CONNECTING GENERATOR CLUSTERS TO THE VICTORIAN ELECTRICITY TRANSMISSION NETWORK: A TECHNICAL PERSPECTIVE

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Contents

Glossary

Definitions and abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics.
AEMO	Australian Energy Market Operator.
Connection application	Formal application to connect to the electricity network sent in writing to AEMO
Gas Declared Transmission System	Gas transmission pipe lines owned by APA group
Electricity declared shared network	The Minister, by Order published in the Government Gazette, may declare a transmission system, or a part of a transmission system, situated wholly or substantially in Victoria to be the declared transmission system. Electrical declared transmission network includes 500 kV and 220 kV transmission network
Flow path	Those elements of the electricity transmission networks used to transport significant amounts of electricity between generation centres and major load centres.
Forced outage	An unplanned outage of an electricity transmission network element (transmission line, transformer, generator, reactive plant, etc).
Generation proposal	A publicly announced plan to generate electricity often without a formal application submitted.
GWh	Giga watt hours.
Hub	Terminal station located so that multiple generators can be connected.
kV	Kilovolts. 1 kV = 1000 Volts
MW	Megawatts. 1 MW = 1 million Watts
Network capacity	The power limit in MW beyond which a network can not support.
Petajoule	Petajoule (PJ), SI unit, 1 PJ equals $1x10^{15}$ Joules. (3.6PJ = 1 TWH) Also PJ/yr or petajoules per year.
Planned outage	A controlled outage of a transmission element for maintenance and/or construction purposes, or due to anticipated failure of primary or secondary equipment for which there is greater than 24 hours notice.
Renewable generation	Electricity generation using resources which do not depend on fossil fuels and nuclear
RET	Renewable Energy Target.
SEA Gas Pipeline	The 680 km pipeline from Iona to Adelaide, principally constructed to ship gas to South Australia.
South-West Corridor	Region defined in the Victorian Annual Planning Report covering the region surrounding Moorabool to Heywood.
South-West Pipeline	The 500 mm pipeline from Lara (Geelong) to Iona.
Switched connection	Connection using automatically controlled circuit breaker so that outages on one side of the connection do not cause outages on the other side of the connection point.
TNSP	Transmission network service provider.

Transmission network	Connected lines which carry electricity at voltages in excess of 132 kV.
Terminal Station	Terminal station is a location where the transmission lines are switched.
VAPR	Victorian Annual Planning Report.
VENCorp	Victorian Energy Networks Corporation.

1 Purpose

In response to government initiatives on carbon policy, many new generation projects are seeking access to the Victorian Electricity Declared Shared Network. A large number of these projects seek connection in the same part of the network namely along the 500 kV transmission line between Moorabool and Heywood and in the vicinity of the Moorabool to Ballarat 220 kV transmission line.

There are technical and economic issues associated with the connection of many generation projects in the same area. It is not desirable to establish many connections on a high voltage transmission line, nor is it the most economic outcome overall.

This paper looks at some of the planning issues associated with the design and administration of many applications to connect, realising that it is unlikely that all projects will proceed. The timing of connections could also be affected by factors such as economic growth, government policy and the introduction of other technologies.

AEMO intends to keep new and potential generators informed of the concept of transmission hubs, the method of connecting generator clusters to these hubs and the work it is undertaking to progress this concept. The information provided is also intended to raise the awareness of the concept and the associated issues with regulatory agencies and policy makers.

2 Scope

This document discusses:

- the current network's capability and issues arising from connection of new generators.
- AEMO's approach for connecting multiple users to the electricity declared shared network.
- benefits provided by the hubs to the connecting parties.
- prospective power generation within the Regional Victoria (Ballarat region) and South-West Corridor to illustrate the concept of hubs and clusters.
- the possible staged development of hubs for 500 kV and 220 kV networks for accommodating the generation clusters between:
    - Moorabool and Ballarat
    - Moorabool and Heywood.
- flexibility of the hubs in accommodating future development of the transmission network.

3 Current Situation

AEMO's strategic objective is to develop an economical and technically robust approach for connecting generators to the electricity declared shared network in the long-term.

As the Victorian transmission network service provider (TNSP), AEMO receives and typically processes connection applications on a case-by-case basis, carefully addressing the short and long-term impact of their integration with the electricity declared shared network. This approach has worked well in the past but is raising concerns for the case where there are multiple connection applications in the same area expecting to connect approximately at the same time.

The technical requirements for connecting a new generator are primarily dependent on the:

- timing of the connection application
- location of the connection
- complexity of the connection arrangements and their flexibility for future development
- impact on the reliability of the electricity declared shared network
- project commissioning order, relative to other projects connecting to the electricity declared shared network in the same region.

Amid carbon emission concerns, AEMO has received many formal connection applications and enquiries from potential generators who are in the process of developing electricity generation proposals using energy resources other than coal. Additionally, there are a number of generation proposals that have been or are in the process of being assessed by the local council or state planning minister.

AEMO has received 5,000 MW of connection applications and enquiries wanting to connect to the Victorian transmission system. Of these, about 3,600 MW are expected to be connected to the 500 kV lines between Moorabool and Heywood and the rest to the 220 kV lines out of Ballarat.

These new generation development proposals are aiming to capitalise on Victoria's substantial wind and gas resources while utilising the existing electricity infrastructure along the south-western coast of Victoria and in the Ballarat region.

Such projects pose new challenges for transmission planning due to their dispersed nature and associated uncertainty of the generation projects proceeding. The technical challenge here for AEMO is to facilitate the timely connection of new generators at optimal cost, while maintaining current levels of power quality and acceptable transmission network reliability.

The wind generation developments as proposed exceed the present electricity declared shared network's capability in the Ballarat area (i.e. 220 kV transmission lines between Moorabool - Ballarat - Horsham) and between the Moorabool to Heywood region (i.e. the Moorabool - Heywood 500 kV line). With perfect foresight of which projects would proceed and by when, it would be relatively straight forward to design one or more cost effective connection points. There is however uncertainty that they will all proceed. On the other hand, if many of these projects proceed, the capacity of the existing network will require augmentation.

While the capacity of the existing Gas Declared Transmission system is limited for powering new, large gas-powered generation, the new generation proposals are making use of either the capacity available in other gas pipelines within the region or are building newly dedicated pipelines.

The potentially limited network capability for the future means AEMO continues to face the following issues:

- keeping the system's cost to the market to a minimum by reducing the planned transmission network outages required for connecting new generators to the transmission system
- maintaining the electricity declared shared network's reliability , including continuity of flow during construction , particularly through high-capacity interconnections
- developing sufficient transmission capacity, taking into account current connection applications, uncertainty of project timing and the expected future generation developments
- ensuring timely availability of transmission capacity to the potential generators.

4 AEMO's Options

AEMO's options for connecting new generators are:

- connecting each new generator through its own new dedicated terminal station potentially creating many short line segments, complex protection requirements and higher overall costs.
- connecting each new generator through an existing terminal station creating additional costs for those generators located remotely from existing terminal stations.
- creating strategically located new terminal stations as 'hubs' and connecting new generators to the closest hub potentially reducing overall economic costs while maintaining the integrity of the existing transmission network.

4.1 Dedicated Terminal Station Connection

AEMO's typical connection process is to establish a new terminal station at the location requested by the generator. New generators favour this approach where an existing terminal station is distant from its fuel source or the terminal station requires substantial augmentation to enable the connection.

In these cases, AEMO adopts a 'facilitatory' approach when connecting which specifies that the technical configuration of the terminal station must not impede the connection of future generators at that location; nor should it adversely affect the reliability or expandability of the electricity declared shared network or system security.

A drawback of this approach is that when a large number of generators need to connect to the electricity declared shared network, their relatively close proximity to each other potentially affects the reliability of the electricity declared shared network for those already connected.

Also, the network's availability is reduced by the many planned outages needed when connecting new generators to the electricity declared shared network; eg 600 hours of outages on the 500 kV line to connect a new terminal station.

Thus, this arrangement poses significant cost to the existing generators and does not capture the economic benefits that can be obtained by sharing the connection assets. There could be lower overall cost and better reliability if a coordinated approach was taken for connecting new generators.

