1. SCOPE

This document defines the functional performance and test requirements for earthing systems at substations 132kV and above.

The requirements of this document shall apply to new substations /cable sealing end compounds and where reasonably practical to extensions or modifications of existing substations/cable sealing end compounds.

Where a substation or cable sealing compound is being extended or modified, The Engineer will state if it is necessary to control the earth potential rise in accordance with this document.
This document is a SPEN modified version of NGTS 3.1.2.

2. ISSUE RECORD

This is a Reference document. The current version is held on the EN Document Library.

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4. REVIEW

This is a Reference document which has a 5-year retention period after which a reminder will be issued to review and extend retention or archive.

5. DISTRIBUTION

This document is not part of a Manual maintained by Document Control and does not have a maintained distribution list.

6. CONTENTS

7. REFERENCE AND RELATED DOCUMENTS

This specification refers to, or implies reference to, the following documents. It is important that users of all standards, specifications and other listed documents ensure that they are applying the most recent editions together with any amendments.

The Health and Safety at Work Act, 1974.	
The Electricity At Work Regulations, 1989.	
The Electricity Safety, Quality and Continuity Regulations 2002	
Electricity Supply Regulations 1988, Statutory Instrument No 1057	
Electricity Supply (Amendment) Regulations 1990, Statutory Instrument No 390.	
The Management of Health and Safety at Work Regulations, 1999, Statutory Instrument No 3242	
DD IEC/TS 60479-1:	International Electrotechnical Commission, Technical Report, Effects of Current on Human Beings and Livestock - Part 1 General Aspects.
BS EN 50522	Earthing of power installations exceeding 1 kV a.c.
BS EN 62305	Protection against lightning. General principles.
BS EN 61936-1	Power installations exceeding 1 kV a.c. Part 1: Common rules.
BS 6004	Electric Cables. PVC Insulated and PVC Sheathed Cables for Voltages up to and Including 300/500 V, for Electric Power and Lighting.
BS 7430	Code of practice for protective earthing of electrical installations.
ENA TS 41 24	Guidelines for the Design, Installation, Testing and Maintenance of Main Earthing Systems in Substations.
ENA ER 34	A Guide For Assessing the Rise of Earth Potential at Substation Sites.
ENA S 36	Identification and Recording of 'Hot' Sites - Joint Procedure for Electricity Industry and Communications Network Providers
ENA TS 43-94	Earth Rods and their Connectors.
ENA ER C55	Insulated sheath power cable systems
CCITT Directive, Volume VII,	Protective Measures and Safety Precautions.
Earth Resistances, G F Tagg, George Newnes, London, 1964.	
EPS-03-033	Ratings and General Requirements for Plant and Apparatus for the Connection to The Company's System.
TS 2.1	Substations.
SCT 46	Schedule of Site Commissioning Tests: Substation Earthing.
TGN(T)18	Power Line Carrier (PLC) Channels
TGN(E)114	Replacement or Repair of Stolen or Defective Earth Tapes.

TGN(E)133	Protection against ROEP and Induced Voltages on Telecommunications Cables at Substation Sites.
TGN(E)152	Location of Substation Sites with a Rise of Earth Potential under Fault Conditions above 650 V (Hot Sites).
TGN(E)187	Guidance for conductor Jointing in Substations.
TGN(E)199	Management of Rise Of Earth Potential at New and Refurbished Towers
PS(T)045	Management of Rise Of Earth Potential at New and Refurbished Towers

8. DEFINITIONS

For the purpose of this specification, the following definitions shall apply and are reproduced in *italic fon*t throughout this document:

Backup Protection	Protection set to operate following failure or slow operation of primary protection. (See *Normal Protection* also).
Bonding Conductor	A protective conductor providing equipotential bonding.
Earth	The conductive mass of earth whose electric potential at any point is conventionally taken as zero.
Earth Electrode	A bare conductor or group of bare conductors buried directly in the *Earth* to provide a direct electrical connection with the general mass of *Earth*. This includes earth rods driven into the ground, bare stranded conductors, bare earth tape and mesh.
Earth Electrode Resistance	The resistance of an *Earth Electrode* with respect to *Earth*.
Earth Fault	A fault causing current to flow in one or more earth-return paths. Typically, a single-phase to *Earth Fault*, but this term may also be used to describe two-phase and three-phase faults involving *Earth.*
Earth Fault Current (I_F)	The worst-case steady state RMS current to earth, resulting from a single-phase to *Earth f*ault. Not to be confused with *Ground Return Current* (I_{GR})
Earth Fault Current (Design)	Fault current used to calculate *Earthing Conductor* size based on maximum permissible system fault current design limit.
Earth Potential Rise (EPR))	The difference in potential which may exist between a point on the ground and a remote *Earth*. Formerly known as RoEP (rise of earth potential).
Earthing Conductor	A protective conductor connecting a main earth terminal of an installation to an *Earth Electrode* or to other means of earthing.
Earthing System	The complete interconnected assembly of *Earthing Conductors* and *Earth Electrodes* (including cables with uninsulated sheaths).
Global Earthing System (GES)	An *Earthing System* of sufficiently dense interconnection such that all items are bonded together and rise in voltage together under fault conditions. No true earth reference exists and therefore safety voltages are limited.
Ground Return Current (I_{GR})	The proportion of *Earth Fault Current* returning through soil via the general mass of *Earth*.

Hot / Cold Site	A *Hot Site* is defined as one which exceeds ITU limits for *EPR*. Typically, these thresholds are 650 V (for reliable fault clearance time ≤ 0.2 seconds), or 430 V otherwise.
High EPR	*High Earth Potential Rise* resulting from an *Earth Fault*. An *EPR* greater than twice the permissible *Touch Potential* limit.
Low EPR	*Low Earth Potential Rise* resulting from an *Earth Fault*. An EPR less than twice the permissible *Touch Potential*
Normal Protection	Clearance of a fault under normal (usual) circumstances. The normal clearance time will include relay operating time and mechanical circuit breaker delays for all foreseeable faults and may be calculated for design purposes.
Network Contribution	The electrode effect of the wide area HV (and LV) interconnected network. Large networks provide multiple parallel electrodes which can provide a relatively low impedance path to *Earth.*
Portable Earths	An earthing device made up of flexible leads
Primary Substation	An installation on the SPEN Distribution System where the highest operating voltage is 33kV. This includes 33/11kV substations, 33/11/6.6kV substations, 33kV switching stations and 33kV connected customer substations.
Supplementary Electrode	An electrode that improves the performance of an *Earthing System*, and may increase resilience, but is not critical to the safety of the system.
Step Potential (U_S)	Voltage between two points on the ground surface that are 1 m distant from each other, which is considered to be the stride length of a person
Stress Voltage	Voltage difference between two segregated *Earthing Systems*, which may appear across insulators/bushings etc. or cable insulation.
The Company	Refers to SP Distribution Limited, SP Transmission Limited and SP Manweb plc.
The Engineer	Energy Networks nominated representative having authority over technical matters contained in this specification.
Touch Potential (U_T)	Voltage between conductive parts when touched simultaneously.
Transfer Potential	Potential transferred by means of a conductor between an area with a significant *EPR* and an area with little or no *EPR* and results in a potential difference between the conductor and earth in both locations
Transmission Substation	An installation on the SPEN Transmission System operating at 400kV kV, 275 kV or 132 kV

9. INTRODUCTION

This document defines the functional performance and test requirements for earthing systems forming part of The Company's System and protected by fast acting protection systems[1]. It supports the more general conditions defined in the companion documents EPS-03-033 and TS 2.1.

The requirements of this document shall apply to new substations, cable sealing end compounds, terminal steel lattice towers, metallic and wood poles constructions and where reasonably practicable to extensions or modifications of existing installations.

Where a substation, cable sealing end compound or terminal tower is being extended or modified, The Engineer will state if it is necessary to control the rise of earth potential in accordance with 10.2. If not stated, this requirement need not be applied.

10. GENERAL REQUIREMENTS

The earthing system shall comply with BS EN 50522, ENA TS 41-24 and ENA EREC S34, unless otherwise stated.

10.1 Statutory Requirements

The earthing system shall be designed and installed to comply with all relevant statutory instruments. Specifically, The Electricity Safety, Quality and Continuity Regulations 2002 require that:
"A generator or distributor shall ensure that, so far as is reasonably practicable, his network does not become disconnected from earth in the event of any foreseeable current due to a fault".

Further requirements are contained in the Electricity at Work Regulations 1989 and Management of Health and Safety at Work Regulations 1999.

10.2 Earth Potential Rise (EPR)

The safety of all persons on high voltage sites, as well as in the immediate environs of such sites, and persons who may contact any conducting services to, or passing through such sites, is dependent on the design of the earthing system and its associated electrical isolation. The design of the earthing system at substations shall limit the step and touch potentials to safe levels given in Tables 1A, 1B and 1C.

The design of the substation earthing system shall assume that bare surface contact conditions apply i.e. no insulating layer should be taken into account for the calculation of step, touch and transfer potentials.

Deviations from the above will only be allowed under exceptional circumstances and shall be agreed with The Engineer.

Where chippings are to be used the resistivity of the chippings and layer thickness shall be stated and agreed by The Engineer.

	Maximum Voltage for Touch	Maximum Voltage for Step
Chippings surface (150 mm)	2.06kV	Limits could not foreseeably be exceeded.
Chippings surface (75 mm)	1.77kV	
Soil surface	1.57kV	

[1] Note: Fast acting protection systems are those designed to achieve a target total fault clearance time of less than 200ms.

Table 1A Touch and Step Potential Limits for 132kV and above[Source: ENA 41-24 Table 1 and 2]

The limits in Table 1A assume a 200ms clearance time, 1m step distance and footwear resistance of 4kΩ per shoe. They are based upon the curves in BS EN 50522 UK National Annex A.

10.2.1 The management of EPR at transmission towers shall be in accordance with TGN(E) 199.

10.2.2 In the event that an insulating coating is required to be applied to the tower legs or metallic and wood poles in order to manage the risks associated with touch potentials, then the coating specification shall comply with the minimum requirements below:

a) Minimum rated voltage withstand: 50kV.
b) Coverage: From ground level to 2.5m above ground level.
c) Minimum service life: 10 years,
d) The coating shall not serve to aid climbing of the tower.
e) The coating shall not prevent the fitting of step bolts.
f) The coating shall be resistant to minor impact damage.
g) The coating shall be dark or light grey and shall generally be unobtrusive.

10.2.3 Cable sealing end compounds shall be treated as substations unless otherwise agreed by The Engineer.

10.2.4 Critical third party EPR impact voltage thresholds via proximity effects are given in Table 2. If these levels are exceeded provision for mitigation, engagement with the owner and implementation of mitigation measures shall be made.

Third Party Infrastructure	Threshold Limit Voltage
Domestic residence or commercial property	1700V
Large hazardous process plant e.g. refinery	650V
Railways	645V

Table 2 - Third Party Impact Threshold Voltages via Proximity Effect [2]

10.2.5 Where The Company's substation provides a HV connection to a third party, the applicable threshold limit values via conduction are given in Table 3.

Third Party Infrastructure	Threshold Limit Voltage
Domestic residence or commercial property	Not Applicable
Large hazardous process plant e.g. refinery	650V
Railways	645V

Table 3 Third Party Impact Threshold Voltages via Conduction [3]

10.2.6 The design of the earth electrode system (whether this is as a result of adding to an existing system or the installation of new system), shall be optimised in so far as is reasonably practical to ensure third party impact threshold voltages are within the limits in Tables 2 and 3. In particular, consideration shall be given to the arrangement of the electrode system and the use of all land within the substation boundary. It is only necessary to use land outside the substation boundary (within The Company's ownership) if stated by The Engineer. The earth electrode

[2] Proximity effect refers to EPR conduction via the ground[data from NGTS 3.01.02 Table 2].
[3] Conduction refers to electrical conduction via metallic conductors[data from NGTS 3.01.02 Table 3].

depth and geometry shall be optimised to make use, as far as practicable, of lower resistivity ground strata.

