



Electricity Substation Construction

Civil, Structural and Building Engineering

Design Handbook

DH 10
Issue 4

Authorised by:

Keith Hanley

Technical Assurance Manager

Date: April 2013

REVISION HISTORY

Issue	Date	By	Description
P1	November 2006	NJ Tobin	For Comment
1	July 2007	NJ Tobin	First Issue
P2	June 2008	NJ Tobin	Issue 2 - Draft
P3	August 2008	NJ Tobin	Issue 2 – 2 nd Draft
2	September 2008	NJ Tobin	Second Issue
P4	June 2010	NJ Tobin	Issue 3 – 1 st Draft
3	Aug 2010	NJ Tobin	Third Issue
P5	Mar 2013	NJ Tobin	Issue 4 – 1 st Draft
4	Apr 2013	NJ Tobin	Fourth Issue

CONTENTS

	PAGE
Preamble	1
1) INTRODUCTION	2
2) NEW ASSETS	5
2.1 Oil Containment	5
• General Principles	
• Oil Separators	
• Containerised Diesel Generators	
• Cable Sealing End Header Tanks	
• Bund Water Control Units (BWCU)	
• National Spare Transformers and similar plant	
2.2 Perimeter Security	6
• Introduction	
• Fence Systems - General Requirements for both systems	
• Gates – General Requirements for both systems	
• Electric Pulse Fence – General Requirements for both systems	
• Traffic Signal Control – General Requirements for both systems	
• SEAP 'Class 3' Intermediate Security Palisade Fence System	
• NGTS 2.22, Category 2, 'medium risk' fence system	
• Approved Product Suppliers	
2.3 Site Lighting	7
2.4 Piling Works	8
2.5 Access Covers	9
2.6 Buried Service Ducts & Surface Level Covered Trenches	10
2.7 Earth Link Pits	13
2.8 Fire Protection and Control	13
2.9 Plant Noise Attenuation - Acoustic Enclosures and Barriers	15
• Specific Requirements Relating To Brick Built Acoustic Enclosures	
2.10 Drainage	20
2.11 Excavation, Backfilling, Restoration & Surfacing	22
2.12 Structural Steel & Aluminium	24
• Fire Protection to Steelwork	
• Protective Treatment	
2.13 Foundations	26
2.14 Holding Down Systems	28
• Holding Down Bolts	
2.15 Other Enabling Infrastructure	28
• SF ₆ Gas Washing Facilities	
• Mechanically Switched Capacitor/Mechanically Switched Capacitor Damping Network (MSC/MSCDN) Compounds	
3) EXISTING ASSETS	31
3.1 General Requirements	31
3.2 Acceptance Criteria for Re-use	31
3.3 Roof Repairs	31
• Renewal of Built-Up Bituminous Felt Roofing on Metal Roof Decks	
• Built-Up Bituminous Felt Roofing on Concrete Roof Decks	

4) COMMISSIONING AND TESTING	34
5) BEST PRACTICE	36
5.1 SuperGrid Transformer Infrastructure	36
• <i>Introduction</i>	
• <i>General Principles</i>	
• <i>Noise Attenuation</i>	

Preamble

- (i) NGTS 2.10, 'Generic Specification for Civil Engineering Work' has been withdrawn and replaced by a suite of documents, TS 3.010.xx, that are based on the Civil Engineering Specification for the Water Industry, 6th Edition ('CESWI6'). All cross-references made to NGTS 2.10 in existing National Grid documents shall therefore be read against the equivalent applicable clauses in the relevant section of TS 3.010.xx. Any ambiguity, contradiction or confusion shall be notified to National Grid for clarification via the appropriate contract channels.
- (ii) On 31st March 2010 the British Standards governing structural design, some of which are referenced by current National Grid Technical Specifications, were formally withdrawn and replaced by a new set of European structural design codes for building and civil engineering works. These European Standards, often called the Eurocodes, have been issued by the British Standards Institute with the prefix BS EN and are now the de facto standards for structural design in the UK. The term 'Eurocode' refers exclusively to BS EN 1990 to BS EN 1999 and the associated National Annexes.

