EARTHING

This document is for Relevant Electrical Standards document only.

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PURPOSE AND SCOPE

This document describes the technical requirements for User's equipment directly connected to the England and Wales Transmission system and located within NGET's busbar protection zone operating at nominal voltages of 400 kV, 275 kV, 132 kV and 66 kV unless otherwise agreed with the user as defined in the Bilateral agreement. The principles of this document applies to equipment connected at other voltages".

It supports the more general conditions defined in the companion documents TS 1 (RES) and TS 2.1 (RES).

PART 1 – PROCEDURAL

1 GENERAL REQUIREMENTS

The earthing system shall comply with EA TS 41-24, BS EN 50522 and BS 7430, unless otherwise stated.

1.1 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.

1.2 Earth Potential Rise (EPR)

1.2.1 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 Table 1.

Table 1 Touch and Step Potential Limits

	Maximum Voltage for Touch	Maximum Voltage for Step
Chippings surface (150mm)	2.06kV	Limit could not foreseeably be exceeded
Chippings surface (75mm)	1.78kV	Limit could not foreseeably be exceeded
Soil surface	1.57kV	Limit could not foreseeably be exceeded

The limits in Table 1 assume a 200ms clearance time, a 1m step distance, a footwear resistance of 4kΩ per shoe, and effective earth foot resistance values respectively. They are based upon the approach agreed within BS EN 50522 UK national annex ‘A’.

Informative: Current design practices show that touch voltage has always been the more critical design criteria, comparing to step voltage. As a key change to its 1994 version, IEC 60479-1 (2005) has since introduced the remarkable heart factor of 0.04 for step voltage scenarios, which directly resulted in the values ‘Maximum Voltage for Step’ to be in excess of 130kV. As the step voltage limit values are not foreseeable to be exceeded in reality, following the convention of BS EN 50522 (2012), they are not listed in Table 1 above.

1.2.2 From earthing perspectives, cable sealing ends shall be treated as substations unless otherwise agreed by NGET.

1.2.3 Critical third party EPR impact voltage thresholds via proximity effects are given in **Table 2.**

Informative: Although RES applies to where National Grid provides direct connections to the Users,it is important to ensure that other 3rd parties are not affected inadvertantly due to Proximity Effects. These limits will need to be reviewed pending the publication of the revised ENATS 41-24.

Table 2 Third Party Impact Threshold Voltages via Proximity Effect **

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

**: Proximity effect refers to EPR conduction via the ground

1.2.4 Where a NGET substation provides a HV connection to a third party, the applicable threshold limit values via conduction are given below**Table 3**.

Table 3 Third Party Impact Threshold Voltages via Conduction ***

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

***: Conduction refers to electrical conduction via metallic conductors.

1.2.5 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 **Table 2** and **Table 3**.

Where reasonably practicable, the earthing system shall be designed using an earth return current which is 20% greater than that calculated by NGET, to allow for future increases in system fault current.

1.2.6 Calculations to design the main earth system shall be carried out using the MALZ module of CDEGS software package (***C***urrent ***D***istribution, ***E***lectromagnetic Fields, ***G***rounding and ***S***oil Structure Analysis) or equivalent. The design models produced shall be made available once completed and shall become the property of NGET as part of the contract.

1.2.7 Communication cables connecting to all NGET substations must be fitted with appropriate electrical isolation.

1.3 Earth Electrodes

1.3.1 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 7430. The fault duration times to be used for rating the electrodes are 1 second for 275kV and 400kV and 3 seconds for all other voltages.

1.3.2 The preferred burial depth of bare copper horizontal earth electrodes is 500mm. If the indigenous soil is hostile to copper, see section 3.1.1 (b), the electrode shall be surrounded by 150mm min of non-corrosive soil of fine texture, firmly rammed. Conductors installed in ploughed farmland shall be buried at least 1m deep, at all points, measured from undisturbed ground level.

1.3.3 Care shall be taken to whether soils could be hostile to copper, whether indigenous soils are of high resistivity, as well as the use of back-fill materials, which are usually of high resistivity. Guidance should be sought from EA TS 41-24 and BS 7430.

1.3.4 Driven rod electrodes in accordance with EA TS 43-94 shall be used to exploit lower resistivity ground strata where present to reduce the EPR in accordance with clause 1.2. 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.

