WESTERN POWER DISTRIBUTION

Serving the Midlands, South West and Wales

Company Directive

STANDARD TECHNIQUE: TP21GH

Standard Earthing Designs
Part H
HV Connection Substation Integrated Within A Larger Building

Summary

This Standard Technique describes the standard earthing design to be employed on an 'HV Connection' substation which is integrated within a larger building and which is to be owned or adopted by Western Power Distribution.

Author: **Graham Brewster**

Implementation Date: **June 2021**

Approved by

Engineering Policy Manager

Date: **28th June 2021**

Target Staff Group	**Network Services Teams & ICPs**
Impact of Change	**AMBER - The changes have an impact of current working practices that are not safety critical - Communication at next team meeting or as part of a retraining programme**
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 describes the standard earthing design to be employed on an 'HV Connection' substation which is integrated within a larger building and which is to be owned or adopted by Western Power Distribution.

This Standard Technique applies where the WPD HV switchgear is close-coupled to a WPD metering unit and WPD's HV Customer is connected via a cable box on the metering unit, or an IDNO metering unit and the IDNO's HV Customer is connected via a cable box on the metering unit, or an IDNO cable

Main Changes

ENA TS 41-24 & S34 have been revised. These are Distribution Code Annex 2 documents and it is a breach of the Code (& hence Licence Conditions) not to comply.

This ST implements the latest requirements. Whilst it is a new document, it supersedes parts of Standard Technique TP21D/3.

Impact of Changes

Target Staff Group	Network Services Teams, Engineering Trainers & ICPs involved with the design and construction of earthing systems for ground mounted distribution substations
Impact of Change	AMBER - The changes have an impact of current working practices that are not safety critical – Communication at next team meeting or as part of a retraining programme

Implementation Actions

- Managers to notify relevant staff & Contractors that this document has been published
- Network Planners and any other staff who are required to use the associated 'Earthing Design Tool' to complete the following online training
- This document, the associated 'Earthing Design Tool' and the online training to be made available to ICPs on the www.westernpowertechinfo.co.uk website
- TP21D to be marked up to indicate the sections that have been superseded
- There are no retrospective actions

Implementation Timetable

This ST shall be implemented with effect from 1st August 2021.

Where a connection offer is accepted prior to this date, the substation may be constructed in accordance with the requirements applicable at the time of acceptance, subject to the construction works being completed on or before 31st December 2021.

Where a requote is provided after the release of this document, the connection offer shall comply with the requirements of this document.

REVISION HISTORY

Document Revision & Review Table		
Date	**Comments**	**Author**
June 2021	• Initial issue	Graham Brewster

Contents

1.0 INTRODUCTION

This Standard Technique describes the standard earthing design to be employed on an HV Connection substation which is integrated within a larger building and which is to be owned or adopted by Western Power Distribution.

This Standard Technique applies where the WPD HV switchgear is close-coupled to:

- A WPD metering unit and WPD's HV Customer is connected via a cable box on the metering unit, or
- An IDNO metering unit and the IDNO's HV Customer is connected via a cable box on the metering unit, or
- An IDNO cable

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

The close-coupling arrangement means that an IDNO owned metering unit is located entirely within the area covered by the WPD HV earthing system. Accordingly, WPD has design authority for the HV earthing arrangements.

2.0 DEFINITIONS

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

TERM	DEFINITION
HV Connection substation	A HV substation where the WPD HV switchgear is close coupled to: • A WPD metering unit and WPD's HV Customer is connected via a cable box on the metering unit, or • An IDNO metering unit and the IDNO's HV Customer is connected via a cable box on the metering unit, or • An IDNO cable
Substation Integrated Within A Larger Building	A substation which is contained within, and employs the foundations of, a building or structure used for residential, commercial, institutional or industrial occupancy, or a combination thereof.
Substation Compartment	That portion of the larger building which has been set aside to house the HV/LV substation and which is of a fire-resisting construction.

TERM	DEFINITION
Cold Site [1]	A site where the earth potential rise (EPR) or the transfer potential from the source substation is: • Less than 430V (or, in the case of transfer potential, 650V where a fault at the source substation is cleared by high reliability protection with a fault clearance time less than 200ms), and • Less than the touch voltage limit for shoes on soil or outdoor concrete *[Except at HV/LV substations where the neutral of the LV system is connected to earth at multiple locations (i.e. a PME LV system) where the applicable value is less than 2x the touch voltage limit for shoes on soil or outdoor concrete]*
Hot Site [1]	A site which is not a cold site i.e. a site where the earth potential rise (EPR) or the transfer potential from the source substation is: • Greater than 430V (or, in the case of transfer potential, 650V where a fault at the source substation is cleared by high reliability protection with a fault clearance time less than 200ms), and • Greater than the touch voltage limit for shoes on soil or outdoor concrete *[Except at HV/LV substations where the neutral of the LV system is connected to earth at multiple locations (i.e. a PME LV system) where the applicable value is greater than 2x the touch voltage limit for shoes on soil or outdoor concrete]*

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 British Standards

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

[1] This is a WPD definition which differs from that in ENA TS 41-24 (which relates to the 430V / 650V limit for telecommunication equipment). It is a reflection of the fact that the terms 'hot' & 'cold' have become ubiquitous within WPD to mean sites where HV & LV earths should be segregated / combined, or where limits for telecommunication equipment have / have not been exceeded respectively.

3.2 Energy Networks Association

NUMBER	TITLE
ENA TS 41-24	Guidelines for the design, installation, testing and maintenance of main earthing systems in substations

4.0 DESIGN REQUIREMENTS

4.1 Preamble

The earthing design requirements in this document are based upon the use of bare earth electrode laid with incoming HV cables to achieve the requisite electrode resistance.

The use of the building foundations as an earth electrode[2] or earth rods which penetrate through the ground floor slab[3] and into the soil beneath is outside the scope of this document. Where this approach is proposed an earthing specialist must be employed to carry out the design.

The earthing design in this document is predicated on the exterior walls and doors of the compartment housing the substation being electrically non-conductive and forming a barrier which prevents anyone external to the compartment from touching any metalwork which is bonded to the substation HV earth electrode.

In the event that the compartment housing the substation has externally accessible metallic parts then the design requirements specified in the following document shall additionally apply:

- Standard Technique TP21G-I: Standard Earthing Designs - Part I - Additional Requirements For Substations With Externally Accessible Metallic Parts

These design requirements are an abridged version pertaining to 'HV Connection' substations accommodated within a larger building. Comprehensive earthing design requirements are specified in the following document:

- Standard Technique TP21D-D: Design Of Earthing Systems - Part D - Ground Mounted Distribution Substations.

[2] Such an earthing design will need to consider the effects of the passage of fault current through the foundations (thermal cracking of concrete), electro-chemical corrosion of earthing conductor (i.e. by concrete or concrete additives, and by connections between dissimilar metals), and other factors which may reduce the efficacy of the earth electrode system (use of waterproof concrete, externally applied bitumen sealing, below slab thermal insulation, below slab damp-proof membranes, dimpled membrane tanking, below slab soil layers formed from recycled materials with poor electrical conductivity etc).

[3] The building owner's consent for these must be sought, and they must also accept responsibility for the measures necessary to prevent groundwater penetration via these points

4.2 Earthing Design Tool

The following Earthing Design Tool (Microsoft Excel Workbook) shall be employed in order to design and analyse the performance of a proposed earthing system for a 'HV Connection' substation in a freestanding GRP or masonry housing.

Earthing Design Tool (TP21G Version 1)

4.3 Principal Requirements For The WPD HV Earth Electrode

The WPD HV earth electrode shall comply with the following principal requirements:

a) The HV earth electrode shall consist of a horizontal electrode laid in a radial direction away from the substation buried at a depth of 600mm (1000mm in arable land). The electrode shall be insulated where it is laid within the building and be uninsulated (bare) where it is laid in the soil.

b) The conductors employed for the HV earth electrode system shall have a minimum cross sectional area of 70mm^2

c) The HV electrode shall have a resistance not greater than 20Ω for 11kV substations and 15Ω for 6.6kV substations. This resistance shall be determined solely by the installed electrode system i.e. shall not include any parallel contribution from the HV Customer's installation or from the IDNO network[4].

