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NPS/003/033 – TECHNICAL SPECIFICATION FOR SUBSTATION SUPPORT STRUCTURES

1. Purpose

The purpose of this document is to specify the technical requirements for substation support structures utilised in open terminal substations on the distribution networks of Northern Powergrid (the Company).

This document supersedes the following documents, all copies of which should be destroyed.

Reference	Date	Version	Title
NPS/003/033	April 2015	2.0	Technical Specification for Substation Support Structures

2. Scope

This specification details the requirements for support structures utilised within substations up to and including 132kV to facilitate the support of bus-bars, EHV plant and equipment. This specification shall be used in conjunction with any project specific requirements detailed in Appendix 1, Addendum to Supplier Requirements.

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3. Technical Requirements

3.1. Design of Structures

The structures shall be designed to support post insulators, bus-bars, cable terminations, Switch Disconnectors, Current Transformers and Voltage transformers together with any associated earthing connections. The structures shall be suitable to support the equipment under all stated loading conditions included in this document and detailed in BS 61936.

For specific details on the interfaces with support insulators and busbars further information can be found in NPS/003/015 Technical Specification for 33, 66 and 132kV Post Insulators and NPS/003/028 Technical Specification for Tubular Busbars, Busbar Connectors and Terminal Fittings, respectively.

This shall be achieved by establishing the maximum force that any piece of equipment would be expected to withstand in its lifetime, rather than apply estimated safety margins over assumed working loads. In order to establish the total mechanical forces acting on electrical equipment and supporting structures it is necessary that consideration be given to forces resulting from:

- Short-circuit current
- Wind loading
- Dead weight
- Ice covering
- Conductor tension (where appropriate)

Once the maximum structural forces have been determined from the above, the structure designers shall provide base reactions (unfactored critical combinations) to the Northern Powergrid project engineer to allow appropriate foundations capabilities to be designed.

Each structure type shall be so designed that no failure or permanent distortion shall occur in any part when subjected to the maximum applied loads.

Aluminium structures shall be designed in accordance with BS EN 1999-1-1:2007 Euro code 9

Steel structures shall be designed in accordance with BS EN 1993-1-1:2005 Euro code 3

Provision shall be made on all structures for the attachment of earthing connections in accordance with BS 50522. Appendix 5A and 5B have been provided to detail the typical earthing requirements.

3.2. Design Parameters General

All equipment should be designed to meet the maximum values of the following:-

- The stated wind speed applied to the equipment, without ice covering, plus the appropriate short-circuit force.
- The stated wind speed applied to the equipment with a stated radial thickness of ice but not including short-circuit force.

3.2.1. Design Parameters

- Maximum and minimum ambient air temperatures + 40°C -25°C
- Ice, coating 10mm (Class 10)
- Wind speed not exceeding 34m/s

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- Altitude less than 1000m

3.2.2. Forces Due to Short Circuit

3.2.2.1. Forces Between Parallel Conductors

The force between two parallel conductors carrying symmetrical current I is given by:

$$F = \frac{0.2KI^2}{d}$$

Where

F is the average force (in N/m)

I is the symmetrical short-circuit r.m.s. fault current (in kA)

D is the spacing between conductors (in m)

K is the stress factor

Assuming the supporting structures and conductors to be rigid, they will have to withstand the force due to peak current which is $\sqrt{2}F$ at the beginning of a short circuit where the current may be approaching full asymmetry and have an instantaneous peak value which is a function of X/R ratio of the circuit.

$$F_{\max} = \frac{0.2KI^2}{d}$$

Where

X is the reactance

R is the resistance

Note – The maximum values of the asymmetrical peak current can usually be taken as 2.5 times the symmetrical r.m.s current and gives a K value of 2.5^2 for the maximum force.

3.2.2.2. Forces Between Rigid Conductors

For two-phase faults, a value of $K = 4$ and for three-phase faults a value of $K = 3$ should be used.

Note: - (Forces due to single phase-to-earth faults are less than for conditions described above)

3.2.2.3. Forces Between Flexible Conductors

In the case of flexible conductor arrangements, forces can be determined from clause 3.2.2.1 but the overall flexibility of conductor/structure is increased and the factor K becomes a function of span length as follows:

- For a span of 15m to 30m. $K = 1.6$
- For a span of 60m, $K = 0.8$
- Values of K for a span of between 30m and 60m can be obtained by linear interpolation.

Where multiple conductors are employed for a single phase, allowance should be made for the short time “snatch” force produced by the mutual attraction between parallel conductors. This force is a function of the conductor spacing and the distance between the spacers.

