Document Reference: XDS-GFS-12-001-R4

Functional Specification

Earthing and Lightning Protection

Revision History					
Revision	**Date**	**Description**	**Originator**	**Checker**	**Approver**
R0	31/08/2011	First Issue – This document supersedes XDS-WTS-12-001-R1.	Paul Moran	-	Christy Kelleher
R1	29/05/2014	Section 4 revised to include process for station specific fault level requests minor modifications to section 5.1, 5.2, 8, 17 and 18.1	Sandra Howard	-	Paul Moran
R2	20/12/2019	Significant review and update to all sections of document	Kelvin McGurk	Conor Farrell, Philip Kennedy and due-diligence process.	Brendan Murray
R3	05/10/2020	Minor review to align with update of Earthing Drawings XDS-DGA-00-004 to R4	Niall McMahon	Neil Keegan and due diligence process.	Brendan Murray
R4	08/03/2022	Appendix A - Interim Optional Application of EN50522 & Clarification of EPR Calculation	Neil Cowap	Aidan Geoghegan Daniele Giustini Niall McMahon	Neil Cowap

1 Scope

This technical specification covers the technical requirements of the design, supply at site, installation and testing of Substation earthing and lightning protection system complete with all accessories.

This specification should be read in association with the project specific contestable works document / CPP and all other relevant functional specifications as issued by EirGrid. Note: For earthing practice requirements this document must be read in close conjunction with the associated earthing practice drawings.

For the purpose of this specification, fenced cable termination / interface compounds shall be treated as substations unless specifically agreed with EirGrid.

For the purpose of this specification the term Customer shall refer to any party (Independent Power Producers, Demand Customers, Transmission Asset Owner, or other developers) responsible for the design and build of assets for connection to the Irish transmission system.

For the purpose of this specification the terms "earth grid" and "earth electrode" are considered interchangeable.

Appendix A has been included for the following purposes

1. To allow the use of the EN50522 standard for the calculation of step and touch voltages.
2. To clarify how the EPR (Earth Potential Rise) is calculated

The intention is to get feedback from industry to allow a future revision of the Earthing standard.

The use of Appendix A is optional. All Revision 4 changes except for Appendix A are highlighted by a blue box.

2 Specifications and Standards

2.1 Standards

All installations shall comply with the latest version of the Grid Code. The Irish Grid Code is available on the EirGrid website www.eirgridgroup.com.

Refer to drawing series XDS-DGA-00-004 "110kV/ 220kV/ 400 kV General Arrangement Earthing Practice", which provides examples of common earthing practice. Except where otherwise stated in the functional specification, materials shall be designed, manufactured, tested and installed according to relevant IEC/EN standards. Where applicable the Irish adaptation of the standard (IS EN version), including any national normative aspects, shall apply. Where no IEC/EN standards have been issued to cover a particular subject, a recognised international standard shall be applied.

The earthing and lightning protection system shall comply with this specification and with the latest edition of the following Standards:

IEC 60028 International Standard of Resistance for Copper.

IEC 60227 PVC insulated cables of rated voltages up to 450/750 V

IEC 60228 Conductors of insulated cables

IEC 61138 Cables for portable earthing and short circuiting equipment.

IEC 61219 Live Working - Earthing or Earthing and Short-Circuiting Equipment Using Lances as a Short-Circuiting Device - Lance Earthing

IEC 61230 Live working – Portable equipment for earthing or earthing and short-circuiting

IEC 61238 Compression and mechanical connector.

EN 61936 Power installations exceeding 1kV a.c.

IEC 62305 Protection against lightning (parts 1-4).

EN 62561 Lightning protection system components (all relevant parts).

IEEE 80 Guide for safety in alternating current substation grounding.

IEEE 81 Guide for measuring earth resistivity, ground impedance, and earth surface potentials of a ground system.

IEEE 142 Grounding of Industrial and commercial power systems.

IEEE 367 Recommended Practice For Determining The Electric Power Station Ground Potential Rise And Induced Voltage From A Power Fault

ITU-T Directives concerning the protection of telecommunication lines against harmful effects from electric power and electrified railway lines Volume VI.

EN 1011 Recommendations for welding of metallic materials.

EN 50522 Earthing of power installations exceeding 1 kV ac

I.S. 10101 National Rules for Electrical Installations (2020)

ET 103National Rules for Electrical Installations Power installations exceeding 1 kV a.c. (1.5 kV d.c.)AC, 1st Edition.

Pol_St_17 EirGrid Policy on Calculation of the Maximum Fault Level for Substation Earth Grid Design

In case of conflict between this specification and any of the listed standards, this specification shall take precedence, however the Customer may seek a clarification to any conflict if necessary.

The Customer shall state in their proposal the standards and codes of practice which he proposes for any items of plant not covered by IEC standards. If required by EirGrid, the Customer shall submit two English language copies of these standards not later than the design submission date.

In addition, there shall be compliance with the provisions of all relevant Directives of the European Communities relating to work equipment, i.e. in regard to safety of personnel who operate and maintain the equipment. In order to prove compliance, the equipment shall carry the CE Mark (where required) in accordance with Direction 93/465/EEC.

2.2 Units of Measurement

The SI system of units shall be used throughout the project.

Temperature shall be in degrees Celsius.

Electrical energy shall be in kWh and gas and fluid pressure shall be expressed in MPa.

2.3 Interchangeability and Standardisation

To limit the stock levels of spare parts required, all equipment and parts thereof performing similar duties shall preferably be interchangeable

3 Service Conditions

The earthing and lightning protection systems are to be installed indoors and outdoors in electrically exposed locations, less than 1,000 metres above sea-level.

The following air temperatures apply: -

Maximum ambient temperature	40°C
Maximum daily average ambient temperature	30°C
Annual average ambient temperature	20°C
Minimum ambient temperature	-25°C

The maximum wind (gust) velocity is 50 metres per second.

The humidity is high and the atmosphere is often salt-laden.

The humid salty atmosphere in Ireland is particularly severe on non-galvanised ferrous parts and on aluminium and its alloys.

It shall be the responsibility of the Customer to determine the characteristics of the native soil for each project.

4 Network Parameters

The earthing and lightning protection systems shall be suitable for installation on the Transmission system in accordance with the following EirGrid Network Parameters:

- Maximum earth fault (short circuit) level shall be taken to be the 3 Phase Short Circuit Level (rms) outlined in EirGrid General Functional Specification XDS-GFS-00-001.

- Equipment withstand and current carrying capabilities shall be based on the duration of Short Circuit outlined in EirGrid General Functional Specification XDS-GFS-00-001.

- Tolerable safety voltage limits shall be based on a fault clearance time of 500 ms.

- Where earth conductor ratings are calculated, they shall be based on a maximum system fault clearance time of 500 ms, or as otherwise agreed by Eirgrid. Refer also to Table 3.

The following process shall be followed for the production of the earthing report and earth grid design:

- In designing the earth electrode systems the relevant system equipment design earth fault short circuit levels shall be used as the starting point of the design study.
- If this results in an impractical design then the Customer may request EirGrid to carry out further analysis to determine if a reduced fault level or duration can be considered. (Note: this only applies in respect of touch and step voltages, all conductor sizing shall be based on Table 3)
- Such requests shall follow the normal derogation procedure and shall be accompanied by comprehensive supporting documentation which clearly demonstrates that all reasonably practicable solutions have been considered.
    - This shall include an assessment of all other potential mitigations including grid mesh size, electrode/rod depth, surface treatment and bonding to adjacent electrode systems.
- It is not acceptable to incorporate such requests into a report submitted as part of the normal design review process.

The rated withstand voltage of auxiliary circuits shall be 2 kV r.m.s.

5 Earth Grid

5.1 Soil Tests & Site Selection

The Customer shall carry out soil resistivity measurement at the proposed substation location.

These measurements should be used as a determining factor in the selection of the substation location. Site selection should also consider potential hot zones and effect on nearby property and infrastructure.

Poor site selection shall not be accepted as a justification for derogation requests.

The results of the testing shall be the basis on which the earth grid shall be designed.

As the site selection may have been undertaken prior to engagement with EirGrid, EirGrid may request that electrical resistivity measurements be repeated to allow witnessing by EirGrid or its representative.

The results of these measurements shall be the basis on which the earth grid shall be designed.

The Wenner four-electrode method shall be used. The proposed test method shall be submitted to EirGrid for review. The positions of the probes used for the test, and their variation shall be chosen such to result in the most accurate results.

The extent of measurements shall be sufficient to determine the thickness and resistivity of surface, bedrock and any intermediate layers. Typically, measurements shall be taken at a range of probe spacings from 0.3 m out to 100 m and further subject to site constraints.

The following probe spacings are typically used: 0.3, 0.5, 0.7, 1, 2, 3, 4, 5, 7, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130 meters.

At least two sets of measurements shall be made on site at approximately 90º angles. Further measurements (e.g. at 45º) shall be taken as appropriate to help clarify any potential anomalous measurements.

Probe positions adjacent to existing earth systems or buried metal objects shall be avoided as far as possible.

The results of these tests shall be submitted to EirGrid for review.

Also, notwithstanding any civil or structural requirements, the customer shall carry out an analysis of the native soil to determine its suitability (or otherwise) as a bedding layer for the bare earth electrode system. This analysis shall identify contaminated soils or other characteristics (e.g. high salt content) which may be particularly corrosive to any buried elements of the earthing system. Where required, suitable mitigation shall be by agreement with EirGrid.

