NSP/007/020 – Guidance on Substation Design: Transformer Noise

1. Purpose

The purpose of this document is to list the key parameters that shall be applied in the design of Primary and Supply Point Substations for use on the Northern Powergrid network.

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

Reference	Version	Date	Title
NSP/007/020	1.1	May 2013	Guidance on Substation Design: Transformer Noise

2. Scope

This document defines the design considerations and construction requirements of all Primary and Supply Point Substations connected to the Northern Powergrid network. It provides guidance necessary for customers, external service providers and independent connection providers (ICPs) to construct substations to a standard that is suitable for adoption.

The guidance applies to both new build sites and where modifications are required to existing sites

2.1. Table of Contents

3. Technical Specification

3.1. General

Any Primary or Supply Point transformer located within 50 metres of an occupied building shall be contained within an enclosure with a fire resistance of at least 4 hours irrespective of any noise nuisance consideration.

Every care shall be taken to ensure that the design and manufacture of all transformers, reactors and auxiliary plant limits noise and vibrations. To reduce the transmission of noise and vibration, fans and pumps shall be mounted either independently from coolers or on an approved form of anti-vibration mounting on the cooler structures. Transformers should be suitable for a sound attenuation enclosure. To permit erection of such enclosures, all substations shall be so arranged that, if required, enclosures or other structures such as screens can be added, either initially or at a later date following a justifiable complaint.

A "structure" could be either a full four sided enclosure, with or without a roof or with a partially open roof to allow construction around live high voltage equipment or an arrangement of screens, built bespoke to site-specific requirements to reduce noise in specific directions and these may be either single, double or multiple elevation structures.

The structure shall allow for installation of fire detection measures as prescribed by Northern Powergrid either before or after installation.

The structure where appropriate shall allow for installation of electrical wiring for lighting, emergency lighting and power outlets as prescribed by Northern Powergrid either before or after installation.

The acoustic media employed in the panels of an acoustic enclosure or other structure shall be inert, non-hygroscopic, vermin proof and rot proof, shall not support bacterial growth and have as a minimum, class 1 rating for the surface spread of flame as measured to BS 476 Part 7 (1997) Fire tests on building materials and structures. Part 7: Method to determine the classification of the surface spread of flame of products. All considerations of 4 hour rating for enclosures as mentioned earlier take priority.

Sound power levels of transformers shall be measured in accordance with IEC 60076-10 and comply with the current editions of ENATS 35-2 for CER transformers and ENATS 35-3 for CMR transformers and create sound pressure levels that would not result in justified complaints of noise being raised and comply with current environmental requirements and legislation.

Transformer manufacturers shall carry out ONAN and OFAF sound power levels to prove compliance with ENATS 35-2 or ENATS 35-3.

The design and construction of all Primary and Supply Point substations shall comply with the statutory instruments and noise criteria.

- Planning Policy Guidelance 24 (PPG 24) – guides local authorities in England in the use of planning powers to minimize impact of noise.
- Environmental Protection Act 1990 (EPA) – gives local authorities in England and Wales considerable and wide ranging powers to tackle noise problems leading to abatement notices and hefty penalties.
- BS4142 – method of rating industrial noise affecting mixed residential and industrial areas.
- WHO guidelines on community noise

If a substation is to be built in a residential area, a noise impact assessment survey should be carried out to show what the effect of the substation noise would be throughout that area, on the existing background noise levels. This should ideally include a 3D topographical predictive noise study that includes sound levels shown in one third octaves and pay particular attention to tones commonly associated with transformer noise and should include noise measurements made at particular times of the day or night when the nuisance is liklely to be most perceptible. It is recommended that sound power levels of the transformers should be measured. The report shall provide suitable recommendations for acoustic enclosures giving details of the sound attenuation value required.

