

# National Grid UK Electricity Transmission plc

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## NATIONAL SAFETY INSTRUCTION


### Guidance Notes

#### NSI 10 EQUIPMENT CONTAINING SULPHUR HEXAFLUORIDE (SF<sub>6</sub>)

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## DOCUMENT HISTORY

Issue	Date	Summary of Changes / Reason	Author(s)	Approved By (Title)
1	7 <sup>th</sup> July 2009	New Guidance document to follow 3 <sup>rd</sup> edition Electricity Safety Rules layout	NSI Working Group	MDE Manager Les Adams 

## KEY CHANGES

Section	Amendments

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## EQUIPMENT CONTAINING SULPHUR HEXAFLUORIDE (SF<sub>6</sub>)

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## 1 Purpose and Scope

To provide guidance on National Safety Instruction 10, when applying principles established by the Safety Rules to achieve **Safety from the System** for personnel working on **Equipment** containing or which has contained Sulphur Hexafluoride (SF<sub>6</sub>) gas.

There is no requirement for **Personnel** to be formally appointed to this NSI in the following situations:-

- When working on Air Insulated Switchgear (AIS) and internal access to a *Gas Zone* is not required
- When performing timing or operational testing on AIS in accordance with National Grid's maintenance policy
- When performing operational and safety switching in accordance with Management Procedure NSI 1 "Operational and Safety Switching"
- Routine topping up and sampling of *Gas Zones* in accordance with a routine risk assessment and method statement (RAMS)

The layout of this guidance note 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.

## 2 Definitions

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

Title	Definition
<i>Gas Zone</i>	Discrete sections of SF <sub>6</sub> <b>Equipment</b> which may comprise of one or more compartments and can be independently isolated and evacuated of SF <sub>6</sub>  A <i>Gas Zone</i> may comprise of:- <ul style="list-style-type: none"> <li>• A single-phase enclosure</li> <li>• A single enclosure containing the three phases of an item of <b>Equipment</b></li> <li>• Three single-phase enclosures of a common item of <b>Equipment</b> connected by inter-phase pipe work</li> </ul>
<i>Designated Gas Zone Access Point Notice</i>	A notice which shall be attached to a <i>Gas Zone</i> access point(s) which requires venting prior to access
<i>Vented Gas Zone Access Point Notice</i>	A notice which shall be attached to a <i>Gas Zone</i> which has been <b>Vented</b> and can be entered

### 3 Dangers

The **System Danger(s)** to personnel from **Equipment** containing SF<sub>6</sub> gas are, asphyxiation, electric shock, stored energy, poisoning and burns arising from:-

- Oxygen deficiency within a confined space
- Failure of a **Point of Isolation** or inadvertent re-energisation
- Contact with SF<sub>6</sub> by-products
- Failure to control energy within spring / hydraulic mechanisms, face plates under pressure
- Failure of a gas barrier

**NSI 10**  
4.1 to 4.2

**4 General Requirements for Work**

- 4.1 Work areas shall be clearly demarcated.
- 4.2 When depressurisation is not required to allow work to be done, the following precautions shall be taken to achieve **Safety from the System**:-
- a) Limiting the work or work area, followed by the issue of a **Limited Access Certificate** if appropriate
  - or
  - b) Applying appropriate safety precautions, followed by the issue of a **Permit for Work** or **Sanction for Work**

**Guidance**  
NSI 10  
4.1 to 4.2

4.1 Demarcation shall be carried out in accordance with Management Procedure NSI 6 – “Demarcation in Substations”.

4.2(a) Where contractors are carrying out work which falls into either Category 1 or Category 2 work as defined in Management Procedure – “Work and Work Execution” and the means of achieving **Safety from the System** is by limiting the work or work area, a **Senior Authorised Person** shall confirm these instructions in writing by the issue of a **Limited Access Certificate**.

The only exception to this requirement is where the identified work, and / or work area are limiting in their own right, and controls are identified in the risk assessment and method statement, thus ensuring there is no risk from the **System**.