The implementation of Eurocodes has raised a number of technical and legal issues throughout the construction industry. This has necessitated detailed consideration and guidance from client organisations.

National Grid's long term objective is to revise the suite of Technical Specifications to ensure new construction projects are fully compliant with Eurocodes. In the meantime National Grid's current position on the use of structural Eurocodes on UK Electricity Transmission construction projects is as follows:

- *For the structural design of new items of HV plant and supporting structures subject to short circuit forces the current guidance given in TS 3.1.4 'Busbar Systems for AIS Substations' shall continue to be applied with the associated British Standards until further notice. Eurocodes will not be applied to these structures at this time.*
- *Where existing Technical Specifications require the use of Eurocodes e.g. oil retaining areas in TS 2.20 Issue 4, then any assumptions or interpretation required by designers shall be recorded in the Design Intent Document (ref. UKBP/TP188) or its contractual equivalent.*
- *Where existing Technical Specifications require the use of withdrawn British Standards for the design of stand alone structural items with no direct HV plant interface, e.g. substation buildings, this remains the default position. However, where it can be demonstrated that the Eurocodes can be applied in their entirety to specific items, then individual applications to use the codes will be considered via the Technical Deviation Process (ref. UKBP/TP188) or its contractual equivalent.*

1 INTRODUCTION

- 1.1** This document details mandatory prescriptive and functional requirements and/or performance characteristics relating to new build and existing 'Civil, Structural and Building Engineering' assets forming part(s) of substation construction projects. It is an elaboration on, and shall be read in conjunction with, all relevant National Grid standards as appropriate.
- 1.2** Design work shall comply with all appropriate National Grid Technical Specifications (NGTS's and TS's), British Standards, European Standards and Codes of Practice as appropriate and be in accordance with recognised analytical methods. It is noted that there are several National Grid standards which, whilst not explicitly associated with Civil, Structural and Building Engineering nonetheless contain requirements which may impact on aspects of such designs. For example earthing requirements will, in certain configurations, be applicable to fencing and handrail installations. It shall be the designer's responsibility to ensure a holistic design solution is achieved.
- 1.3** The term 'Civil, Structural and Building Engineering' shall apply to the design, manufacture, installation and demolition of the following permanent works items:
- Access roads
 - Footpaths
 - Drainage
 - Oil containment works
 - Fencing
 - Site security
 - Surfacing
 - Service ducts and trenches
 - Buildings
 - Site and Building services (excluding electricity and telecommunications services)
 - Foundations
 - Piling works
 - Earthworks
 - Ground Improvement/Stabilisation
 - Plant support structures
 - Holding down systems
 - Fire protection & control
 - Cable Tunnels
 - Acoustic enclosures
 - Site Lighting
 - Landscaping
 - Other enabling infrastructure (Operational & Non-operational) - e.g. retaining structures, bridges, culverts etc.
- 1.4** Unless stated to the contrary this scope shall also apply to all surveys, site investigations, condition assessments and temporary works necessary to facilitate the construction of these items. It shall additionally apply to the design only of the structural integrity of all items not specifically listed above. This includes all electrical components such as plant, busbars, clamps etc.
- 1.5** Where the terms 'Civil', 'Civil Engineering' or similar are used in any contractual context they shall be deemed to mean 'Civil, Structural and Building Engineering' as defined in this document.
- 1.6** Where there is conflict between the requirements in this document and any other National Grid specifications this document shall generally take precedence otherwise the more demanding standard shall always apply.

