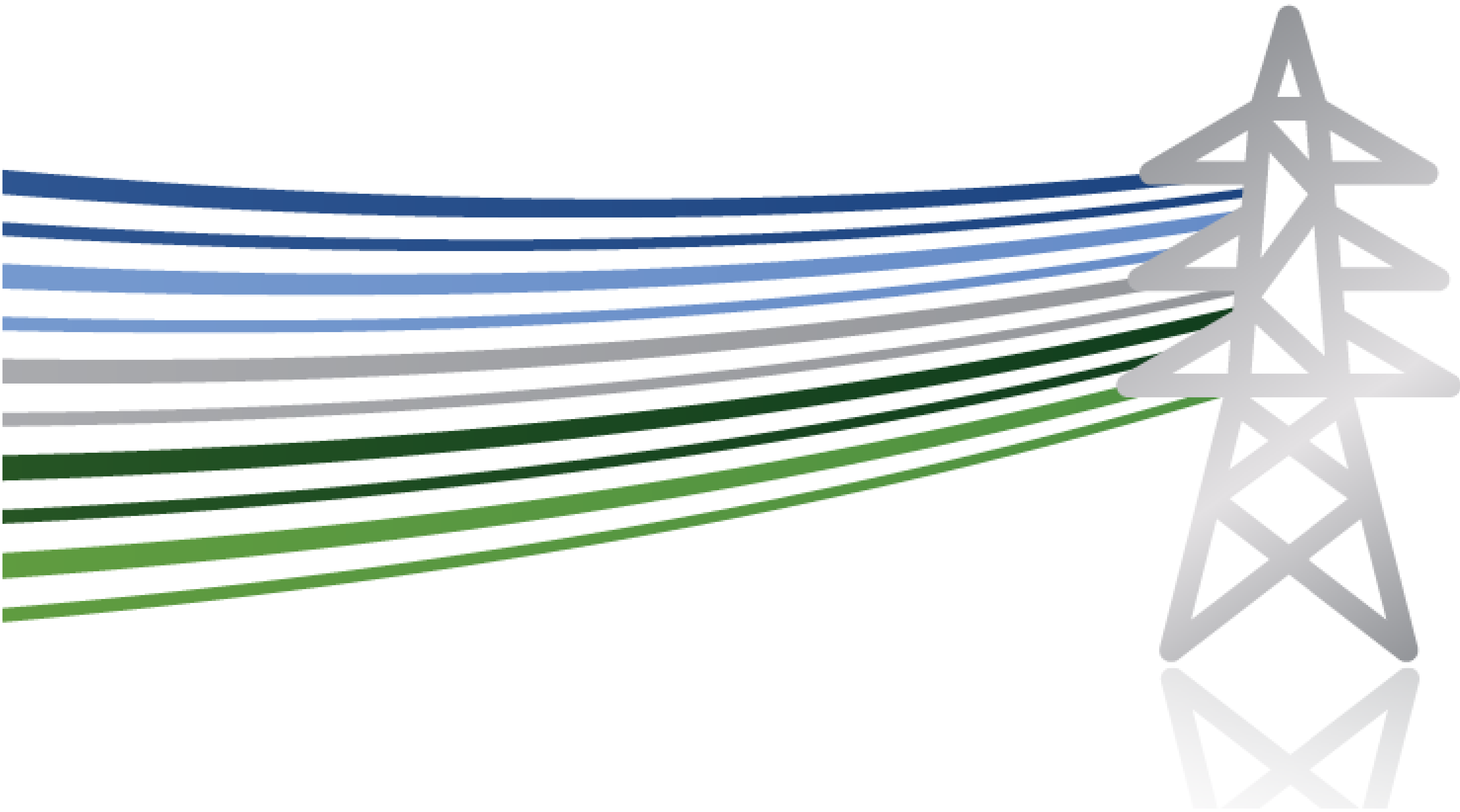
SHE Transmission

New Suite of Transmission Structures: NeSTS (SSEN003)

Creation of Technical Specifications (Appendix 1)

August 2018



132kV Steel Pole Transmission Lines:

Preliminary Technical Specification for NeSTS 132 kV Double Circuit - Medium Duty

Issue 1

DRAFT FOR COMMENT

August 2018

REVISION HISTORY

Prep	Chkd	Appr	Issue	Date	Comments:
MDL	ST, MH, JS	TS	1	22/8/2018	First draft for comment

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Foreword

This Preliminary Technical Specification (PTS) is published by the NeSTS Project. It sets out the functional requirements and design bases for the new suite of 132kV double circuit, steel, monopole supports. The development process is not complete at the time of publication as further development and verification work is planned, including technical reviews and physical testing of supports.

The intention is that the NeSTS support series will be suitable for application anywhere within Great Britain, subject to the limits of application stated herein.

The design parameters adopted for the development of this issue of the PTS correspond to the 132kV Double Circuit Medium Duty (DCMD), subsequent issues may incorporate details for other application duties. The upper limits of the adopted design parameters are considered to correspond to the environmental conditions encountered on a wide range of the network in Great Britain.

