National Grid UK Electricity Transmission plc

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NATIONAL SAFETY INSTRUCTION and Guidance

NSI 27
Work on or near to High Voltage Direct Current (HVDC) Equipment

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DOCUMENT HISTORY

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<tr>
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<tr>
<td>1</td>
<td>Dec 2015</td>
<td>New NSI &amp; Guidance Document.</td>
<td>HVDC Working Group</td>
<td>Matt Staley ETAM Operations North Manager</td>
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KEY CHANGES

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# Work on or near to High Voltage Direct Current (HVDC) Equipment

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1 Purpose and Scope

To apply the principles established by the Safety Rules and provide guidance on working on or near to HVDC Equipment. To protect personnel from Danger arising due to working on or near a HVDC System.

National Grid Personnel when working or testing within the scope of this document will be authorised specifically in accordance to their understanding of this NSI document.

The layout of this guidance notes reflects that of legislative codes of practice, where the rule (or mandatory obligation) is identified by a green panel on the left-hand side. The guidance follows after the rule and is identified by a blue panel.

Within National Grid the guidance notes hold equivalent status of an Approved Code of Practice (ACOP) in law. If not followed, you will be required to demonstrate that your Safe System of Work is of an equal or higher standard.

This document covers the following:

- Safety Distance(s) for Approach to HVDC Equipment
- Access to Equipment within a HVDC Converter Station
- Work or testing on HVDC Equipment within a Converter Station
- Work or testing on HVDC Cables, including submarine cables.
- Work or testing on Auxiliary Equipment which is specific to a Converter Station
- Specific Switching Instructions for work on a HVDC System

This NSI addresses further specific hazards found within a Converter Station and its associated Equipment. This does not negate any compliance with any other obligation or directive within the existing Safety Rules or National Safety Instructions unless explicitly stated.

This NSI provides generic as well as site-specific information. Authorisation to this NSI is relevant to all location(s) referenced within this document but personnel shall have supplementary site-specific knowledge and training relevant to the task they are undertaking.
## 2 Definitions

Terms printed in bold type are as defined in the Safety Rules.

<table>
<thead>
<tr>
<th>Title</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>Bipole</td>
<td>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.</td>
</tr>
<tr>
<td>Converter Unit</td>
<td>Operative unit comprising Valves, converter transformer(s), control and protection Equipment, switching devices and auxiliaries used for conversion.</td>
</tr>
<tr>
<td>DC Current Measuring Device</td>
<td>These may comprise one of following types;</td>
</tr>
<tr>
<td></td>
<td>DCCT</td>
</tr>
<tr>
<td></td>
<td>Direct Current Current Transformers. These use an Uninterruptible Power Supply (UPS), alternating current excitation scheme, or laser light technology to measure the DC current in a HVDC circuit.</td>
</tr>
<tr>
<td></td>
<td>RCS</td>
</tr>
<tr>
<td></td>
<td>Resistive Current Shunt. This Equipment uses laser light technology to read the voltage across a known resistance (shunt) in the HVDC circuit.</td>
</tr>
<tr>
<td>DC Voltage Divider</td>
<td>Devices used to measure the voltage of a HVDC circuit. They may include capacitors, resistors and/or laser light technology.</td>
</tr>
<tr>
<td>DC Hall (DC Area / DC Compound)</td>
<td>Restricted room or location in which HVDC Equipment associated with the Converter Station is located.</td>
</tr>
<tr>
<td>Heating, Ventilation and Air Conditioning (H-VAC)</td>
<td>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. Positive Pressure may be used to limited dust ingress to an area)</td>
</tr>
<tr>
<td>Converter Station</td>
<td>Part of a HVDC System which consists of one or more converter units installed in a single location together with buildings, reactors, filters, reactive power supply, control, monitoring, protective, measuring and auxiliary Equipment</td>
</tr>
<tr>
<td>HVDC System</td>
<td>Equipment which transfers energy in the form of high-voltage direct current (HVDC) between two or more alternating current buses.</td>
</tr>
<tr>
<td>Neutral Bus</td>
<td>A conductor connecting the DC neutral terminals of two Poles.</td>
</tr>
<tr>
<td>Power Line Carrier ( PLC ) Equipment</td>
<td>A device that may be used to impose signalling or block signalling and system generated frequencies onto a conductor. This may be used for communications between HVDC Converter Stations.</td>
</tr>
<tr>
<td>Pole</td>
<td>Part of a HVDC System consisting of both AC and DC Equipment at the HVDC Converter Station and the interconnecting transmission medium, if any.</td>
</tr>
<tr>
<td>Valve</td>
<td>Device used for conversion which is connected between an AC terminal and a DC terminal.</td>
</tr>
<tr>
<td>Valve Hall</td>
<td>Restricted room or enclosure in which the Valves are located.</td>
</tr>
<tr>
<td>Valve Cooling Equipment</td>
<td>The means by which heat is transferred from the HVDC Valves to atmosphere to maintain the HVDC valves within their operating temperature limits. This usually comprises a closed loop liquid cooling system.</td>
</tr>
<tr>
<td>Bypass Switch</td>
<td>Switching Device connected across the DC terminals of a Pole which may be used during the switch on/off procedure and allows operational re-configuration during a Pole outage.</td>
</tr>
</tbody>
</table>
3 Dangers

