National Grid UK Electricity Transmission plc

NATIONAL SAFETY INSTRUCTION 24

and

Guidance

MODIFICATION OR REPAIR OF EARTH CONDUCTORS ON MAIN EARTH SYSTEMS

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DOCUMENT HISTORY

Issue	Date	Summary of Changes / Reason	Author(s)	Approved By (Title)
1	Dec 2011	Reformatted and re-drafted to follow 3rd. edition Electricity Safety Rules layout	NSI Working Party	MDE Manager Les Adams 
2	April 2014	Renamed as "National Safety Instruction and Guidance" which now incorporates and replaces NSI 24 Issue 4 and NSI 24 Guidance Issue 1	NSI Review Group	ETAM Operations North Manager Mike Dean
3	Feb 2021	Updated & Reformatted	Electricity Transmission Operations Safety Rules Team	Head of ET Operations Matt Staley
4	Dec 2021	Reorganisation role updates.	Safety Rules Team	Director of Asset Operations Matt Staley

KEY CHANGES

Section	Amendments
4.5 & 4.6 – Rule & Guidance, 8.3 Guidance	Network Engineering replaced with Engineering and Asset Management.

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MODIFICATION OR REPAIR OF EARTH CONDUCTORS ON MAIN EARTH SYSTEMS

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1 Purpose and Scope

To apply the principles established by the Safety Rules and provide guidance on National Safety Instruction 24, for approaching and working on *Main Earth System(s)*. It incorporates the principles contained in:

- TGN (E)114 “Replacement or Repair of Stolen or Defective Earth Tape”
- TGN (E)187 “Guidance for Conductor Jointing in Substations”
- TGN (E)204 “Model Procedure for Terminal Tower Earth Tape Tests”
- TGN (E)215 “Procedure for Terminal Tower Earthing with a Temporary Bond Prior to the Reinstatement of the Fixed Earth with a Permanent Repair”

A correctly designed and maintained *Main Earth System* is inherently safe under both steady state and transient fault conditions and therefore presents no **Danger** to personnel present within its vicinity. If a *Main Earth System* becomes an *Inadequate System,* then work shall be undertaken in a safe manner to restore the *Main Earth System*.

If a *Main Earth System* has become an *Inadequate System,* it is not always practical to de-energise the network to carry out corrective repair work; therefore *Earth Bond(s)* shall be applied to remove any **Danger** prior to the commencement of any permanent repair.

This procedure covers work on the donor substation *Main Earth System* and interconnections which may include:

- Generator / Distribution Network Operators *Main Earth System(s)*
- Overhead Line terminal tower leg(s)

Work on the Overhead Line earth conductor is managed by the application of Management Procedure NSI 4 “Work on or Near High Voltage Overhead Lines”.

Work on cable earths or sheaths etc. are managed by the application of Management Procedure NSI 5 “Cable Systems”.

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, 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.

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2 Definitions

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

Title	Definition
Temporary Earth Bond(s)	A Type Registered bridging connection used as an initial connection to eliminate **Danger** on any *Inadequate System.* Leads are coloured blue and are not fully fault rated. The *Temporary Earth Bond* consists of two 50mm^2 Aluflex leads (blue sheathed), ends crimped and affixed with a CE20/2 earth end clamp and a CE57 earth end clamp.
Pole(s)	A Type Registered device for the application of *Temporary Earth Bond(s)*.
Earth Bond(s)	*A* Type Registered bridging connection used for the purpose of providing earth continuity on earth connections. They are clear in colour and are fully fault rated when applied in appropriate numbers. Type A - An *Earth Bond* consisting of; two CE 20 earth end clamps supplied with one 150 mm^2 Aluflex lead (clear sheath), ends crimped with ESI/T1 compression terminations. Type B – As a Type A *Earth Bond* except the tower end of the *Earth Bond* will simply have crimped ends for direct bolting to the new connection point. This is to provide protection against interference from third parties.
Main Earth System	Interconnected, buried or surface conductors providing an electrical connection to earth and intended to carry fault current from **HV Equipment**.
Intact System	A *Main Earth System* in which there are no defects such as breaks or disconnections in any of the earth conductors that may affect the design performance of the earthing system.
Inadequate System	A *Main Earth System* in which there are defects such as breaks or disconnections in any of the earth conductors that may render the earthing system ineffective at managing **Danger**.
Step Potential	Potential difference which can be shunted by a human body with a stride 1 m long, the current path passing from foot to foot
Transfer Potential	Potential difference appearing between a conductor and earth which is remote from the *Main Earth System*, as a result of the *Main Earth System* being above the earth potential of the local earth.
Touch Potential	Potential difference which can be shunted through the human body, the current passing from hand to foot or from hand to hand