4.2(b) Where work is on **LV** or mechanical parts of the **HV Equipment** and there is:

- No depressurisation of the *Gas Zone*
- No **Danger** from infringement of the **HV System**
- No operation of **Earthing Device(s)**

Then there are no requirements to establish **HV** safety precautions.

**Guidance**  
NSI 10  
4.2 Cont:

Examples of work where **HV** safety precautions are not required are:-

- Timing an SF<sub>6</sub> circuit breaker where all test leads are external to the *Gas Zone* and no earth connection is required e.g. via:-

Optical Interface  
Electrical Transducer  
Mechanical transducer

- Topping up a *Gas Zone* where **Safety Distance** is not infringed and no **Point(s) of Isolation** are established
- Work on **LV** electrical system where **Safety Distance** and integrity of the *Gas Zone* are not compromised
- Work on mechanical systems where **Safety Distance** and integrity of the *Gas Zone* are not compromised e.g.:-

Written Scheme of Examination on safety valve / local air storage vessel  
Topping up hydraulic system  
Topping up accumulator  
Replacement of hydraulic pressure switch / mechanism

As **HV Equipment** also contains, **LV** and mechanical components safety across control boundaries shall be established and maintained.

If the **HV Equipment** is required for a short duration outage to enable non intrusive **LV** / Mechanical work to be undertaken the following process shall be adopted:-

- The **Control Person** for the **LV** / Mechanical **Equipment** shall contact the **Control Person (Operation)** for the **HV Equipment** and receive an instruction as per Management Procedure NSI 1 "Operational and Safety Switching", to take operational control / operate as required the relevant **HV Equipment**
- The relevant **HV Equipment** shall then be selected to local control at either the substation control point or the local control point by the **Authorised Person**.
- **LV** and mechanical safety precautions shall then be established as per the requirements of the Safety Rules
- On completion of the work the **Control Person LV** / Mechanical shall contact the appropriate **Control Person (Operation) HV** to return control of the relevant **HV Equipment** via an instruction as per Management Procedure NSI 1 "Operational and Safety Switching"

**Guidance**  
NSI 10  
4.2 Cont:

If the **HV Equipment** has been transferred to the NOC due to other work the following process shall be adopted:-

- The **Control Person** for the **LV / Mechanical Equipment** shall contact the **Control Person (Safety)** for the **HV Equipment** and receive an instruction as per Management Procedure NSI 1 “Operational and Safety Switching”, to take operational control / operate as required for the relevant **HV Equipment**
- The relevant **HV Equipment** shall then be selected to either the substation control point or the local control point by the **Authorised Person** if applicable
- An “Operate as Required” shall not be instructed on a **System State Certificate** boundary isolator due to trapped charge issues
- **LV** and mechanical safety precautions shall then be established as per the requirements of the Safety Rules
- On completion of the work the **Control Person LV / Mechanical** shall contact the appropriate **Control Person (Safety) HV** to return control of the relevant **HV Equipment** via an instruction as per Management Procedure NSI 1 “Operational and Safety Switching”

**NSI 10**  
4.3

4.3 When depressurisation of a *Gas Zone* is required a **Competent Person** shall establish the toxicity of the gas contained within the *Gas Zone* prior to evacuation.

**Guidance**  
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4.3

4.3 The **Competent Person** shall ensure the gas is drawn through a dry filter to avoid contaminating the gas handling equipment.

**DETERMINATION OF THE PRESENCE OF HYDROGEN FLUORIDE (HF) AND SULPHUR DIOXIDE (SO<sub>2</sub>)**

The unlikely presence of significant quantities of these gasses may be determined by use of a stain tube indicator or gas titration. The method of use is described in the literature that comes with the tubes. It should be remembered that Hydrogen Fluoride is produced when the arc products make contact with moisture.

Once moisture is introduced into the *Gas Zone* e.g. after breaking vacuum with air, the Hydrogen Fluoride readings may change due to the introduction of moisture. Therefore measurements will need to be taken both inside the chamber and in the vicinity of the arc products exposed to ambient air to determine if **Danger** exists.