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

e) All equipment / conductive parts within the substation compartment, excluding rebar but including the galvanised steel apron (where installed), shall be bonded to the HV earth electrode.

f) When the doors to the substation compartment are closed, there shall be no metal parts which are bonded to the HV earth electrode which can be touched from outside the compartment[5] [6].

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[4] The parallel contribution from WPD's HV Customer's installation or from the IDNO network can be utilised to reduce the resistance of the HV earth electrode below this 20Ω / 15Ω level.

[5] The compartment housing the substation is an integral part of the arrangements for ensuring safety i.e. non-conductive material for the outer walls which prevents earthed metal parts from being touched from outside and extraneous conductive parts being touched from the inside. The substation must not be energised with the compartment walls missing or in a compromised state.

[6] Earthed telecoms aerials/masts require special consideration, especially at 'hot' sites. They shall be positioned not less than 2.5m above ground level and not less than 2.5m away from any exposed conductive part or extraneous conductive part.

g) When the doors to the substation compartment are open, 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 exposed conductive part[7] or extraneous conductive part[8] located outside of the housing.

h) The earth potential rise shall be 3kV or less.

4.4 Additional Requirements For The WPD HV Earth Electrode AT 'Hot' Sites

At 'Hot' sites (see Section 2.0 above) the following additional earthing and bonding requirements will apply:

a) The HV electrode shall be separated by sufficient below-ground distance from (i) LV earth electrodes, (ii) from buildings and enclosures supplied from the LV system, and (iii) from other specified installations[9], in order to ensure that the potential impressed on them in the event of a HV fault does not exceed safe limits, or limits for telecommunication equipment.

b) When required by the earthing design, a galvanised steel apron shall be laid in the substation compartment around the HV switchgear and HV Metering Unit and be bonded to the HV earth electrode.

4.5 Principal Requirements For The Customer's HV Earth Electrode

The Customer's HV earth electrode shall comply with the following principal requirements:[10]

a) The Customer's HV electrode shall have a resistance not greater than 20Ω for 11kV substations and 15Ω for 6.6kV substations. This resistance shall be determined solely by the customer's installed electrode system i.e. shall not include any parallel contribution from the WPD network. [11]

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

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[7] A conductive part which can be touched and which is not normally live, but which can become live under fault conditions, for example, light switch, electrical equipment enclosure, etc.

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

[9] Customer TT electrode, railway, tramway, telephone exchange, pipeline with cathodic protection, outdoor swimming pool, outdoor paddling pool, outdoor shower, zoo, stable, pond/lake used for commercial fishing, buried metalwork associated with the hazardous zone in a fuel filling station.

[10] Strictly speaking the IDNO is responsible for specifying the requirements for an IDNO Customer's HV Electrode since the Customer is connected to the IDNO network. However, these requirements shall be applied given that WPD's protection systems are required to detect and clear faults between the IDNO metering unit and the Customer's HV switchgear.

[11] This requirement is necessary in order to ensure that a fault on the Customer's HV equipment is able to be detected and cleared by WPD's protection systems in the event that interconnection between the WPD HV electrode and the Customer's HV electrode has been inadvertently lost.

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 earth bonds shall be insulated and laid in ducts for their entire length. This means they are clearly identifiable at the WPD substation and that periodic testing can be undertaken in order to check whether interconnection has been lost.

4.6 Additional Requirements For The WPD HV Earth Electrode At Two Interconnected RMU Sites

Where the supply to the HV Customer / IDNO is provided via two interconnected RMUs which are located more than 10m apart, then each RMU installation shall be treated as a separate standalone substation and the requirements of Sections 4.3, 4.4 and 4.5 shall apply in full to both.

Where the two interconnected RMUs are located 10m or less apart, then both RMU installations shall be treated as a single integrated substation. The requirements of Sections 4.3 and 4.4 shall apply in full to the first of the RMU installations, and the following additional requirements shall apply to the second RMU installation:

a) A single insulated earth bond with a minimum cross sectional area of 70mm^2 shall be provided between the two RMU HV electrode systems. [12]

b) All equipment / conductive parts within the substation compartment associated with the second RMU, excluding rebar but including the galvanised steel apron (where installed), shall be bonded to the HV earth electrode.

c) When the doors to the substation compartment associated with the second RMU are closed, there shall be no metal parts which are bonded to the HV earth electrode which can be touched from outside the compartment[13] [14].

d) When the doors to the substation compartment associated with the second RMU are open, 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[15] located outside of the compartment.

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[12] A single earth bond is required on the basis that the sheath of the HV cable which interconnects the two RMUs is solidly bonded at both ends. A second earth bond shall be provided in the event that this cable sheath is bonded at one end only.

[13] Earthed telecoms aerials/masts require special consideration, especially at 'hot' sites. They shall be positioned not less than 2.5m above ground level and not less than 2.5m away from any exposed conductive part or extraneous conductive part.

[14] The Freestanding GRP or masonry housing is an integral part of the arrangements for ensuring safety i.e. non-conductive material for the outer walls which prevents earthed metal parts from being touched from outside and extraneous conductive parts being touched from the inside. The HV Connection substation must not be energised with the housing missing or in a compromised state.

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

e) At 'Hot' sites, a galvanised steel apron in accordance with Section 4.4 b) above shall be provided on second RMU installation where required by the earthing design. The galvanised steel apron shall be bonded to the HV earth bar.

f) The requirements of Section 4.5 above shall apply to the Customer's HV earth electrode. One of the two bonds shall be connected to the first RMU installation, and the other shall be connected to the second RMU installation.

5.0 CONSTRUCTION DRAWINGS

This section contains the following drawings:

5.1 HV Earthing Arrangement

WPD Drawing Number TP21G-H Drg 1

5.2 HV Earthing Arrangement For Two Interconnected RMUs

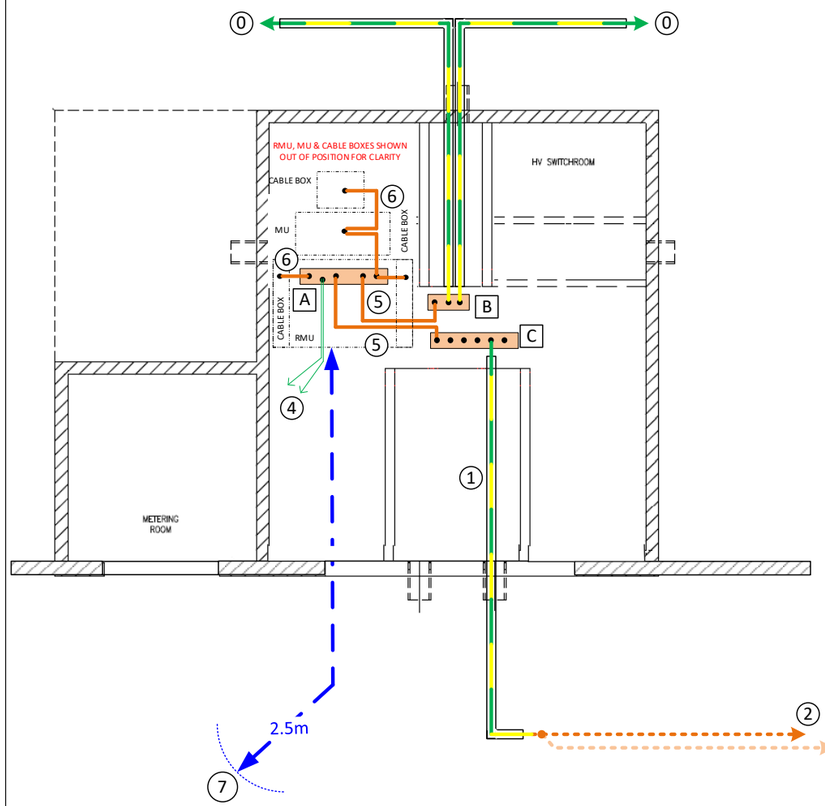
WPD Drawing Number TP21G-H Drg 2

5.3 HV Separation Distance

WPD Drawing Number TP21G-H Drg 3

5.4 Galvanised Steel Apron

WPD Drawing Number TP21G-H Drg 4



KEY

CABLE BOX	=	Cable Box - RMU or MU Mounted
MU	=	HV Metering Unit
RMU	=	Ring Main Unit
[A]	=	RMU / HV Switchgear Earth Bar
[B]	=	HV Customer Earth Bar
[C]	=	HV Earth Bar
(0)	=	Bonding Conductor Between WPD HV Electrode and Customer HV Electrode - 70mm^2 Insulated Stranded Copper Conductor – Two Continuous Lengths With Copper Compression Lug at WPD end – Laid On Diverse Routes and Bonded To Different Parts Of Customer HV Electrode
(1)	=	70mm^2 Insulated Stranded Copper Conductor Within Duct For Electrical Cable To Exterior Of Larger Building
(2)	=	70mm^2 Bare Stranded Copper Conductor To Achieve Electrode Resistance And/Or Surface Area Requirement
(3)	=	Conductor (6) Doubled / Trebled Up Where Necessary To Achieve Surface Area Requirement
(4)	=	16mm^2 Green / Yellow Insulated Stranded Copper Conductor To Metallic Fittings
(5)	=	70mm^2 Bare Stranded Copper Conductor With Copper Compression Lug On Each End
(6)	=	3x25mm^2 Copper Tape Connections To Earth Points On Plant Items & Cable Boxes
(7)	=	No extraneous conductive parts within 2.5m reach of any metalwork bonded to 'HV Earth' bar when doors to GRP housing are open

- See WPD Drawing Number TP21G-H Drg 2 for details of HV earthing arrangement for two interconnected RMUs
- See WPD Drawing Number TP21G-H Drg 3 for details of HV separation distance
- See WPD Drawing Number TP21G-G Drg 4 for details of galvanised steel apron

NOTES

- All items of plant to be bonded to the 'HV Earth' bar [C].
- Where metallic fittings are employed (for example, ventilation panels, door frames etc), these shall be bonded to the 'RMU / HV Switchgear Earth' bar using 16mm2, green/yellow PVC insulated, stranded copper conductor.
- Resistance of HV earth electrode to be less than 20Ω (11kV) or 15Ω (6.6kV) before WPD, IDNO & Customer HV cables and bonding conductor between WPD & Customer HV electrodes are connected.
- Electrode (2), and where necessary electrode (3), to be laid in direct contact with the soil and at a depth of 600mm. Conductor to be separated from any cable by not less than 150mm.
- Bonding conductors to Customer HV electrode to be laid in 38mm duct for electric cables for entire length.

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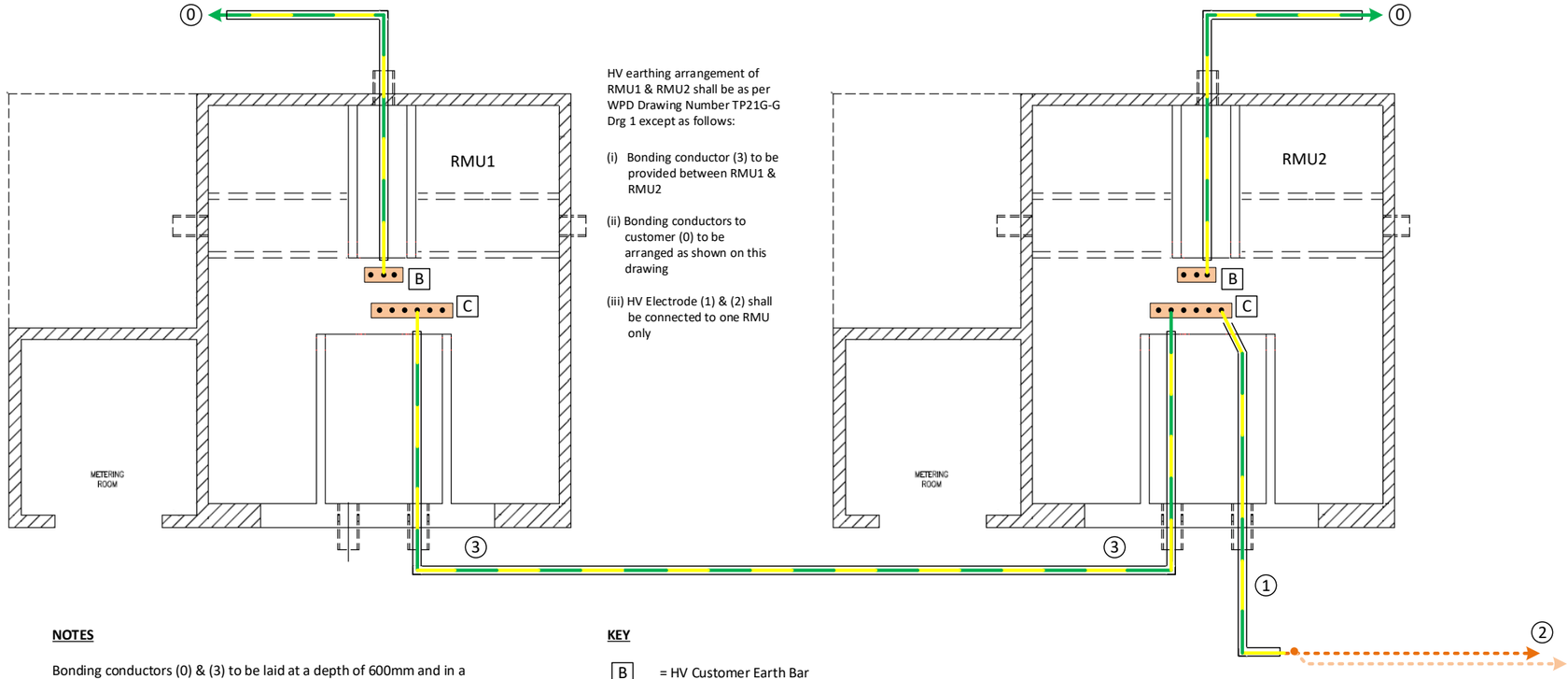
WESTERN POWER DISTRIBUTION

Title: HV Earthing Arrangement For HV Connection Substation Integrated Within A Larger Building

Drg. No.: TP21G-H Drg 1

Rev No.:



HV earthing arrangement of RMU1 & RMU2 shall be as per WPD Drawing Number TP21G-G Drg 1 except as follows:

(i) Bonding conductor (3) to be provided between RMU1 & RMU2

(ii) Bonding conductors to customer (0) to be arranged as shown on this drawing

(iii) HV Electrode (1) & (2) shall be connected to one RMU only

NOTES

Bonding conductors (0) & (3) to be laid at a depth of 600mm and in a 38mm duct for electric cables for their entire length.

Resistance of HV earth electrode to be less than 20Ω (11kV) or 15Ω (6.6kV) before any HV cable or the Customer bonding conductors are connected.

