Electricity Distribution

nationalgrid

Company Directive

STANDARD TECHNIQUE: TP21DD/2

Design of Earthing Systems
Part D
Ground Mounted Distribution Substations

Summary

This Standard Technique defines the earthing design requirements for ground mounted distribution substations which are to be owned or adopted by National Grid Electricity Distribution.

Author: Graham Brewster / Mark Kneebone

Implementation Date: February 2025

Approved By:

Craig Sharp
Engineering Policy Manager

Date: 19th February 2025

Target Staff Group	**Network Services Teams, Secondary Network Design, Engineering Trainers & ICPs**
Impact of Change	**GREEN – No change to working practices**
Planned Assurance Checks	**Policy Compliance Specialists shall confirm whether the requirements have been complied with during their sample checking of completed jobs**

IMPLEMENTATION PLAN

Introduction

This Standard Technique defines the earthing design requirements for ground mounted distribution substations which are to be owned or adopted by National Grid Electricity Distribution

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Main Changes

- References to Western Power Distribution replaced with National Grid Electricity Distribution.
- Removal of Earthing Design Tool (EDT) version numbers and hyperlink

Impact of Changes

Target Staff Group	Network Services Teams, Secondary Network Design Team, Engineering Trainers & ICPs involved with the design and construction of earthing systems for ground mounted distribution substations
Impact of Change	GREEN – No change to working practices

Implementation Actions

- Managers to notify relevant staff that this document has been published
- There are no retrospective actions

Implementation Timetable

This ST shall be implemented with immediate effect.

REVISION HISTORY

Document Revision & Review Table		
Date	**Comments**	**Author**
February 2025	Issue of Version 2 • References to Western Power Distribution replaced with National Grid Electricity Distribution. • Removal of Earthing Design Tool (EDT) version numbers and hyperlink	Mark Kneebone
April 2022	Issue of Version 1 • Amendment to definition of ‘hot’ and ‘cold’ sites and inclusion of new definitions for ‘high EPR’ and ‘low EPR’ sites in section 2.0 • References to ENA EREC S36 and ENA EREP 129 included in section 3.3 • Requirements for substations supplying IDNOs aligned with ENA ER G88 in section 4.5 • Guidance for ICPs on how to obtain soil resistivity data from British Geological Survey included in section 5.4 • Section 5.0. Content partially re-named and re-worded to align with new and amended definitions and with revised layout of Earthing Design Tool. • Separation requirements for substations in proximity to electrified railways & tramways clarified in section 5.16	Graham Brewster
Aug 2021	Initial issue	Graham Brewster

Contents

1.0 INTRODUCTION

This Standard Technique defines the earthing design requirements for 6.6kV and 11kV ground mounted distribution substations which are to be owned or adopted by National Grid Electricity Distribution.

Earth potential rise can present an electric shock hazard. A potential difference across parts of the human body causes current to flow and there is a risk of fatal electric shock if the current flows for sufficient time to cause ventricular fibrillation of the heart. Previously, a threshold of 430V [1] was employed, i.e. the earthing system was deemed to be safe if the HV earth potential rise was 430V or less. IEC 60479-1 defines a series of time-current curves for judging whether ventricular fibrillation of the heart will occur. These curves mean that the previous unconditional 430V limit is no longer tenable.

2.0 DEFINITIONS

For the purpose of this document the following definitions are employed:

TERM	DEFINITION
EHV	33kV, 66kV, 132kV, 275kV or 400kV
Earth Electrode	A conductor or group of conductors in direct contact with the soil and providing an electrical connection to earth.
Earthing Conductor	A protective conductor which connects plant and equipment to an earth electrode.
Earthing System	The complete interconnected assembly of earthing conductors and earth electrodes (including cables with un-insulated sheaths).
Reference Earth	Part of the Earth, the electric potential of which is conventionally taken as zero.
Earth Potential Rise (EPR)	The difference in potential which may exist between a point on the ground and remote reference earth.
Electrode Resistance	The impedance between the earthing system and remote reference earth.
Step Voltage	The potential difference between a person’s feet which are 1m apart.
Touch Voltage	The potential difference between a person’s hands and feet when standing 1m away from the object they are touching.

[1] Or 650V if the earth fault causing the potential rise is cleared by fast acting, high reliability protection which limits the fault duration to 200ms or less.

TERM	DEFINITION
Stress Voltage	The potential difference between locally and remotely earthed parts of cables, plant and apparatus that appears across cable/sheath insulation or across insulators/bushings during an earth fault condition and which, if sufficiently large enough, could result in insulation breakdown, flashover or failure.
Transfer Voltage	The potential transferred by a long metallic object which is connected to earth at one or more points and which bridges locations that are at different potentials with respect to the general mass of earth. As such, the object may transmit the potential rise of an earthing system into an area with low or no potential rise, or transmit reference earth into an area of potential rise, resulting in a potential difference occurring between the object and its surroundings.
Cold Site [2]	A site where the potential rise is less than 430V, or less than 650V where the earth fault causing the potential rise is cleared by fast acting, high reliability protection which limits the fault duration to 200ms or less.
Hot Site [2]	A site which is not a cold site. i.e. a site where the potential rise is greater than 430V, or greater than 650V where the earth fault causing the potential rise is cleared by fast acting, high reliability protection which limits the fault duration to 200ms or less.

TERM	DEFINITION
Low EPR Site [3]	A site where the potential rise is less than the permissible touch voltage limit or telecommunication equipment limit at third-party LV installations beyond the boundary of the site. In other words, a site where the potential rise is: • Less than 1150V, or less than 1700V [4] where the earth fault causing the potential rise is cleared by fast acting, high reliability protection which limits the fault duration to 200ms or less, and • Less than the touch voltage limit for shoes on soil or outdoor concrete, except where the LV system neutral is connected to earth at multiple locations, in which case the applicable value is less than 2x the touch voltage limit for shoes on soil or outdoor concrete

2 The 430V and 650V values derive from telecommunication standards relating to voltage withstand on equipment. These thresholds were also formerly applied as design limits for EPR, however, they no longer relate directly to safe design limits for touch and step potentials.

3 This is a NGED definition which differs slightly from that in ENA TS 41-24. It is important to ensure that third-party LV installations are not adversely affected by the conveyance of potential via combined HV & LV earthing systems, or by the conveyance of potential via the soil. Mitigating measures are necessary at ‘High EPR sites’.

4 The 1150V and 1700V values are limits for telecommunication equipment derived from ENA EREC S36 and ENA EREP 129.

TERM	DEFINITION
High EPR Site [3]	A site which is not a low EPR site. i.e. a site where the potential rise is greater than the permissible touch voltage limit or telecommunication equipment limit at third-party LV installations beyond the boundary of the site. In other words, a site where the potential rise is: • Greater than 1150V, or greater than 1700V [4] where high reliability protection with a fault clearance time less than 200ms is employed, and • Greater than the touch voltage limit for shoes on soil or outdoor concrete, except where the LV system neutral is connected to earth at multiple locations, in which case the applicable value is greater than 2x the touch voltage limit for shoes on soil or outdoor concrete
Ventricular Fibrillation	A state of the heart in which the lower chambers (ventricles) twitch randomly (fibrillate) instead of contacting in a co-ordinated fashion, resulting in an inability to pump blood. Considered to be the main mechanism of death in fatal electrical accidents.

3.0 REFERENCES

This document makes reference to, or should be read in conjunction with, the documents listed below. The issue and date of the documents listed below shall be those applicable at the date of issue of this document, unless stated otherwise.

3.1 IEC Standards

NUMBER	TITLE
IEC 60479-1	Effects of current on human beings and livestock - Part 1: General aspects

3.2 British Standards

NUMBER	TITLE
BS EN 50522	Earthing of power installations exceeding 1 kV a.c.
BS EN 62305	Protection against lightning

3.3 Energy Networks Association

NUMBER	TITLE
ENA TS 41-24	Guidelines for the design, installation, testing and maintenance of main earthing systems in substations
ENA EREC G88	Principles for the planning, connection and operation of electricity distribution networks at the interface between distribution network operators (DNOs) and independent distribution network operators (IDNOs)
ENA EREC S36	Identification and recording of 'hot' sites - joint procedure for Electricity Industry and Communications Network Providers
ENA EREP 129	ROEP risk assessment for third parties using equipment connected to Communications Network Provider lines

4.0 DESIGN REQUIREMENTS

Earthing systems for ground mounted distribution substations shall:

- Satisfy statutory requirements.
- Present a low impedance to earth fault current in order that protection systems can operate assuredly.
- Prevent hazardous voltages appearing in and around the substation.
- Minimise equipment damage from stress voltages caused by earth potential rise.
- Ensure that voltages transferred onto third-party installations as a consequence of earth potential rise do not present a hazard to persons or telecommunication equipment.
- Comply with the requirements for substation LV earthing where PME systems are employed.