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3.2.3. Force Due to Wind Loading

It is essential that a maximum wind speed is stated by the user, and for calculation purposes this will be assumed to be acting normal to the axis of the conductor or item of equipment.

For a typical open-type station, the wind pressure P (in N/m^2) for a nominal height of 10.0m is given by

$$P = 0.613V^2$$

Where V is the wind speed (in m/s).

The force F (in N) applied to the conductor or item of equipment is given by:

$$F = PA C_f$$

Where

A is the projected surface area (in m^2).

C_f is the force coefficient affected by the shape of the item.

Note: For items normally found in open type substations the value of C_f rarely exceeds 1.0 and for practical purposes the following values can be applied:-

For cylindrical shapes including insulators, $C_f = 0.7$ and for rectangular shapes $C_f = 1.0$

When applying the above, allowance should be made for increase in dimensions due to ice.

3.2.4. Force Due to Dead Weight

When calculating the dead weight of conductor or items, the mass of an even thickness of ice should be taken included. The thickness of ice should be stated by the user and its mass per unit volume calculated at 912 kg/m^3 .

3.2.5. Conductor Tension & Loss of Conductor Tension

The tension load shall be calculated from the maximum conductor tension under the most unfavourable local conditions. Possible combinations include:-

- -20°C without ice and without wind
- -5°C with ice and without wind
- $+5^\circ\text{C}$ with wind

Support structures designed to terminate downleads from overhead line towers shall be designed to accept maximum design tensions of 4.5kN under the above design conditions.

A structure with tension insulator strings shall be designed to withstand the loss of conductor tension resulting from breakage of the insulator or conductor which gives the most unfavourable load case. This will normally be assumed to be 0°C , no ice and no wind.

3.3. Equipment Spacing and Clearances

Structures shall be so dimensioned and positioned to provide and maintain phase to phase, phase to earth and safety working clearances that comply with NSP/007/005 Guidance on Substation Design – Electrical Design Clearances.

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3.4. Construction

All structures shall be of approved design and construction, with calculations and drawings issued to the project engineer for approval prior to manufacture. All drawings shall be provided in electronic format as Autocad, Bentley Microstation or PDF files.

Where practicable all structures shall be manufactured from non-lattice type designs, the preferred arrangement shall be UB/Column type metalwork or tubular constructions using Steel or Aluminium.

A structure may be utilised as an earthing continuity conductor if it is shown to be of a suitable cross-sectional area and material, and contains no intermediate bolted faces in the earth path. Where practicable all interfaces shall be welded rather than bolted.

To facilitate the connection of copper earth tape to the base of each structure, the structures shall be designed with earth tags positioned on two diagonally opposite legs of the structure and 150mm above ground level. The earth tape fixing tags shall be manufactured from sections of 63 x 51 x 5mm angle of the same material as the structure which are at least 300mm in length and have two 14mm diameter holes positioned 50mm apart and 50mm from the lower end of the earth tag. The tags shall be designed to accommodate two bolt fixing of the substation copper earth tape and for the provision of portable earthing clamps.

Where the particulars of the support mounted plant requires separate direct earths e.g. for the provision of high frequency earthing for surge diverters or capacitor VT's, the support structure shall be provided with a series of M10 clearance holes up 1 leg and across the top horizontal support member to allow flat copper earth tape to be effectively secured to the structure. These M10 holes shall be no more than 200mm centres apart.

Additionally each structure shall be provided with two earth loops positioned 1200mm above ground level on diagonally opposite legs. The earth loops shall be fabricated from 50 x 6mm aluminium tape as appropriate to the structure design that has been formed into a 300mm loop with 76mm standoff to allow portable earth clamps to be applied to the structures. The earth loop may be created out of part of the continuous aluminium earthing system or be permanently secured to the main support using a low impedance non-bolted connection method.

After erection all supports shall be vertical within a tolerance at the support top of 0.5 per cent of the support height before equipment erection. All metalwork within 150mm of the upper surface of the concrete base shall be painted with two coats of bituminous paint to BS3416.

Structures designs shall include for the provision of a phase identification mounting flags near the top of the structure which shall be manufactured from a similar material to that used for the main structure. The flag shall be dimensioned to accommodate a coloured disc 60mm in diameter with a 7mm hole in the centre for fixing purposes.

Erection Marks:

Before leaving the Manufacturer's Works, all apparatus and fittings shall be painted or stamped in two places with a distinguishing number and/or letter corresponding to the distinguishing number and/or letter on an approved drawing and material list.

