# GUIDELINES FOR ESTABLISHING TERMINAL STATIONS IN VICTORIA

PREPARED BY: Planning / Transmission Services

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FINAL

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# Contents

# 1 Purpose

AEMO plans and directs any augmentations to the Victorian Declared Shared Network (DSN). AEMO has developed these Guidelines to explain the approach AEMO takes during the establishment or development of a terminal station.

AEMO's strategic objective for Victoria is to develop an economically and technically robust approach to connecting generation and load to the DSN in the long term, while maintaining power quality, security and reliability of the network.

These Guidelines apply to the selection and establishment of new terminal stations, as well as for connections to the DSN at voltages of 220 kV or higher, and provide an insight into:

- The need for and location of the terminal station.
- The size and configuration of the terminal station.
- The site and easement access requirements.

# 2 Application

AEMO's functions include planning for the future augmentation to the DSN and for connecting generation and loads to the DSN by establishing new terminal stations or augmenting existing terminal stations. In fulfilling these functions, AEMO undertakes joint planning with SP AusNet, relevant distribution businesses (DBs), and any other interested parties. SP AusNet is the principle (although not the only) transmission asset owner and declared transmission system operator (DTSO) in Victoria.

When planning network augmentations in Victoria, AEMO also considers the alignment of plans with the National Transmission Network Development Plan (NTNDP), which forecasts long-term transmission augmentation requirements across the NEM (National Electricity Market).

A significant proportion of Victorian terminal station elements are connection assets planned by DBs but owned by SP AusNet. In planning new terminal stations, or augmenting existing terminal stations, AEMO consults, coordinates and shares information with SP AusNet and the DBs. AEMO has therefore worked closely with SP AusNet and DBs in developing these Guidelines.

An important element of AEMO's planning is to ensure the compatibility of transmission plans with environmental and land-use planning carried out by local, state and national planning bodies. The need for establishment of a new terminal station is triggered by different events as discussed in the section 6.1 below. AEMO's and other connection applicant's roles and responsibilities vary depending on the need and the trigger. These obligations are detailed in the document "*Connecting Victoria: Transmission Project Development Protocol"* published by AEMO.

In establishing a new terminal station, AEMO must consider:

- the need and expected use of the terminal station, including future new generation and load connections;
- the potential for future generation development and load growth in the region;
- the location of the terminal station, taking into account its impact on communities and the environment;
- the required size of the terminal station;
- the availability of land and easements;
- the configuration and design requirements; and
- the long-term plan for the terminal station, with due consideration of asset life and the need to retain sites and easements for future development of the DSN.

# 3 Legal and Regulatory Framework

The National Electricity Rules (Rules) set out the processes and procedures that Transmission Network Service Providers (TNSPs) and connection applicants must follow for a new connection to the transmission network.

In relation to a declared transmission system, Clause 5.3.7A(a) of the Rules outlines that the powers, functions and responsibilities of the network service provider are divided between AEMO (network service provider in respect of the provision of shared transmission services) and the DTSO (in respect of the provision of connection services).

The joint planning responsibilities of TNSPs, SP AusNet (in the capacity of the declared transmission system operator) and relevant DBs are outlined in the Clause 5.6.2(c)(1) of the Rules.

Depending on the size, scope, timing and location of new connections, augmentations to the DSN may be required to facilitate connection.

While the Rules detail a range of technical requirements for the establishment of a connection, they do not cover certain technical matters regarding acceptable connection point arrangements.

These Guidelines offer parties connecting to the DSN and other stakeholders an insight into AEMO's planning process for the siting and design of new terminal stations or augmentations to existing terminal stations.

# 4 Related Policies and Procedures

AEMO is developing a number of policies and procedures to detail its approach to establishing connections to the DSN.

These Guidelines should be read in conjunction with the following, which are available on AEMO's website:

- Current *National Transmission Network Development Plan (NTNDP).*
- Current *Victorian Annual Planning Report (VAPR).*
- Current *Electricity Statement of Opportunities (ESOO).*
- *Guidelines for Shared Transmission Connections in Victoria.*
- *Policy on the Active Management of Connection Applications in Victoria.*
- *Cost Allocation Policy in Victoria*.
- *Connecting Victoria: Transmission Project Development Protocol*.
- *Contract Principles for Contestable Generator Connections to the Declared Shared Network.*
- *Contract Principles for Contestable Distributor Connections to the Declared Shared Network*.
- *Power System Security Guidelines SO_OP3715.*
- Other information on availability of natural resources for generation, published by AEMO or by other relevant government or industry organisations.

The DBs have responsibility for planning and directing the augmentation of the facilities that connect their distribution systems to the DSN. Planning of distribution network connections to the DSN is outlined in the *Transmission Connections Planning Report (TCPR),* which is published annually by the Victorian DBs.

# 5 Principles

The principles outlined in these Guidelines are to be applied to all terminal stations in Victoria at voltage levels of 220 kV or greater.

Terminal stations will be developed in accordance with the following principles:

**Technical**

- The terminal station will not materially degrade the reliability and security of the DSN.
- Terminal station development will be consistent with long-term plans for the DSN.
- Terminal station development will be compatible with future generation developments and the need to supply future load growth in the region.
- Terminal stations will be developed in stages to meet the future capacity needs of the connection location and the DSN. Development will only occur when the station is required to accommodate additional capacity.

**Economic**

- The location and design of terminal stations will be based on economic efficiency, taking into account feasibility and practicability.

