1. SCOPE

This Safety Instruction applies the principles established by the ScottishPower Safety Rules (Electrical and Mechanical) and the **Company** Safety Instructions to achieve **Safety from the System** for personnel working or testing on ***High Voltage*** *Direct Current* *(**HV**DC)* **Plant** and **Apparatus**.

Persons when working or testing on ***HV****DC* **Apparatus** within the scope of this document shall be authorised specifically for the **Location** where the **Apparatus** is installed or be under **Supervision** from an **Authorised Person** holding an appropriate standby authorisation for the **Location**.

This document covers the following:

- **Safety Distance(s)** for approach to ***HV****DC* **Apparatus**
- Access to ***HV****DC* **Apparatus** within a ***HV****DC Converter Station*
- Work or testing on ***HV****DC* **Apparatus** within a ***HV****DC Converter Station*
- Work or testing on ***HV****DC* cables including *Marine Cables*
- Specific **Switching** instructions for an ***HV****DC* ***System***
- Main auxiliary systems critical to the operation of the ***HV****DC* ***System***

This Safety Instruction addresses specific **Dangers** associated with ***HV****DC* **Apparatus** and related systems. This does not negate any need for compliance with the existing ScottishPower Safety Rules (Electrical and Mechanical), the **Company** Safety Instructions or other PSSIs unless explicitly stated.

2. ISSUE RECORD

This is a Reference document. The current version is held on the EN Document Library.

It is your responsibility to ensure you work to the current version.

Issue Date	Issue No.	Author	Amendment Details
02/12/2016	1	Dave Naylor, Stephen Olson, Willie Falconer	Initial issue
06/08/2020	2	Dave Naylor	Update following usage of issue 1. Angle-DC application added. *Marine Cable* working added.

3. ISSUE AUTHORITY

Author	Owner	Issue Authority
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4. REVIEW

This is a Reference document which has a 5 year retention period after which a reminder will be issued to review and extend retention or archive.

5. DISTRIBUTION

This Energy Networks' Safety Instruction is maintained by EN Document Control and is part of the ScottishPower Safety Rules which is published to the SP Energy Networks Internet site.

6. CONTENTS

7. DEFINITIONS

Terms printed in bold type are as defined in the ScottishPower Safety Rules (Electrical and Mechanical). For the purpose of this Safety Instruction the following definitions apply:

Pole	Part of an ***HV****DC* **System** consisting of all the **Apparatus** in the ***HV****DC Converter Stations* and the interconnecting circuits which during normal operation are at a common direct voltage polarity to earth.
Bipole	Two *Poles* connected such that they operate together as one energy transfer unit. Normally consists of two poles having opposing direct voltages with respect to earth.
Cable*:*	
Marine Cable	An ***HV****DC* cable buried in a riverbed or seabed, requiring specialist marine access/working techniques, personnel and/or equipment.
Land Cable	Any other type of ***HV****DC* cable, installed in any position.
	The boundary between a *Marine Cable* and a *Land Cable* shall be taken to be a designated transition joint, or another point as specified in an **Approved** procedure.
Converter Unit	Operative unit comprising *Valves*, converter transformer(s), control and protection equipment, **Switching** devices and auxiliaries used for conversion between AC and DC.
DC Current Measuring Device	This equipment uses laser light technology to read the voltage across a known resistance (shunt) in the ***HV****DC* circuit.
DC Voltage Divider	Devices used to measure the voltage of a ***HV****DC* circuit. They may include capacitors, resistors and/or laser light technology.
DC Hall (DC Area / DC Compound)	Room or **Location** in which DC **Apparatus** associated with the ***HV****DC Converter Station* is located.
Heating, Ventilation and Air Conditioning (H-VAC)	Equipment used to control the air temperature within a building (e.g. *Valve Hall* or *DC Hall*) and can also create a pressure differential within that building with respect to atmospheric pressure. (N.B. in a *Valve Hall* positive pressure is used to limit dust ingress into the *Valve Hall*).
HV*DC*	***High Voltage*** *Direct Current.*
HV*DC Converter Station*	Part of a ***HV****DC* ***System*** which consists of one or more *Converter Unit*s installed in a single **Location** together with buildings, reactors, filters, reactive power supply, control, monitoring, protective, measuring and auxiliary **Plant** and **Apparatus**.
HV*DC* ***System***	**Apparatus** which transfers energy in the form of ***High Voltage*** *Direct Current* (***HV****DC*) between two or more alternating current buses.
DC Neutral Bus	A conductor connecting the neutral terminals of two poles.