4.1 Design Margin

The following margin [5] shall be incorporated into the earthing system design for ground mounted distribution substations:

a) The ‘design’ earth potential rise shall be 10% in excess of the ‘calculated’ earth potential rise.

b) The ‘design’ fault clearance time for HV faults shall be 400ms in excess of the ‘calculated’ fault clearance time.

[5] Also known as the ‘safety margin’. The additional capability required to compensate for uncertainties or network evolution over the lifetime of the substation. In other words, when assessing compliance with safety and equipment limits, the touch, step, transfer and stress voltages are projected to be greater in magnitude and persist for longer than calculations suggest.

c) The ‘design’ fault clearance time for EHV faults shall be in excess of the ‘calculated’ fault clearance time by the following margins:

- 400ms where the EHV fault clearance is by IDMT / DT / INST earth fault protection

- 100ms where the EHV fault clearance is by fast acting, high reliability protection with a normal earth fault clearance time greater than 200ms

- The time needed to realise an overall clearance time of 200ms where the EHV fault clearance is by fast acting, high reliability protection with a normal earth fault clearance time of 200ms or less.

4.2 Requirements For HV Earth Electrodes

The following design criteria shall be satisfied for HV earth electrodes associated with ground mounted distribution substations:

a) The HV earth electrode and associated earthing conductor shall have a cross sectional area of at least 70mm^2, a minimum strand diameter of 2.5mm where stranded copper conductor is employed, and a minimum thickness of 3mm where copper earth tape is employed.

b) The HV earth electrode shall have a resistance as low as is reasonably practicable but not greater than 20Ω for 11kV substations and 15Ω for 6.6kV substations. The 20Ω / 15Ω limit shall be realised solely by the installed HV electrode i.e. it shall not include any parallel earth contribution from network. [6]

c) The HV earth electrode shall, where practicable, include a ring electrode surrounding the substation, with a 1200mm long, 12.7mm diameter earth rod at each corner.

d) The HV earth electrode shall also consist of a horizontal electrode ‘tail’ laid in a radial direction away from the substation.

e) The surface area of the HV earth electrode in contact with the ground shall be large enough to prevent the soil around the electrode drying and increasing in resistance during a fault.

f) All equipment / conductive parts within the substation shall be bonded to the HV earth electrode.

g) The earth potential rise shall be 3kV or less in order to ensure equipment stress voltages are not exceeded.

h) Touch and step voltages shall be within safety limits both inside and immediately outside the distribution substation.

i) There shall be an above ground separation of at least 2.5m between any metallic part which is bonded to the HV earth electrode and any extraneous conductive part.[7]

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[6] The parallel earth contribution from the network can be utilised to reduce the resistance of the HV earth electrode below the 20Ω / 15Ω limit, but not to achieve it.

[7] A conductive part liable to introduce a potential, generally earth potential, for example, metal fences, crash barriers, etc.

j) Where the magnitude of the earth potential rise exceeds the touch voltage limit for shoes on soil or outdoor concrete for the fault clearance time, the HV electrode shall be separated by sufficient below-ground distance (the HV separation distance) from the following installations such that the potential impressed on them is maintained within the touch voltage limit:

- Railway or tramway [8]
- Telephone exchange
- Pipeline with cathodic protection
- Zoo, stable or pond/lake used for commercial fishing
- Outdoor swimming pool, outdoor paddling pool, or outdoor shower
- Customer TT electrode
- Bulk storage tank for petrol or flammable liquid
- LV systems whose neutral is connected to earth at a single point (i.e. SNE/TN-S LV systems which are not able to be back-fed and have not been modified to permit PME connections, and PNB LV systems) along with buildings and enclosures equipped with an electrical installation supplied from such systems

k) Where the magnitude of the earth potential rise exceeds 2x the touch voltage limit for shoes on soil or outdoor concrete for the fault clearance time, the HV electrode shall be separated by sufficient below-ground distance (the HV separation distance) from the following installations such that the potential impressed on them is maintained within 2x the touch voltage limit:

- LV systems whose neutral is connected to earth at multiple points (i.e. PME/CNE/TN-C LV systems and SNE/TN-S LV systems which are able to be back-fed or have been modified to permit PME connections) along with buildings and enclosures equipped with an electrical installation supplied from such systems.

4.3 Additional Requirements For NGED HV/LV Substations

Where a ground-mounted distribution substation contains a NGED owned HV/LV transformer the HV & LV earth electrodes should be combined where at all possible. Where the criteria for combined HV & LV earth electrodes cannot be met, then segregated HV and LV earth electrodes shall be provided.

[8] The touch voltage limit for electrified railways and tramways is specified in TP21AB

4.3.1 Requirements For Combined HV & LV Earth Electrodes

The earthing system shall comply with the following design criteria in order for combined HV & LV earth electrodes to be employed:

a) Where the LV neutral is to be connected to earth at multiple points (i.e. a PME/CNE/TN-C LV system or an SNE/TN-S LV system which is able to be back-fed or has been modified to permit PME connections), the magnitude of the earth potential rise shall be less than 2x the touch voltage limit for shoes on soil or outdoor concrete for the fault clearance time.

b) Where the LV neutral is to be connected to earth at a single point only (i.e. an SNE/TN-S LV system which is not able to be back-fed and has not been modified to permit PME connections, or a PNB LV system), the earth potential rise shall be less than 1x the touch voltage limit for the fault clearance time for shoes on soil or outdoor concrete.

c) The earth potential rise shall be 1150V or less in order to ensure limits for telecommunication equipment are not exceeded.

d) Where the distribution substation is cable connected to the source substation, the voltage transferred from the source substation to the distribution substation in the event of an EHV (i.e. 33kV, 66kV, 132kV, 275kV or 400kV) fault shall be:

- Less than 2x the touch voltage limit for shoes on soil or outdoor concrete for the EHV fault clearance time where the LV neutral is connected to earth at multiple points (i.e. a CNE/PME/TN-C LV system or an SNE/TN-S LV system which is able to be back-fed or has been modified to permit PME connections).

- Less than 1x the touch voltage limit for shoes on soil or outdoor concrete for the EHV fault clearance time where the LV neutral is connected to earth at a single point only (i.e. an SNE/TN-S LV system which is not able to be back-fed and has not been modified to permit PME connections, or a PNB LV system).

- Less than 1150V, or less than 1700V where the 33kV, 66kV or 132kV faults are cleared by high reliability protection with a fault clearance time less than 200ms.

4.3.2 Requirements For Segregated HV & LV Earth Electrodes

The earthing system shall comply with the following design criteria where segregated HV & LV earth electrodes are required:

a) The LV earth electrode shall consist of a horizontal electrode laid in a radial direction away from the substation.

b) The LV earth electrode shall have a cross sectional area of at least $70mm^2$, a minimum strand diameter of 2.5mm where stranded copper conductor is employed, and a minimum thickness of 3mm where copper earth tape is employed.

c) The LV earth electrode shall have a maximum resistance of 20Ω for 11kV substations and 15Ω for 6.6kV substations. The resistance shall be determined solely by the installed electrode i.e. shall not include any parallel earth contribution from network.

d) The electrode shall be insulated and laid within a 38mm diameter, Class 3, general purpose duct for buried electric cables where it is within the HV separation distance of the HV earth electrode (see Section 4.2 above).

e) The length of the uninsulated/'bare' portion of the electrode shall never be less than 10m.

4.4 Additional Requirements For HV Connection Substations Connecting NGED Customers

This section should be read in conjunction with ST: SD4OA (11kV and 6.6kV Connections to Customers and IDNOs using Secondary Switchgear).

In this arrangement the NGED HV switchgear is close-coupled to:

- A NGED metering unit, and NGED's HV Customer is connected via a cable box on the metering unit

4.4.1 Responsibility For Earthing Arrangements At NGED Customer Connections

The HV earth electrode associated with NGED's HV switchgear shall be owned and maintained by NGED.

NGED shall have design policy responsibility for the earthing arrangements on equipment located entirely within the area covered by the NGED HV earthing system (i.e. within the perimeter electrode). [9]

The Customer's HV & LV systems are connected beyond the NGED "supply terminals" [10] and outside of the perimeter electrode, and consequently are outside of the jurisdiction of NGED. Accordingly, it is the Customer's responsibility to ensure the earthing arrangements on its HV & LV systems are adequate.

4.4.2 NGED's Obligations

The Management of Health & Safety At Work Regulations requires employers to co-operate and co-ordinate where they share a workplace. The regulations require NGED to take all reasonable steps to inform the other employers concerned of the risks to their employees' health and safety arising out of or in connection with the operation of the distribution network.

The Construction (Design & Management) Regulations requires designers and contractors to co-operate when working on or in relation to a project, at the same or an adjoining construction site.