The main dangers when working on HVDC Equipment and their associated components are electric shock, burns and / or other injuries arising from:

- Inadvertently infringing Safety Distance
- The mistaking of Equipment 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.
- 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 Equipment such as air cored reactors, that are Live and generating high magnetic fields.
  - Contact with Equipment which may be operating at harmful temperatures
- Specific Dangers arising from work on H-VAC are:
  - Positive or negative differential air pressure across access doors and hatches
  - Rotating Parts
  - Heater Elements
  - Confined Spaces
  - Sources of Low Voltage Electrical Energy
4 Approach to Exposed HVDC Conductors and Insulators

4.1 Individuals shall not allow any part of their body or objects to approach within the specified Safety Distance(s), to exposed HVDC Equipment as detailed in Section 4.2; the only exceptions to this are where:

- Application of Safety Rule R2.2 or R2.3
- Application of Section 4.3 or 4.4

4.2 Safety Distance(s)

<table>
<thead>
<tr>
<th>Location</th>
<th>Safety Distance (metres)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>High Voltage Equipment</td>
</tr>
<tr>
<td>Sellindge Converter Station</td>
<td>2.4</td>
</tr>
<tr>
<td>Flintshire Bridge Converter Station</td>
<td>Equipment on the Valve side of (and including) the Smoothing Reactor</td>
</tr>
<tr>
<td></td>
<td>5.1</td>
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</table>

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.

4.3 Application of Safety Distance to HVDC Bypass Circuits

Some HVDC Bypass Circuits comprise Equipment of different rated voltages which are connected together. Those conductors which directly connect Neutral Bus switchgear to High Voltage DC switchgear shall be treated as Neutral Bus conductors. The appropriate Safety Distance shall still be maintained in full from the High Voltage DC Equipment, including any corona rings.

4.4 Application and removal of Earthing Device(s) for Operational Purposes

Earthing Device(s) designated to be used for Operational Configuration or for testing may be applied and removed under the instruction of a CP(O)1.

There is no requirement for Point(s) of Isolation to be established prior to application or removal of such Earthing Device(s) when used in this context.
### Guidance NSI 27

4.2 to 4.4

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### 4 Approach to Exposed HVDC Conductors and Insulators

#### 4.2 All HVDC Conductors shall be considered to be operating at their nominal voltage regardless of DC Operating Configuration.

Personnel who are not authorised to this document but are required to work at a Converter Station shall receive instruction and information regarding relevant HVDC Safety Distance(s) via site induction. Where appropriate this shall also be recorded in a written risk assessment prepared for the work.

#### 4.3 Application of Safety Distance to HVDC Bypass Circuits

The following drawings indicate the application of Safety Distance(s) for different Equipment layouts.

- Where the HVDC bypass circuit includes a ‘Bypass Switch’

![Diagram 1](image1)

- Where the HVDC Bypass Circuit includes only a bypass disconnector

![Diagram 2](image2)

#### 4.4 Such Earthing Device(s) may be designated on the Operation Diagram or in an Operational Protocol Document which is jointly visible between site and the relevant control room(s).
5 Specific Requirements for Working in HVDC Converter Stations

5.1 When work is to be carried out on or near to HVDC Equipment, a Safe System of Work shall be established in accordance with the National Grid Safety Rules and associated National Safety Instructions.

5.2 Access shall not be permitted to a Valve Hall until the Pole has Points of Isolation and Earthing established, and a Safety Document Issued.

5.1 HVDC Equipment

- There may be neutral earthing capacitors used as part of the HVDC connections scheme within a Valve Hall or connected to a common neutral busbar between two Poles of a Bipole. These capacitors shall be considered as HV Equipment and earthed as part of a switching instruction or Earthing Schedule.

- No work shall be carried out on or near to the PLC Equipment until the work has been risk assessed. The main Hazards associated with PLC Equipment are: charged Capacitors, Power Amplifiers, Local and Remote Amplifier infeeds. Some Converter Stations feature PLC Equipment in the AC yard. In this case, the Equipment exhibits similar hazards and appropriate safety precautions shall be established.

- DC Voltage Dividers are not considered as a HV infeed. It is not necessary to establish secondary Point(s) of Isolation on this Equipment for work on the High Voltage side.

- DC Current Measuring Devices can exhibit unique hazards. The Operational and Safety implications shall be understood before work is carried out on this Equipment by reference to the Manufacturers manuals or other relevant documentation.

Work on Laser Systems

- When working 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 manufacturers recommendations and any relevant Management 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 would not exist when a cubicle door is opened (e.g. damaged fiber within) and the use of appropriate laser safety goggles shall be considered as a precaution.
Guidance
NSI 27
5.1cont. to 5.2

Auxiliary Equipment

- Valve cooling is achieved by:
  - (i) Closed loop liquid cooling systems comprising pipework, valves, pumps, heat exchangers and control systems.
  - (ii) Air management systems (H-VAC) and their control system. The H-VAC system may also be used to regulate the temperature in other buildings (e.g DC Hall) and may also be capable of heating.

- When working on the Valve Cooling Equipment, isolation, draining, venting and purging may be required to achieve a Safe System of Work.