Once installed, the actual level of attenuation achieved by the completed structure shall be proved by a detailed noise survey using the procedures detailed BS4142:2014 "Methods for rating and Assessing Industrial and Commercial Noise" including one third octave measurement, FFT (fast Fourier transform) analysis or similar to ensure that the tones associated with magnetostrictive hum has been sufficiently reduced. The responsibility for ensuring this reduction should remain with the company who installed the noise reduction measures so that there is no possibility of conflict between the design and build. This survey shall be conducted in a suitable position to compare to readings taken before the structure was installed or in the case of a new substation, before it was built and commissioned.

Consideration shall be made during the design process as to how the structure is to be physically installed on site either built/assembled on site or pre-assembled and lifted as a whole. In either case this shall be agreed and co-ordinated with Northern Powergrid who will assess and manage any issues regarding safe electrical working and access clearances, as detailed in NSP/007/005 Northern Powergrid Guidance on Substation Design - Electrical Design Clearances

The structure shall be designed and built to ensure that all electrical safety clearances are maintained in accordance with Northern Powergrid's Distibution Safety Rules (DSR) and Operational Practice Manual (OPM) as well as NSP/007/005 Northern Powergrid Guidance on Substation Design – Electrical Design Clearances at all times as per the advice and guidance of Northern Powergrid and designs must first be agreed by Northern Powergrid.

The structures shall be designed and built to address the risk of fire and emergency exit and shall ensure access, egress around the enclosed apparatus is maintained at a minimum distance as detailed in the Energy Networks Association Engineering Recommendation S2/4 1976 Limitations of Fire Risk in Substations at 132kV and Below and in Enclosed Cableways.

The structures shall be designed and built to ensure that as a minimum, the clearance distances around the enclosed apparatus shall be maintained to those specified in Energy Networks Association BEBS-T2 1966 Section 13 Revision 1 (1977) Specification for Transformers and Reactors, Section 1 Noise and Vibration.

In addition to maintaining these distances, in certain circumstances it may be necessary to have panels, hatches or doors that can be opened or removed to allow access to areas or items of apparatus for maintenance, repair or test. These shall be designed to allow safe access, lifting, support when open and the size, position and number of these openings as well as the distance between the transformer and the enclosure at that point shall be agreed by Northern Powergrid

The structures shall be designed and built so that they are self-supporting to allow the removal of larger panels without the need to fully dismantle the structure as a whole and shall not have a solid connection to adjacent buildings that could transmit vibration.

All parts of the completed acoustic structure shall be earthed and electrically bonded together in accordance with the relevant Northern Powergrid approved procedures and/or substation earthing study in accordance with ENA Technical Standard 41-24 Issue 1 1992-Addendum, Section 15, Incorporated November 2009: Guidelines for the Design, Installation, Testing and Maintenance of Main Earthing Systems in Substations, or equivalent

The design, manufacture and corrosion protection of the acoustic structure shall provide for an operational life span of a minimum of 40 years before requiring replacement. The supplier of the acoustic structure shall provide details of the recommended / reasonable expected operational life span of each element of the complete structure with supporting evidence and details of any maintenance requirements.

The acoustic enclosure or screen and elements thereof shall be designed and constructed to resist dead and live load deflections and thermal movements and to be suitable for use under the following environmental conditions and loadings.

- Standard wind loading design based on a wind pressure of 2kN/m2. Due allowances shall be made for the effect of any resulting internal pressure rises when the complete enclosure is exposed to this wind pressure.
- Snow loading on the roof up to 3kN/m2. This equates to approximately 2m of fresh snow or 0.7m of compacted snow.
- Capable of containing the distributed loading associated with all the equipment that Northern Powergrid intends to install within the building.
- Thermal properties: The minimum heat gain U value of the walls shall be designed to a value of 0.6W/m2/K with the roof having a value of 0.36W/m2K.
- Further the building shall be insulated to a level which isolates the external and internal temperatures, such that the internal temperature shall not exceed 40 deg C.

