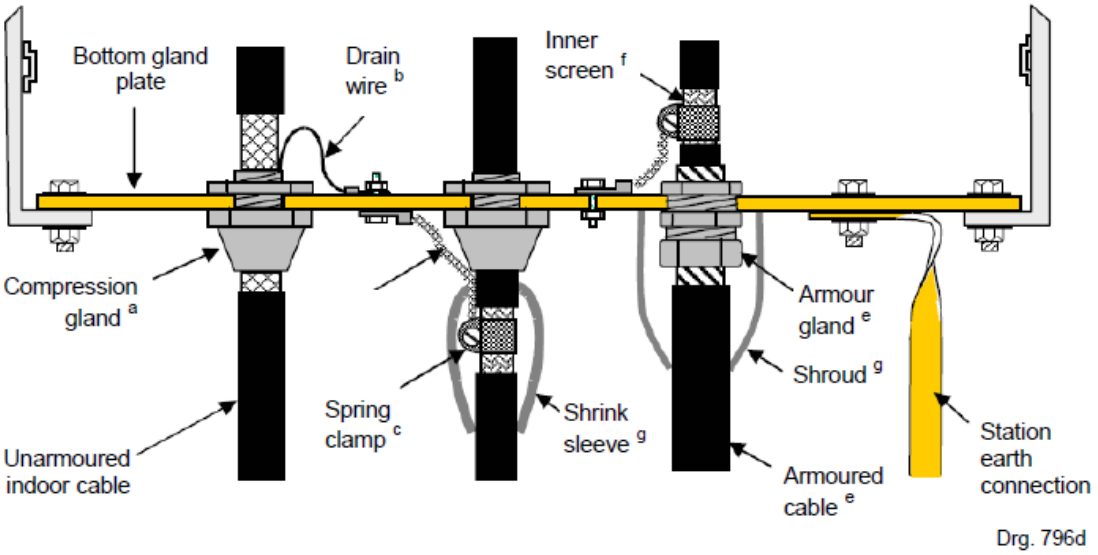
1. The armoured cable must be guarded using a proper armour gland. The armouring of the cable must be bonded to the top gland plate in the case of a painted gland plate, a "kite" washer must be used to ensure that the earth connection and the gland plate is bonded.
2. The flat copper earth (25mm x 3mm) connecting the top gland plate to the earth bar in the overhead rack must be braised.
3. The cabinet earth connecting the top and bottom gland plate securely bolted, and in the case of a painted gland plate, a "kite" washer must be used to ensure that the earth connection and the gland plate is bonded.
4. The drain wire in the cables must only be made off to earth at one point.
5. A gland plate should be installed below the IDF and should be earthed at both ends of the gland plate.
6. The IDF should be earthed at both ends of the items using the copper 25mm x 3mm.

Figure 5: Earthing method for an IDF

3.4 Earthing of cable armouring and screens

All protection, metering, D.C. and auxiliary supply cables are to be steel-wire armoured cable and the armouring shall be bonded to the gland plate at both ends via a suitable gland and covered with an insulating gland shroud.

Figure 6 from NRS083:3 [1] illustrates the earthing procedure for glands of armoured and unarmoured cables, including cables with an inner screen.



NOTE Mirror the procedure for cabinets with top-entry cables.

a Conductive compression gland is the preferred method of earthing cable screens.

b If an unarmoured cable does not have an earthable screen, the drain wire is connected to the gland plate as shown.

c If a suitable conductive compression gland is not available for the type of unarmoured cable, expose the cable screen before the cabinet entry and remove any coating. Fit a spring-loaded clamp of correct size.

d The clamp is fastened to a **short length** of copper braid and terminated on the gland plate using a lug and a bolt.

e For armoured cable, use only a suitable conductive compression gland as specified by the cable manufacturer.

f If the armoured cable has an inner screen, this screen is also earthed to the gland plate with a spring-loaded clamp and a **short length** of copper braid.

g Shrink sleeve covers the exposed copper braid or aluminium laminate. A shroud is fitted over the armour gland. In coastal areas the sleeve or shroud is filled with grease to seal the gland against marine corrosion.