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3 Dangers

The **System Danger(s)** to **Personnel** working on *Main Earth System(s)* are electrocution, burns, effects on eyes, and impact injuries arising from: -

- Being exposed to a hazardous voltage (*Step Potential*, *Touch Potential* or *Transfer Potential*) across parts of the *Inadequate System*.
- Being struck by flying debris as a consequence of faults occurring on **Equipment** which fail catastrophically due to inadequate earthing.

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NSI 24
4.1 to 4.9

4 General Principles

4.1 No individual shall approach an *Inadequate Earth System* as defined in Section 5 until a **Senior Authorised Person** has assessed the means of achieving **Safety from the System**.

4.2 Where **Safety Distance** will be infringed, a **Permit for Work** shall be issued.

4.3 Where **Safety Distance** is not infringed, a **Limited Access Certificate** and or a method statement shall be issued.

4.4 Work shall be carried out by a **Competent Person** under an appropriate **Safety Document**.

4.5 Where there has been significant earth tape disturbance, particularly on buried conductors, which may significantly affect the performance of the *Main Earthing System*, advice should be sought from specialists within Engineering and Asset Management.

4.6 Where the profile or shape of the earthing conductor under repair does not fit with the *Temporary Earth Bond or Earth Bond(s)* clamps, advice should be sought from specialists within Engineering and Asset Management any repair is started.

4.7 Only *Temporary Earth Bond(s) and Pole(s)* shall approach within the distances specified in Sections 5.1 to 5.4 to make the initial connections.

4.8 Once *Temporary Earth Bond(s) have* been applied, Earth *Bond(s)* and individuals may encroach within 1m as specified within section 6.

4.9 The **Competent Person** shall ensure that no work will be undertaken that may prevent any applied *Temporary Earth Bond* or *Earth Bond*(s) from being effective.

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Guidance
NSI 24
4.3 to 4.9

4 General Principles

4.3 Safety Rule R2.4 states that "a distance of 300mm shall also be maintained from that part of the insulators supporting exposed unearthed **HV** conductors". A **Permit for Work** is not required when undertaking repairs on an *Inadequate Earthing System* outside of the 300mm envelope at the base of any support insulator.

NSI 24 manages any exposure to a hazardous voltage that may be present on the remaining earth tape left connected to the equipment and by limiting the approach distance to 1 metre, defined within Section 5.

The **Senior Authorised Person** shall record the number of *Earth Bonds* required on an **Earthing Schedule** or in a Method Statement.

4.5 If there has been considerable damage to the Main *Earth System* e.g. by separation of significant parts of the system through theft or when large parts of a buried *Main Earth System* has been compromised during construction ground work activities, hazardous voltages may be present under both system steady state and fault conditions. In instances such as these, access to the **HV** compound should be restricted and advice should be sought from specialists within Engineering and Asset Management for appropriate bonding and replacement procedures.

4.6 There are instances when it is not possible, or it is impracticable to use the type registered *Temporary Earth Bond or Earth Bond.* In these cases, advice shall be sought from specialists within Engineering and Asset Management.

Examples of when *Temporary Earth Bonds* cannot be fitted are:

(a) When the earth tape is a different profile or shape to that which can be accommodated by the Type Registered *Temporary Earth Bond* clamp.

(b) When there is insufficient earth tape available to accommodate all the earthing clamps needed prior to undertaking the permanent repair.

4.7 As a hazardous voltage may be present under steady state conditions, all initial connections on *Inadequate Systems* shall be made using the *Temporary Earth Bond and Pole.*

4.9 The *Temporary Earth Bond* clamp and *Earth Bond* clamps shall be positioned in such a place as to eliminate disturbance during the action of repairing the defect.