The erection marks are used to ensure the structure are installed in the correct orientation on site the galvanised material shall be stamped before galvanising and the erection mark shall be clearly legible after galvanising.

All markings shall be legible; weatherproofed tags, where used, shall be durable, securely attached and duplicated.

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3.5. Materials

Support Material

All steel shall comply with the requirements of BS EN 10025-1, BS EN 10025-6 or BS EN 10210-1 as appropriate and shall be suitable for all the usual fabrication processes, including hot and cold working within the specified ranges.

The quality of the finished steel shall be in accordance with BS EN 10163-1 or BS EN 10210-1 as appropriate. All steel shall be free from blisters, scale laminations, segregations and other defects. There shall be no rolling laps at the toes of rolled sections or rolled-in mill scale.

Mild steel shall be grade S275JR

Steel section profiles shall be in accordance with the requirements of BS4 part 1, BS EN 10056-1, BS EN 10210-1 and BS EN 10279 as appropriate.

Aluminium for structures shall be to BS EN 485 -2 and BS EN 12020-2 grade 6082 with T6 temper.

All bends in high tensile steel shall be formed hot.

All welding shall be to an approved method. The detailed welding procedures are to be supplied to the Purchasers Representative for approval when welded components are offered. Welding of aluminium shall be by the MIG process, with welds continuous and having a minimum fillet of 5mm.

Bolt holes shall be manufactured with holes that are 1.0mm larger than the corresponding bolt diameter for bolts up to M12 bolts and 2.0mm for M16 – M24 bolts.

As far as possible bolt heads, rather than nuts, shall be on the outer or upper faces of structure connections.

Bolts, Nuts and washers

Unless stated to the contrary in the project specification the following grades shall apply:-

Steel for bolts smaller or equal to 12mm diameter or nuts shall be grade S275JR

Steel for bolts greater than 16mm diameter shall be to grade S355JR

Unless stated to the contrary in the project specification, bolts and nuts shall be ISO Metric Black Hexagon to BS EN 4190, and shall be threaded ISO Metric Course pitch to BS 3643 Part 2. Tolerance class 7H/8g.

Washers

All flat washers shall comply with the requirements of BS 4320, Form E, Grade 4.6 and shall be a minimum of 3mm thick. Pack washers shall have an external diameter of twice the nominal diameter bolt diameter plus 15mm, a hole with a diameter of the nominal bolt diameter plus 2mm and a thickness as specified on the appropriate fabrication drawing.

3.6. Holding Down Bolts

Support structures may be connected to the foundations using either pre-installed holding down bolts or by drilling the base of the structures on site to allow more flexibility in support location. Fixing bolts shall be strength grade 8.8/10 to BS EN 4190 unless otherwise agreed and be of sufficient quantity to match the base reactions (unfactored critical combinations) calculated from clause 3.1. Bolts of sufficient length, complete with a setting template shall be supplied in advance of the support structures. The bolts shall provide a 100mm clearance to the underside of the structure base above the top of the concrete.

Holding down bolts shall be supplied complete with two full nuts and one locknut. The nuts shall be grade S275JR

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3.7. Workmanship

All structure members shall be cut to jig and all holes shall be drilled or punched to jig. All parts shall be carefully cut and holes accurately located so that when the members are in position the holes will be truly opposite to each other before being bolted up. Drifting or reaming of holes will not be allowed. All burrs shall be removed before galvanising.

The drilling, punching, cutting bending and welding of all fabrication shall be carried out before galvanising and shall be such as to prevent any possibility of irregularity occurring which might cause difficulty in the erection of the supports on the site.

Built members shall, when finished, be true and free from all kinks, twists and open joints and the material shall not be defective or strained in any way.

In order to verify the workmanship, the structure members corresponding to each type of support shall, if required, be selected at random and assembled to form complete supports in the presence of the project engineer at the manufacturer's works.

3.8. Galvanising

All support steelwork including nuts and bolts and washers shall be hot dip galvanised and tested in accordance with the requirements of BS EN ISO 1461.

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4. References

4.1. External Documentation

The products described within this specification shall comply with all current versions of the relevant International Standards, British Standard Specifications and all relevant Energy Networks Association Technical Specifications (ENATS) current at the time of supply.