Figure 6: Procedure for earthing cable armour and shield at gland plate [NRS083-3]

Copper communication/data cables are typically unarmoured and include an overall mesh screen with or without a drain wire. The screen/drain wire is terminated on the earth terminal for the communication port/bus. The screen of the complete data circuit/bus is earthed at one point only, typically at the RTU/gateway panel.

Avoid pigtail earthing of cable shields: where possible use earthing glands or clamps with 360° circumferential contact.

The standard practice is that gland plates shall not be painted. In the event that the gland plate is painted, a cable gland earthing lug/tag (typically manufactured from brass) shall be used as illustrated in Figure 7. The earthing lug shall then be bonded to a suitable earthing point via a 4 mm^2 green/yellow insulated multi-strand conductor. The conductor shall be fitted with a suitable lug at each end using a quality crimper.

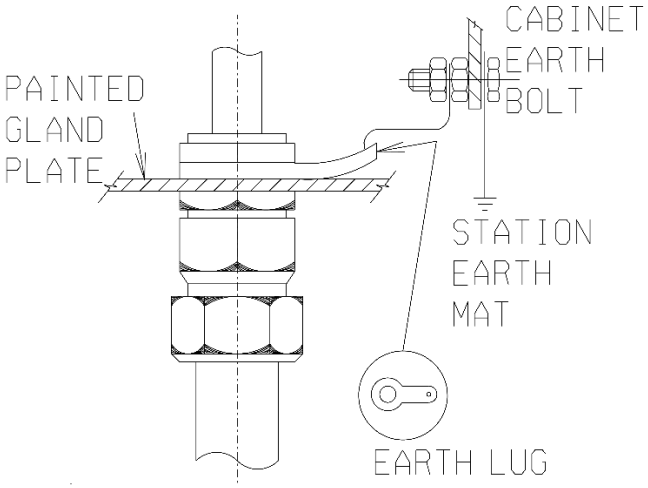


Figure 7: Application of an earthing lug on a painted gland plate

3.5 Earthing of spare cores in control cables

NRS083-3 recommends that spare cores within control cables should be earthed at both ends to enhance the shielding effect of the cable screen and to form a parallel earth conductor (PEC). Eskom practice is to earth only one end of spare cores for the following practical reasons:

a) The enclosures at both ends of the cable seldom have sufficient capacity for earthing of spare cores, both in terms of physical space, and space on the earthing bar/stud.

b) Spare cores must be left long enough to reach the furthest terminal block in the enclosure. The panel earthing bar is often at a different location to the furthest terminal, meaning that excessive spare conductor would need to be left.

Spare cores may be earthed on whichever end is most practical, though the preference is to install the earths on the “source” side of the cables. Yard junction boxes typically include ample earthing bars located above the terminal strips specifically for the purpose of earthing spare cores.

3.6 Yard junction box and enclosure earthing

Durable, metallic equipment enclosures and junction boxes must be in used in switchyards. The raw materials of such equipment include stainless steel, hot dip galvanised steel or cast aluminium. PVC and other non-conducting types are not suitable due to their lack of electrostatic shielding. The enclosure must make provision for earthing of cables at the entry point with earthing glands. The bonding area must be free of paint or coatings. If the structure is made of aluminium, suitable bimetallic washers must be used to prevent corrosion. The internal structure shall be internally treated to prevent corrosion due to condensation. An earthing stud of a minimum size (M10) must be available nearest to the cable entry point from where the unit must be bonded directly to an earthed structure. Hinged doors and internal metallic frames shall be bonded to the junction box or enclosure via copper earth braids.

Section 0 shall apply to the earthing of internal components of junction boxes/enclosures.