Workplace Exposure Limits are:-

HF = 1.8 parts per million by volume  
SO<sub>2</sub> = 2.0 parts per million by volume

**NSI 10**  
**5.1**

## **5 Internal Access to a Gas Zone**

5.1 When internal access to a *Gas Zone* is required the following shall apply:-

- a) A detailed written risk assessment and method statement shall be produced. The **Senior Authorised Person** shall assess the work and method statement to ensure that **Safety from the System** is achieved.
- b) The **Senior Authorised Person** shall prepare a **Permit for Work** or **Sanction for Work** as appropriate.
- c) The **Senior Authorised Person** shall clearly identify each required access point into the *Gas Zone(s)* and ensure the appropriate notices are displayed.
- d) Where reasonably practicable work within a *Gas Zone* shall be undertaken with the adjacent *Gas Zone(s)* reduced to atmospheric pressure. Where it is not reasonably practicable to reduce the adjacent *Gas Zone* to atmospheric pressure, work shall only be undertaken, provided all the following conditions have been met.
  - A vacuum of -1 bar g has been drawn and maintained in the enclosure to be worked in for 1 hour with the pump isolated
  - There is no known or suspected mechanical or electrical damage to the pressurised barrier within the enclosure remaining pressurised
  - No known electrical flashover has occurred
  - No work on the busbar or barrier which may cause stress to the pressurised barrier shall be undertaken
  - A safe system of work is devised and implemented, which shall include, the use of suitable protective equipment to prevent damage to the pressurised barrier
- e) Before opening any designated access point(s) the recipient of the **Safety Document** shall ensure that the relevant *Gas Zone(s)* is **Vented** and Section (A) of Gas Zone Access Control Form completed.
- f) The recipient of the **Safety Document** shall ensure that relevant *Designated Gas Zone Access Point Notice(s)* are replaced with *Vented Gas Zone Access Point Notice(s)*. The recipient of the **Safety Document** can then give permission for members of the **Working Party** to open the access point(s) of the relevant *Gas Zone*.
- g) Following opening of the access points, but before personnel access into the *Gas Zone* is permitted, the recipient of the **Safety Document** shall confirm that the *Gas Zone* is **Purged** of SF<sub>6</sub> and nitrogen and verify the oxygen content within the *Gas Zone*. Section (B) of Gas Zone Access Control Form shall be completed.

**NSI 10**  
5.1 Cont:-

- h) If toxic breakdown products are detected at this point, access to the *Gas Zone* shall be restricted until removal of the breakdown product has been achieved.
- i) When the work requires the *Gas Zone* to be pressurised or drawn under vacuum, the recipient of the **Safety Document**, shall ensure that all members of the **Working Party** are accounted for prior to securing the designated access points. The recipient of the **Safety Document** shall then withdraw the **Working Party** and replace the '*Vented Gas Zone Access Point Notice(s)*' with '*Designated Gas Zone Access Point Notice(s)*'.  
  
The **Working Party** shall then be informed of the change in state of the *Gas Zone* and Section (C) of Gas Zone Access Control Form completed. The *Gas Zone* may then be pressurised, or drawn under vacuum.
- j) The requirements of points (e/f/g) shall be repeated each time that the method statement requires depressurisation to open any designated access point.
- k) The requirements of point (i) shall be repeated each time that the method statement requires the *Gas Zone* to be pressurised or drawn under vacuum.
- l) Upon clearance or transfer of the **Safety Document**, the **Competent Person** shall state the condition of the *Gas Zone* by completing Section (E) or (D) of the Gas Zone Access Control Form immediately prior to the **Safety Document** clearance or surrender.

**Guidance**  
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5.1

- 5.1(a) The risk assessment and method statement shall detail the hazards and controls appropriate to the work including the stages at which the *Gas Zone* shall be refilled with the appropriate gas to prevent moisture ingress and subsequently, **Vented** and **Purged** to allow safe internal access.
- (c) When the **Safety Document** is to be issued with the *Gas Zone* still at pressure a *Designated Gas Zone Access Point Notice* shall be used. When the **Safety Document** is to be issued after completion of *Gas Zone* venting and purging a *Vented Gas Zone Access Point Notice* shall be used.
- (d) Gas Insulated Switchgear (GIS) is divided into discrete *Gas Zones* by cast resin barriers (partitions). The majority of **Equipment** is manufactured to safely withstand full differential pressures across the barrier (i.e. pressure on one side and a vacuum on the other). Operation and Maintenance manuals shall be consulted to confirm full differential pressure can be withstood across the barrier.