1.3.5 Special types of earth rods, e.g. Chem-Rod, may be employed, provided conventional techniques could not meet the design requirements. Due to the use of chemicals, such cases should be considered thoroughly, taking into account the environment concerns and special maintenance needs. Appropriate agreement must be obtained with NGET prior to use.

1.3.6 Where beneficial, reinforcing steelwork incorporated within piling may be connected to the MES for the purpose of equipotential bonding and/or to form part of a common bonding network (CBN). However, care must be taken to ensure that the current carrying capacity of the steelwork is not exceeded.

Although it is acknowledged that buried concrete encased steel reinforcement can, depending on certain conditions, constitute an effective earth electrode, it should not normally be relied upon to provide an earth electrode as part of the earthing system design.

Where reinforcement steelwork in piles is connected to the MES, 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 TS 2.1. 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 pile.

1.4 Earth Electrode Arrangement

1.4.1 Unless otherwise agreed by NGET, 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, groups of earth rods distributed around the periphery shall be connected to this main earthing conductor.

1.4.2 For indoor substations the earthing grid shall be installed with spur connections to the steel reinforcing mat of the concrete floor, preferably 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 metalclad, both at 20m intervals. Earth rod groups shall be connected to the second peripheral conductor as described in clause 1.4.1.

1.5 Test Facilities

1.5.1 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 (min length 75mm). An example of how this can be achieved is shown in Figure 1. 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. All testing points shall be identified both on the design earthing drawings and within the test pit at site.

1.5.2 Disconnectable links must 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.

Figure 1 An example of earthing connection box with test facility*

*Note – The image shown above is without a lid and is meant to simply depict a surface accessible earth test box. This box example is suitably dimensioned to allow the testing of earth rod groups without disconnection in accordance with sections 1.5/1.6.

1.6 More Than One HV Substation

1.6.1 Where the user's and NGET substations earth grids are to be connected together by underground conductors, at least two fully rated conductors, ideally taking secure separate physical route, should be used. In order to facilitate testing of the interconnections, the conductors connecting the systems together shall each be made accessible at a designated point. At this point the conductors shall have dimensions which would fit inside a 50mm diameter circular clamp meter jaws (min length of conductor 75mm). An example of how this can be achieved is shown in Figure 1. All testing points shall be identified both on the design earthing drawing and within the test pit at site.

1.6.2 Measures shall be taken to ensure that persons can not 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, NGET shall be informed by the supplier at the time of production of the earthing design.

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

1.7 Equipment Connected to the Main earth system

1.7.1 The connection of the following items of equipment to the main earthing system shall be fully rated:

Informative: The connection to earth can be provided by more than one connection individual connections i.e. via multiple earth paths.

a) All conductive parts which may sustain damages or become hazardous (to other equipment or personnel) where there is a credible likelihood of direct power fault onto them.

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.

1.7.2 All metalwork, e.g. panels, cubicles, kiosks etc., including the steelwork of buildings, shall be bonded to the main earth system, preferably by a conductor of no less than 70mm^2 cross section or a strip conductor no less than 3mm thick. The minimum conductor can be reduced to 16mm^2 where it is not reasonably practicable to install 70mm^2 conductors, provided the connection is secure.

1.7.3 For all substation fully rated flexible insulator strings, shunt conductors should be used between the arcing ring adjacent to the structure and the earth bars on the structure, so as to by-pass the major proportion of fault current under flashover conditions from the end fittings.

1.7.4 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.

1.8 Installation

Due regards should be given to the installations of earthing systems, following guidance in EA TS 41-24 and other relevant standards. The following clauses in this section form NGET practices hence are preferred methodologies.

1.8.1 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 1.8.7.

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.

1.8.2 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.

1.8.3 When laying stranded conductors, care shall be taken to avoid distorting individual strands.

1.8.4 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.

1.8.5 Where earthing conductors terminate above ground, the connections shall as far as is 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. Moreover, all bolted joints shall be situated at least 150mm above ground level. Bolts and nuts with security features, shall be used, particularly to make the joints where earth tapes are connected to equipment tank/base or structures.

1.8.6 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, to clause 1.8.5.

1.8.7 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.

1.8.8 Due to their 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 practicable, flat copper tapes should be used for all above ground earthing conductors.