PLCF (Power Line Carrier Filter)	A device that may be used to impose and/or block a high frequency signal onto a conductor which can then be used for communications between ***HV****DC Converter Stations*.
Valve	Device used for conversion which is connected between an AC terminal and a DC terminal.
Valve Hall	Restricted room or **Location** in which the *Valves* are located.
Valve Cooling Equipment	The means by which heat is transferred from the ***HV****DC Valve*s to atmosphere to maintain the ***HV****DC Valve*s within their operating temperature limits. This may comprise a closed loop liquid cooling system or other system.

8. PLANT & APPARATUS IDENTIFICATION

Plant and **Apparatus** on which work or testing is to be carried out shall be readily identifiable or have fixed to it a means of identification which will remain effective throughout the course of the work or testing.

9. DANGERS

The main **Dangers** when working or testing on ***HV****DC* **Apparatus** and their associated components are electric shock, burns and / or other injuries arising from:

- Inadvertently infringing **Safety Distance**.
- The mistaking of **Apparatus** on which it is unsafe to work, from that which it is safe to work.
- Inadequate precautions, or security of those precautions, to suppress or safely discharge stored, impressed or induced electrical energy.
- Inadequate precautions, or security of those precautions, to suppress or safely discharge stored mechanical energy.
- Inadequate precautions, or security of those precautions, to suppress or safely discharge pressurised cooling systems.
- Contact with electrical test supplies at dangerous voltages / energy levels.
- Contact with an unearthed **System**.
- Inadequate precautions against laser light sources e.g. fibre optic light signals.
- Inadvertent access to **Apparatus**, such as air core reactors, that are **Live** and generating high magnetic fields.
- Contact with **Plant** or **Apparatus** that may be at a harmful temperature.
- Specific **Dangers** arising from work or testing on *H-VAC* are:
    - Positive or negative differential air pressure across access doors and hatches
    - Rotating **Plant**
    - Heater elements
    - Confined spaces
    - Sources of **Low Voltage** electrical energy
- Working in a marine / offshore environment

Work or testing on ***HV****DC* overhead lines (section 13 of this Safety Instruction) shall be carried out in compliance with OPSAF-10-004 (PSSI 4), OPSAF-10-016 (PSSI 16), or another **Approved** procedure. Specific **Dangers** are listed in those documents.

10. APPROACH TO EXPOSED *HVDC* CONDUCTORS AND INSULATORS

10.1 Objects

When exposed ***HV****DC* conductors are not **Isolated**, the only objects which shall be caused to approach them, or insulators supporting them, within the **Safety Distance(s)** specified in section 10.3 for the appropriate **Location,** shall be **Approved** measuring devices or insulated devices.

When exposed ***HV****DC* conductors are **Isolated** but could be subject to **High Voltage**, the only objects which shall be caused to approach them, or insulators supporting them, within the **Safety Distance(s)** specified in section 10.3 for the appropriate **Location,** shall be **Approved** measuring devices, insulated devices, discharge devices or **Earthing Devices**.

10.2 Persons

Persons shall not allow any part of their body to approach ***HV****DC* conductors designed for, and operated at, **High Voltage**, or insulators supporting such conductors, within the **Safety Distances** specified in section 10.3 for the appropriate **Location**, unless the conductors have been **Isolated**, **Earthed** and **Danger** has been excluded.

10.3 Safety Distance(s)

The nature of ***HV****DC* **Apparatus** dictates that there may be multiple **Safety Distances** applicable and these are specific to each **Location**. Refer to Appendix A for further detail on the derivation of **Safety Distance**.

Location	***HV****DC* **Safety Distance** (metres)		***DC Neutral Bus*** **Safety Distance** (metres)
Hunterston ***HV****DC* *Converter Station*	**Apparatus** on the *Valve* side of (and including) the DC Smoothing Reactor	**Apparatus** on the line side of (and excluding) the DC Smoothing Reactor	0.8
	5.1	4.4	
Angle-DC ***HV****DC*	*All* ***HV****DC* ***Apparatus*** **Safety Distance** (metres)		
	0.8		

A distance of 300mm shall also be maintained from that part of the insulators supporting exposed unearthed **High Voltage** conductors which are outside the appropriate **Safety Distance**.

