Substation Ratings - Specification

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1. Introduction

1.1 Purpose

This specification provides information for planning, calculating ratings, and operating the transmission system and sets standard ratings for substation equipment so that they meet immediate and long term network requirements. It applies to all high voltage substation plant owned and/or operated by Powerlink.

1.2 Scope

This specification outlines the Standard Current Ratings for bays, plant, stranded conductors and tubular busbars in transmission substations. The ratings apply to all new substations and the refurbishment of existing ones in or associated with the High Voltage Transmission Network.

The scope of this document includes:

- Defining the fault levels for substation maximum developments.
- Defining the methodology for calculation of ratings for substation equipment.
- Defining the application of standard ratings for **plant**, **busbars** and **stranded conductors** to gain benefits in design, maintenance and operation during the service life.

1.3 References

Document code	Document title
AS 62271.1-2012	Standards Australia (2012) *High Voltage switchgear and control gear-Common specification.Clause 4.4.1*
AS 62271.301—2005	Standards Australia (2005) *High voltage switchgear and control gear Part 301: Dimensional standardization of terminals*
AS 1531-1991	Standards Australia (1991) *Conductors - Bare Overhead - Aluminium and Aluminium Alloys*
AS 1867:1997	Standards Australia (1997) *Aluminium and aluminium alloys - Drawn tubes*
ESA 2002	Electrical Safety Act *2002* (Qld)
ESR 2013	Electrical Safety Regulation *2013* (Qld)
IEC/TR 61597:1995	International Electrotechnical Commission (1995) *Overhead electrical conductors – Calculation methods for stranded bare conductors*
IEEE Std 605TM-2008	IEEE (2008) *Guide for Bus Design in Air Insulated Substations*
NER V108	National Electricity Rules (2018) *V108, Schedule 5.1.12*
PEA 2002	Professional Engineers Act *2002* (Qld)

1.4 Defined terms

Terms	Definition
Substation Firm Capacity	Substation Firm Capacity can refer to either the ultimate transformed load capability with one transformer out of service or the maximum ultimate generation or the maximum ultimate load through-put capability. For transformed load, the Substation Firm Capacity is calculated using the transformer Short Term Maximum Load Limit under an N-1 condition for the substation. For transformers the factors below are applied to the nameplate rating for Short Term Maximum Load Limit. • equal or greater than 1500MVA, a factor of 1.1 is applied, • greater than 100MVA, a factor of 1.3 is applied, • equal or less than 100MVA, a factor of 1.5 is applied.
AEMO	Australian Energy Market Operator
EMS	Energy Management System
RPEQ	Registered Professional Engineer Queensland

1.5 Monitoring and compliance

For compliance with this document the data generated by this process will be recorded in a Powerlink electronic corporate system that includes revision history and approval control.

Where the design is implemented by a third party, the third party is responsible for calculation and approval of the ratings, and to provide Powerlink the rating data in accordance with this specification, 60 days prior to commissioning.

1.6 Risk management

The standard ratings and the rating calculation methodology detailed in this document are determined to be safe and appropriate, as far as is reasonably practical, for Powerlink's current network and future planned network.

The cost of substation establishment or replacement is a considerable portion of the life cost of the substation. The substation is expected to be suitable for the duration of its economic life. Early equipment replacement due to inadequate rating is a significant financial risk. This specification mitigates that risk by applying minimum standard ratings that have a high probability of being sufficient for the economic life of the substation.

The provision of ratings for Powerlink's planning and operational requirements involves complex and scientific calculations, and therefore is a professional engineering service, as such the provision of rating data must be undertaken in accordance of the Professional Engineers Act 2002, including approval by a Registered Professional Engineer Queensland (RPEQ).

2. Planning for the Maximum Substation Developments

The following configurations are to be used for substation maximum developments (ultimate). It will be used to derive the standard circuit and busbar ratings and to determine the maximum substation design fault levels. Other arrangements are to be regarded as non-standard.

