IMP/010/001 - Code of Practice for Earthing EHV Networks and Substations

1. Purpose

The purpose of this document is to ensure the company achieves its requirements with respect to the Electricity Act 1989 (as amended) (the Act), the Electricity Safety, Quality, and Continuity (ESQC) Regulations 2002, the Electricity at Work (EAW) Regulations 1989, the Distribution Licences and The Distribution Code, by laying out the way in which Northern Powergrid will develop efficient, co-ordinated and economical earth systems on Extra High Voltage (EHV) networks and at EHV substations.

This document supersedes the following documents, all copies of which should be destroyed;

Document Reference	Document Title	Version	Published Date
IMP/010/001	Code of Practice for Earthing EHV Networks and Substations	1.0	Sept 2021

2. Scope

This Code of Practice applies to all EHV networks and at EHV substations in Northern Powergrid (Northeast) plc and Northern Powergrid (Yorkshire) plc, the licensed distributors of Northern Powergrid and to the providers of connections to those networks and covers the requirements, application, and installation of earth systems

It is not intended for this policy to be applied retrospectively with the exception of locations identified as having inadequate earth networks or those where work is being carried out on the network to satisfy the requirements of the ESQC Regulations 2002 as detailed in section 3.1.2 of this code of practice.

All new networks shall be equipped with earth systems in accordance with this document.

The earthing associated with equipment located on EHV transmission towers is not covered by this Code of Practice and reference should be made to ENA EREC G78.

Contents

3. Policy

3.1. Assessment of Relevant Drivers

The key internal business drivers relating to Earthing policy are:

- Customer Service

This Code of Practice contributes toward quality of supply to customers by defining the design of earthing systems so as to minimise the damage to equipment and prevent interruption of supply.

- Employee Commitment

This Code of Practice contributes toward safety by specifying the requirements, application, and installation of earthing systems so as to prevent danger.

- Financial Strength

This Code of Practice contributes to financial strength through the correct selection and economic development of earthing systems.

- Environmental Respect

This Code of Practice contributes toward the environment by defining the application of earthing systems so as to minimise the damage to equipment during earth fault conditions.

- Regulatory Integrity

This Code of Practice ensures that Northern Powergrid complies with current legislation relating to earthing systems.

- Operational Excellence

This Code of Practice ensures that Northern Powergrid adopt current best practice relating to earthing systems through referencing national level working groups.

The external business drivers relating to the application of earthing systems are detailed in the following sections.

3.1.1. Requirements of the Electricity Act 1989 (as amended)

The Electricity Act 1989 (as amended) ('the Act') lays down the core legislative framework for the Northern Powergrid operations as a distributor. Specifically, it gives force to the ESQC Regulations 2002, and in section 9 creates the key obligation to develop and maintain an efficient, co-ordinated and economical system of electricity distribution. Discharge of this obligation shall be supported in this document by providing guidelines on efficient application of earthing systems to the wider network.

3.1.2. Requirements of The Electricity Safety, Quality and Continuity (ESQC) Regulations 2002.

The ESQC Regulations 2002 impose a number of obligations on the business, mainly relating to quality of supply and safety. All the requirements of the ESQC Regulations that are applicable to the application of earthing shall be complied with, specifically:

Reg. No	Text	Application to this policy
3(1)(b)	…distributors…shall ensure that their equipment is so constructed…as to prevent danger…or interruption of supply, so far as is reasonably practicable	This will be achieved by installation of earth systems to standard or bespoke designs by trained personnel.
6	A…distributor shall be responsible for the application of such protective devices to his network as will, so far as is reasonably practicable, prevent any current, including any leakage to earth, from flowing in any part of his network for such a period that that part of his network can no longer carry that current without danger.	This will be achieved by installation of systems and conductors to provide a low impedance path back to source for earth fault currents as far as is reasonably practicable
8(1)	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.	This will be achieved by installation of earth systems and conductors of sufficient rating and in such a manner as to prevent disconnection
8(2)a	A generator or distributor shall, in respect of any high voltage network which he owns or operates, ensure that – the network is connected with earth at, or as near as is reasonably practicable to, the source of voltage but where there is more than one source of voltage in that network, the connection with earth need only be made at one such point	This will be achieved by design of the network
8(2)b	A generator or distributor shall, in respect of any high voltage network which he owns or operates, ensure that – the earth electrodes are designed, installed and used in such a manner so as to prevent danger occurring in any low voltage network as a result of any fault in the high voltage network	This will be achieved through standard designs and where appropriate the separation between the HV and LV earth electrodes.
10	This regulation requires that any metalwork enclosing, supporting or otherwise associated with his equipment in a network and which is not intended to serve as a phase conductor is, where necessary to prevent danger, connected with earth (there are exceptions for metalwork connected to wood poles more than 3 metres clearance from ground level)	This will be achieved by following the guidance in this Code of Practice