The NeSTS supports are to be designed and constructed to have a minimum design life of 80 years. The supports will require limited maintenance; the period to first maintenance is to exceed 20 years.

1. Scope

This PTS is applicable to new overhead lines constructed with NeSTS (132) DCMD steel pole supports.

The extent of the application of BS EN 50341-1 (Part 1) in the United Kingdom, is defined in BS EN 50341-2-9:2017 (Part 2-9).

Reference should be made to Part 1, Part 2-9, and the Project specification for details of design, manufacture, installation and testing of all other components for the OHL, including the fabrication and installation of the supports.

Only specific support types and ranges of extensions have been analysed for compliance with Part 1 and Part 2-9, based on a defined set of generic loading conditions, as set out in the main body of text and design load schedules 90SS686-95-011, 012, 013, 014, 015 and 016.

Where loading conditions, support types or extensions are outside the parameters quoted, the users of this PTS are responsible for undertaking their own specific checks.

2. Normative references

The following referenced documents, in whole or part, are indispensable for the application of this PTS. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

2.1. Standards publications

BS EN 1992 and NNAs to BS EN 1992
Design of concrete structures

BS EN 1993 and NNAs to BS EN 1993
Design of steel structures

BS EN 1997 and NNAs to BS EN 1997
Geotechnical design

BS EN 10025
Hot rolled products of structural steels

BS EN 50341-1:2012
Overhead electrical lines exceeding AC 1 kV.
General requirements. Common specifications

BS EN 50341-2-9:2017
Overhead electrical lines exceeding AC 1 kV.
National Normative Aspects (NNA) for Great Britain and Northern Ireland

ASCE 48-11: 2012
Design of Steel Transmission Pole Structures

2.2. Other publications

ENA TS 43-125: Issue 2:2017
Design guide and technical specification for overhead lines above 45kV[1]

Electricity Safety, Quality and Continuity Regulations 2002 (and Amendments)

National Grid Company Linesman's Manual M1,
132 kV, 275 kV and 400 kV Overhead lines, ('Dead Line' Working)[2]

[1] The foreword to ENA TS 43-125 Issue 2 implies that it applies to lattice steel supports in particular, and not to pole supports, however, useful guidance is given for overhead lines in general, and to supports for double circuit configurations. Reference has been made to ENA TS 43-125 for certain aspects of the design.

[2] Note Manual M1 has been withdrawn, however, reference is still made to the procedures therein.

3. Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1. Deterministic design basis

Consideration of the effects of fixed sets of loadings and weather conditions on the overhead line to ensure that the stress in each tower component is limited to be within the yield stress or ultimate tensile strength by a factor described as the factor of safety.

The Deterministic design basis has not been used in the development of the NeSTS (132) supports.

3.2. Probabilistic design basis

Consideration of the effects of random variability of loadings and weather conditions on the overhead line to ensure that risk of failure of each support component is acceptably low but using and assumption of a small probability of failure instead of using a factor of safety.

3.3. Partial load factor

Factor dependent on the selected reliability level, used to modify the calculated loads, taking into account the possibility of unfavourable deviations from the characteristic values of the loads, inaccurate modelling and uncertainties in the effects of the loads. [BS EN 50341-1 modified]

3.4. Partial strength factor

Factor used to modify the mechanical strength of a component covering unfavourable deviations from the characteristic values of material properties, inaccuracies in applied conversion factors and uncertainties in geometric properties and the structural resistance model.

[BS EN 50341-1 modified]

3.5. Reliability level

Classification denoting the selected values for wind and ice actions corresponding to a theoretical time-period for return of those climatic actions.

[Reliability levels I, II and III correspond to returns periods 50, 150, and 500 years respectively. Lesser return periods and hence reliability are adopted for some temporary loading conditions and temporary construction.]

4. The Electricity Safety, Quality & Continuity Regulations 2002

Overhead lines constructed using steel monopole supports in accordance with this PTS shall comply with the Electricity Safety, Quality & Continuity Regulations 2002, with either one or both circuits erected.

5. Historical background

5.1. General

The NeSTS (132) specification has been developed as part of the Network Innovation Competition (NIC) project code SSEN03, to provide a steel pole solution to support of 132 kV overhead lines.

5.2. Design basis

Historically, lattice steel tower designs in the United Kingdom have been based on either deterministic design principles or more recently probabilistic design principles, but the NeSTS (132) supports are based only on probabilistic design principles. Probabilistic design principles correspond Approach 1 in both Part 1 and Part 2-9 of BS EN 50341.

6. Conductor system

6.1. Phase conductor and earthwire

The NeSTS (132) DCMD design of supports permit the of alternative conductor systems as detailed in Table 1[3].