1.9 Steel Support Structures

1.9.1 Where the current carrying capacity of steel support structures is at least equal to the switchgear rating, 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.

1.9.2 Where a steel structure is relied upon to provide an earth connection for supported equipment, current carrying joints across the earth path within 2.4m of ground level shall be bridged across with fully rated earth tapes. Above 2.4m, the normal structural joints are considered adequate for electrical integrity during fault conditions.

1.9.3 Steel structures shall not be relied upon to conduct high frequency currents or for earth connections to earth switches.

1.9.4 Where post insulators, other than those forming part of shunt connected equipment (e.g. voltage transformers and surge arresters) are supported by a steel structure, the insulator base does not require a bridging connection to the structure.

1.10 Fences

1.10.1 Measures shall be taken to ensure that dangerous touch or transferred potentials cannot arise on substation fences.

1.10.2 Perimeter fences may be independently earthed using 4.8m long rod electrodes in accordance with EA TS 41-24. Alternatively, perimeter fences may be connected to the main earth system in accordance with EA TS 41-24 with permission from NGET.

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

1.10.4 Unless otherwise agreed by NGET, where a perimeter fence is connected to the main earth system, then 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 min intervals and adequately protected from theft using the techniques identified within section 1.8.

1.10.5 Metallic internal fences within the curtilage of the main earth system shall be connected to the earthing system at 50m min intervals and at changes of direction and where power lines cross overhead. Earth tapes should be protected from theft using the techniques identified within section 1.8.

1.10.6 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 Figure 2.

An alternative to insulating bushes is to have a separate section of fence supported on its own posts at either end and separated by a 5cm gap as illustrated in Figure 3. Note that this is not suitable for security fences.

1.10.7 Most NGET perimeter fences are electrified, i.e. they are fitted with a secondary security system of electrified conductors on the inside of the fence. These ‘power fence’ systems are supplied via step-up transformers which provide inherent isolation between their LV supplies (and hence the main earthing system) and their HV conductors. One pole of the HV conductors must be connected to the perimeter fence earth to comply with current standards and this is normally done by installing bonds between one pole of the HV conductors and the fence at the fence corners. It is important that this power fence HV earth does not compromise any fence insulating sections. This could inadvertently be done by connecting the earthed HV pole to both an independently earthed fence and an MES earthed fence. This should therefore be avoided by ensuring the power fence is earthed to only either the independently earthed fence or the MES earthed fence, or by having additional power fence zones fed by separate step up transformers.