**Community, Planning and Environment**

- The terminal station development process will be clear and transparent. Connection applicants together with AEMO will provide for adequate and inclusive consultation with all parties and stakeholders potentially affected.
- Connection applicants and/or AEMO will select terminal station locations that minimise adverse environmental and social impacts as much as is reasonably practicable.
- The terminal station location will be selected to minimise adverse impacts on affected landowners as much as is reasonably practical, particularly in relation to easements.
- The terminal station design will minimise the environmental and visual impacts while balancing the cost of construction.

# 6 Need for and Location of Terminal Station

## 6.1 Need for a Terminal Station

The establishment of a new terminal station can be initiated by:

- the *VAPR*, which identifies the need for augmentations to the DSN to deliver future capacity requirements;
- AEMO receiving an application to connect to the DSN; or
- plans for new terminal stations necessary to meet the demand from distribution networks as outlined in the TCPR.

AEMO may plan a terminal station to accommodate one dedicated connection or multiple connections to the DSN. The number of connections planned at a terminal station will depend on:

- the requirements of connecting parties;
- planned expansions of the DSN;
- the likelihood of multiple generating systems connecting to the terminal stations, due to factors such as the availability of a large energy resource; and

- the forecast needs of the DBs, due to expanding load centres.

## 6.2 Location of a Terminal Station

The parties responsible for determining the location of a terminal station are based on the identified need, as set out below:

- For augmenting the transmission capacity or security to the DSN, the location is determined by AEMO to provide maximum economic benefit to all NEM participants;
- For augmenting the capacity of the distribution system to meet increasing demand, the location is determined jointly by AEMO and the respective DBs to reduce the overall cost of meeting the demand; and
- For connecting new generation, while AEMO will identify a preferred location, the connection applicant will be responsible for selecting the terminal station location to best suit the applicant’s needs.

In determining the location of a terminal station, the connecting parties and/or AEMO must consider the following factors:

1. **Existence of sufficient concentration of energy resources to create a cluster of generation (and therefore connections) in the area**

   Availability of generation resources such as gas, wind, solar or geothermal energy will be considered when assessing this factor. This information is obtained from a wide range of sources, including AEMO’s ESOO*, Gas Statement of Opportunities*, NTNDP and VAPR; Victorian DB’s TCPR; and other similar forecasts published by government or industry organisations.

2. **Alignment of the location of the terminal station with AEMO’s future development plans for the DSN**

   Considerations for the future development of the network likely to influence the location of the terminal station include:

   - proximity to existing transmission lines or to existing or planned transmission easements;
   - need and plans for replacing, refurbishing or upgrading the existing transmission assets including addition of new circuits to existing lines, alternatives available to serve the generation, and the loads that are presently connected to the DSN or anticipated to be connected in the future;
   - ability of the connection to relieve any existing or anticipated future constraints;
   - sufficiency of the existing assets and the planned future assets to meet future capacity required by generation and load connections;
   - impact of future plans on the capacity of the DSN to service the connection through the terminal station and surrounding stations;
   - future needs to upgrade the transformation voltage at the connection point; and
   - future plans that have been identified for distribution networks.

3. **The reliance on the existing network in the area to support loads and other (potentially inter-regional) networks.**

   AEMO will consider industrial or residential loads connected to the relevant section of the DSN and its role in facilitating inter-regional power transfer. This consideration will determine whether service quality (reliability) to existing customers will be affected by, say, multiple separate connections as opposed to connections being directed to one terminal station.

4. **Reduction in the overall costs of potential connections, as a result of establishing a single terminal station, relative to the establishment of multiple separate connections**

   The reduction in costs should include savings to the connecting generation through co-location and sharing of land and assets; savings to the market and DTSO through a reduction in line outages; and savings from the overall streamlining of planning and consenting approval processes. The terminal station will be planned in stages so that the establishment costs carried by each connecting generating system or load are minimised.

5. **Most cost-efficient option for terminal station location in relation to connecting entities**

   AEMO will seek to identify terminal station locations that minimise costs, taking into consideration the probabilities of future connections. We will look at the proximity of energy resources, future distribution and transmission development requirements, availability of land and easements, ability to manage environmental impacts and the known connection applications or enquiries.

6. **Availability of suitable land for the construction of the terminal station and the associated easements required for connections to the terminal station**

   A terminal station should be located in an area with suitable access to construction, transport infrastructure, and services including communications, water and sewerage. The site should be feasible to procure and enable stakeholders to minimise the environmental impact of the terminal station development.

   There must be suitable land for easements to allow generation to connect to the terminal station. The easement should provide a continuous connection corridor between each generating system and the terminal station, unconstrained by incompatible land uses (e.g. national parks).

   Further, the topography and other characteristics of the site must be favourable to expanding the terminal station in stages to accommodate future needs. The ability to expand and stage the development of the terminal station will be critical to mitigate the risk of future connections not proceeding.

   The site should be suitable and adequate to accommodate the ultimate station configurations and area requirements as outlined in Section 7 of these Guidelines.

   The site location and the impact on the surrounding environment should be such that the likelihood of obtaining the required planning approvals is high.

7. **Existence of connection enquiries or applications from multiple generators**

   AEMO will consider connection enquiries and applications received by AEMO and by the DBs. AEMO may also seek information from NEM participants and other relevant stakeholders to identify potential new generation projects seeking connection to the network. It will also consider planning applications submitted to the Victorian Government by generation developers to identify any expansion plans for generation.

