Victorian Annual Planning Report

July 2018

Electricity transmission network planning for Victoria

Important notice

PURPOSE

The purpose of this publication is to provide information relating to electricity supply, demand, network capability and development for Victoria's electricity transmission declared shared network.

AEMO publishes the Victorian Annual Planning Report (VAPR) in accordance with clause 5.12 of the National Electricity Rules. This publication is based on information available to AEMO as at March 2018, although AEMO has incorporated more recent information where practical.

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VERSION CONTROL

Version	Release date	Changes
1	4/07/2018	

Executive summary

The Australian Energy Market Operator (AEMO) is responsible for planning and directing augmentation on the Victorian electricity transmission Declared Shared Network (DSN), and for publishing the *Victorian Annual Planning Report* (VAPR). The VAPR considers the adequacy of the DSN to meet Victoria's future reliability and security needs efficiently over the next 10 years.

The Victorian DSN has been performing well while, in common with other power systems across Australia and globally, being subject to increasing operational challenges.

The key focus areas for the DSN are:

- **Control of voltages in the power system,** which is now experiencing different patterns of power flow due to the changing generation mix and distributed energy resources (DER).
  - AEMO has commenced a Regulatory Investment Test for Transmission (RIT-T) for increasing reactive power support[1] to help manage voltage at times of low grid demand.
- **The ability of the network to connect renewable generation** and unlock its potential contribution by avoiding inefficient congestion on transmission lines.
  - AEMO is progressing the Western Victoria Renewable Integration RIT-T which will identify the preferred option for augmentation, as well as the optimal timing for investment.
- **Managing reducing levels of system strength** in a system with a greater proportion of non-synchronous generation connecting to remote renewable energy zones (REZs).
  - The VAPR provides information to assist prospective parties looking to connect new generation at these REZs in Victoria.
  - AEMO, as the system operator, will determine system strength requirements for Victoria, as well as other NEM regions, and identify any fault level shortfall, by July 2018.
- **Integrating network development in Victoria to match the national development pathway identified in AEMO's Integrated System Plan (ISP)**[2] which will support optimised integration of existing resources, renewable generation, DER, and storage, to minimise costs to consumers.
  - AEMO's analysis indicates that augmentations within the Victorian DSN which support increased Victorian exporting capability on the Victoria – New South Wales interconnector is economically justifiable, and a RIT-T should begin in the next year.

For the first time, the VAPR also includes consideration of asset replacement, retirement and de-rating. This is an important development in the regulatory regime, seeking to ensure all network investment, whether to augment the network or replace or refurbish existing assets, is aimed at efficiently meeting future needs.

AEMO will continue to work with industry and government to promote efficient network and non-network solutions to meet the needs of the DSN and keep it operating securely and reliably for Victorian businesses and households.

Performance of the Victorian DSN in the last year

The Victorian DSN performed well in the last year while being subject to increasing operational challenges. Notable observations from the past 12 months are:

[1] An AC (alternating current) power system, like Australia's National Electricity Market, operates using both active (real) and reactive power. Active power moves through the system and is delivered to consumers. Reactive power regulates voltage so active power keeps moving and the system works securely and safely.

[2] To be published in July 2018.

- In the last year, AEMO has had to rely more on operational measures than we have in the past. For example, at times AEMO temporarily de-energised 500 kilovolt (kV) lines, the backbone of the Victorian transmission network, to keep voltages within operating limits during periods of low demand from the grid.
- After the withdrawal of Hazelwood Power Station in March 2017, interconnector flows shifted, with reduced exports flowing from Victoria and increased imports from other regions to meet Victorian demand at peak times. During summer 2017-18, AEMO, under a function conferred on us to maintain power system reliability and system security using reserve contracts, activated Reliability and Emergency Reserve Trader (RERT) twice to enable enough generation and demand resources to supply Victorian consumers and have sufficient generation reserves.
- Over the past 12 months[3], there was one significant period, after the occurrence of a non-credible contingency[4], in which the DSN was not in a secure operating state. A further contingency during this period may have resulted in a breach of operational limits. The non-credible contingency also caused a voltage disturbance leading to a reduction in customer load. Operational procedures and protection schemes have been updated to minimise the risk of this contingency occurring in future. AEMO's review of the incident found that, given the low probability of occurrence, the level of major network investment required to minimise the impact of the non-credible contingency would not be economically justified.
- There was no load shedding directed by AEMO on the DSN over the past 12 months.

Maintaining a resilient power system in Victoria

AEMO continues to work with key stakeholders and asset owners to address power system trends and needs, and a number of key initiatives have been progressed:

- **Unlocking the potential of Western Victoria.** High levels of renewable generation connections continue to drive the need for augmentation in Western Victoria. A significant volume of additional generation has become committed in western Victoria and south-west New South Wales since the 2017 VAPR was published. Most recently, approximately 600 MW of large scale renewable projects became committed in late 2017 and early 2018 in Western Victoria.

  AEMO is progressing the Western Victoria Renewable Integration RIT-T[5] to identify the preferred option for increasing capacity in the area.
- **Keeping voltage within operational limits at times of low demand.** As distributed energy resources (DER) like rooftop photovoltaic (PV) systems increase, the daily profile of demand continues to change. This shifts the time of minimum demand from early morning to middle of the day and is resulting in a trend of reducing minimum demand. AEMO forecasts this trend to continue[6], and minimum demand in summer to fall, from approximately 2,300 MW in 2016-17 to approximately 900 MW in 2027-28.

  If voltage is not regulated effectively, the lower minimum demands will lead to high voltages and potentially high voltage violations (voltages exceeding defined operating limits). High voltage violations are undesirable, because there is a risk of damage to power system plant if no measure is taken to suppress them.

  To date, AEMO has managed voltage at times of low demand using short-term operational measures, such as temporarily de-energising 500 kV lines.

  Given the increased risk to reliability[7] and the potential market impacts of this measure, AEMO is pursuing more efficient longer-term options for sourcing reactive power and managing voltages at times of low minimum demand, through a reactive power RIT-T[8]. The required lead time for major augmentations from a RIT-T can be up to three years, depending on the preferred option. The VAPR also presents AEMO's short- to medium-term reactive power management strategy until the RIT-T preferred option is identified and implemented.

  AEMO is also reviewing its methodology for forecasting minimum demand at connection point level to assist in understanding future risks and requirements for reactive power support on the network.