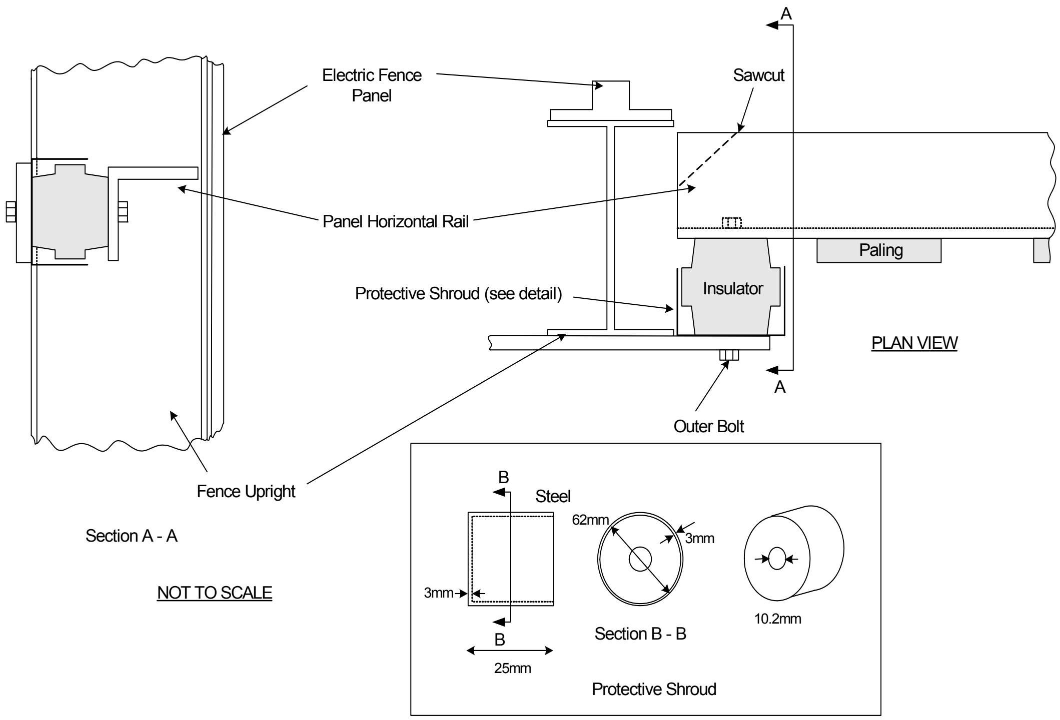


Figure 2 An example installation of insulating bushes on palisade fence

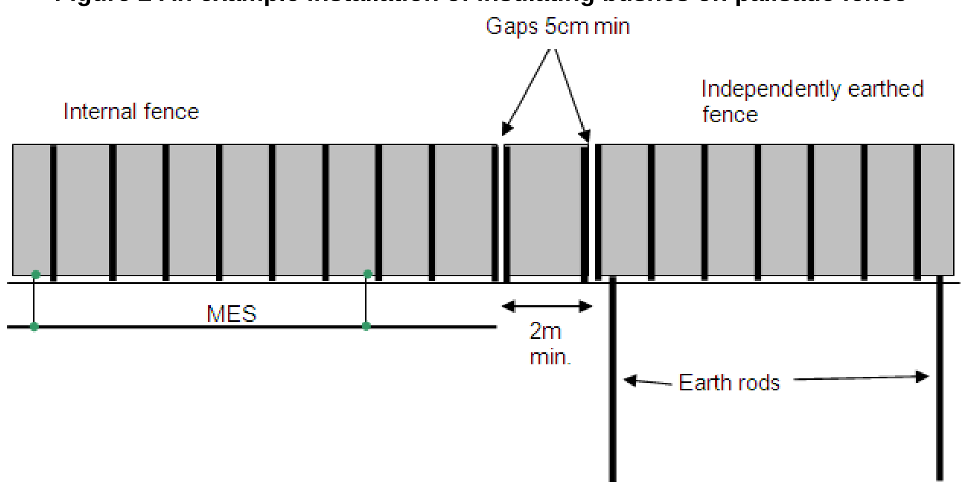


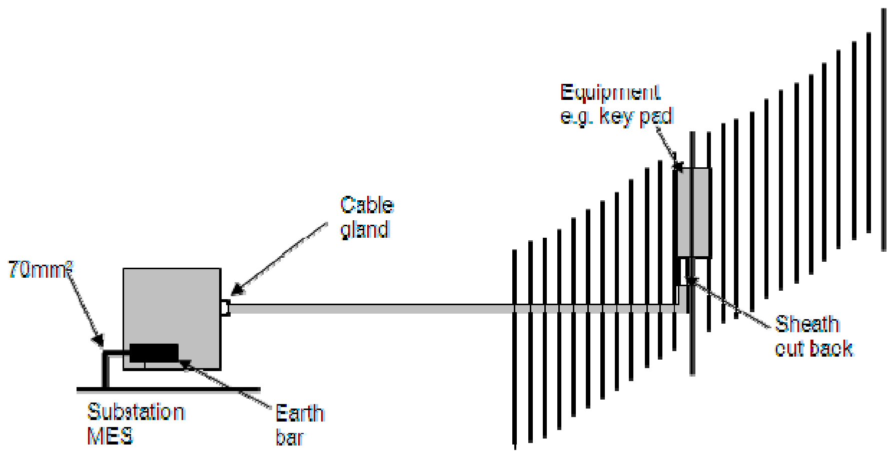
Figure 3 An example arrangement of separately earthed fences

1.10.8 When it is necessary to fit ancillary equipment, e.g. security key pads, to independently earthed perimeter fences, the equipment shall be effectively bonded to the fence. It is important that the connections to the equipment do not inadvertently serve to connect the equipment (and hence the fence) to the MES. Therefore the armouring of any Steel Wire Armoured (SWA) cables should be insulated from the equipment, i.e. they should be cut back at least 50mm from the cable gland and insulated. As an alternative, an insulating cable gland plate may be used. The armour of the cable should remain earthed at the remote end of the cable. No conductors (say from a multi-core conductor feeding the equipment) should be allowed to provide a connection to the MES. A warning notice, as shown in Figure 4 a), should be affixed to the equipment, to alert anyone carrying out maintenance on it, that a transferred potential hazard exists. **Note that it is preferred that**

where practicable a non-metallic junction box is used to reduce the risks from a transferred potential hazard. The arrangements are illustrated in Figure 4.