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NSI 24
5.1 to 5.4

5 Approaching Inadequate Main Earth System(s)

5.1 Concrete structures supporting **Equipment** with missing or suspected defective connections to the *Main Earth System*:

(a) When there is an increased risk of a System fault, individuals shall not encroach any closer than 10 metres to the support structure.

(b) When there is no increased risk of a System fault, Individuals may encroach up to 1 metre to the missing or defective earth tape or structure.

5.2 Metallic structures, excluding Overhead Line terminal towers, Supporting **Equipment** with missing or suspected defective connections to the *Main Earth System*:

(a) Individuals may encroach up to 1 metre to the missing or defective earth tape or its' structure.

5.3 Disturbed (normally buried) earth tape:

(a) Individuals may encroach up to 1 metre to the missing or defective earth tape.

5.4 On Overhead Line terminal tower(s), with missing or suspected defective earth connection(s) back to the substation *Main Earth System*:

(a) When there is an increased risk of a System fault, individuals shall not encroach any closer than 10 metres to the missing or suspect earth tape or the tower leg(s).

(b) When there is no increased risk of a System fault, individuals shall not encroach any closer than 1 metre to the missing or suspect earth tape or its terminal tower leg(s).

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Guidance
NSI 24
5.1 to 5.4

5 Approaching Inadequate Main Earth System(s)

5.1(a) The potential of a **System** fault is significantly increased during poor local weather conditions, (e.g. lightning, snow, fog, mist, high winds persistent heavy rain), during a local switching event, or when **Live** water washing of insulators is taking place within the substation.

A concrete structure supporting un-earthed **Equipment** may under fault conditions conduct **System** fault currents through the steel reinforcement members of the structure with the result that in extreme circumstances, the structure may rupture catastrophically. The establishment of a 10-metre hazard zone is there to manage the **Danger** of potentially being struck by flying concrete or hot metal.

5.1(b) When there is no increased risk of a system fault, a 1 metre exclusion zone is there to manage any accidental contact with the unearthed **Equipment,** or the remaining earth tape still secured to the **Equipment**.

5.2(a) The 1 metre exclusion zone is there to manage any accidental contact with the unearthed **Equipment,** or the remaining earth tape still secured to the **Equipment**.

5.3(a) Under steady state conditions, in a *Main Earth System* where parts of the below ground earth tape has been compromised; dangerous voltage differences may be present between isolated sections. The 1 metre exclusion zone around the disturbance is there to manage any risk from accidental contact.

5.4(a) During a local **System** fault (see guidance 5.1a), when the connection between the Overhead Line terminal tower and the substation *Main Earth System* has been compromised, unsafe touch voltages will exceed safe limits around the tower legs. Also, *Step Potential* safe limits during this time may also be exceeded for up to several metres from the tower legs. The 10-metre exclusion zone is there to manage the **Danger** from exposure to potentially hazardous *Touch* and *Step Potentials*.

5.4(b) The 1 metre exclusion zone is there to manage any accidental contact with the unearthed tower legs, or the remaining earth tape attached to it.

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NSI 24
6.1 to 6.6

6 Application of Temporary Earth Bonds and Earth Bonds to the Main Earth System

6.1 When the *Main Earth System is* an Inadequate *System, the* application of a *Temporary Earth Bond* and *Earth Bond* shall not be undertaken where there is an increased risk of a local **System** fault.

6.2 Before a permanent repair of an *Inadequate System* commences, an initial bridge connection across the defect shall be made by the **Competent Person** using the *Temporary Earth Bond* and *Pole.*

6.3 Once the *Temporary Earth Bond* is secured in place, the correct number of Type A *Earth Bond(s)* shall be attached across the defect by the **Competent Person**.

6.4 When the Type A *Earth Bond(s)* are all in position, the *Temporary Earth Bond* can then be removed, and a permanent repair undertaken.

6.5 Once a permanent repair has been completed, no control measures are required to remove the Type A *Earth Bond(s).*

6.6 Before breaking an *Intact System*, for instance to divert an earthing conductor because of construction work, the planned break shall first be bridged using either:

(a) A fully rated earth tape jointed in parallel (across) the break to be made.