The recommended earthing method of cables connecting to primary plant equipment is to earth both ends of the shield/armouring (noting that almost all control cables in Eskom are earthed at both ends). NRS083-2 singles out instrument transformers as problematic with respect to electromagnetic interference and recommends that the issue of large shield/armouring currents being generated during transients may be addressed by using a copper parallel earthing conductor (PEC) of at least 50 mm^2 between each instrument transformer and its junction box and from the junction box to the relay/meter panel. Eskom experience with CT and VT cabling in substations is that a PEC is not required.

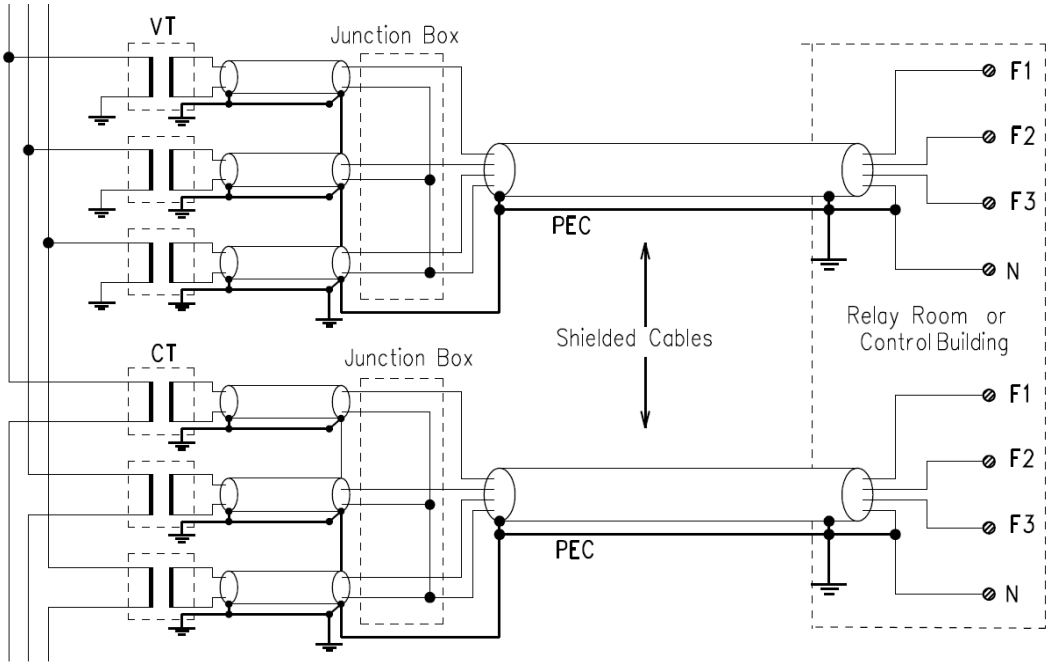


Figure 8: Earthing arrangement of VT & CT cabling [NRS 083-2]

3.7 Secondary neutral earthing of instrument transformers

Each Instrument Transformer circuit shall be earthed at one point only, either in the junction box or in the control/relay room. Eskom's secondary-side earthing practice for instrument transformer circuits is as follows:

- Current Transformers. For star-connected three phase circuits, earth the neutral wire as the circuit enters the first relay/metering panel in the control room. For delta-connected three phase circuits (e.g. auto-transformer tertiary overcurrent protection), earth one of the phases as the circuit enters the first relay panel in the control room – typically Blue phase (Transmission) or White phase (Distribution). For single phase circuits, earth the wire facing the protected object as it enters the first relay panel in the control room. Refer to Figure 9 and Figure 10 for application examples. SANS 474 [4] recommends that CT secondary earths are applied in the metering panel with the result that shared metering CT cores are mostly routed to the metering panel as the first panel in the control room.
- Voltage Transformers. Earth the secondary neutral wire in the VT junction box.