The correct implementation of testing/ measurement and use of the results is the sole responsibility of the Customer.

5.2 Design (Modelling)

5.2.1 General

The substation shall be provided with a complete earthing system, comprising of a buried earth grid electrode, connections to steel structures and where applicable the contribution of overhead shield wires or cable sheaths to ensure safe step and touch potentials.

Where the Customer earthing system is adjacent to the substation and separation cannot be ensured, the two earthing systems shall be interconnected using permanent connections.

However, as outlined in section 5.2.3.4, the EirGrid substation earth grid shall also be designed to perform independently from any adjacent customer system.

The design report shall include sufficient information on the various potential interconnection scenarios to allow direct comparison between the model and site measurements. The designer shall outline clearly any particular testing required to validate any assumptions made during the design process.

The earth grid shall be designed as per the latest IEEE standards. ‡

This design shall be submitted to EirGrid for review. The design shall include drawings and calculations, demonstrating a safe step and touch potential level is maintained in the substation under all conditions.

‡ Permissible touch and step voltages may be based on IEEE 80 or EN 50522. See also section 5.2.3.2 and Appendix A.

The design shall also include an OS map indicating the value and position of anticipated Earth Potential Rise contours around the perimeter of the substation (including any adjacent connected towers) during fault conditions.

5.2.2 Soil Model

As outlined in section 5.1, the Customer shall perform soil resistivity measurements to establish an electrical model of the surrounding soil and rock.

A multi-layer resistivity soil model shall be developed using appropriate software. Preferred software is RESAP module of the SESTECH CDEGS software package, capable of modelling up to 5 soil layers.

Justification shall be provided for the soil model(s) selected, with reference to supporting information such as trial pit data, if available, and information regarding the local geological conditions (bedrock types, etc.), where appropriate.

Tables shall also be included showing the measured apparent resistance and/or resistivity versus probe spacing for each of the sets of soil resistivity measurements taken. In cases where there is poor agreement between sets of data, sensitivity analysis shall be carried out and any modifications, simplifications or assumptions made in deriving the soil model clearly explained.

The soil model shall also take account of any required cut or fill civil works at the site.

5.2.3 Electrode Modelling

5.2.3.1 General

The design of the earth grid shall be such that the tolerable values for step and touch as well as transferred potential are not exceeded under any condition.

The model shall utilise the above soil model and accurately reflect the proposed electrode characteristics (conductor type, size and insulation).

In order to ensure consistency with the civil works design, the model shall accurately reflect electrode burial depth (see section 5.3.1) and the design report shall clearly show that the stated depth is from graded rather than finished ground level (i.e. excluding any additional surface layers).

The combined resistance of the substation earth grid to earth shall be minimised as far as possible. All reasonable measures shall be taken to achieve a value less than 1 Ω[§] Where this cannot be achieved, it shall be clearly brought to the attention of EirGrid and appropriate mitigation measures shall be agreed. [**]

The earth grid shall be designed for the fault levels and durations as per section 4.

An assessment of fault current splits may be performed in accordance with EirGrid Policy on Calculation of the Maximum Fault Level for Substation Earth Grid Design Pol_St_17.

[§] This value applies to the EirGrid/ESB substation earth electrode only, independent of any parallel return paths or customer interconnection.

Input parameters, assumptions, and calculation methods shall be proposed and agreed with EirGrid client Engineer in advance of any current splits calculation.

Where a substation involves multiple voltage levels, separate current splits calculations shall be undertaken at each voltage level to determine the most onerous earth fault current. ††.

5.2.3.2 Analysis

A safety analysis shall be carried out to demonstrate that all step and touch potentials are within tolerable limits.

The safety analysis shall also consider transfer potential and particular attention shall be given to:

- Adjacent electrode systems.
- Cable screens (power, LV, & control /telecom).
- Shieldwire and earth continuity conductor (ECC or also commonly referred to as counterpoise).
- Other conductive paths (e.g. fences, railways, gas or water pipes).
- Inadvertent bonding of systems intended to be isolated.

Tolerable touch and step voltages shall be calculated in accordance with IEEE 80 or EN 50522. Refer to Appendix A for further details of the application of EN 50522.

Where IEEE 80 is used, the following parameters shall be applied:

- 50 kg body mass;
- 50Hz frequency,
- Fault level and X/R ratio per section 4‡‡,
- Fault clearance time per section 4.

5.2.3.3 Additional resistances

An additional footwear resistance of 4,000 Ω per foot may be considered inside the substation palisade fence.

The typical additional surface layers in Table 1 may be considered for preliminary design.

Table 1 - Additional surface layers

Surface Layer	Typical Resistivity (Ω.m)	Standard thickness (mm)

†† "Earth fault current" is the ESB term for the portion of fault current returning to source via the general mass of earth and contributing to earth potential rise. "Earth fault short circuit level" is the ESB term for the prospective fault level at the substation.

‡‡ Note: More onerous requirements at designated substations with higher than normal short circuit level or X/R ratio shall also be considered.

Native soil / backfill	Per soil model	N/A
Crushed limestone	2,500	150
Tarmac	>10,000	50

The customer is responsible for ensuring that the resistivity properties of the material on site match those used in the design or that the design is amended accordingly.

Standard layer thickness values in Table 1 shall be considered as minimum. Where greater thickness layers are installed the tolerable limits shall be adjusted accordingly.

5.2.3.4 Interconnections

The substation earth grid shall in the first instance be designed to operate in isolation[§§].

If safe values of step and touch cannot be achieved using a standard electrode grid, suitable additional mitigation shall be applied. The use of additional electrode, earth rods and backfill / surface layer management shall be the primary methods to provide mitigation.

Reliance on external electrode or third party earthing systems, whose ownership will not be transferred to ESBN, to achieve safe step & touch values shall not be considered unless this has been explicitly agreed with EirGrid.

Note: The Customer shall be responsible for all safety issues associated with bonding any customer or third party earthing systems to the substation earth grid. This includes a full assessment of transferred voltages onto other earthing systems.

The Customer shall also agree the approach for assessment with any respective downstream or third party designers. The Customer shall provide clear information to other designers, as required, to ensure the risks associated with bonding earthing systems, are understood.

Where interconnections are considered in the design, the designer shall demonstrate how the earthing system will perform in all potential operational scenarios.

Example scenario list:

1. EirGrid/ESB substation only (i.e. not including any parallel return paths),
2. EirGrid/ESB System (including parallel return paths),
3. EirGrid/ESB System and customer (substation only),
4. EirGrid/ESB System and customer (full connected earthing system).

5.2.3.5 Area of influence

The design shall include an assessment of the hot zone(s) and required mitigations where appropriate. 430, 650 and 2000 V Earth potential rise (EPR) contours shall be

[§§] For this purpose, isolation is taken to mean without consideration of bonding to any earthing which will not be transferred into ESB ownership.

shown. These contours shall also be shown with the appropriate OS map as a background.

Hot zone assessment shall separately consider the substation earthing system in isolation as well as including any other systems intended to be bonded to the substation earthing system.

The hot zone assessment and recommendations shall be site specific, generic recommendations are not acceptable.

The customer shall be responsible for ensuring that adequate surveys are carried out to identify the location and condition of existing earthing systems or nearby conductive parts which may be subjected to hazardous voltages. These surveys shall also consider any known or reasonably expected development plans.

The touch and transfer potentials at any nearby conductive parts (such as street lamps or metal fences) which may be within the influence of the electrode system shall be considered.

5.2.3.6 SOFTWARE

The preferred software for assessment of the proposed earth electrode system is the MALZ module of the SESTECH CDEGS software package.

The use of the MALT module is only acceptable, by formal agreement, for simple systems and situations where a multiple layer soil model is not necessary.

The profile points and density shall be selected appropriate for the area under study. This shall be chosen to ensure all maximum voltages are captured.

Noting computational and software limitations, a larger number of smaller study areas at a sufficient resolution shall be used in preference to increased profile spacing. The spacing between profile points shall be clearly stated and spacings greater than 0.2 m shall be avoided as far as possible.

The outputs in the report shall clearly show the areas considered safe (below tolerable limits) for each of the safety criteria. The colour white shall not be used to represent any voltage thresholds and shall only indicate areas outside the particular assessment.

Outputs showing touch potential shall be provided to cover an area encompassing the entire electrode system and extending a minimum of 1 m beyond any exposed conductive parts which are to be bonded to the electrode system.

The full swing of all conductive gates and doors shall be considered as part of the assessment.

Where conductive parts which could be touched simultaneously are not to be bonded (e.g. isolated fence panels or other metallic structures), hand to hand touch voltages shall be assessed to ensure no tolerable limits are exceeded.

Outputs showing step potential shall be provided to cover an area, sufficient to demonstrate that tolerable limits are not exceeded, extending beyond the electrode system in all directions. The outputs shall also be sufficient to demonstrate safety in adjacent uncontrolled areas where bare foot and bare soil limits apply. Where valuable livestock may be expected within the area of influence of the earth electrode, the requirements of IEC TR 60479-3 shall also be taken into consideration.

The model file (.f05) shall be provided to EirGrid as part of the design submission.

All site based design modifications shall be fed back into the electrical design modelling process for validation.

5.2.3.7 Existing substation extensions

Where works involve the extension of an existing substation the following information may be requested and will be provided by EirGrid subject to availability.