3.1.3. The Health and Safety at Work Act 1974

Section 2(1) states that ‘It shall be the duty of every employer to ensure; so far as is reasonably practicable, the health, safety and welfare at work of all his employees’. Section 3(1) also states that ‘It shall be the duty of every employer to conduct his undertaking in such a way as to ensure, so far as is reasonably practicable, that persons not in his employment who may be affected thereby are not thereby exposed to risks to their health or safety’.

This is addressed in this code of practice by specifying the requirements of earth systems.

3.1.4. Electricity at Work Regulations

The UK Electricity at Work Regulations (Statutory Instrument 1989, No 635) was made under the 1974 Health and Safety at Work Act. Regulation 8 relates to earthing which quotes "Precautions shall be taken, either by earthing or by other suitable means, to prevent danger arising when any conductor (other than a circuit conductor) which may reasonably foreseeably become charged as a result of either the use of a system, or a fault in a system, becomes so charged; and, for the purposes of ensuring compliance with this regulation, a conductor shall be regarded as earthed when it is connected to the general mass of earth by conductors of sufficient strength and current-carrying capability to discharge electrical energy to earth."

These requirements are met within this code of practice by common referencing to earth, connection of plant to earth and equipotential bonding.

3.2. General Requirements

Earthing systems described within this code of practice shall generally comply with the requirements of, the current versions of ENA Technical Specification 41-24 "Guidelines for the design, installation, testing and maintenance of main earthing systems in substations", unless varied by this code of practice or other Northern Powergrid documentation, in which case the Northern Powergrid documentation shall take precedence.

It is Northern Powergrid policy to ensure that every EHV installation has a suitably designed earthing system that provides a safe environment in terms of touch, step and transfer voltages. Where practicable at reasonable cost, external transfer voltages will be reduced to below recommended levels, or otherwise residual risks will be communicated to affected third parties and mitigation measures implemented where necessary. The earthing system must also retain its functional integrity during any reasonably foreseeable fault condition and earthing conductors must be sized accordingly.

The safety and functional design requirements are set out in this document with detail on how to achieve compliance provided in the Earthing Design Manual[1] and implementation guidance in the Earthing Construction Manual[2].

The main earthing safety hazards are illustrated in Figure 3.1 which has been reproduced from ENA TS 41-24.

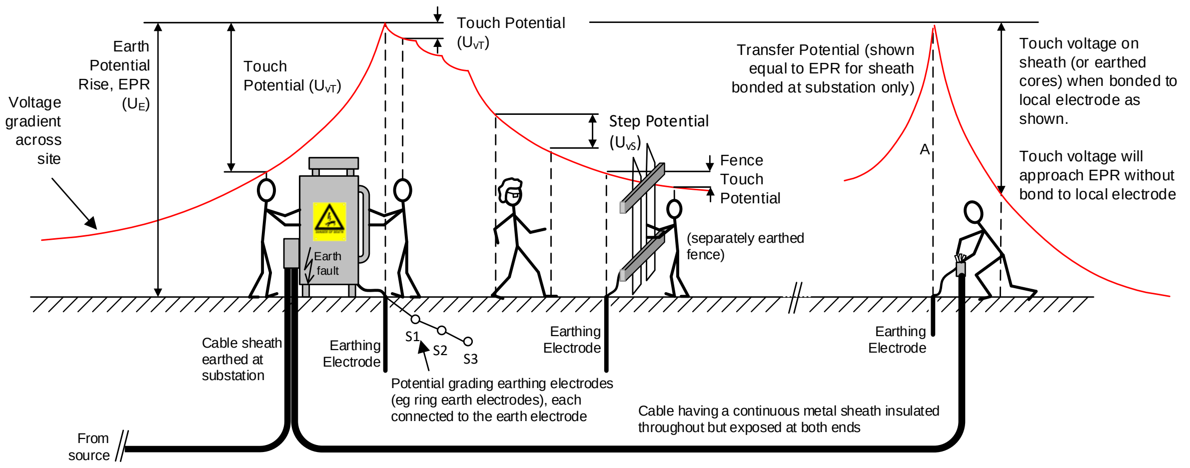

Figure 3.1. Illustration of Earthing Safety Hazards

[1] NSP/007/012 Design Manual for Earthing EHV Networks and Substations

[2] NSP/007/013 Construction Manual for Earthing EHV Networks and Substations

During earth fault conditions, the passage of current through the earth electrode resistance creates an earth potential rise (EPR). Current flowing through the earth, away from the electrode, causes a voltage gradient on the ground surface which can result in dangerous potential differences being experienced by persons depending on their location and contact points. The main hazards shown in Figure 3.1 are touch, step and transfer voltages and these are the criteria used to demonstrate design compliance. These are covered in the next section together with the associated design limits.