Table 1 - Conductor systems permitted on NeSTS(132)DCMD supports

Design reference	Phase conductor	Earthwire
NeSTS(132)MD	1 x 821-AL5 (Araucaria AAAC)	AACSR/ACS 177/61 2C (HS Keziah)[1]
Notes [1] The use of OPGW earthwire is envisaged		

For the reassessment of the applied loadings, a conductor system equivalent to:
1 x 821-AL5 (Araucaria AAAC) phase conductor and AACSR/ACS 177/61 2C (HS Keziah) earthwire has been adopted.

Where alternative conductor systems and span criteria etc., are used, the users of this PTS are responsible for ensuring that the quoted loadings etc., are applicable for their proposed application.

Users of this PTS should ensure that the basic meteorological parameters of the transmission line are in less onerous than those stated in Table 9. When the conditions are in excess of the values in Table 9, the users shall ensure the adequacy of the design.

6.2. Ultimate limit state sagging basis

The limit state sagging basis for the conductor system adopted for the assessment of the applied loadings is given in Table 2.

Table 2 - Ultimate limit state sagging basis

Conductor	Everyday tension		Maximum Erection Tension		Creep compensation (°C)
	Tension (kN)	Temperature (°C)	Tension (kN)	Temperature (°C)	
Araucaria AAAC	40	5	50	-20	20
HS Keziah	[1]	5	27	0	
Notes [1] Earthwire tension to achieve sag match with Araucaria AAAC at 5°C Conductor tensions under maximum working conditions shall not exceed nominal break load divided by partial materials factor (strength factor) = 1.25. NBL = 0.95 * rated tensile strength. Refer to ENA TS 43-125, Pt 2, cl 2.3.5 for further guidance.					

6.3. Conductor fittings

For details of the design, manufacture, installation and testing of the appropriate conductor's fittings for use with the conductor systems defined in Clause 6.1, reference should be made to the Project Specification.

Conductor fittings shall comply with NG TS 3.4.5.

[3] This PTS applies only to the single conductor system given in Table 1, however, it is envisaged that the use of other conductor systems will be justified in due course.

6.4. Partial strength factors for conductor system

In order to achieve the objectives of strength coordination as discussed in clause 11.12, the following partial strength factors are recommended

Component	Partial strength factor
Conductor	1.25
Insulators	1.6
Fittings	1.6

7. Internal and external clearances

7.1. General

Internal electrical clearances both within the span and at the support are based on the Part 1 Approach 1 requirements. Four distinct clearance checks are required, each under specific climatic conditions. Recommendations regarding the clearances to be used under these conditions have been taken from ENA TS 43-125, and reproduced in Table 3 for ease of reference.

Table 3 – Minimum electrical clearances

Nominal voltage	Loading case	Minimum clearance (m)			
		Within the span		At the support	
		cd - cd	cd – e/w	ph – ph	ph - ep
132 kV	Still air	1.35	1.21	1.35	1.22
	3-yr return wind	0.84	0.75	0.84	0.76
	50-yr return wind	0.41	0.28	0.41	0.28
	3-yr return ice	1.35	1.21	1.35	1.22
Legend: cd = conductor, e/w = earthwire, ph – ph = between phases or circuits, ph – ew = between phase conductor and earthed parts.					

7.2. Internal clearances

Support types D2, D10, D30, and D60 meet the internal electrical clearances specified in Table 3, under the generic meteorological conditions outlined in Clause 10.4 of this Specification. The determination of the conductor or insulator set swing angles was based on the recommendations given in ENA TS 43-125, Pt 1, Annex 3.D.

The use of pilot sets, jumper weights and conductor stiffeners to achieve the specified at-support clearances is acceptable. Post insulators have been assumed for the assessments that have been made in the preparation of this PTS.

At-support clearances have been checked for single conductor and twin-conductor systems, in accordance with 90SS686-DN-007, Wire Clearance Information Requirements 132kV.

7.3. External clearances

For details of the external in-span clearances to the ground or other obstacles reference should be made to SSEN document PR-PS-340, Application of Clearances to Overhead Lines at LV to 400kV.

7.4. Downleads

The down-lead clearances quoted in Table 4 are based on the Part 1 'Empirical Approach'.

Table 4 - Minimum down-lead clearances within span

Nominal voltage	Loading case	Minimum clearance within span (cd-cd)(m)
132 kV	Still air	2.5 [1]
	3-year return wind speed	1.5 [2]
Notes cd-cd – spacing between conductors [1] At maximum continuous conductor temperature [2] The minimum 3-year return period wind speed conductor to conductor clearance should be achieved with the conductors of one phase subjected to the 3-year return period gust wind speed, while the conductors of the adjacent phase are subjected to the 3-year return period mean hourly wind speed.		

7.5. Earthwire shade angle

The earthwire shade angle for NeSTS (132)DCMD supports is 45 degrees from the vertical in still air.

7.6. Phase to phase separation

Phase-to-phase separation (Dpp) determines the reliability of the overhead line during switching overvoltages and is based on the minimum value of Dpp which will be maintained under the environmental conditions defined in BS EN 50341-2-9:2017, namely, high wind, combined wind and ice, and heavy ice.