- A Safe System of Work shall be in place prior to work or testing and before inspections or pre-assessed routine operations are to be undertaken. The Safe System of Work may include a Safety Document and/or RAMS.

- 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. The main Dangers are:
  - Positive or negative differential air pressure across access doors and hatches.
  - Rotating plant
  - Heater elements
  - Confined Spaces
  - Sources of Low Voltage Electrical Energy

5.2 Valve Halls

- Access to a Valve Hall is usually prevented by interlocks whilst the Pole is in operation.

Where Earthing Device(s) are located inside the Valve Hall, correct engagement of the Earthing Device shall be confirmed where reasonably practicable. Where such Earthing Device(s) fails to operate or cannot be confirmed as fully closed an alternative means of Earthing either external and/or internal to the Valve Hall will be required, this will be determined by a Senior Authorised Person. The Senior Authorised Person shall consider any residual hazards which remain within the Valve Hall (e.g Equipment which may still be charged but could easily be touched) and implement suitable precautions to prevent danger.

- Where external Earthing is applied which does not satisfy the Valve Hall door interlock, it will be necessary to defeat interlocks to allow access to the Valve Hall. Where access is to be gained by defeating interlocks, this should be identified in the Safety Document and RAMS along with any further controls necessary to be implemented in the absence of the internal Earthing Devices.

- Testing of Equipment within the Valve Hall could introduce High Voltage hazards that need to be controlled. A risk assessment shall be undertaken during the work planning stage to ensure compliance with the provisions of NSI9.
Guidance
NSI 27
5.2 cont.

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<th>Additional General Safety Hazards Specific to HVDC Equipment</th>
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<td>- There are other risks within a Valve Hall that are not normally found in National Grid’s conventional substations. Some of the significant hazards are: Thyristor Banding, Glycol, Pressurised cooling pipes, laser light sources and Capacitors. Reference shall be made to the Operation and Maintenance Manuals to identify all hazards at a particular Location and then appropriate Safe Systems of Work shall be developed. Authorisation to this NSI does not in itself imply competence to work on HVDC Equipment. All personnel involved in the work shall be familiar with the requirements of the operation and maintenance manuals and have received equipment specific training.</td>
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</table>
6 HVDC Cables

6.1 When working on HVDC cables and/or associated terminations, precautions shall be taken to protect personnel against Impressed Voltage Conditions. This shall include consideration of energy retained in the cable due to effects of dielectric polarisation.

6.2 When work or testing is to be carried out on or near to HVDC land cables, then a Safe System of Work shall be established in accordance with the National Grid Safety Rules and associated National Safety Instructions. Specific methods for working on HVDC land cables shall be in accordance with NSI 5.

6.3 When work or testing is to be carried out on or near to HVDC marine cables, a Senior Authorised Person (NSI 27) shall assess the means of achieving Safety from the System.

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

Offshore work may necessitate the use of a G3 procedure, an example of which is provided in Appendix D.

6.4 There may be circumstances whereby it is preferable to conduct offshore work without application of National Grid’s Electricity Safety Rules or a G3 Procedure. In this case, the Equipment shall be removed from the System and a specialist contractor’s Safe System of Work implemented. This does not imply that any aspect of safety, quality or documentation may be of a lower standard.

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Guidance
NSI 27
6.1

HVDC Cables

6.1 HVDC cables are subject to Impressed Voltage Conditions and Safe Systems of Work shall be developed accordingly. In addition, particular attention shall be given to the effects of dielectric polarisation which is only prevalent in HVDC cables.

Dielectric polarisation is known to re-charge HVDC cables (even if they have previously been briefly discharged or Earthed) to up to 15% of their previous operating voltage if they become free of Earth before the cable has de-polarised.

It is important that Earthing Devices are only applied to HVDC cables which are confirmed as discharged or already Earthed. If the cable has been left free of Earth and it is not possible to establish its voltage (for example if measurement devices have been isolated from the cable), an assessment must be made as to whether sufficient time has elapsed for the cable to have de-polarised prior to application of an Earthing Device.

Reference shall be made to manuals, manufacturers recommendations and site-specific operational experience to determine the time necessary for polarisation energy to decay once the cable is Earthed (or conversely left free of Earth), after which time the cable can be considered to be de-polarised. A means of force-discharging the cable may also be available, for example the use of an adequately rated bypass switch.
Guidance
NSI 27
6.2 to 6.4

6.2 Work on or near to HVDC land cables shall be in accordance with NSI5. The Safety Document shall be issued by a Senior Authorised Person holding NSI5 and NSI27 (or counter-signed by a combination of both).

The boundary between land and marine is normally the shoreline. In some circumstances an assessment must be made as to the working environment & which method of work to adopt (i.e land or marine).

6.3 Work on or near to HVDC marine cables requires assessment by a Senior Authorised Person. Non-intrusive work may be delivered under RAMS or a Limited Access Certificate. Where the work requires a Permit for Work or Sanction for Work, this shall be issued by a Senior Authorised Person holding NSI5 and NSI27 (or counter-signed by a combination of both).