A well-designed earthing system limits dangerous potential differences from occurring at the installation, primarily by:

- Connecting together all metalwork that can be simultaneously touched – equipotential bonding.
- Reducing the EPR as far as practicable, e.g. by reducing the earth resistance.
- Careful positioning of earth electrodes to raise ground surface potential throughout the installation, bringing them closer to the EPR, and thus limiting potential differences.
- In special cases, physical separation or insulation to prevent simultaneous contact between items connected to different earthing systems.
- Using a high-resistivity surface material to reduce the touch and step potential by increasing the resistance between feet and earth.

The earthing system must remain intact over the expected lifetime of the installation and the design shall include consideration of long-term corrosion and mechanical deterioration.

3.3. Design Criteria - Safety

In accordance with ENA TS 41-24 earthing designs on the Northern Powergrid network shall comply with the following safety criteria.

3.3.1. Earth Potential Rise

Earth potential rise (EPR) is the voltage, with respect to a remote zero-volt potential, that temporarily exists on the earthing system and connected substation metalwork during earth fault conditions. It is calculated by the product of the earth resistance at the fault location and the ground return current flowing through it. Knowledge of the EPR is essential in assessing the following design safety criteria.

The EPR shall be calculated using the ground return current. This is the component of the earth fault current that flows through the earth resistance not including current returning directly to source via parallel metallic current paths and not through the earth, e.g. underground cable screens or overhead line earth wires. The ground return current shall represent reasonably foreseeable growth in network fault levels. It should be obtained from the 5 – 10 year long term development statement or by applying a 15% uplift to present fault current levels, whichever is the greater.

The earth impedance may include the contribution from the substation earth grid and connected extended electrodes. It may also include the contribution from other reliable network components, e.g. a tower line chain impedance or bare underground cable sheath, etc.

3.3.2. Touch Voltage

This is the main safety criteria and compliance is mandatory. It is the difference between the EPR present on earthed metalwork and the ground surface potential 1m away. Touch voltages may therefore be limited by reducing the EPR or by increasing the local ground surface potential.

Table 3.1 provides the maximum permissible touch voltages for Northern Powergrid networks. The limits are dependent on the fault duration and the surface covering used.

Table 3.1. Touch Voltage Limits[3]

Fault Duration (s)	0.2	0.3	0.4	0.45	0.5	0.6	0.7	0.75	0.8	0.9	1.0	1.5	2.0	3.0
Soil Limit* (V)	1570	1179	837	685	578	420	332	304	281	250	233	188	173	162
Indoor Areas and Chippings Limit (V)**	1773	1331	944	772	650	471	371	340	314	279	259	209	192	180

* Assumes a person with footwear standing on bare soil or grass or outdoor concrete.

** To be used for indoor areas or compounds with a minimum of 75mm of crushed rock chippings. At the designer's discretion, lower limits may be applied where the wearing of footwear cannot be justified, or higher limits where different surface coverings are used, e.g. asphalt or thicker layers of chippings, as per ENA TS 41-24.

The fault duration shall be determined assuming a normal operation of primary protection. In the absence of site-specific information, the durations stated in Table 3.2 shall be used.

Table 3.2. Typical Fault Durations

System Voltage (kV)	Fault Duration (s)	
	NPg Northeast	**NPg Yorkshire**
132	0.2	0.2
66	0.45	0.45
33	0.45	0.45
20 & 11 Cable Fed	1.0	1.0
20 & 11 Overhead Fed	1.0	1.0

The above limits are based on a hand-feet shock current. Hand-hand touch voltages in a substation are controlled by equipotential bonding of equipment but may require consideration where remote earths are available at the substation, more commonly a problem that needs to be managed during installation works, e.g. installation of a new pilot wire into a substation with a metallic sheath.

3.3.3. Step Voltage

Although also a mandatory requirement, step voltage limits are significantly higher than touch voltage and are unlikely to be exceeded in practice where touch voltage requirements have been met.

Table 3.3 provides the maximum permissible step voltages for Northern Powergrid networks. The limits are dependent on the fault duration and the surface covering used.