DANGER TRANSFERRED POTENTIAL
Electric Shock Hazard
Do Not Proceed Without Authorisation

a) Notice on equipment installed on independently earthed perimeter fences



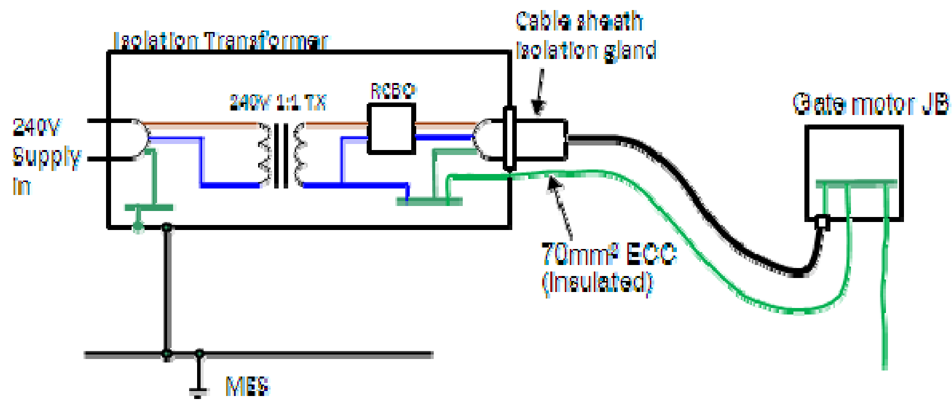
b) Earthing arrangement

Figure 4 Typical earthing arrangement for equipment (e.g. key pad) installed on independently earthed perimeter fences

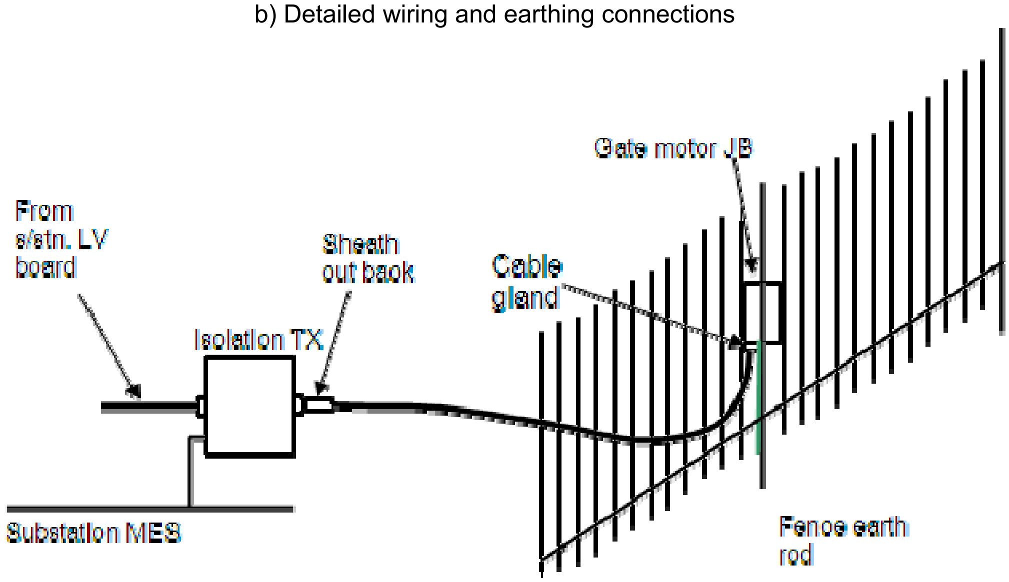
1.10.9 When it is necessary to fit LVAC supplied equipment, e.g. gate motors, to independently earthed perimeter fences, the LVAC supply to the gate shall not inadvertently serve to connect the gate (and hence the fence) to the MES. Therefore LVAC supply should be routed via an isolation transformer, ideally located where the supply is derived within the substation. The arrangements are illustrated in Figure 5. The isolation transformer enclosure should be connected to the MES via a 70mm^2 min conductor. A warning notice, as shown in Figure 5 a), should be affixed to the isolation transformer enclosure to alert anyone carrying out maintenance on equipment within the enclosure that a transferred potential hazard exists between the enclosure and its internals.