The standard external finish of the structure shall be applied in accordance to ISO 12944-5:2007(en) Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 5: Protective paint systems, using a marine paint system, or equivalent. Unless there is an extraordinary, specific requirement for a textured coating such as brick or stone effect cladding, normally the exterior shall be painted. The colour should be RAL 7040 Window Grey Semi-Gloss or other RAL colour to be confirmed by Northern Powergrid to meet specific requirement. This specification shall offer a life expectancy of at least 15 years before its' first major maintenance in a C4 environment described in ISO 12944-5:2007(en) Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 2: Classification of environments, or equivalent as a High Urban and industrial atmospheres with moderate sulphur dioxide pollution and/or coastal areas with low salinity.

The acoustic structure (in this case, typically an enclosure) shall be designed to ensure that the ambient temperature inside the building does not exceed the ambient temperature ranges specified for the equipment and components located within so that no de-rating of the equipment is necessary. Tradionally primary substations transformers have had sepearte cooler banks which can be excluded from acoustic enclosures ensuring adequate cooling of the equipment so natural ventilation shall be calculated and provided to dissipate any heat created by the equipment located within the acoustic enclousre, plus the solar gain from the roof surface and to prevent condensation. Natural high and low level ventilation will be incorporated into the main body of the acoustic enclosure. Ventilation openings shall be of robust, vandal and corrosion resistant, steel welded construction and be designed to avoid vermin intrusion. They must not provide hand or footholds and must not compromise the sound mitigation of the enclosure or screen. Also because of noise, forced ventilation or air conditioning is not normally permissible unless specific consideration needs to be made for transfomers with integral cooler banks that can not be excluded from the acoustic enclosure.

Vents, louvres, ducts, etc. shall not present sharp edges or corners, either inside or outside the enclosure.

The design of the enclosure shall address the issue of drainage and shall not allow standing water to collect on the roof but provide a natural fall away from the doors and shall not allow it to drain into any apertures on the roof that allow for construction around exposed external transformer bushings or turrets.

In the specific case of an enclosure, two doors shall be provided on diagonally opposite corners. The main entry and exit doors shall be equipped with a lock and internal push (panic) bar and emergency escape doors to be fitted with an internal push bar and no exterior lock to meet the requirements of the Energy Networks Association Engineering Recommendation S2/4 1976 Limitations of Fire Risk in Substations at 132kV and Below

and in Enclosed Cableways and BEBS T2-1966 Section 13 (Revision 1 1977) Specification for Transformers and Reactors Section 13 Noise and Vibration

Where necessary and specifically requested by Northern Powergrid, the structure shall be equipped with a metal clad distribution board complying to BS EN 60439-3 or equivalent, supplied by a suitably rated separately controlled and isolatable circuit, to supply suitable lighting, emergency lighting in accordance with the Energy Networks Association Engineering Recommendation S2/4 1976 Limitations of Fire Risk in Substations at 132kV and Below and in Enclosed Cableways, as well as electrical sockets with IP ratings appropriate to the relevant environment, using suitably rated MCB's and RCD's. Consideration shall be made to the position of the wiring and fixtures in regards to removable panels, hatches and doors and all electrical installation shall be carried by a fully qualified electrician in accordance with the current edition of British Standard BS 7671 "Requirements for Electrical Installations. IET Wiring Regulations.

When considering whether to install a transformer sound attenuation enclosure, a noise impact assessment survey should be carried out to show what the effect of the substation noise would be throughout that area, on the existing background noise levels. This should ideally include a 3D topographical predictive noise study usind a computer program such as CADNA or its' equivalent that includes sound levels shown in one third octaves and pay particular attention to tones commonly associated with transformer noise and should include noise measurements made at particular times of the day or night when the nuisance is liklely to be most perceptible.