Table 3.3. Step Voltage Limits[4]

Fault Duration (s)	0.2	0.3	0.4	0.45	0.5	0.6	0.7	0.75	0.8	0.9	1.0	1.5	2.0	3.0
Soil Limit* (kV)	NFE	NFE	NFE	NFE	NFE	NFE	NFE	NFE	21.6	19.1	17.6	13.8	12.6	11.7
Indoor Areas and Chippings Limit (kV)**	NFE	NFE	NFE	NFE	NFE	NFE	NFE	NFE	24.9	22.0	20.3	15.9	14.6	13.5

NFE – not foreseeably exceeded.

[3] Touch voltage limits presented here are based on fibrillation limits.

[4] Step voltage limits presented here are based on fibrillation limits.

*Assumes a person with footwear standing on bare soil or grass or outdoor concrete.

** To be used for indoor areas or compounds with a minimum of 75mm of crushed rock chippings. At the designer's discretion, lower limits may be applied where the wearing of footwear cannot be justified, or higher limits where different surface coverings are used, e.g. asphalt or thicker layers of chippings, as per ENA TS 41-24.

3.3.4. Transfer Voltage - Low Voltage Networks

The design shall prevent dangerous voltages being transferred onto the low voltage neutral / earth system and the applicable safety criteria are the touch voltage limits provided in Table 3.1. Where the low voltage network is multiply earthed (PME), it is assumed that the soil voltage in and around LV customer installations will raise to at least 50% of the EPR. In this case, the limits in Table 3.1 may be doubled, i.e., application of the F=2 factor from ENA TS 41-24. The design should consider that transfer potentials may be exported to the LV network via the earthed screens of the 11kV underground cable network and distribution substations with combined HV/LV earths.

Where a low voltage network supply is required at an EHV substation, and the EPR exceeds the applicable limit, transfer potentials shall be mitigated. This may be achieved by effective separation between the EHV and LV earthing systems or by the use of a suitably rated isolation transformer.

At high EPR sites the EPR may impact external third parties and guidance is provided in ENA EREC S41. Where the EPR at the EHV installation exceeds the applicable touch voltage limit, the extent of the relevant ground surface voltage contour shall be calculated using computer simulation. A touch voltage assessment is required for any LV installations enclosed by the contour by calculating the difference between the potential transferred onto the LV neutral / earth network and the local ground surface voltage at the customer installation(s). Excessive touch voltages at customer properties shall be mitigated by reducing the EPR at the EHV installation, reducing the transfer potential onto the LV network, or by increasing the ground surface voltage at the affected location. Examples of possible mitigation methods are increasing the separation between the EHV and LV earthing systems or converting the LV earthing system from PME to a TT arrangement.

The continuity of other metallic services entering the EHV installation that are capable of transferring the EPR shall be interrupted, e.g. plastic inserts in metallic water pipes.

3.3.5. Transfer Voltage - Telecommunication Networks

EHV installations where the EPR exceeds industry agreed threshold values are deemed 'Hot Sites' and additional mitigation is required to control transfer potentials onto telecommunication equipment. The threshold values of EPR are dependent on the speed and reliability of the protection schemes, are provided in ENA EREC S36 and are reproduced in Table 3.4.

Table 3.4. Telecommunication Network Transfer Voltage Mitigation Thresholds

Protection	Hot Site Threshold Voltage (V)	Domestic Property Threshold (V)
High reliability, clearing in <0.2s	650	1700
Low reliability or clearing in >0.2s	430	1150

Where the EPR exceeds the lower thresholds the EHV installation is declared as a Hot Site and the following information must be provided to a Communication Network Provider (CNP) on request:

- EPR
- A plan showing the area where the soil voltage exceeds the threshold (Hot Zone), which is normally calculated using computer simulation. The CNP will assess the impact on their equipment and plan to relocate it or apply special working procedures.

Isolation equipment is required to be fitted to any metallic telecommunication circuits entering the EHV installation.

Where the EPR exceeds the upper thresholds, the associated ground surface voltage contours shall be added to the Hot Zone plot. Domestic properties enclosed by these contours may also require isolation equipment to be installed on metallic telecommunication circuits if deemed necessary following a detailed calculation and risk assessment.

3.3.6. Stress Voltage

Stress voltage is a potential difference that may exist during earth fault conditions between two conductors or the soil and a conductor. It is normally controlled by insulation with a sufficiently high withstand or breakdown strength.