KEY

B = HV Customer Earth Bar

C = HV Earth Bar

0 = Bonding Conductor Between WPD HV Electrode and Customer HV Electrode

1 = Insulated Section Of HV Electrode

2 = Bare Section Of HV Electrode

3 = Bonding Conductor Between The Two WPD HV Electrodes

- See WPD Drawing Number TP21G-G Drg 1 for details of HV earthing arrangement
- See WPD Drawing Number TP21G-G Drg 3 for details of HV separation distance
- See WPD Drawing Number TP21G-G Drg 9 for details of galvanised steel apron

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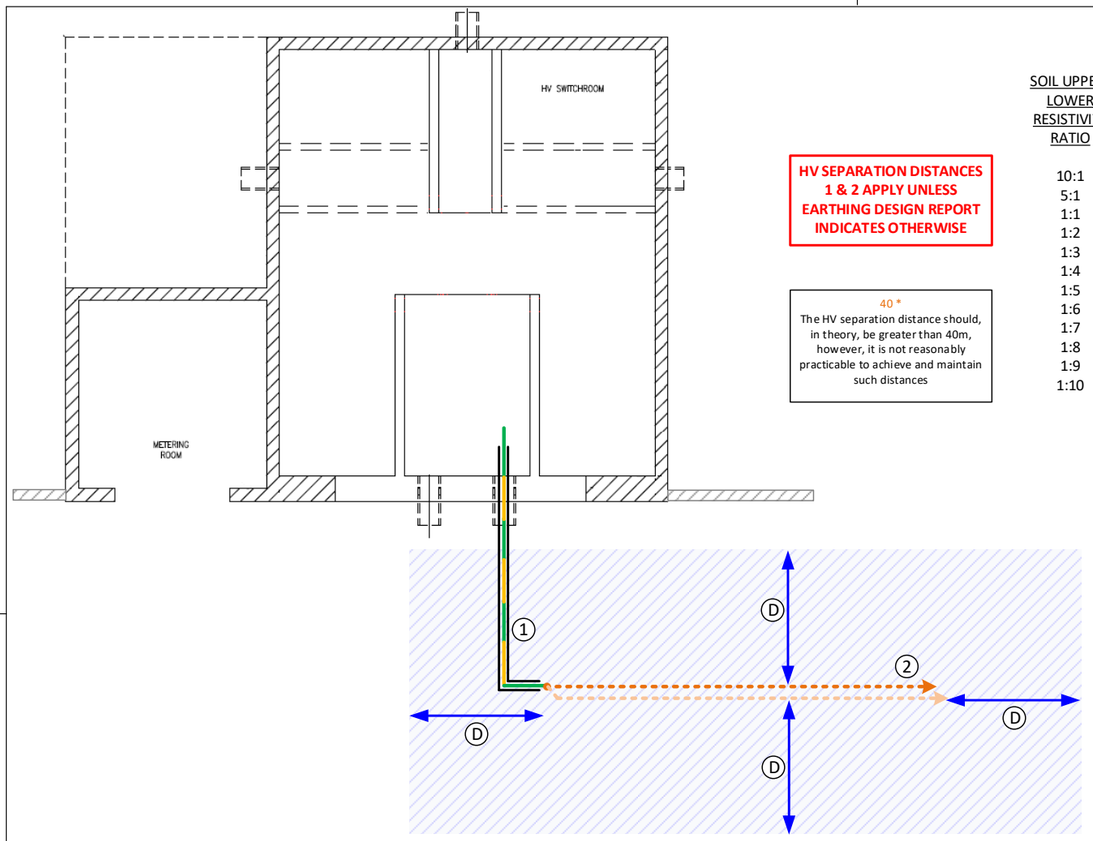
Title: HV Earthing Arrangement For Two Interconnected RMUs At HV Connection Substation Integrated Within A Larger Building

Drg. No.: TP21G-H Drg 2

Rev No.:



HV SEPARATION DISTANCES 1 & 2 APPLY UNLESS EARTHING DESIGN REPORT INDICATES OTHERWISE

40 *
The HV separation distance should, in theory, be greater than 40m, however, it is not reasonably practicable to achieve and maintain such distances

SOIL UPPER/ LOWER RESISTIVITY RATIO	HV SEPARATION DISTANCE 1 (m)				HV SEPARATION DISTANCE 2 (m)			
	EPR UPTO 500V	EPR UPTO 1000V	EPR UPTO 2000V	EPR UPTO 3000V	EPR UPTO 500V	EPR UPTO 1000V	EPR UPTO 2000V	EPR UPTO 3000V
10:1	3	3	4	6	3	4	8	12
5:1	3	3	4	6	3	4	8	12
1:1	3	4	8	14	4	8	18	28
1:2	3	6	14	22	6	14	28	40 *
1:3	3	8	18	28	8	18	36	40 *
1:4	3	8	20	32	8	20	40 *	40 *
1:5	3	10	24	38	10	24	40 *	40 *
1:6	3	10	26	40 *	10	26	40 *	40 *
1:7	3	12	30	40 *	12	28	40 *	40 *
1:8	4	12	32	40 *	12	32	40 *	40 *
1:9	4	14	34	40 *	14	34	40 *	40 *
1:10	4	14	36	40 *	14	36	40 *	40 *

NOT PERMITTED WITHIN HV SEPARATION DISTANCE 1:

(1) WPD multiply-earthed LV system (i.e. CNE or SNE derived from CNE) along with buildings and enclosures equipped with an electrical system supplied from this system. This includes any part of bare LV earth electrode, LV PILC / PILCSWA cable, PME electrodes, LV joint electrodes (including stop ends)

NOT PERMITTED WITHIN HV SEPARATION DISTANCE 2:

(1) Railway or tramway

(2) Telephone exchange

(3) Pipeline

(4) Zoo, stable or pond/lake used for commercial fishing

(5) Outdoor swimming pool, outdoor paddling pool or outdoor shower

(6) Customer TT electrode

(7) Buried metalwork associated with hazardous zone in fuel filling station

(7) WPD single-point-earthed LV system (i.e. pure SNE) along with buildings and enclosures equipped with an electrical system supplied from this system. This includes any part of bare LV earth electrode and LV PILC / PILCSWA cable)

KEY

(1) = Insulated & Ducted Section Of HV Electrode

(2) = Bare Section Of HV Electrode

(D) = HV Separation Distance 1 or 2

- See WPD Drawing Number TP21G-H Drg 1 for details of HV earthing arrangement
- See WPD Drawing Number TP21G-H Drg 2 for details of HV earthing arrangement for two interconnected RMUs
- See WPD Drawing Number TP21G-H Drg 4 for details of galvanised steel apron

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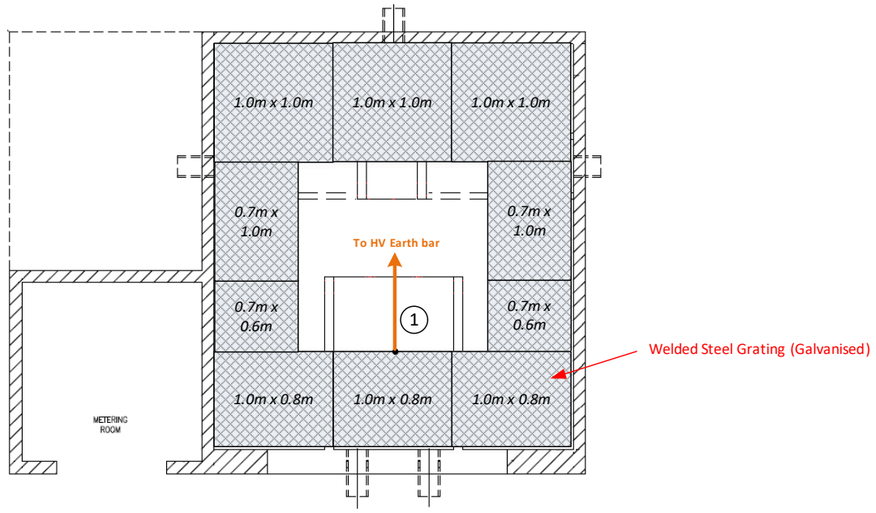
Title: HV Separation Distance For An HV Connection Substation Integrated Within A Larger Building

Drg. No.: TP21G-H Drg 3

Rev No.: 0



- See WPD Drawing Number TP21G-H Drg 1 for details of HV earthing arrangement
- See WPD Drawing Number TP21G-H Drg 2 for details of HV earthing arrangement for two interconnected RMUs
- See WPD Drawing Number TP21G-H Drg 3 for details of HV separation distance

NOTES

Galvanised steel apron to be installed only when required by earthing design .

Gratings to be bolted together using five stainless steel fixings per side (comprising nut , bolt, two plain washers & spring washer). Mating surfaces of grating to be smeared with contact grease prior to bolting together .

70mm^2 bare stranded copper conductor with copper compression lug on each end to be connected between 'HV Earth' bar and the grating immediately below the HV ring main unit .

Under no circumstances shall the grating be accessible by anyone outside the substation compartment when the compartment doors are closed .