**Guidance**  
NSI 10  
5.1 Cont:-

5.1(e) The recipient of the **Safety Document** shall sign; time and date Section (A) of the Gas Zone Access Control Form, refer to Appendix B of this document. For work involving multiple *Gas Zones* a separate Gas Zone Access Control Form shall be used for each individual *Gas Zone*.

(g) The oxygen content shall be measured by the use of an appropriate calibrated instrument and the resultant figure recorded on Gas Zone Access Control Form. Personnel access, without breathing apparatus, can only be permitted if the oxygen content is within the range of 19% to 21% and can be maintained within this value throughout the course of the work by suitable ventilation and/or monitoring.

(h) **PROCEDURE FOR ENTRY INTO A CHAMBER WHERE THE EXISTENCE OF BY-PRODUCTS IS SUSPECTED OR HAVE BEEN FOUND**

This includes routine entry into any circuit breaker or disconnector *Gas Zone* containing contacts/interrupters, as well as emergency work following a fault.

An HF and SO<sub>2</sub> test if practicable should be carried out on the gas in the *Gas Zone*, this is to determine if significant abnormal levels of arc product gases are present and assist in fault location.

After a fault, e.g. post arc, at least 24 hours should be allowed to let the molecular sieve absorb gas arc products and then a further period of 1 hour after breaking the vacuum, to allow solid contaminants to settle, before personnel are exposed to the post arc environment.

Before opening a chamber for work a vacuum will be drawn on the chamber - this is both to evacuate the gas and, in some cases, to prove the integrity of the gas barrier to adjacent **Point(s) of Isolation**.

If the chamber or a bursting disc has ruptured, in order to establish the integrity of the Gas Zone(s) the following shall apply:-

- A **Permit for Work** shall be issued
- Use of appropriate PPE to control any exposure to by-products
- Bursting disc(s) shall be replaced
- Draw a vacuum to determine integrity of the chamber / gas barriers



Figure 5.1 A – Example of SF<sub>6</sub> Contamination

**Guidance**  
NSI 10  
5.1 Cont:-

It will not normally be necessary for the access point to be tented to exclude contamination of the surrounding area, unless advised by the **Senior Authorised Person**. Tenting may however be necessary to provide a clean environment for subsequent work on the equipment.

The vacuum shall be broken to dry air.

A **Permit for Work** will be issued. A confined space risk assessment and method statement will be completed by the **Senior Authorised Person** if a confined space is involved.

One point of access shall be identified by a *Designated Gas Zone Access Point* notice and opened for the initial inspection by the **Senior Authorised Person** prior to work commencing.

To assist in the opening of the access point, the chamber should be at a very small positive pressure (a few millibar). This pressure shall be released by breaking the seal on the point of entry before completely releasing retaining bolts. This process may result in the release of a small quantity of by-products.

Suitable PPE shall be worn by personnel involved who may be exposed to SF<sub>6</sub> by-products as detailed in Management Procedure – ‘Personal Safety Equipment and Personal Protective Equipment’.