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[3] The VAPR reviews the period 1 April 2017 to 31 March 2018.

[4] A credible contingency event is defined in the NER as a "contingency event" which AEMO considers to be reasonably possible in the circumstances. Examples could include the unexpected automatic or manual disconnection of one operating generating unit, or the unexpected disconnection of one major item of transmission plant (other than as a result of a three-phase electrical fault anywhere on the power system). A non-credible contingency event is defined in the NER as a "contingency event" other than a "credible contingency event". Examples include three-phase electrical faults on the power system, or simultaneous disruptive events such as multiple generating unit failure or double circuit transmission line failure.

[5] More information is available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Victorian-transmission-network-service-provider-role/Regulatory-investment-tests-for-transmission.

[6] This trend is forecast, despite more Victorians being expected to charge batteries and electric cars from their rooftop PV.

[7] Increased risk of load shedding should there be an unplanned loss of a single of multiple network assets.

[8] More information is available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Victorian-transmission-network-service-provider-role/Regulatory-investment-tests-for-transmission.

- **Supporting increased interconnector capacity between Victoria and New South Wales.** AEMO has completed the pre-feasibility analysis foreshadowed in the 2017 VAPR, and as highlighted in the impending 2018 ISP, found that augmentations within the Victorian DSN that support increased Victorian export capability on the Victoria – New South Wales interconnector appear to be economically justifiable[9]. The benefits of this augmentation arise from sharing of renewable generation across National Electricity Market (NEM) regions. Following the release of the ISP, AEMO will commence a RIT-T process to verify the preferred option.

  AEMO is also investigating options to increase import capacity from NSW to Victoria which will help support Victoria during high demand periods.

- **Assessing transmission assets.** Under new requirements in the National Electricity Rules[10], AEMO's 2018 VAPR provides more information on asset renewal and replacement and an assessment of future needs:
  - AusNet Services has provided a more detailed asset renewal plan for DSN infrastructure, to make network asset retirement, de-rating, and replacement decisions more transparent.
  - AEMO has worked with AusNet Services to select DSN assets which – because of their age or performance – may retire in the next 5-7 years. Where potential retirements are identified, AEMO has analysed future system needs and the requirement to replace or refurbish these assets.

Longer-term strategic outlook

The VAPR focuses on Victorian DSN performance and development, but the network also operates as part of a larger market and system. At both a state and national level, the power system is changing and will continue to change. For this 2018 VAPR, AEMO has assessed the potential impacts on the DSN of current and projected changes in generation, demand, and interconnection from a longer-term strategic perspective, taking into consideration the outcomes of the ISP.

AEMO has assessed the impacts of the national development pathway identified in the upcoming 2018 ISP, and developed a long-term strategic vision to maintain a secure and resilient network in Victoria which is consistent with the ISP.

The national development pathway identified in the ISP that AEMO has analysed for the 2018 VAPR includes:

- New generation centres in western Victoria.
- A new interconnector between South Australia and New South Wales (Riverlink), connecting into Victoria via the Buronga – Red Cliffs transmission path.
- Augmentation of the interconnector capacity between New South Wales and Victoria.
- A new interconnector between New South Wales and Victoria (Sydenham – Wagga via Bendigo, Kerang, and Darlington Point).

AEMO's analysis shows the following DSN impacts of this scenario, and potential solutions that would manage these impacts in a timely, efficient, and strategic way:

- Increased renewable generation connections in Western Victoria would increase the need for additional capacity on the Western Victoria to Melbourne (via Keilor) 220 kV transmission path. The need to facilitate the development of this REZ is aligned with recommendations of the ISP.
- The proposed new South Australia – New South Wales interconnector (Riverlink) connected through Buronga would increase the need for additional capacity on the Western Victoria to Melbourne (via Keilor) 220 kV transmission path, as well as the North West Victoria to Melbourne (via Shepparton and Bendigo) 220 kV transmission path.
- Additional generation from Snowy 2.0 would impact existing transmission limitations in Northern Victoria, and in turn may increase the need for additional capacity of the transmission paths between Snowy and Victorian load centres.
- A new, large New South Wales – Victoria interconnector (Sydenham – Wagga via Bendigo, Kerang, and Darlington Point) would increase inter-regional transfer capacity and relieve transmission constraints between Kerang and Sydenham. It would increase the need for additional capacity on the Sydenham – Keilor 500kV line, and on the Keilor 500/200 kV transformers.

While the VAPR focuses on maintaining security in the Victorian DSN, AEMO, as system and market operator for the NEM, and the national planner, will continue to take a national perspective on the energy sector and the broader needs of the transmission system and consumers across Australia. More information on the national strategic perspective is available in AEMO's 2018 ISP.

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[9] This assessment is discussed in Chapter 3 of this 2018 VAPR.

[10] Amendments to NER rule 5.12 under the Replacement Expenditure Planning Arrangements rule change commenced 18 July 2017.

Contents

Tables

Introduction

The Australian Energy Market Operator (AEMO) is responsible for planning and directing augmentation on the Victorian electricity transmission Declared Shared Network (DSN). The *Victorian Annual Planning Report* (VAPR) considers the adequacy of the DSN to meet future reliability and security needs over the next 10 years, and identifies development opportunities that may deliver net market benefits.

AEMO publishes the VAPR as part of its role as Victorian transmission planner under the National Electricity Law (NEL), in accordance with clause 5.12.1 of the National Electricity Rules (NER). This year's VAPR:

- Reviews the performance of the DSN throughout 2017-18, including performance at times of high network stress. The outcome of this review is presented in Chapter 2 and is consistent with the review undertaken in last year's VAPR.
- Does not identify any new priority limitations and provides an update on network development opportunities identified in last year's VAPR.
- Includes a new chapter to address a recent rule change requiring additional information on AusNet Services' Asset Renewal Plan outlining expected network asset retirements, deratings, renewals within the APR timeframe, and the results of an assessment by AEMO of future network needs and the potential need for asset replacements.
- Includes a new chapter presenting a long-term vision of the Victorian DSN, incorporating projected changes in generation, demand, and interconnection, and takes into consideration the recommendations of AEMO's first *Integrated System Plan* (ISP). This chapter is included to present information and insights on current topics of interest, in addition to NER clause 5.12.1 requirements.