Reference	Title
BS 3416:1991	Bitumen-based coatings for cold application, suitable for use in contact with potable water
BS 3643-2 : 2007	ISO metric screw threads. Principles and basic data
BS 4 Part 1:2005	Structural steel sections. Specification for hot-rolled sections
BS 4320 : 1968	Specification for metal washers for general engineering purposes. Metric series
BS EN 10025-1:2004	Hot rolled products of structural steels
BS EN 10025-6:2004	Plates and wide flats made of high yield strength structural steels in the quenched and tempered or precipitation hardened conditions. General delivery conditions
BS EN 10056-1:1999	Specification for structural steel equal and unequal angles
BS EN 10163 -1: 2004	Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections. General requirements
BS EN 10210-1:2006	Hot finished structural hollow sections of non-alloy and fine grain steels. Technical delivery requirements
BS EN 10279:2000	Hot rolled steel channels. Tolerances on shape, dimension and mass
BS EN 12020-2 - 2008	Aluminium and aluminium alloys. Extruded precision profiles in alloys EN AW-6060 and EN AW-6063. Tolerances on dimensions and form
BS EN 1993-1-1:2005 Euro code 3	Design of steel structures - General rules and rules for buildings
BS EN 1999-1-1:2007 Euro code 9	Design of Aluminium Structures – General structural rules
BS EN 4190 : 2001	ISO metric black hexagon bolts, screws and nuts. Specification
BS EN 485-2 - 2013	Aluminium and aluminium alloys. Sheet, strip and plate. Mechanical properties
BS EN 50522:2010	Earthing of Power Installations exceeding 1kV a.c
BS EN 61936-1:2010	Power Installations Exceeding 1 kV a.c
BS EN ISO 1461:2009	Hot dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods

4.2. Internal Documentation

Reference	Title
NPS/003/015	Technical Specification for 33, 66 and 132kV Post Insulators
NPS/003/028	Technical Specification for Tubular Aluminium Bus-bars, Bus-bar Connectors and Terminal fittings
NPS/007/005	Guidance on Substation Design – Electrical Design Clearances

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4.3. Amendments from Previous Version

Reference	Amendments
Whole Document	Doc approved by email Paul Black 30/10/2023 Doc republished to grid and externally - LB 07/02/2024

5. Definitions

Term	Definition
EHV	EHV (Extra High Voltage) in the context of this document this refers to voltages in the range of 33kV – 132kV
ISO	ISO (International Organisation for Standardization)
MIG	MIG (Metal Inert Gas) welding Technique
The Company	Northern Powergrid

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6. Authority for Issue

6.1. CDS Assurance

I sign to confirm that this document has been assured for issue on to the CDS system

		Date
Liz Beat	Governance Administrator	07/02/2024

6.2. Author

I sign to confirm that I have completed and checked this document and I am satisfied with its content and submit it for approval and authorisation.

Standard CDS review of 3 years	Non Standard Review Period & reason	
No	Period: 5 Years	Reason: Update will be dictated by contract renewal date or any significant changes in the specification or documents referenced.
		Date
Ged Hammel	Senior Policy & Standards Engineer	02/03/15

6.3. Technical Assurance

I sign to confirm that I am satisfied with all aspects of the content and preparation of this document and submit it for approval and authorisation.

		Date
Steve Wilkinson	PEP Engineering Specification and Design Manager	02/04/15

6.4. Authorisation

Authorisation is granted for publication of this document

		Date
Paul Black	Head of System Engineering	30/10/2023

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Appendix 1 - Addendum to Supplier Requirement

Manufacturers may provide alternative tenders for items not complying with the above specification. This shall be clearly stated together with detailed descriptions of any variation from the specification, together with drawings and test results.

The supplier shall provide with the tender full technical details of the equipment offered and shall clearly state and describe all technical non-conformances and divergence from these standards or specifications.

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Appendix 2 - Logistical Requirements

PACKING FOR SHIPMENT

The Contractor shall be responsible for the packing, loading and transport of the plant from the place of manufacture, whether this is at his own works or those of any supplier, to site including off-loading. All off-loading of equipment on site will be undertaken to the satisfaction of the Purchasers Representative.

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Appendix 3 - Pre-Commission Testing, Routine Inspection and Maintenance Requirements

Suppliers shall provide details of the recommended pre-commission testing and inspection required. They shall also provide information regarding periodic inspection and maintenance requirements to be undertaken during the lifetime of their product.

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Appendix 4 - SELF CERTIFICATION CONFORMANCE DECLARATION

Plant and switchgear support structures shall comply with the latest issues of the relevant national and international standards, including BS 61936-1, BS EN 62271, 10025-6, 458, and 12020-2. Additionally this technical specification is intended to amplify and/or clarify requirements relating to these Standards.