An example of non intrusive work is the operation of a remotely operated vehicle taking images of the cable, or towing a submerged sensor near the sea bed to detect the level of sediment cover above the cables. The Senior Authorised Person shall make an assessment as to the risk of such apparatus making contact with the cable (including inadvertent contact). An expert marine consultant or the contractor may provide information to support this risk assessment. An example of intrusive work is a cable fault repair.

National Grid Electricity Safety Rules are not primarily written to suit the marine environment and dependant on work location and nature, may prove to be impractical, even prohibitive to adopt. An example G3 procedure is provided in Appendix D which shall be reviewed, Approved and issued before use and suspended thereafter.

6.4 Whilst NSI27 makes provision for anticipated marine work, circumstances may arise whereby it remains impractical to conduct the work under National Grid Electricity Safety Rules. In this case it may be necessary to temporarily remove Equipment from the System and use a specialist contractor's Safe System of Work. In this case, safety and its management shall be of the same high standard as if the work were subject to the safety rules.

A Safe System of Work shall be developed between National Grid, other relevant stakeholders and the Competent Contractor and should include:

- Co-ordination meeting (TP153 / AMBP 310) between National Grid Senior Authorised Person and the Competent Contractor undertaking the Cable Works;
- Clear definition of the roles and responsibility of all personnel in all parties including their location during work;
- Submission of RAMS for cable identification, cable maintenance or repair by the Competent Contractor;
- The RAMS shall detail the method of addressing impressed voltage during work and make use of insulated/non-insulated techniques as appropriate;
- The RAMS shall clearly define the requirements for earthing throughout the repair procedure and may be used in lieu of an Earthing Schedule, only if to the equivalent standard;
- Specific and robust means of communication between land based personnel and the marine vessel(s). This may require the contractor to provide a link-person based onshore, who remains in regular contact with the vessel(s).
Guidance
NSI 27
6.4 cont.

It is the Contracted Service Provider’s responsibility to provide the RAMS for the identification for testing working upon cables offshore. The National Grid Senior Authorised Person shall agree the Safe System of Work being used by the Contracted Service provider. It is a legal duty of the Contractor to provide suitable and sufficient RAMS to manage the work being undertaken.

General Guidance and Information to SAPs

Those involved in offshore cable repair work will typically be specialists operating multi-nationally. It is imperative that clear communication is possible, especially between the vessel and land-based personnel. During a cable repair operation there may be 50+ mariners onboard a vessel. Around 12 of these may be on the cable deck at any time. It is typical that personnel working offshore are trained and assessed in offshore survival techniques (BOSIET qualification), plus offshore medical and drugs and alcohol checks.
Appendix A - HVDC Clearances

Defining electrical clearances and Safety Distance(s) for HV DC Equipment.

The clearance in air required to provide adequate insulation for HV DC Equipment in converter stations is usually governed by the level of switching impulse voltage to which the Equipment might be exposed.

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 Distance(s) are determined from the electrical clearances by the addition of a safety margin. Values of Safety Distance for converter stations are given in section 4.2.

Note that, since the Safety Distance is not directly related to HV DC operating voltage, it is necessary to specify Safety Distances by site.

Refer to the technical report TR (E) 502 ‘ELECTRICAL CLEARANCES AND SAFETY DISTANCE(S) IN HV DC CONVERTER STATIONS’ for further information.

Changes to system configuration or Equipment and its effect

During the life of a HV DC system, a major change to the Equipment, 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).
Appendix B - Specific Switching Instructions

Flintshire Bridge Converter Station

The Western HVDC Link is a 2250MW Bipole System. Its Southern Converter Station (Flintshire Bridge) is National Grid owned and operated, and the Northern Converter Station (Hunterston) is Scottish Power Transmission owned and operated.

The control system features a high degree of automation, including Operational and Safety switching sequences. This appendix describes a safe method of implementing such automation.

Use of Automated Switching Sequences

Prior to the issue of any ‘automated switching instruction’, the Control Person (NSI 27) and Authorised Person (NSI 27) shall familiarise themselves with the status of Equipment at the Converter Station and where appropriate, the remote end. They shall agree with reference to site specific documentation, exactly which Equipment is both desired and expected to operate when the automatic sequence is executed. This Equipment 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 Equipment 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 Station; Execute Connect* Command.  
*Substitute ‘Connect’ for desired Switching Sequence

The AP 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 Earthing Device(s) for the purposes of safety switching, provided that adequate safeguarding of those Earthing Device(s) is achieved during the same switching instruction. Note some Earth Switches may be within the Valve Hall and inaccessible during switching. This method presumes that Earth Switches will be operated by telecommand from the site SCP, and subsequently checked and locked accordingly.

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 removing those Earthing Device(s), 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 Equipment is expected to operate when automatic sequences are commanded, switching must be carried out manually using the method described in NSI1. 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.
Sellindge

Switching Sequences

As the Sellindge Converter Station was built in the 1980’s the philosophy for interlocking and therefore Valve Hall access was derived from the then agreed standard design criteria, therefore compatible with NSI 1 & 2. The standard isolation and earthing required to gain access to all areas is detailed in site specific procedures.

There are two aspects of this overall philosophy that should be noted.