8. **Forecast demand that may require additional connections to the network to meet industrial or distribution demand**

   AEMO develops regional and terminal station medium and long-term load forecasts using information it receives from a variety of sources, and develops plans to ensure that future load growth can be met. Accordingly, AEMO will review the need and size of a terminal station based on:

   - long-term strategic plans and shorter term plans and proposals by DBs with respect to forecast loads and requirements for provision of connection points at a terminal station;

  - enquiries from larger consumers for connecting directly to the DSN;
  - existing and planned arrangements for supplying the regional demand at other stations, considering cost and reliability impacts of the numbers of stations over which the demand is spread;
  - forecast demand published in AEMO's NTNDP, VAPR and ESOO; and
  - planned connections between the DSN and distribution networks (as outlined in the DB's TCPR).

More detailed aspects of the development of a terminal station will be considered in the design phase.

# 7 Terminal Station Configuration

Determining the terminal station configuration, both at the initial stage and as an ultimate station configuration, is important for a number of reasons including:

- determining suitability of a proposed station site based on site size to accommodate final station configurations;
- determining transmission line and associated easement requirements to transmit power to and from the station;
- determining the need for other station sites and line easements in the vicinity;
- determining plant ratings, including station earthing, and associated staged development costs;
- allocating quality of supply levels to connecting parties, mindful of the capacity of connections ultimately connected the station and existing levels of quality of supply;
- managing the environmental impact of the terminal station, such as allocating sufficient buffer zones to address, noise, electric and magnetic fields (EMF) and aesthetics.; and
- reviewing consistency with town and land-use planning and community requirements.

Alternative designs and configurations will be considered alongside considerations of cost.

Sections 7.1 and 7.2 of these Guidelines describe the factors that will influence the size and layout of the ultimate station configuration. Appendix A provides two examples of ultimate terminal station configurations, which are intended to accommodate connections at 220 kV and 500 kV transmission voltages.

## 7.1 Design Considerations

This section describes guidelines for determining a suitable ultimate station configuration. The initial and ultimate station configurations are developed considering the aspects of design listed in Table 7–1, as well as those factors addressed in Section 6 of these Guidelines.

| Factor | Consideration |
|---|---|
| Alignment with AEMO's long-term plans | AEMO will seek to ensure that the ultimate station configuration is appropriate for its planning needs beyond the next 30 years; however, the designed life of the station is for a minimum of 50 years.<br>AEMO's long-term plans take into account the long-term plan presented in the DB's TCPR. |
| Land-use planning | The station must be capable of being expanded to the final configuration while mitigating environmental impact, including noise and EMF levels. |
| Load forecasts | When sizing power transformers, standard ratings will be adopted. |
| Likely and possible generation connections | The size of the largest generation contingency will be assessed. If this exceeds a defined value[1], further costs may be incurred. |
| Transmission tie transformers | Provision will be made for installation of transmission tie transformers, switchgear, instrument transformers and busbars. |
| Reactive power support | AEMO will review reactive power requirements at the station and, if required, allow space for voltage control plant including: circuit breaker switched shunt capacitors, static VAR compensators (SVCs) and shunt reactors. |
| Fault level mitigation | AEMO will consider the maximum fault levels for the life of a station, including the impact of planned future modifications to the DSN. Equipment ratings will be selected to meet this fault level. Equipment such as fault level reduction equipment will only be considered once the installation approaches the ultimate station configuration. |
| Power quality | The ultimate station configuration will include any necessary provision required to maintain power quality. Maintaining harmonic levels below the allocated limits may require provision of filtering equipment in addition to any required reactive power support plant. |
| Alternative termination and switching | AEMO will review whether it is likely that a station will be connected to a major transmission augmentation; for example, a new High Voltage Direct Current (HVDC) termination point. If so, space will be allocated for this. |
| Reliability and security | The station design will be such that power system security is maintained for the credible loss of any single element of the DSN (as discussed in Section 9 of AEMO's *Power System Security Guidelines SO_OP3715)*.<br>The ultimate station configuration will take into consideration any benefits that might arise from diversity and the mitigation of high- |

[1] A value that AEMO will assess and define from time to time depending on the existing capability of the transmission system.

| | |
|---|---|
| | impact low-probability events. |
| Site requirements | Sufficient land must be allowed to ensure road and service access, environmental impact mitigation, new (or extension of) control and service buildings, diversion of transmission circuits (if required) and the required number of switching bays. |
| Staged development to accommodate future needs | The design of the terminal station must be flexible and provide for staged development up to the final capacity of generation or load serviced by the terminal station. |

*Table 7–1: Factors to be considered in the design of the terminal station*

## 7.2 Number of Switchyard Bays

A switchyard bay is the location of the physical connection to the generator or load, with one bay per connection. The required number of bays in the ultimate station configuration will be established following consideration of the relevant issues influencing the ultimate station configuration, including the key evaluation guidelines.. AEMO will ensure that the size of the land it specifies to be provided for a terminal station is the minimum required to enable the ultimate station configuration to be developed.