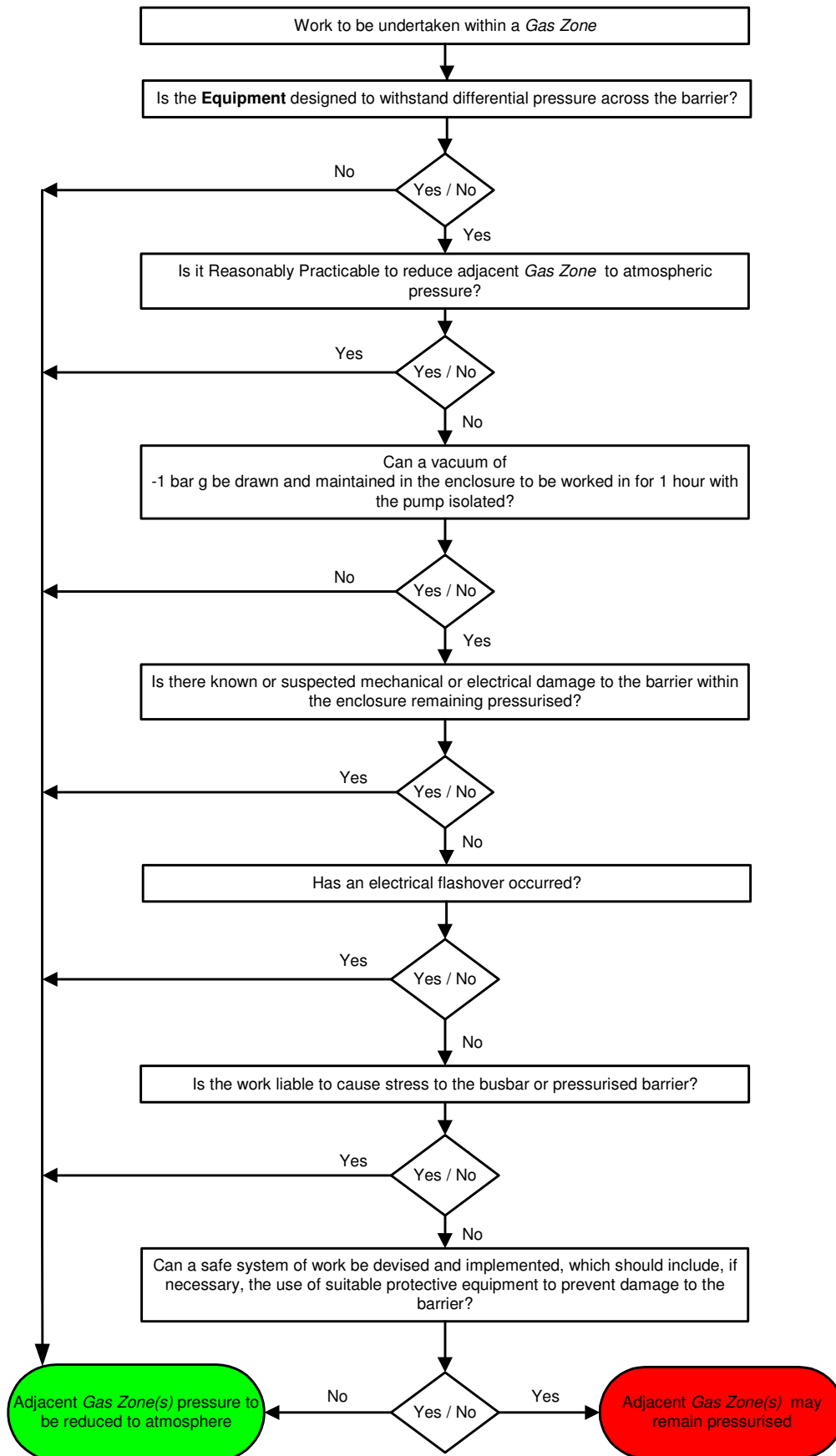
The **Senior Authorised Person** shall identify from his initial inspection whether it is necessary for an initial clean to remove arc products. At this stage, if white metal fluorides are observed in small quantities, the **Equipment** should be cleaned using a high efficiency vacuum cleaner by personnel wearing appropriate PPE.

It will not be necessary to tent the area unless a considerable amount of metal fluoride is present, and there is a likelihood of the dust being dispersed beyond the immediate confines of the switchgear.

Once the **Senior Authorised Person** is satisfied that metal fluorides are not present in visible quantities the safety precautions adopted for SF<sub>6</sub> by-products need no longer be taken and work can proceed after a new **Permit for Work** detailing the revised further precautions is issued. Clean conditions clothing shall be worn when working in SF<sub>6</sub> switchgear.