4.2 Existing Terminal Station Connection

Some generators who have highly transportable fuel choose to connect at an existing station. This connection is a technically easy solution when the terminal station has significant spare capacity and the reliability or system security requirements (such as the ability to handle faults in the transmission system) will not be violated.

However, the benefits of this approach depend on the availability of a fuel resource near an existing terminal station. When this is not the case, there is significant cost associated with building either a fuel transport structure from the resource site to a terminal station (e.g. a gas pipeline) or transmission lines for transporting electricity generated from a location near the fuel resource to a terminal station (e.g. such as wind-generated electricity).

4.3 Creating New Connection Hubs

A third available option is to connect generators into hubs that are created at appropriate locations within an assigned region, like Regional Victoria or the South-West Corridor.

Creating new connection hubs is AEMO's approach for solving the technical issues associated with the connection of new generators to the electricity declared shared network. Hubs provide the following benefits to the connecting parties:

- they maintain the transmission system's reliability and ensure flow path continuity.
- they reduce the transmission constraints during construction, and during planned and unplanned outages.
- they allow for easier network expansion when accommodating future connections and system augmentations.
- they enable generation proponents to incorporate AEMO's planned connection arrangements and readily available infrastructure in their project plans.
- they save costs to connecting parties by sharing connection assets.

However, there is a risk that the expected economic benefits may not be achieved if the anticipated generator connections do not eventuate. This risk can be reduced by development of hubs in stages.

AEMO has considered various connection options for connecting new generators to a hub and believes that a switched connection (as shown in section 8) will ensure reliability, flexibility, expandability and maintainability of the electricity declared shared network to an acceptable level.

4.3.1 Hub Location Criteria

AEMO proposes that hub locations are determined by the following criteria:

- sufficient concentration of energy resource around the hub to make a generator cluster
- proximity to an existing transmission line corridor and the alignment with future transmission development plans
- minimising the overall cost of connecting generators to the collector hub
- the number of current generator enquiries, connection applications and projects with planning applications submitted to the Victorian Government, including the ability of the generators within the cluster to expand their capacity over time
- the ability of stakeholders to mitigate environmental impacts of both the development of the hub and the connection of respective generators to the hub
- accessibility to the hub site for construction and suitable construction transport infrastructure (such as roads, bridges, etc.)
- availability of easements or land for constructing the hub and the transmission lines connecting to it.

Based on the above criteria, a hub would be centrally located within a cluster of generators with a bias towards the larger generators within the cluster. Centrally positioning the hub would reduce the costs of building higher capacity lines and the overall loss in power transmission to the hub.

4.4 AEMO's Approach

Our initial views are that the development of hubs as a technically robust approach for dealing with the long-term technical challenges associated with connecting multiple generators within close proximity of each other.

AEMO is presently investigating the development of hubs along the 220 kV network in Regional Victoria and 500 kV network in the South-West Corridor to ensure long-term reliability of the shared Victorian transmission network.

AEMO will continue to work with new and potential generators, regulators and policy makers on the technical matters that are raised for connecting generators to the Victorian electricity declared shared network.

AEMO will also investigate regulatory and economic issues that may hinder the development of hubs within Victoria.

5 Prospective Power Generation within Victoria

Power generation and its supporting infrastructure within Victoria can be categorised using the type of energy source (i.e. fuel type) used in generating electricity. Figure 1 indicates the registered installed capacity of power generation, expressed in terms of the fuel resource as listed on the National Electricity Market (NEM) Registrations and Exemptions List[1].

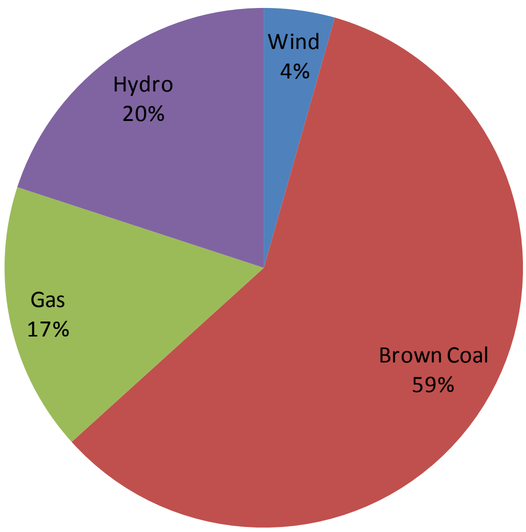

Figure 1: Victorian-Installed Generation Mix by Fuel Type[2]

AEMO is seeing increases in proposals for natural gas, wind and solar generation out of the many types of energy resources available in Victoria. Wind power in particular is gaining popularity in the new generation mix as a renewable resource in response to the Renewable Energy Target (RET) and likely drivers to reduce carbon emissions..

5.1 Wind Generation

The primary driver for wind generation development is an expanded Renewable Energy Target (RET) issued by the Australian Government, guaranteeing 20% of Australia's energy by 2020 will

[1] NEM Registrations and Exemptions List (http://www.aemo.com.au/registration/registration.html#electricity)

[2] NEM Registrations and Exemptions List (http://www.aemo.com.au/registration/registration.html#electricity)

be produced by renewable sources. This expanded RET equates to about 45,000 GWh of annual electricity being generated from renewable sources.

Assuming the RET is met, the contribution of wind generation combined with other renewable energy sources such as geothermal, solar, biomass[3] and tidal towards this target is around 6,000 to 8,000 MW throughout Australia.

A wind map in Figure 2 shows the average wind speeds 65m above the ground across south-western Victoria. Areas with annual average wind speeds around 6 m/s or greater are generally considered suitable resources for wind generation development.

The map highlights there is an abundance of wind resource in the areas along the southern coastal region between Portland and Geelong, and around Ballarat. These areas are also supported by significant transmission infrastructure, as seen on the map.

