

BUSBAR SYSTEMS FOR AIS SUBSTATIONS

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PURPOSE AND SCOPE

This document forms part of a suite of documents, which define National Grid functional, and performance requirements for new plant and equipment for the use on the national Grid UK Electricity Transmission system

This specification covers the technical and general requirements applicable for designing a Busbar and flexible conductor systems including structures suitable for operational use on all 145kV, 300kV and 420kV National Grid open-terminal, air insulated substations (AIS) only. This specification does not include detailed requirements for sub components of the above systems.

PART 1 – PROCEDURAL

1 GENERAL REQUIREMENTS

The main supplier shall produce installation, maintenance and replacement procedures for the Busbar system and its components, taking into consideration National grid maintenance requirements.

National Grid seeks to type-register complete busbar and conductor systems.

National Grid seeks to procure a system having optimised life cycle costs over a service life that is stated in TS 2.1. The minimum engineered design life of individual components shall be as stated in the component level Technical Specifications. The supplier shall indicate the pattern of maintenance required to achieve this service life together with the cost and frequency of replacement of those elements which may require mid-life replacement.

The minimum composition which constitutes a type-registered system shall include substation conductors, support insulations and connectors. Other fittings may be required in order to meet the performance requirements of this specification.

1.1 Compatibility

Sub components identified, as part of the system shall be selected to facilitate interchangeability between components where multiple product sourcing is proposed.

1.2 Maintenance

The supplier shall provide procedures for safe erection, maintenance and replacement of the system and/or any of its sub components, taking into consideration National Grid requirements and shall provide suitable equipment as required. Proposed procedures and equipment shall be agreed with National Grid prior to Type registration of the busbar system.

1.3 Drawings

Drawings of busbar systems shall comply with the requirements of TP183 and the following specific requirements:

- 1.3.1 The technical data required for busbar systems shall be included on drawings. These shall confirm that the busbar systems are to the specified tolerance and shall include other dimensions which significantly affect the functional and performance characteristics of the busbar system and its components.
- 1.3.2 Sub station layout drawings shall show the complete busbar system, together with the positioning of each type of clamp and section of busbar.
- 1.3.3 The busbar layout shall enable easy reference between layout drawings and the busbar and clamp schedules.

1.4 Packaging

Fittings shall be packaged to provide adequate mechanical and corrosion protection of components in transit and for reasonable storage periods of time.

2 PERFORMANCE REQUIREMENTS

The mechanical design of the busbar and conductor system shall be verified by calculation, and where necessary by test, by considering the limit states at which the components become unfit for their intended use.

Informative: Tests are normally only required where the busbar and conductor system is not amenable to verification by calculation or where the design method deviates from accepted methods and/or Industry best practice.

The calculated stresses in materials shall not exceed the following limits:

- a) Porcelain: 100% of guaranteed minimum failing load.
- b) Metals: Guaranteed minimum 0.2% proof stress.

Informative: It is not necessary to apply a material factor γ_m as this has been accounted for in the load factors γ_f .

Consideration of mechanical forces shall include bending, shear and torsion and combinations thereof. Calculations shall take into account end restraint conditions for conductors.

The design of the conductor system shall consider the effect of loading combinations on associated switchgear to ensure that this switchgear is not subject to loadings beyond its design capabilities.

Loadings due to foreseeable abnormal conditions must be considered.

Informative: For example, forces due to flexible spans either side of a supporting gantry may partially cancel under intact conditions. However the design of the conductor system must cater for breakage of a span on one side of the gantry.

2.1 Mechanical Loads

In order to establish the total mechanical forces, consideration shall be given to the loading types listed below.

2.1.1 Dead Load

Is defined as the self-weight of the conductor system and support structures.

2.1.2 Wind Loads

Wind loading for all conductor system components excluding overhead line (OHL) downleads shall be determined in accordance with BS 6399 part 2.

- a) The wind load shall be based on an effective wind speed (V_e) of 34 m/s corresponding to a dynamic pressure (q_s) of 709 Pa.

Informative: The effective wind speed of 34 m/s incorporates factors for site location, altitude, height etc and shall be used for all National Grid sites.

- b) Net pressure coefficients shall be obtained using table 20 and fig 25 in clause 2.7 of BS 6399.

Informative: In the design of the support structure a shielding factor may be used where this is considered to be significant.

- c) Where the short circuit load on flexible spans is calculated in accordance with IEC 60865-1 the tension due to wind load shall be added to the calculated short circuit load except where the drop force is limiting. In this case the wind load shall be neglected.