(1) = 70mm^2 Bare Stranded Copper Conductor With Copper Compression Lug On Each End

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WESTERN POWER DISTRIBUTION

Title: Galvanised Steel Apron For HV Connection Substation Integrated Within A Larger Building

Drg. No.: TP21G-H Drg 4

Rev No.: 0

6.0 CONSTRUCTION REQUIREMENTS

6.1 Preamble

This section should be read in conjunction with the construction drawings in Section 5.0 and the following documents:

- Standard Technique NC1V: Standard Foundation and Enclosure Details and Specifications for HV Substation Plant. [16]
- Engineering Equipment Specification 132: Earthing Materials and Associated Sundry Items

6.2 Common Construction Requirements

The earthing system for a HV Connection substation integrated within a larger building shall comply with the following common construction requirements.

6.2.1 HV Electrode System

The location of the HV electrode system shall comply with the HV Separation distance requirement.

The HV electrode system shall minimise the number of below ground, and maximise the number of above ground, joints and connections in order to facilitate joint resistance measurements during planned routine maintenance of the earthing system.

6.2.1.1 'HV Earth' Bar

A 'HV Earth' bar shall be provided directly above the cable trough for the incoming WPD HV cables.

The earth bar shall be mounted above floor level on the HV switchgear or supporting steelwork. Its location shall not restrict access to the HV cables or other equipment, nor interfere with the opening of any of the equipment doors.

The earth bar shall be manufactured from copper, have a cross section of not less than 50mm x 6mm, and be provided with six M10 studs at 50mm centres for the connection of cable lugs associated with the HV electrode system.

[16] The earthing arrangements are based around drawings EKV0017, EKV018, EKV0020, EKV021, EKV0091, EKV0092 and EKV0093.

6.2.1.2 'HV Customer' Earth Bar

A 'HV Customer' earth bar shall be provided directly above the cable trough for the outgoing cable to the HV Customer.

The earth bar shall be mounted above floor level on the HV switchgear or supporting steelwork. Its location shall not restrict access to the HV cables or other equipment, nor interfere with the opening of any of the equipment doors.

The earth bar shall be manufactured from copper, have a cross section of not less than 50mm x 6mm, and be provided with three M10 studs at 50mm centres for the connection of cable lugs associated with the bonding conductors to the Customer's HV electrode system.

6.2.1.3 Insulated Section Of HV Electrode

A single continuous length of 70mm^2 insulated, stranded, copper conductor shall be connected to the HV Earth bar and laid radially away from the 'HV Connection' substation until it is outside the building and in the surrounding soil.

The insulated conductor shall be laid for its entire length in a 38mm diameter, Class 3, general purpose duct for buried electric cables (see Engineering Equipment Specification 113 for further details).

The insulated conductor and the duct shall be buried at a depth of 600mm (1000mm in arable land) when it is located within the soil.

6.2.1.4 Bare Section Of HV Electrode

A single continuous length of 70mm^2 bare, stranded, copper conductor shall be exothermically welded or 'C' crimped to the end of the insulated conductor at one end, and laid radially away from the 'HV Connection' substation for the requisite distance in direct contact with soil at a depth of 600mm (1000mmm in arable land). The requisite distance shall never be less than 20m.

Where the bare HV electrode is laid in the same trench as a cable, the bare conductor shall be laid not less than 150mm away from the cable.

When required by the earthing design, the bare section of HV electrode shall be doubled-up or trebled-up by laying additional lengths of 70mm^2 bare, stranded, hard-drawn copper conductor in parallel with it. These extra conductors shall be laid 100mm away from the HV electrode and be 'C' crimped onto it adjacent to the start of the bare section.

6.2.2 Rebar

No connection shall be provided between the HV Earth bar and the foundation rebar.

6.2.3 HV Cables & Cable Boxes

All HV cable sheaths / screen wires shall be connected to the HV Earth bar, as shown in Figure 1 below. The bonding conductor shall have a cross sectional area not less than 70mm^2.

Where a HV cable passes through an earth fault passage indicator (EFI) CT, the cable sheath / screen wires for that cable shall be brought back through the CT before being connected to the RMU / HV switchgear earth bar.

It is not acceptable for HV cable sheaths / screen wires to be directly connected to the cable box and rely on a fortuitous connection to the HV earth electrode system.

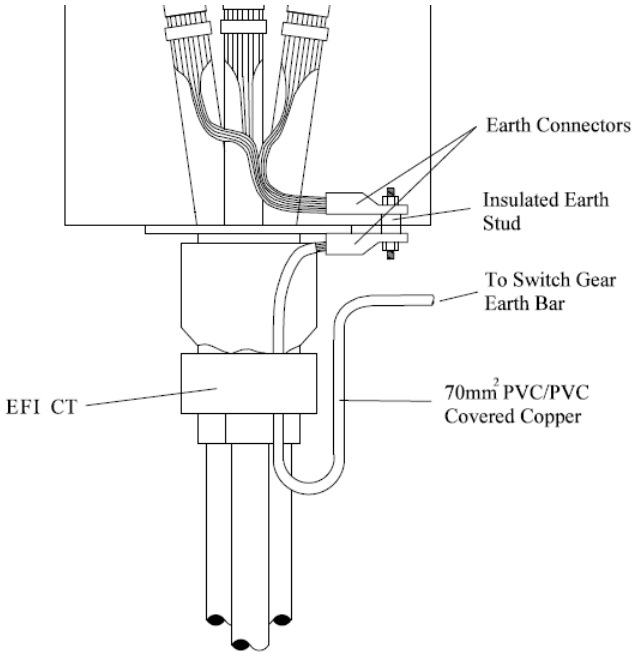


Figure 1: HV Cable Sheath Bonding Arrangement

6.2.4 HV Switchgear (RMU)

The RMU / HV switchgear earth bar shall be bonded to the HV Earth Bar. The bonding conductors shall have a cross sectional area not less than 70mm^2.

6.2.5 HV Metering Unit

The HV Metering Unit earth terminal shall be bonded to the HV Earth bar. The bonding conductors shall have a cross sectional area not less than 70mm^2.

6.2.6 Other Metal Boxes / Cabinets Within The GRP Or Masonry Housing

6.2.6.1 Metal Boxes / Cabinets Mounted On HV Switchgear Or Metering Unit

Metal boxes or cabinets which are bolted to the RMU / HV switchgear or Metering Unit are effectively bonded to the HV earth electrode via the equipment they are mounted on. Consequently there is no requirement to provide a discrete bonding cable between the metal box/cabinet and HV Earth Bar.

6.2.6.2 Freestanding Metal Boxes / Cabinets

Metal boxes or cabinets which are freestanding shall be bonded to HV Earth Bar using a minimum of 16mm^2 insulated stranded copper cable.

6.2.7 Substation Compartment

The walls and doors of the substation compartment shall be electrically non-conductive.

Small metallic parts that form part of the substation compartment do not need to be bonded to HV Earth Bar.

When the doors to the substation compartment are closed it shall not be possible, from a position outside the substation compartment, to touch any metal parts which are bonded to HV Earth Bar.

6.2.8 Extraneous Conductive Parts Located Outside Of The Substation Compartment

When the doors to the substation compartment are open, there shall be a minimum above ground separation of at least 2.5m between any metallic part which is bonded to HV Earth Bar and any extraneous conductive part[17] located outside of the substation compartment.

6.3 Additional Construction Requirements For 'Cold' Sites

The earthing system shall comply with the following additional construction requirements where the HV Connection substation is a 'cold' site:

6.3.1 Substation LV Auxiliary Power Supplies

Unless otherwise agreed with WPD, the HV Customer normally provides WPD with a 230V supply from its installation.

At 'cold' sites the LV auxiliary supply for the HV Connection substation (e.g. for lighting, sockets, etc.) may be derived directly from the Customer's LV installation.

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

6.4 Additional Construction Requirements For 'Hot' Sites

The earthing system shall comply with the following additional construction requirements where the HV Connection substation is a 'hot' site:

6.4.1 Galvanised Steel Apron

When required by the earthing design, a galvanised steel 'apron' shall be provided around the HV switchgear and Metering Unit inside the substation compartment. [18]

The apron shall consist of a number of galvanised steel gratings bolted together such that they extend not less than 1m away from any metalwork which is bonded to the HV steelwork earth bar.