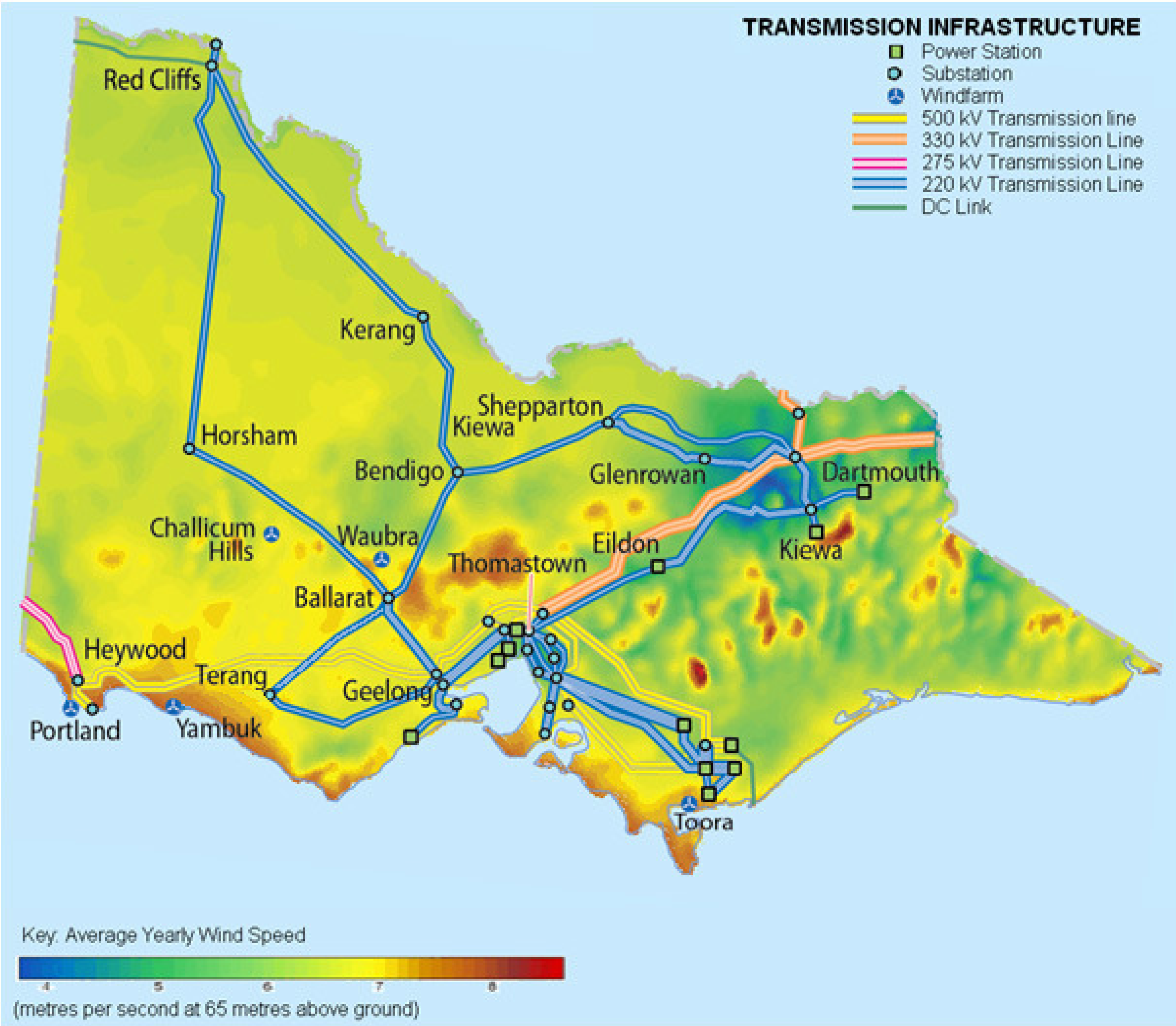

Figure 2: Victorian Wind Resource map[4]

[3] Capacity factors for wind, geothermal, solar and biomass are assumed to be approximately 0.35, 0.9, 0.25 and 0.9 respectively.

[4] wind map published in 2006 by sustainability Victoria has been used in creating this figure. http://www.sustainability.vic.gov.au/www/html/2123-wind-map.asp

5.2 Gas Generation

Natural gas power generation (GPG) is a popular form of new electricity generation within Victoria. Operational statistics maintained by AEMO reveal that approximately an average of 25 PJ of gas is being used per year to support electricity generation within Victoria; this equates to about 10% of the total gas usage in Victoria.

Table 1 below indicates the conventional natural gas resource/reserves estimated at 31 December 2008[5]. Figure 3 indicates the relative location of these resources.

Table 1: Summary of Conventional Gas Resources/Reserves Estimates at 31 December 2008 in Petajoules (PJ)

Basin	Initial (Probable)	Remaining (Probable)	Remaining (Possible)	Contingent (Probable)	Prospective
Adavale	26	17	21	4	5
Bass	552	502	617	115	172
Bowen and Surat	6	6	8	2	3
Cooper and Eromanga	7,562	1,173	2,262	1,089	1,628
Gippsland	15,714	7,647	9,910	2,263	3,383
Gunnedah	6	6	8	2	3
Otway	1,990	1,613	2,339	726	1,085
TOTAL	27,010	11,178	15,526	4,348	6,497

Figure 3: Gas Resources in Victoria (Source: Gas Statement of Opportunities 2009)

[5] Gas Statement of Opportunities 2009 published by AEMO.

The statistics in *Table 1* highlight that a considerable amount of gas resource in the Otway and Bass basins is available for electricity generation.

The gas-fired generating stations being considered in the South-West Corridor are listed in *Table 5*, along with prospective wind farms.

The South-West Pipeline between Melbourne and Port Campbell can sufficiently supply potential gas-powered generation near Moorabool. However, the capacity of the gas transmission system in the vicinity of Ballarat and Bendigo is extremely limited. The gas transmission system is unable to supply any significant gas-powered generation in the region without augmentation.

The gas pipeline between Ararat and Horsham, that is owned and operated by Gas Pipelines Victoria, may have sufficient capacity to supply a small gas-powered generator.

The Gas Declared Transmission System in the South-West Corridor needs augmentation to support new gas-powered generation. However, the SEA Gas pipeline, which supplies gas from Port Campbell to Adelaide, will have sufficient capacity to do so.

New large gas-powered generation may be supplied from the Otway Basin gas production facilities via dedicated pipelines. For example, the 500 MW Mortlake power station with a planned ultimate capacity of around 1,000 MW, will be supplied with natural gas via a 83 km dedicated underground natural gas transmission pipeline from the Port Campbell area.

The proposed Shaw River power station, with ultimate planned capacity of 1,500 MW, will involve the development of an approximate 100 km underground gas transmission pipeline from Port Campbell to this power station.

6 Potential Hubs in Regional Victoria

Regional Victoria is a geographical location in the south-west of Victoria, defined in the Annual Planning Report Victoria 2009 as the region with a transmission network linking the terminal stations Bendigo, Ballarat, Moorabool and Terang.

In this section, the potential locations for developing collector hubs for a 220 kV network within Regional Victoria are discussed, taking into consideration the criteria outlined in Section 4.3.1.

6.1 Regional Victoria Generation Potential

There are substantial generation resources in Regional Victoria. The Vision 2030 Update[6] predicts a ‘Strong Economic Growth’ scenario of 7,725 MW of installed generation within the region by 2030.

Table 2 below shows a list of potential wind-generating facilities totalling 2,100 MW, as identified by the Australian Bureau of Agricultural and Resource Economics (ABARE)[7] within the region.

[6] Vision for Victoria’s Energy Transmission Networks, Published by VENCorp 2009 (http://www.aemo.com.au/planning/v400-0003.pdf)

[7] http://abare.gov.au/publications_html/energy/energy_09/energy_09.html

Table 2: Potential Wind Generators in Regional Victoria (central-west)

Dwg. Reference	Project	Fuel Type	Capacity (MW)	Probable start up
W1	Ararat Wind Farm	Wind	225	2011
W2	Crowlands Wind Farm	Wind	126	Not available
W3	Lexton Wind Farm	Wind	38	2011
W4	Stockyard Hill Wind Farm	Wind	484	Not available
W5	Tuki Wind Farm	Wind	38	Not available
W6	Waubra North Wind Farm	Wind	75	Not available
W7	Yendon	Wind	150	Not available
W8	Moorabool Wind Project	Wind	220 - 360	2014
W9	Mount Mercer Wind Farm	Wind	192	2010
W10	Elaine	Wind	90	Not available
W11	Morrisons	Wind	195	Not available
W12	Lal Lal Wind Farm	Wind	131	2012
W13	Yaloak	Wind	30	Not available
W14	Woorndoo	Wind	30	Not available

The potential wind generators are geographically dispersed by nature as can be seen in Figure 4 Figure 4. The current wind generation proposals show there is 150 MW of generation within a 10 km radius of the Ballarat terminal station, with another 1,000 MW located between the Moorabool and Ballarat terminal stations, and approximately 1,000 MW of prospective wind farm capacity between the Ballarat and Horsham terminal stations.

Figure 4 displays the relative location of these generators from the Victorian transmission network and existing terminal stations.