- d) For rigid busbar systems the wind load shall be added to the short circuit load and the sum of these shall then be vectorially added to the dead load.

2.1.3 Ice Loads:

A 10mm radial thickness of ice with a density of 912 kg/m³ shall be applied to the conductor system and support structures, excluding downleads.

2.1.4 Short Circuit Loads:

Informative: IEC 60865-1 enables the calculation of mechanical forces due to short circuit currents in simple busbar arrangements. More complex arrangements e.g. inclined spans; conductors with droppers etc are not covered by IEC 60865-1. Furthermore, IEC 60865-1 does not cover the combination of other mechanical loads with those arising from short circuit. This clause gives guidelines on how to treat these conditions using IEC 60865-1 and by making pessimistic assumptions. It is recognised that this leads to some degree of over engineering.

IEC 60865-1 does not adequately address the structural application of short circuit loading and it is recommended that IEC 60865-1 is not used for structural analysis. For rigid conductors IEC 60865-1 should be used to calculate V_{FVrFm} or V_{oVrFm} whichever is the greater. This should be treated as a uniformly distributed load (UDL) in elastic structural analysis in accordance with appropriate standards.

The use of IEC 60865-1 is not mandatory: other methods may be used subject to the supplier demonstrating validity. For example, finite element analysis packages may provide more accurate design tools. Such methods may also be used to determine the effect of load combinations and for structural analysis. The idealised structural design process incorporating short circuit forces is shown in Figure 1.

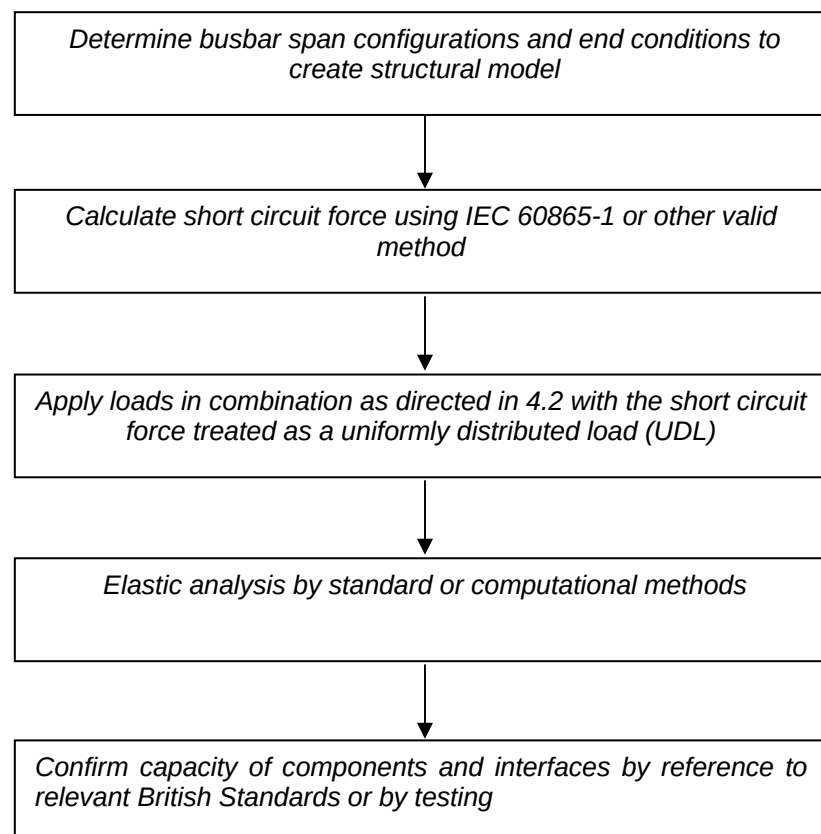


Figure 1: Flow chart showing idealised structural design process incorporating short circuit forces

- a) When calculating the short circuit load for both rigid and flexible conductors the substation rated three-phase short circuit current I_k shall be used. The peak three phase short circuit current i_{p3} is equal to 2.5 times I_k , giving a factor $\kappa = 1.77$. (Fig 4 IEC 60865-1).

- b) The effect of auto reclose need not be taken into account and therefore the factor V_r in IEC 60865-1 shall be taken as equal to 1.0.
- c) The duration of short circuit current shall be taken as 300 ms for 275kV and 400 kV and 1.5s for 132 kV.