This self-declaration sheet identifies the clauses of the aforementioned standards relevant to Plant and switchgear supports structures for use on the Northern Powergrid distribution network. The manufacturer shall declare conformance or otherwise, clause by clause, using the following levels of conformance declaration codes.

Conformance declaration codes

N/A = Clause is not applicable/ appropriate to the product

Cs1 = the product conforms fully with the requirements of this clause

Cs2 = the product conforms partially with the requirements of this clause

Cs3 = the product does not conform to the requirements of this clause

Cs4 = the product does not currently conform to the requirements of this clause, but the manufacturer proposes to modify and test the product in order to conform.

Instructions for completion

- When Cs1 code is entered no remark is necessary
- When any other code is entered the reason for non-conformance shall be entered
- Prefix each remark with the relevant 'BS EN' 'IEC' or 'ENATS' as appropriate.

Manufacturer:

Product Reference:

**Details of the Support Structure (s)
designed to be used with:**

Name:

Signature:

Date:

NOTE: One sheet shall be completed for each item or variant submitted.

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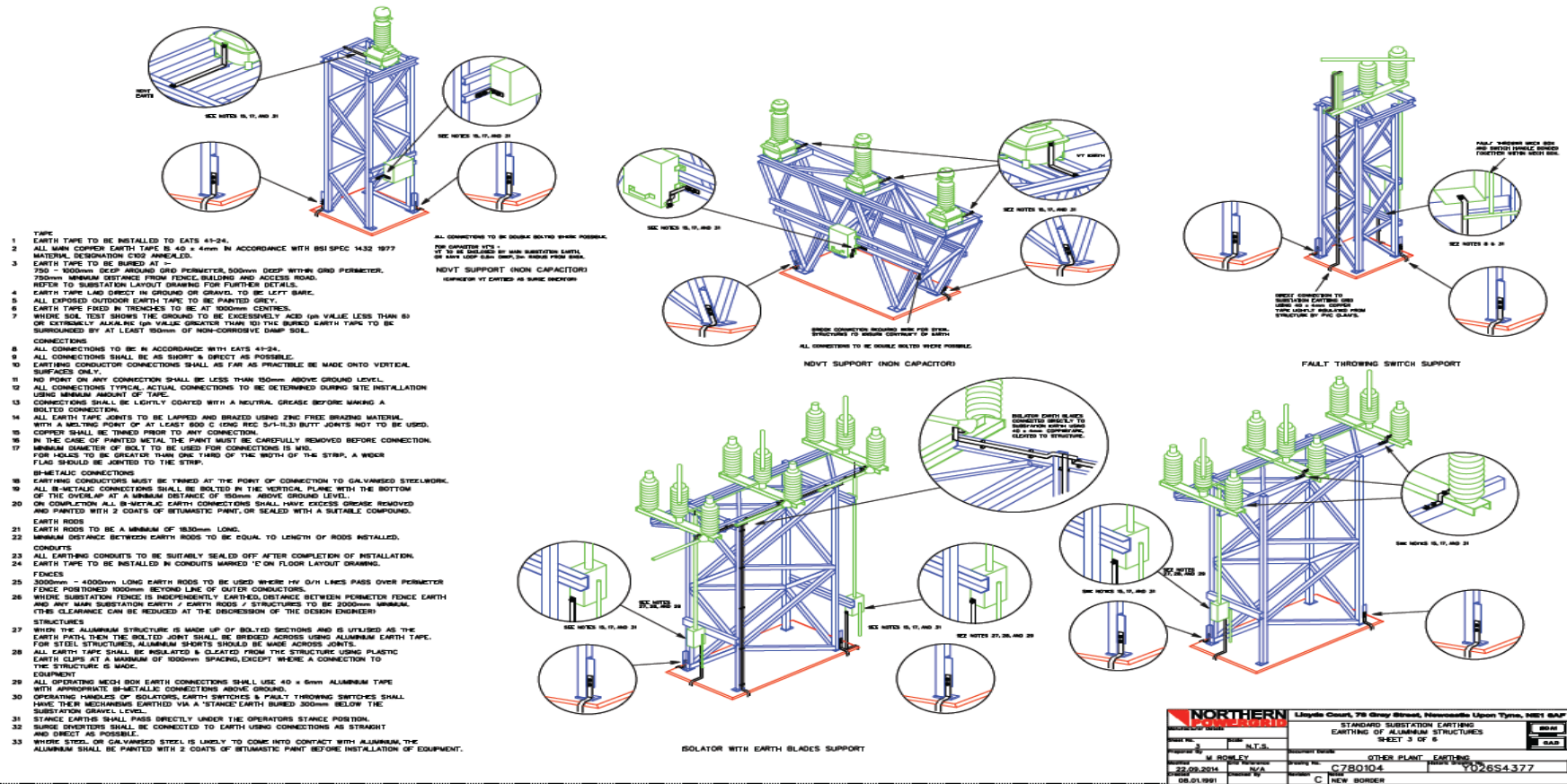
Technical Specification

