National Grid UK Electricity Transmission plc

Uncontrolled when printed

NATIONAL SAFETY INSTRUCTION
and
Guidance

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

DOCUMENT HISTORY

Issue	Date	Summary of Changes / Reason	Author(s)	Approved By (Title)
1	Dec 2015	New NSI & Guidance Document.	HVDC Working Group	Matt Staley ETAM Operations North Manager

KEY CHANGES

Section	Amendments

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

CONTENTS

1 Purpose and Scope

To apply the principles established by the Safety Rules and provide guidance on working on or near to **HV**DC **Equipment**. To protect personnel from **Danger** arising due to working on or near an ***HV****DC Transmission* ***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 **HV**DC Equipment
- Access to **Equipment** within an **HV**DC *Converter Station*
- Work or testing on **HV**DC **Equipment** within a *Converter Station*
- Work or testing on **HV**DC Cables
- Specific Switching Instructions for work on a ***HV****DC* ***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 explicitally stated.

2 Definitions

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

Title	Definition
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.
Converter Unit	Operative unit comprising *valve*s, converter transformer(s), control and protection **Equipment,** switching devices and auxiliaries used for conversion.
DC Current Measuring Device	These may comprise one of following types; DCCT 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 an **HV**DC circuit. RCS Resistive Current Shunt. This **Equipment** uses laser light technology to read the voltage across a known resistance (shunt) in the **HV**DC circuit.
DC Voltage Divider	DC Voltage Dividers are 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)	Restricted room or location in which DC **Equipment** associated with the *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*).
***High Voltage** Direct Current (**HV**DC) Converter Station*	Part of a **HV**DC S**ystem** 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 **Equipment**
HV**DC **System	**Equipment** which transfers energy in the form of high-voltage direct current (**HV**DC) between two or more alternating current buses.
*HVDC transmission **System***	**HV**DC **System** that transfers energy between two or more geographical locations
Neutral Bus	A conductor connecting the neutral terminals of two poles
Power Line Carrier (PLC) and associated equipment	A device that may be used to impose signalling or block signalling and system generated frequencies onto a conductor which can then be used for communications between **HV**DC Converter Stations
Pole	Part of a ***HV**DC **System*** consisting of both AC and DC **Equipment** at the **HV**DC *Converter Station* and the interconnecting transmission medium, if any.
Valve	Complete valve device assembly 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 usually comprises a closed loop liquid cooling system.

3 Dangers

The main dangers when working on **HV**DC **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 signals.
- Pressurised rooms.

NSI 27
4.1 to 4.4

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 **HV**DC **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)**

Location	Safety Distance (s) (metres)	
	High Voltage Equipment	Neutral Bus
Sellindge Converter Station	2.4	0.8
Flintshire Bridge Converter Station	4.4	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**.

4.3 Application of **Safety Distance** to **HV**DC Bypass Circuits

Some **HV**DC 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

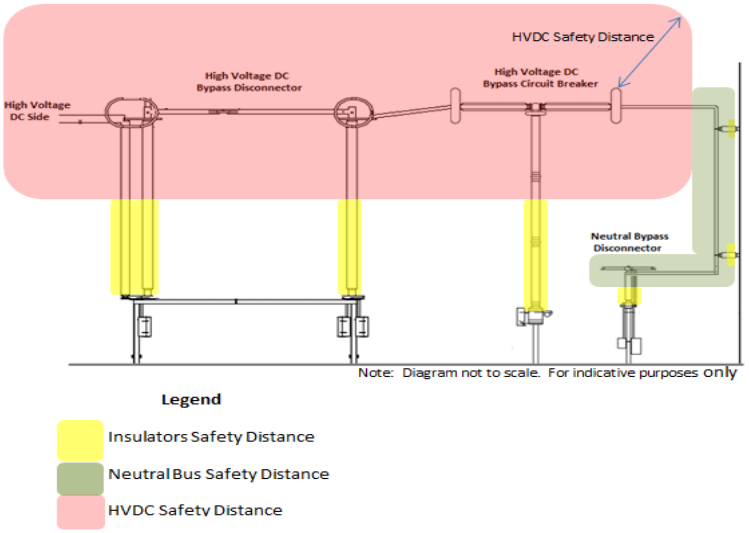
4 Approach to Exposed HVDC Conductors and Insulators