The gratings shall be bolted together using five stainless steel fixings per side (comprising nut, bolt, two plain washers & spring washer). Mating surfaces of the gratings shall be smeared with contact grease prior to bolting together.

A length of 70mm^2 bare stranded copper conductor with a copper compression lug on each end shall be connected between the HV earth bar and the grating immediately below the HV ring main unit.

6.4.2 Substation LV Auxiliary Power Supplies

Unless otherwise agreed with WPD, the HV Customer normally provides WPD with a 230V supply from its LV installation.

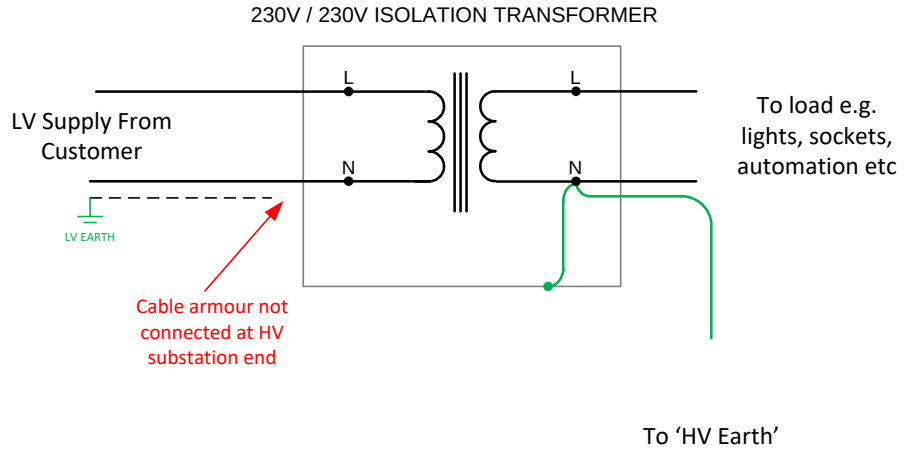
At 'hot' sites the LV auxiliary supply for the HV Connection substation (e.g. for lighting, sockets, etc.) shall not be derived directly from the Customer's LV installation where the Customer employs segregated HV & LV earth electrodes, but indirectly via a 230V/230V isolation transformer, as shown in Figure 3 below.

The isolating transformer shall be capable of providing 7kV galvanic isolation between its primary and secondary windings in order to ensure HV and LV earthing systems are segregated.

The isolating transformer shall have a VA rating in excess of the maximum anticipated LV auxiliary supply load. Standard values used by WPD include 500VA (2A), 3.7kVA (16A) and 7.4kVA (32A).

[18] Substation compartments generally have more than 1m between the HV switchgear, metering unit and the walls and doors (drawings EKV0018). A 1m deep apron will be wholly contained within the housing and consequently may be made from either an insulating or conductive material. A galvanised steel apron is considered to be the most practical.

The armouring / protective conductor associated with the LV supply cable shall not be connected to earth at the HV Connection substation end, for example, by the use of isolation glands or by terminating the cable onto a non-conducting gland plate. Suitable precautions shall be taken to prevent the armouring / gland from being touched due to the hazard of transfer potentials.



Note: Fuses, Links, RCDs etc not shown for clarity

Figure 2: Isolation Transformer Arrangement

6.4.3 HV Metering

Only non-metallic remote meter cabinets shall be employed.

Where the HV Customer elects to ensure safety on its LV installation by segregating its HV & LV earth electrodes, the earthing implications of any cabling which enters/exists the area enclosed by the WPD and Customer HV electrodes needs to be considered carefully.

Where the HV Customer requires access to meter pulses and the signal cable is to be taken outside of the area enclosed by the WPD and Customer HV electrode, the armouring and screen wires associated with the signalling cable shall be connected to earth at one end only. Suitable precautions shall be taken to prevent the armouring and screen wires from being touched at the unearthed end due to the hazard of transfer potentials.

Where the remote meter cabinet is to be located outside the area enclosed by the WPD or Customer HV electrode, the armouring associated with the cable from the HV metering unit shall be connected to earth at one end only. Suitable precautions shall be taken to prevent the armouring from being touched at the unearthed end due to the hazard of transferred potentials. [19]

[19] Note that the metering CT and VT secondary circuits will be earthed via the HV earth electrode and hence there will be a transfer potential hazard whenever the secondary circuits are being worked upon.

6.4.4 HV Customer Interface Cabling

Where the HV Customer elects to ensure safety on its LV installation by segregating its HV & LV earth electrodes, the earthing implications of any cabling which enters/exists the area enclosed by the WPD and Customer HV electrodes needs to be considered carefully.

Where the interface cabling connects to plant or apparatus located outside the area enclosed by the WPD or Customer HV electrode, the armouring associated with the cable shall be connected to earth at one end only. Suitable precautions shall be taken to prevent the armouring from being touched at the unearthed end due to the hazard of transferred potentials.

6.4.5 HV Customer's LV Earth Electrodes

Where the HV Customer elects to ensure safety on its LV installation by segregating its HV & LV earth electrodes, then no uninsulated part of the Customer's LV earth electrode shall be located closer than the HV separation distance to any part of the bare HV earth electrode of the HV Connection substation.

In the event the HV Customer employs TT earth electrodes on part of its LV installation, then no TT earth electrode shall be located closer to any part of the HV earth electrode than the HV separation distance.

6.4.6 Other LV Electrode Systems

6.4.6.1 Substation LV Electrodes

In the event that another HV/LV substation is located within the neighbourhood of the HV Connection substation, then no uninsulated part of a separate LV earth electrode or combined HV & LV electrode shall be located closer than the HV separation distance to any part of the bare HV earth electrode of the HV Connection substation.

6.4.6.2 Network LV Electrodes

In the event that the WPD LV network is located within the neighbourhood of the HV Connection substation, then no part of the following items shall be located closer than the HV separation distance to any part of the bare HV earth electrode of the HV Connection substation:

- PME electrodes
- LV PILC cable
- LV Joints

<u>Guidance Note</u>
Note that LV joints which do not have an associated earth electrode would be acceptable within the HV separation distance. However, the option to omit the earth electrode does not currently feature in WPD LV Jointing Procedures.

6.4.6.3 Other Customer LV Electrodes

In the event that another customer is located in the neighbourhood of the HV Connection substation, then no LV earth electrodes associated with that other customer (for example, TT electrodes) shall be located closer than the HV separation distance to any part of the bare HV earth electrode of the HV Connection substation.

6.5 Construction Requirements For The Customer's HV Electrode

The WPD HV electrode and the Customer HV electrode shall be interconnected with two insulated earth bonds, each with a minimum cross sectional area of 70mm^2.

At the WPD substation end, the earth bonds shall be connected to the 'HV Customer' earth bar.

The insulated conductors shall be laid for their entire length in separate 38mm diameter, Class 3, general purpose ducts for buried electric cables (see Engineering Equipment Specification 113 for further details) and at a depth of 600mm.

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.

6.6 Additional Construction Requirements For Two RMU Type Connections

The HV electrodes associated with the two RMUs shall be interconnected with an insulated earth bond with a minimum cross sectional area of 70mm^2.

The earth bond shall be connected to the 'HV Earth' bar.

The insulated conductor shall be laid for its entire length in separate 38mm diameter, Class 3, general purpose ducts for buried electric cables (see Engineering Equipment Specification 113 for further details) and at a depth of 600mm (1000mm in arable land).

7.0 COMMISSIONING REQUIREMENTS

The earthing system associated with HV Connection substation shall be commissioned in accordance with Standard Technique TP21T-A: Commissioning of Earthing Systems: Part A: Ground-Mounted Secondary System Substations.

The commissioning tests shall include the following:

a. The resistance of the complete WPD HV electrode shall be measured prior to the connection of (i) any WPD HV cable, (ii) any Customer/IDNO HV cable, or (iii) any earth bond between the WPD and Customer HV electrodes. For 11kV substations the measured resistance shall be 20 ohms or less, and for 6.6kV substations the measured resistance shall be 15 ohms or less.

b. The resistance of the complete Customer HV electrode shall be measured prior to the connection of (i) the Customer HV cable, or (ii) any earth bond between the WPD and Customer HV electrodes. For 11kV substations the measured resistance shall be 20 ohms or less, and for 6.6kV substations the measured resistance shall be 15 ohms or less.

c. The resistance of the complete HV electrode shall be measured again once all HV cables and earth bonds have been connected to the HV Connection substation. The measured resistance shall be not greater than the calculated design value for the substation.