• BS EN 10025-6			
Clause/Sub-clause	Requirement	Conformance Code	Remarks
BS EN 10025-6	Steel to grade S275 JR		
• BS EN 485-2 and BS EN 12020-2			
Clause/Sub-clause	Requirement	Conformance Code	Remarks
BS EN 485-2 BS EN 12020-2	Grade 6082 Aluminium with T6 Temper		

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Appendix 5a - Example of Standard Substation Earthing

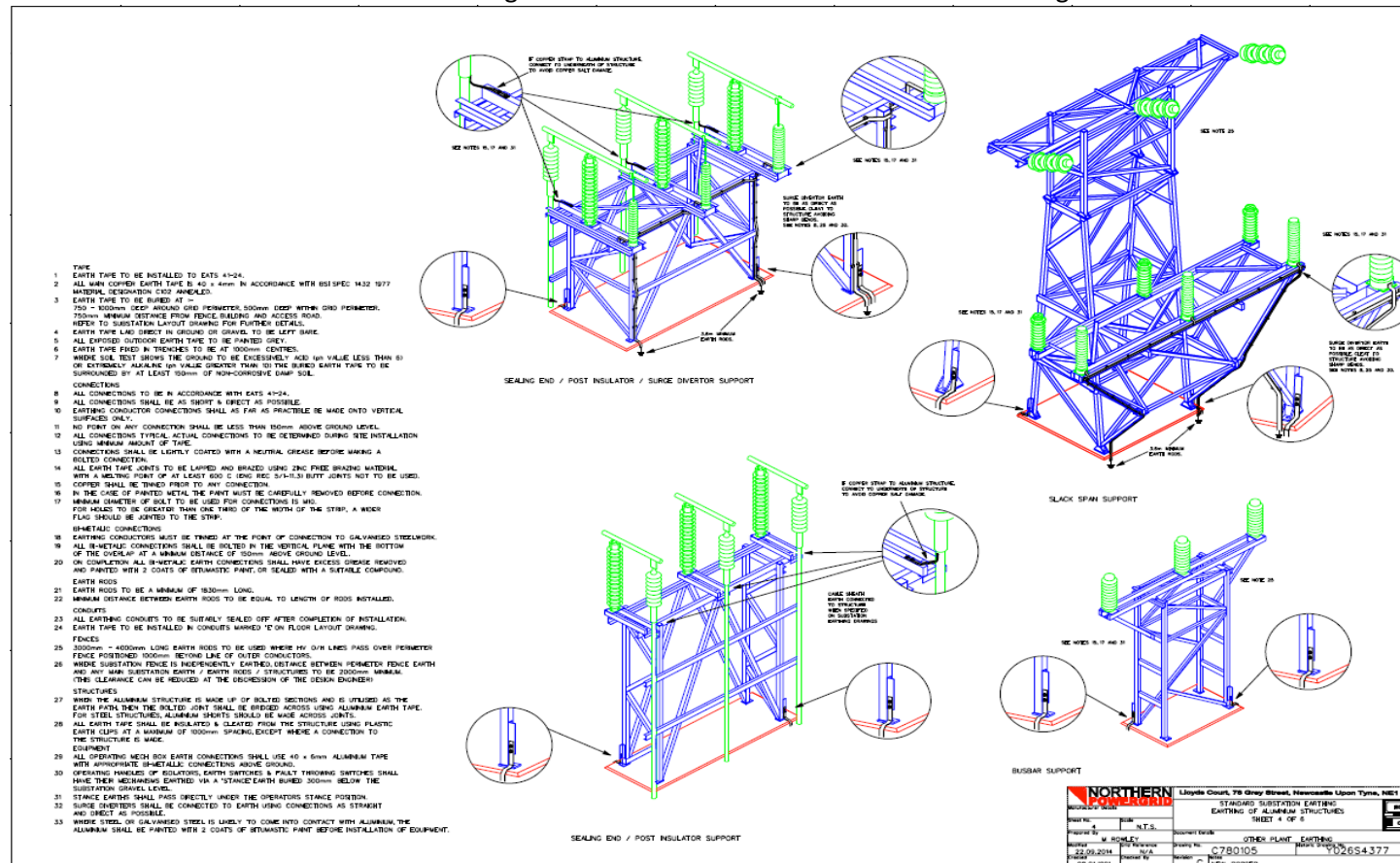
Earthing of Aluminium Structures - Sheet 3 of 5 Drawing Ref C780104