This report is supported by an online, user-friendly interactive map that provides data and analysis for a range of National Electricity Market (NEM) topics including current and emerging development opportunities, transmission connection point forecasts, and national transmission plans.

1.1 Supporting material

A suite of resources have been published on the AEMO website to support the content in this report.

Table 1 2018 VAPR resources and links

Resource	Description and links
Interactive map	Provides data and analysis for a range of NEM topics including emerging development opportunities, transmission connection point forecasts, short-circuit levels, and national transmission plans. http://www.aemo.com.au/electricity/planning/interactive-map
Historical DSN rating and loading workbook	Presents ratings and loadings for the 2017-18 maximum demand and high export periods presented in Chapter 2 and the interactive map. http://www.aemo.com.au/Electricity/Planning/Victorian-Annual-Planning-Report/VAPR-Supporting-Information
AusNet Services 2018 asset renewal plan	Outlines AusNet Services' transmission asset renewal process and provides a list of its planned asset renewal projects, including asset retirements and de-ratings for the next 10-year period, including changes since last year and the various options considered. http://www.aemo.com.au/Electricity/Planning/Victorian-Annual-Planning-Report/VAPR-Supporting-Information
Constraint reports	AEMO uses constraint equations to operate the DSN securely within power system limitations. The constraint equations are implemented in the National Electricity Market Dispatch Engine (NEMDE), which dispatches generation to ensure operation within the bounds of power system limitations. AEMO's annual and monthly constraint reports detail the historical performance of these constraint equations. http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Congestion-information/Statistical-Reporting-Streams
Demand forecasts	AEMO's independent connection point forecasts for Victoria. http://www.aemo.com.au/Electricity/Planning/Forecasting/AEMO-Transmission-Connection-Point-Forecasting/Transmission-Connection-Point-Forecasting-Report-for-Victoria

2. Network performance 2017-18

This chapter assesses the performance of the Victorian electricity transmission DSN over 2017-18[11].

Key insights of this chapter

- While the Victorian DSN mostly (except for a single period) operated reliably and securely in the past year, this performance was achieved with significant levels of operational intervention by AEMO.
- There was one significant period where, after the occurrence of a non-credible contingency[12], the power system was not in a secure operating state. A further contingency during this period may have resulted in a breach of operational limits.
  - The non-credible contingency also caused a voltage disturbance leading to a reduction in customer load.
  - Operational procedures and protection schemes have been updated to minimise the risk of this contingency occurring in future. AEMO's review of the incident found the level of major network investment required to minimise the impact of this non-credible contingency, should it reoccur, would not be economically justified, given the low probability of occurrence.
- The Victorian DSN is becoming increasingly reliant on operational measures to manage high voltages within operating limits during minimum demand periods, including the de-energisation of 500 kilovolt (kV) lines on some occasions.
  - This increases operational risk due to reduced availability of transmission infrastructure and potentially constrains generation, incurring a market impact.
- After the withdrawal of Hazelwood Power Station in March 2017, the supply-demand balance has been tight in Victoria during peak demand periods:
  - During summer 2017-18, AEMO, as market operator, activated Reliability and Emergency Reserve Trader (RERT) twice to enable enough generation and demand resources to supply Victorian consumers and have sufficient reserves.
  - Interconnector flows changed, with reduced exports flowing from Victoria and increased imports from other regions to meet Victorian demand at peak times.

The following sections summarise AEMO's analysis, and more detailed information is available on AEMO's online interactive map[13].

In this chapter, unless otherwise stated:

- Generation is defined as all scheduled, semi-scheduled, and non-scheduled generation greater than 30 megawatts (MW), and does not include rooftop photovoltaic (PV).
- Demand and consumption are as generated, meaning they include generator auxiliary loads (electricity used by generators in their operations).

[11] The period 1 April 2017 to 31 March 2018.

[12] A credible contingency event is defined in the NER as a "contingency event" which AEMO considers to be reasonably possible in the circumstances. Examples could include the unexpected automatic or manual disconnection of one operating generating unit, or the unexpected disconnection of one major item of transmission plant (other than as a result of a three-phase electrical fault anywhere on the power system). A non-credible contingency event is defined in the NER as a "contingency event" other than a "credible contingency event". Examples include three-phase electrical faults on the power system, or simultaneous disruptive events such as multiple generating unit failure or double circuit transmission line failure.

[13] Available at http://www.aemo.com.au/aemo/apps/visualisations/map.html.

2.1 How does AEMO assess network performance?

In evaluating the adequacy of the Victorian DSN over 2017-18, AEMO has considered the following key network performance indicators:

- **Loading of transmission network elements at times of high network stress** – whether the transmission network had sufficient capacity to supply the demand (see Section 2.2).
- **Reactive power adequacy at times of high network stress and low demand periods** – the network's ability to maintain voltages within operational and design limits throughout the network (Section 2.2).
- **Notable power system incidents** – the frequency of incidents which resulted in system security violation or loss of customer load or generation (Section 2.4).
- **Interconnector capability** – the extent to which the operational and design limits of interconnectors restricted the import or export of generation (Section 2.5).
- **Impact of constraint equations** – how much impact constraints on the transmission network had on generation dispatch (Section 2.6).
- **Impact of the changing generation mix on the network** – how network flows are impacted by the increasing penetration of renewable generation and generation retirements (Section 2.7).

2.2 Network performance at times of high network stress

AEMO reviewed the loading of network elements to examine how stressed the network was during 2017-18.

The Victorian DSN has three distinctive drivers of network stress:

- Maximum demand conditions (which typically occur on hot summer days) stress the network, as the required power transfers may exceed ratings of network elements.
- Under minimum demand conditions, voltages may exceed allowable operating limits.
- High network stress can also occur at times where high levels of Victorian generation are being exported to other regions, typically New South Wales[14].

To understand how the network is performing at these times of high stress, AEMO used four operational 'snapshots'[15] of the power system to capture network conditions[16] during periods of:

- maximum demand,
- minimum demand overnight,
- minimum demand during the day
- and high export[17] periods.

Minimum demand currently occurs overnight, but AEMO's latest forecasts[18] project that it will move to midday by 2022, influenced by continuing increases in rooftop PV generation[19], so both overnight and midday minimum demand snapshots have been considered in this section.

