# Common Requirements for Transmission Substation Equipment

## Design Standard (Technical Specification)


### DOCUMENT HIERARCHY

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Record of endorsement, approval, stakeholders, and notification list is provided in EDM# 47467694 appendix

### RESPONSIBILITIES

Western Power's Engineering & Design Function is responsible for this document

### CONTACT

Western Power welcomes your comments, questions, and feedback on this document, which can be emailed to standards.excellence@westernpower.com.au

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## Revision Details

| Version | Date | EDM Version | Summary of change |
|---|---|---|---|
| 0 | 28/2/2019 | 1 | First issue. |
| 0a | 28/1/2020 | 3 | Revised clause 4.3.6 static terminal load for other equipment |
| 1 | 18/05/2023 | 4 | Remove distribution related content;<br>Revise 4.2 structural loading and 4.3.7 terminal load;<br>Add 4.3.3 structure fabrication;<br>Review currency of standards. |
| 2 | Feb 2024 | 5.0 | Standards Online Update |
| | | | |

# 1 Introduction

This technical specification specifies the common requirements for all plant and equipment used in Transmission Substations, to be purchased for use in Western Power's South West Interconnected System(SWIS). The application of common requirements, over and above the Australian and International standards, enables Western Power to further demonstrate

- due diligence as required by the new Workplace Health and Safety (WHS) legislation adopted in Australia, and
- compliance with AS 5577 by ensuring the risk of the site is So Far As Is Reasonably Practicable (SFAIRP).

## 1.1 Purpose and scope

All Equipment procured for use in Transmission Substations in the SWIS shall adhere to these requirements. Where requirements differ, they will be included in the individual Equipment specification and will supersede requirements stated in this document.

## 1.2 Acronyms

| Acronym | Definition |
|---|---|
| | |
| | |

## 1.3 Definitions

| Term | Definition |
|---|---|
| | |
| | |

## 1.4 References

References which support implementation of this document

**Table 1.1 References**

| Reference No. | Title |
|---|---|
| | |
| | |
| | |

## 2 Supporting Documentation[1]

## 3 Compliance[2]

The Design Standard (Technical Specification) should encompass all requirements of the relevant Australian Standards which are current at the time. These relevant Standards and Guidelines are listed in below in Table 3.1. A period will be set when the standard needs to be reviewed. If significant changes occur on an Australian Standard which affects safety, then an out of cycle review can be completed.

**Table 3.1: Standards and Guidelines**

| Standard Number | Standard Title |
|---|---|
| IEC 60376 | Specification of technical grade sulfur hexafluoride (SF6) and complementary gases to be used in its mixtures for use in electrical equipment |
| IEC 60480 | Specifications for the re-use of sulphur hexafluoride (SF6) and its mixtures in electrical equipment |
| IEC 62155 | Insulators - Ceramic or glass - Hollow pressurized and unpressurized - Voltages greater than 1000 V a.c. |
| IEC 61462 | Composite insulators - Hollow insulators for use in outdoor and indoor electrical equipment |
| AS 1170.2 | Structural design actions – Wind actions |
| AS 1170.4 | Structural design actions – Earthquake actions in Australia |
| AS/NZS 1214 | Hot-dip galvanized coatings on threaded fasteners |
| AS 1627 | Metal finishing – Preparation and pre-treatment of surfaces |
| AS 1768 | Lightning protection |
| AS 2312 | Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings |
| AS 2700 | Colour standards for general purposes |
| AS 4398.1 | Insulators – Ceramic or glass – Station post for indoor and outdoor use – Voltages greater than 1000 V a.c. – Characteristics |
| AS 4398.2 | Insulators – Ceramic or glass – Station post for indoor and outdoor use – Voltages greater than 1000 V a.c – Tests |
| SA TS 60815 | Selection and dimensioning of high-voltage insulators intended for use in polluted conditions |
| AS/NZS 4680 | Hot-dip galvanized (zinc) coatings on fabricated ferrous articles |
| AS/NZS 5131 | Structural steelwork - Fabrication and erection |
| AS 5577 | Electricity Network safety management systems. |

[1] See Western Power Internal Document
[2] See Western Power Internal Document

| Standard Number | Standard Title |
|---|---|
| AS/NZS 7000 | Overhead Line Design – Detailed Procedures |
| AS 60076.2 | Power Transformers – Part 2 – Temperature rise for liquid immersed transformers |
| AS/NZS 60137. | Insulated bushings for alternating voltages above 1000 V |
| AS 60296 | Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear |
| AS 62271.1 | High-voltage switchgear and controlgear – Common Requirements |
| AS 62271.301 | High voltage switchgear and controlgear – Dimensional standardization of terminals |
| | Engineering Design Instruction - Substation Secondary Systems Design |
| | Substation Building Design Instruction – Transmission Substations |
| | Engineering Design Instruction- Substation Structures and Foundations |
| | Technical Specification-Transmission Substation Structural Steelwork |
| | Engineering Design Instruction – AC Auxiliary Systems |
| | Engineering Design Instruction – DC Systems |
| WHS | Workplace Health and safety Legislation |

# 4 Functional Requirements

The function of this document is to provide the common requirements that all primary equipment within a transmission substation must comply with. Some of the requirements list are above what is required by Australian Standards as they have been tailored to suit the environment in Western Australia.