(b) By fitting the appropriate number of Type A *Earth Bond(s)* in parallel (across) the planned break. Type A *Earth Bond(s)* shall remain in-place until the planned break is completed.

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Guidance
NSI 24
6.1 to 6.2

6 Application of Temporary Earth Bonds or Earth Bonds to the Main Earth System

6.1 Refer to Guidance Section 5.1 (a) for advice on scenarios that will increase the risk of a **System** fault.

6.2 A *Temporary Earth Bond* does not have a recognised fault rating and is applied initially to manage any voltage difference across the break on an *Inadequate System*.

A *Temporary Earth Bond Pole* comes in two sections, each 0.6 metre in length, the top section fitted with an OL1 operating socket. It has blue banding on each pole.

The top section pole incorporates a single flexible shed that prevents the operator from accidently touching the earth end clamp during an application or removal action.

Figure 6.2A - Temporary Earth Bond and Pole

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Guidance
NSI 24
6.2 Cont

Figure 6.2B - CE20/2 clamp

The first connection of the *Temporary Earth Bond* shall be made by hand by applying the earth end clamp (CE20/2) to a cleaned section of earth tape connected onto the *Main Earth System*, in proximity to the defect location.

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Guidance
NSI 24
6.2 Cont: to 6.6

Figure 6.2C - CE57 clamp

The second connection to make the bridge complete will be done by applying the CE57 clamp of the *Temporary Earth Bond* using the supplied pole onto the tape section of the **Equipment** on the other side of the defect.

6.3 Once the *Temporary Earth Bond* has been successfully applied, appropriate numbers of Type A *Earth Bond(s)* shall be applied as soon as is reasonably practical by the **Competent Person** in order to achieve the fault rating / circulating current capacity as defined within Appendix A in NSI 2 - “Earthing High Voltage Equipment”.

After the appropriate number of Type A *Earth Bond(s)* are applied the *Temporary Earth Bond* can be carefully removed.

It is acceptable for a **Primary Earth** to be dependent on the application of the Type A *Earth Bond(s)* within the earth path.

6.4 Type A *Earth Bond(s)* shall not remain in place for a period greater than 6 months due to possible joint deterioration. After this period has time expired, an additional Type A *Earth Bond* shall be applied in parallel to supplement the existing Type A *Earth Bond(s)* before each of the existing Type A *Earth Bond(s)* within that group are in turn removed, inspected for damage and re-applied.

An inspection routine shall be imposed to ensure that the Earth Bond(s) are routinely visually inspected.

6.6(b) The Type A *Earth Bond(s)* should be protected from disturbance from local ground work activities.

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NSI 24
7.1 to 7.2

7 Equipment - Neutral Earth Connection

7.1 **Equipment** with defective or missing neutral earth connections shall be **Isolated** from the **System**.

7.2 **Point(s) of Isolation** shall be established, and a **Permit for Work** shall be issued for repairs to be carried out on the neutral earth connections of **HV Equipment**.

Guidance
NSI 24
7.1 to 7.2

7 Equipment - Neutral Earth Connection

7.1 **Equipment e.g.** Transformers, MSC, SVC, MSCDN etc. with a defective neutral earth connection shall be **Isolated** from the **System** by ENCC in line with UK TP105 “Operational Liaison and Practice” Section 5.8.

7.2 A defective or missing neutral connection on the **HV Equipment** side of the star point has the potential for the connections to rise to line voltage when the **HV Equipment is** energised. The practicalities of applying a *Temporary Earth Bond* or *Earth Bonds* may well be difficult due to the complexity of the connections to be replaced and the limited space within which to apply the *Earth Bond(s).*