Where a stress voltage may occur, equipment insulation shall be sufficient to withstand a voltage that is in excess of the EPR. An example would be a low voltage cable buried near an EHV installation where the ground may rise to a high potential. If the LV cable neutral/earth conductor is earthed remotely (near zero potential) and the local ground potential exceeds the cable insulation during EHV fault conditions, then the cable insulation may breakdown. Mitigation methods may include increasing the insulation strength of the LV cable or installing it inside a plastic duct. As a general rule, the EPR at an EHV installation shall be limited to 2kV to avoid exceeding equipment stress voltage limits. Where it is not practical to achieve an EPR of below 2kV, higher values may be acceptable providing a detailed assessment of stress voltages has been carried out and special mitigation implemented as required.

3.4. Design Criteria - Functional

In accordance with ENA TS 41-24 earthing designs on the Northern Powergrid network shall comply with the following functional design criteria.

3.4.1. Conductor Current Carrying Capacity

Earthing conductors shall have sufficient cross-sectional area to carry the required current, calculated using the adiabatic equation found in ENA EREC S34. The duration of current flow shall be 3s.

Northern Powergrid have selected standard conductors that shall be used at all EHV installations and, where duplicated, are suitable for a 31.5kA/3s current rating. These are shown in Table 3.5 together with their 3s current ratings.

Table 3.5. Standard Earthing Conductors – up to 31.5kA / 3s Rating

Conductor	3s Current Rating (Single / Spur Connection)	3s Current Rating (Duplicate Connection / Earth Grid)
40 x 4mm Copper Tape	19.6 kA	32.6 kA
40 x 6mm Aluminium Tape	17.9 kA	29.8 kA

Copper conductors shall be used below ground, in buildings and for short connections to outdoor plant near ground level. Aluminium conductors shall be used where exposed over longer lengths in outdoor compounds to deter against theft.

At grid supply points (National Grid), a higher rating of up to 40kA/3s may be required for Northern Powergrid 132kV equipment. At these locations, duplicated conductors as shown in Table 3.6 shall be used.

Table 3.6. Earthing Conductors for Joint National Grid Substations – up to 40kA / 3s Rating

Conductor	3s Current Rating (Single / Spur Connection)	3s Current Rating (Duplicate Connection / Earth Grid)
50 x 4mm Copper Tape	24.5 kA	40.8 kA
40 x 6mm Aluminium Tape	26.1 kA	43.5 kA

3.4.2. Electrode Surface Current Density

The conductors forming the electrode (bare and in contact with the soil) shall not overheat as this may cause their earth resistance to increase due to soil drying at the electrode surface. There must be sufficient electrode surface area to dissipate the anticipated electrode current for a duration of 3s. The current must allow for future growth based on the 5 – 10 year long term development statement, or the present fault current with a 15% uplift, whichever is the greater. The current density limit at the electrode surface is determined by the equation, found in ENA EREC S34 which is also dependent on the soil resistivity at the depth where the electrode is installed details are provided in the Northern Powergrid EHV Earthing Design Manual.

3.5. Planning

Early consideration of the earthing design is important to allow preliminary measurements to be taken where required, e.g. soil resistivity. Sufficient time is also required to obtain the necessary input data, e.g. fault currents, cable datasheets, etc.

Prior to major works at an EHV installation the Northern Powergrid earthing database should be consulted to determine records and information already available for use in the new design process, e.g. a soil resistivity model may already be available that will avoid the need for further site measurements. Historical earth resistance measurement results may also be used, providing there has been no significant changes to the substation electrode or its connected cable network since it was taken.

Construction efficiencies can be gained by careful planning of earthing installation to coincide with other excavations, such as those required for foundation plinths or cable trenches. The earthing design and installation should commence before cable/ducts are laid, as it may be necessary to lay bare copper electrode in trenches before they are backfilled. If it is deemed necessary to install electrode outside the immediate area of the substation, and away from cable routes, this may require wayleaves to be obtained and co-ordination with third parties.

Whilst an initial design can be produced using empirical calculations, or by using standard layouts, the final design for all new/proposed EHV substations shall be modelled using appropriate software and a multi-layer soil model before the design is finalised and accepted.