10.4 Application of Safety Distance to *HVDC* Bypass Circuits

Some ***HV****DC* Bypass Circuits comprise **Apparatus** of different rated voltages which are connected together.

Those conductors which directly connect *DC Neutral Bus* switchgear to ***HV****DC* switchgear shall be treated as *DC Neutral Bus* conductors. The **Safety Distance** to be applied relates to the design voltage of the **Apparatus** itself, not its configured running voltage, see diagrams below for guidance.

The following diagrams indicate the application of **Safety Distance(s)** for different **Apparatus** layouts.

Diagram 1: Typical ***HV****DC* **Apparatus**, where the ***HV****DC* bypass circuit includes a 'Bypass Switch' or circuit breaker performing the function of a 'Bypass Switch', illustrating combinations of **Safety Distance**

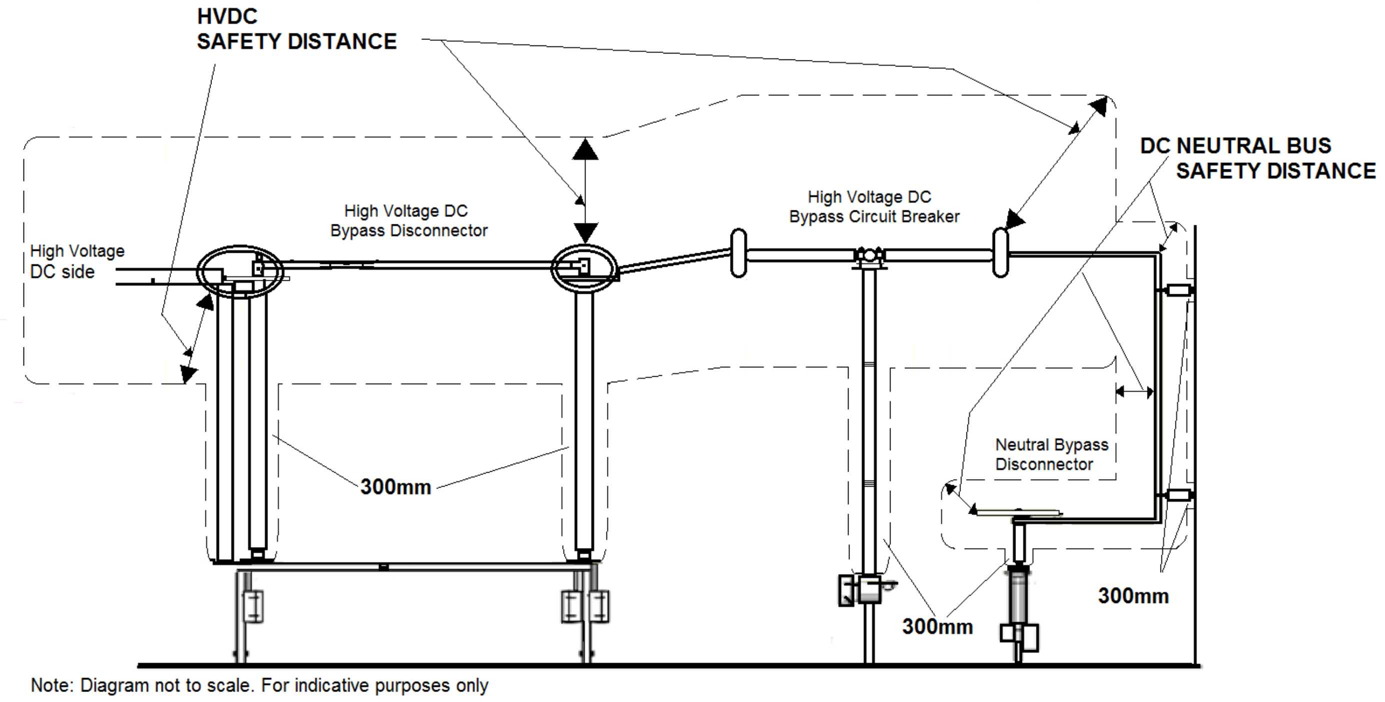
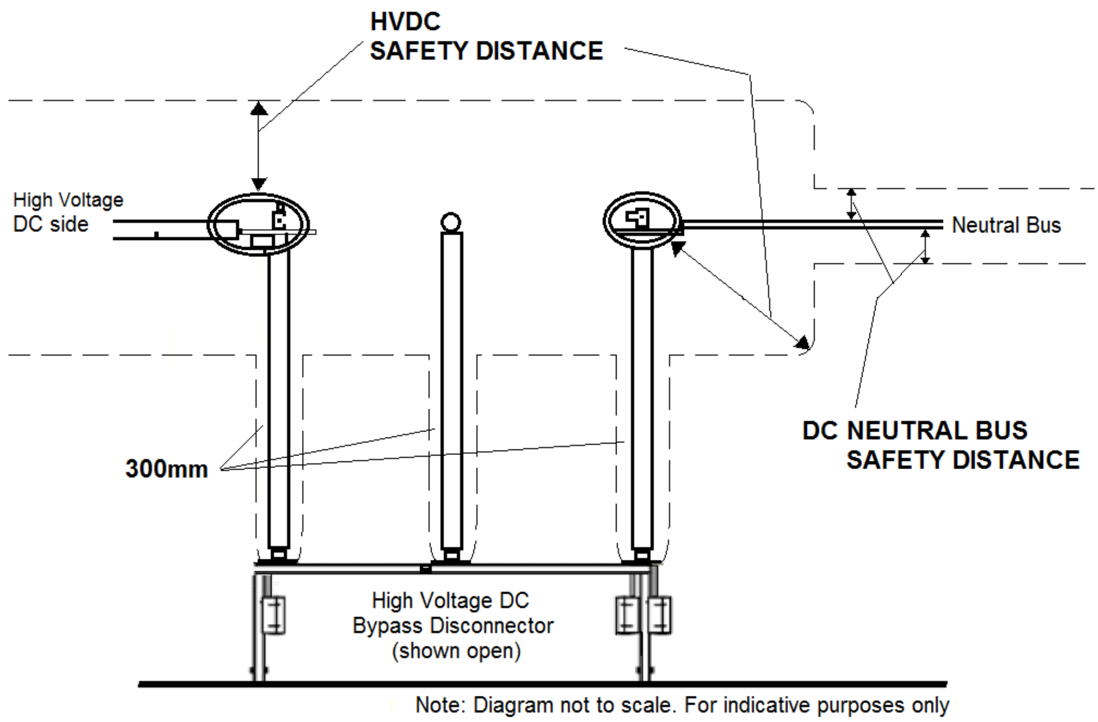