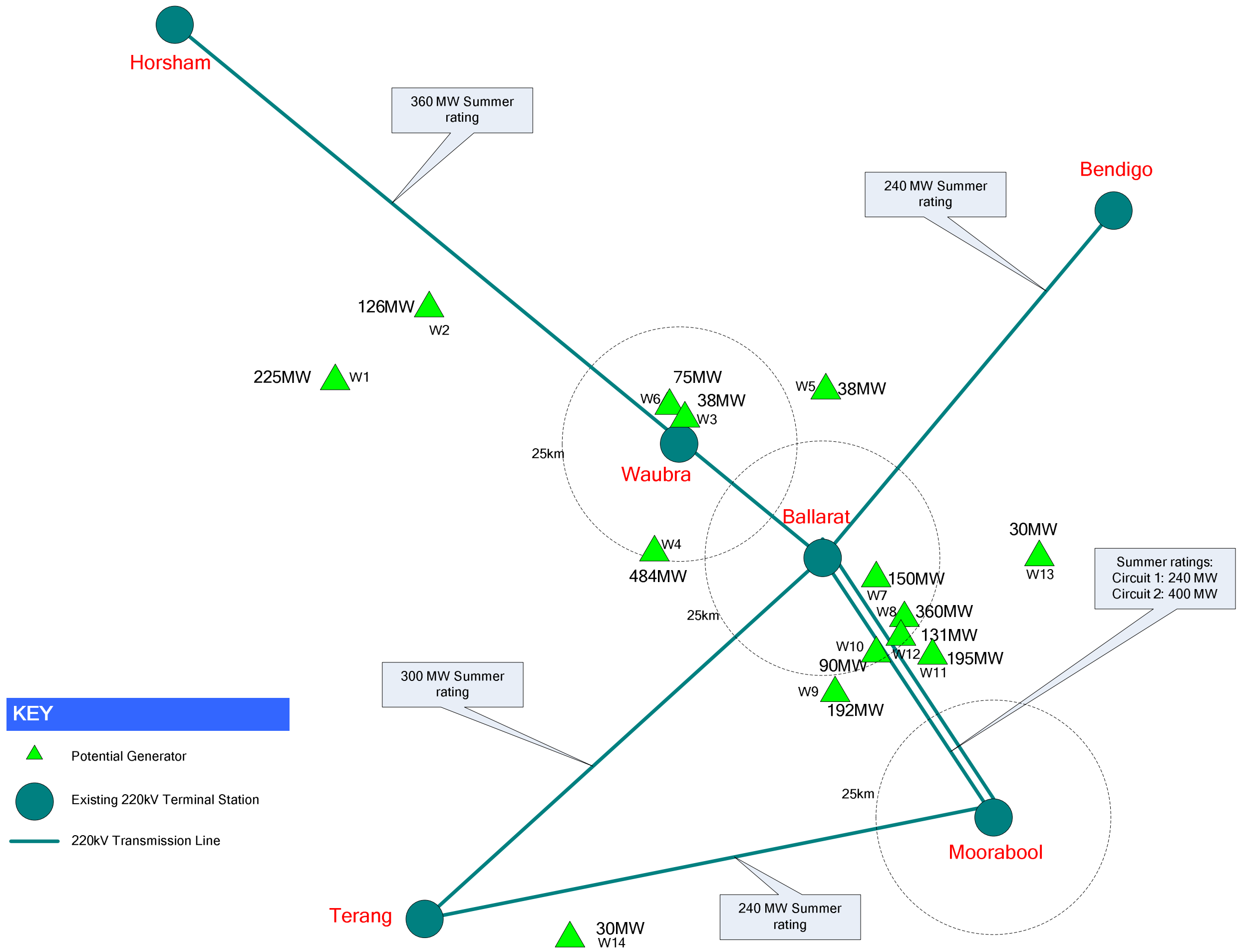

Figure 4: Relative Locations of Potential Regional Victoria Generators[8]

6.2 Current Regional Victoria Network Capacity

The transmission lines likely to be affected by the generation in this area are shown in Figure 4.

In *Table 3* below, two transmission lines that are running between the Moorabool and Ballarat terminal stations (Moorabool - Ballarat circuits No.1 and No.2) are more likely to transmit the majority of any additional generation from the region. The lines are currently loaded to approximately 50% of their rating during summer.

These two lines will be loaded to full capacity when the generation between Moorabool and Ballarat exceeds approximately 1,000 MW. Additional transmission capacity may be needed when the generating capacity increases between Moorabool and Horsham terminal stations.

[8] In some cases, the maximum line capacity is limited below what is indicated in Table 3 following due to capacity limitations associated with the terminal equipment. These limitations can be relieved with minor modifications to the equipment or transmission network.

Table 3: Transmission Capacity Available

LINE	MAXIMUM CAPACITY OF TRANSMISSION LINE		PERCENTAGE LOADING ON THE LINE AT PRESENT (WITH ALL CIRCUITS IN SERVICE)
	CURRENT (A)	APPROX POWER FLOW (MW)	
Moorabool - Ballarat circuit No.1	710	240	52.9%
Moorabool - Ballarat circuit No.2	1,180	400	41.2%
Ballarat - Waubra - Horsham	1,050	360	21.4%
Ballarat - Terang	910	300	17.6%
Moorabool - Terang	710	240	38%

A small increase in transmission capacity over the above designed values can be realised during higher wind speeds, if wind monitoring equipment are installed along these lines.

6.3 Future Regional Victoria Network Development

Predicted development in Regional Victoria indicates that the Victorian transmission network will require a major augmentation as generation grows. The 'Vision 2030 Update' expects augmentations to at least these lines:

- Ballarat - Bendigo
- Ballarat - Horsham
- Moorabool - Terang
- Moorabool - Ballarat
- Ballarat - Terang.

The possible augmentations required involve upgrading existing 220 kV lines, replacing 220 kV lines with high capacity and low resistance lines, building additional 220 kV lines and/or replacing the 220 kV lines with 500 kV lines to increase power flow capacity. Line augmentations will be dependent on the precise location and timing of new generation developments in the future.

6.4 Location of Hubs in Regional Victoria

The merits of existing terminal stations at Horsham, Waubra, Ballarat and Moorabool, plus potential new terminal stations near the proposed wind farms should be considered when determining the possible locations for hubs in Regional Victoria.

Figure 5 displays the relative location of the potential generators from the Victorian transmission network and the potential hub locations.

Possible locations for hubs in Regional Victoria considering the relative locations of the potential generators are evaluated against selection criteria in Section 4.3.1. The same criteria and approach can be used for assessing the suitability of any other location as hubs if the circumstances change.