Table 2-1

Substation/ Switching Station Nominal Voltage Level	Transformer Arrangement (based on Nameplate Rating)	Substation Firm Capacity	Substation Fault Level (refer Section 4)		
			500kV	275&330kV	132&110kV
500/330kV & 500/275kV	3 x 1500MVA	3300MVA	63kA	50kA	-
330/275kV	3 x 1500MVA	3300MVA	50kA	50kA	-
275/132kV & 275/110kV	3 x 375MVA	975MVA	-	40kA	40kA
132/69kV	2 x 160MVA or 3 x 100MVA	240MVA 300MVA	-	-	31.5kA
132/33kV & 110/33kV	3 x 100MVA	300MVA	-	-	31.5kA
132/22kV	3 x 65MVA	195MVA	-	-	31.5kA
132/11kV & 110/11kV	3 x 60MVA	180MVA	-	-	31.5kA

The circuit, busbar ratings and fault levels for power stations (generators) and transmission switchyards will be derived to suit the maximum generation and future network requirements in the area or maximum through capacity envisaged for that switchyard.

3. Calculation of Current Ratings

Substation plant generally has a manufacturer ratings plate. The ratings plate details provided by the manufacturer must be considered for calculation of the bay ratings. For other equipment such as interplant connections and busbar that do not have manufacturer ratings, ratings must be calculated.

3.1 Bay Ratings

The current rating of a substation bay, known as the “Bay Continuous Rating” is calculated by taking the most limiting element in the bay. The following should be included in the Bay Continuous Rating however other elements may need to be included as determined by the approver.

- Bus dropper including the compression fittings and the palm terminal ratings.
- HV plant i.e. line trap, isolators, Circuit Breaker (CB), Current Transformer (CT), Metering Unit etc.
- Interplant connections including the bolted and compression fittings and the palm terminal ratings.
- The strung bus.
- Line dropper or final connection to the transformer / Cap Bank / Reactors/ Static VAR Compensator (SVC) etc.

The bay continuous rating for each substation bay must be calculated, approved and recorded in SAP.

3.1.1 Plant Current Rating

The current rating of an item of plant is known as its “Rated Normal Current” as specified in Clause 4.4.1 of AS 62271.1-2012.

For current transformers in substation bays, the maximum allowable primary current to prevent exceedance of the manufacturer nameplate secondary thermal current rating must be calculated, approved and recorded in SAP.

3.1.2 Tubular Busbar Current Rating

The current rating of a tubular busbar is known as its “Normal Continuous Current” for a Weathered Summer Noon condition, as calculated in accordance with IEEE Std 605™-2008. Ambient temperature is taken as 40°C with a wind velocity of 0.6m/s (at an angle of 90 degrees to the bus). For tubular aluminium busbar the maximum operating temperature must not exceed 90°C.

The bus continuous rating for each section must be calculated, approved and recorded in SAP.

3.1.3 Stranded Conductor Current Rating

The current rating of stranded conductor is known as its “Normal Continuous Current” for a Weathered Summer Noon condition, as calculated in accordance with IEC/TR 61597:1995. Ambient temperature is taken as 40°C with a maximum operating temperature of 90°C.

For stranded conductor, the wind velocity (at an angle of 90 degrees to the conductor) shall be taken as,

- 0.6 m/s at within a bay/diameter and
- 1.0 m/s at for strung bus.

3.1.4 Palm Terminal Ratings

Terminals in substations for both equipment and fittings shall be rated as specified in Clause 5 of AS 62271.301—2005.

4. Substation Fault Level

The duration for the Substation Fault Level shall be assumed to be 2 seconds for Transformer and Reactor design purposes, 1 second for Primary Plant design purposes and the duration quoted in the appropriate Substation Design Standards for the design of all other Substation Equipment, such as Earth Grid, Busbars, Plant connectors, Strung Bus, Earthwire's and Structures.

The substation minimum fault levels are often limited by the downstream Distribution Network, but where there is no cost penalty to achieve higher than the ratings in Table 2-1, the higher rated standard Equipment/Plant offered, will be used (e.g. 132 & 110kV Equipment/Plant is likely to be rated at 40kA). This decision can be made by the Substation Design Engineer in conjunction with the relevant Procurement specialist.

Transformers and reactive plant installed in substations should be compatible with the specified substation (bus) prospective fault level and duration to which they will be connected (refer to the fault levels as listed in Table 2-1.

5. Application of Standard Ratings

The maximum useful life of any item of plant depends on the manner in which it is operated and the environmental conditions imposed upon it during its service life. In general, effective aging of plant increases exponentially with age, the life decreases faster than the increase in the available capacity. This means with increased loading, the cost per year, per MVA, increases. On the other hand, too low a loading means low utilisation and can become uneconomic as the future benefit of postponed capital expenditure is discounted over time.