It should be noted that busbars will be sectionalised via the necessary number of bus coupler circuit breakers, taking into consideration the following:

- Total amount of generation to be connected to one busbar.
- Risk of losing this generation during a busbar fault.
- Impact of loss of generation on the power system.
- Expected resilience of the terminal station configuration under high-impact low-probability events.

| Station Element | Key Aspects to Consider | Guidelines |
|---|---|---|
| Incoming and outgoing 220 kV and 500 kV transmission bays | • Alignment with AEMO long-term plan<br>• Reliability and security | • Provide bays for maximum number of incoming and outgoing transmission circuits as identified in the long-term planning documents.<br>• Bay allocation of incoming and outgoing transmission lines will be on a case-by-case basis with due consideration of reliability and security of supply. |
| Incoming generation bays, connecting to 220 kV or 500 kV | • Connection enquiries<br>• Likely and possible generation connections | • Provide one connection bay for each connection, or additional bays as justified by the generation enquiry.<br>• Allow two generator connections per diameter, provided the effects of simultaneous failure have been considered and allowed for, and if economic. |

| | | |
|---|---|---|
| | | • Restrict the station to a maximum aggregate connected generation capacity. This is a reliability consideration for low-probability events. Typically the maximum aggregate generation will be of the order of 2,000–3,000 MW. For some stations, the maximum generation limit may be much lower. |
| Outgoing bays for supply of loads (220 kV or 500 kV) | • Load forecasts | • Provide for connection of future load forecast in consultation with the local DBs.<br>• Allocate connection bays for supplying future demand, allowing a typical maximum of 250 MVA per connection. The actual maximum will be calculated based on the probabilities and consequences of possible failures. |
| Transmission tie (220 kV or 500 kV) requirements | • Connection capacity requirements between the two voltage levels | • Provide, if required, for future voltage transformation capacity between 220 kV and 500 kV.<br>• Allocate bays for 220/500 kV transformers, allowing a typical maximum of 1,000 MVA per transformer (3-phase). |
| Capacitor and/or reactor bays (220 kV or 500 kV) | • Reactive power support requirements<br>• Fault level mitigation requirements | • Provide for connection of circuit breaker-switched shunt capacitors, allowing a typical maximum of 200 MVAr per connection, unless analysis shows another maximum value is appropriate.<br>• Provide for connection of SVCs with a rating of at least 200 MVAr in the electrical vicinity of a major load centre, allowing one connection per SVC.<br>• Provide for series reactors for 220 kV lines and/or busbar ties in stations, if analysis shows these might be required.<br>• Provide for 50–200 MVAr shunt reactors to compensate for 220 kV underground cables or long 500 kV lines (if anticipated) terminating at the station. |

| | | |
|---|---|---|
| Spare incoming and outgoing bays (500 kV or 220 kV) | • Alternative termination and switching requirements | • Provide for at least two line connections at each transmission voltage anticipated for the station (currently 500 kV or 220 kV). These may not necessarily be on the same diameter. |

*Table 1: Evaluation of final number of bays*

The proposed layout will be arranged for ease of connection of existing and future transmission circuits, whether this provision is via overhead line, cable or Gas Insulated Line (GIL).

If the standard connections outlined in AEMO's *Guidelines for Shared Transmission Connections in Victoria* are not appropriate, AEMO will determine alternative arrangements based on switchyard needs. The alternatives may include double switched, ring bus and multi-bus configurations.

The approximate minimum area of land required for accommodating different bay configurations at terminal stations is shown in Appendix B. AEMO will plan for the ratings identified in Appendix B to be provided for station elements at various transmission voltages.

# 8 Establishing the Terminal Station

The need for a terminal station may be identified either through the annual planning processes followed by AEMO and the DBs or through a connection application. When the need for a terminal station is identified, AEMO, SP AusNet, relevant DBs and interested parties will undertake joint planning in order to determine most effective and economical plans for fulfilling the identified need.

Establishing a terminal station will involve a series of activities that includes:

- determining what will be built in the initial stage of the connection to the network (future expansion of the terminal station will be on a needs basis;
- determining the requirements for expansion to the ultimate station configuration, including access arrangements for subsequent connections to the terminal station;
- selecting a suitable site or identifying site options to be considered;
- engaging and communicating with the community and stakeholders;
- procuring land and easements;
- determining how the costs of land, earthworks and infrastructure will be shared between multiple connecting parties and
- securing planning approvals.

During the establishment of a terminal station, applicants should consider technical aspects, commercial aspects, planning and approvals, and community and stakeholder engagement.

## 8.1 Technical Considerations

AEMO will develop an engineering feasibility design, including a conceptual site layout of the switching station that shows arrangements for switching the connections to the station. The initial feasibility design will support AEMO's preference to develop terminal stations that flexibly and economically allow for future expansion to accommodate geographically dispersed generation sources.

The design will be guided by AEMO's connection philosophy and functional design requirements as outlined in Section 7 of these Guidelines and AEMO's *Guidelines for Shared Transmission*

*Connections in Victoria*. AEMO will use the engineering feasibility design to provide further detailed information on the new terminal station to stakeholders.

The location of the station with respect to local issues and planning considerations will have a bearing on the technology to be adopted for the terminal station primary plant. The three currently available technologies in common use for the voltages involved are:

- Air Insulated Switchgear (AIS).
- Gas Insulated Switchgear (GIS) (usually located indoors).
- Mixed Technology Switchgear (MTS) (i.e. hybrid AIS/GIS switchgear).

AIS or MTS technology is easier to expand and adapt; therefore, it is unlikely to require much equipment at the initial development stage. However, it will require significantly more land area than GIS. If GIS technology is to be adopted, then:

- additional bays or adaptor sections may be required at the initial development stage to minimise the need and duration of outages when future extensions are undertaken; and
- the possible future unavailability of a particular type of GIS switchgear for future extensions may lead to potential interconnection issues requiring additional space to resolve.

## 8.2 Commercial Considerations

The key activities that involve AEMO and connection applicants in making commercial arrangements are as follows:

- Acquisition of land for the terminal station.
- Engaging service providers for the required augmentations.