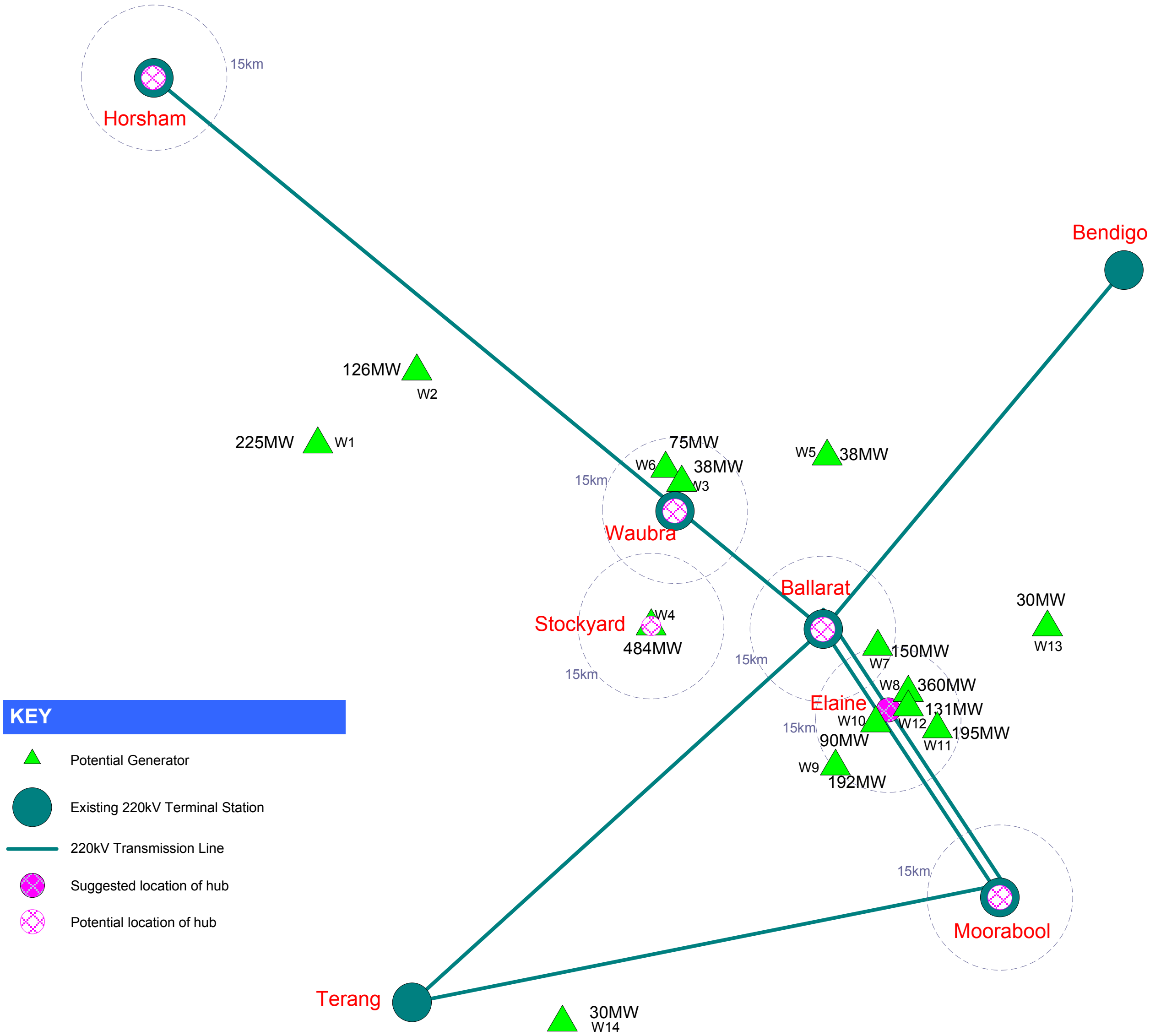

Figure 5: Potential Collector Hub Locations in Regional Victoria

Table 4: Assessment for Hub Locations within Regional Victoria

HUB SELECTION CRITERIA	HORSHAM	WAUBRA	BALLARAT	ELAINE	MOORABOOL	STOCKYARD
Concentration of energy resource around the hub sufficient to make a generation cluster	x	✓	✓	✓	X	✓
Proximity to an existing transmission line corridor	✓	✓	✓	✓	✓	x
Accessibility for construction and availability of suitable transport infrastructure	✓	✓	✓	✓	✓	✓
Sufficient generation enquiries and connection applications at present	x	x	x	✓	x	x
Overall cost of connecting generators to the hub	x	✓	✓	✓	x	x
Ability to mitigate environmental impacts	TBA	TBA	TBA	TBA	TBA	TBA
Availability of land for line easements or terminal stations. (under investigation)	TBA	TBA	TBA	TBA	TBA	TBA
Rating Result	**2/7**	**4/7**	**4/7**	**5/7**	**2/7**	**2/7**

Note: TBA indicates items still to be assessed. Ability to mitigate environmental impacts and availability of suitable land for line easements or terminal stations are critical in selecting a satisfactory site for a hub. AEMO has not yet assessed any sites against these criteria and hence do not consider any sites more or less favourable on the basis of environmental impacts and land/easement availability.

Following the assessment results in *Table 4*, and subject to the availability of land and line easements as well as the ability to satisfactorily manage the environmental impacts, AEMO considers that a new hub could be established between the Moorabool and Ballarat terminal stations, approximately 25 km south east of Ballarat near Elaine (Elaine hub).

In Elaine's vicinity, there is wind generation potential exceeding 1,000 MW. The development of Elaine hub could be staged to match connection of new generation likely to take place at different points in time. As will be discussed in depth in Section 8, the initial development stage could be a single transformer station with only one 220 kV line switched at the hub. The hub could then be expanded as the generating capacity grows.

Provision could be made for the future connection of a double circuit 500 kV line through the region in the event that capacity grows to a level that justifies such a line.

Presently, there are not enough existing generation applications or enquiries near Waubra to justify a hub at or near Waubra, but the existing terminal station in Waubra may be developed into a hub in the future if required.

7 Potential Hubs in the South-West Corridor

The two Moorabool to Heywood 500 kV lines are part of a Victorian region denoted as the 'South-West Corridor', as defined in the Victorian Annual Planning Report Victoria 2009. The transmission lines run directly between the towns Moorabool and Heywood and span approximately 270 km.

In Section 7, the potential hub locations for a 500 kV network within the South-West Corridor are discussed, taking into consideration the criteria outlined in Section 4.3.1.

7.1 South-West Corridor Generation Potential

Table 5 below shows a list of potential generating facilities totalling 6,200 MW, as currently identified by ABARE[9] for sites located approximately 50 km within the No.1 and No.2 Moorabool to Heywood lines. Some of these generating facilities have been reported in Section 6 for Regional Victoria to show the relative locations of proposed generator clusters.

Table 5: Potential Generators in the South-West Corridor

Dwg. Reference	Project	Fuel Type	Capacity (MW)	Probable start-up
W15	Mortlake Stage 1	Gas	550	2010
W16	Mortlake Stage 2	Gas	450	Not available
W17	Darlington Wind Farm	Wind	270-450	2012
W18	The Sisters Wind Farm	Wind	30	2013
W19	Drysdale Wind Farm	Wind	30	2011
W20	Mortlake Wind Farm	Wind	144	Not available
W21	Woorndoo (Salt Creek)	Wind	30	Not available
W22	Mount Gellibrand Wind Farm	Wind	232	Not available
W23	Hawkesdale Wind Farm	Wind	62	2011
W24	Naroghid Wind Farm	Wind	42	2011
W25	Orford Wind Farm	Wind	100	Not available
W26	Portland Stage 4	Wind	54	Not available
W27	Shaw River Stage 1	Gas	500	2012
W28	Shaw River Stage 2 & 3	Gas	1,000	Not available
W29	Tarrone Wind Farm	Wind	30-40	2013
W30	Macarthur Wind Farm	Wind	330	2010
W31	Berrybank Wind Farm	Wind	180-250	2011
W32	Woolsthorpe Wind Farm	Wind	40	2011
W33	Ryan Corner Wind Farm	Wind	136	2011
W34	Oaklands Hill Wind Farm	Wind	63	2011
W35	Morton's Lane Wind Farm	Wind	30	Not available
W36	Tarrone Power Station	Gas	500	2012

[9] http://abare.gov.au/publications_html/energy/energy_09/energy_09.html

Figure 6 below displays the relative locations of the generators listed in *Table 5* above. There is about 4,400 MW of generation expected within 30 km of the Moorabool - Heywood lines. Most of this generation is likely to connect to the 500 kV Moorabool - Heywood lines; however, some may also connect to the Terang - Moorabool or Ballarat - Terang 220 kV lines.

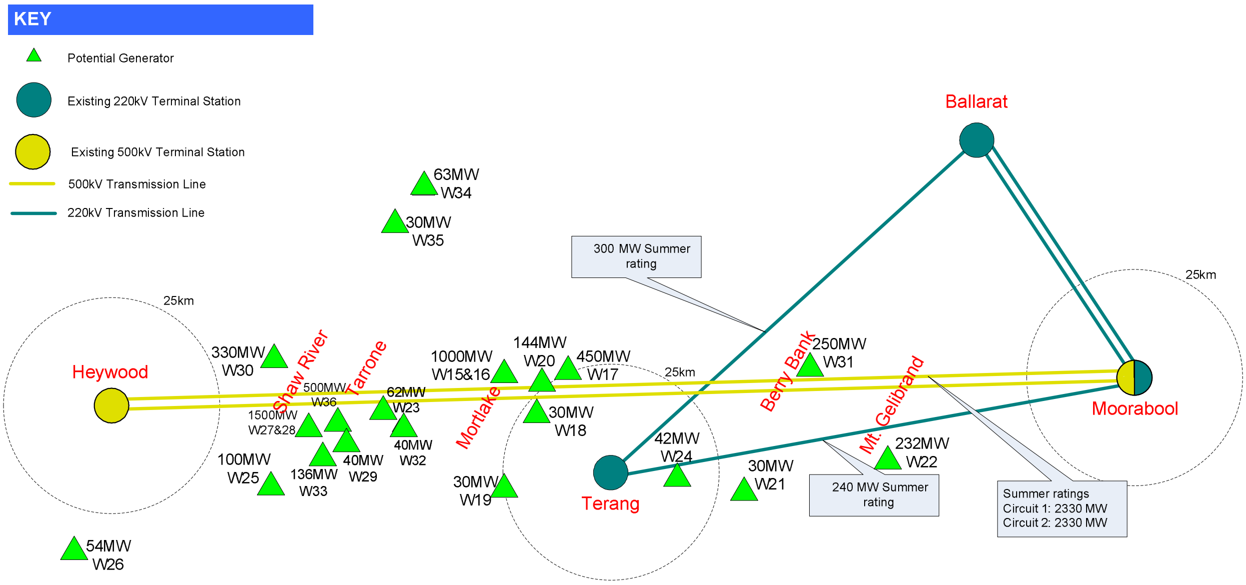

Figure 6: Relative Locations of Potential South-West Corridor Generators

7.2 Current South-West Corridor Network Capacity

As seen in *Table 6*, the two transmission lines between the Moorabool and Heywood terminal stations are currently loaded to approximately 20% of their rating for summer respectively. Significant capacity is thus available in these circuits for the connecting of new generation, but the indicated maximum capacity may not be realised due to other considerations such as stability of the power system.