Where reasonably practicable, the earthing system shall be designed using an earth return current which is 20% greater than that calculated by The Engineer or at a value specified by the System Design department, to allow for future increases in system fault current. Where this is considered unreasonable(e.g. the substation earthfault can not reasonably be expected to rise to these hgher levels), lower design current values can be employed in the design of the earthing system with the agreement of The Engineer.

10.2.7 Calculations to design the main earth system shall be carried out using CDEGS software package (Current Distribution, Electromagnetic Fields, Grounding and Soil Structure Analysis). The design models produced shall be made available once completed and becomes the property of The Company as part of the contract.

10.2.8 Telecommunication services delivered to all of The Company's substations on metallic cables shall be in accordance with TGN(E) 133. Please note that where services are delivered to site by optical fibre, there is no need for fibre isolation. Within a hot zone, the optical fibres shall be free of metallic components.

10.2.9 The substation earth electrode system EPR shall be calculated using the earth return current calculated (actual) by The Engineer. Note any future increase in substation earth return current will require the EPR to be reviewed. The EPR, at the 20% growth fault current shall be provided for information purposes or at a value specified by the System Design department.

10.3 Earth Electrodes

10.3.1 Earth electrodes shall be designed to operate satisfactorily during faults, taking into account the area of the electrodes in contact with earth, the soil resistivity and earth electrode current magnitude and duration, in accordance with BS EN 50522. The fault duration times to be used for rating the electrodes are shown in the table below; 1 second for 275kV and 400kV, and 3 seconds for all other voltages. The design will comply with the recommendations given in ENA TS 41-24. Preferred conductor sizes are supplied in 11.1.

Maximum Site Voltage	Fault duration(s)
275kV and higher voltages	1
Over 1kV, up and including 132kV	3

Table 4: Clearance time for conductor size(Source: ENA 41-24)

10.3.2 Buried bare copper horizontal earth electrodes shall be installed at a minimum of 500mm depth. If the indigenous soil is hostile to copper, see section 12.1.1 (b), the electrode shall be surrounded by 150mm of non-corrosive soil of fine texture, firmly rammed as detailed in . Conductors installed in ploughed farmland shall be buried at least 1m deep, at all points measured from undisturbed ground level.

10.3.3 Earthing electrodes should not be directly buried in high resistivity materials, for example backfills. These could include MOT type 1 crushed concrete aggregate. Sand is also not suitable. In these cases, the electrodes shall be surrounded by 150mm of non-corrosive soil of fine texture, as per clause 10.3.2. Alternatively, the properties of any backfill materials may be established through laboratory testing and shall be deemed acceptable if commensurate with the indigenous ground properties.

10.3.4 Driven rod electrodes in accordance with ENA TS 43-94 shall be used to exploit lower resistivity ground strata where present to reduce the site EPR in accordance with 10.2. Where the ground is hard and rods cannot be driven, consideration shall be given to drilling holes to install the rods and back filling with a suitable low resistance fill material to achieve the designed earth impedance.

10.3.5 Buried conductors and electrodes shall be at least 3m away from buried cables with uncovered metallic sheaths, unless the sheaths are used as part of the earthing system.

10.3.6 Where beneficial, reinforcing steelwork incorporated within piling shall be utilised as an earth electrode. However, care must be taken to ensure that the current carrying capacity of the steelwork is not exceeded. Connections shall be made to the vertical steel bars within the pile cap. Connections brought out through the pile cap shall be provided with appropriate means to prevent moisture ingress into the cap. Current carrying connections to and within the steelwork shall be in accordance with BS EN 50522. Fortuitous connections must not be relied upon. Welded connections are preferred.

Where sheet steel piles of the interlocking kind are used as an earth electrode, connections shall be made to each sheet steel pile.

Where steel reinforcing bars are used as part of the earthing system the size of the steel reinforcing shall have a minimum cross section of $50mm^2$.

Where steel reinforcing is used as the potential grading for the protection of the operator, all relevant parts of the steel reinforcing shall be connected together to ensure that no differences in potential exist. The connections shall be dimensioned in accordance with BS EN 50522.

Where steel reinforcing is used as an electromagnetic shield associated with high frequency currents all relevant parts of the steel reinforcing shall be connected together to form a very low impedance path for high frequency currents. Multiple connection points will need to be provided to the steel reinforcing, to enable equipment connections to be kept as short as possible, to minimise the electromagnetic influences.
Where steel reinforcing bars are used for any of these purposes care shall be taken to ensure that the possibility of corrosion is kept to a minimum. The connection to the steel reinforcing bars shall be in accordance with BS EN 50522.

10.4 Earth Electrode Arrangement

10.4.1 Unless otherwise agreed by The Engineer, the earthing electrode arrangement shall be based on a peripheral buried main bare earthing conductor, generally encompassing the plant items to be earthed, with buried spur connections from the main conductor to the items of plant. The main earthing conductor shall be augmented with inter-connected buried bare cross-connections to form a grid. In addition, where beneficial and practical to install, groups of earth rods distributed around the periphery shall be connected to this main earthing conductor.

10.4.2 For indoor substations the earthing grid shall be installed with spur connections to the steel reinforcing mat of the concrete floor, every 20m. Additionally, a second peripheral main earthing conductor shall be buried at 1m distance from the building, which shall be bonded to the first main conductor and to the building if it is metal clad, both at 20m intervals. Earth rod groups shall be connected to the second peripheral conductor as stated in 10.4.1.

10.4.3 Stranded earth electrode below ground may be used subject to the The Supplier providing detailed calculations to show that it is no less effective than copper earth tape and a cost benefit can be achieved.

10.5 Test Facilities

10.5.1 In order to facilitate testing of all earth electrode groups, a section of conductor connecting to each group shall be made accessible and shall have dimensions that would fit inside 50mm diameter circular clamp meter jaws (minimum length of 75mm). This section of conductor shall be a part of a spur connection to the rod group i.e. so that all the test current flows into the rod group and is not diverted into the main earth system.

10.5.2 Disconnectable links shall not be fitted in the connections from the main earth system to terminal towers or rod groups or in the connections between main earth systems, e.g. between earth systems on joint sites. A sample picture is shown in Appendix C.

10.6 More Than One HV Substation

10.6.1 Where there is more than one Company substation on the same site a separate earth grid shall enclose each substation and these grids shall be connected together at the extremities by at least two fully rated conductors ideally taking secure separate physical routes.

10.6.2 Where a Company substation is located on the same site as another user's substation, the earthing systems shall be interconnected as defined by The Engineer.

10.6.3 Measures shall be taken to ensure that persons cannot come into contact with hazardous transferred potentials between substations or directly connected customers, particularly where sites are separated. Where control of these potentials requires measures to be taken by a third party, The Engineer shall be informed by the supplier at the time of production of the earthing design.

10.6.4 In all cases where HV earthing systems are connected together, disconnectable test links shall not be fitted.

10.6.5 On shared sites where the customer operates HV switchgear/infrastructure, there will be a boundary between The Company's ownership and customer ownership. Where reasonably practical The Company shall not rely on the customer's earthing system to ensure electrical safety in regard to safe touch, step and third party impact voltages. If safe levels cannot be achieved consideration of alternative locations should be made providing they are technically or economically viable. For single customer owned sites in the event that no alternative locations can be found then it is permissible to connect to the customers earthing system providing the connection agreement can be altered to include a requirement for the customer to maintain the earth resistance established at commissioning for the duration of their connection. For a site where multiple customers are connected the connection shall not rely upon a customer earthing system. In practice, for single and multiple customer sites, the systems will be connected together but each system should (where possible) be designed to be safe (touch voltages) in the absence of any contribution from the other system.

10.7 Equipment Connected to the Main earth system

10.7.1 The following items of equipment shall be connected to the main earth system by a fully rated conductor:

a) All points which may form the earth of a high voltage fault path.
b) Transformer winding neutrals required for HV system earthing. For 66kV and below, the connection may be via earthing resistors or other current limiting devices.
c) In the case of a manually operated earthing or HV switch, a dedicated fully rated conductor shall be run from the handle or mechanism box to the main earth system as directly as possible and this conductor shall pass under the stance position of the person operating the switch. The conductor runs to any fault points associated with the switch shall, where practicable, be maintained separate from the handle or mechanism of the switch and connecting metalwork.
d) Line entry earth switches shall be directly earthed via dedicated earth connections to the main

earth electrode.

e) Substation maintenance earth switches which are fully interlocked may be earthed via the main support structure which has been designed to accommodate the required earth fault rating. The design of the support structure shall comply with section 10.10.

10.7.2 All metalwork e.g. panels, cubicles, kiosks etc., including the steelwork of buildings, shall be bonded to the main earth system by a conductor of no less than 70mm^2 cross section. Strip conductor shall be no less than 3mm thick. Where a 70 mm^2 conductor is not reasonably practicable, small electrical appliances, or small non fault current carrying metallic items, may be connected by a smaller conductor (no smaller than 16mm^2). Care should be taken that the smaller conductor is adequately secured and protected against accidental damage in particular below 1.5m height.

10.7.3 Mechanical linkages, e.g. turnbuckles, shackles etc., which could form part of the earth connection shall be shunted across using fully rated flexible conductor to prevent damage by the passage of fault current.

10.7.4 Metallic trench covers shall be earthed to cater for the possibility of an earth fault on cabling in the trench and to cater for the possibility of induced or transferred potentials. To achieve this, metal trench covers may be laid on conducting support(s) that shall each be connected to the main earth system by a conductor as specified in 10.7.2.

10.7.5 Computer flooring metallic systems shall be earthed in accordance with the manufacturers guidelines.

10.8 Installation

10.8.1 Earthing conductors laid in trenches in outdoor substation compounds should be avoided where possible due to the vulnerability of the copper to theft. Where this is unavoidable, the earthing conductor should be protected from theft using the techniques detailed within section 10.8.9.

Where a trench contains power cables and/or multicore cables, the earthing conductor shall be fixed to the walls of the trench approximately 100mm from the top to maintain separation from the cables.

10.8.2 Due regard shall be given to the possibility of mechanical damage to buried conductors and, where necessary, either marker tapes and/or mechanical protection shall be installed. A separation of at least 500mm to civil works such as drainage pits shall be maintained. Conductor runs above ground shall be designed to minimise the possibility of mechanical damage.

10.8.3 Where permitted when laying stranded conductors, care shall be taken to avoid distorting individual strands.

10.8.4 Due to its vulnerability to theft, all above ground earthing conductors shall be fixed firmly and tidily to structures at a spacing of no more than 200mm between fixings. The fixings shall not promote galvanic corrosion. Where earthing conductor fixing systems require the earth conductor to be drilled, checks shall be undertaken to ensure that the loss of cross sectional area of the earthing conductor does not de-rate its operational performance requirements. Due to the lack of security fixing techniques for stranded conductors, where reasonably practical, flat copper tapes should be used for all above ground earthing conductors.

10.8.5 Where below ground earthing conductors cross, they shall be jointed (other than in the case of rod groups where these must be maintained separate to permit testing). Bolted joints are not acceptable below ground other than for earth rod screw couplings which shall be thoroughly greased. Connections to buried earth rods shall be welded in accordance with TGN(E) 187.

10.8.6 Where earthing conductors terminate above ground, the connections shall as far as reasonably practical be made onto equipment surfaces in the vertical plane to avoid standing water. Connections to metal cladding of buildings shall be made on the inside of the building. All bolted joints shall be in accordance with section 10.8.8. Moreover, all bolted joints shall be situated at least 150mm above ground level.