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[9] 'Design policy responsibility' means that the earthing arrangements shall be designed and constructed in accordance with NGED policy. This does not mean the design and construction has to be carried out by NGED. ICPs may carry out the design and construction of the earthing system for subsequent adoption by NGED in accordance with the ENA EREC G81 arrangements.

[10] Supply terminals means the end of the NGED owned electric lines where the supply is delivered to the Customer's installation. Also known as the point of supply.

The Electricity Safety, Quality & Continuity Regulations requires NGED to withhold its consent to the making or altering of the connection from the distribution network to a NGED Customer's installation where there are reasonable grounds for believing that the NGED Customer's installation, or the connection itself, is not so constructed, installed, protected and used so as to prevent danger or interruption of supply.

From an earthing design perspective this will typically mean:

- Informing the NGED Customer of the earth potential rise and fault clearance time of the NGED substation in order that the Customer can eliminate or mitigate foreseeable risks to persons or telecommunication equipment, so far as is reasonably practicable

- Withholding consent to make or alter a connection to the NGED distribution network where there are reasonable grounds for believing that the Customer's earthing system is not designed and installed so as to prevent danger.

4.4.3 Additional Requirements For The NGED HV Earth Electrode

NGED shall, where at all possible, provide an HV earthing system for its substation which is adequate to ensure safety in the absence of the earthing system provided by the NGED Customer.

Where two distribution substations supply the NGED Customer and these are located in close proximity to each other[11], the two HV earth electrodes shall be interconnected with an earth bond having a minimum cross sectional area of 70mm^2.

4.4.4 Requirements For The Customer's HV Earth Electrode

The earthing system for the Customer's HV substation shall satisfy the following requirements:

a) The earthing system shall be designed in accordance with BS EN 50522 or BS 7430. Alternatively, the Customer may elect to design the earthing system in accordance with ENA TS 41-24 or the relevant NGED directives.

b) The Customer shall, where at all possible, provide an HV earthing system for its installation which is adequate to ensure safety in the absence of the earthing system provided by NGED.

c) The Customer's HV electrode shall, in the absence of any interconnection to the NGED earthing system, have a maximum earth resistance as specified in the table below. This ensures there will be sufficient earth fault current to operate the protection even if the interconnections between the NGED and Customer earthing systems have been compromised.

Voltage	Maximum Earth Resistance
11,000V	20Ω
6,600V	15Ω

[11] For example, two non-extensible Ring Main Units positioned less than 10m apart

4.4.5 Requirements For Interconnecting NGED And Customer HV Earth Electrodes

The NGED and Customer HV earthing systems shall be interconnected with two earth bonds, each with a minimum cross sectional area of 70mm^2.

The earth bonds shall be laid on diverse routes and connected to different parts of the Customer's HV electrode in order to mitigate against accidental disconnection or severing of both connections concurrently.

The bonds shall be insulated and laid in ducts for their entire length.

The ends of the earth bonds in the NGED distribution substation shall be clearly identifiable in order that periodic testing can be undertaken to assess whether interconnection has been lost.

<u>Guidance Note</u>

These earth bonds are in addition to any interconnection provided by the sheath of any HV cable between the NGED and Customer substations.

These earth bonds are particularly important where the NGED or Customer substations are dependent upon each other in order to ensure safety.

Bonding the NGED and Customer HV earthing systems together allows standard steel wire armoured multi-core and multi-pair cables to be employed across the NGED - HV Customer interface.

4.4.6 Requirements For The Customer's HV/LV Substation

The Customer's HV/LV substation is connected beyond the NGED "supply terminals" [12] and outside of the perimeter electrode, and consequently is outside of the jurisdiction of NGED.

The Customer is responsible for ensuring the HV & LV earth electrodes associated with its HV/LV transformer(s) are designed, installed and used in such a manner to prevent danger occurring in the Customer's LV network as a result of any fault in the Customer's HV system or on the NGED HV network. In other words, deciding whether to combine or segregate the associated HV and LV earthing systems.

<u>Guidance Note</u>

BS EN 50522 states that "w*here the LV system is totally confined within the area covered by the HV earthing system both earthing systems shall be interconnected*". Where the electrical installation at the Customer's premises satisfies this condition, the HV and LV earth electrodes will often be combined, even if the earth potential rise is greater than the touch voltage limit for shoes on soil or outdoor concrete for the fault clearance time. This clause is also a reflection that, for industrial and commercial installations, it is often not practicable to separate earthing systems due to the close proximity of equipment.

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[12] Supply terminals means the end of the NGED owned electric lines at which the supply is delivered to the Customer's installation. Also known as the point of supply.

Note that where NGED owns the HV/LV transformer the LV system invariably leaves the area covered by the HV earthing system and hence does not satisfy this BS EN 50522 condition. Consequently NGED company policy is for its HV and LV earthing systems to be segregated where the earth potential rise is greater than the touch voltage limit for shoes on soil or outdoor concrete for the fault clearance time, or greater than 1150V.

Electricity Safety, Quality & Continuity Regulation 8(2)(b) states that a generator 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. Regulation 8(5) states that Regulation 8(2)(b) shall not apply to a network which is situated within a generating station if, and only if, adequate alternative arrangements are in place to prevent danger. Accordingly, HV Customers who are ‘generators’ may also elect to combine HV and LV earth electrodes, even if the earth potential rise is high.

4.5 Additional Requirements For HV Connection Substations Connecting IDNOs

This section should be read in conjunction with ST: SD4OA (11kV and 6.6kV Connections to Customers and IDNOs using Secondary Switchgear).

There are essentially three arrangements employed at ground mounted distribution substations connecting IDNOs, namely:

- NGED HV switchgear close-coupled to an IDNO HV cable
- NGED HV switchgear close-coupled to an IDNO HV/LV transformer
- NGED HV switchgear close-coupled to an IDNO HV metering unit

4.5.1 Responsibility For Earthing Arrangements On IDNO Connections

4.5.1.1 NGED Switchgear Close-Coupled To An IDNO HV Cable

In this arrangement the NGED HV switchgear is close-coupled to a cable box, inside which the IDNO’s HV cable is terminated. In other words, the ground mounted distribution substation provides HV supplies to an IDNO network.

NGED has design policy responsibility for the earthing arrangements at the distribution substation because, apart from the cable termination, the IDNO has no other HV assets at the substation. [13]

The HV earth electrode associated with NGED’s HV switchgear shall be owned and maintained by NGED.

[13] ‘Design policy responsibility’ means that the earthing arrangements shall be designed and constructed in accordance with NGED policy. This does not mean the design and construction has to be carried out by NGED. ICPs/IDNOs may carry out the design and construction of the earthing system for subsequent adoption by NGED in accordance with the G88 arrangements.

Where two distribution substations supply the IDNO and are located in close proximity to each other the two HV earth electrodes shall be interconnected with an earth bond having a minimum cross sectional area of $70mm^2$.

4.5.1.2 NGED Switchgear Close-Coupled To An IDNO HV/LV Transformer

In this arrangement the NGED HV switchgear is close-coupled to the IDNO's HV/LV transformer, which provides LV supplies to the IDNO network.

ENA EREC G88 specifies that the IDNO is accountable for the earthing arrangements at substations where it owns the HV/LV transformer and has responsibility for all of the customers and LV network fed from the substation. Accordingly, it is the IDNO's responsibility to ensure the HV & LV earthing arrangements are adequate. This includes designing and installing HV & LV earthing systems in such a manner so as to prevent danger occurring to persons or telecommunication equipment as a result of any fault in the IDNO's or NGED's HV assets.

The HV earth electrode associated with NGED's HV switchgear shall be owned and maintained by the IDNO.

ENA EREC G88 requires DNOs and IDNOs to take all reasonable measures to ensure the maximum physical separation of their respective underground cables. Accordingly, the IDNO's HV electrode shall not be laid in the same trench as NGED's HV cables.

4.5.1.3 NGED Switchgear Close-Coupled To An IDNO HV Metering Unit

In this arrangement the NGED HV switchgear is close-coupled to an IDNO HV metering unit. The IDNO's HV customer is connected via the cable box on the metering unit.

NGED has design policy responsibility[13] for the HV earthing arrangements at the distribution substation because, apart from the metering unit, the IDNO has no other HV assets at the substation.

The HV earth electrode associated with NGED's HV switchgear shall be owned and maintained by NGED.

Where two distribution substations supply the IDNO and are located in close proximity to each other the two HV earth electrodes shall be interconnected with an earth bond having a minimum cross sectional area of $70mm^2$.

The IDNO Customer is connected to the IDNO's network and consequently is outside of the jurisdiction of NGED.

The IDNO is responsible for specifying the requirements for the IDNO Customer's HV electrode. It is strongly recommended that requirement c) in Section 4.4.4 above is applied as a minimum in order to ensure the NGED protection system is able to detect and operate for HV earth faults in the IDNO Customer's installation.