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

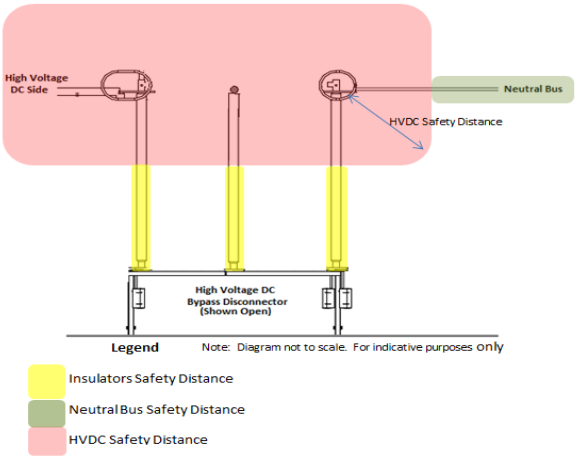
4.3 Application of **Safety Distance** to **HV**DC Bypass Circuits

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

- Where the **HV**DC bypass circuit includes a 'Bypass Switch'



- Where the **HV**DC Bypass Circuit includes only a bypass disconnector



4.4 Such **Earthing Device**(s) may be designated on the Operation Diagram or in an Operational Protocol Document.

Note:- NG **Staff** that are not authorised to this NSI, instruction and information regarding site specific **HV**DC **Safety Distance(s)**will receive the information via site induction and if necessary via a written risk assessment.

NSI 27
5.1

5 Specific Requirements for Working in HVDC *Converter Station*s

5.1 When works to be carried out on or near **HV**DC **Equipment**, *Valve Cooling Equipment* and / or associated Cable Terminations of a **HV**DC Converter Station, then a safe system of work **shall** be established in accordance with the National Grid Safety Rules and associated National Safety Instructions.

Guidance
NSI 27
5.1

5 Specific Requirements for Working in HVDC *Converter Station*s

5.1 *Valve Halls*

- Access to a *Valve Hall* is prevented by interlocks whilst the *converter station* is in operation. Access shall not be permitted until the *Pole* has **Points of Isolation** and **Earthing** established, in accordance with NSI 1 & 2 and NG Safety Rules, and a Safety Document Issued.

  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 local procedure, as determined by the Team Leader and SAP.

- Where external Earthing is applied which does not satisfy the *Valve Hall* door interlock, it willbe necessary to defeat interlocks to allow access to the *Valve Hall*. This shall be carried out by an NSI 27 authorised SAP.

- 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.

HVDC **Equipment**

- There may be neutral earthing capacitors used as part of the **HV**DC connections scheme within a *Valve Hall* or connected to a common neutral busbar between two *Pole*s 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 Station*s feature a *PLC* in the AC yard. In this case, the **Equipment** exhibits similar hazards and safety precautions shall be established accordingly.

Guidance
NSI 27
5.1 cont.

- *DC Voltage Dividers* are not considered as a **HV** infeed in a similar way as High Accuracy Metering Voltage Transformers on a **High Voltage** AC **system**. Therefore it is not necessary to establish **Point(s) of Isolation** on this E**quipment**.

- *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.

Auxiliary Equipment,

- *Valve* cooling is achieved by:
  - (i) Closed loop liquid cooling systems comprising pipework, *valve*s, 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 or Filter Hall) and may also be capable of heating.
- When working on the closed loop liquid cooling **system**; **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 on the cooling **Equipment** 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

Additional General Safety Hazards Specific to **HV**DC Equipment

- There are other risks within a *Valve* Hall that are not normally found in National Grid's conventional substations. Some of the significant risks 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.

NSI 27
6.1 to 6.4

6 HVDC Cables

6.1 When work or testing is to be carried out on onshore **HV**DC cables, then a safe system of work **shall** be established in accordance with the National Grid Safety Rules and associated National Safety Instructions.

6.2 Cable records shall be used to identify a cable on which work or testing is to be carried out. The identification of the cable to be worked upon shall be confirmed and recorded by the **Senior Authorised Person**.

6.3 For cable work being undertaken offshore a procedure, provided by the competent Contracted Service Provider, shall be used for the identification of the cable and referenced by the **Senior Authorised Person** issuing the **Safety Document**.

6.4 A **Senior Authorised Person** shall ensure a written risk assessment for work on or near to **HV**DC cable systems is undertaken. The assessment shall consider whether the cable system(s) to be worked on, including any cable accessories, are subject to Impressed Voltage Conditions.