10.8.7 Aluminium conductor used for earthing systems shall only be installed above 250mm from ground level. All joint interfaces between the below ground copper earth conductors and the above ground aluminium earth conductors shall be jointed to manage any potential galvanic corrosion issue.

10.8.8 All earthing conductor bolted joints shall be installed in accordance with TGN(E) 187.

10.8.9 All vulnerable shallow buried earth tapes (tapes installed with less than 400mm of covering), shall be protected from theft at 2m intervals with either concrete anchors or driven earth rods. All above ground earth tape shall be proactively protected from theft using the following techniques.

10.8.10 Where concrete structures are used within the substation design solution and/or where earth tapes run across equipment concrete foundation pads, then stainless steel concrete anchor pins shall be used to secure the earth tapes in place. Any anchor pins installation must be in accordance with 10.8.4. The shape of the anchor pin head shall be shaped to resist impact, chiselling and interference. All earth conductors shall be fixed to equipment concrete foundation pads for a minimum depth of 300mm below the finished surface level to deter interference.

Care should be taken to avoid forming conductive loops, where pins are in contact with rebars, which may result in inadvertent circulating current in earthing installations.

10.8.11 Where steel structures are used within the substation design solution, then stainless steel panel bolts and shear nuts shall, where practicable, be used to secure the earth tape to the equipment structure. The bolts shall, where practicable, utilise a keyed design to deter interference and be sized in length to accommodate the structure profile thicknesses. Any bolt installation shall be in accordance with 10.8.4. The shape of the bolt head shall be shaped to resist impact chiselling and interference.

Shear nuts shall be designed to deter interference once fully installed.

10.8.12 On occasion, some steel support structures used within the substation design solution may not, because of their physical construction or the materials used, lend themselves easily to direct security bolting of earth tapes described in section 10.8.11. Until such structure designs are modified to accommodate direct fixing, alternative arrangements to deter theft shall be considered. One such alternative approach is to encapsulate and fix all above ground earth tape within a steel capping cover system before fastening to the design points made available on the structure steelwork. The perceived benefit from taking this approach is to make the solution difficult to separate into its component parts, making it inherently more difficult to steal, to manhandle and to sell on without its value being considerably reduced.

10.8.13 All above ground earthing tape conductor shall be stamped continuously throughout its length with *"PROPERTY OF SCOTTISH POWER"* to deter theft and devalue the product. At the completion of the installation, the stampings should be made visible as far as reasonably practical.

10.9 Portable Earthing

10.9.1 Loops for portable earths shall be provided on the earthing conductor at each location where portable earths may be required to be applied.

The earthing D-Loops shall be appropriately sized to comply with the substation's design rating and for the point for attachment of the earth end of The Company Standard: Portable Earths. The loops shall be not less than 230mm long and shall be 75mm clear of the earthing conductor.

Loops for portable earths shall be installed at a convenient height and shall be directly connected to the MES by copper conductors.

The loops for portable earths shall employ designs which minimise the provision of climbing aids.

The locations where earthing D-Loops shall be attached to the structure leg of a plant item are as follows:

a) For the structures of rotating centre post disconnectors, there shall be one D-Loop for each leg e.g. a typical RCP disconnector and structure would have 4 D-Loops.
b) For the structures of pantograph disconnectors and freestanding earth switches, there shall be one D-loop for each phase.
c) Any structures which are either part of, or immediately adjacent to, the transition point of a substation, i.e. cable sealing end structure or surge arrester structure next to overhead line downleads entries, there shall be one D-loop for each phase.
d) Any structures and associated plant which are in proximity to an internal substation access road, these structures should have one D-loop for each 3 phase set facing the access road (with the exception of structures from the above points) to allow for connection of a trailing earth from a vehicle (crane) passing along the access road.
e) Any area of the substation which is not in the vicinity of an access road and there are no disconnectors or earth switches in proximity then a structure within that area should have one D-loop for each of the 3 phases to allow for earthing of MEWPs working in that area.

The earthing spigots shall be appropriately sized to comply with the substation's design rating and for the primary attachment points of the required Portable Earths. A drawing shall be provided to show all spigot and D-loop locations for agreement with The Engineer.

Earthing spigot locations shall match the placement of the above-mentioned earthing D-Loops (excluding points required for trailing/MEWP earths) however it will only be applicable to any busbar or stranded conductor which is greater than 90mm in diameter.
Earthing spigot locations for main and reserve busbar shall be in accordance with guidance provided in NGTS 2.01 or it's Scottish Power equivalent.

10.10 Support Structures

10.10.1 Where the current carrying capacity of support structures is at least equal to the design rating, with the exception of line earth switches, it is preferred that the structure is utilised to form part of the connection to the main earthing system, in which case there is no need to fix an earth conductor along this section.

Where support structures form part of the equipment earth connection to the main earth system, where practical, welded steel or aluminium type structures shall be used.

10.10.2 Where a structure is relied upon to provide an earth connection for supported equipment, current carrying joints within 2.4m of ground level shall be in accordance with TGN(E) 187. Above 2.4m the normal structural joints are considered adequate for electrical integrity during fault conditions. Where lattice (bolted) structures are relied upon to provide part of the equipment earth connection to the main earth system, all current carrying bolted joints shall be designed to accommodate fully rated shunt connections in accordance with NGTS 2.1. The support structures shall be designed to ensure two diagonally opposite structure legs each provide a fully rated earth continuity connection equivalent to the design rating.

10.10.3 Support structures shall not be relied upon to conduct high frequency currents, or for earth connections to line earth switches.

10.10.4 Where post insulators, other than those forming part of shunt connected equipment (e.g. VTs or SAs) are supported by a metallic structure the insulator base does not require a bridging connection to the structure.

10.11 Fences

10.11.1 Measures shall be taken to ensure that dangerous touch or transferred potentials cannot arise on substation fences. The fence EPR parameters shall be established using a CDEGS model for the substation earthing system through the inclusion of the fence earthing system within the model.

10.11.2 Perimeter fences may be independently earthed using 4.8m long rod electrodes, where this is not possible alternative earthing arrangements may be used by agreement with The Engineer. The rod electrodes shall be fitted at 50m intervals and at changes of fence direction and either side of where overhead power lines cross the fence line. In certain circumstances perimeter fences may be connected to the main earth system. Directly earthed fences shall be used with the agreement of The Engineer and be in accordance with 10.11.4.

10.11.3 Where a perimeter fence is independently earthed, 2m separation shall be maintained between the fence and the main earth system and equipment connected to it.

10.11.4 Unless otherwise agreed by The Engineer, where a perimeter fence is connected to the main earth system an additional buried bare conductor shall be installed 1m outside the fence buried at a depth of 0.5m to control touch potentials. This conductor shall be connected to the main earth system and fence at 50m minimum intervals and at changes of direction of the independently earthed fence. This conductor is to be protected from theft in accordance with 10.8.9.

10.11.5 Metallic internal fences within the curtilage of the main earth system shall be connected to it at 50m minimum intervals and at changes of direction and where power lines cross overhead. Unless otherwise agreed by The Engineer, internal fences not within the curtilage of the main earth system shall have an additional buried bare conductor installed 1m on either side of the fence buried at a depth of 0.5m connected to the fence at 50m intervals to control touch potentials.

10.11.6 Where a fence, which is connected to the main earth system, abuts an independently earthed fence they shall be electrically separated using either a non-metallic fence panel or an insulating section having 5cm (approx.) creepage at each end of a 2m section which is not connected electrically to either of the fences. A suggested method of installation using insulating bushes is shown in Appendix B figure 2. Any modification to the standard fence design to incorporate an insulated section shall not compromise the security of the fence or provide a climbing aid.

10.11.7 A cable having a metallic covering effectively in contact with the ground or a bare conductor which passes underneath an independently earthed fence shall be covered with insulation for a distance of 2m on either side of the fence. For example, this may be achieved by running the conductor in an alkethene pipe 2m either side of the fence.

10.11.8 Where galvanised steel chain link internal fencing is used, a separate earth conductor shall be installed along the fence (minimum $70mm^2$) and shall be connected to each section of fence every 10m or less and to the main earth system at 50m intervals.

10.11.9 Where coated fence panels are used they shall be earthed and precautions are necessary to cater against damage or erosion of the coating. The support posts shall be earthed via a bolted connection and ideally the metal of each panel should in turn be similarly connected to the post.

These shall be via manufacturer provided facilities. The overall fence shall be connected to earth in a manner similar to a separately earthed or bonded metal palisade fence.

10.11.10 Where plastic coated steel chain link internal fencing is used, connection to the main earthing system shall be made at all fence guide wire anchor points (minimum $70mm^2$).

10.11.11 Connections to the fence shall be via a conductor which shall be accessible. Where bolted joints are used to connect to the fence, these shall be protected with Denso Mastic and Tape.

10.11.12 The earthing design shall take cognisance of the insulated panels when used in the perimeter fence and where applicable anti-vermin fence protection shall be non-metallic.

10.12 Access/Egress Gates

10.12.1 Gate posts shall be bonded together with a below ground connection.

10.12.2 Access/egress gates are required to be bonded to their supporting post in such a way as to ensure dangerous potentials do not arise. Flexible copper bonds (minimum $16mm^2$ Cu or equivalent) shall be used.

10.13 Temporary Fences

10.13.1 Temporary metallic fences shall be installed with appropriate measures to limit touch or transferred potentials to safe levels.

10.13.2 An internal metallic fence within the curtilage of the main earth system shall be connected to the main earth system at 50m intervals, at changes of direction and where power lines cross overhead.

10.13.3 Where a temporary metallic fence which is connected to the main earth system abuts an independently earthed fence they shall be electrically separated in accordance with EA TS 41-24.

10.13.4 A fence outside the curtilage of the main earth system may present a greater hazard where it crosses the ground voltage profile. In this case, in order to limit the transferred potential, the fence shall either be non-metallic or shall have its sections electrically insulated from each other at intervals depending on the ground voltage profile at the site.

10.14 Temporary LVAC supplies

10.14.1 During construction activity adjacent to an existing live substation, it is often desirable to make available temporary LVAC supplies from the substation to the construction area. The substation supply earth and neutral will be connected to the MES at the LV board and hence the LV supply will attain the full substation EPR under earth fault conditions. This can create a transferred potential hazard where the supplies are provided to an area of lower EPR, i.e. to a construction area outside the substation.

If it can be established (e.g. through site records) that the difference in potential is equal to or below the safe transferred potential limit of 650V, no special precautions are required in respect of providing the supplies. However, where the difference in potentials are above 650V, the supplies shall be provided via an isolation transformer. The transformer shall have sufficient inter-winding withstand appropriate to the maximum EPR level.

In some rare circumstances, the potential gradient across the construction area itself is sufficient to create a transferred potential hazard, irrespective of whether a remotely derived supply is provided. This may require the initial establishment of an earthing system for the construction area to equalise the surface potentials across it. This should be checked through reference to the site earthing records and associated studies.

10.15 Terminal Towers/Poles

10.15.1 Where the earth wire of an incoming line terminates on a tower/pole, it shall be connected to the top of the tower/pole.

10.15.2 The tower/pole shall be connected to the adjacent substations main earth system (not rod groups) at two separate points by two fully rated spur copper strap conductors following secure separate routes. There shall be no disconnectable links in these connections. These conductors shall be connected to different legs of the tower, preferably climbing legs, and shall be adequately protected to prevent damage and deter theft. Where these conductors cross or come close to rod groups they shall be insulated to maintain an electrical separation between bare conductors of 2m minimum.

10.15.3 Where a terminal tower leg is within 2m of an independently earthed fence, the affected sections of fence shall be connected to the tower and insulated sections fitted either side of the affected sections. The insulated sections shall not be fitted to the fence within 5m of overhead conductors crossing the fence line.

10.15.4 Terminal tower footer resistance shall be in accordance with BS EN 50341(I) in general the tower resistance is to be less than 10Ω. The mitigation of terminal tower EPR shall be in accordance with TGN(E) 199.