Table 6: Transmission Capacity Available

LINE	MAXIMUM CAPACITY OF TRANSMISSION LINE		PERCENTAGE LOADING ON THE LINE AT PRESENT (WITH ALL CIRCUITS IN SERVICE)
	CURRENT (A)	APPROX POWER FLOW (MW)	
Moorabool - Heywood circuit No.1	3,000	2,330	19%
Moorabool - Heywood circuit No.2	3,000	2,330	19%
Ballarat - Terang	910	300	18%
Moorabool - Terang	710	240	38%

7.3 Future South-West Corridor Network Development

The transfer capacity of the South-West Corridor could potentially required to be increased approximately to 8,500 MW by 2030 depending on generation developments, according to the Vision 2030 Update[10]. To provide for this capacity a number of options are being presently considered as a part of the joint transmission planning between South Australia, Victoria and New South Wales. One option is to establish two new 500 kV transmission lines between the Moorabool and Heywood terminal stations.

7.4 Location of Hubs in the South-West Corridor

The merits of terminal stations at Heywood and Mortlake (which is currently under construction), plus the potential terminal stations near new generators should be considered in determining the suitable locations for hubs in the South-West Corridor.

Figure 7 displays the relative location of the proposed generators from the Victorian transmission network and the potential hub locations. In this assessment while the hubs near proposed generators Tarrone, Shaw River, Mt Gellibrand and Berry Bank are considered as examples, the suitability of locations near other proposed generators could be assessed using the same approach and criteria.

The hubs' location assessment is detailed in Table 7.

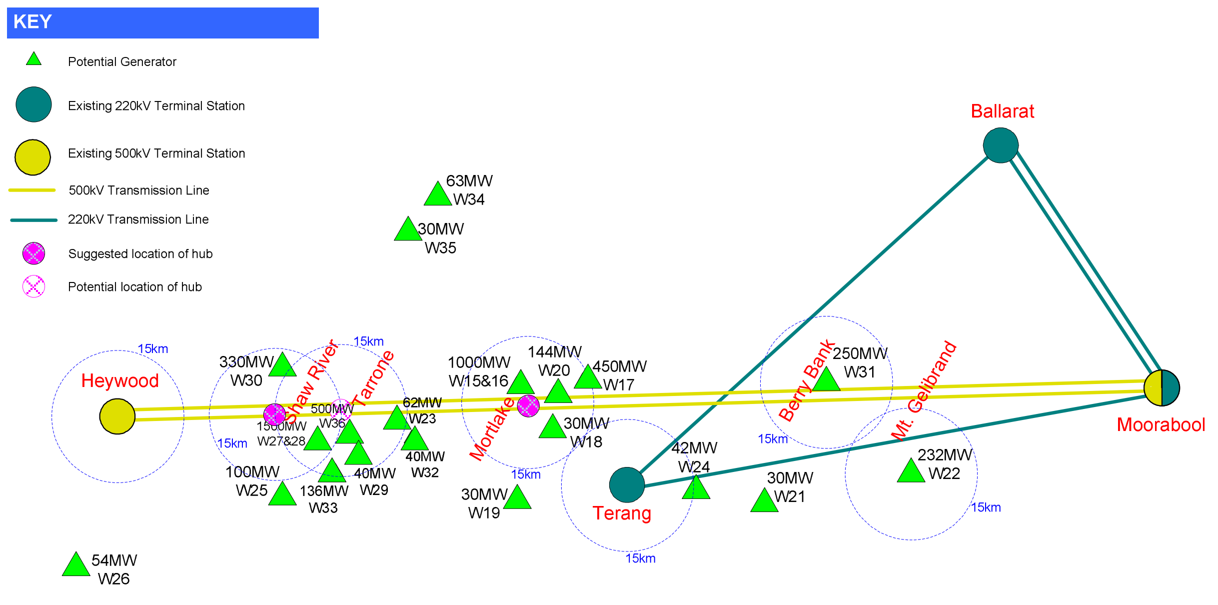

Figure 7: Potential Collector Hub Locations in the South-West Corridor

[10] Published by VENCorp, 2009 (http://www.aemo.com.au/planning/v400-0003.pdf)

Table 7: Assessment for Hub Locations within the South-West Corridor

HUB SELECTION CRITERIA	HEYWOOD	TARRONE	SHAW RIVER	MORTLAKE	MT GELLIBRAND	BERRYBANK
Concentration of energy resource around the hub sufficient to make a generation cluster	x	✓	✓	✓	X	x
Proximity to an existing transmission line corridor	✓	✓	✓	✓	✓	✓
Accessibility for construction and availability of suitable transport infrastructure	✓	✓	✓	✓	✓	✓
Sufficient generation enquiries and connection applications at present	x	✓	✓	✓	X	x
Overall cost of connecting generators to the hub	x	✓	✓	✓	X	x
Ability to mitigate environmental impacts	TBA	TBA	TBA	TBA	TBA	TBA
Availability of land for line easements or terminal stations. (under investigation)	TBA	TBA	TBA	TBA	TBA	TBA
Rating Result	**2/7**	**5/7**	**5/7**	**5/7**	**2/7**	**2/7**

Note: TBA indicates items still to be assessed. Ability to mitigate environmental impacts and availability of suitable land for line easements or terminal stations are critical in selecting a satisfactory site for a hub. AEMO has not yet assessed any sites against these criteria and hence do not consider any sites more or less favourable on the basis of environmental impacts and land/easement availability.

As per the assessment results in *Table 7, Tarrone, Shaw River and Mortlake equally qualify to locate a hub. Given the close proximity of Tarrone and Shaw River (within 8 km of each other) and the connections AEMO currently knows about, it would be economical to develop only one of these locations as a hub.* Shaw River may be more suitable as a location when compared to Tarrone due to the larger generating capacity planned at Shaw River; however, the order of commissioning these projects will favour one location over the other.

Subject to the availability of land and line easements as well as the ability to satisfactorily manage the environmental impacts, AEMO considers that it is possible to establish two new hubs between the Moorabool and Heywood terminal stations, as shown in *Figure 7*. Of the nominated hubs, one would be located approximately 50 km east of Heywood, at Tarrone or Shaw River. The terminal station presently under construction, located about 25 km north-west of Terang in Mortlake, could be expanded and developed as the other hub.

Thermal ratings of the components and physical space availability may be limiting factors for how much generation can be connected at these two hubs; thus additional hubs may need to be built once their designated limits are reached.

The identified proposed generator cluster between Terang and Moorabool does not have sufficient high density of prospective generators to justify a hub. Therefore, these generators may connect radially to the nearest point on the Moorabool -Terang 220 kV transmission line or to Terang terminal station.

Matching the potential generation resources within the area, it is expected that a hub at either Tarrone or Shaw River would ultimately have the capacity to connect approximately 2,000 MW - 2,500 MW of generation. A hub at Mortlake would have capacity to connect about 1,500 MW - 2,000 MW of generation.

8 Design and Development of Hubs

The hubs would be developed in stages, keeping in line with the generation growth. As seen above, there will be two major hub designs: one for a 220 kV network in Regional Victoria and the other for a 500 kV network in the South-West Corridor.

The key features of the ultimate design for each hub type are:

- capacity for present and future incoming and out going transmission lines
- switched connection to the transmission network, to ensure through-flow reliability
- sufficient transformer and feeder capacity to connect the future generators
- ability to expand to three voltage levels (132 kV, 220 kV and 500 kV) if required
- ability to develop in stages as required.

Sections 8.1and 8.2 that follow indicate the possible development stages of the 220 kV and 500 kV hubs. Considerations such as stability of the power system following a transmission fault may require more secure connection arrangements. Further enhancement of the reliability of the switching arrangements shown may be considered on a case by case basis after undertaking more detailed analysis.

8.1 Hub Design for a 220 kV Network in Regional Victoria

Figure 8 shows the first stage of a 220 kV hub development. In this stage, it is anticipated that the capacity of the generator connecting to the network will be less than approximately 250 MW. The generator will be connected to a single circuit through a switched connection, commonly known by the engineering term ‘breaker and half connection’.