3.6. Earthing Layout

The earthing design shall be based on the standard layouts and features described in the Northern Powergrid EHV Earthing Design Manual and associated standard drawings. The layout may be optimised to achieve the most economical solution for the given installation and location. The final design shall be shown to comply with the design criteria by an earthing study documented in a technical report. The final design shall be presented on a suitable earthing layout drawing. The earthing design shall include the following features:

- A main electrode system (MES) buried throughout the installation whose primary function is to contribute to lowering the earth resistance and reduce touch voltages. The MES shall, as a minimum, consist of:
    - A perimeter horizontal electrode buried a minimum of 0.6m below the surface, encompassing all earthed equipment, and extending up to 1m beyond exposed metalwork and bonded metallic fences.
    - Further horizontal electrodes inside the perimeter to reduce potential gradients across the site and to facilitate equipment connections. Horizontal electrodes should be buried direct in soil where possible and connected where they cross to form a grid for increased resilience.
    - As a minimum, vertical earth rods shall be installed at each corner of the perimeter electrode. Rod lengths should be optimised to suit the local soil resistivity conditions. At least two of the rods shall be fitted with inspection / test facilities.

- All equipment capable of passing HV earth fault current is to be connected to the MES by a fully rated earth conductor. Transformers, switchgear, circuit breakers, NERs and earth switches shall have two diverse fully rated connections.
- Transformer neutrals are to be connected to the MES via fully rated earth conductors. At 132kV the connection shall be via a solid connection. At lower voltages the neutral connection may be solid, via neutral earth impedance or via an arc-suppression coil depending on the system earthing design.
- Surge arresters and capacitor voltage transformers shall have special earthing provisions to conduct transients with high frequency components to earth. This will include short and straight above ground connections with no sharp bends, together with a supplemental vertical electrode (HF rod) as close as possible to each equipment base.
- Steel terminal towers shall be connected to the substation MES via two fully rated conductors, one connected to two diagonally opposite legs. Where towers are located outside a separately earthed substation fence the connections shall be insulated 2m either side.
- Underground feeder cable sheaths / screens shall be effectively connected to the MES at the switchgear. Where single-point cable sheath bonding is employed the sheath earthing shall be considered by the cable designer in accordance with ENA EREC C55.
- Earth electrode or an earth mat shall be installed at operator switch handle locations and the handle connected to it.
- All other metalwork, e.g. panels, kiosks, lighting supports, etc., are to be connected to the MES to prevent induced voltage hazards. Small metallic objects that will not present an induced voltage hazard, e.g. small vents in a brick building, window frames, etc. do not require to be connected to the MES.
- Metallic fencing is to be connected to the MES where within 2m of earthed metalwork, otherwise separately earthed via independent earth electrodes. Separately earthed fencing shall be kept a minimum of 2m away from bonded fence sections using a floating section of fence mounted on insulators.
- The horizontal reinforcing bars in significant foundations (switchgear buildings and transformers) shall be connected to the MES at a minimum of two locations at diagonally opposite corners.

Additional guidance on the above is provided in the Northern Powergrid EHV Earthing Design and Northern Powergrid EHV Earthing Construction Manuals.

3.7. Design Assessment Procedure

Compliance with the design criteria stated in this policy shall be demonstrated using the procedure described in the Northern Powergrid EHV Earthing Design Manual. The methodology used and supporting calculations shall be documented in a suitable technical report.

3.8. Construction

Earthing systems associated with EHV networks and substations shall be constructed in accordance with the Northern Powergrid Earthing Construction Manual.

3.9. Risk Assessment

A quantitative risk assessment may be necessary where third party impact outside the substation cannot be avoided at reasonable cost. The procedure is detailed in ENA TS 41-24 and EREC S41, but its use is discouraged where risk can be mitigated at the design stage. In general, all substations shall be safe by design, i.e. the touch voltages in and around the substation shall be below the touch voltage limits in Table 3.1. If a new (third party) development adjacent to an existing substation changes this situation, quantitative risk assessment may be applied if other solutions cannot be found.

3.10. Shared Sites

It is common for a Northern Powergrid EHV installation to be co-located with another operator e.g. National Grid or Network Rail, or customer owned EHV or HV equipment, e.g. a 33kV metering circuit breaker at a renewable energy generation site. At these joint sites, Northern Powergrid has a duty of care to coordinate the earthing design with the other parties. This is to ensure that the two earthing systems interact safely with each other and that their operational staff can safely access Northern Powergrid equipment located within a joint site where necessary. In general, the Northern Powergrid and third-party earthing systems shall be combined unless a safer arrangement is otherwise demonstrated by calculation. At joint sites, the design assessment shall include the worst-case fault condition regardless of whether this occurs on Northern Powergrid or third-party equipment. Further requirements are provided for different types of installation as follows:

3.10.1. Joint Transmission Substation and Railway Supply Sites

Where a Northern Powergrid installation is co-located with a National Grid transmission substation, additional considerations shall apply. These may include a higher EPR associated with earth faults on the transmission system or the need to use larger earthing conductors to cater for the higher fault levels. The earthing design shall be coordinated with National Grid to ensure that the overall design meets the requirements of each party.