NOTE: VT circuits are earthed in the junction box because for busbar VTs this is the point of distribution to load panels. Historical Transmission practice was to also earth line VTs at the point of distribution, with the result that protection VT circuits were often earthed in the relay panel, whilst measurement VT cores were earthed in the line VT JB. To achieve consistency all line VT neutral earths were moved to the line VT JB in around the year 2000. SANS 474 [4] recommends that VT secondary wiring for metering be earthed in the junction box.

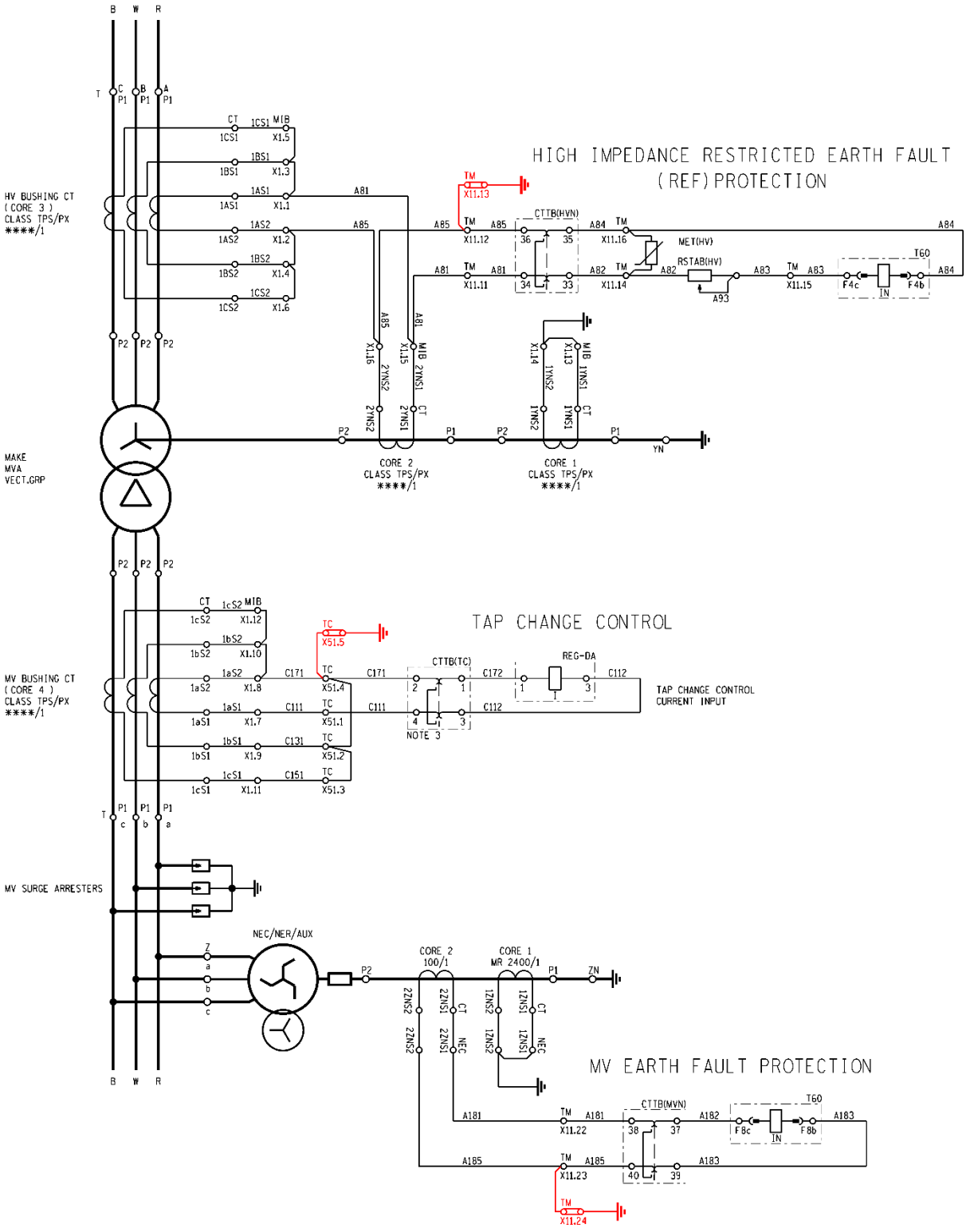


Figure 9: Application example: neutral earthing of star-connected three phase and single phase CTs in a transformer protection scheme

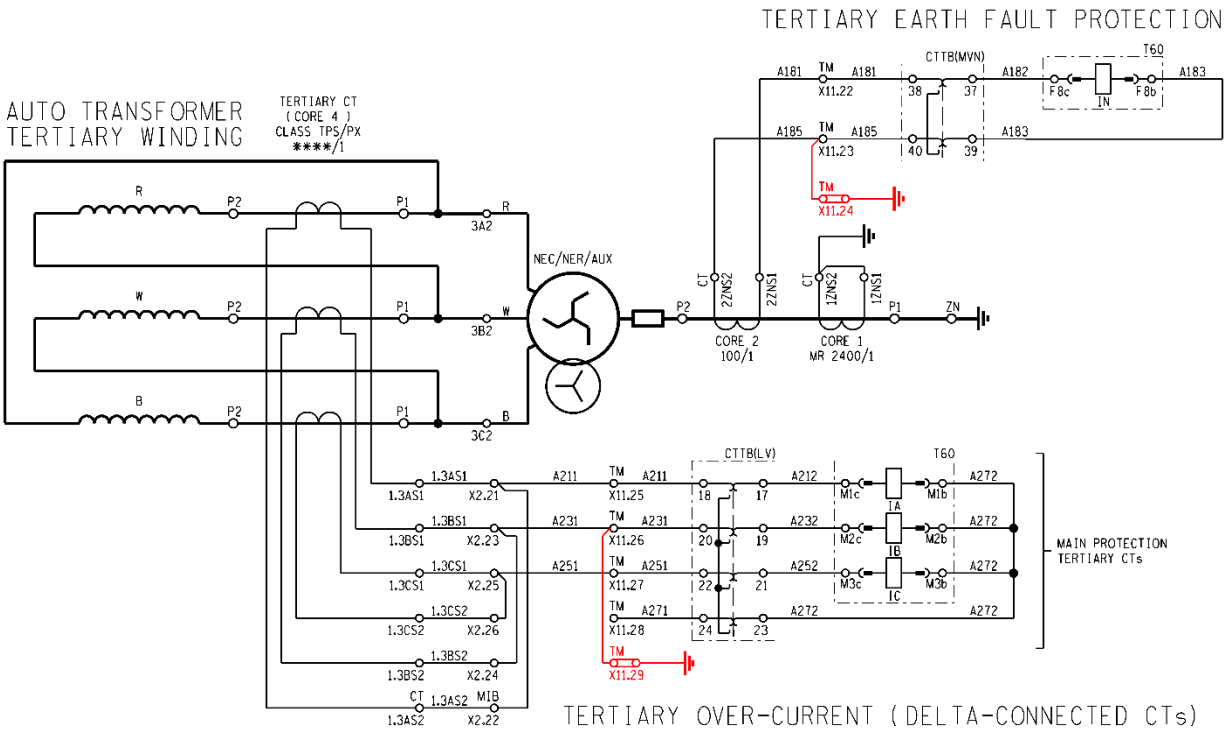


Figure 10: Application example: neutral earthing of delta-connected three phase CTs in autotransformer tertiary winding protection

In new designs, instrument transformer secondary neutral earths shall be wired via dedicated terminal blocks (as illustrated in Figure 9 and Figure 10) such as to allow easy disconnection of the earth connection for testing purposes. It is preferred that the terminal block features a disconnector with banana-plug sockets on each side to allow connection of a secondary insulation resistance tester, and execution of the test to confirm that the circuit is earthed at one point only. This is done by "Meggering" across the earthing terminal with the disconnector closed, proving continuity. Open the disconnector and "Megger" again, proving that there is now no continuity to earth, and finally close the disconnector and "Megger" to prove that the earth connection has been re-established. Use a test voltage of 500V.