For phase-to-phase in-span clearances, the adopted value of gap factor Kg is 1.35 [NG TS 2.27]. The minimum electrical clearances have been calculated in accordance with IEC 60071-1 and 60071-2.

7.7. Conductor offsets

Tower top geometry, and in particular attachment point offsets, has been designed to facilitate lowering of conductors. The minimum offset between phase conductors is 600 mm.

8. Insulators and insulator sets

8.1. General

For details of phase conductor and earthwire attachment points, reference should be made to the appropriate general arrangement drawings.

8.2. Suspension insulator sets

For details of the suspension insulator sets that are suitable for use with the NeSTS (132) supports reference should be made to drawings

- 90SS686-68-015 for 1 x Araucaria AAAC and
- 90SS686-68-017 for 2 x Rubus AAAC

The nominal lengths of insulators assumed for the design studies for single Araucaria and twin Totara are 2063 mm and 2261 mm respectively.

Nominal tension capacity of suspension insulators 125 kN.

8.3. Tension insulator sets

For details of the tension insulator sets that are suitable for use with the NeSTS (132)DCMD supports reference should be made to drawings

- 90SS686-68-016 for 1 x Araucaria AAAC and
- 90SS686-68-018 for 2 x Rubus AAAC,

The nominal lengths of insulators assumed for the design studies for single Araucaria and twin Totara are 3021 mm and 2775 mm respectively.

Nominal tension capacity of tension insulators 300 kN

8.4. Low duty tension insulator sets

For details of low duty insulator sets that are suitable for use with the NeSTS (132)DCMD supports reference should be made to drawings

- 90SS686-68-[TBC] for 1 x Araucaria AAAC and
- 90SS686-68-[TBC] for 2 x Totara AAAC,

The nominal lengths of low duty tension sets assumed in the design studies for single Araucaria and twin Totara are [TBC] mm and [TBC] mm respectively.

8.5. Earthwire suspension sets

For details of OPGW earthwire suspension sets and tension sets that are suitable for use with the NeSTS (132) DCMD supports reference should be made to drawings

- 90SS686-68-[TBC], OPGW suspension set
- 90SS686-68-[TBC] OPGW tension set

The nominal length for the earthwire suspension set assumed for the design studies is 355 mm [TBC].

9. Supports

9.1. General

A complete range of steel pole supports has been designed, including D2, D10, D30, D60 and DT.

At the time of drafting, full scale testing of the D2 and D60 supports is proposed.

9.2. Types and uses

The range of standard support types available is shown in Table 5, together with their respective angles of deviation and or angles of entry. Each of these support types has been designed so that the support heights may be altered by the extensions or reductions defined in clause 9.3 of this PTS.

Table 5 – Support Suite – Angles of deviation

Code	Description	Deviation (°)
D2	Suspension	0-2
D10	10° Angle	0-10
D30	30° Angle	10-30
D60	60° Angle	30-60
DT	Double circuit terminal	0-5 (entry)

D10 supports may be used in straight in line positions where it is necessary to arrange for sectioning and tensioning of the phase conductors and earthwire in a straight run of a line route.

All angle supports are suitable for zero weight spans combined with maximum wind spans throughout the full ranges of line deviations for which the angle supports are designed.

For angle supports at the minimum line deviation, the mean horizontal separation of the circuits is not less than the D2 type support with zero angle of deviation.

For the DT type support, the outermost down-lead take-off points on the top crossarm with auxiliary extensions and middle crossarms, have been designed to overhang those on the crossarm below by 1.8 m (see drawing 90SS686-132-xxx) [TBC]

9.3. Extensions

Details of the extensions and reductions available for the standard types of support are given in Table 6.

An extension to the standard height tower is designated by the letter 'E' followed by the height of the extension in metres. A reduction to the standard height is designated by the letter 'M' followed by the height of the reduction in metres.

Table 6 – Support Suite – Range of extensions

Code	Range of normal extensions and reductions to standard height
D2	M6 – E12 (in 2.0m increments)
D10	M6 – E12 (in 2.0m increments)
D30	M6 – E12 (in 2.0m increments)
D60	M6 – E12 (in 2.0m increments)
DT	M6 – E12 (in 2.0m increments)

9.4. Spigot base connections

For each support, the connection between steel pole and foundation is via a truncated reinforced concrete cone, sized to achieve a 1.5 x diameter insertion into the bottom section of steel pole, and formed using permanent steel shuttering. The truncated cone is referred to in this PTS as a spigot; other specifications and design guides refer to spigots by other terms including immured foundations, dowel foundations and foundation pins.

The initial verticality of the axis of each spigot is critical to the overall verticality of the support. Depending on the type of support and the proposed angle of deviation, there may be a requirement to set at a rake the axis of the spigot during construction, to achieve optimised verticality of the support in everyday conditions, and to suit site-specific construction sequencing.