DANGER TRANSFERRED POTENTIAL
Electric Shock Hazard
Do Not Proceed Without Authorisation

a) Notice on isolation transformer enclosure



b) Detailed wiring and earthing connections



c) Overall view of LVAC supply and earthing arrangement

Figure 5 Typical earthing arrangement for LVAC supplies to gate motors

The armour of the SWA cable should be insulated from the isolation transformer enclosure, i.e. it should be cut back at least 50mm from the cable gland and insulated. Alternatively an insulating gland plate may be used. The armouring should be earthed at the motor junction box on the gate via a cable gland. The neutral from the LVAC supply should be connected via a $70mm^2$ earth continuity conductor (ECC) to the fence earth via the gate motor junction box. A fence earth rod should be installed at this location and connected directly to the motor junction box earth bar.

No conductors (say from a multi-core conductor to the gate) should be allowed to provide a connection from the gate to the MES.

1.10.10 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.

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

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

1.10.13 Earthing connections to the perimeter fence shall be via a conductor which shall be accessible and shall have dimensions which would fit inside 50mm diameter circular clamp meter jaws. Where bolted joints are used to connect to the fence, these shall be protected from the environment.

1.11 Access/Egress Gates and Hinged Height Barriers

1.11.1 Access/egress gates and hinged height barriers are not required to be bonded to their supporting posts. Note that this should not be confused with the requirement to cross bond between gate and barrier supporting posts, and that this requirement should still be met.

1.12 Temporary Fences

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

1.12.2 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.

1.12.3 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.

1.12.4 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.

1.13 Terminal Towers and Gantries Supporting HV Conductors

1.13.1 Where the earth wire of an incoming Overhead Line (OHL) terminates on a tower it shall be connected to the top of the tower.

1.13.2 The terminal tower/gantry shall be directly connected to the adjacent substation main earth system.

1.13.3 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.

1.14 LV Distribution Transformers

This section should be read in conjunction with TS 3.12.3 (RES) in respect of the earthing connection arrangements for LV supplies.

1.14.1 The earthing and isolation of DNO derived LV distribution transformers associated with NGET substations shall be designed assuming that the substation EPR is greater than 650V rms. Appropriate mitigation measures shall be agreed with the local DNO to manage the hazards associated with step/touch/transferred potentials seen under fault conditions on the NGET network.

1.14.2 The incoming HV supply earth shall be electrically isolated from the substation MES at a minimum level of 10kV rms. This may be achieved (for cable fed HV supplies) through the use of HV cable sheath insulating gland or a HV cable sheath barrier joint. Where an insulating gland is used this shall be clearly labelled to indicate a transferred potential hazard. For pole mounted transformers, the transformer earthing shall be configured so as to prevent the export of EPR directly from the substation into the DNO HV network. The DNO would normally achieve this by segregating the HV and LV earthing.

1.14.3 An LV distribution transformer, which supplies a NGET substation, must not be used to provide LV supplies external to the substation, other than to an adjacent DNO or Generator Operator, which effectively share a common earthing system with that of the NGET substation.

1.15 Gas Insulated Substations (GIS)

The earthing requirements for gas insulated substations are substantially dependent on the particular type of equipment and its configuration. For this reason, the earthing arrangements should principally be determined by the supplier in conjunction with the manufacturer. However, the following minimum requirements shall apply, unless it can be demonstrated by the supplier/manufacturer that they are not required:

The main earth system shall be well integrated in the regions close to equipment with short spur connections taken to specific points. The GIS floor rebar system shall be connected to the MES at frequent intervals throughout the installation to provide an overall conductive mesh and this should not be relied upon to carry fault current. Connections to the MES, together with direct connections between phases shall be made at all line, cable and transformer terminations, at busbar terminations and at approximately 20m min intervals in busbar runs. Inter-phase connections shall be rated to carry induced currents resulting from the flow of rated normal current in the primary conductors. As a guide, the resistance of the bonded flanges should not exceed 5μΩ.