Diagram 2: Typical ***HV****DC* **Apparatus**, where the ***HV****DC* bypass circuit includes only a bypass disconnector, illustrating combinations of **Safety Distance**



10.5 All ***HV****DC* conductors shall be considered to be operating at their designated voltage regardless of DC operating configuration.

10.6 Application and removal of **Earthing Device(s)** when full isolation is not practicable for specific testing purposes shall be done in accordance with an **Approved** procedure, prepared in accordance with OPSAF-11-015 (MSP 2.4).

10.7 **Live Apparatus** within ***HV****DC Converter Stations* may emit magnetic fields. ***HV****DC Converter Station*s are designed so that harmful exposure to strong magnetic fields is managed by appropriate positioning of **Apparatus** and by access control and barriers while the **Apparatus** is **Live**. Site-specific procedures and training shall ensure personnel are not exposed to harmful magnetic fields – either by magnitude or duration of exposure. Reference shall be made to ScottishPower policy UKHS-GSP-SMS3029 'Electromagnetic Fields Procedure' for guidance.

11. SPECIFIC REQUIREMENTS FOR WORKING OR TESTING IN *HVDC CONVERTER STATIONS*

11.1 All Areas

Harmful Temperatures

Where work or testing is to take place on or near to **Apparatus** that may have been operating at a harmful temperature, the risk shall be assessed and adequate control measures put in place. Control measures may include taking measurements, allowing time for **Apparatus** to warm or cool to a safe level or leaving *H-VAC* or other ventilation / cooling systems in service. The control measures may need to be observed whilst establishing **Safety from the System** in addition to whilst carrying out work or testing. No **Safety Document** shall be issued where the presence of harmful temperatures may be a hazard that is not adequately controlled.