- As built drawing showing existing earth electrode system.
- Any available recent earthing design reports and studies.
- Any available recent earthing system commissioning or maintenance records.

The Customer shall remain responsible for satisfying themselves regarding the accuracy of any such information prior to incorporating it into their design model.

The Customer shall be responsible for ensuring that the earthing system of the proposed extension is in full compliance with this specification. The customer shall also bring to the attention of EirGrid any potential non-compliances or areas for potential improvement associated with the existing earthing system which may be identified during the design of the extension.

In general, the extension shall be built off-line as far as possible. The two earth grids (Works compound and existing substation) shall generally be kept separate during the construction phase. The means of separation and associated distances shall be confirmed by the Customer.

5.3 Design (Construction)

5.3.1 General

The main earth grid shall be buried at least 600 mm below the substation graded ground level.

Where earthing conductors cross cable trenches or ducting it shall be laid a minimum of 300 mm below these trenches. Earth grid conductors fouling foundations shall be re-routed.

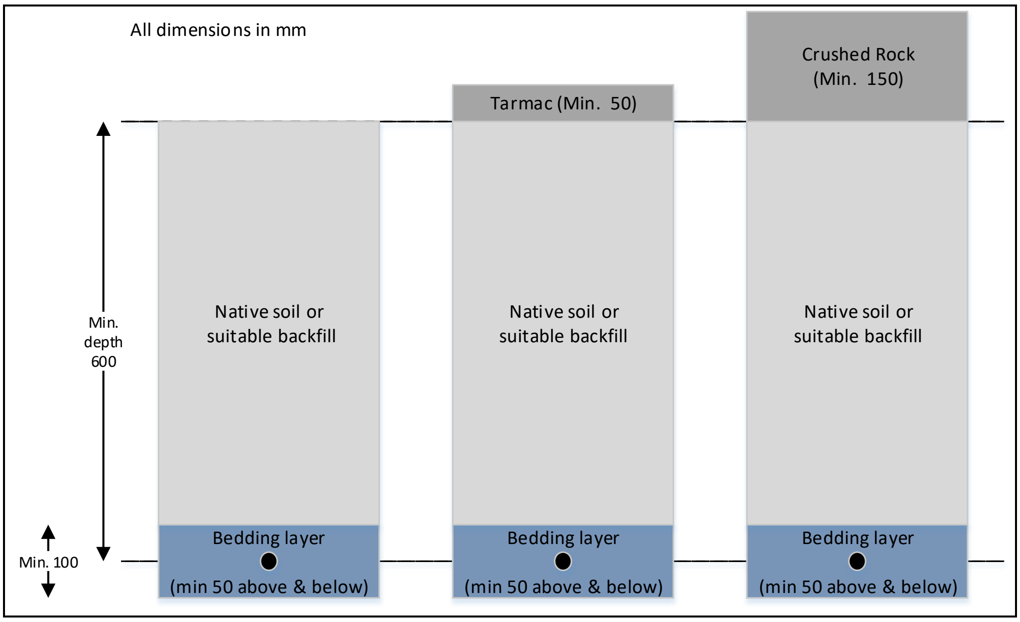

Figure 1 - Electrode depth

Uninsulated copper shall not be installed directly in concrete. Where earth conductor passes through walls, at least 50 mm PVC piping shall be provided for the passage of the conductor. Both ends of the piping shall be sealed using a silicone based sealer after the installation of the conductor.

All backfill shall be compacted to ensure maximum contact to reduce the contact resistance.

Metallic conduits and water pipes shall not be used as part of the earth grid, or as continuity conductor. All pipes supplying water to the substation shall be PVC or Polyethylene.

The earth grid electrode shall be installed in a suitable bedding layer with a minimum layer of 50 mm above and below the conductor. The bedding layer shall be free of stones or other sharp objects which may damage the electrode. The use of contaminated soil or sand or other with a high salt content shall not be permitted.

The number of splices shall be minimised as far as practical.

The use of plastic cable ties to hold/clamp the earths in place is not acceptable as they will not survive long term, metal straps are required.

5.3.1.1 Existing Substation Extensions

As per 5.2.3.7, substation earth grid extensions shall be built offline as far as possible, however the Customer shall be responsible for determining the approach based on their own Risk Assessment.

Where appropriate, the Customer shall outline the process for maintaining the separation between the 2 earth grids and the appropriate point in the programme for bonding them together.

Separation may include physical separation or insulation/shrouding.

Typical separation distances for electrode are included, for guidance only, in Table 2.

Table 2 - Typical Earth grid separation distances

Voltage (kV)	110	220	400
Separation (m)	3	5	5

Construction vehicles and other equipment shall only be connected to the earth grid which they are working above (i.e. nothing inside the existing substation fence shall be connected to the Works compound earth grid, and vice versa). Special care shall be taken at the interface with the existing earthing system which is likely to extend beyond the existing substation palisade fence.

A deliberate and permanent connection between the 2 grids shall be made before any other connections which could effectively bond the 2 systems. Special care shall be taken to ensure the following potential mechanisms for inadvertent bonding of the adjacent systems are considered:

- Metallic contact or close proximity between electrodes & tails.
- Metallic contact or close proximity between other earthed metallic structures (e.g. fences).
- HV/MV/LV power cables or ECC passing between or through the 2 earth grids. This includes bonded sheaths and any phase conductors which are earthed.
- Bonded Control or telecoms cable sheaths passing between or through the 2 earth grids.
- Earthed LV neutral passing between or through the 2 earth grids.

The Customer shall have a clear process to ensure that no temporary isolations are left in place prior to completion of works.

Special consideration shall be given to all works involving or in close proximity to the existing earthing system. Due consideration shall be given to the fact that this is part of the Transmission system and could experience significant rise of potential during system faults.

Where the earth grid (or elements thereof) for the extension compound has already been installed under previous works and is already connected to the existing substation, this shall be considered as part of the Transmission system and treated as live.

Suitable additional precautions shall be considered to ensure safety during the following activities:

- Where separation of adjacent systems cannot be achieved or is not practical,
- During process of making deliberated connections between adjacent systems,
- Works on or in close proximity to the existing earth grid.

These precautions shall be determined by the Customer, but might typically include:

- the use of additional communication & hazard identification,
- Demarcation / control of areas,
- Use of insulated gloves & boots,
- Use of insulated workmats.

5.3.2 GALVANIC ACTION

The Customer shall protect all joints between dissimilar metals against corrosion. In particular where a copper earth conductor is supported on galvanised steelwork, contact between the two shall be prevented, in order to avoid galvanic action. Contact shall be avoided by use of insulated conductors for connecting equipment to the earth grid.

The conductors shall be secured to the steelwork by means of suitable clips or saddles. Plastic clips or saddles are not acceptable as they will not survive long term, metal straps are required.

All connectors in contact with galvanised steel shall be tinned. Where possible, connections shall be made to vertical faces only.

5.3.3 CONDUCTOR & CONNECTORS

All components of the earth electrode system, including earthing "tails" which are required to carry earth fault currents, shall be sized to carry the highest rated short circuit current at the substation.

Table 3 indicates the required sizing for conductors to cater for earth fault currents:

Table 3 - Sizing of Earth Grid conductors and Tails carrying Earth Fault Currents

	Standard Design for 110 kV and 220 kV Stations	400 kV Stations/ Special Case Designs at 110 kV and 220 kV
Tails	2 x Green PVC Sheathed 95mm^2 Copper	To be determined by Customer and agreed by Eirgrid. Conductors shall be Green PVC Sheathed Copper with min size of 95 mm^2
Earth Grid Conductor	Stranded bare 95 mm^2 copper	To be determined by Customer and agreed by Eirgrid. Conductors shall be Stranded Copper with min size of 95 mm^2

Calculation notes

- Where sizing of conductors is required, either for 400 kV stations, or for particular applications at 110 kV and 220 kV, the temperature of conductors shall not exceed 300ºC based on the fault clearance time outlined in section 4.
- A starting temperature of 20ºC can be assumed.
- Where two tails are used to carry fault current (e.g. for double direct or looped connections) each tail shall be sized to carry up to 60% of the total current.
- Earth grid conductors shall be arranged in a meshed or circular arrangement such that both ends of any one earth grid conductor are connected to other parts of the earth grid (i.e. there are no isolated ends). It shall be assumed that up to 60% of the current may flow in either direction away from the point of connection of each tail.

In general, stranded copper wire with a minimum area of 95 mm^2 shall be used for the main earth grid electrode. Alternative proposals may be considered, but only by formal agreement with EirGrid, and these shall not introduce any non-standard proprietary connection methods.

The earth grid shall be formed by establishing permanent connections at all crossing points.

Where connection between conductors is by compression connector, H type crimps shall be used. The use of C type crimps is not permitted.

Suitable reducing sleeves or other type tested proprietary clamping system shall be used where different sized conductors are being connected (i.e. 35 mm^2 tail onto 95 mm^2 electrode).

Where earth rods are used, these shall be copper-clad steel with a minimum diameter of 12.5 mm and a length of 1800 mm.

Connection to earth rods shall be made with proprietary connectors in accordance with the earth rod manufacturer's recommendation.

Where steel structures supporting high voltage equipment form part of the earth conductor, the cross section of steel shall be electrically equivalent to a 2 x 95 mm^2 stranded copper conductor.

Suitable clamps or cast in earth points shall be used to connect the earth electrode to rebar where required.

All reasonable measures shall be taken to reduce the probability of theft (e.g. minimise amounts of visible copper).