1.15.1 The earthing arrangements shall, in so far as is reasonably practicable, minimise the possibility of external arcing due to high frequency transients during switching operations.

1.15.2 The earthing arrangements shall ensure that circulating currents in supporting steelwork etc. are below levels which could result in hazards to persons or electrical interference with electronic equipment.

1.16 Substation Lightning Protection Systems

1.16.1 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.

1.17 Design Life of the Installation

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.

2 PERFORMANCE REQUIREMENTS

2.1 Conductors

2.1.1 All conductors which may carry fault point current shall be fully rated. Earth conductors shall be rated so as 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 1sec duration (A/mm^2)	Current density for 3secs duration (A/mm^2)
Copper	212	123
Aluminium	130	75
Galvanised Steel	80	45

Table 5b Maximum Conductor Current Densities

Short-circuit current requirement	63kA/1sec		40kA/1sec		40kA/3secs	
Type of	Spur	Duplex	Spur	Duplex	Spur	Duplex
Copper	50x6mm	50x4m	50x4mm	40x3m	50x7mm	50x4mm
Aluminium	75x6.5mm	50x6m	50x7mm	50x4m	75x8mm	50x7mm

Table 5c Preferred Conductor Sizes

3 DESIGN INFORMATION

3.1.1 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, etc.) 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 switchgear rating

f) Existing third party infrastructure, including future known developments, in the vicinity of the substation

3.1.2 If available, NGET will provide the supplier with some or all of the above information. The availability of this information will be stated in the tender document.

4 TEST REQUIREMENTS

4.1.1 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. NGET reserves the right to witness all tests. The measurement methods are outlined in Appendix A.

4.1.2 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.

4.1.3 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 some sites it may not be practicable to carry out this measurement due to the surrounding environment and it may be necessary to rely on calculation alone. In this case, careful attention must be given to establishing accurate data for the calculation, e.g. the soil resistivity profile, the layout of the main earth system, and any interactions between earthing systems owned by others.

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

4.1.5 Tests of all electrical joints shall be made. Wherever specific acceptable criteria are not available, as a principle guide, the measured resistance across a joint should not be more than that of a plain conductor of similar length. For instance, half a meter of 50mm×6mm copper tape would typically present a resistance value of ~25μΩ.

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

5 ACCEPTANCE PROCEDURE

5.1.1 The supplier shall provide evidence that the tests described in this document have been carried out satisfactorily. The test results shall be recorded.

5.1.2 The supplier shall provide evidence that the necessary precautions have been taken to prevent unsafe touch, step and transferred potentials from arising.

5.1.3 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 (see also section 1.2.6).

The map accuracy should be checked during site assessment to include all 3rd party properties within the proximity with detail of its occupation.

5.1.4 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 practicable, 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.

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

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

6 DEFINITIONS

Cold Site A site at which the **earth potential rise** is less than or equal to 650V rms (based on a 200ms clearance time).

Earth The conductive mass whose electric potential at any point is conventionally taken as zero.

Earth Electrode A conductor or group of conductors in intimate contact with, and providing an electrical contact to **earth**.

Earth Electrode Area The area contained by the **earth electrode** system.

Earth Electrode Current The maximum value of current which the total substation **earth electrode resistance** may be required to conduct. In single earthed neutral systems fitted with current limiting devices the maximum **earth electrode current** is limited by that device unless there are secure parallel circuits offering an alternative current path to that provided by the **earth electrode resistance**.

Earth Return Current The proportion of **fault point current** which returns to source via the ground.

Earth Electrode Resistance The resistance of an **earth electrode** with respect to **earth**.

Fault Point Current The maximum value of current which could flow at any fault point. This shall be taken as the single-phase short-circuit rating (or three-phase if higher) of the installed switchgear, unless otherwise specified by NGET.

Fully Rated Rated to carry 63kA for 1s at 400kV, 40kA for 1s at 275kV and 31.5kA or 40kA (special application) for 3s at 132kV.

Ground Voltage Profile The radial ground surface potential around an earth electrode referenced with respect to earth.

Hot Zone The internal area encompassed by a contour representing points at which the EPR is greater than 650V rms (based on a 200ms clearance time).

Main Earth System (MES) The complete interconnected assembly of earthing conductors and earth electrodes which are intended to carry HV system fault current.