The details of commercial considerations and processes are provided in the two documents, "*Contract Principles for Contestable Generator Connections to the Declared Shared Network*" and "*Contract Principles for Contestable Distributor Connections to the Declared Shared Network*".

## 8.3 Development Approvals and Community Engagement

The responsibility for obtaining development approvals, and community and stakeholder engagement will be shared between the connection applicant and AEMO. The lead party could be either of these two parties, depending on whether the generation plant connection, transmission augmentation or distribution capacity augmentation is the key focus, with the other party facilitating and supporting as required. Community participation is a key aspect in establishing a terminal station and should result in outcomes that have been carefully considered and accepted by well-informed communities, connection applicants and AEMO.

The level of community involvement can change through the project lifecycle. The activities necessary to establish a terminal station call for a Stakeholder Engagement and Community Consultation Plan to identify the level of community and stakeholder involvement required at each stage – planning and design, acquisition, and development application.

AEMO's approach and the detail process for obtaining development approvals and engaging communities and stakeholders is provided in the document "*Connecting Victoria: Transmission Project Development Protocol*".

# Appendix A: Examples of Ultimate Station Configurations

## A.1 220 kV Ultimate Station Configuration

### A.1.1 220 kV Terminal Station Single Line Diagram

The ultimate single line diagram in Figure A–1 provides for an applicant – Wind Farm 1 – to connect to a new terminal station via an existing 220 kV single circuit transmission line rated at 800 MVA per circuit. There is a long-term requirement to convert the existing line to a double circuit line with a capacity of 2 x 800 MVA.

The final potential generation expected to connect to the new station via 220 kV circuits is 1,500 MW. Provision is also made for connection at 220 kV to supply DB loads. The station line entry and exit layouts are shown as per existing practice of connections to the busbars in Victorian terminal stations. Alternative layouts can be considered at the detailed design stage.

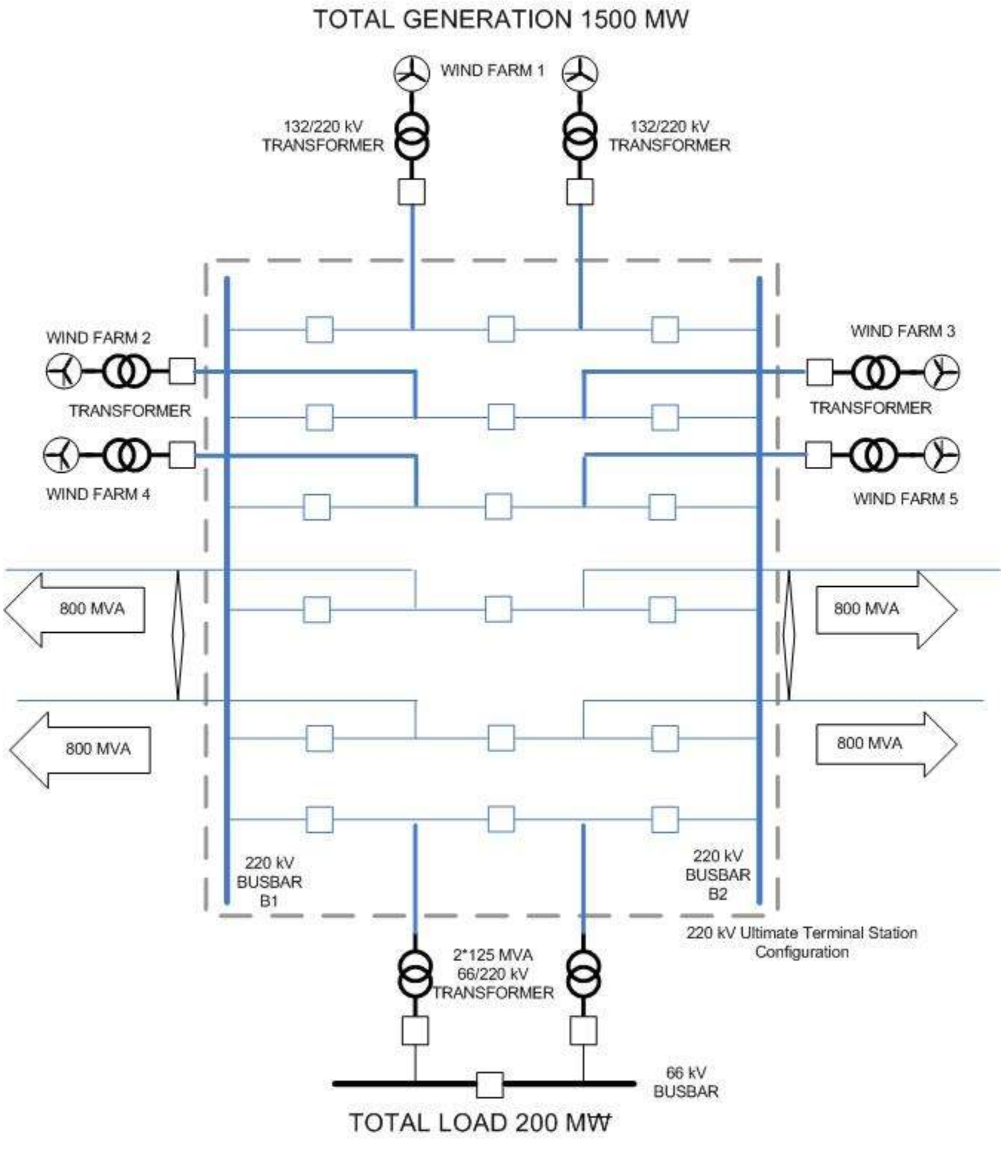


*Figure A–1: Ultimate single line diagram for 220 kV terminal station*

### A.1.2 220 kV Terminal Station Bays

The 220 kV ultimate single line diagram shows a one-and-a-half circuit breaker terminal station comprising a total of six 220 kV diameters as per Table A–1.