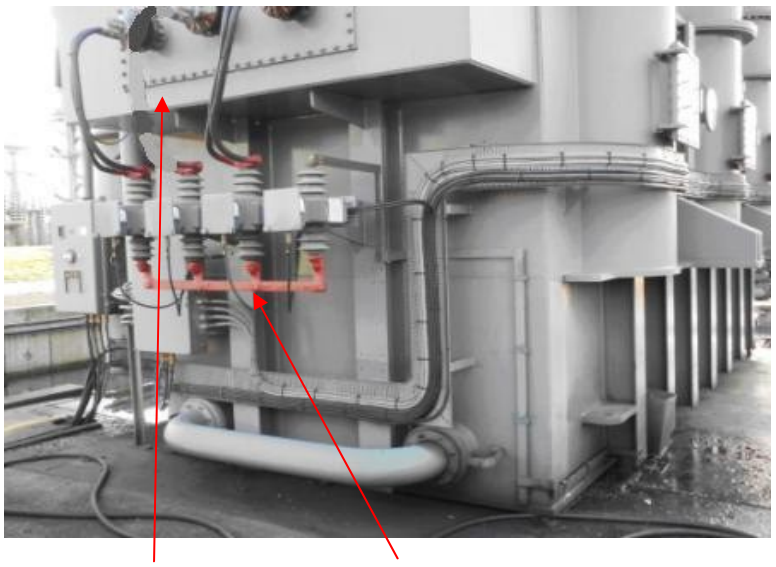

Figure 7.2a - Defective neutral connection on the **HV Equipment** side of the star point

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Guidance
NSI 24
7.2 Cont

Equipment with *Inadequate Earth System(s) e.g.* defective or missing earth connections away from the **HV Equipment** star point towards the *Main Earth System (MES)* may have dangerous voltage differences between the equipment neutral connection and the MES.

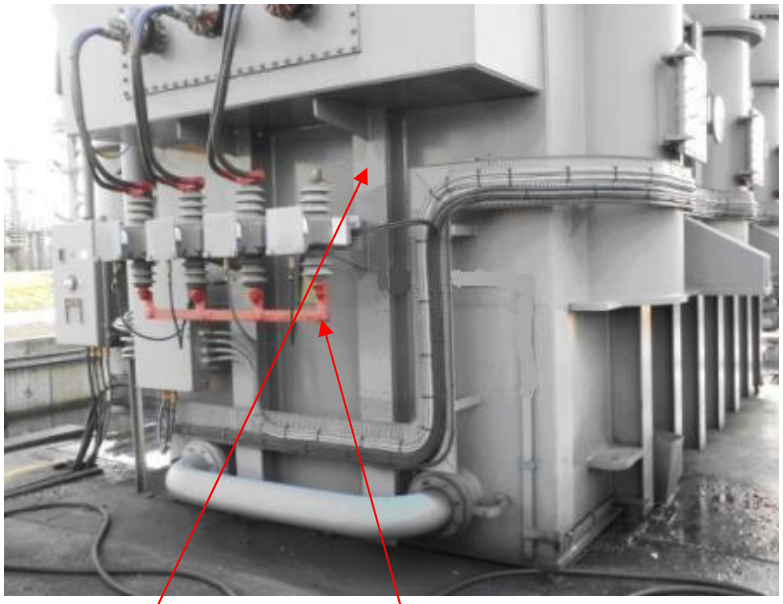

Figure 7.2b - Defective or missing neutral earth connections between the **Equipment** star point and the *Main Earth System*

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NSI 24
8.1 to 8.9

8 Application of Temporary Earth Bonds and Earth Bonds between a Substation Main Earth System and an Overhead Line Terminal Tower

8.1 No work shall be undertaken where there is an increased risk of a **System** fault.

8.2 Insulated footwear shall be worn prior to work commencing.

8.3 On double circuit terminal towers where one circuit is **Live** and one circuit is **Isolated** and **Earthed**, tests should be undertaken by the **Competent Person** to confirm that no hazardous voltages are present on the tower steelwork prior to the application of *Temporary Earth Bonds*.

8.4 Before a permanent repair of an *Inadequate System* commences the **Competent Person** shall establish a new connection point on the tower leg.

8.5 The *Temporary Earth Bond* shall be laid out prior to its application with the CE20/2 clamp end nearest the terminal tower under repair and the CE57 clamp end adjacent to the point of connection on the substation *Main Earth System*. Care should be taken to ensure that the clamps do not make contact with the ground at this time. Suitable precautions shall be established to ensure the *Temporary Earth Bond* is not touched or inadvertently interfered with.

8.6 The *Temporary Earth Bond* pole shall be inserted onto the CE57 clamp in readiness for its application.

8.7 The first connection of the *Temporary Earth Bond* shall be made by hand by applying the CE20/2 earth end clamp to the terminal tower new connection point copper tape.