11.2 *Valve Halls*

Access to a *Valve Hall* shall be prevented by interlocks whilst the *Pole* is in operation. Access shall not be permitted until the pole has **Points of Isolation** and earthing established, in accordance with OPSAF-10-001 and OPSAF-10-002 (PSSIs 1 and 2) and the ScottishPower Safety Rules (Electrical and Mechanical), and a **Permit for Work** or **Sanction for Test** issued.

Where **Earthing Device(s)** are located inside the *Valve Hall*, correct engagement of the **Earthing Device(s)** shall be confirmed as far as reasonably practicable. Where such **Earthing Device(s)** fail to operate or cannot be confirmed as fully closed, an alternative means of earthing, either external and/or internal to the *Valve Hall*, shall be established in accordance with an **Approved** procedure.

Testing of **Apparatus** within the *Valve Hall* could introduce **High Voltage** hazards that need to be controlled. A risk assessment shall be undertaken during the planning stage to ensure the provisions of OPSAF-10-009 (PSSI 9) can be complied with.

11.3 Other *HVDC* Apparatus

There may be neutral earthing capacitors used as part of the ***HV****DC* connections scheme within a *Valve Hall* or connected to a *DC Neutral Bus* between two poles of a *Bipole*. For work on or testing of these capacitors they shall be considered as **HV Apparatus** and OPSAF-10-011 (PSSI 11) shall apply.

PLCF **Apparatus** have specific hazards such as: charged capacitors, power amplifiers, local and remote amplifier infeeds. This equipment shall be made safe in accordance with a site-specific **Approved** procedure.

DC Voltage Dividers are not based on wound transformer technology and are therefore not considered as a **HV** infeed in a similar way as wound metering voltage transformers on a **High Voltage** AC **System**. Therefore it is not necessary to establish **Point(s) of Isolation** on this **Apparatus** for work on **HV** Conductors. In addition, *DC Voltage Dividers* utilise power lasers for signalling. When work or testing necessitates access to the lasers, they shall be made safe in accordance with an **Approved** procedure.

DC Current Measuring Devices can exhibit unique hazards such as laser power and signalling. This equipment shall be made safe in accordance with an **Approved** procedure.

11.4 Auxiliary Equipment

Valve Cooling Equipment may contain liquid cooling systems comprising pipework, *Valves*, pumps, heat exchangers and control systems. When working on the *Valve Cooling Equipment*, it may need to be **Vented** or **Purged** and isolation or draining may be required, in which case a **Safety Document** shall be issued prior to work commencing.

The *Valve Hall*, *DC Hall* and Filter Halls may have an air management system (*H-VAC*). When working in a pressurised hall or the *H-VAC* air ducting or air handling unit(s), the work shall be risk assessed prior to starting and suitable control measures adopted.

When working on the *H-VAC* system, it may need to be **Vented** or **Purged** and isolation or draining may be required to achieve a safe system of work, in which case a **Safety Document** shall be issued prior to work commencing.

11.5 Additional General Safety Hazards associated with *HVDC* Apparatus

For guidance on how to manage these risks, reference shall be made to operation and maintenance manuals and the **Approved** operational procedure for the particular **Location**. All work or testing shall be done under an appropriate **Safety Document**..

11.6 High Voltage AC Filters and Reactive Equipment

Where access into individual filter compounds is controlled by interlock arrangements, such access shall only be possible when an earth switch has been closed to earth the filter busbars.

For access to, or for work or testing on, the filter capacitors, reactors, resistors and other associated equipment, additional **Primary Earths** or **Drain Earths** shall be applied in accordance with an **Approved** procedure. A **Permit for Work** or **Sanction for Test** shall be issued.

11.7 Work on or near Laser Systems

When working or testing on or near to laser systems a safe system of work shall be established. Consideration shall be given to the risk of inadvertent exposure to laser hazards. Reference shall be made to the manufacturer's recommendations and any relevant **Company** procedure.

In order to implement safety precautions it may be necessary to enter a cubicle containing a live laser system. Note that although usually safe by design, it is not always possible to guarantee that a hazard will not exist when a cubicle door is opened (e.g damaged fibre within) and the use of appropriate laser safety goggles shall be considered as a precaution.