5.3.4 Equipment And Structures

5.3.4.1 General

All substation steelwork including control and marshalling kiosks shall be connected to the earth grid by means of at least one stranded copper tail.

Metallic structures (including fences, gates etc.) even if painted or powder coated shall be considered as bare metal unless covered in an approved insulated coating that will not degrade over time.

Connections shall generally be by crimped lugs bolted to suitable earthing points. Other proprietary connection types shall be by agreement with EirGrid.

As per Table 4, and the below individual equipment requirements, earthing connections to primary plant earth points & support structures shall consist of double connection. These connections shall be capable of carrying the maximum prospective short circuit fault level current. As per section 5.3.3, a split factor may be applied.

Earthing conductors connecting equipment, housings and structures to the earth grid shall be as short as practicable and shall be made as spur connections (i.e. their removal shall not break the continuity of the earth grid conductor).

Except where a dedicated connection is specified, double connection paths may be achieved by looping between a number of earthing points in proximity. The extent of looping shall be agreed with EirGrid. Looping shall be limited to a single equipment plinth and shall be such that it has a minimal effect on the tail lengths.

In such looped cases, suitable double lugs shall be used to ensure that no paths are broken when adjacent connections are removed from the equipment. The minimum size of conductor to be used for these tails shall be 95 mm².

All above ground earthing tails shall be neatly arranged and secured noting the following:

- All outdoor tails shall be green PVC insulated in accordance with IEC 60227.
- Where an earthing conductor runs along any steel structure, it shall be insulated with green PVC.
- Tails shall be free of kinks and splices.
- All tails, ducts & containment shall be arranged to minimise trip hazard.
- Plastic cable ties to hold/clamp the earth tails in place are not acceptable as they will not survive long term, metal straps are required.
- Tails shall be kept as short as possible.
- Where tails traverse concrete plinths:
    - They shall be laid flat (i.e. not bundled).
    - The length of the earthing tails run on top of the concrete base should be kept to a minimum.
    - Number of runs shall be kept to a minimum.
    - Tails shall be free of kinks and splices.

The earth tails shall be connected to the steelwork by means of suitable lugs, details of which needs to be submitted to EirGrid for review.

All earthing lugs shall be tinned, otherwise suitable bimetallic lugs shall be used.

Where earthing lugs are bolted to steelwork, the surfaces shall be thoroughly cleaned and free from scale, grease, paint, rust or dirt.

- Where an earthing conductor runs along any steel structure, it shall be insulated with green PVC.
- The earth tails shall be bolted to the steelwork by means of suitable lugs, details of which needs to be submitted to EirGrid for review.
- All earthing lugs shall be tinned; else suitable bimetallic lugs shall be used.
- Where earthing lugs are bolted to steelwork, the surfaces shall be thoroughly cleaned and free from scale, grease, paint, rust or dirt.
- The earth tails shall be welded or crimped to the main earth grid. Details of all crimping clamps and welding processes to be used shall be submitted to EirGrid for review.

Table 4 - Equipment earth connections

<table>
<tr><th>Connection type</th><th>Applies to</th><th>Conductor size (mm^2)</th></tr>
<tr><td>Single</td><td>Plant mechanism box[***]</td><td rowspan="3">Per primary fault level.
Minimum 95</td></tr>
<tr><td>Double
(can be looped)</td><td>All HV equipment bases & support steel,
Earth switch,
Instrument transformer,
Fixed earthing points,</td></tr>
<tr><td>Double
(direct)</td><td>System neutral[†††],
Surge arrester
LPS,
Line tower & portal structure[‡‡‡]</td></tr>
<tr><td>Multiple</td><td>Transformer (tank),
GIS</td><td>Per primary fault level & manufacturers recommendation
Minimum 95</td></tr>
</table>

[***] Not required if mechanism box is integrated into support structure and requirements of section 5.3.4.1 are satisfied.
[†††] This can be transformer neutral or earth connection at neutral earthing device (switch, resistor etc.).
[‡‡‡] Applies to structures within the substation. Special consideration shall be given to structures in close proximity to the substation earth electrode

Connection type	Applies to	Conductor size (mm^2)
Single	Outdoor Kiosk, Metallic fence, Lighting column, Metal door frames & gate posts	Minimum 95
Single	Indoor LV (C&P etc.) panels & cabinets, Crane rails[§§§],	Minimum 25
Single	Metal doors (building), Metal gates.	Minimum 50 (flexible)

Galvanised support structures shall:

- Be connected to the earth grid by a double connection, larger support structures may require more connections points to the earth grid.
- Have structural joints such that a durable electrical connection is assured,
- Not contain any parts which are normally removed during maintenance,
- Not be used to earth High Voltage equipment which requires a separate connection directly to earth.

5.3.4.2 HV Earth Switches

Support steelwork shall be earthed using a double connection.

Each earth blade shall be connected to the earth grid by means of a double connection. This also applies to the earth switch element(s) of combined disconnect & earth switches.

The manufacturer’s terminals shall be used for the earth connection. If a flexible connection is provided by the manufacturer between the earth blade and the base, it is sufficient to connect the base to the earth electrode with a double connection.

Except for neutral earth switches (see section 5.3.4.8), these connections may be looped to provide the double paths required.

5.3.4.3 HV Disconnect

Support steelwork shall be earthed using a double connection. Any fixed earthing points (parking bars) mounted on the steelwork shall also have a double connection.

These connections may be looped to provide the double paths required.

[§§§] Connected in at least 2 places.

5.3.4.4 SURGE ARRESTERS

Support steelwork shall be earthed using a double connection.

Surge arresters shall incorporate a surge counter and a milliammeter in the earth path. Mounting requirements for these are listed in the Surge Arrester Specification in the Project Functional Specification.

The earthing terminal of the arrester shall be connected to the counter (and milliammeter if separate) with a double tail. This shall be suitably supported and insulated from all other earthed metalwork. Suitable insulated bushing terminals shall also be installed as required.

The connection from the counter/ milliammeter to the earth electrode shall use a dedicated double connection separate from the support structure double tails.

The earth connections from the arresters to the earth grid shall be kept as short and straight as possible.

As well as earthing for power frequency flashovers the earth conductor should provide a low impedance path for high frequency surges.

Because of the protective function of lighting arresters it is important that close attention be paid to the earthing requirements. A low impedance path for high frequency discharge currents shall be achieved by ensuring that there is a high density mesh in the vicinity of the arresters, thus providing multiple discharge paths.

In addition, earth conductors from the arrester to the grid shall be as short and straight as possible.

5.3.4.5 INSTRUMENT TRANSFORMERS

Support steelwork shall be earthed using a double connection.

The earth terminal of each instrument transformer shall also be connected to the earth grid by a double connection.

These connections may be looped to provide the double paths required.

Special consideration shall be given to earthing at capacitive Voltage Transformers. A low impedance path for high frequency discharge currents shall be achieved by ensuring that there is a high density mesh in the vicinity of the equipment, thus providing multiple discharge paths.

The secondary wiring of instrument transformers shall be earthed in accordance with EirGrid functional specification XDS-GFS-06-001. This shall generally be done in the protection cabinet or marshalling kiosk, but it should be noted that “slip over” or “ring” type CT housings and support structures shall be connected to the earth electrode with a single connection. If the terminal box is not an integral part of the steel support, or the conditions specified in section 5.3.4.1 above cannot be adhered to, the box shall be earthed separately with a single connection.

5.3.4.6 CIRCUIT BREAKERS

Bases and steel support structures shall be connected to the grid by a double connection.

If the mechanism is not an integral part of the steel support, or the conditions specified in section 5.3.4.1 above cannot be adhered to, the mechanism shall be earthed separately with a single connection.

5.3.4.7 Gas Insulated Switchgear

The earthing of the GIS equipment shall be as per the manufacturer's requirements and recommendations. The Customer shall obtain approval from the manufacturer that the earthing design meets or exceeds these requirements.

The earthing shall also satisfy the below minimum requirements:

A dedicated earth collector bar shall be installed around the GIS in the switchroom. This shall be connected to the collector bar in the cable basement (typically installed near ceiling level) at a number of points.

Surge Voltage Limiters (SVLs) shall be connected between the HV cable termination box on the GIS (This does not apply to separable connections at 110 kV, e.g. Pfisterer Connex) and the HV cable screen to dissipate fast acting transients at this location during switching.

An earth bar shall be provided from the GIS cable sealing end earth bar to the high voltage cable link box. The route of this bar shall be kept as short as possible and sharp bends in the bar shall be avoided.

The Customer shall outline any additional measures recommended to minimise the Transient Enclosure Voltage.

Additional requirements are also outlined in section 5.3.5.3 and EirGrid functional specification XDS-GFS-25-001.

Requirements for external test connections for earth switches and VT neutral points are outlined in EirGrid functional specification XDS-GFS-25-001.

5.3.4.8 System Neutral

The transmission system neutral points shall be earthed or isolated in accordance with the project specific requirements. If there is any ambiguity regarding the treatment of system neutrals, clarification may be requested from the EirGrid Client Engineer.

This can involve direct connection to system neutral point (e.g. transformer bushing) or via other switching devices, impedances or surge arresters.

An insulation co-ordination study shall be performed if required to determine the insulation requirements of any intermediate connections.

The final connection to the earth electrode from the last equipment terminal point shall be a double connection. It is not acceptable to loop this connection.