Other Earth System Earth conductors which are part of the System (as defined in NGET Safety Rules) but which are not part of the Main Earth System.

Earthing System Earth conductors which are part of either the Main Earth System or Other Earth System.

Earth Potential Rise (EPR) The voltage difference between the substation metalwork and earth due to fault current. It is calculated from the product of the total substation earth electrode impedance and the current flowing through it. EPR was previously known, in many national and industrial documents, as RoEP (Rise of Earth Potential).

Step Potential/Voltage The electrical potential between two points, on the surface of the ground, bridgeable between a person's feet, due to a ground voltage profile. The step distance is assumed to be 1m.

Touch Potential/Voltage The electrical voltage between two points, for instance predominantly bridgeable by a person's hand(s) and feet, due to a ground voltage profile. The touch distance is assumed to be 1m. For occasions, hand-to-hand touch voltage may need considerations.

Total Substation Earth Electrode Resistance The resistance of the main earth system and other connected electrodes with respect to earth.

Total Substation Earth Electrode Impedance The impedance of the main earth system and other connected electrodes with respect to earth.

Transferred Potential An electrical potential between two points due to a ground voltage profile which is transferred to the points by a conducting object.

7 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	October 2014	New document	Dongsheng Guo - Asset Policy	GCRP

7.1 Procedure Review Date

5 years from publication date.

PART 3 – GUIDANCE NOTES AND APPENDICES

8 REFERENCES

This document makes reference to or shall be read in conjunction with the documents listed below:

The Health and Safety at Work Act, 1974

The Electricity at Work Regulations, 1989, Statutory Instrument No 635

The Electricity Safety, Quality and Continuity Regulations 2002, Statutory Instrument No 2665

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, Effects of Current on Human Beings and Livestock - Part 1: General Aspects

BS EN 50341 Overhead lines exceeding AC 45kV

BS EN 50522 Earthing of power installations exceeding 1kV a.c.

BS EN 60228 Conductors of insulates cables

BS EN 62305 Protection against lightning

BS 638:Part4 Arc welding power sources equipment and accessories, Part 4. Specification for welding cables

BS 6004 Electric cables — PVC insulated, non-armoured cables for voltages up to and including 450/750 V, for electric power, lighting and internal wiring

BS 7354 Code of Practice for Design of High Voltage Open Terminal Substations

BS 7430 Code of practice for Earthing 2011 (Formerly CP 1013: 1965)

Department for Transport (DfT): The Manual of Contract Documents for Highway Works (MCHW), Volume 1 - Specification for Highway Works, Series 0800 - Road Pavements - Unbound, Cement and Other Hydraulically Bound Mixtures (http://www.dft.gov.uk/ha/standards/mchw/vol1/pdfs/series_0800.pdf)

EA TS 41-24 Guidelines for the Design, Installation, Testing and Maintenance of Main Earthing Systems in Substations, Issue 1: 1992

EA TS 34 A Guide for Assessing the Rise of Earth Potential at Substation Sites, May 1986

EA TS 36-1, Procedure to Identify and Record hot Substations, 2007

EA TS 43-94 Earth Rods and their Connectors, Issue 3, 1990

ITU-T K.33 Limits for people safety related to coupling into telecommunications system from a.c. electric power and a.c. electrified railway installations in fault conditions (previously CCITT Recommendation)

CCITT Directive, Volume VII, Protective Measures and Safety Precautions

Earth Resistances, G F Tagg, George Newnes, London, 1964

APPENDIX A: MEASUREMENT METHODS

MEASUREMENT OF EARTH ROD AND EARTH ROD GROUP RESISTANCE

Unless otherwise agreed by NGET, 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 very much lower resistance compared with the rod or rod group. Care must 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.

MEASUREMENT OF TOTAL SUBSTATION EARTH ELECTRODE IMPEDANCE

The total substation earth electrode impedance shall be measured using the AC Fall of Potential Method [1]. The 61.8% rule or the Slope Method must not be used.

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 [1]. The 61.8% rule or the Slope Method must 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 [1]. The 61.8% rule or the Slope Method must not be used.

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 7430. The method described is also known as the Wenner Method. Resistivity shall be measured up to a depth of 60m 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^{o} to each other).

Ref [1]: Earth Resistances, Tagg G F, George Newnes, London 1964.