12. HVDC CABLES

12.1 When working or testing on ***HV**DC* cables and/or associated terminations, precautions shall be taken to protect personnel from induced or impressed voltages. This shall include consideration of energy retained in the cable because of dielectric polarisation. Dielectric polarisation is only prevalent in ***HV**DC* cables and is known to re-charge ***HV**DC* cables (even if they have previously been discharged or **Earthed**) to up to 15% of their previous operating voltage if they become free of earth before the cable has de-polarised.

Where the work or testing involves contact with the ***HV**DC* cables or there is a significant risk that inadvertent contact could be made then work or testing shall only proceed under an appropriate **Safety Document**.

***HV**DC* cables shall where reasonably practicable be confirmed as discharged or already **Earthed** before an **Earthing Device** is applied. If it is not reasonably practicable (for example if measurement device(s) have been **Isolated** from the cable) an assessment shall be made to determine if sufficient time has elapsed for the cable to have de-polarised before applying an **Earthing Device**. The assessment shall consider manufacturer's manuals and/or recommendations and site-specific experience.

12.2 For work or testing on or near ***HV**DC Land Cables*, a safe system of work shall be established in accordance with the ScottishPower Safety Rules (Electrical and Mechanical), and the supporting documents that apply to **High Voltage** AC cables.

It is a requirement of OPSAF-10-005 (PSSI 5) Appendix 1 that the insulation condition of the cable cores shall be established before and after spiking using an insulation tester. This requirement shall be met where reasonably practicable. It may not be reasonably practicable to use an insulation tester e.g. on particularly long and/or heavily insulated cables. Where it is found not to be reasonably practicable, an alternative method shall be used (e.g. time-domain reflectometry – TDR).

12.3 The Safety Rules are not primarily written to suit the marine environment meaning that whereas it would normally be expected that all work or testing on ***HV**DC* **Apparatus** should be carried out in accordance with the ScottishPower Safety Rules (Electrical and Mechanical) and supporting documents, for work on *Marine Cables* it is recognised that the full requirements of the Safety Rules cannot and should not be applied. For example, it may not be practicable to implement all of the requirements of part B of the Safety Rules, or certain requirements of OPSAF-10-005 (PSSI 5). Therefore, an **Approved** procedure shall be written and implemented in accordance with OPSAF-11-015 (MSP 2.4).

Only if it remains impracticable for work or testing to proceed under an OPSAF-11-015 **Approved** procedure then **Apparatus** may be Permanently Disconnected in accordance with OPSAF-11-024 (MSP 3.2).

If the **Apparatus** is to be Permanently Disconnected for work or testing on a *Marine Cable*, the management of safety from electrical **Dangers** shall be of the same high standard as if the work or testing were subject to the Safety Rules with appropriate risk assessment and method statements for the proposed work and testing procedures approved by a **Senior Authorised Person**.

A procedure provided by the competent Contracted Service Provider shall be used for the identification of the *Marine Cable* (refer to Appendix C) and this shall be referenced by the **Senior Authorised Person** issuing the **Safety Document**.

12.4 It is imperative that clear communication is available between the vessel(s) and land-based personnel.

12.5 Where work is required adjacent to a *Marine Cable* e.g. burial, examination, rock/mattress replacement and is of a non-intrusive nature, a **Senior Authorised Person** shall review the specialised contractor's proposed work plan, procedures and safety precautions. It may be required to gain additional advice from a **Selected Person** who can advise on any risk of damage or contact with the *Marine Cable* during such operations. If deemed necessary, the cable shall be **Isolated** and **Earthed** and a **Safety Document** issued.

12.6 If additional precautions are identified and the *Marine Cable* is to remain **Live** these shall be recorded in writing and form part of the revised work procedures agreed by the **Senior Authorised Person**.

12.7 The **Senior Authorised Person** shall instruct any work to commence whether or not a **Safety Document** is issued. They shall be kept informed of progress and given written confirmation that all work has ceased.

13. HVDC OVERHEAD LINES

For work or testing on ***HV****DC* overhead lines a safe system of work shall be established in accordance with the ScottishPower Safety Rules (Electrical and Mechanical), the **Company** Safety Instructions and PSSIs and other supporting documents that apply to **High Voltage** AC overhead lines.