1. At the time of construction it was normal for Safety Document recipients to view the earth switches from their point of work. Consequently, the current on-site procedure for a Safe System of Work is to establish the HV isolation and earthing for a Valve Hall then issue an Earthing Schedule to apply the Converter Transformer valve hall side earth switches and Valve Hall side HVDC through wall bushing earth switch. These Valve Hall side earths ensure the mechanical interlocks are satisfied and therefore allow the doors into this HV Compartment to be unlocked.

2. The 2012 Valve Replacement Project allowed partial updates to the HVDC Switchgear controls. These allow only the HVDC switchgear associated with the Poles to be automatically configured in Pole or Bipole modes.

3. There are no interlocks between the Sellindge and Les Mandarins Converter Stations. All isolation and earthing for a Bipole, Pole or Cable circuit must therefore be completed in agreement with the French and UK Converter Station Operators. The basis of these coordination requirements are set out in the agreement within the operational document known as “The Pink Version”. (RISSP Process)

** Refer to onsite Operational Procedures for detailed site specific diagrams, configurations and switching sequences.
Appendix C – Marine Fault Location Techniques

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
- Identification of poles

Time Domain Reflectometers (Echo-Meters)

This kind of equipment is particularly useful for 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 the repair method and the relevant Vessel and equipment. It may be necessary to conduct TDR tests from both ends of the cable system to improve accuracy. It may also be desirable to carry out TDR tests from the vessel.

![Figure 1: Example TDR trace from a defective cable](image)

Other techniques such as Murray Loop and Varley Loop can be used to better pinpoint problem areas but require a healthy parallel cable.

Signal / Tone Generation cable locator

To locate the position on the sea bed and to measure the burial depth of the submarine 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 (ROV) 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 20A, 250V, 10-20Hz. The tone may need to be injected from both ends of the cable to isolate 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 cables route and in conjunction with the signal / tone generator establish positive identification of an offshore cable.

An example of Pole identification

For the Sellindge Cross Channel Link and 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 Spare cable usually has completely black serving and dependant 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.

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

For Sellindge Cross Channel Link - the cables are laid in pairs for the whole of the submarine cable crossing. The routes are clearly defined on drawings and in addition are one kilometre apart, thus allowing positive location. Safety precautions at the Converter Stations in France and UK will isolate and earth a pair of cables for the whole route between converter stations.

For the Western Link - Submarine 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.
Appendix D – Example G3 Procedure for Offshore Intrusive Work

National Grid Electricity Transmission plc
Electricity Safety Rules

General Provision G3 Procedure
For

Work on submarine cables associated with the Western HVDC Link

KEY CHANGES

<table>
<thead>
<tr>
<th>Section</th>
<th>Amendments</th>
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<tbody>
<tr>
<td>All</td>
<td>New Document</td>
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<td>XX</td>
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</table>

1 Introduction

The Western HVDC Link was commissioned in 2017. It is a 2400MW HVDC Link between Connah’s Quay (North Wales) and Hunterston (North Ayrshire, Scotland). The link comprises a converter station at both ends, plus a 420km cable route of which 380km is submarine cable.

The National Grid Electricity Safety Rules are not designed for marine work. Marine work is unique in several ways, not least that special authorisations are required and that access and egress is not readily available whilst work is under way.

This G3 Procedure is expected to cover aspects of a submarine cable repair which cannot reasonably comply with the requirements of the National Grid Electricity Safety Rules, and presents risk assessed alternative solutions.

It shall be reviewed, Approved and issued prior to use and suspended thereafter.
It shall be used in conjunction with NSI27 and a Sanction for Work procedure (where required).
2 Procedure

2.1 Definitions

<table>
<thead>
<tr>
<th>Role</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine Co-ordinator</td>
<td>A Competent Person who discharges his role and responsibilities through regular and robust communication with the Offshore Supervisor(s) and is not required to be at the Location.</td>
</tr>
<tr>
<td>Offshore Supervisor</td>
<td>A specialist individual who is on board the vessel and available at the point of work representing the Competent Person.</td>
</tr>
<tr>
<td>Offshore Working Party</td>
<td>Individuals or Persons working under the Local Supervision of the Offshore Supervisor.</td>
</tr>
<tr>
<td></td>
<td>NB Qualifications and Pre-Requisite experience to undertake this role are detailed in 6.4(Guidance)</td>
</tr>
<tr>
<td></td>
<td>NB This shall only include those present on the cable deck. The ship's captain plus auxiliary staff (e.g engine mechanic) are not included.</td>
</tr>
</tbody>
</table>

2.2 Application of the G3 Procedure

2.2.1 A specialist contractor will be appointed who shall nominate a Competent Person(s) who shall be able to demonstrate competence and experience in high voltage cable systems and be conversant in marine cable repair practise.

2.2.2 The Safety Document shall be issued to the Contracted Service Provider’s Competent Person authorised to relevant National Safety Instructions. The preferred method of conducting the work is that the Competent Person is authorised for offshore work and renders Local and/or Personal Supervision at sea. Where this is not reasonably practicable, the Competent Person may enact the role of Marine Co-Ordinator, remaining onshore and discharging his duty via an Offshore Supervisor.

2.2.3 With the exception of a Sanction for Work, duplicate safety documents may be issued to multiple Competent Persons (Marine Co-Ordinators) to avoid the requirement for Safety Document transfers during shift changes. The content of duplicate safety documents shall be identical (with exception of their unique number). The Competent Persons shall conduct their own shift handover face-to-face and document any issues, the status of work, the status of earths etc. The specification for handover shall be included in RAMS.

