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Substation Design Instruction

Support structures

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Substation Design Instruction

ASSET STANDARDS & DESIGN

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SDI 518 SUPPORT STRUCTURES

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1.0 PURPOSE

To set out in detail the broad design requirements for support structures used in transmission/zone substations and switching stations.

2.0 SCOPE

This instruction defines the minimum requirements for materials and design of structures used to support busbar conductors, landing spans, switchgear and other equipment in transmission/zone substations and switching stations.

3.0 REFERENCES

Internal

- Company Policy 9.2.5 - Network Asset Design
- Endeavour Energy Network Management Plan 2011-2013
- Earthing Design Instruction EDI 516 - Major substation earthing design, construct and commissioning
- Substation Design Instruction SDI 505 - Minimum design and construction requirements for transmission and zone substations and switching stations
- Drawing no. 050870E - Overhead Transmission Basic Concrete Pole Arrangement
- Drawing no. 051125G - Overhead Transmission Earthing Connections for Concrete Poles
- Drawing no. 050871C - Concrete Poles Hole Former and Ferrules Details
- Drawing no. 398005A - Overhead Transmission 33/66kV Substation Landing Structure 2 Pole Concrete
- Drawing no. 397798A - Overhead Transmission 132kV Substation Landing Structure 2 Pole Concrete

External

- ENA National Electricity Network Safety Code (Doc. 01-2008)
- AS 1101.3:2005 - Graphical Symbols for General Engineering- Welding and Non-destruction Examination
- AS 1214:1983 - Hot-dip galvanized coating on threaded fasteners
- AS 1252:1996 - High strength steel bolts with associated nuts and washers for structural engineering
- AS 1379:2007 - Specification and supply of concrete
- AS 1720.1:2010 - Timber Structures - Design Methods
- AS 1720.2:2006 - Timber structure - Timber properties
- AS 1852:1988 - International Electrotechnical Vocabulary
- AS 2067:2008 - Substation and high voltage installations exceeding 1kV a.c.
- AS 2159:2009 - Piling - Design and installation
- AS 2177:2006 - Non-destructive testing- Radiography of welded butt joints in metal
- AS 2207:2007 - Non-destructive testing - Ultrasonic testing of fusion welded joints in carbon and low alloy steel
- AS 3600:2009 - Concrete Structures
- AS 3995:1994 - Design of steel lattice towers and masts
- AS 4100:1998 - Steel structures
- AS/NZS 1163:2009 - Cold-formed structural steel hollow sections
- AS/NZS 1170.0:2002 - Structural design actions - General principles
- AS/NZS 1170.1:2002 - Structural design actions - Permanent, imposed and other actions
- AS/NZS 1170.2:2011 - Structural design actions - Wind actions
- AS/NZS 1170.3:2003 - Structural design actions - Snow and ice actions

- AS/NZS 1170.4:2007 - Structural design actions - Earthquake actions in Australia
- AS/NZS 1554.1:2014 - Structural steel welding - Welding of steel structures
- AS/NZS 3678:2011 - Structural steel-Hot-rolled plates, floor plates and slabs
- AS/NZS 3679.1:2010 - Structural steel - Hot-rolled bars and sections
- AS/NZS 3679.2:2010 - Structural steel - Welded I sections
- AS/NZS 4065:2010 - *Concrete utility services poles*
- AS/NZS 4671:2001 - Steel reinforcing materials
- AS/NZS 4676:2000 - Structural design requirements for utility services poles
- AS/NZS 4680:2006 - Hot-dip galvanized (zinc) coatings on fabricated ferrous articles
- IEEE Std 605:2008 - Guide for Design of Substation Rigid-Bus structures
- The Building Code of Australia 2012

4.0 DEFINITIONS AND ABBREVIATIONS

coating thickness	The total thickness of hot-dip galvanized coating, on a single surface, expressed in micrometres - AS/NZS 4680:2006.
dead load	The weight of the structure and any permanent fixed loads.
maintenance and construction load	Temporary load applied on a structure during construction, such as weight of person/s, or machine/s or tool/s.
grout	Mixture of cement and water, with or without the addition of sand, or chemicals admixture, proportioned to produce a pourable liquid without segregation of the constituents - AS 3600:2009.
hot-dip galvanising	A process comprising pre-treatment and molten zinc baths in which steel products are dipped so as to form adherent zinc and zinc-iron alloy coatings - AS/NZS 4680:2006.
live load	A variable load resulting from the intended use or occupancy of the structure - AS 1170.0:2002.
reinforced concrete	Concrete containing more than 0.6% by volume of reinforcing steel in the form of bar, rod or mesh. Tensile forces within the concrete section are designed to be resisted by the reinforcement in accordance with AS 3600:2009 - Concrete structures.
rigid busbar	A substation busbar which is made up of metallic tubes or bars and supported by insulator posts - AS 1852:1988.
fault current forces	Mechanical forces imparted to conductors, bus conductors and structures resulting from strong magnetic fields, produced by fault current. Fault current forces are dependent on conductor spacing, magnitude of fault current, type of short circuit, and degree of short circuit asymmetry.
stranded busbar	Flexible busbar - a substation busbar, which is made up of flexible conductors - AS 1852(605):1988.
substation support structures	The assembly of rigid frameworks for hanging and supporting conductors, busbars, switchgear and other equipment - AS 1852(605):1988.
tension load	Load on a structure caused from the pull of permanent or temporary connected strings, ropes or conductors.
failure containment loads	The load on a structure arising from the failure of an adjacent structure.