Spigots are constructed with a diameter and a taper to match that of the bottom of the pole, and at a level that results in the bottom of the pole resting at nominally 500 mm above ground level.

9.5. Ancillary support fittings

9.5.1 Access Facilities

Two access ladders are provided to each support located on plan approximately mid-angle between the transverse axis of the support and the longitudinal axis of the support, but close enough to the crossarms to allow linesmen to safely step from the ladder onto the crossarms. The ladders comprise a central rail with alternate step bolts, extending from a notional plane 3.0 m above ground level to the top of the pole. The ladder is split into sections and secured to the pole via bolted cleats such that nominal slippage in slip-joints is accommodated.

Three access rings are provided at each crossarm level, one below the crossarm, one a nominal step height above the crossarm and one above the stay attachment level. The access rings allow access from one ladder to the other at each crossarm level, and they facilitate access during construction and maintenance activities.

9.5.2 Anti-climbing devices

An assessment of the risk of climbing has been undertaken with reference to ENA TS 43-90. The smooth, near vertical sides of the bottom sections of poles deters climbing. No additional anti-climbing devices are detailed for standard installations.

9.5.3 Safety signs and identification plates

Provisions have been made for attachment of safety signs and identification plates to the supports in accordance with the requirements of ENA TS 43-90.

9.5.4 Livestock guards

The smooth, near vertical sides of the bottom sections of poles is not considered hazardous to livestock; no livestock guards are detailed for standard installations.

9.5.5 Earthwire bonding

To facilitate the attachment of flexible earthwire bonds to the support, a cleat with a 17.5 mm hole is provided on each pole adjacent to the earthwire attachment points.

9.5.6 Earthing of supports

To facilitate connection of earth electrodes to the pole body, welded cleats with 17.5 mm diameter holes have been provided close to ground level. This provision is to be provided in the bottom section of pole at each site.

In addition to direct earthing of steel poles, reinforcement cages in foundations shall be earthed.

10. Design basis, actions and reliability

10.1. General

For the assessment of applied support loadings, a generic set of reliability levels, corresponding partial load factors, span criteria and basic meteorological parameters have been adopted. Based on these parameters, a generic set of climatic, 'construction and maintenance' and accidental actions have been derived as outlined in the following clauses.

The actual actions considered for the design of specific support types are given in the design load schedules listed here

D2	90SS686-95-011
D10	90SS686-95-012
D30	90SS686-95-013
D60	90SS686-95-014
DT	90SS686-95-016

The loads stated are an indication of the upper boundary limits which the supports will safely withstand. Other conductor systems, span criteria, meteorological parameters, e.g. higher winds with reduced radial ice thicknesses, may be proved satisfactory provided that the effects of these boundary loads are not exceeded. However, the users of this PTS are responsible for ensuring that the quoted loadings and partial load factors etc., are applicable for their proposed application.

10.2. Reliability levels and partial load factors

The reliability levels and associated partial load factors adopted for the generic tower loadings are shown in Table 7.

- For suspension supports designed for use in open country reliability level 2 has been adopted.
- For suspension supports constructed in areas adjacent to habitation, or at critical crossings, i.e. critical suspension supports, reliability level 3 has been adopted, and
- For tension and terminal supports, reliability level 3 has been adopted.

Table 7 - Reliability levels and partial load factors

Action (load)	Application	Partial load factor	
Variable actions			
Climatic loads		**RL 2**	**RL 3**
(1a) High wind	γ_v on wind speed	1.1	1.2
(2a) Heavy ice	γ_v on ice thickness r_o	1.1	1.2
(3a) Combined wind and ice	γ_v on ice thickness r_w, and wind speed [1]	1.1	1.2
Safety loads (construction and maintenance loads)			
Active conductor tension	γ_L	2.0	
Landed conductor tension	γ_L	1.5	
Construction loads [2]	γ_L	1.5	
Permanent actions			
Self-weight [3]	γ_{DL}	0.9 or 1.1	
Self-weight for calculation of conductor tensions	γ_{DL}	1.0	
Accidental actions – security loads			
Conductor tensions [4]		1.0	
Climatic loading [5]	γ_v on ice thickness r_w, and wind speed [1]	0.75	0.75

Notes
[1] Factor B1 = 0.68 also applied to wind speed for 3a loading
[2] Applied to access platforms, weight of linesmen etc.
[3] Select value which causes most onerous effects
[4] Unbalanced conductor tensions in broken wire conditions
RL = Reliability level as defined in Part 2-9

10.3. Span criteria

For the assessment of applied support loadings, the generic span criteria adopted for use with 1x 821-AL5† conductors (herein referred to as Araucaria) and 1 x AACSR/ACS 177/61 2C earthwire (herein referred to as HS Keziah), is shown in Table 8. The span criteria are applicable to support types D2, D10, D30, D60 and DT, and for extension ranges M6 – E12.