10.16 Power Cable Earthing

10.16.1 The earthing requirements for power cables are detailed in ENA ER C55/5.

10.17 High Frequency Earths

10.17.1 Where shunt-connected equipment is required to pass high frequency(HF) current (e.g. surge arrestor or capacitive voltage transformer), a low impedance path to earth shall be provided to prevent voltage transients appearing at the earthed end of the equipment.

10.17.2 High frequency earth rods shall be driven vertically into the ground to a depth of approximately 4.8m. Where this is not achievable, a high density earth mesh arrangement or (four nominally 10m) long horizontally buried conductors dispersed at 90° may be used in place of the rod. Calculations shall be provided to demonstrate that any proposal is equivalent to the 4.8m long earth rods. The high frequency connection shall be made to the centre of the alternative HF earthing designs.

10.17.3 The connection to the rod or horizontal conductors shall be as short as practicable, shall have no sharp changes in direction and corners shall be smooth. To facilitate this, and where reasonably practicable, it may be necessary to route the connection in a duct through the concrete foundation. The connection to the rod shall also have a fully rated connection to the main earth system.

10.17.4 In order to facilitate testing of the rod, a section of conductor connecting to it shall be stood away from any mounting surface (minimum 35mm) and have dimensions which would fit inside 25mm diameter circular clamp meter jaws. This section of conductor shall be a part of the spur connection to the rod i.e. so that all of the test current flows into the rod and is not diverted into the main earth system. The conductor shall be insulated between the accessible section and the rod.

10.17.5 The connection to the top of the rod shall be brazed or welded in accordance with TGN(E) 187.

10.17.6 The high frequency connection between the equipment and the earth rod may either be fully rated insulated copper earth tape or a PVC or EPR insulated stranded copper conductor coloured black to BS 6004 type 6491X. Insulated conductor is preferred since it provides suitable insulation for the spur connection above the surge counter. The insulation also distinguished the conductor from fully rated conductors, thereby avoiding inadvertent connection of portable earths. All bolted HF connections above the surge counter shall be suitably shrouded to the required insulation level.

An example of a HF earth installation satisfying the above requirements is illustrated in SPEN drawing SP2043169 provided in Appendix B.

10.18 Surge Arresters

10.18.1 For a surge arrester protecting a specific item of equipment e.g. a transformer the arrester shall be sited as close to the equipment as possible. The arrester shall not be sited more than 10m away from the protected equipment, without the agreement of The Engineer. The earth end of the surge counter shall be directly connected to the protected equipment earth by a fully rated copper conductor. Where practicable, the route of this conductor shall shadow that of the high voltage conductor between the arrester and the protected equipment. This connection shall have no sharp changes in direction and all corners shall be smooth and shall also have a fully rated connection to the main earth system. An example of transformer surge arrester and HF earthing installation satisfying The Company's requirements are illustrated in standard drawings SP2056909 and SP4049492 provided in Appendix B.

10.18.2 A separate earth rod shall additionally be provided in accordance with 10.17.2. An example is provided in Appendix B figure 3.

10.18.3 The connection between the arrester and the surge counter shall be insulated (minimum 3kV rms to 15kV impulse level). Note: for new generation surge counters positioned underneath the arrester this is not applicable.

10.18.4 For surge arrester protection specific to substation overhead line entry the arrester and HF earthing installation satisfying The Company's requirements is illustrated in standard drawing SP2056928 provided in Appendix B.

10.19 Capacitor Voltage Transformers (CVTs)

10.19.1 A separate high frequency earth rod is required for CVTs in accordance with 10.17.2. The rod shall be connected to the CVT tank and to the Power Line Carrier coupling device earth terminal in accordance with TGN(T) 18. The connection to the PLC coupling device shall be via minimum 70mm^2 copper conductor. The connection between this conductor and the main HF earth conductor shall be above an accessible section of conductor forming a spur connection to the rod to allow for testing (see 10.17.4).

10.19.2 A high frequency earth rod is required irrespective of whether power line carrier equipment is fitted or not.

10.20 LV Distribution Transformers

10.20.1 The earthing and isolation of LV distribution transformers associated with substations at a voltage of 132kV and above shall be designed assuming that the substation EPR is greater than 650V rms.

10.20.2 Where an LV distribution transformer is used to provide LV auxiliary supplies to the substation and is supplied externally, the following requirements shall apply:

a) Where the transformer is sited within The Company substation, the transformer steelwork and LV neutral shall be connected to the substation main earth system at the LVAC board only. The incoming HV supply shall be electrically isolated from the main earth system at a minimum level of 10kV rms. The HV cable sheath and any metalwork connected to it shall be insulated at a minimum level of 10kV rms plus HV supply phase to neutral voltage and the cable termination shall be clearly labelled to indicate a transferred potential hazard. The transformer shall not be used to provide LV supplies external to The Company substation. This arrangement is illustrated in Appendix B figure 1.

b) Where the transformer is sited outside The Company substation and the hot zone boundary, the transformer LV neutral and LV cable sheath shall be connected to the substation main earth system and electrically isolated from the external HV supply, including its associated earth, at a minimum level of 10kV rms plus HV supply phase to neutral voltage. The LV cable sheath insulation shall be rated at 10kV rms minimum. At the transformer end, the LV cable sheath and any metalwork connected to it shall be insulated at a minimum level of 10kV rms and the cable termination shall be clearly labelled to indicate a transferred potential hazard. The transformer shall not be used to provide LV supplies external to The Company substation. This arrangement is illustrated in Appendix B figure 1.

10.20.3 RMUs forming part of the distribution networks shall not be positioned within transmission substation sites.

10.21 Gas Insulated Substations

10.21.1 Gas insulated substations with single phase enclosures have specific earthing requirements to reduce circulating currents in supporting steelwork. The earthing system shall be designed in conjunction with the GIS manufacturer. The main earth system shall be well integrated in the regions close to equipment. The enclosure of the GIS should be connected to the earthing system at the following points:

a) Inside the bays
- Close to the circuit breaker
- Close to the cable sealing end
- Close to the SF6/Air bushing
- Close to the instrument transformer

b) On the busbars
- At both ends and at approximately 20m intervals in busbar runs.

The three enclosures of a single phase type GIS shall be bonded together before earthing. The bonding conductor shall either be rated to carry the nominal current of the bays and busbars, or if a lower rated bonding conductor is used, then it shall be proved by tests that no danger will arise during operation. Earthing conductors of surge arrestors for the protection of gas insulated installations shall be connected by as short a connection as possible to the enclosure.

Metallic sheaths (for example metal enclosures, armoured coverings, screens) of cables with nominal voltages above 1kV shall be connected directly to the GIS enclosure.

In some special cases, e.g. cathodic protection of cables it may be necessary to separate the earth connection of the cables from the GIS enclosure. In this case, the installation of a voltage surge protection device is recommended between the sealing end and enclosure.

The design of the main earth system shall include the recommendations made in ENATS 41-24 Clause 6.11.2 CIGRE Working Group 23-10:- Report on earthing of GIS – Application Guide and also BS EN 50522 Annex F Measures on earthing systems to reduce the effects of high frequency interference.

10.22 Reactive Compensation Compounds

10.22.1 Reactive compensation equipment may include air-cored reactors (line traps also include air-cored reactors, and other equipment may in the future). These air-cored reactors can produce high magnetic fields. If these fields couple with closed conducting loops, then high currents can be induced in those loops. The current can be many times the current in the reactor. Induced current also results in increased power losses.

10.22.2 The earthing system design shall not result in equipment damage due to induced current. Also, as far as reasonably practicable, the earthing system shall be designed to minimise power losses due to induced current.

10.22.3 Unless otherwise agreed by The Engineer, no part of the main earth system which is part of a closed loop shall be within a distance from the top, bottom or any part of the surface of the reactor equal to 1.2 times the diameter of the reactor, unless specified otherwise by the reactor manufacturer and agreed by The Engineer.

10.22.4 Unless otherwise agreed by The Engineer, no part of the main earth system shall be within a distance from the top, bottom or any part of the surface of the reactor equal to 0.6 times the diameter of the reactor, unless specified otherwise by the reactor manufacturer and agreed by The Engineer.

10.22.5 The use of fibre-reinforced concrete or other non-metallic reinforcement solutions is recommended for the construction of reactor foundations. Where reinforcement bars in reactor supports and foundations are used, these shall be plastic coated unless the supplier can demonstrate that the level of induced current would be less than that which would cause damage.

10.22.6 It shall not be possible to join two pieces of exposed metal with a metallic object 300mm long to create a closed loop infringing 10.22.2 above.

10.23 Anti-climbing Precautions Along the Tops of Walls

Where barbed wire or other metal anti-climbing devices are erected along the tops of brick walls etc. these shall be connected to earth using the same procedure as with fencing. Care shall be taken to ensure that anti climbing guards do not bridge fencing sections that are designed to be separately earthed or isolated.

10.24 Electric Security Fences

10.24.1 Where electric security fences are fitted to isolated fence panels, the design of the electric fence installation shall not compromise the fence isolation. This may be achieved by ensuring that the electric fence earth is isolated from the palisade fence or by having independent electric fence zones either side of the isolated panel.

10.24.2 Where electric security fences are fitted to substation perimeter fence which are earthed independently, the design of the electric fence installation shall not compromise the fence earthing.

10.24.3 Substation perimeter security fencing shall be designed to ensure the main earth system is not connected to the perimeter fence via the security equipment, e.g. location of fence control boxes and earthing of electric fence supplies.

10.25 Substation Lightning Protection Systems

10.25.1 Where required, lightning protection systems shall be in accordance with BS EN 62305. All lightning protection system conductors shall be connected to the substation main earthing system.

10.26 Design Life of Installation

10.26.1 All parts of the earthing installation, both below and above ground, shall have a design life of 40 years taking into account the anticipated corrosion of the conductors resulting from site chemical pollution.

11. PERFORMANCE REQUIREMENTS

11.1 Conductors

11.1.1 All conductors which may carry fault point current shall be fully rated. Earth conductors shall be rated not to exceed the maximum temperatures in Table 5a. Corresponding maximum current densities for a 30°C ambient are given in Table 5b. Duplex or loop connections shall be de-rated by a minimum of 40% to allow for unequal current sharing. Preferred conductor sizes for copper and aluminium conductors are given in Table 5c.

Type of conductor	Maximum recommended conductor temperature during a short circuit
Bare conductors, solid or stranded: Cu	405°C
Bare conductors, solid or stranded: Al or Al alloy	*325°C*
Bare conductors, solid or stranded: steel	*300°C*

Table 5a Highest Temperatures for Non-Mechanically Stressed Conductors

Type of conductor	Current density for 1 sec duration (A/mm^2)	Current density for 3 sec duration (A/mm^2)
Copper	212	123
Aluminium	130	75
Galvanised Steel	80	45

Table 5b Maximum Conductor Current Densities

Type of conductor	55kA 1 sec		40kA 1 sec		25kA 3 sec	
	Spur	Duplex	Spur	Duplex	Spur	Duplex
Copper	50x6mm	40x4mm	50x4mm	30x4mm	38x6mm	31.5x4mm
Aluminium	61x7mm	50x6mm	50x6.3mm	40x6mm	56x6mm	40x6mm

Table 5c Preferred Conductor Sizes

If higher conductor current densities are required, the justification for the conductor size will be presented to The Engineer for review.

12. DESIGN INFORMATION

12.1.1 The designer of the earth electrode system should consider the following:

a) The site soil resistivity profile and suitability for driving earth rods (see Appendix A for measurement methods).
b) The chemical and/or physical nature of the site soil structure. For example, the presence of corrosive soils (acids, nitrates, sulphides, sodium silicates, ammonium chlorides, sulphur dioxides) should be considered in the design of an earthing system with a 40 years' life design requirement.
c) Details of the civil engineering structures existing, or to be built on site shall be ascertained to determine if the reinforcing steelwork incorporated within the structures or piling can be used as an earth electrode.
d) For existing sites, the latest site earthing survey.
e) The earth return current and the design rating.
f) Existing third party infrastructure, including future known developments, in the vicinity of the substation.
g) Proposals for mitigation for third party impact shall be considered and discussed with The Engineer.