| Station Bays | Details |
|---|---|
| Incoming and outgoing 220 kV transmission bays | • a single one-and-a-half circuit breaker diameter providing for two transmission circuit connections for the existing circuits<br>• a single one-and-a-half circuit breaker diameter providing for two transmission circuit connections for the future planned circuits |
| Incoming 220 kV generation bays | • three one-and-a-half circuit breaker diameters providing for six generation circuit connections |
| Outgoing 220 kV bays for supply of loads connected to transmission circuits | • a single one-and-a-half circuit breaker diameter providing two line connections to a remote DB substation |
| Voltage transformation bays | • nil |
| 220 kV capacitor and/or reactor bays | • nil |
| Spare bays | • nil |

*Table A–1: Allocation of terminal station bays for connections (220 kV)*

## A.2 500/220 kV Ultimate Station Configuration

### A.2.1 500/220 kV Terminal Station Single Line Diagram

Figure A–2 shows an ultimate single line diagram for a 500/220 kV terminal station. Depending on the capacity of generation available, it is feasible to expand the terminal station to accommodate both 500 kV and 220 kV generation connections via new or existing transmission lines.

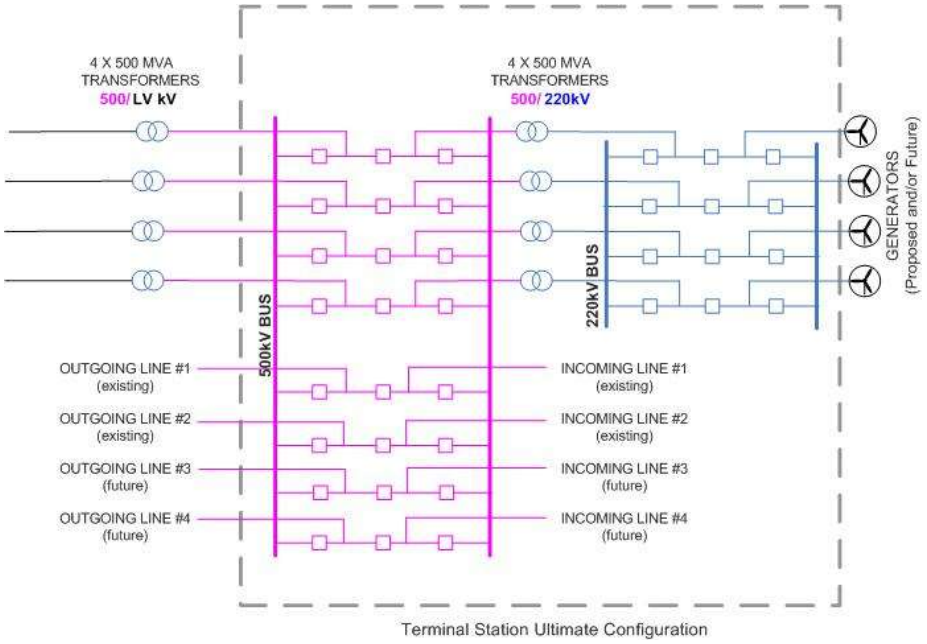


*Figure A–2: Ultimate single line diagram for 500/220 kV terminal station*

### A.2.2 500/220 kV Terminal Station Bays

The 500/220 kV ultimate single line diagram shows a one-and-a-half circuit breaker terminal station containing a total of eight 500 kV diameters and four 220 kV diameters as per Table A–2.

| Station Bays | Details |
|---|---|
| Incoming and outgoing 500 kV transmission bays | • two one-and-a-half circuit breaker diameters providing for four transmission circuit connections for existing circuits<br>• two one-and-a-half circuit breaker diameters providing for four transmission circuit connections for planned future circuits |
| Incoming 500 kV and 220 kV generation bays | • four 500 kV generation circuit connections to four one-and-a-half circuit breaker diameters<br>• four 220 kV generation circuit connections to four one-and-a-half circuit breaker diameters |
| Outgoing 220 kV bays for supply of loads connected to transmission circuits | • nil |
| 500/220 kV transmission tie transformer bays | • four 500 kV transformer connections to four one-and-a-half circuit breaker diameters<br>• four 220 kV transformer connections to four one-and-a-half circuit breaker diameters |
| 220 kV capacitor and/or reactor bays | • nil |
| Spare bays | • nil |

*Table A–2: Allocation of terminal station bays for connections (500/220 kV)*

# Appendix B: Land Area and Equipment Ratings

Nominally the land areas referred to in are required for a single connecting bay at the various voltage levels. Extra land may be needed for ground-mounted line traps, or other plant generally not installed. The number of bays required depends on the number of different transmission assets expected to finally connect to the terminal station (e.g. number of lines, number of generators, number of power transformers).

In addition to the terminal station bays, land area must be made available for:

- Access roads.
- Buildings to house control and protection equipment.
- Lightning protection.
- Other transmission assets, such as transformers and capacitors.