Table 8 - Span criteria

Criteria	Type	Value
Standard span	All	300
Maximum sum of adjacent spans	All except DT	630
	DT	330
Maximum single span	All	330
Maximum weight span	All except DT	500
	DT	376
Minimum weight span, D2 suspension supports	D2	221
Minimum weight span, D10 – D60 supports	All except D2	0
Maximum equivalent span	All	300
Notes Maximum and minimum weight-spans, conductor self-weight only, at -10°C All span criteria given in metres (m)		

For suspension supports, the maximum sum of adjacent spans, and hence wind-spans, have been based on an angle of deviation of 2 degrees; at sites where the AOD is zero, the wind-span may be increased by nominally 40 m, subject to site specific verification of support reliability.

10.4. Basic meteorological parameters

The basic meteorological parameters and associated coefficients considered in the assessment of the applied support loadings are given in Table 9

Table 9 - Meteorological parameters

Basic 10 minute mean wind speed $v_{b,map}$ (m/s)		28 m/s
Radial ice thickness without wind, r_o (mm)		77mm
Radial ice thickness with wind, r_w (mm)		27mm
Terrain roughness category [1]		II
Wind direction factor C_{dir} [2]		1.0
Combined wind and ice factor B1 [3]		0.64
Number of wires Nc adopted for calculation of shape factor Kc [4]		7
Maximum altitude above ordnance datum (m)		260m
Notes [1] Terrain roughness category II: Flat grassland, parkland or bare soil, without hedges and with very few isolated obstructions [2] In the assessment of applied support loading the value of C_{dir} in the table above was adopted. Site specific values may be adopted for site specific checks. [3] The use of factor B1 is explained in Part 2-9, it reduces the wind speed that is considered in conjunction with ice thickness r_w [4] Nc = 7 adopted for double configurations and Nc = 4 for single circuit configurations		

10.5. Climatic loadings

The following standard climatic loading cases have been considered in the assessment of the applied support loadings.

- Case 1a – Extreme wind at 0°C
- Case 2a – Heavy uniform ice accretion on all spans at -10°C, with unit weight of ice 5.0 kN/m^3
- Case 3a – Combined wind and ice, uniform glaze ice on all spans at -10°C, with unit weight of ice 9.0 kN/m^3

Both circuits strung (DCT) and single circuit strung (SCT) have been considered in the derivation of design loads. Reference should be made to design load schedules listed in clause 10.1 for details of the specific generic climatic loadings that were adopted for the design of individual support types.

10.6. Construction and maintenance loadings

The following generic construction and maintenance (C&M) loading conditions have been considered in the assessment of the support loadings.

- Case 4a – Suspension supports – 'catch-off' of phase conductors under still air conditions
- Case 4b – Tension supports – conductor erection or lowering, pulling along the line, still air conditions
- Case 4c – Tension supports – conductor erection or lowering, square-rigged, still air conditions
- Case 4d – Tension supports – earthwire erection or lowering, square-rigged, still air conditions

For loadcases 4a – 4c, a load factor of 1.5 has been applied to conductor tension and to vertical loads arising from landed conductors; a factor of 2.0 has been applied to active conductor tensions, to vertical loads arising from active conductors, and to attached equipment.

The C&M loading conditions have been based on procedures set out in National Grid Linesman's Manual M1. In addition to conductor and earthwire tensions, allowance has been made for attachment of an access platform and for linesmen access on crossarms supporting active conductors and earthwires; for further details refer to design note 90SS686-DN-016.

In accordance with EN 50341-1, clause 4.9, an allowance of 1.0 kN has been included in the derivation of C&M loading where linesmen may require access. A load factor of 1.50 has been applied, which results in a design load of 1.5 kN for each linesman. It has been assumed that two linesmen may be working together at the end of a crossarm that is supporting an 'active' conductor.

It has been assumed that an access platform may be attached to the ends of tension support crossarms during C&M activities, on 'active' conductors. A characteristic weight of 5.85 kN has been adopted in the assessment of C&M loading scenarios.

C&M loading scenarios have been considered in the design of the NeSTS supports, however, the users of this Specification must ensure that the derived loadings together with any associated limitations are adequate for their own particular application.

10.7. Accidental actions – security loadings

The following generic security loading cases have been considered in the reassessment of the applied tower loadings.

- Case 5a – Suspension towers – two broken wires, conductor or earthwire, in still are at 5°C, with a tension reduction factor (β) of 0.7
- Case 5a1 – tension towers – two broken wires, conductor or earthwire, in still are at 5°C, with a tension reduction factor (β) of 1.0
- Case 5b tension towers - one broken wire, conductor or earthwire, in 3-year return period combined wind and ice conditions at -10 °C.

10.8. Permanent actions

For the assessment of applied loading on the supports due to the self-weight of insulators, and the self-weight of the components of the support the partial load factors shown in Table 10 have been adopted in the derivation of the design loads.

In the calculation of conductor tension, a dead load factor of 1.0 has been adopted.