Earthing directly onto a neutral or phase CT wire is not preferred as the CT circuit may become compromised during disconnection of the secondary neutral earth for continuity testing.

3.8 Secondary plant earthing check list

The following checks should be conducted on all secondary plant equipment, keeping in mind that a visual inspection of panel and equipment earthing should be considered merely an indication of earthing condition and under no circumstances should be substituted for comprehensive earthing resistance tests. Nonetheless inspect and document the condition of:

- Presence and condition of the panel earth bar,
- Confirmation that the earth bar is properly bonded to the substation earth mat or overhead cable rack (minimum 75 mm^2 for trench earth connections, 50 mm^2 for overhead racking connections).
- Inspect if all metal panel doors are earthed (12 mm^2 copper braiding (preferred) or 2.5 mm^2 stranded copper wire).
- Check if all terminal rails are earthed (irrespective of size).
- Check if every rack, sub-rack or frame is earthed.

- Check if every IED, relay, meter, transducer and electronic device is earthed by means of 2.5mm^2 copper wire.
- Check if all control switches and push buttons with metal mechanisms or housings are earthed.
- Check if all blanking plates are earthed.
- Check if all earth connections are:
  - Clean to the metal;
  - Utilising correct lugs, bolts, and washers (where applicable) and are properly fastened;
  - Corrosion free; and
  - Made-up with correct colour combination (Green/Yellow) insulated wire.

4. Authorization

This document has been seen and accepted by:

Name and surname	Designation
Mbulelo Kibido	General Manager Grids / Transmission Grid Manager's Forum Chair
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Anita Oommen	Ops Performance Manager
Comfort Masike	Technical Operations – Senior Manager
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Sikelela Mkhabela	Distribution Network Operations & Support Committee Chair
Martin Pietersen	Distribution Specialised Maintenance Manager's Forum Chair

5. Revisions

Date	Rev	Compiler	Remarks
March 2022	3	SJ van Zyl	Document structure altered for readability. References to NRS083 added. Definitions added. Section 3.2.3: Bonding of cabinet metallic components. Daisy chaining permitted for earthing of blanking plates. Section 3.2.4: Connections to trench or tray earth conductor. Detail added from unpublished work of Paul Gerber. Figure 4 added. Figure 6 and Figure 7 added. Section 3.5: Earthing of spare cores updated as per Eskom practice (single end earthing). Section 3.6: Yard junction box and enclosure earthing. Clarified that CT and VT cabling does not use a PEC. Section 3.7: Secondary neutral earthing of instrument transformers. Section added as per Eskom practice.
March 2017	2	C Hitchin	Area of applicability changed to Engineering and document “Seen and Accepted By” list updated.
Sept 2013	1	C Hitchin	First issue.

6. Development team

This document is based on previous Transmission standards by Asad Ally, Paddy Griffith and Sandy Ndamase. Revisions 0 and 1 of this document were compiled by Chris Hitchin. Stuart van Zyl compiled Revision 3, incorporating unpublished work by Paul Gerber.

7. Acknowledgements

Figure 4 and Figure 7 are from unpublished work by Paul Gerber, drawn by Veronica van Zweel.

Figure 5 is based on an original drawing by Paddy Griffith redrawn by Veronica van Zweel.

Figures 9 and 10 are adapted from the Distribution 5TM-5200 transformer protection scheme Master Drawing D-DT-15209 sheets 6A and 6C.