The IDNO Customer has HV & LV systems which leave the area covered by the NGED HV earthing system. The IDNO Customer is responsible for ensuring the HV & LV earth electrodes associated with its HV/LV transformer(s) are designed, installed and used in such a manner to prevent danger occurring in its LV installation as a result of any fault in the Customer's HV system, or on the IDNO HV equipment, or on the NGED HV network. In other words, deciding whether to combine or segregate the associated HV and LV earthing systems.

Guidance Note

BS EN 50522 states that "w*here the LV system is totally confined within the area covered by the HV earthing system both earthing systems shall be interconnected*". Where the electrical installation at the IDNO Customer's premises satisfies this condition, the HV and LV earth electrodes will often be combined, even if the earth potential rise is greater than the touch voltage limit for shoes on soil or outdoor concrete for the fault clearance time. This clause is also a reflection that, for industrial and commercial installations, it is often not practicable to separate earthing systems due to the close proximity of equipment.

Note that where NGED owns the HV/LV transformer the LV system invariably leaves the area covered by the HV earthing system and hence does not satisfy this BS EN 50522 condition. Consequently NGED company policy is for its HV and LV earthing systems to be segregated where the earth potential rise is greater than the touch voltage limit for shoes on soil or outdoor concrete for the fault clearance time, or greater than 1150V.

Electricity Safety, Quality & Continuity Regulation 8(2)(b) states that a generator 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. Regulation 8(5) states that Regulation 8(2)(b) shall not apply to a network which is situated within a generating station if, and only if, adequate alternative arrangements are in place to prevent danger. Accordingly, IDNO Customers who are 'generators' may also elect to combine HV and LV earth electrodes, even if the earth potential rise is high.

Since the IDNO Customer is to be connected to the IDNO network, it is the responsibility of the IDNO to carry out the ESQC Regulation 25 obligations (Connections to installations or to other networks).

4.5.2 NGED's Obligations

The Management of Health & Safety At Work Regulations requires employers to co-operate and co-ordinate where they share a workplace. The regulations require NGED to take all reasonable steps to inform the other employers concerned of the risks to their employees' health and safety arising out of or in connection with the operation of the distribution network.

The Construction (Design & Management) Regulations requires designers and contractors to co-operate when working on or in relation to a project, at the same or an adjoining construction site.

The Electricity Safety, Quality & Continuity Regulations (ESQCR) requires NGED to disclose such information to the IDNO as might reasonably be required and to otherwise co-operate with the IDNO in order to ensure compliance with the Regulations.

The ESQCR requires NGED to withhold its consent to the making or altering of the connection from the distribution network to an IDNO's network where there are reasonable grounds for believing that the IDNO's network or the connection itself is not so constructed, installed, protected and used so as to prevent danger or interruption of supply.

From an earthing design perspective this will typically means informing the IDNO of the earth potential rise and fault clearance time of the NGED substation in order that the IDNO can eliminate or mitigate foreseeable risks to health or safety, so far as is reasonably practicable.

4.6 Standard Designs

Standard designs of ground mounted distribution substations shall be identified from the following list.

SUBSTATION FORMAT	ASSOCIATED STANDARD TECHNIQUE
Unit Substation In Freestanding GRP or Masonry Housing	TP21G-A
Unit Substation Integrated Within A Larger Building	TP21G-B
Padmount Substation	TP21G-C
LV Connection Substation In Freestanding GRP or Masonry Housing	TP21G-E
LV Connection Substation Integrated Within A Larger Building	TP21G-F
HV Connection Substation In Freestanding GRP or Masonry Housing	TP21G-G
HV Connection Substation Integrated Within A Larger Building	TP21G-H

The associated Standard Technique(s) shall be read in conjunction with this document.

They include:

- An Excel calculation tool (aka Earthing Design Tool) for the earthing design calculations and other assessments required by this Standard Technique
- Detailed construction information for the earthing system

4.7 Special Designs

Special designs of ground mounted distribution substations shall be identified from the following list.

SUBSTATION FORMAT	ASSOCIATED STANDARD TECHNIQUE
HV & LV supplies to power stations or substations which have an operating voltage in excess of 20kV	TP21F-A
HV & LV supplies to mobile phone base stations or other equipment mounted on steel overhead line towers or poles	TP21F-B
HV & LV Non-traction supplies to AC electrified railways	TP21F-D
HV Traction Supplies To DC Light Rapid Transit Systems	TP21F-E
LV Non-Traction Supplies To DC Light Rapid Transit Systems	TP21F-E

The associated Standard Technique(s) shall be read in conjunction with this document. They include detailed construction information for the earthing system.

4.8 Bespoke Designs

Standard Techniques communicate NGED requirements in relation to standard and special designs. Occasionally it is necessary to construct a ground mounted distribution substation in a format not covered by the Standard Techniques.

In these instances the spirit of the closest matching of the aforementioned associated Standard Techniques shall be followed. Engineering judgement, within the limits of an individual's competence, shall be exercised where appropriate, and advice should be sought from the NGED 'Engineering Policy' team where necessary.

Where the ground mounted distribution substation is located within 20m of the following installations it is recommended that an Earthing Specialist is engaged to carry out a bespoke design:

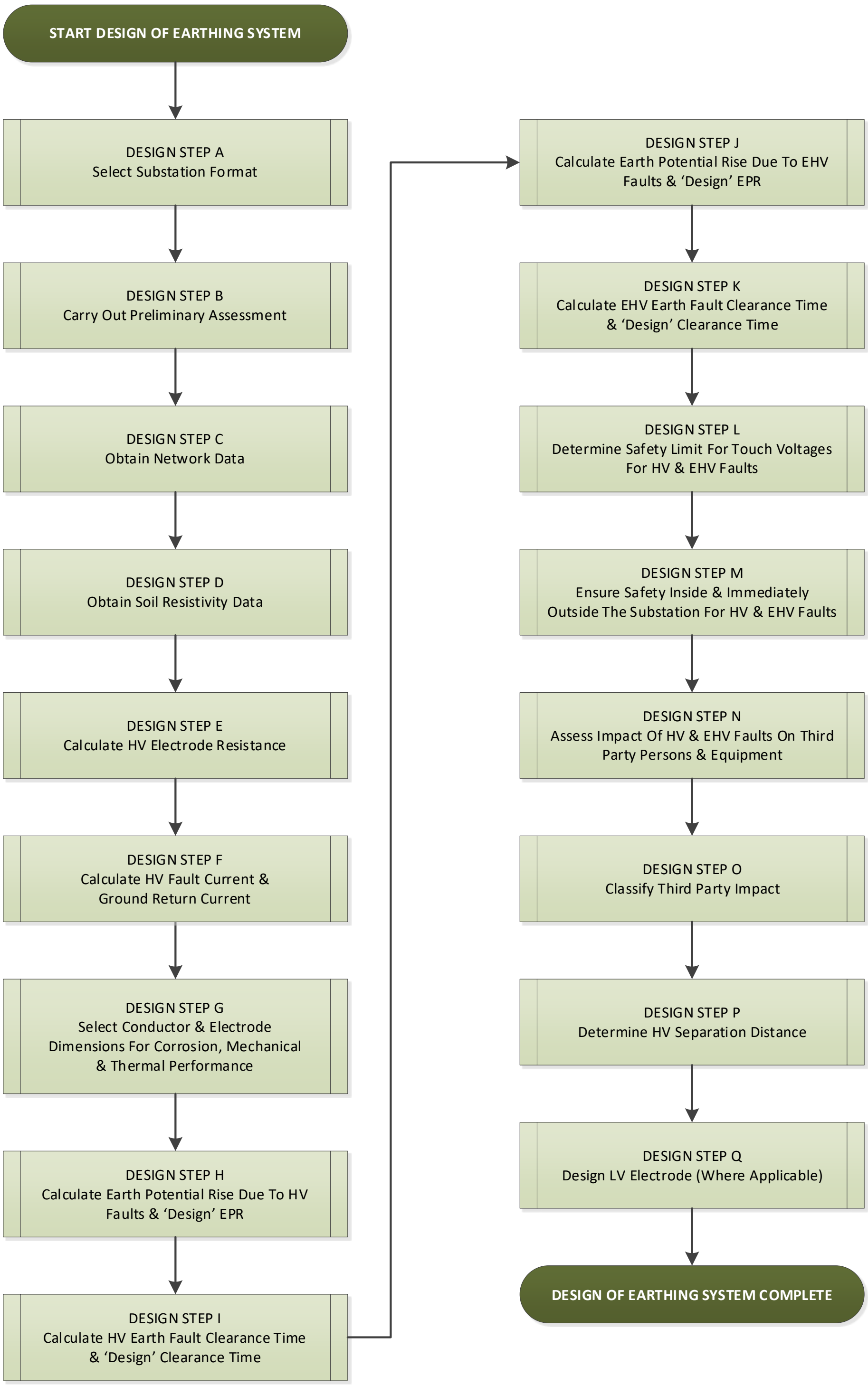
- Railway or tramway
- Telephone exchange
- Pipeline[14]
- Bulk storage tank for petrol or flammable liquid
- Zoo, stable or pond/lake used for commercial fishing
- Outdoor swimming pool, outdoor paddling pool, or outdoor shower
- Steel tower/pole operating at 132kV, 275kV or 400kV

HV separation distances in excess of 40m are considered to be unrealistic to achieve and maintain in practice. In these instances it is recommended that an Earthing Specialist is engaged to carry out a bespoke design.