5.3.4.9 Post insulators

Support steelwork shall be earthed using a double connection. These connections may be looped to provide the double paths required.

5.3.4.10 Control And Marshalling Kiosks (outdoor)

All steel parts of these kiosks, intended to be earthed shall be bonded to the kiosk frame.

Each kiosk shall be provided with internal earthing bars in accordance with EirGrid functional specification XDS-GFS-07-001.

Bases and steel support structures shall be connected to the grid by a single connection, unless these form part of primary equipment support in which case a double connection shall be applied.

5.3.4.11 Line towers and portal structures

Steel towers within the grid area, including the individual towers of portal structures, shall be connected to the substation earth grid by double connection.

If the structure is marginally outside the safety fence (such as an OHL end tower) a double connection shall be run from the substation grid to a potential control ring surrounding the structure.

The structure shall be bonded to the potential control ring by a double connection in the following cases:

- Where there is a shield wire terminated on the mast
- Where the potential control ring is less than 2 m from the earth grid
- Where the mast is less than 2 m from accessible metallic parts which are bonded to the earth grid.

Where overhead shield wires are provided on the transmission lines they may be used to provide the necessary connection from the end tower to the substation portal structure, which shall be bonded to the substation earth electrode. This is subject to agreement with EirGrid and generally only permitted at 220 and 400 kV.

5.3.4.12 Power Transformers and Reactors

System neutral earthing requirements are outlined in section 5.3.4.8, these shall be kept separate from all other earth connections and routed in accordance with the equipment specification. Where necessary they shall be suitably contained in dedicated PVC ducts.

The main tank shall be connected to earth as recommended by the manufacturer. A minimum of two separate connections shall be provided, each consisting of a double connection to the earth electrode. These shall not be looped.

Equipotential bonding of all associated steelwork shall be as per the manufacturers design.

Any separate free standing accessories (such as radiator banks etc.) shall have a separate double connection to the earth electrode.

5.3.4.13 Special cases

Special consideration shall be given to the earthing arrangements around plant with high electromagnetic fields such as filters and series / shunt compensation devices.

In order to avoid induced currents, care shall be taken to ensure that conductive components (especially those forming closed loops) are not installed within the limits recommended by the equipment manufacturer.

Solutions may require the use of insulated rebar in foundations, radial (rather than mesh) earth electrode and isolated fence panels.

5.3.4.14 Moving Parts And Operating Handles

Where moving parts are to be connected to earth (including building doors, compound gates etc.), flexible earthing conductors of minimum 50 mm^2 shall be used.

All equipment manufacturers recommended earthing requirements shall be implemented.

In order to provide mechanical protection and also allow visual inspection of the condition of the conductor, flexible connections shall have clear PVC insulation. Alternative proposals (e.g. due to security or other concerns) shall be subject to formal agreement with EirGrid.

5.3.4.15 Maintenance Earths

This section describes requirements for AIS substations, maintenance earthing facilities shall be incorporated into GIS equipment in accordance with EirGrid functional specification XDS-GFS-25 and the project specific requirements.

It is a requirement that all maintenance work must be carried out between earthed points on all circuits by which the plant could be made live (i.e. there must always be an earth connection between the equipment being worked on and all potential sources).

Earthing shall be achieved through the use of temporary earth leads. Temporary earth connections are not required at points where fixed earth switches, capable of being locked in the closed position, are available.

Suitable earthing stirrups shall be provided on the HV conductor at appropriate locations in the substation.

It shall be possible to earth each phase independently of the others and all three phases together.

Earthing points shall be provided for each busbar section.

Fixed earth points (also known as parking bars) for attaching temporary earth leads during maintenance operations shall be provided as required by the primary plant layout.

These shall be connected to the earth electrode using a double connection. These connections shall be separate to any support structure earth point, but may be looped to provide the double paths required.

In determining the location of the fixed earthing points the designer shall consider:

- Location of earthing stirrups.
- Length and routing of earthing leads.

- Accessibility to plant when leads are applied.

Temporary earth leads shall be suitably rated for the maximum expected short circuits.

The customer shall propose the quantity of leads to be provided. This shall be based on the substation configuration and shall be subject to agreement by EirGrid.

These leads shall each be 8 m in length and comprise of PVC insulated 95 mm² flexible copper with a clamp at each end.

The leads, fixing points, stirrups and arrangement shall be subject to review by EirGrid before installation takes place.

5.3.4.16 CABLES

HV cable sealing end support steelwork shall be earthed using a double connection. These connections may be looped to provide the double paths required.

The cable sheath link box shall be separately earthed using a dedicated double connection. The link box earthing shall generally be carried out and verified by the cable jointer however alternative arrangements may be agreed on a project basis.

The arrangement and connection of screens inside the link box shall be co-ordinated with the cable design.

Specific arrangements are required at GIS cable sealing ends or where ring CTs or external surge voltage limiters are to be installed. Section 5.3.4.7 and EirGrid functional specification XDS-GFS-25-001 also refer.

Metallic sheaths or armour of control and protection (multicore) cables shall generally be earthed at both ends.

Certain data cables may also be earthed at one end only, subject to the following;

- Requirement being explicitly brought to the attention of EirGrid,
- Suitable insulating glands used at the unearthed end,
- Clearly indicated on design and as-built records.

The sheaths of data cables or multicore cables terminating in GIS switch rooms shall follow the relevant EMC requirements. Suitable (EMC type) glands shall be used.

Sheath and armour of HV power cables shall be earthed at the switchgear end only.

Multicore cables shall be routed to run parallel to the earth electrode and avoid being parallel to nearby primary conductors as far as possible.

Refer to section 6.2 for requirements for cables which pass outside the earth electrode.

5.3.5 BUILDINGS

An earth electrode shall be provided around all buildings within the substation earth electrode. This shall be installed m away from any touchable metalwork surrounding the building, including the external doors, hand rails etc.

All building steelwork, cladding and miscellaneous support steelwork shall be bonded to the earth electrode. Doors shall be bonded using a flexible connection.

This includes all outbuildings, relay rooms, stores and buildings housing ancillary items such as compressors, pumps, generators etc.

Particular requirements are outlined below, all other metalwork shall be earthed in accordance with the requirements of ET101.

5.3.5.1 Control room

A main earthing conductor ring (minimum 95 mm² bare stranded copper) shall be installed on the concrete floor in the control / relay room.

This conductor shall be connected to the substation earth electrode at two separate points (at opposite sides of the control room where possible), through the walls as described in this specification.

All the metallic stands of the raised flooring system shall be connected to this main earth.

Conductors (minimum 95 mm² stranded copper) shall be installed under each row of cabinets to serve as a collector for all panel earth connections.

The collectors shall be connected to each other or the main earthing conductor ring at the end of each row (both ends).

All relay cabinets inside the control room shall be earthed with a single connection to the collector. Conductor to be used for this shall be a minimum of 25 mm². Further internal cabinet earthing arrangements are outlined in EirGrid functional specification XDS-GFS-07-001 and EirGrid drawing XDS-DGA-00-002.

A separate telecoms earthing bar shall be provided[****]. This shall be suitable for connection of multiple 95 mm² and 35 mm² Copper cables (typically 50 x 6 x 600 mm copper strip), wall mounted on suitable bushings, located in close proximity to the telecoms cabinets (generally near the DCC RTU) and clearly labelled Telecoms.

Telecoms cabinets shall be connected to this earth bar using minimum 35 mm².

The earth bar shall be connected to the main earthing conductor ring by a double connection (minimum 95 mm² stranded copper). These shall be PVC insulated and clearly labelled to distinguish them from all other connections to the bar.

These requirements also apply to any dispersed relay rooms or cabins. It should be noted that where such cabins or rooms are of metallic construction, the frames will also need to be bonded to the earth grid using a double connection.

5.3.5.2 Battery room

No exposed earthing connections are to be made in the battery room.

Metal battery stands inside the battery room shall not be connected to the substation earth grid and shall remain isolated regardless of the provision or otherwise of an earth connection point.

[****] This is often commonly referred to as the main earthing bar or M.E.B.

Other Class I electrical equipment in the battery room shall be earthed using the relevant protective earth conductor that is part of the associated supply cable.

Any other metalwork which is deemed to require to be earthed per regulations shall also consider clearance to batteries to avoid the potential for simultaneous contact. Such instances shall be brought to the attention of EirGrid for consideration.

5.3.5.3 GIS BUILDING

In addition to the requirements listed elsewhere, the following section outlines requirements specific to GIS buildings.

The GIS switch room and HV cable room/basement earthing shall be adequately rated to cater for the full short circuit current rating of the primary equipment.

The GIS switch room and equipment earthing must be installed as per the manufacturers' requirements.

Re-bar in the GIS switchroom and HV cable room floor/wall shall be earthed.

A High Frequency (HF) mesh shall be installed in the GIS switchroom[††††]. HF mesh grid dimensions and properties shall be as per specific switchgear manufacturers' requirements. HF meshing shall be additional to rebar required for structural purposes, unless specifically agreed by the GIS manufacturer.

Where HF mesh is installed it shall be interconnected by suitable clamps to ensure electrical continuity.

Where no manufacturer requirements are outlined, guidance may be sought from the EirGrid Client Engineer.

The HV cable room / cable basement shall contain a main earthing bar conductor along the length of the room. This shall be minimum 50 x 6 mm Copper strip, wall mounted on suitable bushings and located to minimise the length of connections to the bar (i.e. typically near ceiling level).

