

## **GENERIC DESIGN PRINCIPLES FOR OVERHEAD LINES**

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### **TABLE OF CONTENTS**

|                                                                      |           |
|----------------------------------------------------------------------|-----------|
| PURPOSE AND SCOPE.....                                               | 1         |
| <b>PART 1 – PROCEDURAL .....</b>                                     | <b>1</b>  |
| 1 GENERAL REQUIREMENTS .....                                         | 1         |
| 2 TOWER DESIGN.....                                                  | 3         |
| 3 ACTIONS ON TOWERS AND LINES .....                                  | 4         |
| 4 CLEARANCES .....                                                   | 6         |
| 5 ELECTRICAL REQUIREMENTS .....                                      | 8         |
| 6 SUPPORTS .....                                                     | 9         |
| 7 FOUNDATIONS.....                                                   | 9         |
| 8 CONDUCTORS .....                                                   | 12        |
| 10 CONDUCTOR AND INSULATOR FITTINGS.....                             | 14        |
| 11 FORMS AND RECORDS .....                                           | 14        |
| <b>PART 2 - DEFINITIONS AND DOCUMENT HISTORY .....</b>               | <b>15</b> |
| 12 DEFINITIONS .....                                                 | 15        |
| 13 REFERENCES .....                                                  | 15        |
| 14 AMENDMENTS RECORD .....                                           | 16        |
| 15 IMPLEMENTATION.....                                               | 17        |
| <b>PART 3 - GUIDANCE NOTES AND APPENDICES .....</b>                  | <b>18</b> |
| APPENDIX A - NATIONAL GRID CONDUCTOR BUNDLES & STRINGING BASES ..... | 18        |
| APPENDIX B – GUIDANCE ON DOWNLEAD STRINGING TENSIONS .....           | 19        |

### **PURPOSE AND SCOPE**

This specification forms part of a suite of documents which define the National Grid functional and performance requirements for new plant and equipment.

This Specification covers the requirements applicable to designs of overhead lines to be operated by National Grid at 132, 275 or 400kV, with highest system voltages for overhead line design purposes of 145, 300 and 420kV respectively. It applies to new designs and for the refurbishment and/or modification of existing overhead lines.

For refurbishment and modification of existing lines, some modified clauses apply.

### **PART 1 – PROCEDURAL**

#### **1 GENERAL REQUIREMENTS**

##### **1.1 General**

The design of a new or reassessment of an existing overhead line for use on the National Grid System shall comply with TS1 'Ratings and General Requirements for Plant, Equipment & Apparatus for the National Grid System'. It shall also comply with BS EN 50341-1 'OHL Exceeding AC 1kV - General Requirements - Common Specifications' and BS EN 50341-2-9 'OHL Exceeding 45kV National Normative Aspects for Great Britain & Northern Ireland'.

The hierarchy of functional design specifications shall be:

- EN 50341, as modified by:
- BS EN 50341-2-9 (NNA), as modified by:
- This specification, as modified by:
- Technical Specification level 3 series, as modified by:
- The Project Specific Works Information

Overhead line designs for National Grid shall enable the conductor or insulator system to be safely maintained or replaced with one circuit live.

An overhead line is an assembly of sub components or sub systems. The requirements for these are covered by Level 3 Technical Specifications and only equipment registered by National Grid to these specifications and in line with the Type Registration process, described in UKBP TP183 'Type Registered Equipment Procedural Requirements' shall be used on an overhead line. Foundations shall be deemed as being 'registered' through application of the Design Assurance process.

All designs for Phase Conductor, Earthwire & Insulator Systems shall be based upon the generic type registration drawings, specific scheme design requirements shall be detailed on the 'As Built' records.

Deviations from this specification must be agreed in accordance with UKBP TP188 'Transmission Capital Delivery Electricity Design Management'.

## **1.2 Statutory and Non Statutory Requirements**

All overhead line design shall comply with UK Statutory requirements and all relevant National Grid Policy Statements shall be applied.

## **1.3 Red Routes**

Red Routes will be identified in the Project Specific Works Information, in such cases the design criteria used shall not result in a reduction of the reliability of the asset.

## **1.4 Conductor Type, Size and Bundle Configuration**

The required rating for each circuit of a scheme that must be achieved by the conductor system will be specified by National Grid. Selection of a conductor system must also take into account the following requirements;

- Aerodynamic Performance
- Voltage Considerations
- Mechanical Characteristics
- Clearances
- Circuit Impedance

National Grid recognised conductor bundles are detailed in Appendix A of this specification.

## 2 TOWER DESIGN

### 2.1 General Requirements

Towers shall be designed, fabricated and treated for a minimum design life of 80 years and shall be designed to withstand the loading resulting from extreme weather patterns at the line location, deemed to be equivalent to a 50 year return period with the partial factors on load.