# 5 Safety in Design[3]

Safety in Design (SID) is integral to all parts of design within transmission substations. Defining the right requirements for primary plant is integral to ensure this can be done. It is an essential thought process that focuses on making the design safer and easier to understand, to eliminate or mitigate potential hazards during the design phase of a project.

Compliance to this Design Standard (Technical Specification) is necessary to provide a safe working environment within a substation. All interlocking requirements must be implemented where applicable to ensure full compliance.

[3] See Western Power Internal Document

# 6 Common Requirements

## 6.1 Normal Service Conditions

Normal Service conditions set out in this document represent the normal operation of the transmission equipment.

### 6.1.1 Equipment for Indoor installation

- The "Normal service conditions" as stated in AS 62271.1 shall apply.
- All new Transmission substation control and switch rooms are fitted with air-conditioning equipment.
  - a) Room temperature will vary between 22 °C to 30 °C[4]
  - b) Humidity will be maintained between 40% and 60%.

### 6.1.2 Equipment for Outdoor installation

- The "Normal service conditions" as stated in AS 62271.1 shall apply for all equipment except Power Transformers regarding ambient temperature.
- For Power Transformers, the values stated in Table 6.2 of AS60076.2 shall apply and the relevant ambient temperatures are included in Table 6.1 below:

**Table 6.1. Ambient temperatures**

| Ambient Temperature $^0$C | | | |
|---|---|---|---|
| Minimum | Yearly average | Monthly average | Maximum |
| -5 | 25 | 35 | 45 |

- The other service conditions applicable for all outdoor Equipment is stated in Table 2 below:

**Table 6.2. Other service conditions**

| Condition | Minimum | Maximum |
|---|---|---|
| Relative humidity – outdoor enclosures | 10% | 90% |
| Site Pollution Severity<br>(SA TS 60815– Selection and dimensioning of high-voltage insulators intended for use in polluted conditions | Class e – 'Very Heavy' | |
| Average annual thunder-days per year<br>http://www.bom.gov.au/jsp/ncc/climate_averages/thunder-lightning/index.jsp | 20 | |

[4] Room temperature range covers both new and existing buildings. The new Functional Specification - Substation buildings Air Conditioning requires room temperature between 22°C and 25°C, whereas the previous requirement was 24°C to 30°C.

| | |
|---|---|
| Average annual lightning ground flash density (flashes/km$^2$/year) (AS1768 – Figure 2.3) | 1 |
| Corrosion Level<br>(Refer AS/NZS 2312:1 - Section 2.3 and AS/NZS 2312.2:2014 - Section 6.2, section 6.3 and Table 6.1) | C5 – M: Very High (Marine) |
| Durability in coating life for exposed metal structures<br>(AS/NZS 2312.1 - section 5.4 & 5.5<br>AS/NZS 2312.2 - section 6.2, section 6.3 and Table 6.1) | 25 years (Very-long term) |

### 6.1.3 Earthing

The following table outlines the type of earthing for different system voltages.

**Table 6.3. Earthing for different system voltages**

| System nominal Voltage | 330kV | 220kV | 132kV | 66kV | 33kV | 22kV | 11kV | 6.6kV | 440/415V |
|---|---|---|---|---|---|---|---|---|---|
| **System Earthing** | Effectively Earthed | | | | | Non-effectively Earthed | | | Effectively Earthed |

## 6.2 Structural Loading Criteria

### 6.2.1 Wind Conditions

The following wind conditions shall apply (refer to AS/NZS 1170.2):

**Table 6.4. Western Power Specific Wind Condition Requirements**

| | | |
|---|---|---|
| 1 | Regional Wind Speed ($V_R$ m/s) for region B2 with an average recurrence interval of 1000 years | 60 |
| 2 | Direction multiplier ($M_d$) | 0.95 |
| 3 | Climate change multiplier ($M_c$) | 1.0 |
| 4 | Terrain Category (TC) | 2 |
| 5 | Height Multiplier ($M_{z,cat}$) | 1.0 |
| 6 | Shielding Multiplier ($M_s$) | 1.0 |
| 7 | Topographic Multiplier ($M_t$) | 1.0 |
| 8 | Site wind speed(m/s) $V_{sit,B}=V_R.M_c.M_d.(M_{z,cat}.M_s.M_t)$ | 57 |

The above table outlines the criteria for calculating the wind pressure per Australian Standards. Alternatively, the designers could use a wind pressure of 2.0 kPa to calculate applicable wind forces.