5.0 ACTIONS

5.1 Material requirements

5.1.1 General

Substation support structures can be manufactured from tubular steel, reinforced concrete, steel lattice, treated timber supports or other materials depending on their intended use.

All steel structures and components shall be hot dip galvanised. Materials that cannot be galvanised shall be anodised or otherwise treated to prevent corrosion of the core material.

5.1.2 Support structure material

The selection of support structure material shall be based on design, environmental and economic requirements.

Refer to Table 1 for the recommended material for use in the fabrication of support structures.

Table 1: Support structure materials and application

Material	Application
Steel tubular and universal column section	To support rigid or stranded busbars, major or minor equipment, and landing support structures. Note: Beams or crossarms for landing support structures shall be fabricated from the same material used in the columns of the landing structures.
Reinforced steel concrete	To support rigid or stranded busbars, major or minor equipment and concrete poles for landing support structures, with or without crossarms (crossarms fabricated from tubular and universal column section steel). Reference shall be made to Drawing no's. 050870E, 051125J, 050871C, 398005A and 397798A for reinforced steel concrete pole sectional details and arrangements.
Hardwood timber (wood poles)	For landing support structures (crossarms for landing support structures shall be constructed from hardwood timber). All timber shall be durability Class 1.
Lattice steel	To support rigid or stranded busbars, major or minor equipment, and landing support structures.
Taper line steel	To support lightning and lighting mast support structures.

5.1.3 Steel structures

All workmanship and material shall be in accordance with AS 4100:1998.

Fabrication and erection shall be in accordance with sections 14 and 15 of AS 4100:1998.

Lattice steel support structures shall comply with AS 3995. These structures shall be equipped with a guard or anti-climbing protective device with locking facility to prevent use of unauthorized personnel.

All steel shall be in accordance with the following table.

Table 2: Support structure steel grade

Type of steel	Australian Standard	Grade
Universal beams and columns, parallel flange channels and large angles	AS/NZS 3679.1:2010	300
Welded I sections	AS/NZS 3679.2:2010	300
Hot milled plates, floats, floor plates, small angles and slabs	AS/NZS 3678:2011	250
Hollow sections	AS 1163:2009	C350

Bolts, nuts and washers

Bolting and holing shall comply with clause 14 of AS 4100:1998.

Bolts shall be constructed from high class of strength of minimum grade of 8.8 to AS 1252:1996.

Welding of steel structure

All welding shall comply with AS 1554.1:2014 and all welds shall be Category SP in accordance with AS 1554.1:2014.

Testing of welding

The extent of non-destructive weld examination shall be in accordance with Table 3.

Table 3: Non-destructive weld examination

Examination method	Percentage of total weld length
Visual inspection	100%
Radiographic or ultrasonic inspection	10%

Radiographic or ultrasonic examination shall be to AS 1554.1:2014, AS 2177.1:2006 and AS 2207:2007, as appropriate.

Corrosion protection

All structural steelwork shall be hot-dip galvanised after fabrication according to AS/NZS 4680:2006. Normal galvanizing thickness shall be 240g/m². The coating thickness for structures to be installed within 5 km of the coast shall be of a minimum of 85 microns (equivalent to an average coating mass of 600 g/m²).

All bolts, nuts and washers shall be hot-dip galvanised according to AS 1214:1983.

5.1.4 Concrete structures

All workmanship and materials shall comply with AS 3600:2009, and supply of all concrete shall comply with AS 1379:2007.

All deformed ribbed reinforcement bars shall be grade D500N to AS/NZS 4671:2001.

5.1.5 Timber structures

Timber design, material and construction shall comply with AS 1720.1:2010 and AS 1720.2:2006.

Timber shall be hardwood timber with durability class 1.

Bolt holes shall be drilled to the exact bolt size to maintain a tight and secure fit. Washers under bolts and nuts shall be at least 2.5 times the diameter of the bolt. All bolts, nuts and washers shall be hot-dip galvanised in accordance with AS 1214:1983.

5.2 Design requirements

5.2.1 General

All support structures shall be designed and approved by an engineer on the National Professional Engineers Register (NPER) of Engineers Australia for Structural Engineering.

All possible combinations of loads/forces for establishing stresses in the various elements of the support structures shall be considered in the design calculations.

All support structures (including foundations) shall be designed to withstand the gravitational, mechanical and electrical stresses/loading that may be expected during their operational life. They shall also be designed to withstand the mechanical forces that are exerted under system fault condition.

Stresses/loading on support structures shall be determined using combinations of a variety of loads, as set out in clauses 5.2.2 and 5.2.3.

Loads, along with their combinations, shall be investigated, and the most unfavourable shall be used to determine the mechanical strength of the structures.