8.8 Once the *Temporary Earth Bond* connection to the tower is secure, the connection to the *Main Earthing System* with the CE57 clamp should follow immediately by the use of the *Temporary Earth Bond Pole.*

8.9 Once the *Temporary Earth Bond* has been applied*, Earth Bond(s)* shall be selected and immediately applied by a **Competent Person** using the following rules:

(a) Repairs expected to be completed on the day of application of the *Earth Bond(s)* by the application with sufficient Type A *Earth Bond(s)*.

(b) Repairs expected to be completed beyond the day of application of the *Earth Bond(s*) or when concern is felt that the connections could potentially be interfered with by the general public, then by the application of sufficient Type B *Earth Bond(s).*

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NSI 24
8.10 to 8.13

8.10 The number of Type A or B *Earth Bond(s)* to be applied shall be of adequate strength and capability to provide an effective connection between the terminal tower and the *Main Earth System*.

8.11 After application of the *Earth Bond(s)*, the **Competent Person** shall remove the *Temporary Earth Bond*.

8.12 *Earth Bond(s)* shall not remain in place for periods greater than 6 months.

8.13 Before breaking an *Intact System*, for instance to divert an earthing conductor because of construction work, the planned break shall first be bridged using either:

(a) Fully rated earth tape brazed in parallel (across) the break.

(b) By fitting the appropriate number of *Earth Bond(s)* in parallel (across) the planned break. *Earth Bond(s)* must remain in-place until the planned break is permanently repaired.

Guidance
NSI 24
8.1 to 8.4

8 Application of Temporary Earth Bonds and Earth Bonds between a Substation Main Earth System and an Overhead Line Terminal Tower

8.1 Refer to section 5.4 guidance.

8.2 Insulated footwear having a 20 kV withstand and conforming to BS EN 50321 shall be used. These are available via the PPE catalogue.

8.3 In such cases advice shall be sought from specialists within Engineering and Asset Management.

8.4 Due to the physical constraints of the existing earth tape connection to a tower leg it is rarely practicable to apply a *Temporary Earth Bond* or *Earth Bond(s)* at this point, thus a new connection point is required. The connection point shall be a short length of 50mm x 6mm copper tape fixed to a leg of the terminal tower sufficient to accept the *Temporary Earth Bond* clamp and the correct number of *Earth Bond* clamps.

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Guidance
NSI 24
8.4 Cont to 8.12

The **Competent Person** shall ensure that when installing the new connection point, it is not possible to accidentally bridge across the defective earth tape and / or the defective existing earth tape bolted connection, due to the possibility of electric shock.

Figure 8.4 - Example Defective Earth Tape Connection

The copper tape shall be connected to the inside surface of the tower leg, at a height of 300mm to 600mm above ground level, by a bolted joint prepared in line with TGN(E) 187 or where a convenient bolt hole cannot be located or established via drilling, welded in line with TGN(E) 215.

8.9 The reasons why Type A or B *Earth Bond(s)* are applied without delay following application of the *Temporary Earth Bond* is because the *Temporary Earth Bond(s)* are not fully fault rated or continuously rated for maximum potential circulating currents.

A Type A *Earth Bond* consists of two CE 20 earth end clamps supplied with one 150 mm^2 Aluflex lead (clear sheath), ends crimped with ESI / T1 compression terminations.

A Type B *Earth Bond* is the same specification as a Type A *Earth Bond* except the tower end of the *Earth Bond* will have crimped ends only for direct bolting to the new copper tape connection point thus providing protection against interference from third parties.

8.10 Type A or B *Earth Bond(s)* are applied in sufficient numbers as per Appendix A in NSI 2 - “Earthing High Voltage Equipment” line end **Equipment**.

8.12 *Earth Bond(s)* shall not remain in place for a period greater than 6 months due to possible joint corrosion. After this period of time, additional *Earth Bond(s)* shall be applied in parallel to the existing *Earth Bond(s)* prior to the existing *Earth Bond(s)* being removed.

Security measures, visual inspections or both may be needed to manage the risk from 3rd party interference of the *Earth Bond(s)* during the time of their application prior to a permanent repair.