14. APPENDIX A: *HVDC* CLEARANCES

Defining Electrical Clearances and Safety Distance(s) for HV*DC* Apparatus

The clearance in air required to provide adequate insulation for ***HV****DC* **Apparatus** in ***HV****DC Converter Stations* is usually governed by the level of switching impulse voltage to which the **Apparatus** might be exposed.

HV*DC Converter Stations* tend to be of a bespoke design in order to achieve an optimum solution for a given application and a number of design-related factors influence the switching impulse voltage. Consequently, the switching impulse voltage and hence the electrical clearance is not directly related to the DC operating voltage.

The level of switching impulse is determined by the manufacturer in the insulation coordination studies which are performed at the design stage of a ***HV****DC* scheme. The value is rounded up to the nearest standard switching impulse level and the necessary air clearance determined from values given in the international standards. **Safety Distances** are determined from the electrical clearances by the addition of a safety margin. Values of **Safety Distance** for ***HV****DC Converter Station*s and overhead lines are given in section 10.3.

<u>Note that, since the **Safety Distance** is not directly related to ***HV****DC* operating voltage, it is necessary to specify **Safety Distances** by **Location**</u>.

Changes to System Configuration or Apparatus and its Effect

During the life of an ***HV****DC* **System**, a major change to the **Apparatus**, such as a *Valve* replacement, may be necessary. In such circumstances, a new insulation coordination study will be required as it may be found that the standard switching impulse withstand level has changed. Where any work is planned that requires a new insulation coordination study, it will be necessary to confirm whether the existing **Safety Distance**(s) remain applicable and, where necessary, to derive new **Safety Distance(s)**.

15. APPENDIX B: SPECIFIC SWITCHING INSTRUCTIONS

The control systems of ***HV**DC Converter Stations* feature a high degree of automation, including operational and safety **Switching** sequences. This Appendix describes safe methods of implementing such automation.

Where **Points of Isolation** cannot be created because it is not safe to enter the vicinity in order to apply a **Safety Lock** and **Caution Notice**, the required **Approved** procedure for the specific **Location** shall be produced in accordance with OPSAF-11-015 (MSP 2.4).

15.1 Western HVDC Link

The Western ***HV**DC* Link is a 2250MW Bipole **System**. Its southern ***HV**DC Converter Station* (Flintshire Bridge) is National Grid owned and operated, and the northern ***HV**DC Converter Station* (Hunterston) is ScottishPower Transmission owned and operated.

Use of Automated Switching Sequences

Prior to the issue of any automated **Switching** instruction, the **Control Person** and **Authorised Person** shall familiarise themselves with the status of **Apparatus** at the ***HV**DC Converter Station* and where appropriate, the remote end. They shall agree with reference to site-specific documentation, exactly which **Apparatus** is both desired and expected to operate when the automatic sequence is executed. This **Apparatus** shall be listed individually on the **Switching** instruction, along with reference to the execution of the desired automatic sequence.

Automated Operational Switching Instructions

Automated **Switching** sequences may be used to operate **Apparatus** for the purposes of operational reconfiguration. Reference to site-specific documentation may be necessary to determine which sequence is required.

The **Switching** instruction shall take the form:
On Pole 1, execute Connected command.

The **Authorised Person** shall ensure that the **Switching** sequence was successful (with reference to the site control system) before reporting back the **Switching** instruction.

Automated Safety Switching Instructions

Automated **Switching** sequences may be used to operate earth switch(es) for the purposes of safety **Switching**, provided that adequate safeguarding of earth switch(es) is achieved during the same **Switching** instruction. Note that some earth switches may be within the *Valve Hall* and inaccessible during **Switching**. This method presumes that earth switches will be operated by remote control from the **Location** control room and subsequently confirmed closed and **Locked** appropriately.

The **Switching** instruction shall take the form:
On Pole 1, execute **Earthed** command.
Check closed and apply lock to earth switches x, y. Confirm closed only earth switch z.

When opening earth switch(es), the **Switching** instruction shall take the form:
On Pole 1, render operative earth switches x, y, z.
Execute **Isolated** command.
Check open earth switches x, y, z.

NB. Care must be taken to ensure that the correct sequence is discussed. There are two sets of sequence controls for Pole Sequences and Station Sequences respectively. There are earthing sequences in both Pole and Station control.