**Schedule 1: Minimum Land Area Requirement for Terminal Station Bays**

| AIS element | Minimum required land area for AIS/outdoor[2] in square metres (width x length in metres) | | | |
|---|---|---|---|---|
| | 500 kV | 330 kV | 275 kV | 220 kV |
| one-and-a-half CB diameter | 5,670 (30.48x186 | 2,350 (18.29x128) | 2,300 (18.29x125) | 1,830 (15.24x120) |
| double bus diameter | 4,090 (30.48x134) | 1,570 (18.29x85.35) | 1,540 (18.29x84) | 1,270 (15.24x82.7) |
| shunt reactor bay | 1,020 (30.48x33.2) | 520 (18.29x28) | 520 (18.29x28) | 390 (15x26) |
| | 500/220 kV | 330/220 kV | | 220/66 kV |
| transmission tie transformer bay outdoor | 1,250 (43x29) (1,000 MVA) | 670 (18.29x36.6) (340 MVA transformer)<br>800 (40x20) (700 MVA transformer) | 650 (18.29x34) (340 MVA transformer)<br>780 (40x19.4) (700 MVA transformer) | 400 (22x18) (150 MVA) |

*Table B–1–1: AIS/Outdoor Required Land Area*

[2] No line traps allowed in the bay.

| GIS element | Minimum required land area for GIS/indoor in square metres | | | |
|---|---|---|---|---|
| | 500 kV | 330 kV | 275 kV | 220 kV |
| one-and-a-half CB diameter | 112 | 112 | 112 | 112 |
| double bus diameter | 91 | 91 | 91 | 91 |
| shunt reactor bay | 63 | 63 | 63 | 63 |
| | 500/220 kV | 330/220 kV | | |
| transmission tie transformer bay outdoor | 320<br>(1,000 MVA) | 270<br>(400 MVA) | 270<br>(400 MVA) | 200<br>(150 MVA) |

*Table B–1–2: GIS/Indoor Required Land Area*

## Schedule 2: Minimum Ratings for Equipment at Terminal Stations

AEMO will plan for the minimum ratings identified in Tables B–2–1 to B–2–5 to be provided for station elements at various bay voltages.

Note:

1. Plant selected may typically have ratings within the ranges.
2. Insulation levels are less common and were selected to meet special criteria, particularly in the early stages of development where plant could be connected to a single line. They are no longer specified.
3. Some distribution 66 kV or 22 kV feeder circuit breakers at remote locations may require higher insulation levels than shown.
4. Transformers are always protected by surge arresters.

| System Nominal Voltage | System Maximum Voltage | Transformers | | | Other Plant | | |
|---|---|---|---|---|---|---|---|
| | | Power Frequency | LIWL[3] | SIWL | Power Frequency | LIWL | SIWL |
| kV | kV | $kV_{RMS}$ | $kV_{PEAK}$ | $kV_{PEAK}$ | $kV_{RMS}$ | $kV_{PEAK}$ | $kV_{PEAK}$ |
| 500 | 550.0 | 680 | 1550 | 1175 | 620 | 1550 | 1175 |
| | | | 1675[1] | | 680[1] | 1800[1] | 1300[1] |
| 330 | 362.0 | 510 | 1175 | 950 | 520 | 1300 | 950 |
| 275 | | | | | | | |
| 220 | 245.0 | 360 | 850 | - | 460 | 1050 | - |
| 66 | 72.5 | 140 | 325 | - | 140 | 325 | - |
| 22 | 24.0 | 50 | 125 | - | 50[2] | 125[2] | - |
| 11 | 12.0 | 28 | 75 | - | 28[2] | 75[2] | - |

**Note 1**: These insulation levels are less common and were selected historically in Victoria to meet special criteria, particularly in the early stages of development where plant could be connected to long single lines. They are therefore generally no longer specified.

**Note 2**: Feeder CBs at remote locations on 66 kV or 22 kV distribution systems may require higher insulation levels than those shown. Although these would not be considered as transmission system circuit breakers and therefore specification of this plant would be the responsibility of the relevant DNSP.

**Note 3**: Transformers are always to be protected by surge arresters

*Table B–2–1: Insulation withstand voltage levels (kV)*

| System Nominal Voltage<br>kV | System Maximum Voltage<br>kV | Location | Bay Design Rating(1): Circuit Breaker Disconnector Current Trafo & Interplant Connections Rating at 40°C(5)<br>Amps | Bay Design Rating(1): Busbar Rating at 35°C<br>Amps | Special Plant(1): Transformer Rating<br>MVA | Special Plant(1): Shunt Cap Bank Rating at 40°C(5)<br>MVAr |
|---|---|---|---|---|---|---|
| 500 | 550 | Latrobe Valley | 4000 | 6000 | 600 | - |
| | | Metro | 4000 | 6000 | 1000 | - |
| | | Country | 3150 | 6000 | 370 | - |
| 330 | 362 | All | 3150 | 4500 | 600, 225 | 150, 225 |
| 220 | 245 | Latrobe Valley | 3150(2) | 4500 | 225, 150 | 100, 200 |
| | | Metro | 3150(2,3) | 6000(6) | 225, 150 | 100, 200 |
| | | Country | 3150(2) | 4500 | 150, 70 | 100, 150 |
| 66 | 72.5 | All | 1600 | 1585(4) | 60,40 | 25,50 |
| | | | 2000 | 2000(4) | 60,40 | 25,50 |
| | | | 3150 | 3300 | 60,40 | 25,50 |
| 22 | 24 | All | 1250(5) | 2500 | 30,20 | 12,25 |
| | | | 1600(5) | 2500 | 30,20 | 12,25 |
| | | | 2500(5) | 2500 | 30,20 | 12,25 |
| | | | 3150(5) | 2500 | 30,20 | 12,25 |

**Note 1:** These values are indicative and indicate the likely maximum capacity. AEMO, the connection applicant and any distribution utilities requirements over and above these requirements will also affect the ratings and will take precedence.