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Appendix 5b -Example of Standard Substation Earthing

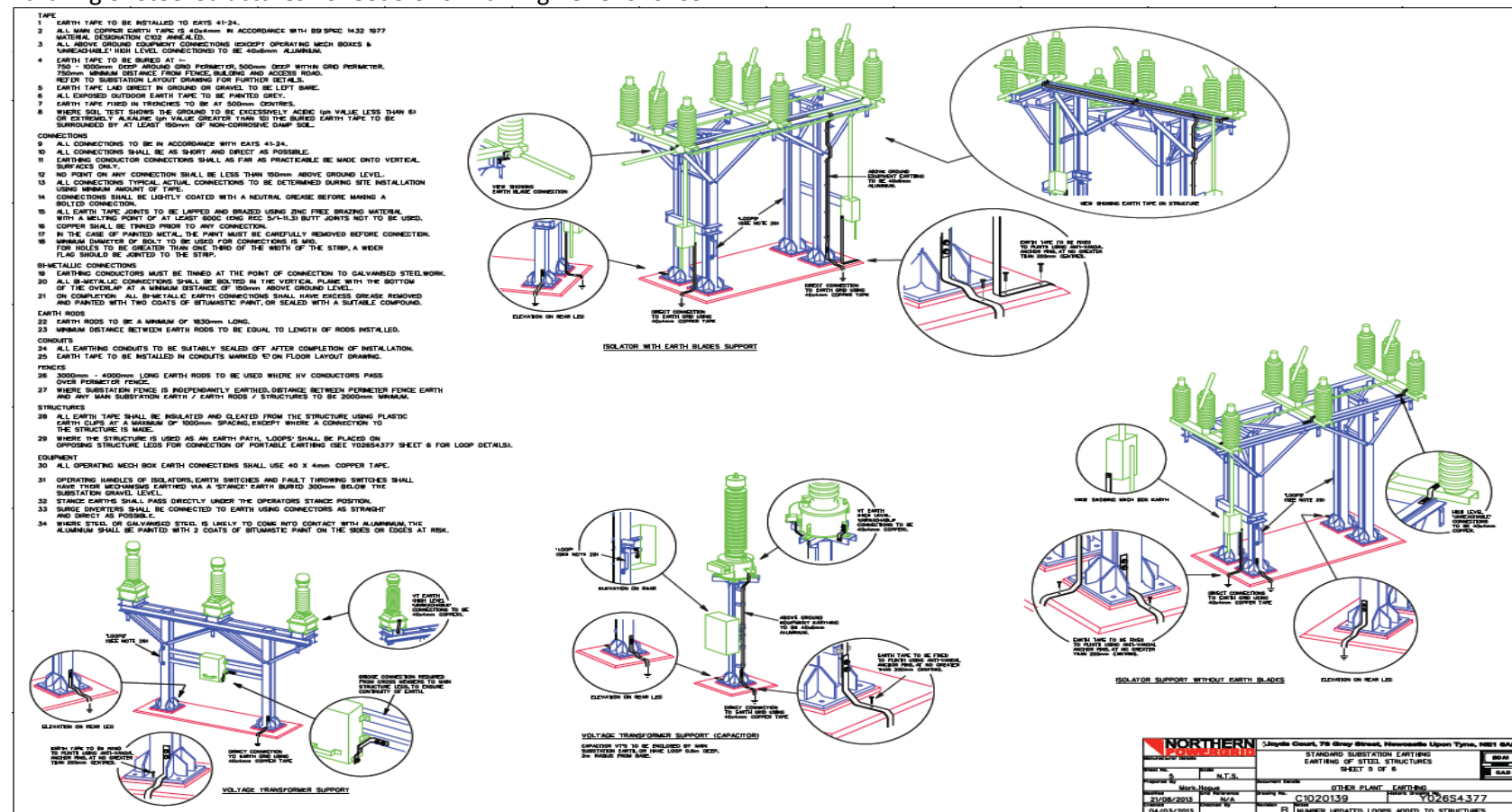
Earthing of Aluminium Structures - Sheet 4 of 6 Drawing Ref C780105



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Appendix 5c - Example of Standard Substation Earthing