Table 1 Summary of operational conditions

	Maximum demand snapshot	Minimum demand (overnight) snapshot	Minimum demand (day) snapshot	High export from Victoria snapshot
Date and time*	19 January 2018 16:00:48	12 November 2017 6:01:48	25 December 2017 13:30:47	24 September 2017 04:00:48

[14] The New South Wales interconnector has a higher transfer capacity than the Heywood or Basslink interconnectors.

[15] Network adequacy assessment uses these snapshots, including any DSN outages. The snapshot data is obtained from the state estimator, which estimates the states (such as power, voltages, and angles) of the power system based on certain measurements in AEMO's Energy Management System (EMS).

[16] These snapshots do not necessarily represent the maximum loading experienced by every DSN asset, as this depends on prevailing system conditions such as generation patterns, interconnector flows, and time of localised peak demand, as well as factors that influence dynamic ratings such as local temperature and wind speed.

[17] A high export period is classified as the snapshot with the highest flow through the South Morang F2 500/330 kilovolt (kV) transformer.

[18] AEMO, 2017 *Electricity Forecasting Insights* report, available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Electricity-Forecasting-Insights/2017-Electricity-Forecasting-Insights.

[19] This trend is discussed in Section 2.7.1.

	Maximum demand snapshot	Minimum demand (overnight) snapshot	Minimum demand (day) snapshot	High export from Victoria snapshot
Victorian operational demand at time of snapshot**	9,153 MW	3,217 MW	3,442 MW	3,620 MW
Sum of Victorian loads at time of snapshot	8,717 MW	3,148 MW	3,332 MW	3,398 MW
Sum of Victorian generation at time of snapshot	8,673 MW	3,259 MW	4,578 MW	4,034 MW
Sum of total Victorian available generation capacity at time of snapshot***	9,473 MW	3,892 MW	4,675 MW	5,199 MW
Temperature in Melbourne	36.9°C	14.5°C	20.5°C	10.1°C
Power flow from Victoria to South Australia (Heywood Interconnector)	350 MW	-194 MW	-148 MW	-315 MW
Power flow from Victoria to South Australia (Murraylink)	60 MW	-51 MW	-41 MW	-174 MW
Power flow from Tasmania to Victoria	490 MW	-463 MW	-493 MW	385 MW
Power flow from Victoria to New South Wales	-234 MW[20]	-169 MW	810 MW	1,365 MW
Reliability and Emergency Reserve Trader (RERT) dispatched	136.5 MW	0 MW	0 MW	0 MW
Renewable generation in Victoria Wind Hydro Rooftop PV	 431 MW 2,089 MW 589 MW	 228 MW 41 MW 39 MW	 545 MW 0 MW 864 MW	 889 MW 0 MW 0 MW
System security (N-1)	System normal, no contingency overloads	Lines de-energised to manage voltage due to low demand as a result of Alcoa Portland (APD) potlines' unplanned outage	A line was de-energised to manage voltage due to low demand	System normal, no contingency overloads

* All values listed, excluding temperature, are the values measured at the exact time of each snapshot for the region of Victoria.

** Operational demand is the sum of all Victorian loads and network losses.

*** Available generation capacity is the maximum capacity (MW output) at the time of the snapshot. It does not include capacity form generators that were out of service at the time. It reflects the maximum target a generator can be requested to reach within a given dispatch interval, and is equal to generation for all semi-scheduled and non-scheduled generators.

2.2.1 Maximum demand snapshot

The maximum operational demand snapshot captures the conditions when many network elements are under their maximum loading for the year. This section is complemented by additional detail in the historical DSN rating and loading workbook (see Section 1.1).

Figure 1 represents the prevailing conditions at the time of maximum operational demand in Victoria (16:00:48 on 19 January 2018). The actual maximum demand of 9,153 MW was closer to the 50% probability of exceedance (POE)[21] maximum demand forecast of 9,491 MW. The 10% POE maximum demand forecast was 10,333 MW[22].

Figure 1 shows that:

- 71% (6,211 MW) of the total Victorian demand (8,717 MW) was concentrated in Greater Melbourne and Geelong.

[20] The interconnector flow is low due to high Murray generation output of 1484 MW.

[21] POE is the likelihood that a demand forecast will be met or exceeded. A 10% POE maximum demand projection is expected to be exceeded, on average, one year in 10, while a 50% POE forecast is based on average weather and is expected to be exceeded, on average, every second year.

[22] For maximum demand forecasts, see NEFR forecasts on AEMO's National Electricity and Gas Forecasting website, at http://forecasting.aemo.com.au/Electricity/MaximumDemand/Operational.