Due account shall be taken of the effect of changes in ambient temperature, wind direction and speed, and ice loading on the specified conductor everyday tension. For design purposes, the lowest temperature of the line conductor shall be considered to be -20 °C with no wind.

For existing towers records shall also be made to confirm the existence of any special design such as suspension clamp offsetting, phase or earthwire over tension or out of bisect towers that have been applied to the section(s) or span(s) under consideration.

Where modification to tower geometry such as change of crossarm length is required the design shall ensure that all tower internal clearances are maintained in accordance with Section 4 of this specification.

In order to further protect the galvanising of any new steel a paint protective system shall be applied before the line is first energised following installation of the steel. All tower painting shall be carried out in accordance with TS 3.04.24 'Painting of Lattice Steel Towers'.

### 2.2 Reliability Levels

The required reliability level values of partial factors on variable actions shall be selected based on the tower type and location in accordance with Table 1 below

| Tower Type & Location                                        | Reliability Level | Partial Factor on Variable Actions, $\gamma_v$ (Note 1) |
|--------------------------------------------------------------|-------------------|---------------------------------------------------------|
| Suspension tower in open country                             | 2                 | 1.1                                                     |
| Suspension Tower adjacent to habitation & Critical Crossings | 3                 | 1.2                                                     |
| High Level River Crossings                                   |                   |                                                         |
| Tension Towers (Deviation & Terminal)                        |                   |                                                         |

Table 1 – Partial Load Factors on Wind Speed & Ice Thickness

The term “adjacent to habitation” shall be considered as being where a tower is located within falling distance of a dwelling, garden or any other property as detailed below.

Critical crossing shall include: motorways, schools, housing, railways, other roads with high traffic loads or providing access to major attractions, other areas where large numbers of people congregate and major industrial plant.

The partial factor for wind shall be applied to the basic wind velocity, in accordance with the NNA, and is not applied to wind load. The partial factor for ice shall be applied to ice thickness, in accordance with the NNA, and is not applied to ice load. Therefore, the partial factor for ice is squared within the calculation.

## 2.3 Strength of Tower Members

The strength of members of lattice towers shall be calculated in accordance with the NNA with a partial safety factor on design strength  $\gamma_m$  taken as 1.15.

# 3 ACTIONS ON TOWERS AND LINES

## 3.1 General

During refurbishment and modification of existing towers and foundation the assessment of such shall take into account the influence of additional 3<sup>rd</sup> party apparatus such as mobile phone antenna mounted on towers.

## 3.2 Design Approach Definition

Wind and ice loadings shall be applied in accordance with European and National standards, as defined below, this implements Design Approach 1 of BS EN 50341-1 and the NNA for climatic loading and tower design.

The design shall consider the following climatic conditions as detailed by the clause in NNA 4.12.1/GB.1:

- Extreme Wind Load – Case 1a
- Extreme Wind Load at minimum temperature – Case 2a
- Combined Wind & Ice Load – Case 3

## 3.3 Wind loads

Wind load shall be applied in accordance with BS EN 50341-1 and the NNA. The standard wind loading condition i.e. extreme wind load, load case 1a in accordance with NNA Table 4.12.1/GB.1 will be that for a wind direction producing the most severe loading on the intact system of conductors and tower with appropriate gust conditions at the most severe part of the overhead line under consideration.

For suspension towers in open terrain, Terrain Category II in accordance with BS EN 50341-1 Table 4.1 shall be assumed.

Patch wind loading shall be applied for tall specialist structures such as river crossings; this shall be achieved by the application of mean wind loading on all tower panels plus gust wind loading on a combination of panels that provide the most onerous wind loading conditions. Reference to BS EN 1993-3-1 may be made for guidance on the application of this type of loading.

## 3.4 Wind forces on overhead line components

For smooth body conductors a drag factor ( $C_d$ ) of 0.9 shall be used in loading calculations.

## 3.5 Combined wind and ice loads

The reference radial ice thickness ( $r_i$ ) for any conductor shall not be less than 40 mm, with all factors included. The minimum reference radial ice thickness ( $r_i$ ) for the combined wind and ice case shall be 7mm, with all factors included.

The reference ice thickness ( $r_i$ ) shall not be greater than 46.5mm with all factors included.

## 3.6 Security Loads

Security loads shall be calculated in accordance with NNA.

A "broken wire" loading condition shall be defined as the static tension of two broken phase bundles or one bundle and the earthwire in the same span (worst combination on the tower). This shall be applied to both suspension and tension towers.

Suspension Towers:

- 1) Design Tension at 5°C - No Wind or Ice Load - Alleviation Factor of 0.7 - Phase conductor only to allow insulator swing.

Note: Alternatively, the tower may be analysed taking into consideration its flexibility and the effects of interaction with all other conductors attached to it. Specialist, commercially available Finite Element Analysis software is acceptable to be used for this purpose.