[14] Means a large bore metal pipe, together with associated apparatus and works, used to convey oil, gas, or other fluids. It does not include small bore metal pipes used to convey fluids to domestic premises, or pipes used for domestic purposes.

5.0 DESIGN PROCEDURE

The overall earthing design procedure is shown in the flowchart below. The aspects which make up each design step are described in subsequent sections of this document.



5.1 DESIGN STEP A: Select Substation Format

The primary consideration when selecting the substation format is whether the substation requires a special earthing system design i.e. it comes under the auspices of one of the special designs listed in Section 4.7 above.

The substation format should be selected from the list of 'standard' or 'special' designs, as appropriate.

The design of the earthing system should be carried out in accordance with this document and the associated Standard Technique for the 'standard' or 'special' design.

5.2 DESIGN STEP B: Preliminary Assessment

A preliminary assessment shall be carried out to identify whether the proposed location of the ground mounted distribution substation is likely to prove challenging to the earthing system design.

Problematic locations include within 20m of the following:

a) An outdoor swimming pool, outdoor paddling pool, or outdoor shower

b) A zoo, stable or pond/lake used for commercial fishing

c) A telephone exchange

d) A railway or tramway

e) A metallic pipeline

f) A bulk storage tank for petrol or flammable liquid

g) A steel tower or steel pole overhead line operating at 132kV, 275kV or 400kV

Installation of ground mounted distribution substations in problematic locations shall be avoided where at all possible. Where this is unavoidable, an Earthing Specialist shall be employed to model the earthing system and carry out detailed analysis using appropriate and commercially available earthing design software tools[15].

5.3 DESIGN STEP C: Obtain Network Data

Network data up to the HV terminals of the ground mounted distribution substation shall be obtained in order to enable earthing design calculations to be performed. The following information is required in order to expedite these calculations:

[15] One example is "CDEGS" (Current Distribution Electromagnetic Interference Grounding and Soil Structure Analysis) by Safe Engineering Services & Technologies Ltd. Earthing design software tools by other vendors are available.

5.3.1 Source Grid / Primary Substation Details

The following details shall be obtained for the source Grid or Primary substation:

a) Earthing system impedance

b) Earth potential rise

c) Clearance time for an EHV (i.e. 33kV, 66kV, 132kV, 275kV or 400kV) fault

d) Whether EHV faults are cleared by 'overcurrent' type protection or by fast acting, high reliability protection

5.3.2 HV System Neutral Earthing Arrangements At The Source Grid / Primary Substation

The system neutral-earthing arrangements at the source Grid / Primary substation shall be obtained, specifically, the number of neutral-earth connections, the type of earthing employed[16], and the current rating of each connection.

5.3.3 HV Circuit Impedance Data

The impedance of the HV circuit between the source substation and the ground mounted distribution substation shall be obtained by measuring the route length of each cable and overhead line section which makes up this connection and multiplying it by the impedance per kilometre for the relevant conductor type.

5.3.4 HV Cable Details

The following details shall be obtained for the HV cable leading back towards the source substation:

a) Whether it is cable all the way back to the source substation or only to a pole termination

b) The total cable length back to the source substation or pole termination, as appropriate

c) The predominant cable type in the connection to the source substation or pole termination, as appropriate.

d) The earthing system impedance of the pole termination

Note that item d) is only required where the cable connection leads to a pole termination. Where this information is unknown, or cannot easily be measured, a 20Ω value should be assumed.

5.3.5 Local HV & LV Network Details

The built-up area covered by the local HV & LV network and the predominant cable type for this network shall be obtained.

The urban area shall be shall be determined in accordance with Standard Technique

[16] Resistance-earthing, reactance-earthing or direct-earthing

5.4 DESIGN STEP D: Obtain Soil Resistivity Data

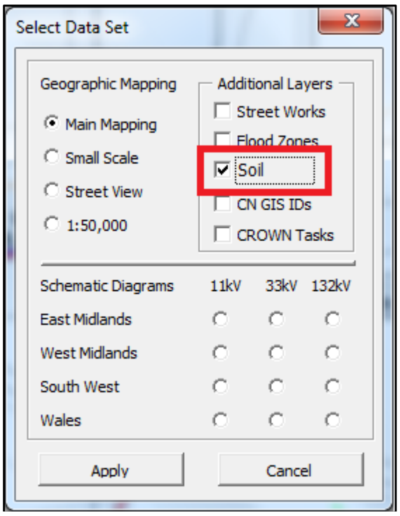
Soil resistivity data shall be obtained for the proposed ground mounted distribution substation.

The soil resistivity data should ideally be obtained by measurement on site using the procedure outlined in Standard Technique TP21O-A.

Alternatively, soil resistivity data shall be obtained from EMU [17] using the following procedure:

a) Ensure the 'Soil' layer is enabled in the data set

- Click on 'Emu'
- Click on 'Select Data Set'
- Check the 'Soil' checkbox, as shown below



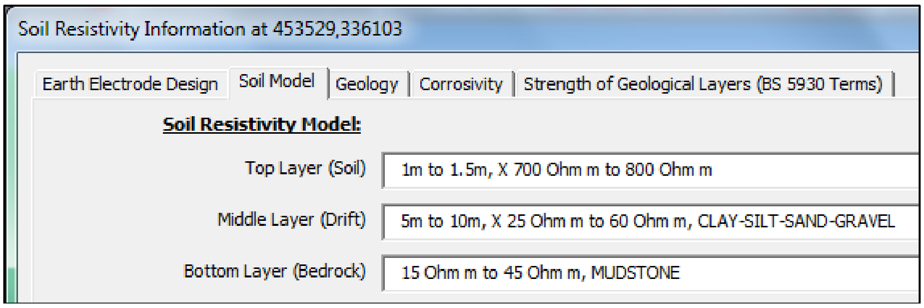
b) Find the location of the ground mounted substation on the geographical map.

c) Click on the 'Information' icon 

d) Place the cursor on the location of the substation and click

e) Select the 'Soil Model' tab. The soil resistivity data is shown as a three layer model, as shown below

[17] ICPs have access to a form of EMU which does not include soil resistivity data. NGED cannot make the British Geological Survey soil resistivity data available on its external facing mapping system because it is a paid-for service and NGED is not permitted to free issue the data to third parties. ICPs can access the same soil data by visiting the British Geological Survey website (www.bgs.ac.uk) and obtaining the 'BGS Resistivity' dataset at a cost of £0.30 per km² (price correct at time of writing)



5.5 DESIGN STEP E: Calculate Substation HV Electrode Resistance

5.5.1 Calculate Substation HV Electrode Resistance (R_E)

The HV electrode resistance (R_E) shall be calculated using the geometry of the electrode and the soil resistivity information. The calculations can be performed using earthing design software tools such as CDEGS[18] or by using the formulae in Appendix B of ENA EREC S34 Issue 2. The preferred approach is to calculate the electrode resistance using an earthing design software tool and a two layer soil resistivity model.

An HV electrode arrangement shall be selected such that its resistance (excluding network contribution) is as low as is reasonably practicable but not greater than 20Ω for 11kV substations and 15Ω for 6.6kV substations.

5.5.2 Estimate Network Contribution To Earth Resistance (R_{NC})

An estimate of the network contribution to the earth resistance (R_{NC}) shall be determined in accordance with Standard Technique TP21A-I.

The network contribution shall be the assessed value or the electrode resistance of the source substation, whichever is the greater.

5.5.3 Calculate Overall Earth Impedance (R_{GMSUB})

The overall earth resistance is the parallel combination of the HV electrode resistance and the network contribution to earth resistance.

$$R_{GMSUB} = \frac{1}{\frac{1}{R_E} + \frac{1}{R_{NC}}} = \frac{R_E \times R_{NC}}{R_E + R_{NC}}$$

[18] “CDEGS” (Current Distribution Electromagnetic Interference Grounding and Soil Structure Analysis) by Safe Engineering Services & Technologies Ltd. Earthing design software tools by other vendors are available.

5.6 DESIGN STEP F: Calculate Fault Current & Ground Return Current

5.6.1 Calculate Total Earth Fault Current (I_F)

The total earth fault current at the ground mounted substation (I_F) shall be calculated taking account of the:

- Earth electrode resistance of the source substation
- HV system neutral-earthing impedance at the source substation
- The impedance of the line and cable sections between the source substation and the ground mounted distribution substation
- HV earth electrode resistance of the ground mounted distribution substation
- The system impedance up to the source substation.