At installations co-located with railway supply substations the earthing design shall be coordinated with the railway operator. Additional considerations may apply including the use of different touch voltage limits (based upon the rail industry standard BS EN 50122), and any adverse effects of EPR on signalling systems. Different design requirements will apply depending on whether the traction supply is AC or DC, and these will need to be considered and coordinated with the railway operator.

3.10.2. Generation and Load Connections - Separate Adjacent Installations

Where a Northern Powergrid installation is contained within a separate enclosure or compound its earthing design shall, where practicable, ensure compliance with touch, step and transfer voltage requirements in isolation of the customer earthing system. Where it is disproportionately expensive or impractical to achieve acceptable transfer voltages in isolation, the customer installation may be relied upon, e.g. the customer earthing system may be relied upon to achieve an overall Cold Site to avoid isolation of telecommunications circuits.

The earthing design in the customer installation is not the responsibility of Northern Powergrid. However, a suitable earthing design report and drawing, in accordance with ENA TS 41-24, shall be provided by the customer for design coordination.

Adjacent installations, within 30m of each other or where there is reliance on the customer earthing system, shall be interconnected by two fully rated and labelled earth conductors. Where the Northern Powergrid installation achieves compliance with the design criteria in isolation of the customer earthing system, and where it is greater than 30m away, the earthing interconnection may be made via the HV cable screens.

3.10.3. Generation and Load Connections - Integrated Installations

Where a Northern Powergrid installation is located within the customer installation, and its earthing system, an integrated earthing design shall be developed. To ensure the safety of Northern Powergrid operational staff entering the customer installation, the overall site earthing system shall, as a minimum, be designed as per the requirements of this policy and approved by Northern Powergrid.

The party responsible for the integrated earthing design shall provide a suitable earthing report and layout drawing to the other parties operating at the site.

3.11. Design Verification

During construction and commissioning of a new site, or new equipment at an existing site, the following activities shall be undertaken:

- Measure and record the resistance of each earthing conductor joint and confirm they are acceptably low before backfilling.
- Measure the individual earth resistance of earth rods or extended radial electrodes and record these for comparison with future maintenance testing.
- Measure the overall earth resistance using the fall-of-potential method and compare the value to the calculated design value. Investigate and remedy any significant difference.
- Produce an as-built earthing layout drawing. Significant deviations from the original design proposal shall be verified by updated calculations.

3.12. Maintenance

As part of ongoing maintenance at an EHV installation the following activities shall be undertaken:

- Annual high level visual inspection of the earthing system to check for defects presenting immediate danger, e.g. earth conductor theft or damage.
- Periodic earthing maintenance survey to carry out bonding tests, sample measurements of joint resistances, measurement of individual earth electrode resistances, fence separation tests, etc.
- Periodic measurement of the overall earth resistance, where practicable using the fall-of-potential method. The value should be compared to previous measured or calculated values so that significant increases can be investigated further.

Defects identified during maintenance checks shall be scheduled for remediation.

3.13. Records

An earthing database shall be maintained to hold earthing related information for each EHV substation. This shall include technical information such as the EPR which may be requested by third parties. It should reference the latest earthing study and records available for each site to allow these to be accessed when required. The database shall be updated as new information becomes available.

At project completion the following information shall be uploaded to the Northern Powergrid earthing database:

- As-built earthing layout drawing.
- Earthing design study report.
- Commissioning test results.
- Add Hot Sites to the Northern Powergrid Hot Site register.

4. References

4.1. External Documentation

Reference	Title
2002 No. 2665: 2003	The Electricity Safety, Quality and Continuity Regulations 2002
BSEN 50122-1	Railway applications - Fixed installations - Electrical safety, earthing and the return circuit - Part 1: Protective provisions against electric shock
ENA EREC C55	Insulated sheath power cable systems
ENA EREC G78	Recommendations for low voltage supplies to mobile phone base stations with antennae on high voltage structures
ENA EREC S34	A Guide for Assessing the Rise of Earth Potential at Substation Sites
ENA EREC S36	Identification and recording of ‘hot’ sites – joint electricity industry and Communications Networks Providers
ENA EREC S41	Guidance on transferred voltages from earthing systems
ENA TS 41-24	Guidelines for the Design, Installation, Testing and Maintenance of Main Earthing Systems in Substations
HASAWA: 1974	The Health and Safety at Work Act 1974

4.2. Internal Documentation

Reference	Title
NSP/007/013	Northern Powergrid Earthing Construction Manual
NSP/007/012	Northern Powergrid Earthing Design Manual