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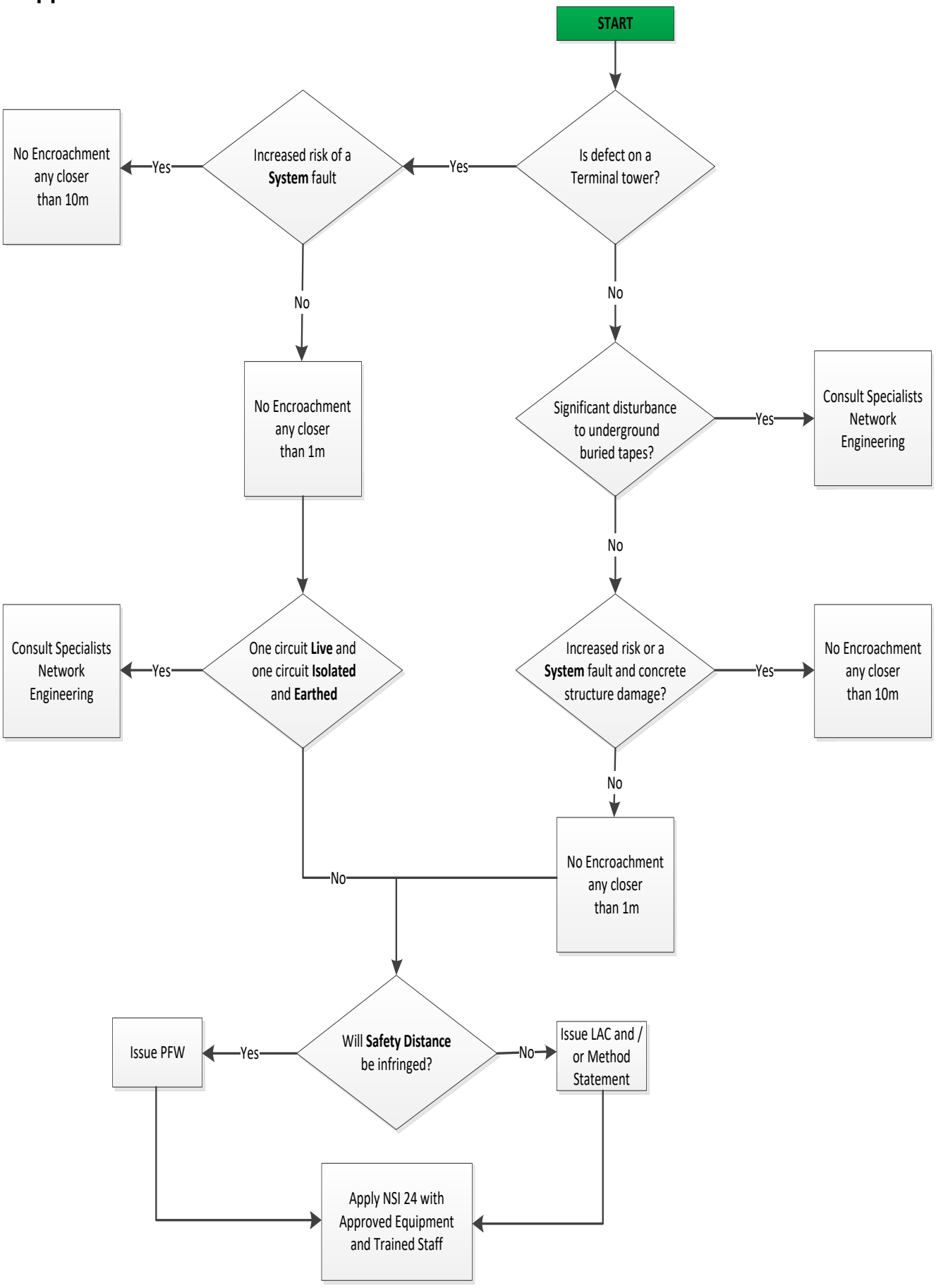
Appendix A – NSI 24 Flow Chart



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Appendix B - Authorisation Matrix for Personnel

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

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 Earth Systems 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 working on Earth Systems and therefore there is no requirement for authorisation under NSI 24.

Before a **Safety Document** is issued the NSI 24 **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 24 are suitably managed.

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

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