Designers shall use a shape/drag coefficient factor of 1.2 and 2.2 for rounded and non-rounded shapes, respectively.

### 6.2.2 Seismic Conditions

The following seismic conditions shall apply (refer AS 1170.4):

**Table 6.5. Western Power Specific Seismic Condition Requirements**

| Requirements | Criteria |
|---|---|
| Category (EDC) | II or III |
| Probability Factor (Kp) | 1.3 |
| Hazard Factor (Z) | 0.15 |
| Soil Class | Ce |

- AS 1170.4 shall be used to calculate earthquake forces for parts and components, alternatively the designers could use an acceleration of 0.4g to calculate horizontal earthquake force for equipment and its associated support structure.
- Vertical earthquake forces shall be taken as 50% of the horizontal earthquake force.

## 6.3 Design considerations

### 6.3.1 Seismic Design Criteria

No failure of any part of the Equipment or structure (if supplied) that could cause the Equipment to malfunction shall occur, as a result of an earthquake. Such failure would include; oil or gas leakages from bushings, failure of internal components, failure of tripping relays, misalignment of disconnectors or any other failures in ancillary equipment.

#### *6.3.1.1 Analysis and Testing*

- Seismic loads shall be considered to act simultaneously in directions that produce the worst stresses on Equipment components.
- The design horizontal earthquake spectra are defined by AS 1170.4.
- The vertical design spectra shall be 50% of the horizontal design spectra.
- Seismic adequacy shall be demonstrated by one of the following methods or a combination of the methods described.
  - Static Analysis
    - Static Analysis may only be used for dynamically rigid support structures. The seismic design factors for static analysis are deliberately very conservative and, in some cases, it may be advantageous to perform a dynamic analysis.
    - Equipment may only be assumed to be rigid when all points of the equipment follow the motion of the support structure without amplification or attenuation.

- Dynamic Analysis
  - Where the equipment is flexible and has one or more modes of vibration below 33 Hz, the design loads may be determined by dynamic analysis methods such as Modal Analysis or Time History Analysis or a valid equivalent. The model shall include sufficient detail to represent accurately the behaviour of the support structure.
  - Damping values greater than 2.0 % used in the analysis for Equipment shall be supported by test. Damping values for supporting structures or stands need not be verified by test but must be appropriate for the type of support construction and the load level.
- Testing
  - Testing shall be performed on a shaking table unless it can be shown that an alternative procedure will provide an equivalent test.
  - The vibratory motion proposed for the tests shall conservatively simulate the expected motion at the base of the Equipment. The Equipment shall be mounted in the same manner as proposed for installation or in a way that conservatively approximates this mounting.
  - Where the vertical acceleration results in negligible stresses the vertical excitation may be omitted.
- Material Stresses
  - The internal stress in ceramic or other brittle components shall not exceed 50 % of the average breaking stress less three standard deviations. If sufficient test results are not available for a statistical determination of the average breaking stress, then the internal stresses shall not exceed 40 % of the tested breaking stress.
  - Testing to determine porcelain strength shall be performed with the same end fittings as proposed for service. End fixings for all porcelain bushings shall avoid local stress concentrations and be designed so the bushing attains the full strength of the porcelain material.

### 6.3.2 Transport Criteria

Equipment shall be designed to withstand without damage, the handling and vibrations during transport from the factory to Western Power's warehouse and from the Warehouse to the final destination.

### 6.3.3 Structural fabrication

All structural steelwork for Western Power Transmission substations shall be fabricated and provided with protective coating as per Technical Specification - Substation Structural Steelwork; if required.

### 6.3.4 Equipment Surface Protection and Painting

All ferrous parts of the Equipment exposed to the weather shall be protected against corrosion in accordance with AS/NZS 2312 with the following requirements:

- Equipment will be used in environments classified in AS/NZS 2312 as "C5 – M: Very High (Marine)". Duration of protection to the first major maintenance for the protection against atmospheric corrosion is provided in Table 6.2.