If either party is unable to agree what **Apparatus** is expected to operate when automatic sequences are commanded, **Switching** shall be carried out manually using the method described in OPSAF-10-001 (PSSI 1). This section serves only to facilitate the use of automatic **Switching** sequences. Manual **Switching** may still be carried out where preferred.

Where a **Switching** sequence fails to complete, the cause shall be evaluated and the **Switching** instruction cancelled. Manual **Switching** may then be required to resolve the problem.

Where **Points of Isolation** cannot be created because it is not safe to enter the vicinity in order to apply a **Safety Lock** and **Caution Notice**, the required procedure for the specific **Location** will be found within an MSP 2.4 sub-document.

15.2 Angle-DC

The Angle-DC DC Link is a 30MW point-to-point interconnector on the 33kV AC network between Bangor Grid and Llanfair PG primary substations and is owned and operated by SP EnergyNetworks.

The ***HV**DC* (positive and negative pole) circuit between the two sites consists of both cable and overhead line. The cable and overhead line are of standard 33kV AC construction. At each converter station end of the DC Link circuit are line isolators and line earth switches which are ganged for simultaneous **Switching** of both poles. These are to be used for the isolation and earthing before work or testing on the cables or overhead line of the ***HV**DC* circuit.

For work or testing within the ***HV**DC* or on the inverter transformers the **Apparatus** shall be isolated and earthed in accordance with an Approved procedure.

There are no automated switching sequences for the Angle-DC link.

16. APPENDIX C: *HVDC* CABLE IDENTIFICATION AND FAULT LOCATION TECHNIQUES

If the cable records are insufficient to identify a cable, the cable shall be positively identified by using the submitted Contracted Service Provider's procedure. The procedure must be suitable and sufficient to ensure absolute identification of the cable to be worked on, with confirmation required from the **Senior Authorised Person** before a cable is considered to be positively identified.

The procedure for identifying the cable may include, but is not limited to using:

- Time Domain Reflectometry (TDR)
- Signal / tone generator cable locator
- The cable route GPS markers marked on charts
- Physical cable (Pole) identification

Methodologies for fault location will be evaluated depending on circumstances, in order to find the best solution to be adopted. All viable solutions may be considered.

Time Domain Reflectometers (Echo-meters)

This kind of equipment is particularly useful for the pre-localisation of faults with precision of a few percent of the cable length and is carried out from an onshore cable termination. In most cases this is enough to allow the choice of repair method and, for *Marine Cables*, the relevant vessel and equipment. It may be necessary to conduct TDR tests from both ends of the cable, or from a vessel, to improve accuracy. Other techniques such as Murray Loop and Varley Loop can be used to better pinpoint problem areas but require a healthy cable.

Signal / Tone Generator Cable Locator

To locate the position on the sea bed and to measure the burial depth of the *Marine Cables*, one of the methods most used is to inject a signal of suitable amplitude and frequency into the cable.

A suitable device (for example a Remote Operated Vehicle in deep waters) will be moved close to the sea bed and (by suitable probes installed on it) will detect the magnetic field created by the injected signal. Then a signal conditioner will analyse the detected field and will evaluate the position of the cable and its burial depth. A typical signal generator may have an output of 20A, 250V, 10 – 20 Hz. The tone may need to be injected from both ends of the cable to narrow-down the suspected area of fault.

GPS Markers and Systems

For offshore operations, it may be appropriate to refer to satellite-based positioning systems such as GPS. GPS systems are now accurate to within a few metres. It is usual to use the GPS markers attached to the cable to identify the cable's route and in conjunction with the signal / tone generator establish positive identification of a*Marine Cable*.

An Example of Pole Identification

For the Western Link – the outer most layer of the *Marine Cable* is covered with a black polypropylene serving. Woven into the serving for the Pole 1 cable is a single yellow stripe and two yellow stripes in the serving for Pole 2.

N.B. The spare cable has completely black serving and depending on the cable repair i.e. length inserted, one pole or two pole cable repair, the inserted sections are to be marked during the repair process as appropriate or recorded otherwise.

For the Western Link – *Marine Cable* installation comprises bundled (paired) installation in shallow waters and segregated installation in deeper water. The routing, method of installation and location of segregated cables are defined on the cable records. *Marine Cable* installation comprises bundles (paired) installation in shallow waters and segregated installation in deeper water. The routing, method of installation and location of segregated cables are defined accurately on the cable records.