12.1.2 If available, The Engineer will provide the supplier with some or all of the above information.

13. TEST REQUIREMENTS

13.1.1 Validation by electrical measurement of any design is required for all installed systems to confirm the satisfactory installation and design of the system. All measurements shall be recorded on Site Commissioning Tests Sheet SCT 46 or its equivalent alternative. The Engineer reserves the right to witness all tests. The measurement methods are outlined in Appendix A.

13.1.2 Where legacy sites are extended or prior to civil or construction works which may potentially degrade existing site earthing system designs, then a pre and post earthing assessment shall be undertaken.

13.1.3 The resistance to earth of all individual rods and rod groups shall be measured and recorded. Where the measured resistance of an individual rod is more than 50% higher than the average for the site the reason shall be investigated and the rod(s) re-installed if necessary.

13.1.4 The total substation earth electrode impedance shall be measured using the AC Fall of Potential Method and the result recorded. The measured result shall be compared with that predicted by calculation and any significant difference investigated. On sites if The Engineer deems it impracticable to carry out this measurement, due to the surrounding environment, it will be necessary to rely on calculation alone. In this case, careful attention shall be given to establishing accurate data for the calculation, e.g. the soil resistivity profile and the layout of the main earth system.

13.1.5 For transmission towers, as far as is reasonably practicable, both the footing resistance and the chain impedance shall be measured.

13.1.6 Tests of all electrical joints shall be made in accordance with TGN(E) 187. A record of all joint resistances shall be kept and presented as part of the final records.

13.1.7 The supplier, at the request of The Engineer may be required to excavate in order to reveal earth conductor joints for testing, or to demonstrate correct installation to drawing.

14. ACCEPTANCE PROCEDURE

14.1.1 The Supplier shall provide evidence that the tests described in this document have been carried out satisfactorily. The test results shall be recorded using SCT 46 or its equivalent alternative.

14.1.2 The Supplier shall provide evidence in the form of voltage contour plots that the necessary precautions have been taken to prevent unsafe touch, step and transferred potential from arising.

14.1.3 The Supplier shall provide documentation to demonstrate that the earthing installation complies with this document and includes with it EPR contour plots showing 430V, 650V, 1150V and 1700V contours overlaid onto an OS map.

The map accuracy should be checked during site assessment to include all 3rd party properties and services within the proximity of the installation, including details of its occupation.

14.1.4 The Supplier shall provide a drawing detailing the new below ground earthing layout. Where an earthing system has been modified or extended, the existing drawing should be updated to reflect the changes. Where reasonably practical, existing drawings should be consolidated onto a minimum number of new CAD drawings to depict the whole site earthing system. This may require the recreation of some legacy drawings which are presently in out-of-date formats.

14.1.5 All results shall be submitted, preferably within an earthing report, and become the property of The Company as part of the contract.

15. APPENDICES

15.1 APPENDIX A - MEASUREMENT METHODS

15.1.1 Measurement of earth rod and earth rod group resistance:

Unless otherwise agreed by The Engineer, individual earth rod and rod group resistances shall be measured. The measurement may be made using the circulating current method with respect to the main earthing system, provided the main earth system has a significantly lower resistance compared with the rod or rod group. Care shall also be taken to ensure that the voltage profile overlap of the main earth system and the rod or rod group does not significantly affect the measurement.

15.1.2 Measurement of total substation earth electrode impedance:

The total substation earth electrode impedance shall be measured using the AC Fall of Potential Method[2]. The 61.8% rule or the Slope Method shall not be used.

15.1.3 Measurement of tower footing resistance or chain impedance:

Where the OHL earth wire is not connected to the tower, the tower footing resistance shall be measured using the Fall of Potential Method[4]. The 61.8% rule or the Slope Method shall not be used.

Where the OHL earth wire is connected to the tower, the tower chain impedance shall be measured using the AC Fall of Potential Method[2]. The 61.8% rule or the Slope Method shall not be used.

15.1.4 Measurement of soil resistivity:

Sufficient resistivity measurements shall be made to determine a suitably accurate soil model. The number of measurements will normally depend on the homogeneity of the ground.

Soil resistivity shall be measured in accordance with BS EN 50522. The method described is also known as the Wenner Method. Resistivity shall be measured up to a depth of 90m where reasonably practicable. No less than two pairs of measurements shall be made at separate locations on site (each pair consists of two traverses at 90° to each other).

15.1.5 Measurement of touch voltages:

Touch voltage measurements should be carried out in accordance with BS EN 50522 Annex H.

[4] Earth Resistances, Tagg G F, George Newnes, London 1964.