Loads may act simultaneously, so the calculation shall be based on the summation of the total combined load that is acting concurrently. The loadings shall consider factors that are dependent on climatic conditions and rare events, such as earthquakes, floods and cyclones.

5.2.2 Structural design

The design is to be in accordance with the Building Code of Australia, accepted engineering practice and principles, and all relevant Australian Standards including the following:

- AS/NZS 1170.0:2002 - Structural design actions - General principles
- AS/NZS 1170.1:2002 - Structural design actions - Permanent, imposed and other actions
- AS/NZS 1170.2:2011 - Structural design actions - Wind actions
- AS/NZS 1170.3:2003 - Structural design actions - Snow and ice actions
- AS/NZS 1170.4:2007 - Structural design actions - Earthquake actions in Australia
- AS 2159:2009 - Piling - Design and installation
- AS 1720.2:2006 - Timber structure - Timber properties
- AS 3600:2009 - Concrete Structures
- AS 4100:1998 - Steel Structures
- IEEE Std 605:2008 - IEEE Guide for Design of Substation Rigid-Bus Structures

5.2.3 Busbars and equipment support structures

These structures are used to support the substation busbars and equipment in position. They shall have sufficient rigidity to assure the satisfactory functioning of the equipment.

As a minimum, the following loads shall be considered when designing busbar and equipment support structures:

- Dead loads.
- Live loads

- Tension loads
- Maintenance, and construction loads
- Wind loads
- Earthquake loads
- Operating and dynamic loads
- Fault current forces
- Ultimate wind speed

The ultimate wind (V_r) speed shall be used to calculate the wind load. The ultimate wind speed is 48m/s (from AS 1170.2:2011 Table 3.1), derived by considering the *Importance Level* = 4 (from BCA Table B1.2a) for buildings associated with hazardous activities, and *Annual probability of exceedance* = 1:2000 (from BCA Table B1.2b).

- Fault current forces

Fault current forces are to be calculated in accordance with IEEE Std. 605:2008, Section 10, Conductor fault current forces, and amendments to IEEE Std 605:1998, issued in February 2000.

5.2.4 Landing support structures

In substations, the landing support structures are used for termination of slack spans from dead-end or terminal towers on one side, and flexible bus conductors or stranded busbars across the substations bays on the other side. Therefore, these structures shall be designed for one side tension/pulls only.

The calculation of loads for landing support structures shall consider the requirements of clause 5.2.3 as well as the tension load of overhead ground wires and conductors, and failure containment loads.

All supporting structures shall be designed in order to prevent vibration at its natural frequency due to current induced vibration and wind induced vibration.

When designing 33/66kV and 132kV landing support structures refer drawings 398005A and 397798A, respectively.

5.2.5 Design calculations

The contractor shall provide typical design calculations, which will include the load cases and structural analysis for each type of support structure used in substations.

5.2.4 Erection

Site cutting and drilling

During erection, steel members shall not be cut, burnt, welded or drilled in a manner that is not in accordance with the structural drawings or approved shop drawings.

Bedding and grouting

All grouting of steel support structures shall comply with Clause 15.5 of AS 4100:1998 and the grout shall comply with AS 3600:2009.

All steelwork structures shall be designed with a nominal separation range of 20 - 40mm, between the bottom of the structure base plate and the foundation design reduced level.

Base plates shall be grouted before the member is substantially loaded. Grout shall have a minimum strength of 20Mpa. Proprietary non-shrink grout or a dry pack mortar comprising of one (1) part cement and three (3) parts coarse sand can be used for this purpose. Grout shall be dampened in accordance with the manufacturer's instructions before jamming into position.

5.3 Earthing of structures

Earthing of metallic and re-inforced concrete support structures shall be in accordance with EDI 516.

6.0 AUTHORITIES AND RESPONSIBILITIES

The **General Manager Asset Management** has the authority and responsibility for approving this instruction.

The **Manager Asset Standards & Design** has the authority and responsibility for making recommendations to the **General Manager Asset Management** in respect of this instruction.

The **Network Substations Manager** is responsible for determining that the content of this instruction is kept up to date.

All **Endeavour Energy employees and contractors and/or contractors** have the authority and responsibility for:

- Complying with the requirements of this instruction and that of Substation Design Instruction SDI 505 - Minimum design and construction requirements for transmission and zone substations and switching stations;
- Working in accordance with local and statutory requirements;
- Maintaining public safety;
- Conforming with the safe design practices to manage public and worker safety; and
- Establishing that Endeavour Energy employees and/or contractors engaged to perform work shall have appropriate qualifications;

All **Project Managers and Design Engineers** are responsible for:

- Establishing that Endeavour Energy employees and/or contractors engaged to perform work shall have appropriate qualifications;
- Meeting the requirements of this instruction within the area of responsibility;
- Working in accordance with local and statutory requirements;
- Maintaining public safety;
- Establishing that staff are conversant with, and work in accordance with, Endeavour Energy's Electrical Safety Rules; and
- Maintaining clearances shown in this standard when designing new substations/switchyards/switchbays.

7.0 DOCUMENT CONTROL

Documentation Content Coordinator : **Network Substations Manager**

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