2.2.4 The Offshore Supervisor, where used, will be a named individual nominated by the specialist contractor. They must be conversant with the full scope of work (including the hazards) and be able to demonstrate experience of supervising the safety of similar work on several previous occasions. Of principal importance is that they are able to communicate effectively with the Competent Person (Marine Co-Ordinator) with consideration given to spoken language. Where the Senior Authorised Person has any doubt as to the competence of the Offshore Supervisor, an experience record / CV may be submitted to the Team Leader and/or National Grid Safety Professionals for additional opinion. Typically the Offshore Supervisor will be the suppliers ‘jointing supervisor’ and may rotate as dictated by a shift working regime, only if formal face-to-face handover occurs.

2.2.5 The Competent Person in receipt of the Safety Document is primarily responsible for safeguarding the Safety Precautions established by the Senior Authorised Person, and shall be the main point of contact between the Vessel(s) and the Senior Authorised Person, co-ordinating as necessary. If not at the point of work, the Competent Person (Marine Co-Ordinator) shall remain in regular and robust contact with the Offshore Supervisor(s) aboard the vessel(s). If contact cannot be maintained then work shall
cease. The frequency and method of ensuring communication channels are functional may be defined in RAMS.

2.2.6 The Offshore Supervisor represents the Competent Person (Marine Co-Ordinator) at the point of work and shall ensure strict adherence to RAMS. Where several vessels are involved in the work, it may be necessary to appoint an Offshore Supervisor(s) on other vessels even if the Competent Person is also at sea.

2.2.6 The cable shall be positively identified and confirmed by the Senior Authorised Person before work commences.

Where being at the point of work does not significantly aid positive identification (e.g. if a remote vehicle on the seabed is producing the image) this assessment and agreement may take place on land.

There is no requirement to carry out spiking as part of cable identification activities.

When the cable ends are brought upon the Vessel, they shall be labelled as agreed with the Senior Authorised Person. Unique identification stripes are considered to be an adequate means of labelling.

Where there is any doubt as to the identification of each cable, all associated cables shall be made safe and positive identification shall be achieved by way of testing.

2.2.7 There is no requirement for the captain and auxiliary staff to be authorised under National Grid Safety Rules. They shall however be fully conversant with the planned operation and the roles and responsibilities of the Competent Person and where appropriate, the Offshore Supervisor(s).

2.2.8 There is no requirement to implement NSI6 for offshore work areas. Instead the work area shall be clearly defined in RAMS with reference to physical attributes (e.g. cable deck, jointing tent etc). This area shall be under the control of the Competent Person and/or Marine Co-Ordinator and Offshore Supervisor.

2.2.9 The application of test voltages or signals, when taking place offshore, shall be by or under the Personal Supervision of the Competent Person. Alternatively it may be co-ordinated by the Marine Co-Ordinator and by or under the personal supervision of an Offshore Supervisor. In the latter case and where the Competent Person (Marine Co-Ordinator) does not hold authorisation to NSI9, the switching instructions relating to the removal of Primary Earth(s) shall be given by a National Grid Senior Authorised Person. Positive confirmation shall be received that all work has ceased prior to switching instructions being given.

The work shall comply with an associated Sanction for Work Procedure.

2.2.10 A Sanction for Work Procedure shall be used when carrying out fault location activities which require a tone to be injected into the cable from remote end(s). Since this activity could persist for several days with no requirement to interrupt or adjust the test equipment, it is deemed acceptable that the work area may be vacated with Primary Earth(s) removed and test equipment still energised.

The Competent Person shall provide Personal Supervision whilst Primary Earth(s) are being removed or replaced and whilst operating the test equipment. Once the test equipment is running and stable, personnel shall be excluded from the work area and the area secured such as to restrict access to personnel.

Access shall only be gained to the work area whilst Primary Earth(s) are removed when under the Personal Supervision of the Competent Person.
2.2.11 National Grid may also appoint an independent marine cable expert to board the vessel. They would be responsible for providing assurance that the method, quality and management of work is undertaken as agreed and also discharge National Grid’s duty of sensible monitoring.