This will allow the site to be categorised as either Rural or Urban. Typically the classifications are:-

1. Rural where the background noise level is below 35dBA daytime, 25dBA during the night

2. Urban where the background noise level is above 55dBA daytime, 45dBA during the night

Note that some urban locations may have high levels of sound during the day but at night with the absence of traffic and other noises they need to be categorised as rural. The figures in Table 2 should be used only when there is definite traffic noise during the night.
The distances in the tables have been calculated with assumptions of typical night time background noise levels

Table 1 - Rural Situations

Substation type	Distance in Metres			
	No enclosure	Normal Enclosure 15dB Attenuation @100Hz	Heavy Enclosure 20dB Attenuation @100Hz	Situations where an enclosure may be deferred (see note 1)
2 x 90MVA	1025 & above	100 to 1025	60 to 100	725 to 1025
2 x 30MVA	515 & above	50 to 515	30 to 50	325 to 515
2 x 24MVA	120 & above	10 to 120	Below 10	85 to 120

Table 2 - Urban situations with traffic or other noise during night hours

Substation type	Distance in Metres			
	No enclosure	Normal Enclosure 15dB Attenuation @100Hz	Heavy Enclosure 20dB Attenuation @100Hz	Situations where an enclosure may be deferred (see note 1)
2 x 90MVA	575 & above	60 to 575	30 to 60	410 to 575
2 x 30MVA	290 & above	30 to 290	15 to 30	205 to 290
2 x 24MVA	70 & above	7 to 70 (see note 2)	Below 7 (see note 2)	50 to 70

Compliance with the above tables does not automatically guarantee that noise complaints will not be raised and even if the distances in the tables above have been maintained at the time the substation was established, there is every possibility that in the future, developers may decide to build on land within these distances which may result in the need to install enclosures or upgrade existing enclosures All noise complaints received after a substation has been commissioned must be investigated and if justified, actions must be taken to eliminate them.

If a developer decides to build a housing estate close to an existing substation, it would be desirable for them to attenuate the noise, or contribute towards the costs of attenuating the noise of the substationat source to make the houses suitable for noise complaint free living. Including sound attenuating features in the houses would do nothing to reduce the effect of noise from the transfomers in gardens and similar areas that Environmental Protection Officers consider when serving notices in cases of statutory nuisance being caused. Every opportunity should be taken by Northern Powergrid to engage with local authorities and their planning systems to ensure that objections are made to these development at the earliest possible opportunity because they may adversely affect the interests of Northern Powergrid in terms of costs for future noise abatement. Not all substations lend themselves to having effective noise abatement measures installed retrospectively.

Note 1
In some situations where residential property is marginally within the distance recommended for a sound enclosure, the transformer bunds shall be designed to accept an enclosure but construction of the enclosure should be deferred until it is ascertained whether an enclosure is necessary.

Any transformer within 50m of occupied buildings shall be "built in" to prevent the spread of fire and damage caused by smoke in the event of a major catastrophe.

Note 2
Modern transformer specifications include sound power levels that are lower than those published in previous specifications. In some cases this may lead to substations being tolerated nearer to residential properties but recent experience of dealing with retrospective noise complaints associated with substations shows that the expectations of the general public and the approach of environmental protection departments of local authorities has shown that this can not be taken for granted .

However consideration should be given to the influences of reflecting surfaces and the layout of the substation relative to the residential properties in order to minimise noise pollution from transformers & forced cooling.

3.2. Design of Transformer Enclosures

As well as being designed in accordance with the aforementioned documents and ENA Engineering Recommendations, the design of transformer enclosures shall also consider the effect of standing sound waves. The distance between large flat faces of the transformer (sides and top) and the structure walls is critical. The distance

should be such that the half wave tones of 100Hz and 200Hz are avoided to prevent the setting up of standing waves or to reduce the efficiency of a noise attenuating structure. These dimensions are 1.68m and 0.84m, +/- 0.08m respectively and any multiple of these values. The 100Hz wave is the major contributor of noise and its associated dimension of 1.68m and its multiples should always be avoided. The 200Hz wave makes a much smaller contribution to the total noise and the dimension of 0.84m and multiples should be avoided wherever possible.