- 1.7** All drawings shall be annotated with cross-references to the appropriate specification clauses.
- 1.8** The designer shall ensure that in all instances new and existing works do not compromise each other either functionally or aesthetically.
- 1.9** Any reference made in this document to a requirement for NG approval shall be taken to mean whichever 'Client side' Design Assurance process is appropriate at the time of contract award.
- 1.10** All construction work shall be classed as 'new build' unless specifically identified as otherwise and as such shall be in accordance with all appropriate standards at the time of contract award.
- 1.11** Unless agreed otherwise with National Grid all structural steel shall be hot dip galvanized and shall be designed in accordance with the relevant British Standard(s) plus the recommendations of the Galvanizers Association (www.hdg.org.uk). The minimum thicknesses stated in the specification shall be increased where necessary to take account of any site specific factors which may affect the corrosion rate.
- 1.12** Where appropriate design shall be in accordance with the National Structural Steelwork Specification for Building Construction.
- 1.13** Where necessary icing conditions shall be designed in accordance with the guidance provided in CP 3:Chapter V-2:1972, 'Code of basic data for the design of buildings. Loading. Wind loads', Appendix F, 'Ice formation on structures'.

INFORMATIVE: The relevant Eurocode (BS EN 1991-1-4) and the related National Annex does not give specific guidance on the effects of ice on the geometry of a structure.

- 1.14** Glass Reinforced Plastic (GRP) shall NOT be employed as a structural material or component for any substation buildings, enclosures or other constructions whose integrity is a direct function of the operation of the HV Electricity transmission system. Kiosks and cubicles may, with the agreement of National Grid, be manufactured from GRP provided an appropriate material specification is produced.
- 1.15** Foamed concrete produced using ash or similar re-cycled materials shall NOT be used. Where there is any doubt consultation shall be carried out with National Grid and the material supplier.

INFORMATIVE: In August 2009 two persons were injured by an explosion involving a foamed concrete mix which included incinerator bottom ash aggregate (IBAA). The subsequent HSE investigation determined that the cause of the explosion was the ignition of flammable hydrogen gas created by the reaction of aluminium, which IBAA is known to contain in significant proportions, with the cement/concrete mixtures. National Grid SHES Bulletin – SB 227 dated 4/09/09 refers.

- 1.16** Reference to 'Design Life' shall mean the period of time (in years) for which an asset is required to perform in accordance with the project specification without any loss in functionality. In achieving the 'Design Life' 'Major Maintenance' and/or 'General Maintenance' will be necessary as described below.
- 1.17** Where appropriate reference to 'Maintenance' activities shall be specified as follows;
- 'Major Maintenance' shall mean any work involving the wholesale or significant inspection, replacement, reapplication or repair of any of the component systems or parts necessary to maintain the function, integrity and design life of the asset in question. It is permissible for 'Major Maintenance' activities to require electrical

outages however these shall be minimised and shall be consistent, in duration and interval, with those required for the associated HV plant and equipment. An example of 'Major Maintenance' would be a complete repaint of an acoustic enclosure or the period of time after which sufficient metal coating still remains to re-establish a steelwork protective system.

- 'General Maintenance' shall mean any work involving inspections, cleaning operations and/or any minor repairs necessary to achieve the first and all subsequent 'Major Maintenance' milestones. 'General Maintenance' shall not necessitate (and therefore pre-assume) any electrical outages however it may be possible to take advantage of these if and when they occur. Examples of 'General Maintenance' are washing down or clearing the gutters of acoustic enclosures, localized repairs to protective treatment systems and roof inspections.

All 'Maintenance' requirements shall be identified/confirmed as part of the design process and, on completion of the project, recorded in the appropriate site documentation - most usually the 'Health and Safety File' as required by the Construction (Design and Management) Regulations).

Copyright National Grid
Provided by IHS Markit under license with National Grid
No reproduction or networking permitted without license from IHS
Full document details: NG DH 10 2013

2 **NEW ASSETS**

The following requirements shall apply to all 'new build' construction work.

2.1 **OIL CONTAINMENT**

The following section shall be read in conjunction with TS 2.20, 'Oil Containment at Substations and other Operational Sites', Issue 4 and the 'Drainage' section of this document as appropriate. Installations not explicitly covered shall, as a minimum, comply with the guidance in CIRIA Report 163, "Construction of Bunds for oil storage tanks" and the Environment Agency document PPG2, "Above Ground Oil Storage Tanks".

General Principles

- 2.1.1 With reference to sections 6.1 and 8.3 of TS 2.20 it shall be noted that Environment Agency (EA) consent may be necessary for the use of soakaways.