This earthing bar shall be connected to the substation earth electrode at a minimum of two separate points (at opposite sides of the cable room where possible), through the walls as described in this specification. These connections (minimum 95 mm^2 stranded copper) shall be PVC insulated and clearly labelled to distinguish them from all other connections to the earthing bar.

GIS earth system requirements and the proposed designs shall be agreed with the GIS manufacturer prior to installation of the earth grid.

Additional requirements are also outlined in section 5.3.4.7 and EirGrid functional specification XDS-GFS-25-001

5.3.6 TELECOMS

As outlined in section 5.3.5.1, a telecoms main earth bar shall be installed in the control room.

[††††] Required in all new build projects. The switchgear manufacturer's requirements shall determine if a High Frequency (HF) mesh is required in the GIS room in brownfield extensions or retrofit projects.

Where required, ESBN Telecoms polling radio aerial shall be connected to the earth electrode.

Earth risers shall also be provided on all 4 sides of control buildings for telecoms use. These shall each be:

- Single green PVC insulated 95 mm^2 stranded copper conductor.
- Bonded to the substation earth electrode.
- Routed (via suitable ducts where necessary) to avoid becoming a tripping hazard on walkways
- Clipped to the wall.
- Terminated with a compression lug at a height of 1000 mm above graded level.

Any alternative telecoms arrangements may also require additional connection to the substation earth grid and these shall be detailed separately on a case by case basis.

5.3.7 Fences And Gates

A distinction shall be made between the substation compound fence and the property boundary fence. Further details can be found in the Civil functional specification and project specific documentation (Contestable Works Package of Committed Project Parameters).

5.3.7.1 Substation Compound Fence

This is the security fence which surrounds the substation compound(s), i.e. the part of the substation containing high voltage equipment, and is generally metallic palisade type.

Generally where a metallic fence is used, the substation earth electrode shall extend for at least 1000 mm beyond the substation fence on all sides. The fence shall be connected to the substation earth electrode at every corner and regular intervals (typically every 10 m) by a single (minimum 95 mm^2 copper) tail.

Unless specifically designed to be isolated, electrical continuity between all parts of the substation fence (e.g. panels and uprights) shall be achieved to ensure the entire fence and its parts are safely bonded to ground potential.

In certain circumstances the fence, or sections thereof, may need to be isolated from the substation earth electrode. In such cases independent earthing using earth rods, and if required dedicated electrode, shall be installed. Such cases shall require careful evaluation to ensure separation and provide mitigation against inadvertent cross bonding and shall only be installed by explicit agreement with EirGrid.

Examples of where this may be required are where site conditions prevent the installation of the perimeter electrode or where isolation is required to avoid circulating current due to high electromagnetic fields

If the compound fence is metallic and the earth grid extends beyond the compound fence, the frame of the gates shall be earthed by a 95 mm^2 copper conductor connection with a minimum of 50 mm^2 PVC coated flexible copper connection between the frame and the gate.

An additional run of 95 mm^2 copper conductor shall be installed in the ground spanning the opening of the gate. Although the gates shall be designed to open inwards only, this shall be confirmed and the full swing of all conductive gates and doors shall be considered as part of the touch voltage assessment.

Where a non-metallic fence or wall is installed, and subject to the tolerable limits (step & touch) not being exceeded, the earth electrode may remain fully inside the fence / wall.

Where a substation compound fence is shared with a third party compound or other cases where third party fence or metallic infrastructure are in close proximity, provision shall be made to ensure that no unintentional cross bonding between the earth systems occurs.

5.3.7.2 Property Fence

This is the fence which demarcates the boundary of the ESB property. The property fence shall generally be constructed from a non-conducting material, and shall be physically separate from the compound fence.

If the property fence is required to be metallic then:

- The design must demonstrate acceptable touch and step potentials on both sides of the fence, taking into account the location of the fence in relation to both the inner compound fence and earthing system.
- The design must consider and prevent the risk of transfer potentials to the outside world, e.g. via third party fencing etc.
- The requirements of section 5.3.7.1 apply.

5.3.8 Rebar

As outlined in section 5.3.5.3, rebar in GIS switch room floor (and wall if appropriate) shall be bonded to the substation earth system.

There is no other general requirement to earth rebar on plinths, provided that all interconnected pieces are fully encased in concrete.

Otherwise, the requirement to connect sections of rebar shall be determined by the safety assessment as outlined in section 5.2.3.

Special consideration shall be given to the use of rebar in areas of high electromagnetic fields as measures may be required to avoid closed loops being formed.

Where rebar is to be bonded to the substation earth grid, the rebar shall be welded or clamped at suitable crossover points (maximum 3 m intervals) to ensure continuous conductive path.

Connections to the rebar shall be made using suitable clamps. Insulated conductor shall be used and the finished joint wrapped in denso tape (or an agreed equivalent).

Under no circumstances shall uninsulated copper electrode be installed directly in concrete.

For precast concrete solutions, the use of a suitable earth connection point shall be acceptable subject to review of the products design and manufacturing process.

5.3.9 JOINTING

The resistance of any unit length of conductor with a joint or splice shall not be more than the resistance of an equivalent length of conductor without any joint. All joints shall be thoroughly cleaned before jointing, free from grease and oxidisation. Joints shall always be made by laying the conductors to be joined parallel next to each other.

A single crimp may be used at cross connections. All in line (or splice) connections shall be achieved by overlapping the 2 conductors and using 2 crimps spaced at least 300 mm apart.

The use of bolted connections is not permitted for buried joints.

Further details of conductor and connector requirements are outlined in section 5.3.3.

All underground joints shall be welded with suitable alloy rod in accordance with EN 1011 or made by an acceptable compression system.

Details of the crimping connectors to be used shall be provided to EirGrid for review prior to installation. All proposed welding processes shall be subject to agreement with EirGrid.

5.3.10 MISCELLANEOUS ITEMS

All steelwork which could become live during HV earth fault conditions shall be connected to the earth grid by two 95 mm^2 connections.

Cable trays, ladders, metallic hand rails metallic conduits and pipes shall be bonded to ensure electrical continuity, and shall be bonded to the earth grid at regular intervals (minimum every 20 m or at least 2 locations for shorter runs.

The minimum size of the conductor connecting to earth shall be a 16 mm^2 copper connection. If small cable trunking has a type tested proprietary earth lead attached, it is acceptable to use that instead.

Bare earthing conductor shall not be run along metallic structures such as cable tray/ ladders, supports etc.

All miscellaneous items such as diesel generators, compressors, etc. shall be connected to the earth grid by a single connection, and buildings housing such equipment shall be encircled by a potential control ring.

All building steelwork and building support steel shall be connected to the earth grid by at least one connection. This includes any metallic stairways and access platforms.

Additional bonding shall be applied where removal of intermediate panels or sections could lead to a section becoming unearthed.

All crane rails within buildings shall be connected to the earthing system in at least two places.

6 INTERCONNECTIONS

All interconnections to remote services shall be carefully considered to ensure that hazardous potentials which could be transferred out of the substation are suitably managed.

6.1 SHIELDWIRE

The requirement for shieldwire on overhead line circuits is outlined on a case by case basis as part of the project OHL design.

Further details can be found in EirGrid Policy statement on AC Overhead lines (Pol_St_5) and Functional Specification (LDS-EFS-00-001).

Where shieldwire is present on a line, or section of line terminating at a substation, this shall be bonded to the substation earth grid. This shall be achieved via the end tower structure, and if necessary the double connection from the tower to the substation earth grid, or by extension of the shieldwire into the substation line gantry as outlined in section 5.3.4.11.

6.2 POWER AND PILOT CABLES

Depending on the cable design, the screens of power cables may also provide a connection between the earthing systems of the respective transmission substations.

The Customer shall ensure that the earthing design at the substation is co-ordinated with the cable design.

Although no longer common practice at new installations, pilot or signalling cables may also be present at legacy substations. Generally the sheaths and screens of these cables are bonded to the earth grids at both ends.

Note: Refer to section 5.3.4.16 for requirements for power and control cables which are within the earth electrode system.

6.3 EARTH CONTINUITY CONDUCTOR

Where earth continuity conductor (ECC) is installed along with a transmission cable circuit this shall be insulated to avoid dangerous step or touch potentials along the route.

The ECC shall be bonded to the substation earth electrode at the associated cable sealing end.

6.4 TELEPHONE LINES

If the EPR exceeds the values in ITU-T directives Volume VI, the substation telecommunications shall require special isolating equipment. This shall be located outside the relevant hot zone contour.

In addition a special insulated cable or fibre optic connection will be required from the isolation point to the substation

For information:

- 2 kV is the typical insulation level for third party telecommunications cables destined towards a transmission substation.

- 15 kV is the typical insulation level for telecommunications cables between the isolation point and substation.

6.5 WATER SUPPLIES

Water supply pipes to the substation shall be polythene or PVC.

6.6 ANCILLARY BUILDINGS

Buildings or equipment located outside the earth electrode area, but within the property and receiving an electricity supply from the substation shall be encircled by a potential control ring, which shall be connected to the main substation grid. All local metal work shall be bonded to this control ring.

As per section 5.2, a safety assessment against tolerable limits in these areas is required.

6.7 AUXILIARY SUPPLY

If required, the preferred location for an auxiliary standby transformer shall be within the earth grid area. In this case, the tank and the LV cable end box shall be connected to the earth grid by a single 95 mm^2 copper earth conductor connection.