Because of these competing drivers, there is an optimum economic life for any item of high voltage plant. As each item of plant will have different loading characteristics, different ambient conditions, and different temperature rises, the effective aging of plant will vary throughout the network. However, the change is not dramatic, and the minimum achieved is fairly flat. Therefore, while units will vary, the optimal age will not be too different from that of an average unit. This then allows the application of standard ratings, for items of high voltage plant to gain benefits in design, maintenance and operation during the service life.

The standard ratings set out in this document shall apply to new substations as well as replacement and augmentations (where possible), and will not be applied retrospectively.

The following current ratings for each substation circuit element is the minimum, which must be achieved in the design and construction of all substations associated with the High Voltage Transmission Network.

5.1 110kV and 132 kV Circuits

Nominal values for voltages, as listed in Table 2-1 are used to calculate current ratings.

Feeder Bays

Landing Span	Match Feeder Current Rating
Feeder Dropper	1600A
Line Trap	1600A
Isolator	1600A
Current Transformer	1600A
Circuit Breaker	1600A
Plant Connectors	1600A

Note that, should a feeder bay be back to back with a 487.5MVA transformer bay in a 1 ½ CB arrangement, the above Feeder and Coupler bay ratings should match the Transformer Bay rating below.

Transformer Bays	< 241MVA	487.5MVA (132kV)	487.5MVA (110kV)
Isolator	1600A	2500A	3150A
Current Transformer	1600A	2500A	3150A
Circuit Breaker	1600A	2500A	3150A
Plant Connectors & Droppers	1600A	2500A	3150A
Strung Bus	1600A	2500A	3150A
Transformer Connection	1600A	2500A	3150A

The **MVA** rating shown at the top of the above table is the **Transformer Short Term Maximum Load Limit** as listed in the table below.

Standard MVA Ratings for Transformers (nameplate and short term) used to determine the above current ratings, are as follows. Current ratings are based on worst case, i.e. full emergency load transformer load on lowest tap.

Voltage Group kV	Maximum Nameplate Rating	Short Term Maximum Load Limit
275/132/19.1	375 MVA	487.5MVA
275/110/19.1	375 MVA	487.5MVA
132/69/11	160 MVA or 100 MVA	240MVA or 150MVA
132/33/11	100 MVA	150MVA
132/22	65 MVA	97.5MVA
132/11	60 MVA	90MVA
110/33/11	100 MVA	150MVA
110/11	60 MVA	90MVA

Bus Coupler Bays and Busbars	< 301MVA	975MVA
Isolator	1600A	3150A
Current Transformer	1600A	3150A
Circuit Breaker	1600A	3150A
Plant Connectors & Droppers	1600A	3150A
Tubular Busbar (load/generation points influence bus rating, refer "Generator Feeder Bays" below)	2000A	4000A

The **MVA** rating shown at the top of the above table is the **Substation Firm Capacity**.

Capacitor Bank Bays

Isolator	1600A
Current Transformer	1600A
Circuit Breaker	1600A
Plant Connectors	1600A
Capacitor Connection	Match the Capacitor Current Rating

Note that the minimum size of conductor used for Capacitor connections may be determined by corona requirements.

SVC Bays

Isolator	1600A
Current Transformer	1600A
Circuit Breaker	1600A
Plant Connectors	1600A
SVC Connection	Match the Capacitor Current Rating

Note that the minimum size of conductor used for SVC connections may be determined by corona requirements.

Generator Feeder Bays

Landing Span	Match Generator Feeder Current Rating
Feeder Dropper	1600A
Isolator	1600A
Current Transformer	1600A
Circuit Breaker	1600A
Metering Unit	1600A
Plant Connectors	1600A

Note that should generation from a single feeder exceed 350MVA, ratings above will need to be reviewed as well as bus rating under "Bus Coupler Bays and Busbars".

Other Equipment

For all other substation equipment, Voltage Transformers, Surge Arresters, Coupling Capacitors etc, which are not in the load carrying circuit paths, the conductor size must be the minimum size to minimise corona.

5.2 275kV Circuits

Nominal values for voltages, as listed in Table 2-1 are used to calculate current ratings.

Feeder & Coupler Bays

Landing Span	Match Feeder Current Rating
Feeder Dropper	2500A
Line Traps	2500A
Isolator	2500A
Current transformer	2500A
Circuit Breaker	2500A
Plant Connectors & Droppers	2500A
Strung Bus	2500A

Note that, should a feeder bay be back to back with a 1650MVA transformer bay in a 1 ½ CB arrangement, the above Feeder and Coupler ratings should match the Transformer bay rating below.