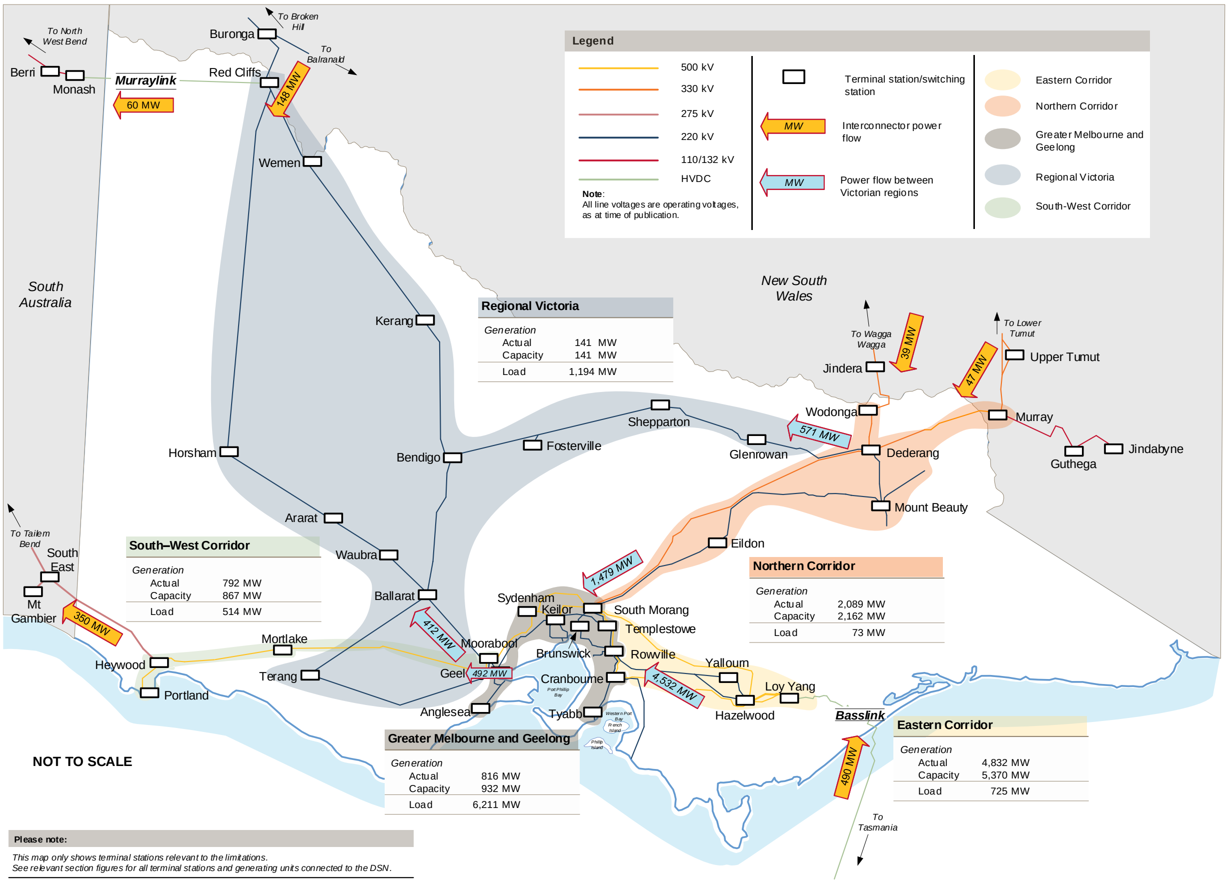
- The majority of Victorian generation (56%) originated from the Eastern Corridor.
- Net power flow from New South Wales to Victoria was low at 234 MW due to thermal limitations. This comprised an import of 86 MW from Murray and Wodonga, and 148 MW from Buronga on the New South Wales – Victoria interconnector. Refer to Section 3.8 for further detail on thermal limitations on New South Wales to Victoria import limits and options to address the limitations.
- Net power flow from Victoria to South Australia was 410 MW, comprised of export of 350 MW on the Heywood Interconnector and 60 MW on the Murraylink interconnector.
- Power flow from Tasmania to Victoria was 490 MW via the Basslink interconnector.
- 136.5 MW of RERT was dispatched.
- All interconnector flows were within their thermal limit.

In addition to Figure 1, at the time of the maximum demand snapshot:

- There was 589 MW of rooftop PV generation, serving 6.3% of end user demand.
- There was 2,520 MW of renewable generation (29.1% of total Victorian generation), comprised of non-scheduled wind (96 MW), dispatched wind (335 MW), and hydroelectric generation (2,089 MW).

A review of asset loading at the time of maximum demand showed that the Victorian DSN performed within technical network limits for secure operation.

Figure 1 Maximum demand snapshot: generation, load, and interconnector flow



2.2.2 Minimum demand (overnight) snapshot

The minimum demand snapshot captures the conditions when voltages may exceed operating limits[23].

[23] There was an unplanned outage at Alcoa Portland (APD) resulting in the minimum demand occurring during the early morning. Otherwise, minimum demand would have occurred during the day, as mentioned in Section 2.2.3.

Figure 2 represents the prevailing conditions at the time of minimum demand in Victoria (06:01:48 on 12 November 2017). It shows:

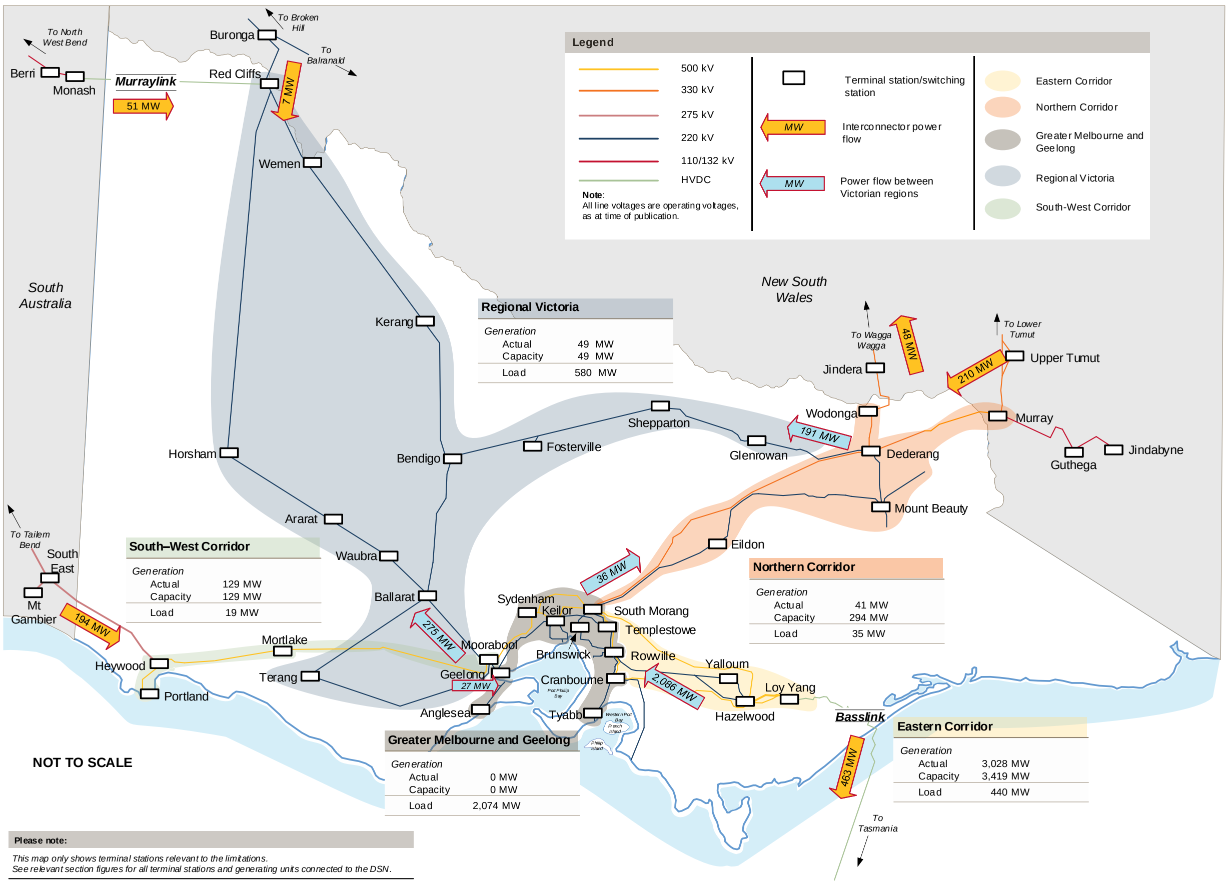
- 66% (2,074 MW) of the total Victorian demand (3,148 MW) was concentrated in Greater Melbourne and Geelong.
- The majority of Victorian generation (93%) originated from the Eastern Corridor.
- Net power flow from New South Wales to Victoria was 169 MW. This comprised an import of 162 MW from Murray and Wodonga, and 7 MW from Buronga on the New South Wales – Victoria interconnector.
- Net power flow from South Australia to Victoria was 245 MW, comprised of import of 194 MW on the Heywood Interconnector and 51 MW on the Murraylink interconnector.
- Power flow from Victoria to Tasmania was 463 MW via the Basslink interconnector.
- All interconnector flows were well below their thermal limits.