15.2 APPENDIX B – DRAWINGS

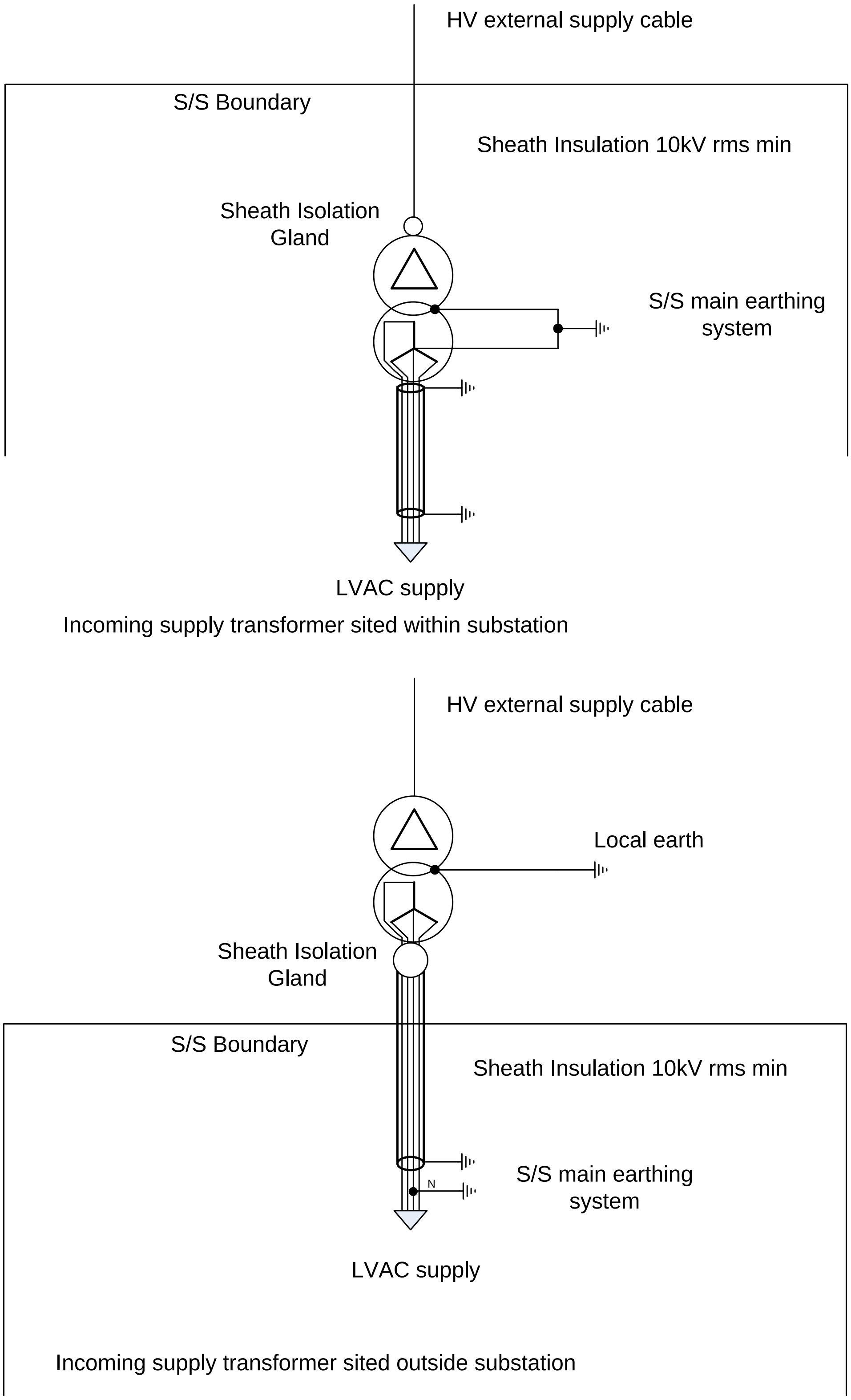


Figure 1 LV Supply earthing

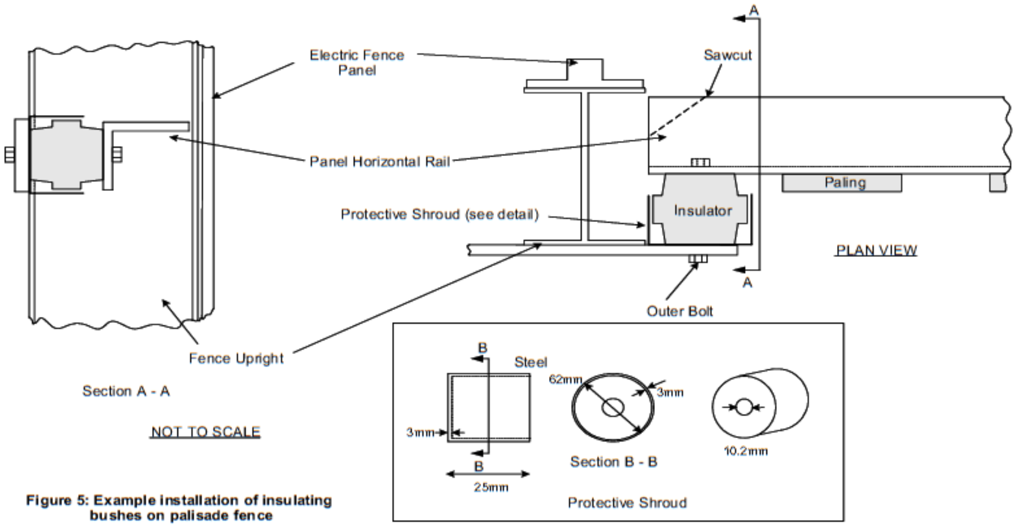


Figure 2 Example Installation of insulating bushing on palisade fence

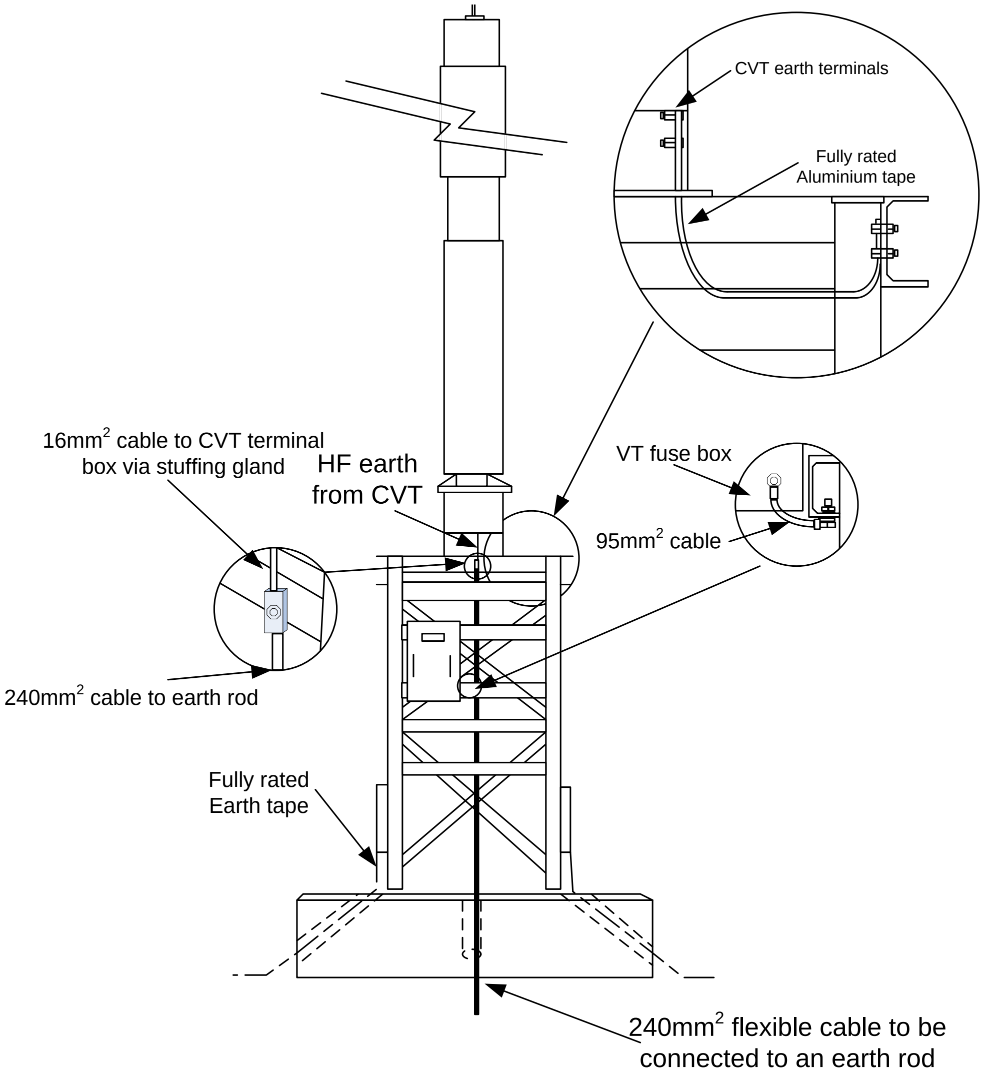
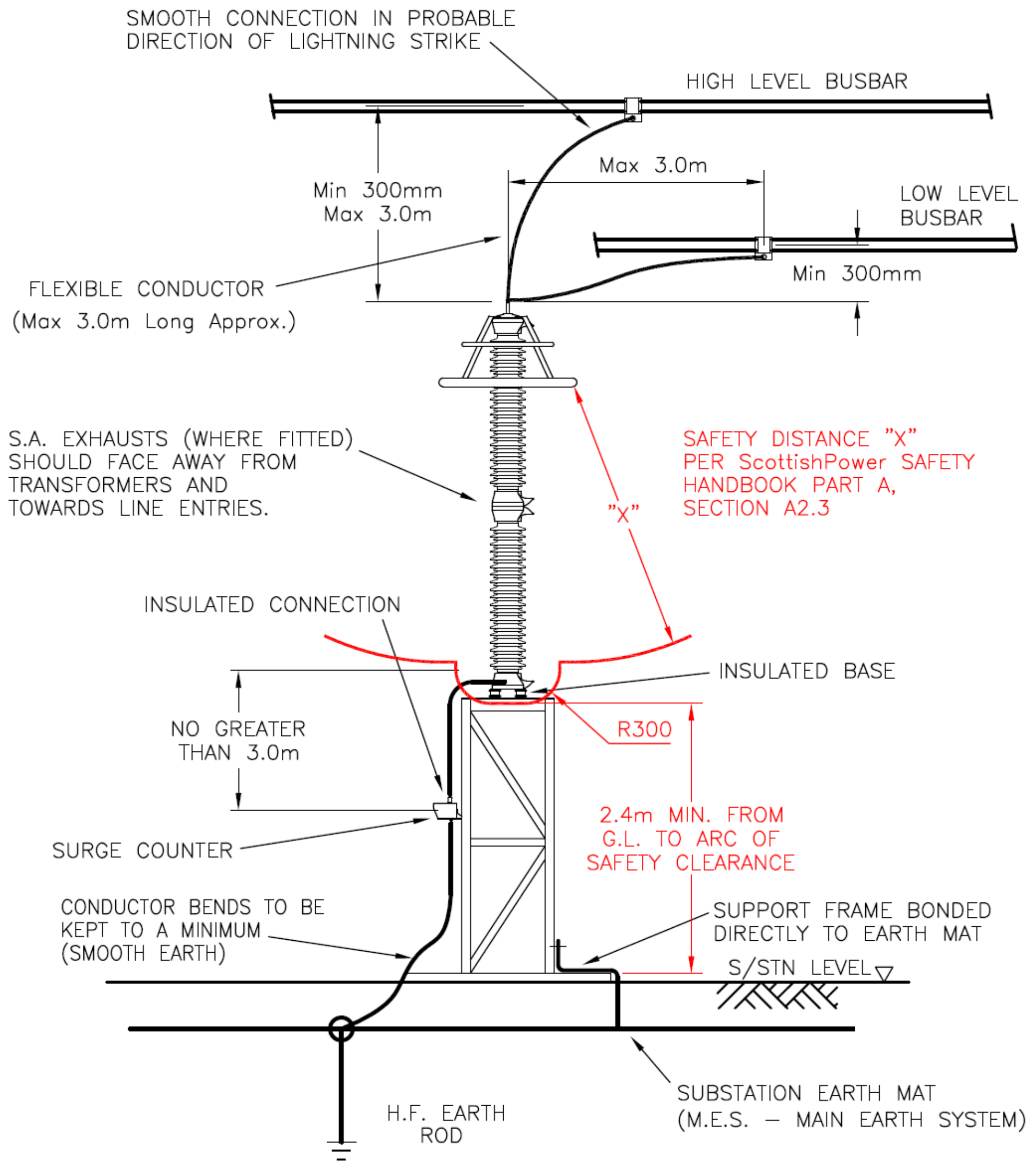


Figure 3 Example CVT earthing



TYPICAL SURGE ARRESTER INSTALLATION

ASSOCIATED DRAWINGS

SP2042813 SURGE ARRESTER CLEARANCES
SP2056928 STANDARD SURGE ARRESTER INSTALLATION ON OVERHEAD LINE ENTRIES.
SP2056909 STANDARD SURGE ARRESTER INSTALLATION LOCAL TO AUTO TRANSFORMERS.
SP4049492 STANDARD SURGE ARRESTER INSTALLATION LOCAL TO GRID TRANSFORMERS.
SP4049426 STANDARD SURGE ARRESTER INSTALLATION ON SEALING END PLATFORMS.

SP ENERGY NETWORKS

Drawn J.F.M.	Date 12:05:98	Title TYPICAL SURGE ARRESTER INSTALLATION
Checked A.S.H.	Date 12:05:98	
Approved N.MacD.	Date 12:05:98	
TRS No.		Location GENERAL / Voltage 33/132/275/400kV

Project				
Rev 3.0	Date 22:11:11	Drawn J.F.M. / Checked / Approved	DRAWING UPDATED. SAFETY DISTANCE FROM LIVE METAL INDICATED.	
Status FOR ISSUE	Drg. No. SP2043169	Rev. 3.0		
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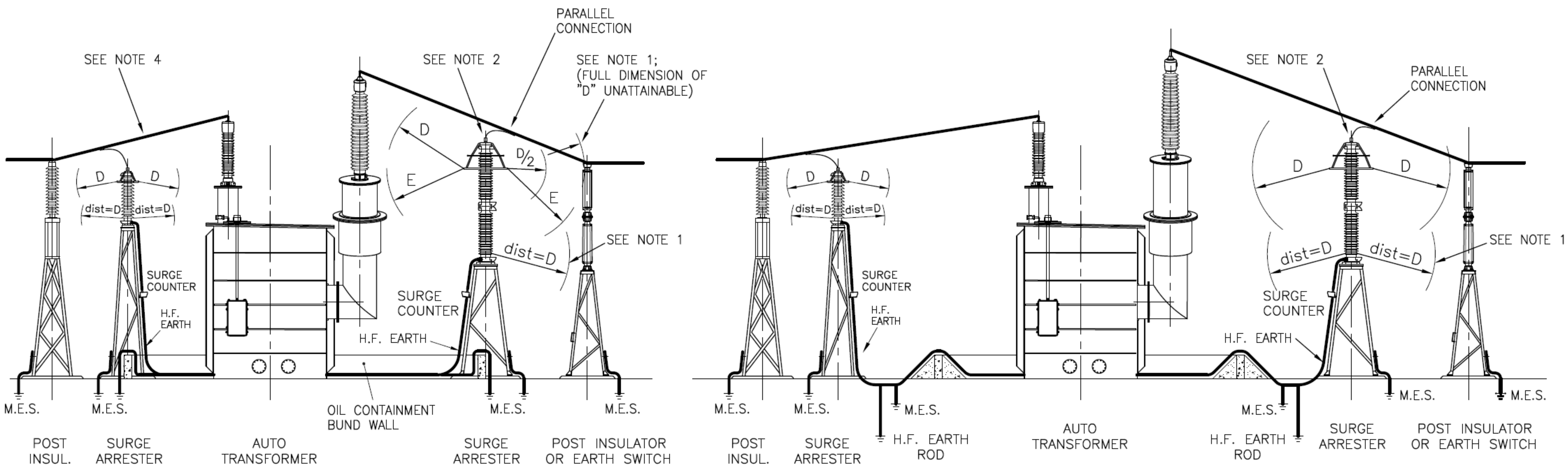

TYPICAL INSTALLATION
SHOWING SURGE ARRESTERS STRADDLING BUND WALL

TYPICAL INSTALLATION
SHOWING SURGE ARRESTERS OUTWITH BUNDED AREA

NOTES:

1. IT IS THE PREFERENCE OF SPEN TO PROVIDE THE FULL DIMENSION OF "D" AT THE UPPER (LIVE) END OF THE SURGE ARRESTER. THE MINIMUM DIMENSION OF "D/2" BETWEEN THE UPPER (LIVE) END OF THE SURGE ARRESTER AND UPPER (LIVE) END OF OTHER HIGH VOLTAGE EQUIPMENT MAY BE ACCEPTABLE UNDER SPECIFIC APPLICATIONS, SUCH AS DETAILED ABOVE, ONLY WHERE THE FULL DIMENSION OF "D" WAS FOUND TO BE UNATTAINABLE.
   A SEPARATION DISTANCE, "dist=D" SHALL BE MAINTAINED IN ALL INSTANCES BETWEEN THE LOWER (EARTH) END OF THE SURGE ARRESTER AND THE LOWER (EARTH) END OF AN ADJACENT INSULATOR ON THE SAME PHASE IN ORDER TO MINIMISE THE VOLTAGE STRESS ACROSS THE INSULATION.
2. USE OF STEM OR PALM CONNECTOR IS DEPENDANT ON ANGLE OF BUSBAR.
3. IF TRANSFORMER IS FITTED WITH TANK-MOUNTED COOLERS OR NOISE ENCLOSURE, THIS WILL IMPACT UPON DESIGN.
4. WHEN THE LV OF TRANSFORMER IS 33kV, A SIMILAR APPROACH TO THAT SHOWN ON DETAIL 'A', DRAWING SP4049492 SHALL BE ADOPTED.
5. TRANSFORMER H.F. EARTH CONNECTION TO BE AS SHORT AS PRACTICABLE.
6. M.E.S. DENOTES MAIN EARTH SYSTEM.