Transformer & Coupler Bays	487.5MVA	1650MVA
Isolator	2500A	3750A
Current Transformer	2500A	3750A
Circuit Breaker	2500A	3750A
Plant Connectors & Droppers	2500A	3750A
Strung Bus	2500A	3750A
Transformer Connection	2500A	3750A

The **MVA** rating shown at the top of the above table is the **Transformer Short Term Maximum Load Limit** as listed in the table below.

(Note: 3750A is not an R10 rating however this allows flexibility in terminal palm selection.)
Standard MVA Ratings for Transformers (nameplate and short term) used to determine the above current ratings, are as follows. Current ratings are based on worst case, i.e. full emergency load transformer load on lowest tap assuming that the range is limited from -7% to +10% for 1500MVA. If a lower tapping limit exists, and this remains a realistic worst case scenario, consideration of increased bay rating may be required.

Voltage Group kV	Nameplate Rating	Short Term maximum Load
500/275	1500 MVA	1650MVA
330/275	1500 MVA	1650MVA
275/132	375 MVA	487.5MVA
275/110	375 MVA	487.5MVA

Busbars	975MVA	3300MVA
Tubular Busbar (load/generation points influence bus rating)	4000A	6000A (at 500/275kV sites, this may require 8000A bus)

The **MVA** rating shown at the top of the above table is the **Substation Firm Capacity**.

Reactor Bays

Isolator	2500A
Current Transformer	2500A
Circuit Breaker	2500A
Plant Connectors	2500A
Reactor Connection	Match the Reactor Current Rating

Note that the minimum size of the conductor used for Reactor connections may be determined by corona requirements.

Capacitor Bays

Isolator	2500A
Current Transformer	2500A
Circuit Breaker	2500A
Plant Connectors	2500A
Capacitor Connection	Match the Reactor Current Rating

Note that the minimum size of the conductor used for Capacitor connections may be determined by corona requirements.

SVC Bays

Isolator	2500A
Current Transformer	2500A
Circuit Breaker	2500A
Plant Connectors	2500A
SVC Connection	Match the Reactor Current Rating

Note that the minimum size of the conductor used for SVC connections may be determined by corona requirements.

Generator Feeder & Coupler Bays

Landing Spans	2500A
Feeder Droppers	2500A
Isolator	2500A
Current transformer	2500A
Circuit Breaker	2500A
Metering Units	1600A (Thermal rating of 2000A)
Plant Connectors & Droppers	2500A
Strung Bus	2500A

Note that should generation from a single feeder exceed 750MVA, ratings above will need to be reviewed as well as bus rating under “Busbars”. Note also that if this feeder backs off another feeder or transformer in the same diameter, the ratings of that feeder or transformer bay should match the rating of the generator and coupler bays.

Other Equipment

For all other substation equipment, Voltage Transformers, Surge Arresters, Coupling Capacitors etc which are not in the load carrying circuit paths, the conductor size shall be the minimum size for corona.

5.3 330kV Circuits

Nominal values for voltages, as listed in Table 2-1 are used to calculate current ratings.

Feeder & Coupler Bays

Landing Spans	Match Feeder Current Rating
Feeder Droppers	2500A
Line Traps	2500A
Isolator	2500A
Current Transformer	2500A
Circuit Breaker	2500A
Plant Connectors & Droppers	2500A
Strung Bus	2500A

Note that, should a feeder bay be back to back with a 1650MVA transformer bay in a 1 ½ CB arrangement, the above Feeder and Coupler ratings should match the Transformer and Coupler Bay rating below.

Transformer & Coupler Bays	487.5MVA	1650MVA
Isolator	2500A	3150A
Current Transformer	2500A	3150A
Circuit Breaker	2500A	3150A
Plant Connectors & Droppers	2500A	3150A
Strung Bus	2500A	3150A
Transformer Connection	2500A	3150A

The **MVA** rating shown at the top of the above table is the **Transformer Short Term Maximum Load Limit** as listed in the table below.

Standard MVA Ratings for Transformers (nameplate and short term) used to determine the above current ratings, are as follows. Current ratings are based on worst case, i.e. full emergency load transformer load on lowest tap assuming that the range is limited from -7% to +10% for 1500MVA. If a lower tapping limit exists, and this remains a realistic worst case scenario, consideration of increased bay rating may be required.