**Note 2:** While 3150 A is a standard, it is acceptable to use 2000 A post current transformers in conjunction with other plant provided that the current transformers do not limit the required rating. All dead tank circuit breakers must contain current transformers capable of the full circuit breaker rating.

**Note 3:** 4000 A circuit breakers (and connecting plant) are needed if 1000 MVA transformers, which have up to 50% overload rating, are connected.

**Note 4:** The 1585 A rating only applies to station rebuilds where the original copper busbars and supports are considered suitable for re-use. 2000 A busbars are only used where the largest transformers are expected not to exceed 150 MVA

**Note 5:** All plant must operate reliably and otherwise satisfactorily up to a maximum ambient temperature of 50°C. As part of any proposed design, AEMO shall be informed of the ambient temperature rating performance and any expected rating reduction over the range from 40°C to 50°C with information provided in increments of 1°C. AEMO may accept the proposed ambient temperature rating performance if it is appropriate or, if necessary, require the specification of higher-rated equipment.

**Note 6:** AEMO will determine whether new 220 kV busbars at metro terminal stations should be rated at 6,000 A or 4,500 A. This determination will be based on the expected ultimate requirements for that station. Busbars that will terminate transformers from a higher voltage, or other high capacity generation/transmission connections, shall be rated 6,000 A. Otherwise 220 kV busbars shall be rated 4,500 A.

**Note 7:** Transformer ratings are based on the ambient temperature and lifetime considerations specified in AS60076 and AS2374.

*Table B–2–2: Continuous rating (kA)*

| System Nominal Voltage | System Maximum Voltage | Location | Bay Design Rating | | Equipment Ratings | | |
|---|---|---|---|---|---|---|---|
| | | | Bus Withstand Current[3] | Peak Withstand Current[2,4] | Nominal Fault Level[5] | Peak Withstand Current[6] | X/R Ratio (CB Interruption)[7] |
| kV | kV | | $kA_{RMS}$ | $kV_{PEAK}$ | $kA_{RMS}$ | $kA_{PEAK}$ | |
| 500 | 550 | Latrobe Valley | 50 | 135 | 50 | 135 | 30-35 |
| | | Metro[9] | 50 | 135 | 50[12] | 135 | 30-35 |
| | | Country | 40 | 100 | 50 | 125 | 14 |
| 330[8] | 362 | All | 40 | 100 | 50[10] | 125 | 14 |
| 220 | 245 | Latrobe Valley | 50 | 135 | 50 | 135 | 30 |
| | | Metro[9] | 40 | 105 | 40 | 105 | 20 |
| | | Country | 26.2 | 71 | 40[12] | 105 | 20 |
| 66 | 72.5 | Latrobe Valley | 21.9 | 59 | 31.5 | 85 | 30 |
| | | Metro[9] | 21.9 | 59 | 31.5 | 85 | 30 |
| | | Country | 21.9 | 55 | 31.5 | 80 | 14 |
| 22 | 24 | Latrobe Valley | 26.2 | 71 | 31.5 | 85 | 30 |
| | | Metro[9] | 26.2 | 71 | 31.5 | 85 | 30 |
| | | Country | 26.2 | 71 | 26.2[11] | 71 | 26 |

**Note 1:** The fault levels shown may not be adequate for design in all instances. Some locations may require higher fault levels to allow buses to be connected together and any higher values are subject to negotiation.

**Note 2:** The majority of peak currents stated are directly related to the rms ratings by a standard factor of 2.5. Although, certain locations where there is a high ratio of inductance to resistance (X/R ratio) require higher peak currents and peak withstand ratings to be specified.

**Note 3:** The 50 kA rating for the Latrobe Valley 500 kV system is based on the effective rating of standard 63 kA plant when the high ratio of inductance to resistance is taken into account in addition to the probability that there will be separation of connections between future generation sources to reduce risk of total outages.

**Note 4:** Where X/R ratios in the range of 30-35 are expected, peak currents stated are directly related to the rms ratings by a maximum standard factor of 2.7.

**Note 5:** In order to obtain the required rms withstand when X/R ratios are high, nominal plant ratings may have to be discounted. For example, 50 kA at X/R = 30+ normally involves a nominal 63 kA circuit breaker tested specially to provide X/R = 30 interruption capability.

**Note 6:** While the peak withstand rating of plant items may exceed the bus ratings, the additional rating cannot be used unless the bus rating is increased. When X/R is >14, the peak withstands are higher than nominal.

**Note 7:** These unloaded X/R values are either in use or proposed, although either the AEMO or customer requirements will set actual ratings. The values have been limited by the maximum capabilities of circuit breakers presently obtainable. Standard circuit breakers are only capable of X/R = 14 and will be tested to a peak withstand value of 2.5 times the rms current.

**Note 8:** 330kV also includes 275 kV connections.

**Note 9:** MLTS and GTS are designated as Metro stations.

**Note 10:** This is a common rating for equipment for this voltage level.

**Note 11:** This is the currently understood to be the practical limit of arc-fault contained switchboards available at an economic cost. Switchboards are rated for faults of up to 1 second.

**Note 12:** This figure has been chosen to limit the range of equipment with a minimal cost over the required ratings.

*Table B–2–5: Fault Level Rating (kA)*