Electrode resistance measurements shall be carried out in accordance with Standard Technique TP21O-B: Earthing System Measurements: Part B: Electrode Resistance.

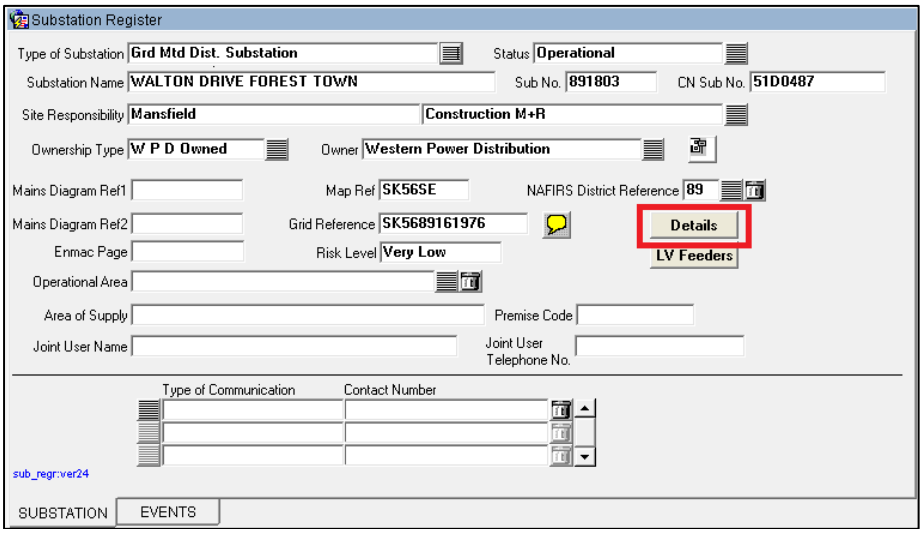
8.0 RECORDS

8.1 CROWN Records

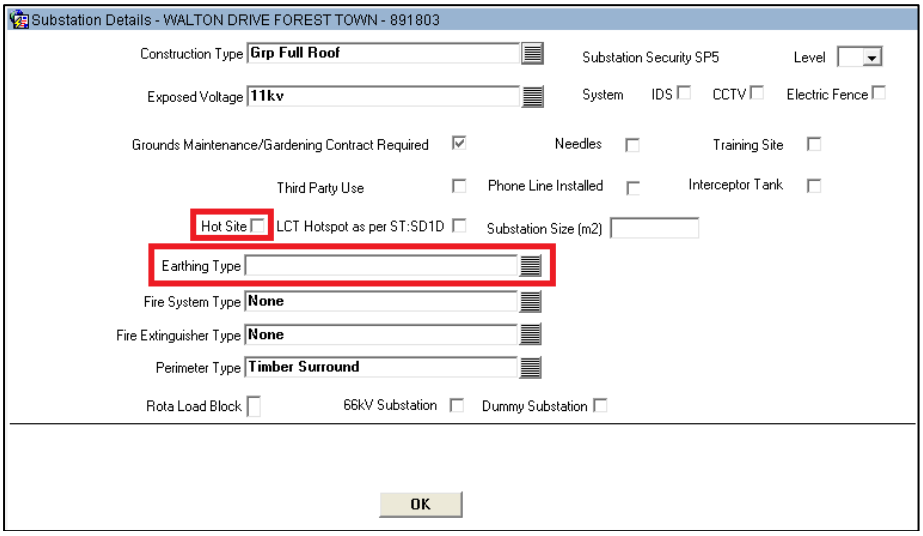
A copy of the 'Earthing Design Report' for the HV Connection substation shall be included within 'DOCS' against the 'Commission' event for the Substation Register, following the process shown below:

a) In CROWN select 'Asset Management' and then 'Substations'. Click on 'Action' and then 'Find'. Search for the HV Connection substation.

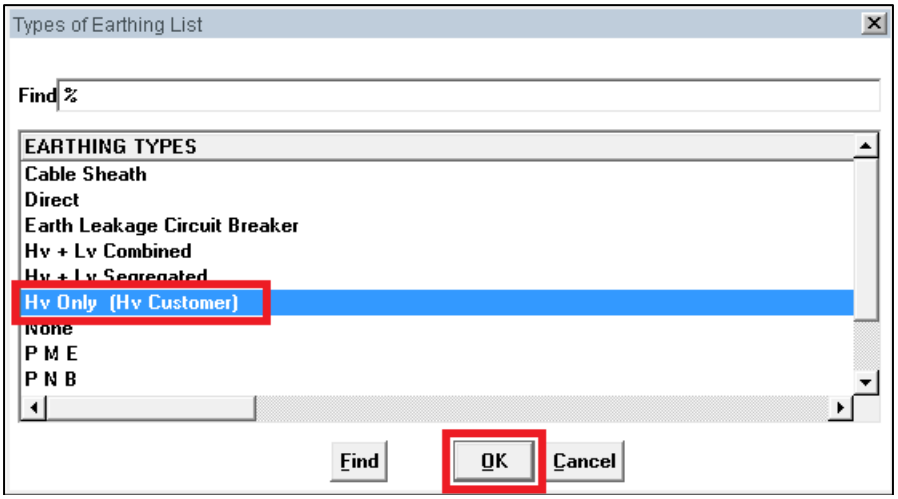
b) On the 'Substation Register' for the site and click on the 'Details' button.



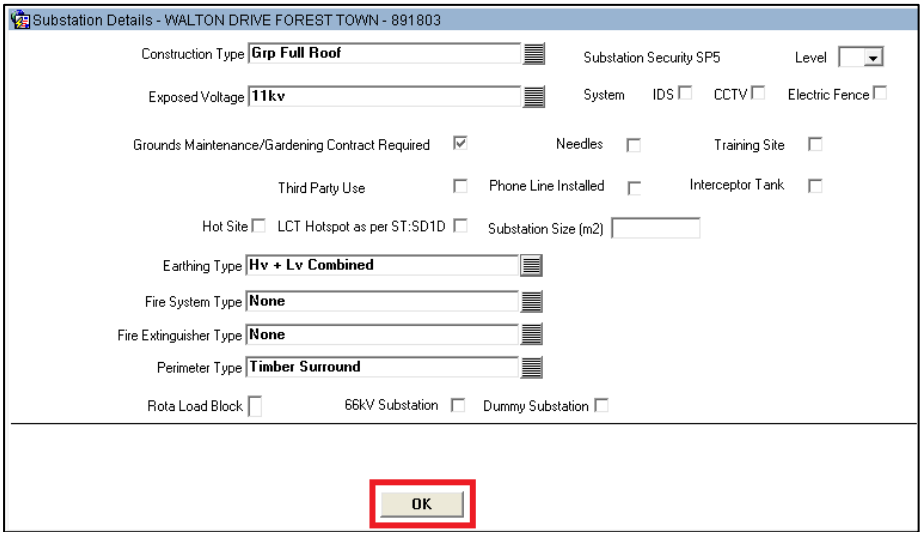
c) Check the 'Hot Site' box (where applicable). Click on the list of values (LOV) adjacent to 'Earthing type'.



d) Select ‘Hv Only (HV Customer)’ from the drop down list and click ‘OK’.

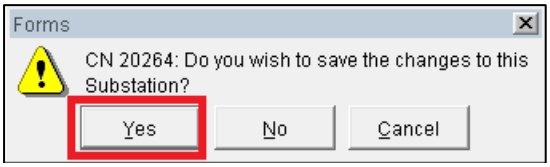


e) Click ‘OK’.