While this connection has the advantage that the through-flow of the transmission system can be maintained with only a very small marginal reduction in the reliability, it has the disadvantage that an outage (either planned or unplanned) of the transmission circuit will also force the generator to be disconnected from the system.

The hub configurations use the following representative symbols:

Transformer

Isolator (without circuit breaker)

Circuit Breaker (with isolators)

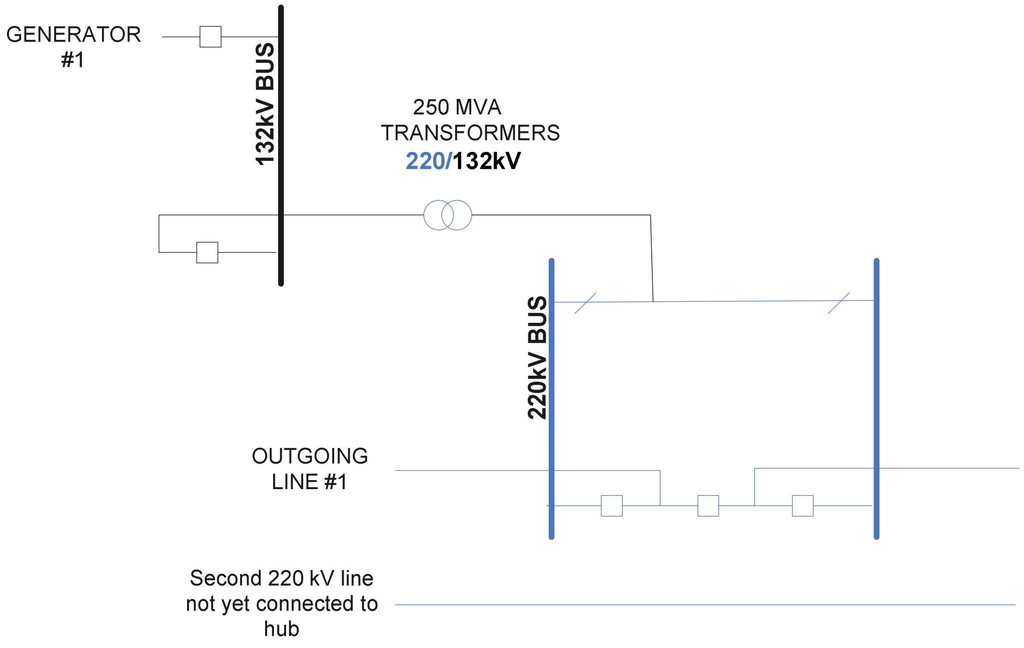

Figure 8: Stage 1 of 220/132 kV Hub to Connect Generation Capacity in the Range 0 MVA - 250 MVA

Figure 9 that follows shows the second stage of a 220 kV hub development, which enables the connection of generation up to approximately 500 MW. In this stage, a second transmission circuit will also be connected to the hub to provide higher hub transmission capacity and increase the reliability of generator connections.

This configuration will maintain the generator connection for a planned or forced outage of a single transmission circuit.

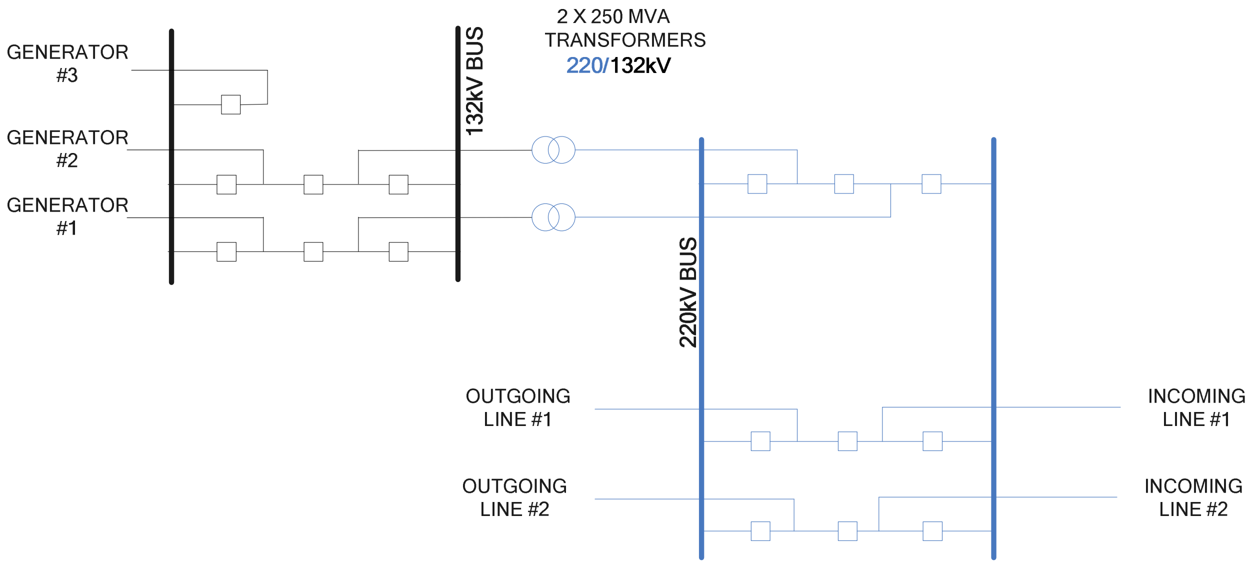

Figure 9: Stage 2 of 220/132 kV Hub to Connect Generating Capacity in the Range 250 MVA - 500 MVA

Figure 10 demonstrates the ultimate development layout of a 220 kV hub. Depending on the capacity of generation available for connecting to the Victorian transmission network through a

220 kV hub, it is feasible to expand the hub when needed by connecting future 500 kV or 220 kV transmission lines.

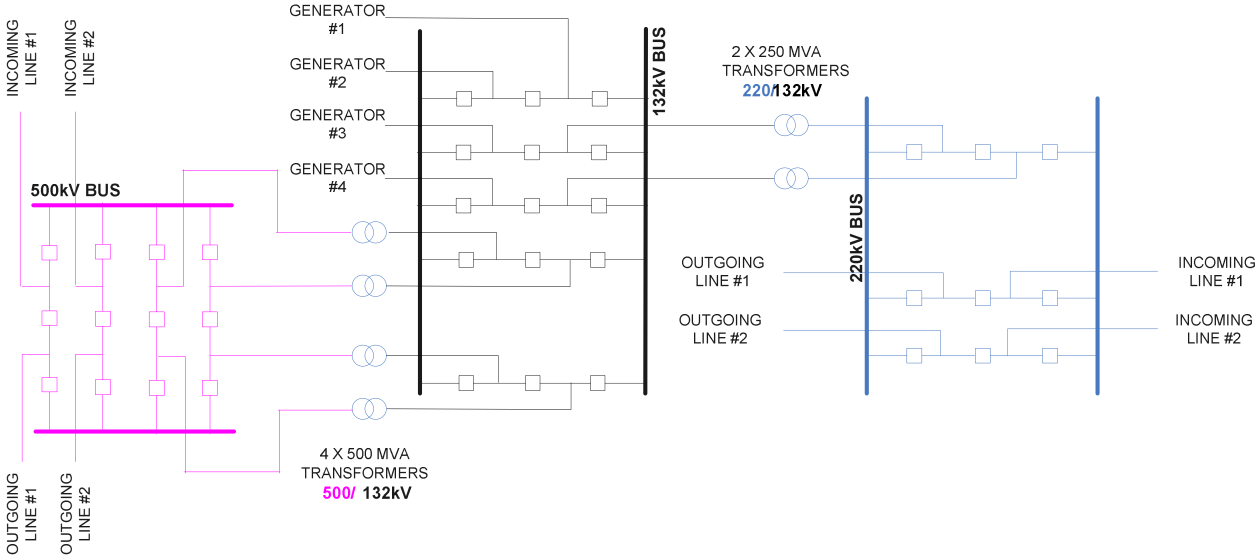

Figure 10: Stage 3 - Ultimate Layout Option for 500/220/132 kV Collector Hub

8.2 Hub Design for a 500 kV Network in the South-West Corridor

The first stage of developing a 500 kV hub is shown in Figure 11. In this stage it is anticipated that the capacity of the generator connecting to the network will be less than approximately 500 MW. Similarly to the 220 kV hub configuration, the generator would be connected to a single 500 kV circuit via a switched connection.