In addition to Figure 2, at the time of the minimum demand snapshot:

- There was 39 MW of rooftop PV generation (1.2% of end user demand).
- There was 269 MW of renewable generation (8.2% of total Victorian generation), comprised of non-scheduled wind (110 MW), dispatched wind (118 MW), and hydroelectric generation (41 MW).

A review of performance at the time of minimum operational demand showed that the Victorian DSN performed within technical limits, with temporary operational measures successfully applied to maintain voltages within operating limits. Nevertheless, the operational steps taken highlight the need for further reactive support to manage voltages during minimum demand conditions, which is further discussed in Chapter 3.

Figure 2 Minimum demand (overnight) snapshot: generation, load, and interconnector flow



2.2.3 Minimum demand (day) snapshot

The minimum demand (day) snapshot captures the conditions when voltages may exceed operating limits. The daytime snapshot was added because AEMO projects the time of minimum demand in the DSN moving from overnight to middle of the day within the next five years.

In line with this trend, it should be noted the minimum demand (day) would have been the event of minimum demand in 2017-18, had there not been an unplanned outage at Alcoa Portland (APD) in early morning on 12 November 2017. This resulted in the 'Minimum demand (overnight) snapshot' having a lower minimum demand than the 'Minimum demand (day) snapshot'.

Figure 3 represents the prevailing conditions at the time of minimum demand during the day in Victoria (13:30:47 on 25 December 2017). It shows:

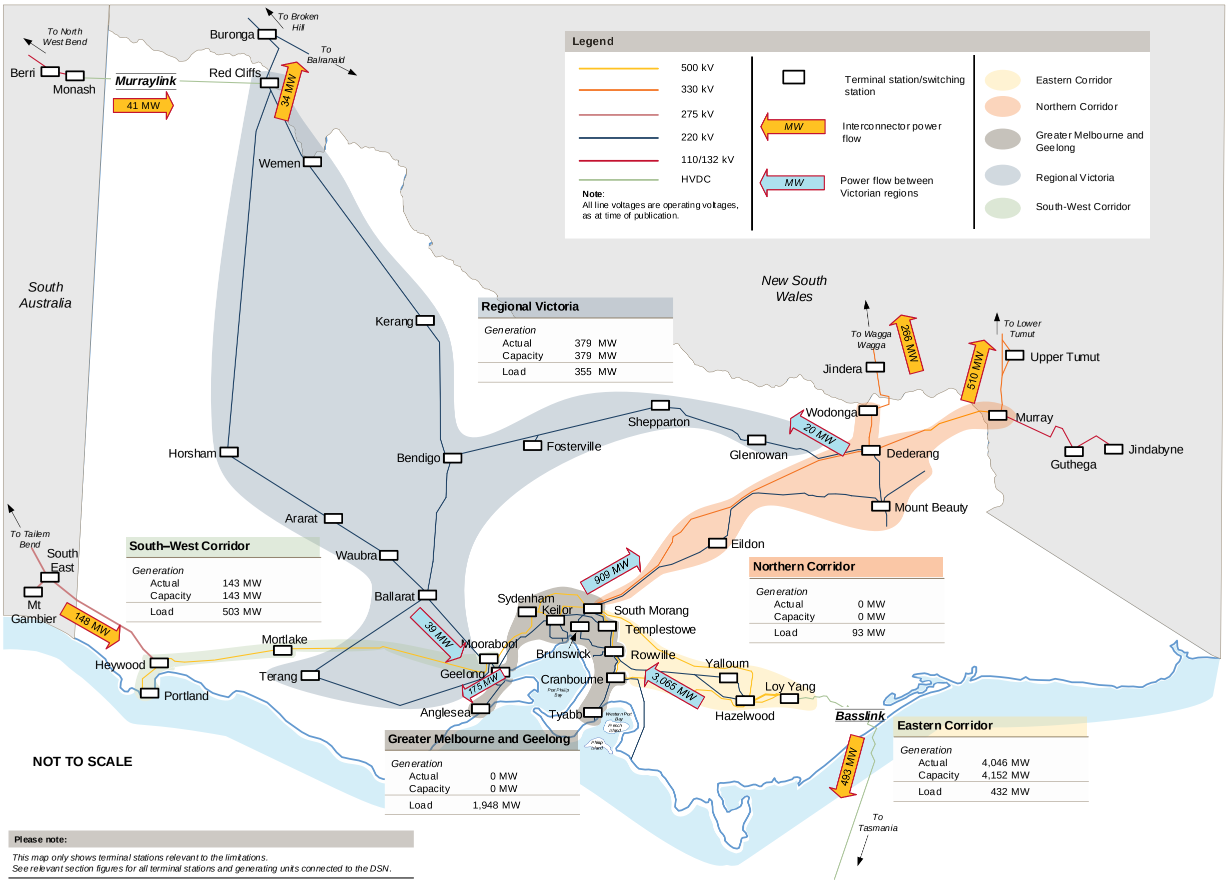
- 57% (1,948 MW) of the total Victorian demand (3,332 MW) was concentrated in Greater Melbourne and Geelong.
- The majority of Victorian generation (89%) originated from the Eastern Corridor.
- Net power flow from Victoria to New South Wales was 810 MW. This comprised an export of 776 MW from Murray and Wodonga, and 34 MW to Buronga on the New South Wales – Victoria interconnector.
- Net power flow from South Australia to Victoria was 189 MW. This comprised of import of 148 MW on the Heywood Interconnector and 41 MW on the Murraylink interconnector.
- Power flow from Victoria to Tasmania was 493 MW via the Basslink interconnector.
- All interconnector flows were well below their thermal limit.