- (i) At each stage of the works requiring evacuation of the gas, the recipient of the **Safety Document** shall ensure that any SF<sub>6</sub> in the *Gas Zone* is recovered in accordance with National Grid environmental policy, relevant manufacturer “Operational and Maintenance Manual” and gas processing equipment instructions.

## Appendix A - Flow Chart for Working Adjacent to Pressurised Barriers



## Appendix B - Gas Zone Access Control Form

Initial Condition of Gas Zone e.g. SF <sub>6</sub> / N <sub>2</sub> / O <sub>2</sub> / and pressure Positive / Negative:	
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Safety Document Number:	Location:	Gas Zone Identification:
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A) Confirmation <i>Gas Zone Vented</i>				B) Confirmation <i>Gas Zone Purged</i> of SF <sub>6</sub> (if internal access required O <sub>2</sub> %)					C) Confirmation Designated Access Points Secured and <b>Working Party</b> withdrawn prior to pressurisation				
Name	Signature	Date	Time	Name	Signature	Date	Time	Oxygen (%)	Name	Signature	Date	Time	Working Party No:

D) Condition of <i>Gas Zone</i> at <b>Safety Document</b> Transfer:									
# Delete as Appropriate									
Competent Person Surrendering <b>Safety Document</b>						New <b>Safety Document</b> Recipient			
Name	Signature	Date	Time	Condition of <i>Gas Zone</i> e.g. SF <sub>6</sub> / N <sub>2</sub> / O <sub>2</sub> # and pressure Positive / Negative #		Name	Signature	Date	Time
E) Condition of <i>Gas Zone</i> at <b>Safety Document</b> Clearance e.g. SF <sub>6</sub> / N <sub>2</sub> / O <sub>2</sub> # and pressure Positive / Negative #									

Note: Form to be filed in maintenance file on completion

## Appendix C - Example Procedure for Timing SF<sub>6</sub> Circuit Breakers with Insulated Earthing Switch

Due to the nature of GIS, it is not always possible to gain direct access to the interrupter contacts to place timing leads across them therefore; a method of utilising one of the earth switches to make contact with the circuit breaker can be used.

Safety Aspects to be considered

1. Circulating currents in the GIS during switching / earthing of circuits. No work on the earth switch to be carried out during switching associated with dissipation of trapped charge.
2. An important pre-requisite to this appendix is that the three position switch to be used has been closed to earth and immobilised prior to the work commencing.

### Timing test carried out under a **Permit for Work**:

The earth switch that is to be used to connect the timing leads shall be recorded on the **Permit for Work as Equipment** to be worked on. The timing leads can then be connected as follows:-

1. Identify the earth connection to the earth switch to be used
  - a. 400 kV – Remove the earth shunts and the earth tape from the earth switch identified.
  - b. 132 kV – Remove earth bar connecting earth switch insulated pillars to earth.
2. Attach one timing lead to earth before attaching the other lead to the insulated metal block of the earth switch. (Repeat for all three phases)
3. Time circuit breaker as normal
4. Remove timing leads and restore the earth connection to normal
5. Record resistance readings to ensure earth connections are good

### Timing test carried out under a **Sanction for Work**

When timing is to be carried out under a **Sanction for Work** the timing leads shall be connected as follows:-

1. Close circuit breaker. (To earth the circuit )
2. Identify flexible earth connection to the earth switch to be used
  - a. 400 kV – Remove the earth shunts and the earth tape from the earth switch identified
  - b. 132 kV – Remove earth bar connecting earth switch insulated pillars to earth
3. Attach one timing lead to earth before attaching the other lead to the insulated metal block of the earth switch. (Repeat for all three phases)
4. Time circuit breaker as normal
5. Remove timing leads and restore the earth connection to normal
6. Record resistance readings to ensure earth connections are good
7. Open circuit breaker