2.3 Justification for Alternative Procedural Requirements

<table>
<thead>
<tr>
<th>G3 procedure clause</th>
<th>To be used in lieu of existing procedural requirement</th>
<th>Description as to why it is not reasonable to apply existing procedure</th>
<th>Description as to why it is reasonable to apply G3 procedure in lieu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section 2.1 - Role defined as ‘Offshore Working Party’</td>
<td>Safety Rules Definitions – Working Party</td>
<td>It is not sustainable due to multinational and specialist nature of offshore teams to require Offshore jointing teams with person/BESC authorisation, therefore the working party will be substantially comprised of ‘individuals’. Owing to the size of offshore jointing teams, it is not feasible for one supervisor to provide Personal Supervision to the entire working party.</td>
<td>The content of BESC training is not relevant to offshore work. The work is carried out by specialists.</td>
</tr>
<tr>
<td>Section 2.2 - Role defined as ‘Marine Co-ordinator’</td>
<td>Safety Rules Procedures P2.2</td>
<td>It is not sustainable due to multinational and specialist nature of offshore teams to require Competent Persons with offshore authorisations.</td>
<td>The work is carried out by specialists. The primary purpose of the Safety Document is to secure HV safety precautions which are remote from the point of work – this is achieved regardless of the CP's location. The roles of ‘marine co-ordinator’ and ‘offshore supervisor’ collectively achieve the equivalent of having the CP at the point of work.</td>
</tr>
<tr>
<td>G3 procedure clause</td>
<td>To be used in lieu of existing procedural requirement</td>
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</tr>
<tr>
<td>Section 2.2.3</td>
<td>Safety Rules Procedures P14</td>
<td>Due to 24/7 nature of jointing work it is not sustainable to transfer safety documents at every shift change. The existing procedure is intended for OHL where a letter suffix is provided to the PFW number.</td>
<td>The alternative procedure is common practice for other shift activities such as oil processing and achieves the same standard.</td>
</tr>
<tr>
<td>Section 2.2.6</td>
<td>NSI5 Clause 4.3</td>
<td>The point of work may be the sea bed. It is common marine practice to identify cables using divers and/or Remote Operated Vehicles.</td>
<td>The alternative procedure maintains SAP hold point but does not require the SAP to work offshore.</td>
</tr>
<tr>
<td>Section 2.2.6</td>
<td>NSI5 Clause 4.4</td>
<td>It is not sustainable to require an SAP to attend the point of work to install the label.</td>
<td>It is impractical to apply NSI5 clause 4.4 in full when working offshore. Cable records are of a high standard and both poles were uniquely marked at installation.</td>
</tr>
<tr>
<td>Section 2.2.6</td>
<td>NSI5 Clause 4.6</td>
<td>It is not common practice to spike marine cables before cutting.</td>
<td>It is impractical to apply NSI5 clause 4.4 in full when working offshore. Typical marine cable cutting equipment is remotely operated. Due to lower congestion and high quality of marine cable records, there is less risk of mis-identification.</td>
</tr>
<tr>
<td>G3 procedure clause</td>
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</tr>
<tr>
<td>Section 2.2.9</td>
<td>NSI6 Section 5</td>
<td>It is not practical to dispatch demarcation equipment to the vessel(s) and the marine work area is self-limiting.</td>
<td>The primary purpose of NSI6 is to identify equipment which has been made safe to work on from that which has not. This is unlikely to be the case on board a vessel which will only handle cables associated with one circuit at a time. The terminations will be appropriate demarcated according to applicable Safety Rules and work content.</td>
</tr>
<tr>
<td>Section 2.2.9</td>
<td>NSI 9 Clause 5.2</td>
<td>It is not sustainable due to multinational and specialist nature of offshore teams to require CPs with offshore authorisations and NSI9.</td>
<td>The roles of ‘marine co-ordinator’ and ‘offshore supervisor’ collectively achieve the equivalent of having the Competent Person at the point of work.</td>
</tr>
<tr>
<td>Section 2.2.9</td>
<td>NSI9 Appendix A</td>
<td>It is not sustainable due to multinational and specialist nature of offshore teams to require CPs with offshore authorisations and NSI9.</td>
<td>It is normally permissible for contractor CP’s without NSI9 to test under PFW however this work requires a SFW due to testing across control boundaries. The operation of Earthing Devices (removal of Primary Earths) will be co-ordinated by an SAP, including the issue of switching instructions to remote ends. This shall be detailed in Safety from the System RAMS.</td>
</tr>
<tr>
<td>G3 procedure clause</td>
<td>To be used in lieu of existing procedural requirement</td>
<td>Description as to why it is not reasonable to apply existing procedure</td>
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<td>--------------------------------------------------</td>
</tr>
<tr>
<td>2.2.10</td>
<td>SFWWP/02</td>
<td>It is not an effective use of time to require a Competent Person to personally supervise a test set, which may be required to run for days without interruption or adjustment.</td>
<td>Personnel are excluded from the test area when Primary Earth(s) are removed and hence danger is excluded. Any access to the test area whilst Primary Earths are removed are subject to the full requirements of the Sanction for Work procedure.</td>
</tr>
<tr>
<td>Section 2.2.11</td>
<td>AMBP310 Section 2.8</td>
<td>It is not sustainable to require a National Grid SAP to board a marine vessel due to specialist authorisations and infrequent nature.</td>
<td>Sensible Monitoring can be discharged by an independent offshore client representative</td>
</tr>
</tbody>
</table>

REFERENCE SHALL ALSO BE MADE TO AMBP 228 - MANAGEMENT OF ET OPERATIONS CONTROLLED DOCUMENTS AND COMMUNICATION BEFORE THIS DOCUMENT IS ISSUED.