INFORMATIVE: EA consent cannot be assumed and consequently early application is essential if only to confirm formal approval is not necessary.

- 2.1.2 Systems such as suspended floors that comprise Glass Reinforced Polymer (GRP) or similar materials shall not be permitted in 'Oil Retaining Areas' ('bunds') connected to 'Underground Oil Containment Facilities' unless they have been independently tested and certified to confirm they are not combustible.
- 2.1.3 The above ground 'bund' floor shall have sufficient fall to prevent the build up of surface moss, silt and other detritus or the formation of ice. Additionally it shall facilitate the flow rate specified in TS 2.20

Oil Separators

- 2.1.4 The material/construction of oil separators shall be capable of resisting pressures arising from ground and ground water, together with any construction/maintenance loads, when the tank is empty.
- 2.1.5 Where an open channel (i.e. ACO type) drainage product forms part of an oil containment system this shall be designed to be oil/water tight and shall be subjected to a maximum head water test on completion.
- 2.1.6 With reference to the 'Testing of Bunded Areas' section of TS 2.20 (as defined in TS 3.010.07, Clause 7.25.1) the water level for the retention test may be reduced to the top of the transformer plinth by agreement with National Grid where this demonstrably benefits the project without compromising functionality.

INFORMATIVE: The specified water level for retention testing is "150 mm above the transformer plinth, or such higher level required by the Engineer". This precludes testing ahead of transformer installation should the chosen method requires that a section of the 'bund' wall be omitted to facilitate this. It also means that during the subsequent test the transformer will be standing in water for at least 3 days. However the purpose of the test is to prove the integrity of the underground compartments (particularly the construction joints) on which this level reduction will have a minimal effect.

Containerised Diesel Generators

- 2.1.7 Containerised diesel generator sets shall have a Secondary Containment System whose minimum gross capacity is 1.15 times the total volume of stored oil.
- 2.1.8 The engine fuel return shall be a braided steel hose and a two level alarm system be introduced into the bund sump. A low level alarm shall indicate the presence of oil (which might be due to a localised spill) and a second higher level one shall shut the engine down with the assumption that this would be indicative of a significant release of oil due to some form of fuel system or other catastrophic containment failure.

2.2 PERIMETER SECURITY

The following section shall be read in conjunction with TS 2.22, 'Perimeter Security for Substations and other Operational Compounds', Issue 4.

Fence Systems - General Requirements

- 2.2.1 The preferred method for connecting the fence system to the substation earthing mat shall be via direct connection to the horizontal rails in the fence panels and suitably sized lugs on the inside face of the gate posts. Otherwise the relevant posts shall have 2 no 14 mm diameter holes in their back (internal) face. These shall be at 50mm vertical centres a minimum of 100mm above the top of the concrete sill and shall not be post drilled (i.e. after hot dip galvanising).
- 2.2.2 Finishes to the concrete surfaces of the anti burrow cill shall be in accordance with TS 3.010.04 as follows;
- Vertical Faces 'Fair finish'
 - Upper surface 'Steel trowel finish'
- 2.2.3 The distance between adjacent changes in horizontal alignment shall not be less than 2.75 metres (i.e. the length of a standard fence panel).
- 2.2.4 Open mesh steel panels shall, as a minimum, be pre-coated with a 95% zinc/5% aluminium alloy (minimum thickness = 85 microns). An additional polyester powder coating may be applied as instructed by National Grid dependent on specific project requirements.

INFORMATIVE: Further to Section 2.5 of TS2.22, Issue 4.

The methods for calculating wind load on palisade and open mesh type fences is not specifically documented in existing design codes and consequently analogous approximations and interpretations are typically employed. Subsequent analysis has determined that the wind load that can be reasonably deduced in this manner is such that it would cause the standard palisade type fence posts detailed in BS1722 to theoretically fail. Consequently on the basis that;

- a) There is a significant population of BS1722 compliant palisade fencing in the UK,*
- b) There are no known documented or anecdotal problems with the performance of the standard fence posts under wind load and*
- c) There is no value in designing foundations and other elements to be significantly more resilient than the majority standard components*

It shall be acceptable to design all bespoke elements of the fencing system to be consistent with the limiting load criteria of the BS1722 standard fence posts as appropriate. Essentially an equivalent wind load (pressure) that equates to the capacity of a standard fence post supporting standard fence panels at standard centres shall be used to design all the non-standard (or bespoke) elements of a fence system.