Again, this connection has the same advantage and disadvantage described in Section 8.1.

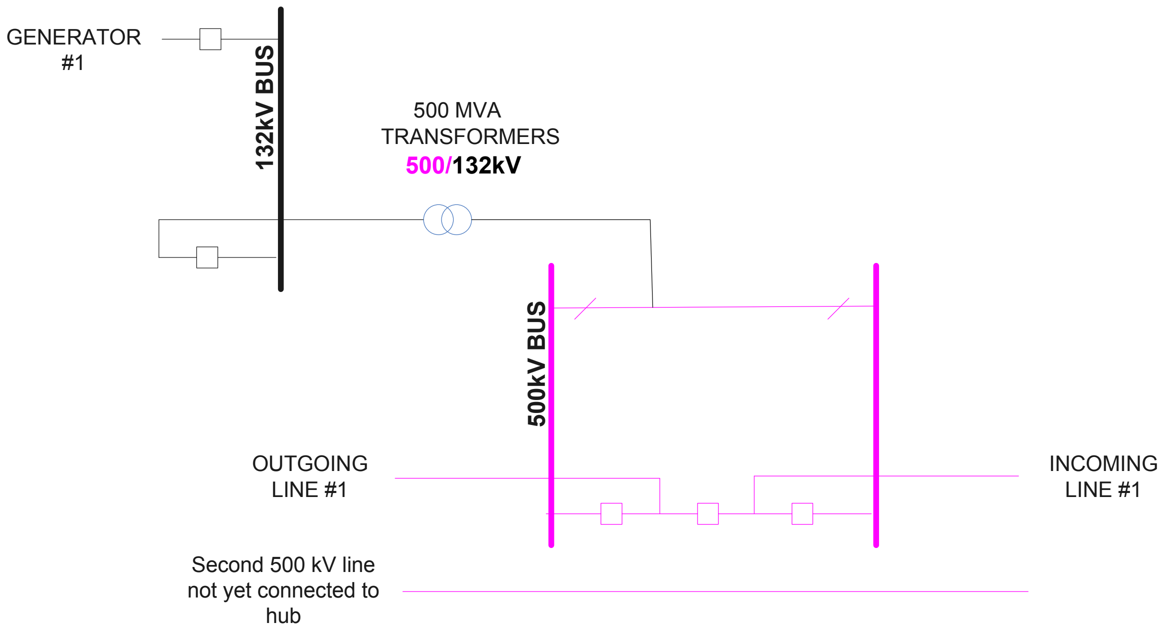

Figure 11: Stage 1 of 500/132 kV Hub for Connecting Generating Capacity in the Range of 0 MVA - 500 MVA

Figure 12 shows the second stage of a 500 kV hub development, which enables connection of generation up to approximately 1,000 MW. In this stage, a second transmission circuit would also be connected to the hub to provide higher hub transmission capacity and increase the reliability of generator connections.

This configuration would not disconnect the generators for a planned or forced outage of a single transmission circuit.

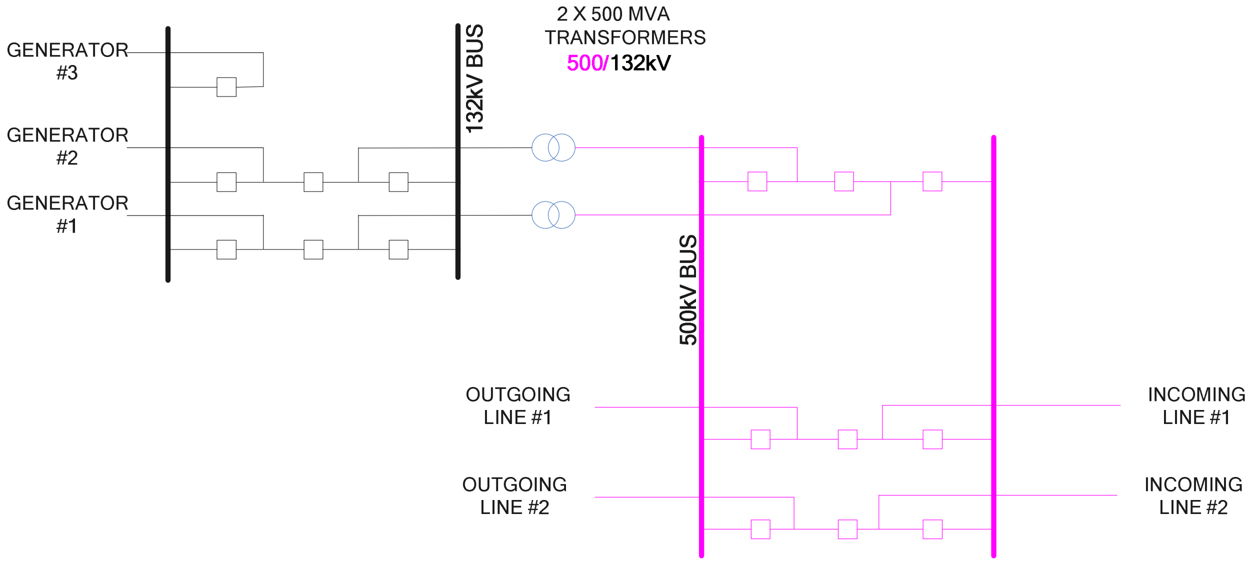

Figure 12: Stage 2 of 500/132 kV Hub for Connecting Generating Capacity in the Range of 500 MVA - 1,000 MVA

Figure 13 demonstrates the ultimate development layout of a 500 kV hub. Depending on the capacity of generation available, it is feasible to expand the hub to accommodate both 500 kV and 220 kV generator connections, via existing or new transmission lines.

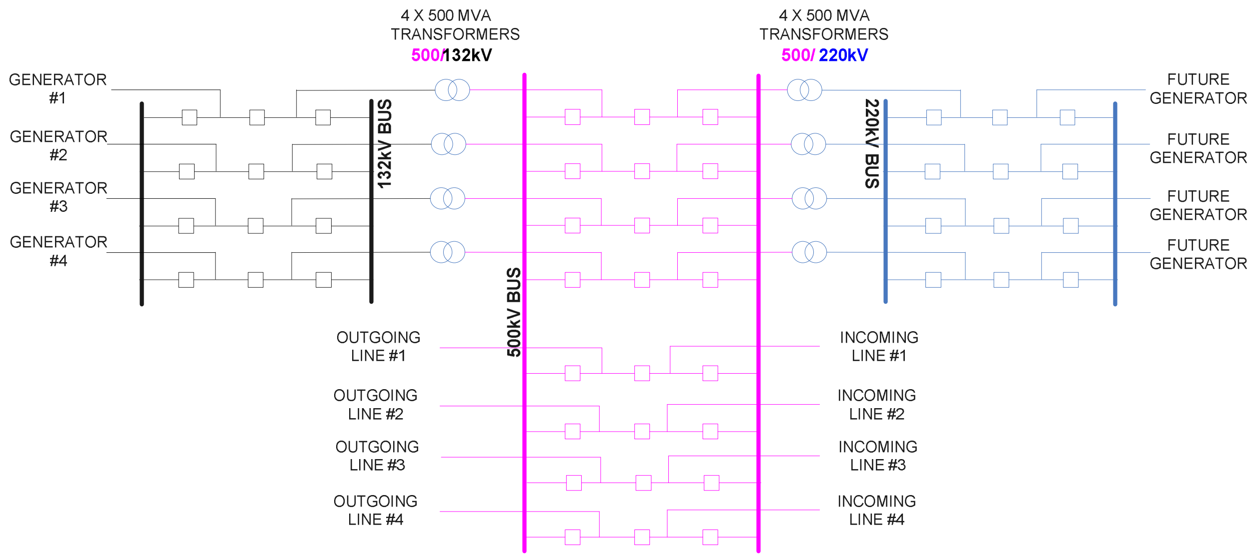

Figure 13: Stage 3 - Ultimate Layout of 500/220/132 kV Hub