Guidance
NSI 27
6.1 to 6.2

6 HVDC Cables

6.1 The safe system of work shall include:-

- Co-ordination meeting (TP153 / AMBP 310) between National Grid Senior Authorised Person, **Control Person (Safety)** and the Competent Contractor undertaking the Cable Works.
- Submission of RAMS for cable identification, cable maintenance or repair to the National Grid Senior Authorised Person by the Competent Contractor.
- Co-ordination across Control boundaries shall be managed by the Control Person Safety.
- Points of Isolation, Primary Earthing, and additional Earthing shall be established as identified by the Senior Authorised Person (NSI 5) issuing the Safety Document.
- NSI 6 demarcation will be followed where practicable.
- The Safety Document shall be issued to the Contracted Service Provider's Competent Person authorised to National Safety Instructions 2,6,8 (Limited), 9.
- The Competent Person is responsible for the work methodology used by all members of the working party undertaking the cable maintenance / repair.

For Cable Work being undertaken onshore, the principles of NSI 5 - Cable Systems and / or NSI 12 – Low Voltage Equipment shall apply.

6.2 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, as confirmed by the Senior Authorised Person.

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

Guidance
NSI 27
6.2 cont.

methodology being used by the Contracted Service provider to ensure **System** Safety is maintained throughout the course of the work. The SAP does not approve the Contractors RAMS' as it is a legal duty of the Contractor to provide suitable and sufficient RAMS to manage the work being undertaken

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

- Signal / Tone Generator cable locator
- The cable route GPS markers marked on charts
- Identification of poles

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.

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 Flintshire Bridge (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 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.

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 Station*s in France and UK will isolate and earth a pair of cables for the whole route between *converter station*s.

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.

Guidance
NSI 27
6.2 cont. to 6.4

Other Fault Location Techniques

The methods for locating an insulation fault are directly related to the resistance of the fault path, water depth, cable length and to the needed precision. Typically, two methods are considered as described below.

Echo-meters (Time Domain Reflectometers)
This kind of equipment is particularly useful for pre-localization of faults with precision of a few percent of the cable length.
In most cases this is enough to allow the choice of the repair method and the relevant Vessel and equipment.

Electroding
The electroding method is particularly useful if used after a pre-localization with other land based methods.

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

6.3 For offshore cable maintenance / repair the safe system of work shall include:-

- Co-ordination meeting (TP153 / AMBP 310) between National Grid Senior Authorised Person, Control Person Safety(s) and the Competent Contractor undertaking the Cable Works.
- Submission of RAMS for cable identification, cable maintenance or repair to the National Grid Senior Authorised Person by the Competent Contractor.
- Co-ordination across Control boundaries shall be managed by the Control Person Safety.
- The cable shall be removed from the system via the NSI 33 procedure to remove the cable from National Grid Safety Rules or by using an existing agreed procedure such as The “Pink Version” agreement between Sellindge and France.

6.4 The SAP shall agree with the principles within the submitted Contracted Service Provider’s RAMS to undertake the work on or near to the cable dependent upon the work being undertaken. The SAP does not approve the Contractors RAMS’ as it is a legal duty of the Contractor to provide suitable and sufficient RAMS to manage the work being undertaken. The work methodology shall incorporate the use of Insulated / Non-Insulated cable working techniques, where applicable, to manage Impressed Voltage Conditions.

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 station*s is usually governed by the level of switching impulse voltage to which the **Equipment** might be exposed.

*Converter station*s 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 station*s 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 Distance**s 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 **HV**DC 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; 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.

The switching instruction shall take the form;

On Pole 1; execute Earthed command.
Check closed and apply lock to Earth Switches x,y,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.

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 **HV**DC Switchgear controls. These allow only the HVDC switchgear associated with the *Pole*s to be automatically configured in *Pole* or *Bipole* modes.

3. There are no interlocks between the Sellindge and Les Mandarins *Converter Station*s. 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 co-ordination 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 - Authorisation Matrix for Personnel

Contractor **Personnel**	**Person**	**Competent Person**	**Authorised Person**	**Senior Authorised Person**	**Control Person Operations**	**Control Person Safety**
N/A	N/A	Sections	Sections	All Sections	All Sections	All Sections

Contractors Personnel

*Note:- Contractors are not authorised to this NSI; instruction and information regarding site specific **HV**DC Safety Clearences should be communicated at site induction and contained within the NG "Safety from the System" RAMS.*

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 **HV**DC 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 **HV**DC 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 reveiwed by the **Senior Authorised Person** to ensure the **Danger(s)** identified in NSI 27 are suitably controlled.

The National Grid **Senior Authorised Person** will issue a **Safety Document** to a contractors **Competent Person** authorised to NSI 6 & 8 onshore or follow the process and procedures established within this NSI when offshore.