Table 3 - Dimensions within which standing waves can be produced

100Hz Wave		200Hz Wave	
Multiple of wavelength	Bandwidth in which standing waves can be generated (m)	Multiple of wavelength	Bandwidth in which standing waves can be generated (m)
0.5	1.60 – 1.78	0.5	0.76 – 0.92
		1.0	1.60 – 1.78
1.0	3.28 – 3.44	1.5	2.44 – 2.60
		2.0	3.28 – 3.44
1.5	4.96 – 5.12	2.5	4.12 – 4.28
		3.0	4.96 – 5.12
2.0	6.64 – 6.80	3.5	5.80 – 5.96
		4.0	6.64 – 6.80
2.5	8.32 – 8.48	4.5	7.48 – 7.64
		5.0	8.32 – 8.48
3.0	10.0 – 10.16	5.5	9.16 – 9.32
		6.0	10.00 – 10.16

Each site should be assessed and consideration given to minimising the spread of fire to or from the substation in order to protect members of the public and adjoining properties. Engineering Recommendation S2/4 provides guidance and shall be complied with at all times.

In addition to complying with Engineering Recommendation S2/4 Specific the provisions of BEBS T2-1966 Section 13 (Revision 1 1977) Specification for Transformers and Reactors Section 13 Noise and Vibration shall also be complied with.

4. References

4.1. External Documentation

Reference	Title
ENATS 35-2	Emergency Rated System Transformers 33/11.5kV Delta/Star and Star/Star Connected
ENATS 35-3	Continuous Maximum Rated (CMR) System Transformers (for use on systems up to 132kV)
Engineering Recommendation S2/4 1976	Limitation of fire risk in substations at 132kV and below and in enclosed cableways
IEC 60076-10	Power Transformers – determination of sound levels
BS4142	Method for Rating Industrial Noise Affecting Mixed Residential and Industrial Areas
PPG24	Planning Policy Guidance 24 – Planning powers to minimise impact of noise
EPA	Environmental Protection Act
BEBS T2-1966 Section 13 (Revision 1 1977)	Specification for Transformers and Reactors Section 13 Noise and Vibration

4.2. Internal Documentation

Reference	Title
N/A	N/A

4.3. Amendments from Previous Version

Reference	Title
Document	Updated to new CDS template

5. Definitions

Reference	Title
ONAN	Transformer rating without pumps and fans running Oil Natural – Air Natural
OFAF	Transformer rating with pumps and fans running Oil Forced – Air Forced
WHO	World Health Organisation
ENATS	Energy Networks Association Technical Specification
IET	Institution of Engineering and Technology
IEC	International Electrotechnical Commission
BS	British Standard
CER	Continuous Emergenct Rating
CMR	Continuous Maximum Rating
ISO	International Organisation for Standardisation

6. Authority for issue

6.1. CDS Assurance

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.

		Sign	Date
Andy Leggett	CDS Administrator	Andy Leggett	24/07/2018

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.

Review Period - This document should be reviewed within the following time period.

Standard CDS review of 3 years	Non Standard Review Period & Reason	
Yes	Period: N/A	Reason: N/A
Should this document be displayed on the Northern Powergrid external website?		Yes

		Sign	Date
Steve Wilkinson	PEP Specification and Design Manager	Steve Wilkinson	24/07/2018

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.

		Sign	Date
Paul Gallon	Technical Services Engineer	Paul Gallon	30/07/2018

6.4. Approval

Approval is granted for publication of this document.

		Sign	Date
Dave Sillito	PEP Manager	Dave Sillito	25/07/2018

6.5. Authorisation

Authorisation is granted for publication of this document.

		Sign	Date
Steve McDonald	Head of Programme Delivery	Steve McDonald	17/01/2019