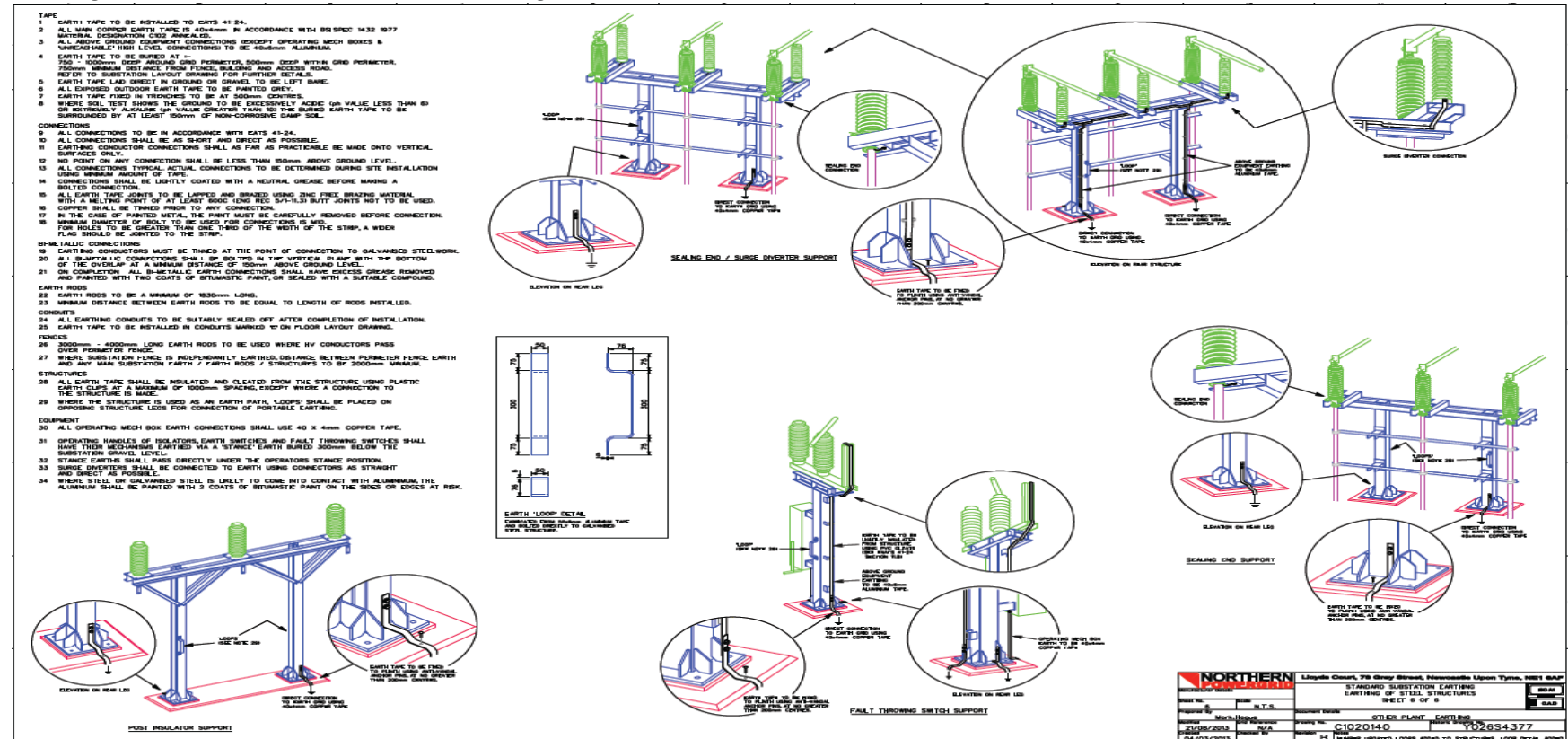
Earthing of Steel Structures - Sheet 5 of 6 Drawing Ref C1020139



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Appendix 5d - Example of Standard Substation Earthing

Earthing of Steel Structures - Sheet 6 of 6 Drawing Ref C1020140



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Appendix 6: Technical Information Check List

The following information shall be provided by the supplier for technical review by Northern Powergrid. Additional information shall be provided if requested.

Requirement	Provided (Y/N)
Full product descriptions and part number/reference, including a complete set of drawings for each variant	
Appendix 3 - Pre-commissioning testing/inspection requirements, including details on the end of life disposal of these units	
Appendix 4 – completed self-certification conformance declaration	
Type test evidence	
Routine test plan (example)	