Note Application for Approval, Examination & Recommendation, Approval and Registration sections omitted for clarity.
Appendix E – Example Sanction for Work Procedure for Offshore Intrusive Work

National Grid UK Electricity Transmission plc

Safety Rules

Approved
Sanction for Work (SFW) Procedure

For

Testing of High Voltage Submarine Cables from aboard a Marine Vessel

(To be used in conjunction with an approved G3 Procedure)

KEY CHANGES

<table>
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<tr>
<td>DRAFT</td>
<td></td>
<td>New SFWWP</td>
<td></td>
<td></td>
</tr>
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</table>

1. **Dangers to Personnel**

The main Dangers to personnel during the course of the work are electric shock, burns or other injuries arising from:

1.1 Test voltages
1.2 Impressed voltages
1.3 The Equipment remaining charged or polarised after test

2. **Approved Work**

2.1 Cable Testing from a marine vessel requiring removal/reapplication of Primary Earths
2.2 Application and removal of HV test leads
2.3 Fault location testing from a marine vessel requiring removal/reapplication of Primary Earths
3. Responsibilities

3.1 The **Competent Person** shall comply with the requirements of the National Safety Instruction Numbers: 9 - Testing of High Voltage Equipment, 27 – Work on or near to **High Voltage Direct Current Equipment** and Number 5 - **Cable Systems**.

3.2 This **Sanction for Work** Procedure is only valid when issued in conjunction with an Approved G3 Procedure. An example of which is provided in NSI27 which shall be reviewed, **Approved** and issued before use.

3.3 This procedure shall be carried out under the **Personal Supervision** of the **Competent Person** or an **Offshore Supervisor** holding the **Sanction for Work**.

3.3 The **Competent Person** shall ensure that only work defined in Section 2 of this procedure is carried out whilst **Primary Earth(s)** are removed.

4. Safety Precautions to be taken before and during the course of removal/application of **Primary Earths**

The **Competent Person** shall:

4.1 Ensure that only the **Equipment** identified in Section 1 of the **Sanction for Work** is affected by the **Approved** Work specified in section 2 of this procedure.

4.2 Warn all persons in the working party of the intention to remove **Primary Earths** and to restore essential supplies/apply test voltage and that they remain clear of primary connections during the period of restoration.

4.3 Warn all persons not in the **Working Party** that could be affected by the work activity of the intention to remove **Primary Earth(s)** and ensure that they remain clear of the **Sanction for Work** area and remote end(s) during the period of testing.

4.4 Ensure that communication has been established and is maintained between the person applying the test voltage/signal and any other persons positioned remote from the location where the test voltage is applied.

4.5 Remove **Primary Earth(s)** specified in section 3 of the **Sanction for Work**. At remote ends **Primary Earths** may only be removed or re-applied by a **Competent Person** in receipt of a formal switching instruction given by the recipient of the **Sanction for Work**. Where the **Competent Person** holding the **Sanction for Work** does not hold authorisation to NSI9 then this instruction shall be co-ordinated and given by a National Grid Senior Authorised Person. This will usually be the case if the recipient of the **Sanction for Work** is undertaking the role of **marine co-ordinator** as part of an **Approved** G3 procedure.

4.6 Carry out Approved Work on **Equipment** stated in section 1 of the **Sanction for Work**.

5. Reinstatement of **Primary Earth(s)** when further work is required

5.1 Ensure the **Equipment** has been discharged to earth following the application of any test voltage.

5.2 Reapply **Primary Earth(s)** removed under section 4.5 of this procedure.

5.3 Repeat actions as specified in Section 2 of the **Sanction for Work** to avoid danger from the system.

REFERENCE SHALL BE MADE TO AMBP 228 - MANAGEMENT OF ET OPERATIONS CONTROLLED DOCUMENTS AND COMMUNICATION BEFORE THIS DOCUMENT IS ISSUED.
## Appendix F - Authorisation Matrix for Personnel

<table>
<thead>
<tr>
<th>Contractor Personnel</th>
<th>Person</th>
<th>Competent Person</th>
<th>Authorised Person</th>
<th>Senior Authorised Person</th>
<th>Control Person Operations</th>
<th>Control Person Safety</th>
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</thead>
<tbody>
<tr>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Appendix B</td>
<td>All Sections</td>
<td>All Sections</td>
<td>All Sections</td>
</tr>
</tbody>
</table>

### Contractors Personnel

*Note:* Contractors are not authorised to this NSI; instruction and information regarding site specific HVDC Safety Clearances should be communicated at site induction and contained within the NG "Safety from the System" RAMS as a minimum.

Contractors by law have a duty to provide a Safe System of Work for their employees.

National Grid have a duty in law to employ Competent Contractors to undertake work on HVDC Equipment and provide them with National Grid’s Safe System of Work to enable them to develop their own Safe Systems of Work.

National Grid Supply Chain Management processes ensure Competent Contractors are selected.

Once a Competent Contractor is selected, National Grid has a duty to ensure the contractor understands Danger(s) associated with undertaking work within a HVDC compound, permit systems, demarcation and safe access and egress, including movement of objects and vehicles etc. This is accomplished by contractors employees being authorised to National Grid Safety Rules and to NSI 6 and 8, via Management Procedure - NSI 30 “Appointment of Persons” for work onshore.

The contractor selected shall be an expert, as deemed by a contracted service providers agreement, in the area of working on HVDC Equipment and therefore there is no requirement for authorisation under NSI 27.

Before a Safety Document is issued the NSI 27 Senior Authorised Person shall establish Safety from the System. The contractors risk assessment and method statement shall be reviewed by the Senior Authorised Person to ensure the Danger(s) identified in NSI 27 are suitably controlled.