Voltage Group kV	Nameplate Rating	Short Term Maximum Load
500/330	1500 MVA	1650MVA
330/275	1500 MVA	1650MVA

Busbars	975MVA	3300MVA
Tubular Busbar (load/generation points influence bus rating)	4000A	6000A (at 500/330kV sites this may require 8000A bus)

The **MVA** rating shown at the top of each table is the **Substation Firm Capacity**.

Reactor Bays

Isolator	2500A
Current Transformer	2500A
Circuit Breaker	2500A
Plant Connectors	2500A
Reactor Connection	Match the Capacitor Current Rating

The minimum size of conductor used for the plant and Reactor connections may be determined by corona requirements, possibly multiple conductors.

Capacitor Bays

Isolator	2500A
Current Transformer	2500A
Circuit Breaker	2500A
Plant Connectors	2500A
Capacitor Connection	Match the Capacitor Current Rating

The minimum size of the conductor used for plant and Capacitor connections may be determined by corona requirements, possibly multiple conductors.

Generator Feeder & Coupler Bays

Landing Spans	2500A
Feeder Droppers	2500A
Isolator	2500A
Current Transformer	2500A
Circuit Breaker	2500A
Metering Unit	1600A (Thermal rating of 2000A)
Plant Connectors & Droppers	2500A
Strung Bus	2500A

Note that should generation from a single feeder exceed 750MVA, ratings above will need to be reviewed as well as bus rating under “Busbars”. Note also that if this feeder backs off another feeder or transformer in the same diameter, the ratings of the generator and coupler bays should match the rating of that feeder or transformer bay.

Other Equipment

For all other substation equipment, Voltage Transformers, Surge Arresters, Coupling Capacitors etc which are not in the load carrying circuit paths, the conductor size must be the minimum size to minimise corona, possibly multiple conductors.

5.4 500kV Circuits

Nominal values for voltages, as listed in Table 2-1 are used to calculate current ratings.

Feeder & Coupler Bays

Landing Spans	Match Feeder Current Rating
Feeder Droppers	4000A
Line Traps	4000A
Isolator	4000A
Current Transformer	4000A
Circuit Breaker	4000A
Plant Connectors & Droppers	4000A
Strung Bus	4000A

Transformer and Coupler Bays	1650MVA
Isolator	4000A
Current Transformer	4000A
Circuit Breaker	4000A
Plant Connectors & Droppers	4000A
Strung Bus	4000A
Transformer Connection	4000A

The **MVA** rating shown at the top of the above table is the **Transformer Short Term Maximum Load Limit** as listed in the table below.

Standard MVA Ratings for Transformers (nameplate and short term) used to determine the above current ratings, are as follows. Current ratings are based on worst case, i.e. full emergency load transformer load on lowest tap.

Voltage Group kV	Nameplate Rating	Short Term Maximum Load
500/330 & 500/275	1500 MVA	1650MVA

Busbars	3300MVA
Tubular Busbar (load/generation points influence bus rating)	8000A

The **MVA** rating shown at the top of the above table is the **Substation Firm Capacity**.

Reactor Bays

Isolator	2500A
Current Transformer	2500A
Circuit Breaker	2500A
Plant Connectors	2500A
Reactor Connection	Match the Capacitor Current Rating

The minimum size of conductor used for the plant and reactor connectors may be determined by corona requirements, possibly multiple conductors.

Capacitor Bays

Isolator	2500A
Current Transformer	2500A
Circuit Breaker	2500A
Plant Connectors	2500A
Capacitor Connection	Match the Capacitor Current Rating

The minimum size of the conductor used for plant and capacitor connectors may be determined by corona requirements, possibly multiple conductors.

Generator Feeder & Coupler Bays

Landing Spans	Match Feeder Current Rating
Feeder Droppers	2500A
Isolator	2500A
Current Transformer	2500A
Circuit Breaker	2500A
Metering Unit	1600A (Thermal rating of 2000A)
Plant Connectors & Droppers	2500A
Strung Bus	2500A

Note that should generation from a single feeder exceed 750MVA, ratings above will need to be reviewed as well as bus rating under “Busbars”. Note also that if this feeder backs off another feeder or transformer in the same diameter, the ratings of the generator and coupler bays should match the rating of that feeder or transformer bay.

Other Equipment

For Voltage Transformers, Surge Arresters, Coupling Capacitors and all other substation equipment which are not in the load carrying circuit paths, the conductor size must be the minimum size to minimise corona, possibly multiple conductors.