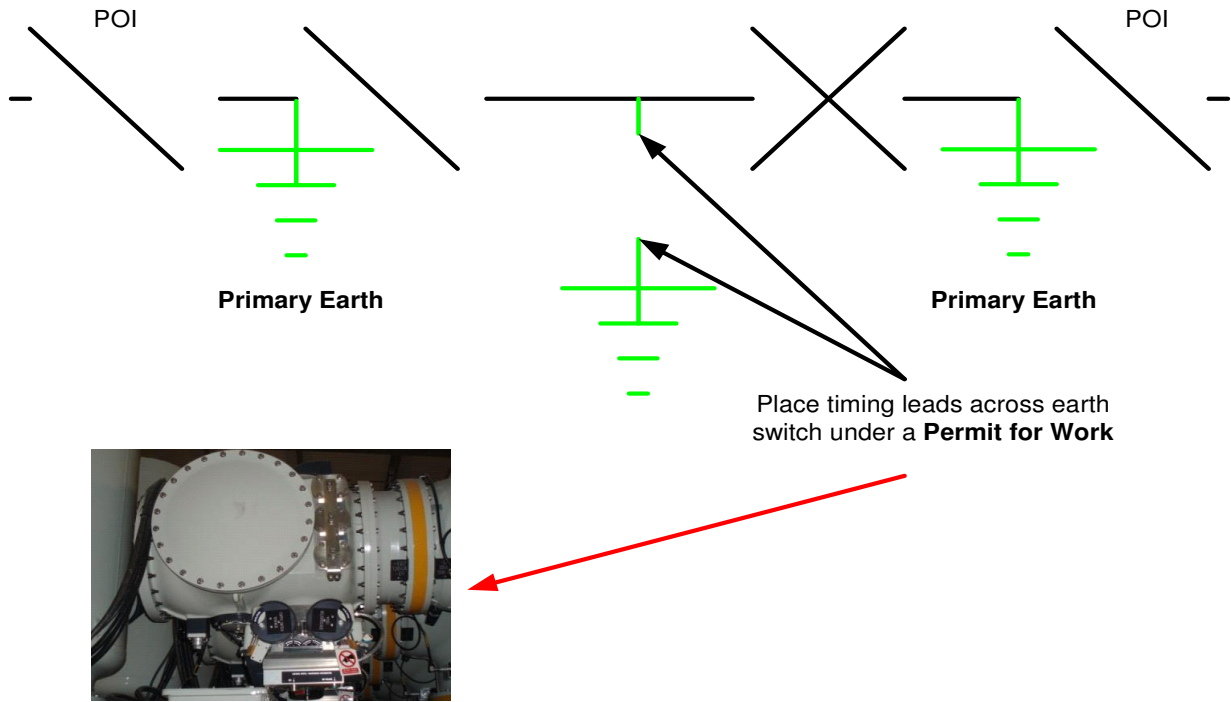


Figure C1 – Earth Connection

The above diagram illustrates that the POI shown on the left is likely to be at the remote end of the circuit, facilitating the **Primary Earth** being the local line earth switch. Therefore, co-ordination with the remote end work is required.

Due to the nature of the design of GIS the timing of Bus Coupler and Bus Section circuit breakers will most likely require a **Sanction for Work** unless an associated busbar section is also out of service.

Not all GIS earth switches are able to be made free of earth. The presence of an insulating barrier between the earth switch to be used and the main GIS should be ascertained as part of the project lead review.

Different manufacturers' maintenance policies differ on the requirements for timing circuit breakers, taking into consideration the mechanism design and possible modes of failure. Therefore, timing the circuit breaker from an auxiliary switch datum can be an alternative to this method if previous records can be compared to and maintenance policy allows it.

## Appendix D - Authorisation Matrix for Contractors Personnel

Contractor Personnel	Person	Competent Person	Authorised Person	Senior Authorised Person
Sections	N/A	N/A	N/A	N/A

### Contractors Personnel

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 SF<sub>6</sub> **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 **HV** 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".

The Contractor selected shall be an expert in the area of SF<sub>6</sub> **Equipment** and therefore there is no requirement for authorisation under NSI 10.

Before a **Safety Document** is issued the **Senior Authorised Person** shall be authorised to NSI 10 and shall ensure the Contractors risk assessment and method statements cover the **Danger(s)** identified in NSI 10.

The National Grid **Senior Authorised Person** will issue a **Safety Document** to a Contractors **Competent Person** authorised to NSI 6 & 8.