Impedance data can be expressed in various ways, for example, in ohms or percentage or per-unit format. The latter two are specified as a multiple of a selected base power, normally 10MVA or 100MVA. Consequently it is necessary to convert them to a common format prior to carrying out the computations.

The total earth fault current (I_F) shall be determined in accordance with Standard Technique TP21A-F.

Note that a simplified calculation, which neglects the system impedance up to the source substation, is acceptable as this results a in a more conservative assessment of earth fault current.

5.6.2 Calculate Fault Current Flowing Into Ground (I_{GR})

The fault current flowing into the ground (I_{GR}) is calculated by multiplying the total earth fault current (I_F) by the percentage of fault current that will flow into the ground ($\%I_{GR}$).

$$I_{GR} = \%I_{GR} \times I_F$$

The percentage of fault current that will flow into the ground ($\%I_{GR}$) shall be determined in accordance with Standard Technique TP21A-H.

5.7 DESIGN STEP G: Determine Conductor & Electrode Dimensions For Corrosion, Mechanical & Thermal Performance

5.7.1 Conductor Cross Sectional Area

In accordance with Section 4.2 above, the earth conductor shall have the following minimum conductor dimensions in order to have adequate corrosion, mechanical and current carrying performance:

- Minimum cross sectional area of $70mm^2$
- Minimum permissible thickness of copper strip / tape = 3mm
- Minimum strand diameter of stranded copper conductor = 2.5mm

Guidance Note

The minimum cross sectional area is significantly in excess of the cross section required to carry the anticipated levels of fault current for three seconds.

The surplus cross sectional area provides a margin for possible conductor corrosion over the life of the substation.

The minimum strip thickness of 3mm and strand diameter of 2.5mm ensures sufficient mechanical performance.

5.7.2 Electrode Surface Area

The soil surrounding an earth electrode has a much higher resistivity than the electrode conductor itself and consequently the fault current flowing through it will generate a greater temperature rise. The effect of the high temperature is to cause the soil to dry out, thus further increasing its resistivity, or even to produce steam, which may drive a separation between the soil and the electrode conductor.

For this reason the current rating of the electrode is very much lower than that implied by the current rating of the conductor and is related to its surface current density i.e. amperes per unit surface area.

The surface area of the earth electrode in contact with the ground shall be sufficiently large enough to prevent the ground around the electrode drying and increasing in resistance during a fault.

5.7.2.1 Calculate Minimum HV Electrode Surface Area Requirements

The minimum surface area of the HV earth electrode shall be determined in accordance with Standard Technique TP21A-J.

5.7.2.2 Assess Compliance With Minimum HV Electrode Surface Area Requirements

An assessment shall be carried out to determine if the surface area of the proposed HV earth electrode is equal to, or greater than, the minimum surface area calculated in Section 5.7.2.1 above. The assessment shall be carried out in accordance with Standard Technique TP21A-J.

Where the surface area of the HV electrode is insufficient, it is necessary to either increase the length of the HV electrode ‘tail’ or to construct the ‘tail’ from a number of parallel conductors spaced 100mm apart in the same trench.

In the case of the latter, the close spacing of these parallel conductors means there will be no reduction in electrode resistance, but it is a way of significantly increasing the surface area of the electrode without having to increase the amount of excavation.

In the event that the HV earth electrode has to be extended in order to meet the minimum surface area requirement it will be necessary to redo Sections 0 onwards.

5.8 DESIGN STEP H: Calculate Earth Potential Rise (EPR) Due To HV Fault and 'Design' EPR

The earth potential rise (EPR) due to a HV fault is calculated by multiplying the HV fault current that will flow into the ground (I_{GR}) by the overall earth impedance of the ground mounted distribution substation (R_{GMSUB}).

$$EPR = I_{GR} \times R_{GMSUB}$$

The 'design' earth potential rise shall be 10% in excess of the 'calculated' earth potential rise in accordance with Section 4.1 above.

5.9 DESIGN STEP I: Calculate HV Fault Clearance Time and 'Design' Fault Clearance Time

The fault clearance time for HV earth fault should be calculated in accordance with Standard Technique TP21A-E using the total earth fault current (I_F), or a default value of three seconds should be employed.

Where the earth fault clearance time is calculated, it shall be based upon the tripping time[19] of the circuit breaker at the source substation and not on the tripping time of a circuit breaker downstream of this position, for example, a pole-mounted recloser.

The tripping time of the circuit breaker shall be based upon the fault being cleared by inverse-definite-minimum-time (IDMT) protection and not by instantaneous or definite-time protection.

The 'design' earth fault clearance time shall be 400ms in excess of the 'calculated' or 'default' fault clearance time in accordance with Standard Technique TP21A-E and Section 4.1 above.

5.10 DESIGN STEP J: Determine Earth Potential Rise (EPR) Due To EHV Fault and 'Design' EPR

The earth potential rise (EPR) at the distribution substation due to an EHV fault is ascertained by calculating the transfer voltage from the source substation i.e. the portion of the source substation EPR that is transferred to the distribution substation via the HV cable sheath.

The transfer voltage from the source substation to the ground mounted distribution substation shall be determined in accordance with Standard Technique TP21AM.

Note that the source substation EPR recorded in the NGED Earthing Database is normally 10% in excess of the 'calculated' earth potential rise (i.e. already includes an allowance for future growth) and consequently the calculated transfer voltage is the 'design' earth potential rise in accordance with Section 4.1 above.

[19] Tripping time shall be from arc inception to arc extinction

5.11 DESIGN STEP K: Calculate EHV Fault Clearance Time and 'Design' Fault Clearance Time

The fault clearance time for an EHV earth fault should be calculated in accordance with Standard Technique TP21A-E.

The 'design' EHV earth fault clearance time shall be in excess of the 'calculated' fault clearance time by the operating margin specified in Standard Technique TP21A-E and in accordance with Section 4.1 above.

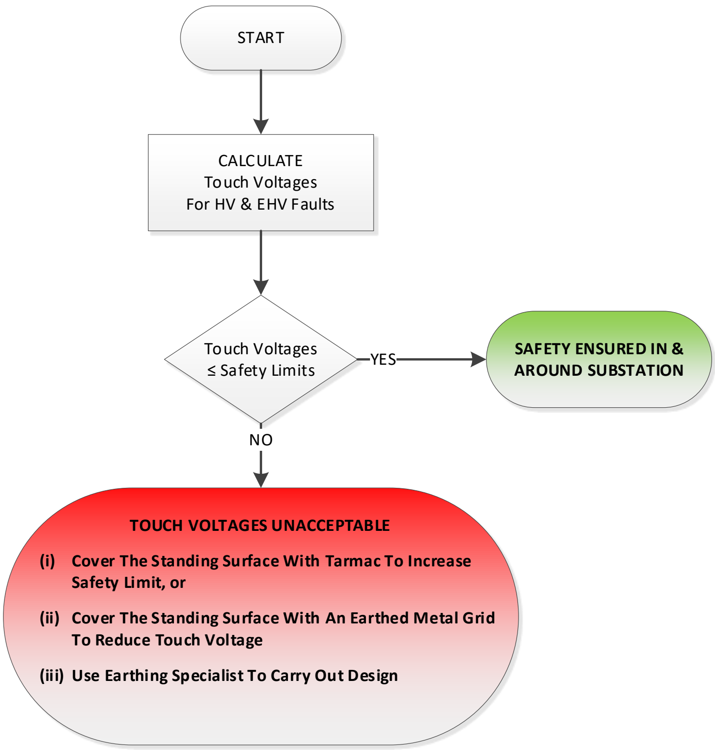
5.12 DESIGN STEP L: Determine Safety Limits For Touch Voltages

The safety limit for touch voltages for the HV and EHV 'design' earth fault clearance times shall be determined in accordance with Standard Technique TP21AA.

5.13 DESIGN STEP M: Ensure Safety Inside And Around The Exterior Of The Distribution Substation

5.13.1 Flowchart

The earthing design procedure for ensuring safety inside and around the exterior of the ground mounted distribution substation is shown below.



5.13.2 Touch Voltage Assessment

The touch voltage (V_{TOUCH}) is calculated by multiplying the ‘design’ earth potential rise (EPR) by the maximum touch voltage for the substation as a percentage of the EPR ($\%_{TOUCH}$).

$$V_{TOUCH} = EPR \times \%_{TOUCH}$$

Touch voltages have to be calculated for both HV and EHV faults.

If the touch voltages for HV and EHV faults are both less than the touch voltage safety limit for HV and EHV faults respectively then safety is ensured inside and around the exterior of the ground mounted distribution substation and the assessment is complete.