Tension Towers:

- 1) As above without alleviation factor.
- 2) Additional requirement assuming only one phase conductor bundle or earthwire broken. The conductor loads shall be determined on the 3 year return period wind on 3 year return period ice, (equivalent to  $\gamma_v = 0.75$ ). No alleviation factor shall be used on this load.

Where a tower design capacity is exceeded by calculation under the specified broken wire condition, the tower shall be re-assessed according to the likely consequence of the specified failure. A tower shall be deemed suitable for the purpose of failure containment if both catastrophic and cascade failures are unlikely.

### 3.7 Maximum Safe Working Loads for Construction and Maintenance Operations

For design purposes, it shall be assumed that the tension in the conductor for combinations including safety loads shall be that derived from a still air condition, without ice, at a minimum temperature of 0°C.

All tower members that could be used to support personnel shall, by calculation, be able to support a characteristic load of 1.0 kN applied vertically at their midpoint. A partial factor of 1.5, as above for static loads, shall be applied to this load.

For new tower design and concepts the erection and maintenance procedures considered in the design shall be stated and the equipment required to carry out the procedures shall be itemised. Any special equipment necessary shall be designed, tested and provided as stated in the Project Specific Works Information. The detailing of the tower shall include all necessary facilities required by the erection and maintenance procedures.

The Design Contractor shall advise National Grid of any 'special' or new working methodologies for maintenance activities. The designer shall assess the suitability of a draft procedure in each case and advise National Grid accordingly.

### 3.8 Forces due to short circuit currents

Forces due to short circuit currents shall be considered for downlead spans between Terminal Towers or other OHL structures and Substation Line Landing Gantries, in accordance with the requirements of TS 3.01.04. Further detail on the requirements for downlead short circuit forces can be found in Section 8.3.4 of this document.

### 3.9 Other special forces

Avalanches, creeping snow and earthquakes shall not be considered.

### 3.10 Partial factors for actions

Values of partial factors for other actions shall be in accordance with Table 2.

| Action                                                                                       | Partial Factor | Value                                                                                                     |
|----------------------------------------------------------------------------------------------|----------------|-----------------------------------------------------------------------------------------------------------|
| <b>Variable Actions:</b><br>Wind Load (No Ice)<br>Combined Wind & Ice<br>Heavy Ice (No Wind) | $\gamma_v$     | 1.1 or 1.2 (See Section 2.2)                                                                              |
| <b>Permanent Actions:</b><br>Self-Weight                                                     | $\gamma_{DL}$  | The more onerous of 1.1 or 0.9<br>1.0 for calculation of conductor tension                                |
| <b>Safety Loads:</b>                                                                         |                | 1.5 on Static Loads<br>2.0 on Conductor tension when conductors are being pulled by powered winches, etc. |
| <b>Security Loads:</b>                                                                       |                | 1.0 for calculation of conductor tension<br>See section 1.4.7 for simultaneous climatic loading           |

Table 2 – Values of Partial Factors

## 4 CLEARANCES

Internal clearances detailed in this specification refer to clearances between parts of the overhead line system (i.e. tower geometry) and external clearances are to objects in proximity but not forming part of the overhead line system.

### 4.1 Internal Clearances

#### 4.1.1 Live Parts to Earthed Components

Unless otherwise specified by National Grid the minimum clearances of live parts (insulator string and jumper loops) to the tower, to earthed fittings and to earthwire are specified in Table 3 below. Clearances shall be maintained with wind normal to the line in the worst section of the line. The use of jumper weights and pilot sets is acceptable.

| System Nominal Voltage, kV                                                                                                                                                                                                                                                                              | 400 | 275 | 132  |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----|------|
| <b>In still air <math>D_{el}</math>, m</b><br>Suspension insulator strings swung up to 10° from the vertical and for jumpers hanging vertically                                                                                                                                                         | 2.8 | 2.4 | 1.4  |
| <b>With 3 year return period wind, <math>D_3</math>, m</b><br>Suspension insulator strings swung 10° to 35° from the vertical and for jumper loops swung up to 20° from the vertical                                                                                                                    | 1.8 | 1.4 | 0.75 |
| <b>With 50 year return period for gust conditions, <math>D_{50}</math>, m</b><br>Where weighted pilot sets are used it shall be assumed that they have an initial swing of 10° in still air with the jumper loop hanging vertically and a maximum swing of 20° when the jumper loop is at maximum swing | 0.7 | 0.5 | 0.3  |

Table 3 – Minimum Clearances

For refurbishments if clearances given in Table 3 cannot be achieved reference shall be made to the original tower design specification and if clearance can be achieved from the original design this shall be deemed acceptable.

On suspension towers the specified clearances between line conductors and any steel tower member shall be obtained on the assumption that the conductor may leave the suspension clamp at any angle up to 15°, measured in the plane containing the insulator string. Where clearances cannot be met at 15°, site-specific assessments by calculation as set out below utilising actual fall-away angles at the conductor's rated temperature should be undertaken. This assessment shall equally be applied to crossing towers and those located on hillsides.