In addition to Figure 3, at the time of the minimum demand (day) snapshot:

- There was 864 MW of rooftop PV generation (20.6% of end user demand).
- There was 545 MW of renewable generation (11.9% of total Victorian generation), comprised of non-scheduled wind (221 MW), dispatched wind (324 MW), and hydroelectric generation (0 MW).

A review of asset loading at the time of minimum demand (day) showed that the Victorian DSN performed within technical network limits for secure operation, with temporary operational measures successfully applied to maintain voltages within operating limits.

Figure 3 Minimum demand (day) snapshot: generation, load, and interconnector flow



2.2.4 High export snapshot

The high export snapshot demonstrates network conditions during times of high export from Victoria to New South Wales, specifically through the South Morang F2 500/330 kilovolt (kV) transformer. This section is complemented by additional detail in the historical DSN rating and loading workbook (see Section 1.1).

Figure 4 represents the prevailing conditions at the time of high export from Victoria to New South Wales (04:00:48 on 24 September 2017). It shows:

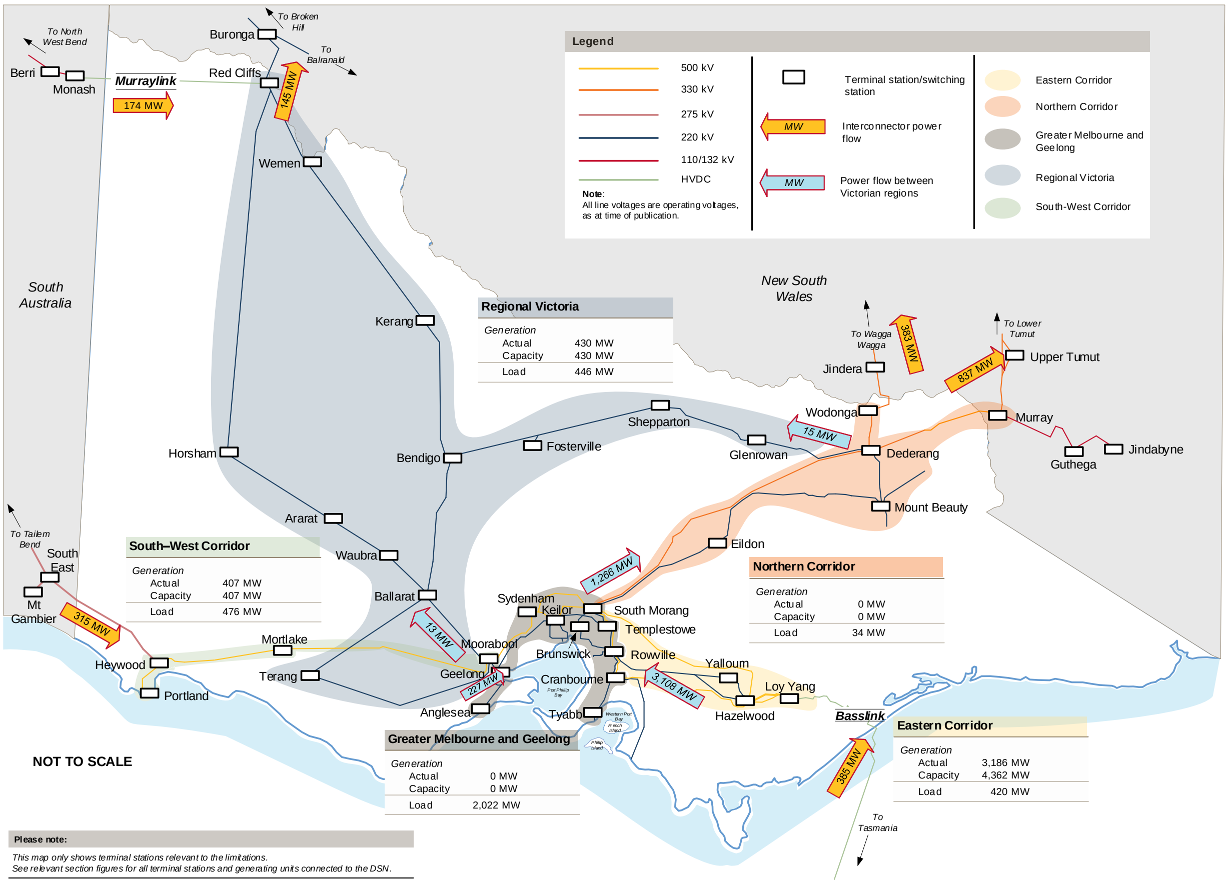
- 59% (2,022 MW) of the total Victorian demand (3,398 MW) was concentrated in Greater Melbourne and Geelong.
- The majority of Victorian generation (79%) originated from the Eastern Corridor.
- Net power flow from Victoria to New South Wales was 1,365 MW. This comprised an export of 1,220 MW from Murray and Wodonga, and 145 MW to Buronga on the New South Wales – Victoria interconnector.
- Net power flow from South Australia to Victoria was 489 MW, comprised of import of 315 MW on the Heywood Interconnector and 174 MW on the Murraylink interconnector.
- Power flow from Tasmania to Victoria was 385 MW via the Basslink interconnector.
- All interconnector flows were well below their thermal limit.

In addition to Figure 4, at the time of the high export snapshot:

- There was no rooftop PV generation because it was the snapshot occurred before sunrise.
- There was 889 MW of renewable generation (22% of total Victorian generation), comprised of non-scheduled wind (333 MW), dispatched wind (556 MW).

A review of asset loading at the time of high export showed that the Victorian DSN performed within technical limits.

Figure 4 High export snapshot: generation, load, and interconnector flow



2.3 Reliability and Emergency Reserve Trader (RERT)

In May 2017, to ensure the NEM would meet the reliability standard in summer 2018-19, AEMO began a process to secure additional reserve across Victoria to address a projected supply shortfall. The reserve AEMO secured fell into three categories: demand response, temporary generation, and voltage-control demand reduction[24].