If the transformer is located outside the earth grid area, a single connection shall be run from the substation perimeter earth loop to the auxiliary standby transformer in the same trench as the LV power cable. It shall terminate in a potential control ring laid around the end-mast or pad mounted transformer. The transformer tank and the LV cable end box shall be bonded to the potential control ring by a single copper earth conductor connection of minimum 95 mm^2.

If there is a large distance between the auxiliary transformer and the substation earth grid, a larger size earth conductor may be required depending on whether or not it satisfies the minimum earth fault loop impedance requirement.

As per section 5.2, a safety assessment against tolerable limits in these areas is required.

Earthing of the low voltage system(s) shall be carried out in accordance with ET101.

Main and supplementary equipotential bonding is created via the substation earth grid.

The LV a.c. system shall typically be TN-C-S/TN-S.

The use of other earthing systems shall only be by specific agreement with EirGrid.

The midpoint of any 110 V a.c. system shall be earthed.

EirGrid functional specification XDG-GFS-09-001 outlines the earthing requirements for the various d.c. systems.

6.8 CUSTOMER AND THIRD PARTY SYSTEMS

Where industrial customers are fed from the substation the earthing arrangement shall be the subject of a special investigation and shall be agreed with EirGrid before any work commences.

As far as possible, Customer earthing systems shall be kept isolated from the transmission substation earthing system.

The Customer shall detail how inadvertent bonding of earthing systems is to be prevented.

As outlined in section 5.2 there are cases when the customers high voltage substation earthing may need to be connected to the transmission substation earthing system. Such cases shall only be by formal agreement with EirGrid and shall be subject to very careful consideration in the design stage.

As a minimum, the following shall be considered:

- The full extent of the earthing system to be connected shall be established and assessed. The customer shall outline how any further inadvertent bonding of earthing systems is to be prevented.
- Whether the connection would form part of a global earthing system.
- Whether the connection would permit transmission substation grid voltages to be exported (e.g. on cable sheaths or other metallic structures) to remote locations.
- The effect on nearby MV or LV network neutral points or earthing systems.
- Step, touch & transfer potentials.
- The effect on the hot zone and existing infrastructure (telephone lines, gas/water pipes, railways, fences etc.)
- Ownership of the earthing system

6.8.1 CUSTOMER ANCILLARY BUILDINGS

Ancillary buildings owned by the customer remain the responsibility of the Customer, but the following should be considered:

- If the buildings are within the influence ("hot") zone of the earth grid;
    - Whether the grid should be extended to the buildings and all metallic structures and facilities in the buildings bonded to it.
    - Whether a potential control ring should be placed around the building at a distance of 1m.
    - Care should be taken to prevent the export of transferred potentials from the buildings to the public domain on telephone or other services.

- If the buildings are outside the influence zone of the earth grid they may be isolated from the grid and separately earthed, taking care to prevent the transfer of potentials from the grid to the buildings on interconnecting cables and services. In this case it is recommended that all metalwork in the buildings be bonded to a local earth at the building. However, if the ancillary building includes a control room or if there are substantial interconnecting services it may not be possible or practical to isolate the two earth electrodes from one another.

As per section 5.2, a safety assessment against tolerable limits in these areas is required.

6.8.2 Earth Potential Rise and Transferred Potentials

The Customer shall examine all existing or expected third party buildings and services located near the substation.

Linear metallic infrastructure (Fences, pipes, telephone lines, railways etc.) can be a significant source of transferred voltage.

The Customer shall not engage directly with public bodies or third party service providers on this issue, all communication shall be via EirGrid and in turn ESB.

Possible hazardous situations and potential mitigation measures shall be clearly identified in the report and brought to the attention of EirGrid.

7 Lightning Protection

A minimum lightning protection system to achieve LPL level IV shall be installed.

A risk assessment shall be conducted based on the methods contained in IEC 62305 Protection Against Lightning, Part 2, Risk management. This risk assessment shall determine whether a more onerous lightning protection system (LPS) is required at the substation.

The design of the LPS shall based on the methods contained in IEC 62305 Protection against lightning, Part 3, Physical damage to structures and life hazard (i.e. the protection angle and rolling sphere methods). Use of the surrounding topography to assist in lightning protection is permitted.

The substation compound equipment and control room shall be protected against damage from lightning strikes. A design, including lighting shielding profile drawings shall be submitted to EirGrid for review with the substation layout drawings.

Down conductors shall be clamped at intervals along the lightning masts, and connected to the main substation earth .

8 Quality Assurance

All materials and workmanship shall be of suitable type and quality to ensure that the earth system will operate satisfactorily in accordance with the specification.

Registration to ISO 9001 is desired.

Connectors shall be class A in accordance with IEC 61238-1.

The Customer shall ensure that all conductors shall be kept free of kinks.

Stranded conductors, particularly uninsulated conductors, are susceptible to unravelling (including “opening” or “birdcaging” effects). The Customer shall ensure that suitable control measures are in place to confirm the integrity of all buried conductors prior to backfilling.

All on site welded connections shall be carried out in accordance with the manufacturer’s recommendation. Only suitably trained staff shall be permitted to carry out on-site welding.

Prior to installation of earthing system, sample connections shall be made to demonstrate the process and equipment used. Samples shall be representative of all connections used in the installation (e.g. splice, cross, lug, double lug) and cover all buried conductor types & sizes.

The same personnel, components and tools used to carry out the installation shall be involved in the sample exercise.

EirGrid shall be provided with an opportunity to witness the preparation of the samples.

The samples shall be sent to an independent facility for mechanical (pull) testing according to section 7 of IEC 61238-1.

Detailed photographic evidence of all below ground earthing installation shall be captured and made available to EirGrid. All photographs shall include clear identification which shall be referenced on a suitable drawing and shall include:

- A photograph of each connection.
- Photographs demonstrating depth of electrode and bedding layer.
- Photographs confirming the condition of the electrode prior to covering.

The Customer shall outline their quality procedure to ensure the correct selection and use of crimping dies and tools.

9 Guarantee

The earth grid shall be guaranteed against all defects arising from faults in material and workmanship, for a period of 5 years from the date of installation.

10 Notification Of Changes

Any changes in design, material, supplier or sub-contractor shall be notified to EirGrid in writing prior to implementation. Such changes must be agreed with EirGrid in writing prior to their introduction.

11 Tests

All components, including conductors and connectors, shall be type and routine tested in accordance with the relevant IEC standards. The relevant test reports shall be provided by the Supplier

Sample pull tests shall be performed on earthing connections as outlined in section 8.

The entire earthing system shall be tested upon completion of installation to verify compliance with the specification and design.

The following aspects shall be measured and recorded (this shall include measurements of the EirGrid Substation earthing system in isolation):

- Earth grid resistance.
- Step voltage.
- Touch voltage.
- Hazardous voltages on other infrastructure.
- Voltage gradient (in several directions away from the electrode).

Measurement of current (magnitude and phase angle) flowing in known return paths (shieldwire, ECC, cable screens, and if possible any pipes etc.) shall be taken to provide a fuller picture of the entire earthing system and validate any current splits calculation.

Low current injection test is the preferred method for measurement. Use of the simple “fall of potential” or “slope” method shall only be used for small isolated earthing systems and subject to agreement by EirGrid.

Testing shall be arranged to allow direct comparison between tested and modelled values. Full details of the test method shall be submitted to EirGrid for review prior to the commencement of the tests. EirGrid shall be given the opportunity to be present during the execution of these tests.

The results of the testing shall be fed back to the designer to confirm that no safe limits are exceeded when extrapolated to designed earth fault short circuit level level and under any alternative interconnection scenarios.

The earthing system shall be modified to attain values within the design and specified limits, if the test results indicate that any of the specified limits may be exceeded. Such modifications shall be subject to the full design, modelling and review process.

Mitigation measures should be proposed for any transferred voltage hazards identified during the tests as a result of the extent of the measured voltage gradients.

All primary connections (e.g. Earth switch, Surge Arrester and VT or power transformer Neutral) to the substation earth grid shall be verified by micro ohmmeter “ductor” testing. A combination of continuity testing and visual inspection shall be considered adequate to verify all other connections.

EirGrid shall be given an opportunity to witness the testing.

Equipotential bonding shall be proven by simple electrical continuity test.

A test sheet and drawing listing the test results shall be submitted to EirGrid for review.

Low voltage earthing and loop impedance measurement shall be performed in accordance with I.S. 10101.

EirGrid reserve the right to request further testing to be carried out by an independent testing authority.

12 Documentation To Be Submitted

12.1 Before Installation

1. Earth resistivity test results.
2. Earthing Report and electrode design (including model file).
3. Lightning Protection Risk assessment.
4. LPS overall design.
5. Detailed (Construction) design.
6. Details and descriptions of materials to be used e.g. conductors, rods, finials, clamps, connectors etc.
7. Details of jointing methods.
8. Proposed Test methods for verification of design values.

12.2 Before Handover And After Installation

1. Photographic and other installation & testing QA records.
2. Test results of electrode resistance, GPR and step / touch / transfer voltages.
3. Results of sample pull tests.
4. Test results of Ductor tests and joints.
5. Relevant information for inclusion in the safety file.

12.3 Substation Handover

1. Full set of as-built drawings.
2. As-built version of earthing model file.
3. Final test results.
4. Details of residual hazards and all other information required in the Safety file.