2.3 SITE LIGHTING

2.3.1 Exterior and interior lighting shall be provided at all substation sites to allow for safe movement and the operation of equipment. All lighting shall be designed in accordance with the appropriate Chartered Institution of Building Services Engineers (CIBSE), British Standards Institution (BSI) and Health and Safety publications. Particular note shall be given to environmental considerations.

2.3.2 The minimum exterior lighting requirements are as follows:

Maintained average illuminance:	6.0 lux
Maintained minimum point illuminance:	2.5 lux

Unless noted otherwise these requirements apply to all substation perimeter fencing and gates and access roads, verges, footpaths, designated walkways and areas occupied by plant or other equipment (whether in service or not) contained by the substation perimeter fencing.

INFORMATIVE: The purpose of exterior lighting is to allow the safe movement of vehicles (using their headlights) and pedestrians between any two points that they might reasonably be expected to negotiate at night within the substation perimeter. It is not intended to facilitate maintenance activities (planned or unplanned) for which it is assumed additional portable equipment will be employed.

Such light sources are not required to reproduce the colours of objects faithfully in comparison with an ideal or natural light source (i.e. have a specific Colour Rendering Index) which is necessary in certain environments where people have to be able to make accurate colour judgements.

The basis of the handbook requirement is CIBSE Lighting Guide LG1, 'The Industrial Environment' Section 4.4, which defines values of 6.0 lux maintained average illuminance and 2.5 lux maintained minimum point illuminance as being appropriate for factory roads, footways or footpaths.

In comparison BS 5489-1:2003+A2:2008, 'Code of practice for the design of road lighting - Part 1: Lighting of roads and public amenity areas' specifies, as a maximum, Class 'S4' lighting for subsidiary roads (that is access roads, residential roads and associated pedestrian areas, footpaths and cycle tracks) in areas having 'Low' traffic flow and 'Low' crime rate. BS EN 13201-2:2003, 'Road lighting - Part 2: Performance requirements' defines Class 'S4' as 5 lux maintained average illuminance and 1 lux maintained minimum point illuminance.

2.3.3 Where the design necessitates regular (i.e. weekly) inspection or maintenance to be carried out on exterior plant or equipment at night the following localised requirements shall be provided as a minimum:

Maintained average illuminance:	100.0 lux
Maintained minimum point illuminance:	50.0 lux

INFORMATIVE: Localised (or 'task') lighting is not a mandatory requirement and shall only be provided where weekly inspection or maintenance is a direct function of the design.

The basis of the requirement is HSG38, 'Lighting at Work' which identifies task lighting requirements of 100 lux maintained average illuminance and 50 lux maintained minimum point illuminance are suitable for work requiring limited perception to detail (i.e. kitchens, factories assembling large components, potteries). This is deemed appropriate for 'general' equipment operations.

- 2.3.4 Exterior lighting shall, wherever possible, be on dedicated, galvanised steel, mid-hinged columns designed to be lowered for maintenance by one person. Where this is not possible lights may be mounted on structures or buildings. Luminaires shall generally be High Pressure Sodium (SON) type with directable light output to minimise light pollution except at each access gate where individual passive infrared (PIR) motion sensor operated "instant on" (i.e. no significant warm-up period) lights shall be provided to facilitate safe entry at night. The installation shall be designed to minimise visual intrusion outside the main substation periphery in accordance with the recommendations in CIBSE FactFile No 7, 'Environmental Considerations for Exterior Lighting'

INFORMATIVE: It is preferable that lighting columns are sized and/or positioned such that, in the event of a failure, they cannot fall across HV plant or equipment.

- 2.3.5 Lighting columns shall be bolted to their foundations rather than cast in to facilitate removal/reinstallation.