- All iron and steel parts of the Equipment shall be pickled, or Class 3 blast cleaned in accordance with AS 1627 to prepare surfaces prior to application of protective coating (e.g. galvanising).
- All ferrous parts of the Equipment not completely protected from the weather shall be galvanised in accordance with AS/NZS 4680.
- The design and preparation of the equipment shall be in accordance with but not limited to Appendices C and E of AS/NZS 4680.
- The colour of the paint shall be in accordance with AS 2700 and as specified for the particular equipment type.

### 6.3.5 Insulators and Bushings

The insulators and bushings shall comply with AS 4398, IEC 61462, IEC 62155 and AS/NZS 60137.

- Polymer type is preferred.
- Porcelain type when provided, shall be chocolate brown in colour.
- The profile shall be an aerodynamic open type. Anti-fog profiles with ribbing on the under side of the sheds will not be accepted.
- The unified specific creepage distance shall not be less than 53.7 mm/kV.

The bushings shall be permanently sealed to prevent breathing.

### 6.3.6 High Voltage Terminals

- All palms on air cored reactors shall be vertical.
- Terminals shall be numbers 4, 5, 8 and 9 from Figure 1 (and Table 1) of AS 62271.301 appropriate for the required rating. For terminal numbers 8 and 9, 18mm bolt-hole diameters shall be used.
- In all cases, if adaptor plates are required to achieve these arrangements, the complete assembly shall be tested to confirm the assigned ratings. Alternatively, calculations may be presented for approval by the Principal Substation Design Engineer.
- Current carrying parts not intrinsically corrosion resistant shall be electroplated.

### 6.3.7 Terminal Load

The Equipment shall be designed to withstand the following minimum static and dynamic terminal loads:

**Table 6.6 Minimum Terminal Loads**

| Minimum Static and Dynamic Load in Any Direction | | | |
|---|---|---|---|
| **Equipment type** | **Voltage (kV)** | **Load (N)** | |
| | | **Static Resultant Force** | **Dynamic Resultant Force** |
| Voltage transformer (connected by droppers) | ≤ 72.5 | 500 | 1000 |
| | 145 (Terminal) | 500 | 1000 |
| | 145 (Zone) | 500 | 1000 |
| | >145 | 500 | 2800 |
| Station Post Insulators | ≤ 72.5 | 2000 | 10000 |
| | 145 (Terminal) | 2000 | 16000 |
| | 145 (Zone) | 2000 | 10000 |
| | >145 | 2500 | 10000 |
| Circuit Breaker | ≤ 72.5 | 500 | 1500 |
| | 145 (Terminal) | 1000 | 2000 |
| | 145 (Zone) | 1000 | 2000 |
| | >145 | 1000 | 3000 |
| Current Transformer | ≤ 72.5 | 500 | 1000 |
| | 145 (Terminal) | 1000 | 2000 |
| | 145 (Zone) | 1000 | 2000 |
| | >145 | 1250 | 2500 |
| Disconnector | 22 | 1000 | 2000 |
| | 33 | 1000 | 2000 |
| | ≤ 72.5 | 2000 | 3000 |
| | 145 (Terminal) | 1500 | 4000 |
| | 145 (Zone) | 1500 | 4000 |
| | >145 | 2000 | 6200 |
| Surge Arrestor (connected by droppers) | ≤ 72.5 | 500 | 1000 |
| | 145 (Terminal) | 1000 | 2500 |
| | 145 (Zone) | 1000 | 2500 |
| | >145 | 1000 | 2000 |

### 6.3.8 Terminal Markings

All markings shall be of a permanent nature and shall be made by punching or engraving such that visibility will not be obstructed when equipment is fully assembled in service.

### 6.3.9 Insulating Fluid

- Insulating mineral oil shall comply with AS 60296.
- When other insulating fluids are used they shall comply with the applicable Australian (or International) standards and presented for approval by the Principal Substation Design Engineer.

### 6.3.10 SF6 Gas

SF6 gas shall be in accordance with IEC 60376 and tested to IEC 60480.

### 6.3.11 Name / Rating Plates

- All plates shall comply with the appropriate Australian Standard for each Equipment type.
- Plates are to be:
  - engraved stainless steel
  - fixed to the surface by permanent fasteners
  - adhesive fixings are not acceptable
- Plates shall not be fixed to any component of the Equipment that can be removed during normal inspection, maintenance, operation etc.
- Plates shall contain the following information, in addition to further requirements specified for each Equipment type:
  - Western Power Specification number
  - Western Power Specification Item Number
  - Western Power Order number
  - Western Power Stock Code

### 6.3.12 Secondary Equipment Requirements

All wiring, terminations and connectors shall comply with Engineering Design Instruction – Substation Secondary Systems Design.

## Appendix A: Approval Record and Document Control[5]

[5] See Western Power Internal Document