Informative: These times are based on the expected circuit breaker fail protection clearance time or equivalent.

- d) Flexible conductor tension due to short circuit shall be calculated at both minimum and maximum operating temperature.
- e) Minimum and maximum operating temperatures shall be based on the service conditions specified in TS 1. The maximum operating temperature shall include temperature rise due to maximum continuous operating current. For tension at minimum operating temperature ice shall not be included. Maximum operating temperature shall not include the effects of solar gain or wind cooling.
- f) Inclined flexible spans shall be treated as un-inclined. However, the conductor static tension may be much greater at one end due to its greater elevation, therefore it will normally be necessary to calculate the short circuit forces for each end using the appropriate static tension.

Informative: Inclined spans are not covered by IEC 60865-1.

Informative: Dropper connections on flexible spans and rigid busbars are not covered by IEC 60865-1 and shall be neglected. Omitting droppers is considered to give worst case short circuit forces. When considering the forces due to dead weight the effect of the droppers shall be included.

- g) Where three phase structures support a rigid bus system it shall be assumed that the force transferred into the structure leg(s), base plate(s) and foundations is that resulting from one phase only.

Informative: This assumption is based on the partial cancellation of forces. It cannot be assumed that there is complete cancellation due to the dynamic behaviour of the busbar and associated equipment, i.e. droppers, pantograph trapezes etc.

Informative: IEC 60865-1 does not cover three phase structures supporting a rigid bus system.

- h) Where busbar lengths are not equal in the three phases, the short circuit force transmitted into the structure leg(s), base plate(s) and foundations shall be calculated using the longest busbar length.

Informative: IEC 60865-1 does not cover the case where busbar lengths are not equal for the three phases.

- i) Where rigid busbar spacing is not equal over a span, the minimum phase spacing shall be used in the calculation of short circuit force.

Informative: IEC 60865-1 does not cover the case where rigid busbar spacing is not equal over a span.

2.1.5 Operational Loads

Informative: Operational loading is that due to mechanical operation of equipment e.g. operation of disconnections and earthing switches etc.

The Supplier shall define operational loadings based on the proposed substation arrangement.

2.1.6 Load Combinations for Conductor System and Support Structures (excluding line landing gantries)

The conductor system shall be designed using the load combinations given in Appendix A.

2.2 Resonant Frequency of Busbar

Where the calculated resonant frequency of a length of busbar is less than 2.75 Hz, calculated in accordance with IEC 60865-1, the busbar shall be damped to minimise Aeolian vibration.

Informative: Damping may be achieved by installing a flexible conductor, of the same material as the busbar, inside the busbar, fixed at one end. Typically the flexible conductor mass per unit length should be between 10 and 33 percent of that of the busbar and the flexible conductor should be no less than two thirds the length of the busbar.

Informative: Other damping alternatives may be considered after agreement with National Grid..

Where the calculated resonant frequency of a length of busbar is equal to or greater than 2.75Hz damping shall only be fitted if Aeolian vibration occurs following installation. In such cases the supplier shall indicate to National Grid the risk of failure due to deterioration of fittings and shall recommend appropriate timescales for application of damping.

The mechanical resonant frequency of rigid busbars shall be calculated so as to determine any requirement for damping to limit Aeolian vibration.

2.3 Mechanical Performance of Busbar Connectors and Conductors

The mechanical design limitations of the busbar connectors shall be established.

Designers shall ensure that the mechanical design limitations of the busbar connectors are established and are not exceeded under the loading conditions specified in Appendix A.

Busbar connectors shall be designed in accordance with TS 3.1.5.

2.4 Support Structures (excluding line landing gantries)

Support structures shall comply with the requirements of TS 3.10 and be designed using limit state methods in accordance with the appropriate British or International standards. Loads and load combinations shall be determined in accordance with Appendices A-C.

2.5 Deflection and Sag (excluding line landing gantries)

The maximum horizontal deflection of the support structure and the support insulator at busbar level shall be limited to a value that will not interfere with the operation of the equipment subject to a maximum of 100mm. The maximum deflection of the support structure shall be limited to 1/300th of its span or height. Deflections shall be assessed under loading conditions 2 and 3 as defined in Appendix A using a load factor $\gamma_f = 1.0$.

The maximum busbar sag shall not exceed $l/140$ where l is the unsupported busbar length measured between the centre lines of the supports. Sag shall be assessed under dead loading only using a load factor $\gamma_f = 1.0$.