Table 10 - Permanent loadings partial load factors

Case	Condition	Partial dead load factor (γ_{DL})		
		Max Wt Span	Min Wt span	Support
1a	High wind	1.1	0.9	1.1 or 0.9
2a	Heavy ice	1.0	1.0	
3a	W&I	1.0	1.0	
4a – 4d	C&M	1.5/2.0 [1]	N/A	
5a and 5a1	Broken wire – still air	1.1	0.9	
5a2	Broken wire – W&I	1.0	1.0	

Notes
C&M – Construction and maintenance loading conditions
W&I – Combined wind and ice loading
[1] 1.5 applied to landed wires, 2.0 applied to active wires

10.9. Supplementary actions

10.9.1 Insulator set wind areas

The following insulator set wind areas have been considered in the assessment of the support loadings:

Suspension insulator set	1 x 1.0 m^2
Tension insulator set	1 x 1.0 m^2
Post insulator (on tension support xarms)	1 x [TBC] m^2

10.9.2 Insulator set self-weight

The following vertical loading due to the self-weight of the insulator sets have been considered in the assessment of the support loadings:

Suspension insulator set	1 x 0.5 kN
Tension insulator set	1 x 0.6 kN
Post insulator (on tension support xarms)	1 x [TBC] kN

10.9.3 Down-leads

The following down-lead loadings have been considered in the reassessment of the tower loadings:

- Maximum limit state tension in down-leads per phase 9.00 kN [TBC]
to substation structures
- Assumed vertical loadings at support when 3.74 kN [TBC]
down-leads are deemed to be horizontal
- Maximum limit state tension in down-leads per phase 6.00 kN [TBC]
to anchor blocks

To ensure a consistency in approach partial load factors of 1.21 and 1.44 have been applied to the limit state down-lead tension for reliability levels 2 and 3 respectively.

Site-specific loading checks are to be undertaken for terminal supports.

10.9.4 Site specific load checks

For loading conditions or support types and extensions that are outside those considered herein, the users of this PTS are responsible for undertaking their own generic or site-specific loading checks.

11. Analysis and design of supports

11.1. Partial strength factors

For the analysis of the supports, the partial strength factors shown in Table 11 have been adopted.

Table 11 - Partial strength factors for supports

Material/element property	Partial strength factor (γv)
Resistance of crossarm hollow sections	1.0
Resistance of principal pole	1.05 [1]
Resistance of net-section at bolt holes	1.25
Resistance of bolts in shear or bearing	1.25
Resistance of bolts in tension	1.25
Resistance of welded connections	1.25
In accordance with BS EN 50341-1:2012, section 7.4 [1] Raised factor, for strength coordination	

11.2. Wind loading on supports

The wind loading on supports has been assessed in accordance with Part 1, clause 4.4.4, and Part 2-9.

Detailed pole loading data has been derived by splitting the pole into sections, the top and bottom of each section corresponding to nodes, and to top and bottom levels of splice connection overlaps.

11.3. Support self-weight

In calculating the self-weight of the supports, the self-weight of the principal components have been taken into account, including the principal pole and splice overlaps, crossarms, and stays; no allowance has been included for vang-plates, end-plates, attachment plates, climbing rails, bolts etc.

In determining the weight of ice on the supports, the thickness of ice on principal members has been calculated in accordance with Part 2-9, with Kc = 1.0.

11.4. Tension supports - applied load distribution

Out of balance loading has been considered in the derivation of design loads. The proportions of vertical load applied to the back span attachments and the ahead span attachments follow from the span differentials arising from maximum sum of adjacent spans, maximum single span and maximum weight span. Typically, the ratio of back span to ahead span equals the ratio of vertical vector load components in the back span and the ahead span.

11.5. Design stresses

Designs of steelwork complies with BS EN 1993-1 and the standards referenced therein. The design strengths adopted in the design of the supports are stated in Table 12 for ease of reference.

Table 12 - Design stresses adopted in the design of the supports

Material	Yield strength (N/mm^2)	Ultimate strength (N/mm^2
Steel grade S275 (< 16mm)	275	410
Steel grade S275 (< 40mm)	265	410
Steel grade S275 (< 63mm)	255	410
Steel grade S275 (< 16mm)	355	470
Steel grade S275 (< 40mm)	345	470
Steel grade S275 (< 63mm)	335	470
Bolts grade Gr 8.8	640	800
Bolts grade Gr 10.5	900	1000

11.6. Member and connection design

Strength checks on tubular members, including principal poles and crossarms have been made in accordance with ASCE 48-11, using PLS Pole software.

The design and location of connections between support elements, between element sections and between supports and foundations, takes into consideration assembly, erection, maintenance and dismantling operations, assuring safe systems of work at all times.

Generic strength checks on crossarm connections and stay connection have been carried out in accordance with BS EN 1993-1-8, Design of steel structures - Design of joints. The principles of the connection designs illustrated by the general arrangement drawings have been verified calculation and by full scale testing.