4.3. Amendments from Previous Version

Reference	Description
Section 2	Added table of content
Section 1 – Section 6	Editorial checks and corrections
Section 3.2	Addition of a general requirement in section 3.2
Section 5	Addition of definitions for PME and TT earthing systems

5. Definitions

Term	Definition
Bonding	The use of protective earth conductors to connect conductive parts and the Earthing System so that they remain at the same potential during fault conditions.
Earth Electrode	A conductor or group of conductors in direct contact with, and providing an electrical connection 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	The worst-case steady state (symmetrical) RMS current to earth, i.e. that returning to the system neutral(s) resulting from a single phase to earth fault. This is normally calculated (initially) for the zero-ohm fault condition. Depending on the circumstances, the value can be modified by including Earth Resistance.
Earth Rise Potential (EPR)	The potential on the Earthing System with respect to a remote (zero) earth potential that occurs during an Earth Fault.
Earth Resistance	The resistance presented to current flowing through an Earth Electrode, primarily due to the earth near to the electrode. In longer electrodes, where there is a significant inductive component, the term Earth Impedance is a more accurate definition. The terms are considered interchangeable in this document.

Term	Definition
Earthing System	The complete interconnected assembly of Bonding Conductors, Earth Electrodes and other metallic paths that are part of the Earthing System design.
EHV	An electrical system operating at a voltage greater than 20,000V.
Electrode Current	The component of the Earth Fault Current that flows through the Earth Electrode that is used to assess the design against the electrode surface current density requirement.
ENA	Energy Networks Association
Ground Return Current	The component of the Earth Fault Current that flows through the Earth Electrode and parallel paths, e.g. bare cable sheaths or tower line chain impedance. This current is used to calculate the EPR.
Ground Surface Potential	The potential on the surface of the ground with respect to a remote (zero) potential. Ground Surface Potential gradients are produced by the EPR in the vicinity of an Earth Electrode.
Hot/Cold Site	Historical terms for classifying electrical installations where the EPR exceeds industry agree threshold limits concerning transfer potentials to telecommunication equipment. A Hot Site is where the EPR exceeds 650V or 430V, the former generally applying to 132kV systems with high reliability protection that clears earth faults in less than 0.2s. A Cold Site refers to an installation where these limits are not exceeded.
HV	An electrical system operating at a voltage greater than 1000V, but less than or equal to 20,000V.
Main Earthing / Electrode System (MES)	A subset of the Earthing System which comprises the interconnected arrangement of the Earth Electrodes and Bonding conductors in a substation.
Protection Multiple Earth (PME)	An earthing arrangement, found in TN-C-S systems, in which the supply neutral conductor is used to connect the earthing conductor of an installation with earth, in accordance with the ESQC Regulations 2002.
Step Voltage	The voltage between two points on the ground surface that are 1m distant from each other, which is the stride length of a person.
Stress Voltage	The voltage occurring between two conductors or one conductor and the earth, normally appearing across insulation or separation in air.
Touch Voltage	The voltage between conductive parts (hand-to-hand), or conductive parts and earth (hand-to-feet), when touched simultaneously.
Transfer Voltage	EPR or Ground Surface Potentials transferred (normally by a conductor) to a location of lower potential where simultaneous contact may cause a Touch Voltage or Stress Voltage. Conversely a low potential may be transferred into an area of higher EPR or Ground Surface Potential.
TT System	A system having one point of the source of energy directly earthed, the exposed-conductive-parts of the installation being connected to earth electrodes electrically independent of the earth electrodes of the source

6. Authority for Issue

6.1. CDS Assurance

I sign to confirm that I have completed and checked this document, and I am satisfied with its content and submit it for approval and authorisation.

		Date
Eve Fawcett	Governance Administrator	17/03/2025

6.2. Author

I sign to confirm that I have completed and checked this document, and I am satisfied with its content and submit it for approval and authorisation.

Review Period - This document should be reviewed within the following time period;

Standard CDS review of 3 years?	**Non Standard Review Period & Reason**		
Yes	**Period: n/a**	**Reason: n/a**	
Should this document be displayed on the Northern Powergrid external website?			Yes
			Date
Muddasser Razzaq	Smart Grid Development Engineer		17/03/2025

6.3. Technical Assurance

I sign to confirm that I am satisfied with all aspects of the content and preparation of this document and submit it for approval and authorisation.

		Date
Mark Thompson	Specification and Design Manager	18/03/2025

6.4. Authorisation

Authorisation is granted for publication of this document.

		Date
Mark Callum	Smart Grid Development Manager	17/03/2025