If one of the touch voltages is greater than the applicable touch voltage safety limit then the design is not acceptable and measures must be taken to make the situation safe. Possible options include:

- Covering the surface a person stands upon in order to touch earthed conductive parts with a layer of insulating material such as tarmac in order to increase touch voltage safety limit.

  The insulated surface shall be of sufficient size so that it is impossible to touch the earthed conductive parts with the hand from a standing position off the insulating layer.

- Covering the surface a person stands upon in order to touch earthed conductive parts with a metal grid[20] which is bonded to those parts in order to reduce the touch voltage.

  The metal grid shall be of sufficient size so that it is impossible to touch the earthed conductive parts with the hand from a standing position off the metal grid.

- Employing an Earthing Specialist to model the earthing system and carry out detailed analysis using appropriate and commercially available earthing design software tools

It is also possible to reduce the touch voltage due to HV faults by extending the HV earth electrode in order to reduce its resistance. However, this generally has a limited effect because of the counteracting increase in fault current. In the event that the HV earth electrode is extended, it will be necessary to redo Sections 0 onwards.

It is also possible to increase the touch voltage safety limit by reducing the fault clearance time. Generally this is only worthwhile where an assumed value has been employed for the fault clearance time and a proper assessment may result in a reduced value.

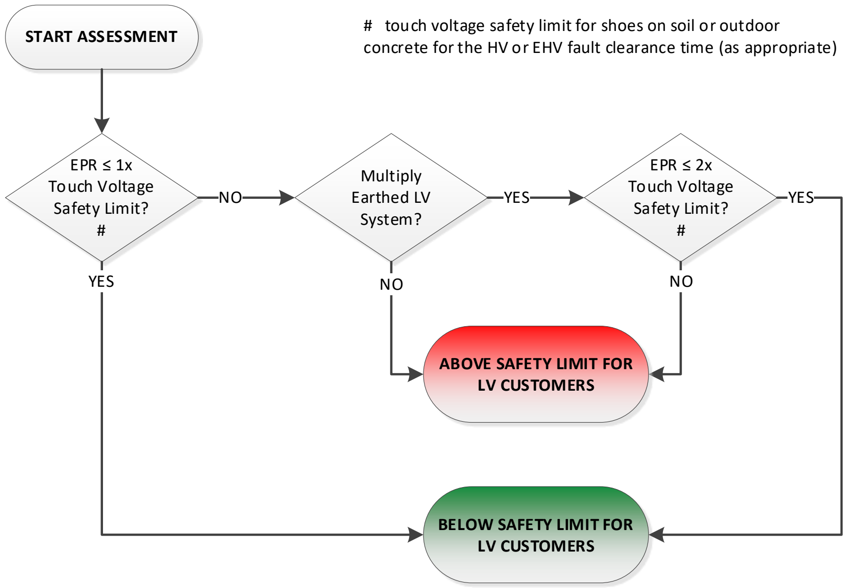
5.14 **DESIGN STEP N: Assess Impact Of HV & EHV Faults On Third Party Persons And Equipment**

5.14.1 Determine whether the EPR is less than the safety limit for LV customers

[20] The use of a metal grid is only acceptable in locations where members of the public are excluded.

5.14.1.1 Flowchart

The procedure for determining whether the EPR at the distribution substation as a result of an HV or EHV fault is less than the safety limit for LV customers is shown below.



5.14.1.2 Assessment

The assessment shall be carried out for the EPR generated at the ground mounted distribution substation during both an HV and an EHV fault.

The EPR will be less than the safety limit for LV customers when the following conditions are satisfied:

- The EPR is less than 1x the touch voltage safety limit for shoes on soil or outdoor concrete for the HV or EHV fault clearance time (as appropriate) where the LV system neutral is connected to earth at a single point (i.e. PNB LV systems and SNE/TN-S LV systems which are not able to be back-fed and have not been modified to permit PME connections)

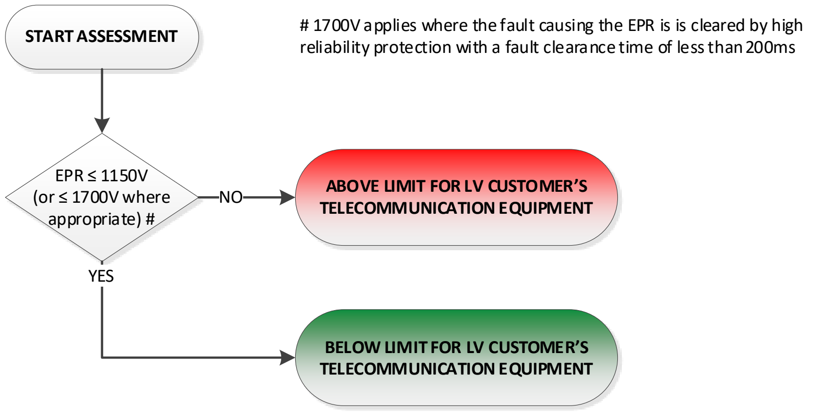
- The EPR is less than 2x the touch voltage safety limit for shoes on soil or outdoor concrete for the HV or EHV fault clearance time (as appropriate) where the LV system neutral is connected to earth at multiple points (i.e. CNE/TN-C LV systems and SNE/TN-S LV systems which are able to be back-fed or have been modified to permit PME connections)

The safety limit for touch voltages shall be determined in accordance with Standard Technique TP21AA and the ‘design’ HV or EHV fault clearance time.

5.14.2 Determine whether the EPR is less than the limit for LV customer’s telecommunication equipment

5.14.2.1 Flowchart

The procedure for determining whether the EPR at the distribution substation as a result of an HV or EHV fault is less than the limit for LV customer's telecommunication equipment is shown below.



5.14.2.2 Assessment

The assessment shall be carried out for the EPR generated at the ground mounted distribution substation during both an HV and an EHV fault.

The EPR will be less than the limit for LV customer's telecommunication equipment when the following conditions are satisfied:

- The EPR is less than 1150V, or less than 1700V if the fault is cleared by high reliability protection with a fault clearance time of less than 200ms

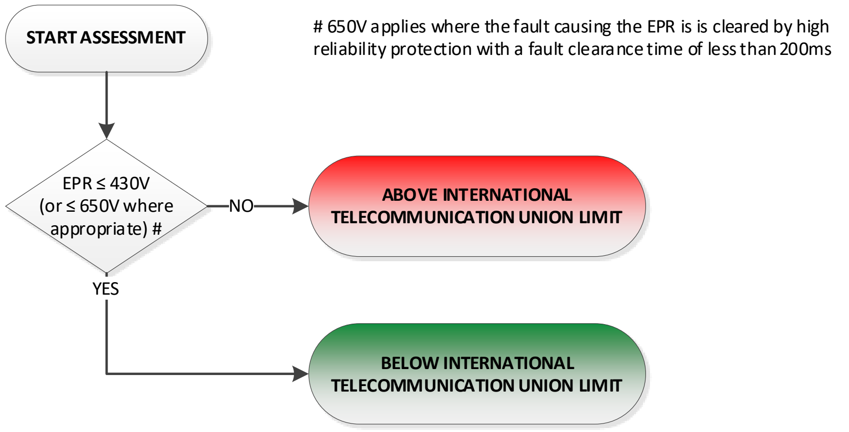
The 1150V and 1700V values are limits for telecommunication equipment derived from ENA EREC S36 and ENA EREP 129.

High reliability protection is protection other than 'overcurrent' type applied to a power circuit having an operating voltage of 33kV or greater, for example, distance or differential (aka unit) protection.

5.14.3 Determine whether the EPR is less than the International Telecommunication Union (ITU) Limit

5.14.3.1 Flowchart

The procedure for determining whether the EPR at the ground mounted distribution substation is less than the International telecommunication Union (ITU) limit is shown below.



5.14.3.2 Assessment

The assessment shall be carried out for the EPR generated at the ground mounted distribution substation during both an HV and an EHV fault.

The EPR will be less than the International Telecommunication Union (ITU) limit when the following conditions are satisfied:

- The EPR is less than 430V, or less than 650V if the fault is cleared by high reliability protection with a fault clearance time of less than 200ms

The 430V and 650V values derive from telecommunication standards relating to voltage withstand on equipment prepared by the International Telecommunication Union (ITU).

High reliability protection is protection other than ‘overcurrent’ type applied to a power circuit having an operating voltage of 33kV or greater, for example, distance or differential (aka unit) protection.).

5.15 DESIGN STEP O: Classify Third Party Impact

5.15.1 Determine NGED Third Party Impact Classification (’High EPR’ or ‘Low EPR’)

The NGED Third Party Impact Classification for the ground mounted distribution substation is ‘Low EPR’ if, for both HV and EHV faults:

- The EPR is below the safety limit for LV customers
- The EPR is below the limit for LV customer’s telecommunication equipment

The NGED Third Party Impact Classification for the ground mounted distribution substation is ‘High EPR’ if, for either HV or EHV faults:

- The EPR is above the safety limit for LV customers
- The EPR is above the limit for LV customer’s telecommunication equipment

It is important to ensure that third-party LV installations are not adversely affected by the conveyance of potential via combined HV & LV earthing systems, or by the conveyance of potential via the soil. Where a site has a ‘High EPR’ classification, the design of the earthing system must incorporate measures to safeguard third parties, for example, by segregating HV & LV electrodes and/or providing suitable separation distance through the soil to the HV electrode.