13 Appendix A – Interim Optional application of EN 50522

<table>
<tr><td colspan="3">Functional Specification Earthing and Lightning Protection</td></tr>
<tr><td>Applicable to: Earthing Design</td><td>Owner: EAM</td><td>Doc Num XDS-GFS-12A-001-R0</td></tr>
<tr><td>Prepared by</td><td>Checked by</td><td>Approved by</td></tr>
<tr><td>Neil Cowap</td><td>Daniele Giustini</td><td>Aidan Geoghegan</td></tr>
</table>

Summary

The purpose of this Appendix is twofold

1. To allow the use of the EN 50522 standard for the calculation of step and touch voltages.
2. To clarify how the EPR (Earth Potential Rise) is calculated

The intention is to get feedback from industry to allow a future revision of the Earthing standard.

It is not a requirement for this Appendix to be applied, however where it is applied it shall be applied in full for example where EN 50522 voltage limits are applied the mesh size requirements shall also be adhered to.

Any Clarifications and/or queries on how to implement this document can be directed to the EAM (Engineering and Asset management Team) in EirGrid.

<table>
<tr><td>IEEE 80 2013 Vs EN 50522</td><td>The existing EIRGRID standard specifies touch and step voltage limits from IEEE 80 2013, using a 50 kg body weight value.

The use of EN 50522 with the following parameters will now be accepted:-
1. A body impedance from IEC/TS 60479-1:2005, Table 1 (exceeded by 50 % of the population)
2. A permissible body current corresponding to the C2 curve of IEC/TS 60479-1:2005, Figure 20 and Table 11 (probability of ventricular fibrillation is less than 5 %)
3. For step voltages use the Heart current factor from IEC/TS 60479-1:2005, Table 12 (Left foot to right foot)
4. The 0.5 second fault duration still applies

This results in the calculated tolerable step and touch voltages in Table 5. These values can be used directly in earth grid designs, without the calculation of project specific touch and step voltage limits.</td></tr>
</table>

Item 2 Calculated Step and Touch Values

Table 5 Typical Values of Step and Touch Voltages to be used

No.	Scenario	Touch Voltage Safety Limit (Volts)	Step Voltage Safety Limit (Volts)
1	**Safety footwear (4,000 ohm per foot)** **Bare soil (50 ohm.m)** Assumed to be outside the substation compound fence, but inside a secure area or within the ESB property boundary	567	42,794
2	**Safety footwear (4,000 ohm per foot)** **150 mm of 2,500 ohm.m crushed rock** Assumed to be inside the substation compound fence, or outside the fence if inside a secure area or within the ESB property boundary	1,060	98,897
3	**Safety footwear (4,000 ohm per foot)** **50 mm of 10,000 ohm.m tarmac** Assumed to be inside the substation compound fence, or outside the fence if inside a secure area or within the ESB property boundary	1,805	N/A – limit will not foreseeably be exceeded
4	**Typical footwear (2,000 ohm per foot)** **Bare soil (50 ohm.m)** Assumed to be outside the substation compound fence but not within a secure area	401	23,958
5	**Typical footwear (2,000 ohm per foot)** **150 mm of 2,500 ohm.m crushed rock** Assumed to be outside the substation compound fence but not within a secure area	894	80,060
6	**Typical footwear (2,000 ohm per foot)** **50 mm of 10,000 ohm.m tarmac** Assumed to be outside the substation compound fence but not within a secure area	1,640	N/A – limit will not foreseeably be exceeded
7	**No footwear** **Bare soil (50 ohm.m)** Only required for identified “higher risk” scenarios, e.g. swimming pools, playgrounds, playing fields…	236	5,121

Notes

1. The above values can be used in lieu of a calculation, but a bespoke calculation will be considered by EirGrid
2. The fault duration is 500 ms for all calculations

Item 3 **Standard Grid sizes**	When the EN 50522 standard is used for the earthing design, then the earth grid shall have maximum mesh size as follows: 1. An 8 m x 8 m mesh size in a 110 kV AIS substation 2. A 12 m x 12 m mesh size in a 220 kV AIS substation 3. A 6 m x 6 m mesh size in a GIS substation 4. A conductor 1 m inside and 1 m outside the perimeter palisade fence Exceptions:- A. For large substations an optimised grid can be designed. a. The maximum mesh size applies only within 20 metres of the palisade fence b. Larger mesh sizes can be used for areas of the grid which are more than 20 m from the palisade fence, provided that calculated step and touch voltages are below the calculated tolerable values. B. For substation extensions it is not a requirement to upgrade the existing grid to meet this mesh size standard, although EirGrid reserve the right to review this on a case by case basis for example if there was a generation connection that significantly increased the short circuit level in the station.
Item 4 **Scenarios**	The following calculations shall be included in each report: **Step and Touch Voltages** Touch and step voltages shall be calculated for the following scenarios: 1. An earth fault current equal to the nominal system short circuit current, applied to the EirGrid compound in isolation. See note 1. 2. An earth fault current equal to the nominal system short circuit current, applied to the EirGrid compound and Customer compound combined. See note 1. **Earth Potential Rise (EPR)** For the calculation of the EPR the earth fault current to be used shall be 120% of the single phase to earth value in the latest edition of the transmission forecast statement. This shall be applied to the entire interconnected earth grid i.e. TAO assets, the customer Low voltage substation and the wider customer compound and assets where bonded. The 650 V and 2,000 V contours shall be included on an OSI type map with sensitive receptors identified for example rail, schools, swimming pools, 3rd party buildings etc See Item 6 for a sample calculation of the fault current to be used. **Notes** 1. For 110 kV stations the nominal system short circuit current is 25 kA, however 31.5 kA is applicable to some stations. EirGrid will advise developers where 31.5kA applies. For 220 kV stations the nominal system short circuit current is 40 kA. For 400 kV stations the nominal system short circuit current is 50 kA. 2. If the proposed connection is for example a thermal generation plant that will significantly contribute to the fault level at the station, then this approximation is not valid and EirGrid will need to advise the short circuit value to use. 3. https://www.eirgridgroup.com/library/

Item 5

Clarifications

1. Conductor Sizing

The expected below ground conductor size is unchanged at stranded 95 mm^2 copper conductor.

The standard earth tails remain unchanged at double stranded 95 mm^2 copper conductor.

2. Fault Current Splits

There is no change to policy Pol_St_17_v1.1. Fault current split factors are allowed when there is shield wire and/or cable sheaths in the return path. This policy document will be updated to consider the use of EN 50522.

3. Target Impedance of 1 Ω

For the substation in isolation the target impedance is still 1 Ohm or less. A low impedance will reduce the EPR and is therefore preferable.

4. Extent of earthing system for EPR calculation

As per item 4 (Scenarios) above the entire interconnected earthing system and fault current split factors can be used for the calculation of the EPR and associated hot zones.

5. Timing of Earthing Design

It is expected that an initial earthing design, including soil resistivity tests will be submitted along with the planning designs for EirGrid review. This is to allow the consideration of hot zones for substation location.

Item 6

Worked examples of for EPR Current

If the proposed substation is not in the transmission forecast statement adopt the sample calculation below to provide an estimate.

1. Tail Connection to Gorman 110 kV busbar

Table E-4 Ireland Short Circuit Currents for Maximum and Minimum Demand in 2026

	Summer						Winter					
	Three phase			Single Phase			Three phase			Single Phase		
Station	X/R Ratio	Ik'' [kA]	Ik' [kA]	X/R Ratio	Ik'' [kA]	Ik' [kA]	X/R Ratio	Ik'' [kA]	Ik' [kA]	X/R Ratio	Ik'' [kA]	Ik' [kA]
Golagh 110 kV	3.51	4.66	4.48	4.11	4.67	4.61	3.99	9.51	7.97	4.90	6.98	6.66
Gorman 110 kV	6.80	13.26	12.19	7.72	14.67	14.22	6.38	18.15	16.50	7.53	18.41	17.81
Gorman 220 kV	9.37	10.65	9.87	10.10	8.94	8.74	8.69	13.31	12.67	9.70	10.23	10.10

a. From the latest edition of the transmission forecast statement, the maximum single-phase fault level on the Gorman 110 kV busbar is 18.41 kA

b. For the initial EPR calculation the short circuit value is 22.09 kA (18.41*1.20)

2. Breaking into the Gorman – Platin 110 kV line

Table E-4 Ireland Short Circuit Currents for Maximum and Minimum Demand in 2026

	Summer						Winter					
	Three phase			Single Phase			Three phase			Single Phase		
Station	X/R Ratio	Ik'' [kA]	Ik' [kA]	X/R Ratio	Ik'' [kA]	Ik' [kA]	X/R Ratio	Ik'' [kA]	Ik' [kA]	X/R Ratio	Ik'' [kA]	Ik' [kA]
Pelletstown 110 kV	14.13	11.22	10.52	7.76	11.88	11.60	13.47	12.99	11.84	7.49	13.39	12.95
Platin 110 kV	5.12	11.48	10.61	5.68	8.79	8.61	4.48	14.43	13.44	5.35	9.94	9.78
Pollahoney 110 kV	10.05	7.37	7.11	10.42	8.42	8.31	9.66	9.67	9.16	10.29	10.35	10.15
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

a. From the latest edition of the transmission forecast statement, the maximum single-phase fault level at Platin is 9.94 kA while at Gorman, as per example 1, it is 18.41 kA. In this case take the higher of the two values

b. For the initial EPR calculation the short circuit value is 22.09 kA (18.41*1.20)