ASSOCIATED DRAWINGS

SP2042813 SURGE ARRESTER CLEARANCES
SP2043169 TYPICAL SURGE ARRESTER INSTALLATION.
SP2056928 STANDARD SURGE ARRESTER INSTALLATION ON OVERHEAD LINE ENTRIES.
SP4049492 STANDARD SURGE ARRESTER INSTALLATION AT GRID TRANSFORMERS.
SP4049426 STANDARD SURGE ARRESTER INSTALLATION ON SEALING END PLATFORMS.

Rev.	Date	
2.0	31:03:09	DRAWING UPDATED. REFERENCE DRAWINGS ADDED.
Drawn	J.F.M.	
Checked	A.S.H.	
Approved	N.MacD.	

Rev.	Date	
3.0	22:11:11	DRAWING NOTES UPDATED.
Drawn	J.F.M.	
Checked		
Approved		

SP ENERGY NETWORKS

Project				TRS No.	
Title: STANDARD INSTALLATION OF SURGE ARRESTERS AT AUTO TRANSFORMERS					
Location: GENERAL				Voltage: 33/132/275/400kV	
Drawn: J.F.M.	Date: 26:03:02	Checked: J.G.A.	Date: 26:03:02	Approved: G.D.C.	Date: 26:03:02
Status: FOR ISSUE			Drg. No.: SP2056909		Rev.: 3.0
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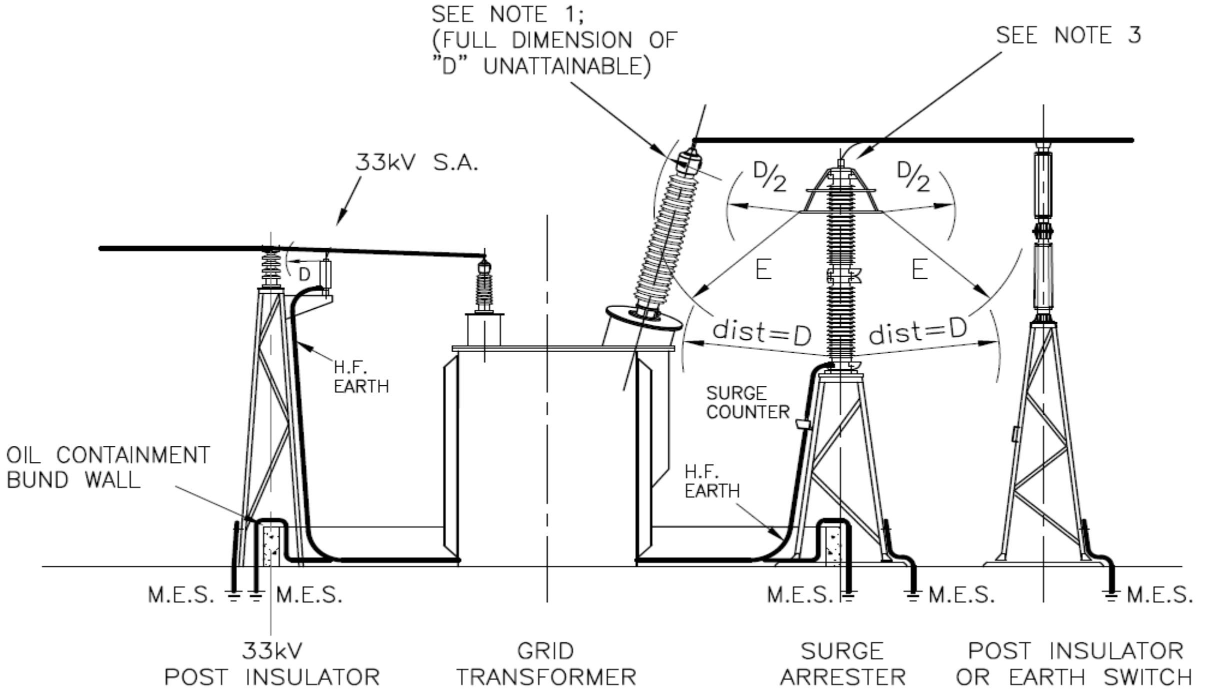
DETAIL 'A'

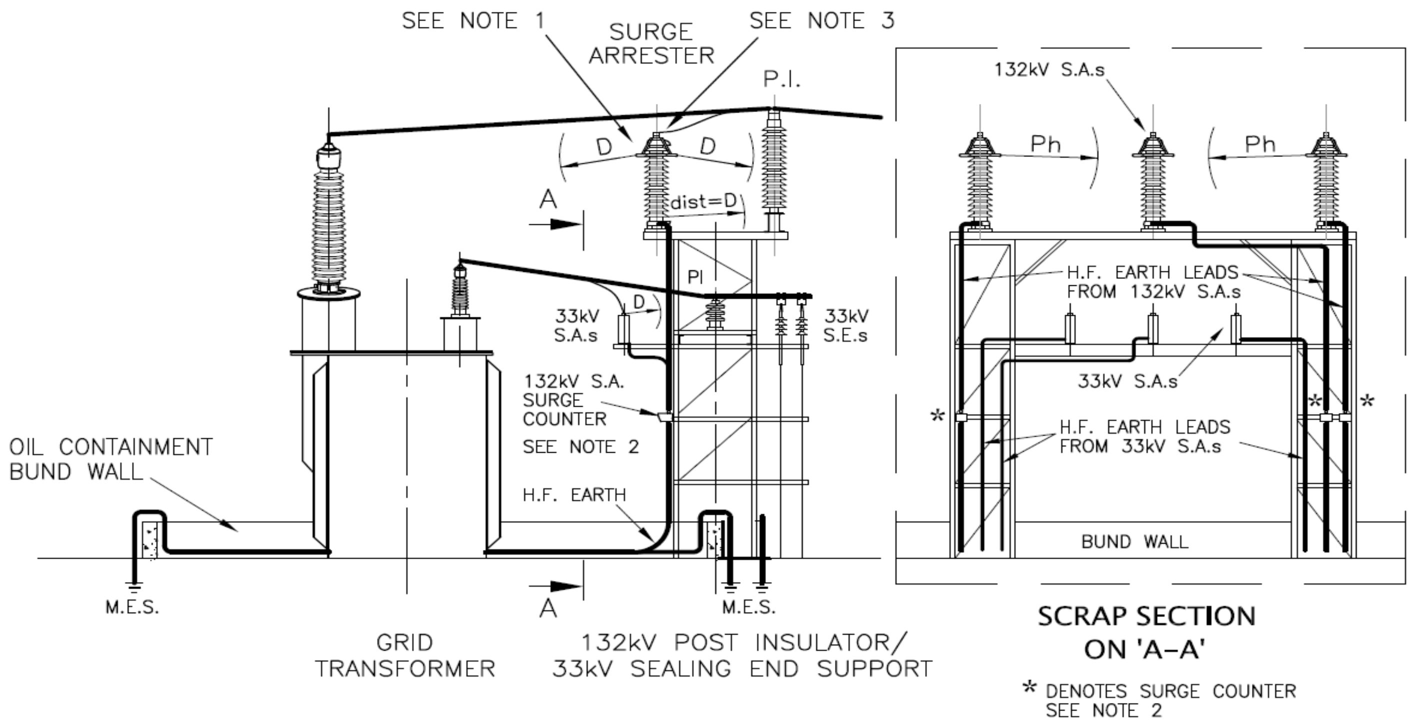


TYPICAL INSTALLATION SHOWING HV & LV SURGE ARRESTERS AND AN EXAMPLE OF PERMITTED REDUCTION TO CLEARANCE "D"

NOTES:

1. IT IS THE PREFERENCE OF SPEN TO PROVIDE THE FULL DIMENSION OF "D" AT THE UPPER (LIVE) END OF THE SURGE ARRESTER.
   THE MINIMUM DIMENSION OF "D/2" BETWEEN THE UPPER (LIVE) END OF THE SURGE ARRESTER AND UPPER (LIVE) END OF OTHER HIGH VOLTAGE EQUIPMENT MAY BE ACCEPTABLE UNDER SPECIFIC APPLICATIONS, SUCH AS DETAILED ABOVE, ONLY WHERE THE FULL DIMENSION OF "D" WAS FOUND TO BE UNATTAINABLE.
   A SEPARATION DISTANCE, "dist=D" SHALL BE MAINTAINED IN ALL INSTANCES BETWEEN THE LOWER (EARTH) END OF THE SURGE ARRESTER AND THE LOWER (EARTH) END OF AN ADJACENT INSULATOR ON THE SAME PHASE IN ORDER TO MINIMISE THE VOLTAGE STRESS ACROSS THE INSULATION.
2. THIS DETAIL IS VALID FOR 400/33kV, 275/33kV AND 132/33kV TRANSFORMERS. IT IS ALSO VALID FOR NETWORK RAIL TRANSFORMERS WITH 25kV LVs.
3. USE OF STEM OR PALM CONNECTOR IS DEPENDANT ON ANGLE OF BUSBAR.
4. TRANSFORMER H.F. EARTH CONNECTION TO BE AS SHORT AS PRACTICABLE.

DETAIL 'B'



TYPICAL SURGE ARRESTER INSTALLATION FOR 132/33kV TRANSFORMER WITH HIGH & LOW LEVEL BUSBARS

NOTES:

1. 132kV SURGE ARRESTER MAY NOT BE EQUIPPED WITH GRADING RINGS. THE WORST CASE HAS BEEN ILLUSTRATED.
2. SURGE COUNTERS ARE NOT REQUIRED TO BE FITTED TO THE H.F. EARTH LEADS FROM 33kV S.A.s.
3. USE OF STEM OR PALM CONNECTOR IS DEPENDANT ON ANGLE OF BUSBAR.
4. TRANSFORMER H.F. EARTH CONNECTION TO BE AS SHORT AS PRACTICABLE.

GENERAL NOTES:
IF TRANSFORMER IS FITTED WITH TANK-MOUNTED COOLERS OR NOISE ENCLOSURE, THIS WILL IMPACT UPON DESIGN.
M.E.S. DENOTES MAIN EARTH SYSTEM.

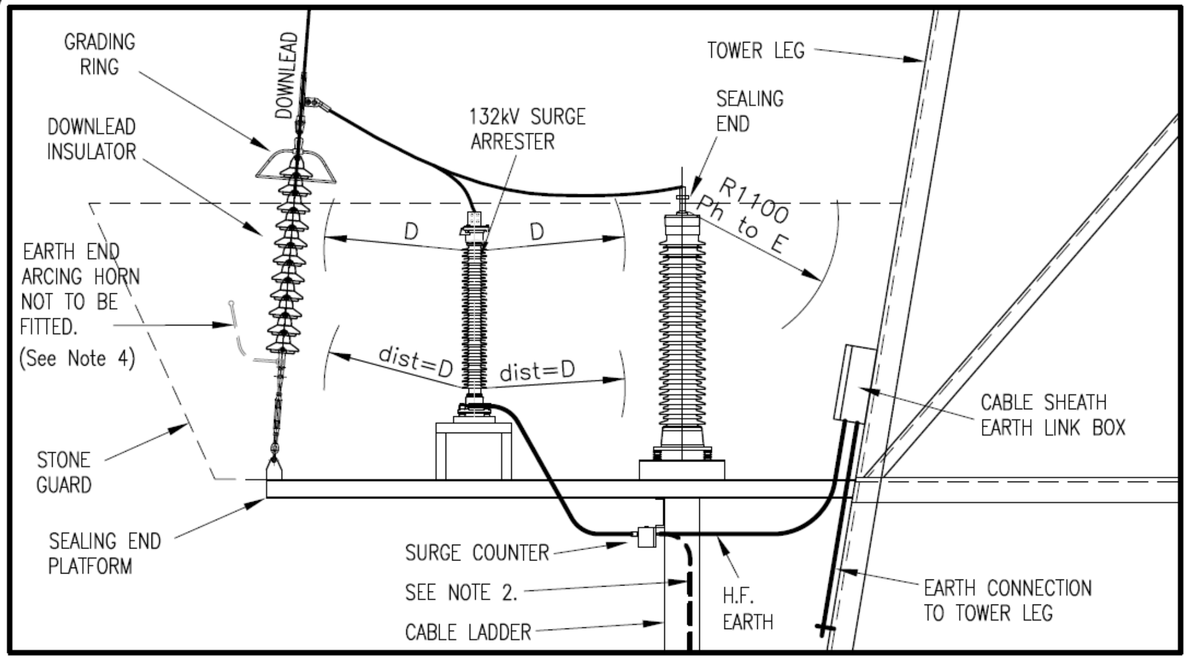
ASSOCIATED DRAWINGS

SP2042813	SURGE ARRESTER CLEARANCES
SP2043169	TYPICAL SURGE ARRESTER INSTALLATION.
SP2056928	STANDARD SURGE ARRESTER INSTALLATION ON OVERHEAD LINE ENTRIES.
SP2056909	STANDARD SURGE ARRESTER INSTALLATION AT AUTO TRANSFORMERS.
SP4049426	STANDARD SURGE ARRESTER INSTALLATION ON SEALING END PLATFORMS.