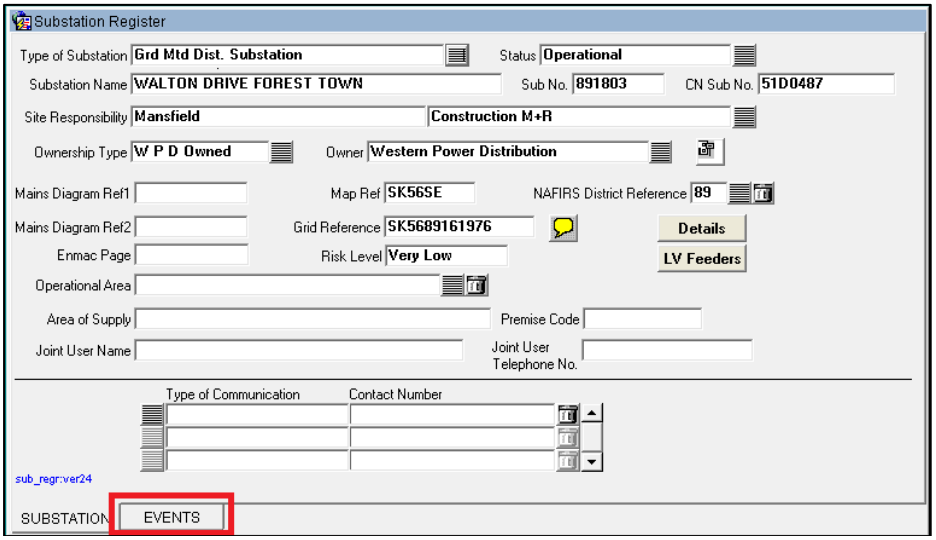


f) Click ‘Action’ and then ‘Save’.

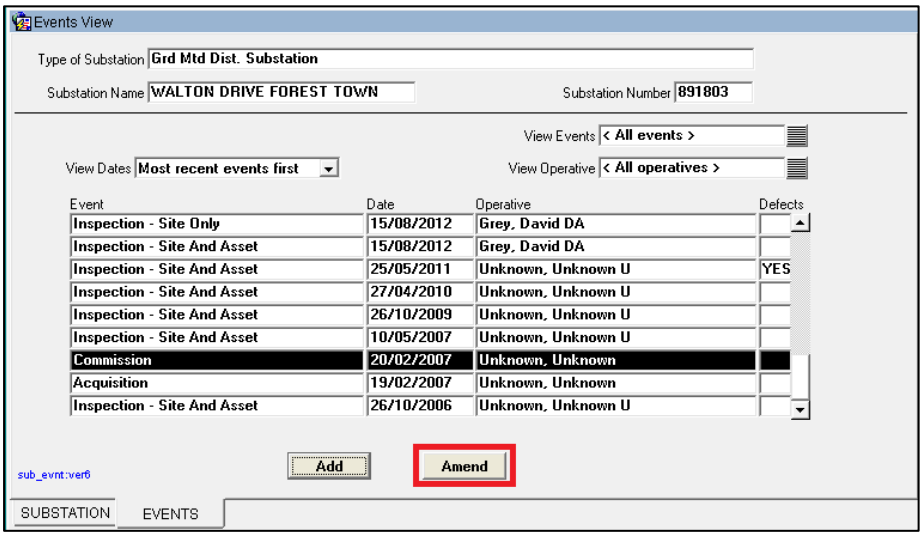
g) Click ‘Yes’ to confirm.



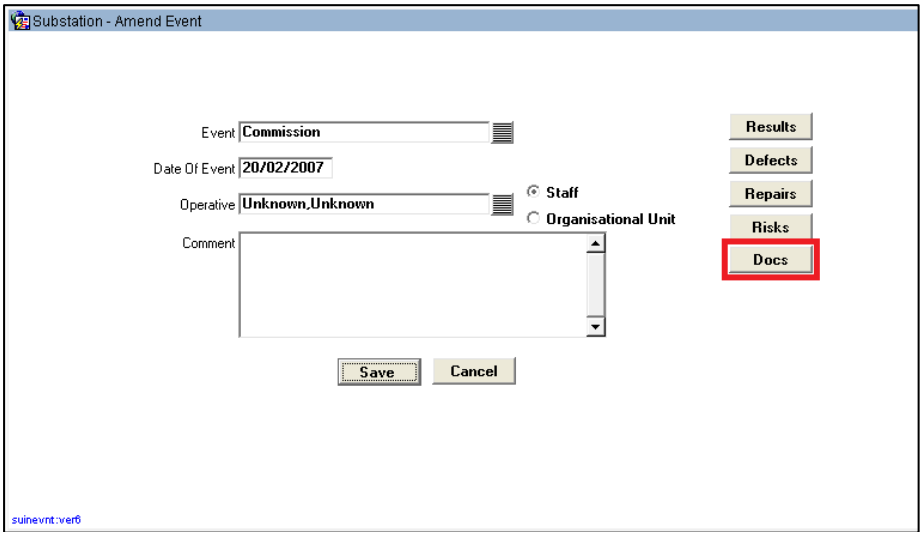
h) Click on the ‘events’ tab



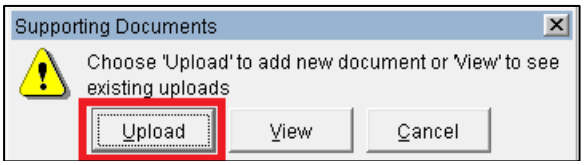
i) Select the ‘Commission’ event and click on the ‘Amend’ button



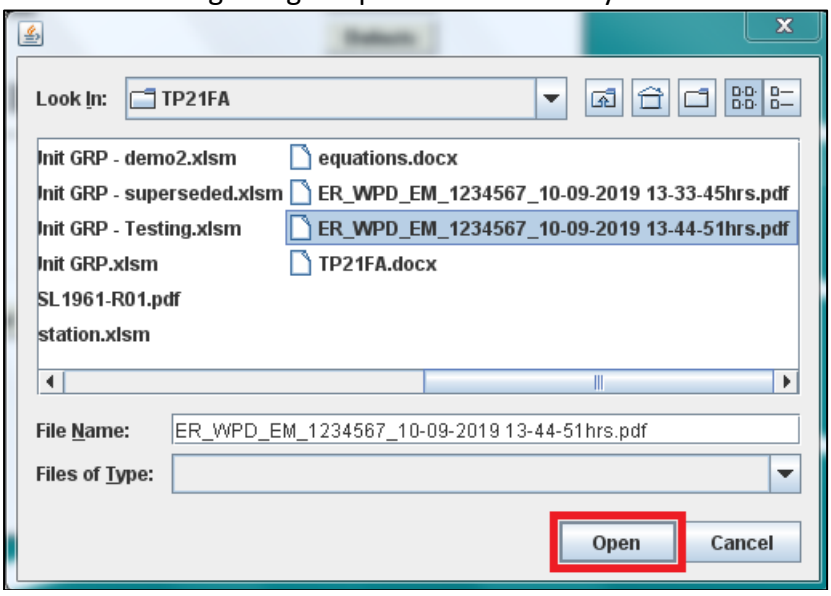
j) Click on the ‘Docs’ button



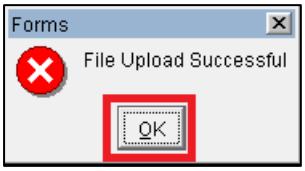
k) Click on the ‘Upload’ button



l) Find the Earthing Design Report in the folder system and click on the ‘Open’ button



m) Click ‘OK’ button to acknowledge.



8.2 EMU Records

The route of the HV earth electrode shall be recorded in EMU using the same methodology employed for cables.

The following information shall be recorded immediately adjacent to the HV earth electrode:

- The ‘as commissioned’ resistance of the complete HV electrode system prior to the connection of any HV cable onto the unit substation.
- The HV separation distance

APPENDIX A

SUPERSEDED DOCUMENTATION

This document supersedes parts of Standard Technique TP21D/3.

APPENDIX B

RECORD OF COMMENT DURING CONSULTATION

Comments Received

APPENDIX C

ANCILLARY DOCUMENTATION

POL: TP21 Fixed Earthing Systems

APPENDIX D

KEY WORDS

Design; Standard; Earthing; Distribution; Substation; Ground; Mounted; Building; Larger; Integrated; HV; Connection; Customer.