Connections are to be justified by calculations, to have sufficient capacity to withstand the design actions and effects of actions. The design actions and effects of actions are given in Annex C.1. [TBC] Connection designs that differ in principle to the generic connection designs are also to be justified by calculations, but also by full scale testing.

Connections between crossarms and principle poles, between stays and principal poles and between stays and crossarms are to be bolted, to facilitate construction and dismantlement.

Connections within the height of principal poles are to be slip-joint connections, designed in accordance with ASCE 48-11.

> *Slip-joints shall be designed to resist the maximum forces and moments at the connection. Taper above and below the slip joint shall be the same. To develop the ultimate capacity of the section, the joint shall have a minimum lap length of 1.5 times the maximum inside diameter across the flats of the outer section (nominal to be dictated by manufacturing tolerances to ensure the minimum).*

11.7. Support analysis

The analysis of the specific support types was undertaken using the 'PLS-Pole version 15.00' computer program, developed by Power Line Systems Inc. 'PLS-Pole' three-dimensional finite element models of the supports were analysed using nonlinear elastic techniques.

If alternative software packages are used, that are unfamiliar to SSEN, then working copies of models and associated software shall be provided free of charge to allow evaluation of the non-standard applications.

11.8. Limitations on deflections

The supports have been assessed when subject to the specified design loading scenarios. Pole top defections do not exceed the limits stated here.

Loading scenario	Return period	Pole to deflection limit (x top diam)
High wind	50-year	2
	3-year	1
Heavy ice	50-year	2
	3-year	1
Combined wind & ice	50-year	2
	3-year	1
Limits [TBC]		

In addition, the pole top deflection for each support does not exceed 8% of the overall height of the support, calculated using second order analysis under ultimate limit state conditions.

The rotation of foundations, starting from the permanent position at EDT through to the position during ultimate loading conditions, shall not exceed 1 degree. Foundations are to be designed to achieve this limit.

The verticality of the axis of each foundation is to be set during construction to result in the centre of the pole top being directly above the pole at ground level in the permanent condition, i.e. at EDT.

11.9. Limitations on mass and size of components

The mass and dimensions of sections of individual support elements have been carefully considered in the development of the NeSTS(132)MD supports, so as to allow for practical, safe and economic; fabrication, transport, assembly, erection, maintenance and dismantlement. The dimensions and weights of components shall not exceed the criteria set out here, without justification and approval.

Maximum length of component	13.6 m (transport and galvanising constraints)
Maximum width of component	2.8 m (galvanising limit)
Maximum mass	15 tonne (galvanising limit)

Further restrictions may apply corresponding to combinations of dimension and mass limits.

11.10. Corrosion protection

The internal and external surfaces of all components are to be protected by galvanising and further protection is to be provided to external faces to result in an approved duplex system. Alternative corrosion protection systems may be considered, however, all corrosion protection systems must be suited to achievement of the specified overall design life, the specified time to first maintenance, operational requirements and environmental requirements.

The specification and colour of finish coatings are to be approved and they are to take into account all of the environmental objectives.

11.11. Limitations on use of this document

This PTS is in a preliminary stage of development, it should not be used as a basis for overhead line design without further development, including testing of supports.

This PTS does not extend to consideration of

- Interface with existing OHL designs and configurations
- Special crossing arrangements e.g. large watercourses.

11.12. Strength coordination

With reference to Part 1, Annex A, strength coordination has been considered in the development of the NeSTS supports. The partial factors given in Table 7 and Table 11 result in achievement of the strength coordination outlined in Table 13.

Table 13 - Strength coordination

	Major Components	Coordination within Major Components *
Lowest strength	Suspension support	Support, foundations, hardware
	Tension support	Support, foundations, hardware
Not having the lowest strength	Terminal support	Support, foundations, hardware
	Conductor system	Conductors, insulators, hardware

12. Foundations

12.1. Foundation loads

Global applied foundation loads inclusive of the partial load factors, are given in Annex C for the support types and extensions considered. Only minimum and maximum height extensions have been considered. The users of this PTS are responsible for determining their own foundation loading, if the generic loading criteria, support types and/or extensions are not met and under any temporary and/or construction - maintenance loading conditions.

12.2. Partial strength factor for foundations

A minimum partial strength factor of 1.35 shall be adopted in the design of foundations. Generally, the strength factors that are adopted for the design of foundations shall be in accordance with BS EN 1997 and the associated NNA.

12.3. Design standards for foundations and spigot connections

Foundations are to be designed in accordance with BS EN 1997-1, Geotechnical Design.

Reinforced concrete components, including spigots, pile-caps, rafts etc. are to be designed in accordance with BS EN 1992-1.

ANNEX A – General information for the assessment of probabilistic design loadings –

ANNEX B – Probabilistic design loadings

ANNEX C – Applied foundation loads

ANNEX C1 – Design forces and effects of forces for connection design

Bibliography

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