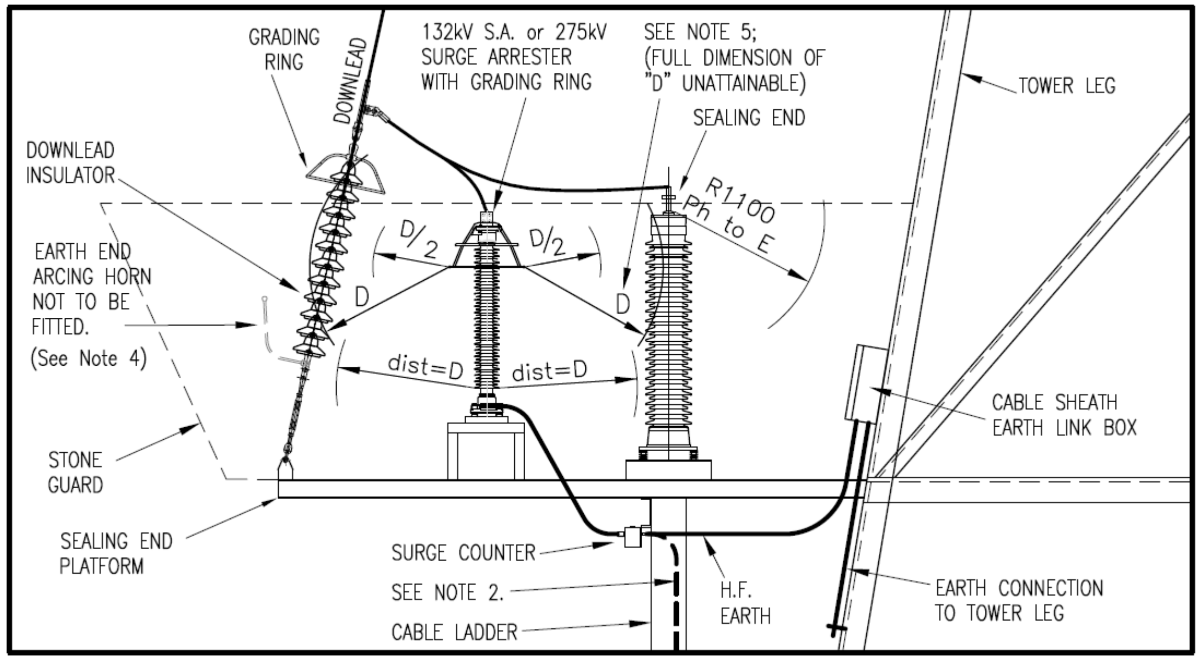
Rev.	Date	
2.0	22:11:11	DRAWING NOTES UPDATED.
Drawn	J.F.M.	
Checked		
Approved		

SP ENERGY NETWORKS

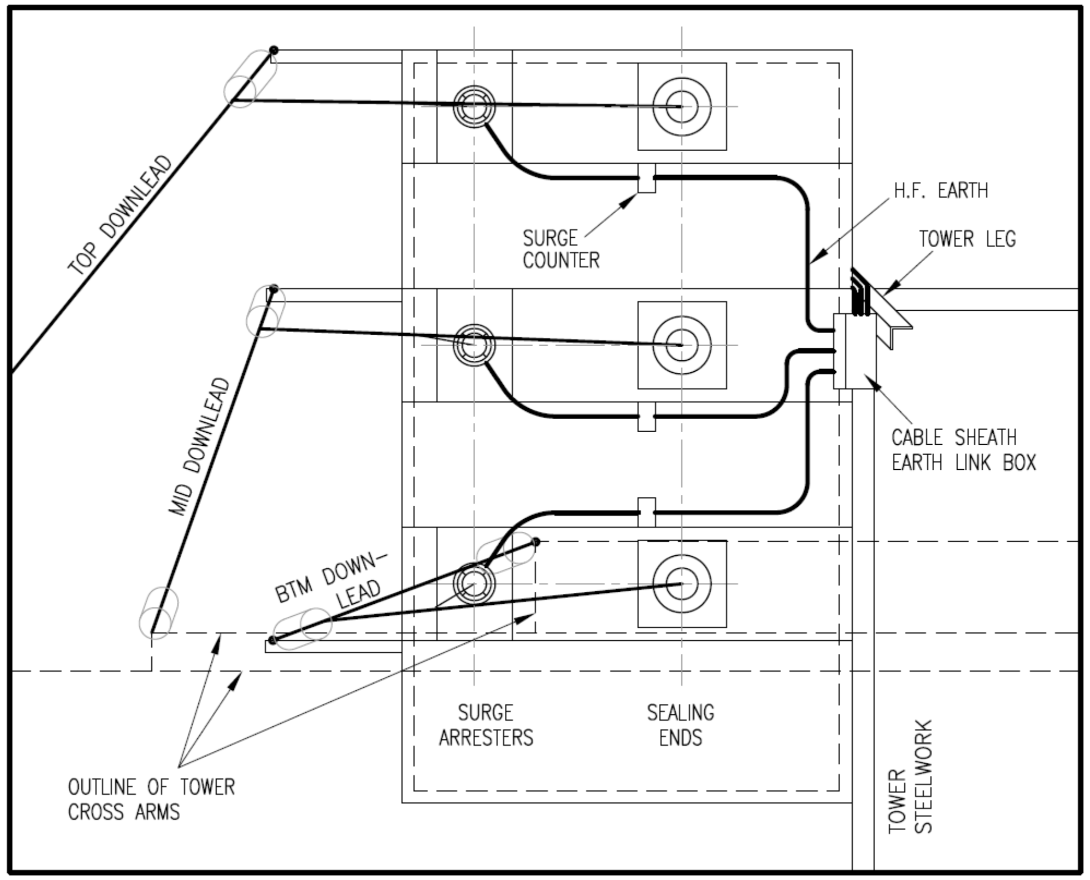
Project				TRS No.	
Title: STANDARD INSTALLATION OF SURGE ARRESTERS AT GRID TRANSFORMERS					
Location: SP STANDARDS				Voltage: N/A	
Drawn: J.F.M.	Date: 31;3;2009	Checked: A.S.H.	Date: 31;3;2009	Approved: N.MacD.	Date: 6;04;2009
Status: FOR ISSUE			Drg. No.: SP4049492		Rev.: 2.0
© Copyright property of SP PowerSystems Ltd.				Scale: N.T.S.	Size: A3



ELEVATION SHOWING RELATIVE POSITIONS OF SURGE ARRESTER TO SEALING END



ELEVATION SHOWING PERMITTED REDUCTION OF SURGE ARRESTER CLEARANCES



PLAN VIEW ON TYPICAL SEALING END PLATFORM

ASSOCIATED DRAWINGS

SP2042813 SURGE ARRESTER CLEARANCES
SP2043169 TYPICAL SURGE ARRESTER INSTALLATION.
SP2056928 STANDARD SURGE ARRESTER INSTALLATION AT OHL ENTRIES
SP2056909 STANDARD SURGE ARRESTER INSTALLATION AT AUTO TRANSFORMERS.
SP4049492 STANDARD SURGE ARRESTER INSTALLATION AT GRID TRANSFORMERS.

NOTES

1. THE H.F. EARTH CONDUCTORS FROM SURGE ARRESTERS SHALL BE CONNECTED TO SURGE COUNTERS MOUNTED BELOW PLATFORM LEVEL IN A LOCATION WHERE THEY ARE VISIBLE FROM GROUND LEVEL AND CAN BE READ USING BINOCULARS. BEYOND THE SURGE COUNTER, THE CONDUCTOR SHALL BE ROUTED TO THE CABLE SHEATH EARTH LINK BOX, BOLTED TO THE TOWER LEG (ONLY A NON-CLIMBING LEG TO BE USED). THE LINK BOX SHALL BE EARTHED TO THE TOWER LEG.
2. IF TOWER FOOTING RESISTANCE EXCEEDS 10 ohms, THEN EACH SURGE ARRESTER WILL REQUIRE A DEDICATED H.F. EARTH ROD. THE EARTH CONDUCTOR SHOULD BE ROUTED DOWN CABLE LADDER.
3. H.F. EARTH CONDUCTOR BENDS TO BE KEPT TO A MINIMUM.
4. EARTH END ARCING HORNS SHALL NOT BE FITTED TO DOWNLEAD INSULATORS WHERE SURGE ARRESTERS ARE INSTALLED. HOWEVER, THE DOWNLEAD INSULATOR GRADING RING AT LIVE END ACTS AS A CORONA SCREEN AND SHALL BE RETAINED.
5. IT IS THE PREFERENCE OF SPEN TO PROVIDE THE FULL DIMENSION OF "D" AT THE UPPER (LIVE) END OF THE SURGE ARRESTER. THE MINIMUM DIMENSION OF "D/2" BETWEEN THE UPPER (LIVE) END OF THE SURGE ARRESTER AND UPPER (LIVE) END OF OTHER HIGH VOLTAGE EQUIPMENT MAY BE ACCEPTABLE UNDER SPECIFIC APPLICATIONS, SUCH AS DETAILED ABOVE, ONLY WHERE THE FULL DIMENSION OF "D" WAS FOUND TO BE UNATTAINABLE. A SEPARATION DISTANCE, "dist=D" SHALL BE MAINTAINED IN ALL INSTANCES BETWEEN THE LOWER (EARTH) END OF THE SURGE ARRESTER AND THE LOWER (EARTH) END OF AN ADJACENT INSULATOR ON THE SAME PHASE IN ORDER TO MINIMISE THE VOLTAGE STRESS ACROSS THE INSULATION.
6. EACH H.V. CABLE SHEATH TO BE CONNECTED FROM SEALING END TO EARTH LINK BOX (NOT DETAILED ON THIS DRAWING) – PART OF THE H.V. CABLE DESIGN.
7. THIS DRAWING COVERS THE INSTALLATION OF SURGE ARRESTERS ON S.E. PLATFORMS; IT IS NOT INTENDED TO COVER DESIGN OR INSTALLATION OF CABLE SEALING ENDS.

Rev.	Date	
2.0	24:11:11	DRAWING UPDATED. NOTE 4 CLARIFIED.
Drawn	JFM	
Checked		
Approved		

SP ENERGY NETWORKS

Project | TRS No.

Title: STANDARD SURGE ARRESTER INSTALLATION ON SEALING END PLATFORMS

Location	Voltage
SP STANDARDS	132/275kV

Drawn	Date	Checked	Date	Approved	Date
J.F.M.	06:11:2008				

Status	Drg. No.	Rev.
PRELIMINARY	SP4049426	2.0

 Scale: N.T.S. Size: A3

15.3 **APPENDIX C – Test Access Example**

Figure 4: An example of earthing connection box with test facility