Note that in the case of a ‘High EPR’ HV Connection substation, the Customer may need to ensure that its LV installation is not adversely affected by the conveyance of potential via combined HV & LV earthing systems, or by the conveyance of potential via the soil. The HV Customer should be advised to consider the risks arising from earth potential rise on their installation.

5.15.2 Determine ITU Classification (’Hot’ or ‘Cold’)

The ITU Classification for the ground mounted distribution substation is ‘Cold’ if, for both HV and EHV faults the EPR is below the ITU limit.

The ITU Classification for the ground mounted distribution substation is ‘Hot’ if, for either HV or EHV faults the EPR is above the ITU limit.

In the case of ground mounted distribution substations the ‘hot’ or ‘cold’ classification is of limited significance because:

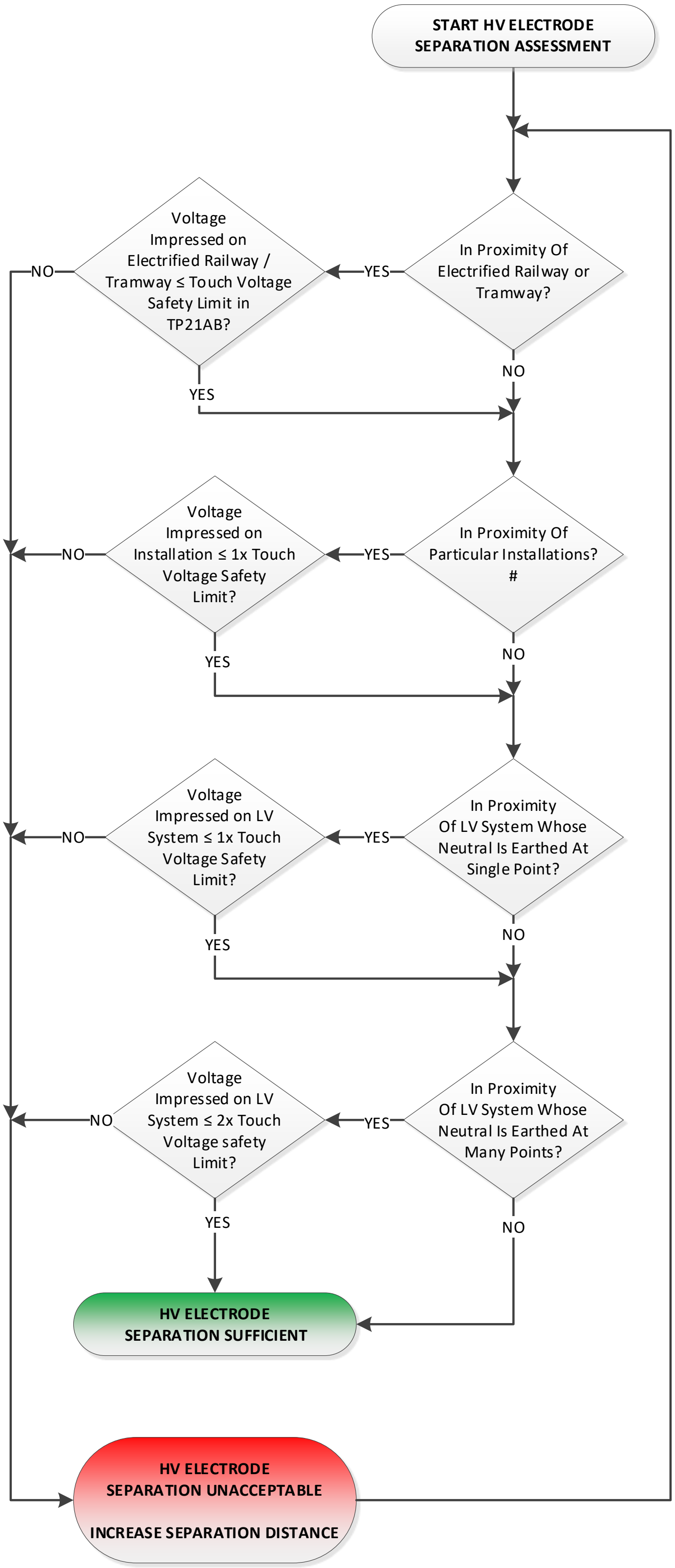
- Metallic services from public telecommunication network providers are not normally brought into these substations and hence there is no need for any special precautions or strict working procedures for telecommunication apparatus.

- The agreement between the electricity industry and public telecommunication network providers does not require a schedule of ‘hot’ distribution substations to be kept, nor for telecommunication network providers to be notified of such sites.

Note that in the case of a ‘Hot’ HV Connection substation, the Customer may require a metallic service from a public telecommunication network provider to be brought into its premises and hence special precautions or strict working procedures for telecommunication apparatus may be necessary. The HV Customer should be advised to notify the telecommunication network provider if they have, or are having, a telecommunication service installed.

5.16 DESIGN STEP P: Determine Separation Distance For HV Electrode

5.16.1 Flowchart



Non-electrified railway or tramway

Telephone exchange

Pipeline

Bulk storage tank for petrol or flammable liquid

Zoo, stable, or pond/lake used for commercial fishing

Permanent outdoor swimming pool, paddling pool or shower

Customer TT electrode

5.16.2 HV Separation Assessment

The HV electrode shall be separated from electrified railways & tramways by sufficient distance such that the voltage impressed on those installations in the event of either a HV or source substation fault is not greater than:

- The touch voltage limit specified in TP21AB for the fault clearance time of the distribution substation or source substation (as appropriate).

The HV electrode shall be separated from non-electrified railways & tramways, telephone exchanges, pipelines, bulk storage tanks for petrol or flammable liquids, zoos, stables, ponds/lakes used for commercial fishing, outdoor swimming pools, outdoor paddling pools, outdoor showers or customer TT electrodes by sufficient distance such that the voltage impressed on those installations in the event of either a HV or source substation fault is not greater than:

- 1x the touch voltage limit for shoes on soil or outdoor concrete for the fault clearance time of the distribution substation or source substation (as appropriate).

The HV electrode shall be separated from NGED, IDNO or Customer LV systems[21] by sufficient distance such that the voltage impressed on the LV system in the event of either a HV or source substation fault is not greater than:

- 2x the touch voltage limit for shoes on soil or outdoor concrete for the fault clearance time of the distribution substation or source substation (as appropriate) where the LV system is connected to earth at multiple locations i.e. PME/CNE/TN-C LV systems and SNE/TN-S LV systems which are able to be back-fed <u>or</u> have been modified to permit PME connections.

- 1x the touch voltage limit for shoes on soil or outdoor concrete for the fault clearance time of the distribution substation or source substation (as appropriate) where the LV system is connected to earth at a single location i.e. SNE/TN-S LV systems which are not able to be back-fed <u>and</u> have not been modified to permit PME connections, PNB LV systems, or TT LV systems.

[21] Except on Customer LV systems where the Customer elects to combine the HV & LV earths on its HV/LV transformers.

5.17 DESIGN STEP Q: Design LV Electrode (Where Relevant)

This step is only necessary for ground mounted distribution substations containing NGED owned HV/LV transformers.

If the entire LV system is confined within the area enclosed by the HV earthing system then a combined HV & LV earth electrode shall be employed even if the distribution substation is a 'High EPR' site. This situation is likely to occur where a dedicated ground mounted distribution substation provides LV supplies to a substation or power station[22] with an operating voltage of 33kV, 66kV, 132kV, 275kV or 400kV.

Where the LV system leaves the area enclosed by the HV earthing system then separate HV & LV earth electrodes shall be provided where the distribution substation is a 'High EPR' site.

An LV electrode arrangement shall be selected such that its resistance (excluding network contribution) is as low as is reasonably practicable but not greater than 20Ω for 11kV substations and 15Ω for 6.6kV substations.

[22] The substation or power station may be owned by NGED, NGET, another DNO/IDNO, a generator, or a customer.

APPENDIX A

SUPERSEDED DOCUMENTATION

This document supersedes ST: TP21DD/1 dated April 2022 which has now been withdrawn.

APPENDIX B

RECORD OF COMMENT DURING CONSULTATION

No comments received.

APPENDIX C

ANCILLARY DOCUMENTATION

POL: TP21 - Fixed Earthing Systems

APPENDIX D

KEYWORDS

Earth; Earthing; Ground; Mounted; Distribution; Secondary; Substation; Design;