INFORMATIVE: The installation of all light columns shall comply with the requirements of TS 3.1.2, 'Earthing'. The preferred connection method is via one of the column holding down bolts.

- 2.3.6 In all instances exterior and interior lighting shall be designed such that safe access is available from ground level or a fixed platform to maintain the lights without the need for electrical circuit outages or specialist temporary equipment.

INFORMATIVE: If the only demonstrable means of maintaining any lighting is from a MEWP (Mobile Elevating Work Platform) or similar plant this must be provided, together with the necessary training, under the contract.

- 2.3.7 Components of the lighting system installed in proximity to an active automatic fire protection system shall have a minimum Ingress Protection (IP) rating of 55.

- 2.3.8 The exterior lighting system shall be switchable as follows;
- Remotely via the SCS (Substation Control System),
 - Locally on site via a control panel at the 'T-Card' board (i.e. site logging in point),
- The system shall be configured such that it cannot be left on inadvertently during the day and shall incorporate a manual over ride to facilitate maintenance. Additionally there shall be an automatic reset to ensure that the lights do not automatically switch back on at night.

2.4 **PILING WORKS**

- 2.4.1 A representative number of each type of pile shall be subjected to maintained load tests, as defined in the Institution of Civil Engineers Specification for Piling, to verify the design. The scope and method of testing shall be agreed with National Grid and recorded in the project specification. A copy of the results shall be supplied to National Grid on completion together with proposals for remedial works in the event of any failures.

INFORMATIVE: Alternative types of static load test, for example constant rate of penetration, may be used by agreement however non destructive methods such as integrity testing and dynamic testing shall not be considered as a direct substitute for static load testing of piles but rather a useful supplement when the correlation between static and dynamic test results is good.

- 2.4.2 All works shall accord with BRE Report BR470, 'Working Platforms for Tracked Plant: good practice guide to the design, installation, maintenance and repair of ground-supported working platforms' plus the recommendations of the Federation of Piling Specialists specifically their Working Platform Certificate (or an equivalent) and 'Handbook on Pile Load Testing'.
- 2.4.3 Single pile foundations shall not normally be installed unless it can be demonstrated that the lateral stability of the pile will not be compromised during the design life.
- 2.4.4 The piling method employed shall make allowance for the ground vibration effect on adjacent National Grid or third party owned equipment and buildings.

INFORMATIVE: Acceptable vibration limits will vary depending on ground conditions, piling methods and the age/type of the adjacent equipment and buildings under consideration. The following peak particle velocity (ppv) values may be used for guidance however if there are any doubts over the validity of these specialist advice shall be sought;

*Equipment and buildings confirmed be in good states of repair or condition with no known operational or structural sensitivities or limitations;
ppv = 30 mm/s for intermittent vibrations and 15 mm/s for continuous vibrations*

*All other equipment and buildings;
ppv = 10 mm/s for intermittent vibrations or 5 mm/s for continuous vibrations*

Refer to BS 5228-4:1992 'Noise control on construction and open sites - Part 4: Code of practice for noise and vibration control applicable to piling operations' for further information.

- 2.4.5 Where concrete is to be placed under water or drilling mud by tremie the cement content shall not be less than 380 kg/m³. Where piles will be exposed to sea water the cement content shall not be less than 400 kg/m³.

2.5 ACCESS COVERS

- 2.5.1 This section applies to ALL access covers (whether to manholes, catchpits, service trenches, road gullies, service duct draw pits etc.).
- 2.5.2 Access covers shall be rated in accordance with BS EN 124, 'Gully tops and manhole tops for vehicular and pedestrian areas - Design requirements, type testing, marking, quality control' and designated as follows:

National Grid Designation	Substation Location	BS EN 124 Class
'Light Duty'	Defined pedestrian areas	A15
'Medium Duty'	Areas (including vehicle crossing points) not designated as 'Light' or 'Heavy Duty'	B125
'Heavy Duty'	All roadways	C250

- 2.5.3 The designer shall ensure that each access cover is suitable for the location in which it is installed. Where a greater wheel (or other) loading regime is appropriate higher specification covers in accordance BS EN 124 shall be used.