AEMO activated RERT twice in summer 2017-18, on 30 November 2017 (in Victoria) and on 19 January 2018 (in Victoria and South Australia) when consumer supply was at risk due to severe weather conditions.

On 29 November 2017, AEMO declared a forecast Lack of Reserve (LOR) 2 condition for the Victoria region between 15:30 and 17:00 on 30 November 2017. AEMO subsequently published market notices seeking market response(s) to alleviate the LOR 2 condition, and determined the latest time for AEMO to intervene to be 12:30 on 30 November 2017. As there was insufficient market response to alleviate the risk to supply reliability, AEMO activated 32 MW of unscheduled reserves from three RERT contracts between 15:30 and 16:30.

On 18 January 2018, AEMO declared a forecast LOR 2 condition for the Victoria region between 14:30 and 16:00 on 19 January 2018. In response to these forecasts and supply uncertainties, AEMO determined that pre-activation of 500 MW of longer notice (20+hr) reserve contracts was required, to ensure these would be available to cover contingency events on 19 January 2018. As there was insufficient market response to alleviate the risk to supply reliability, AEMO activated 130 MW of unscheduled reserves across eight reserve contracts in Victoria, and 6.5 MW of unscheduled reserves across two reserve contracts in South Australia. These contracts were activated between 14:00 and 15:30 on 19 January 2018, with all ten contracts being deactivated by 20:00.

2.4 Victorian power system reviewable operating incidents

Over the 12-month review period[25], the DSN was operated in a secure operating state except for one significant period where, after the occurrence of a non-credible contingency, the power system was not in a secure operating

[24] For more information about RERT and these two activation events, see AEMO's *Summer 2017-18 operations review* report and annexures, available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Summer-operations-report.

[25] The VAPR reviews the period 1 April 2017 to 31 March 2018.

state. A further contingency during this period may have resulted in a breach of operational limits. The non-credible contingency also caused a voltage disturbance leading to a reduction in customer load. Operational procedures and protection schemes have been updated to minimise the risk of this contingency occurring in future.

AEMO's review of the incident found that, given the low probability of occurrence, the level of major network investment[26] required to minimise the impact of the non-credible contingency would not be economically justified. Further detail on this incident is presented in Table 2.

However, it is worth noting that the DSN is aging, with most transmission lines now more than 40 years old, and the frequency of planned maintenance[27] of transmission infrastructure is expected to increase. Minor investment may be justified and AEMO is working with key stakeholders and network asset owners, on a case-by-case basis, to minimise the potential impact of planned outages of key network components on system security and customer reliability.

There was no load shedding directed by AEMO on the DSN over the past 12 months.

Table 2 Summary of significant reviewable power system incident during 2017-18

Date	Incident	Consequence
18 January 2018	Concurrent loss of Rowville A2 500/220 kV transformer and a Rowville – South Morang 500 kV transmission line.	600 MW customer load reduction

A report on the above incident is being finalised, and when available, will appear alongside AEMO's list of power system operating incidents on AEMO's website[28]. Because AEMO is responsible for operating the transmission network, this section does not consider distribution network events that may have resulted in loss of supply.

2.5 Interconnector capability over 2017-18

An interconnector's capability depends on the performance of the network, which varies throughout the year. Notional interconnector limits can be found in AEMO's interconnector capabilities report[29]. A detailed summary of the capability and limits of each interconnector in the NEM is provided in AEMO's Monthly and Annual NEM Constraint Reports[30].

As shown in Table 3, there has been a marked decrease in duration of energy exports from Victoria since the closure of Hazelwood Power Station in March 2017.

Table 3 Percentage (%) of time interconnector is exporting energy from Victoria

Interconnector	5-year average before Hazelwood closure	2017-18
Victoria – New South Wales interconnector	86%	44%
Heywood Interconnector	81%	49%
MurrayLink	43%	40%
Basslink	42%	52%
Victoria (Net)	86%	51%

As mentioned in Section 2.3, supply-demand balance was tight in Victoria and RERT was activated twice over summer 2017-18. Any increase in import capacity will help support Victoria during high demand periods. Refer to Section 3.8

[26] Major investment includes high cost augmentations such as new transformers and lines.

[27] As part of summer 2017-18 readiness, AEMO worked with TNSPs to arrange for TNSPs to complete bushfire mitigation before summer, undertake as much preventative maintenance that could improve reliability outcomes for the network over the summer period by the end of November 2017, and make sure no planned maintenance was scheduled on high demand days. Compared to the previous summer's 12 unplanned outages in Victoria, there were five unplanned transmission network outages in Victoria during summer 2017-18, none of which had an impact on system security or reliability.

[28] AEMO, Power System Operating Incident Reports, available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/Power-System-Operating-Incident-Reports.

[29] AEMO, Interconnector Capabilities Report, available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Congestion-Information/2017/Interconnector-Capabilities.pdf.

[30] Monthly and Annual NEM Constraint reports are available through the Statistical Reporting Streams page at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Congestion-information/Statistical-Reporting-Streams.

for further detail on thermal limitations on New South Wales to Victoria import limits and options to address the limitations.

The Heywood Interconnector is being operated below its maximum design limit of 650 MW in both directions:

- On 28 September 2016, when the South Australia black system[31] occurred, the maximum transfer allowed on the interconnector was 600 MW from Victoria to South Australia and 500 MW from South Australia to Victoria.
- Investigations into the South Australia black system event identified a potential transient stability issue at times of high Victoria to South Australia transfer and high levels of wind generation in South Australia.
- The current limits of 600 MW (Victoria to South Australia) will be increased further following service of a System Integrity Protection Scheme (SIPS)[32] in South Australia, designed to reduce the risk of separation of South Australia from the rest of the NEM when operating Heywood at high power transfer levels.

2.6 Impact of Victorian transmission constraints

0 summarises binding constraints on the Victorian transmission system that resulted in the highest market impact in 2017, with 2016 values shown for comparison. This is a subset of detailed constraint equation information in AEMO's Annual NEM Constraint Reports for 2016 and 2017[33].

[31] AEMO. *Black System South Australia, 28 September 2016*, March 2017, available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/Power-System-Operating-Incident-Reports.

[32] Detail contained in AEMO's initial report on the Hornsdale battery, available at https://www.aemo.com.au/-/media/Files/Media_Centre/2018/Initial-operation-of-the-Hornsdale-Power-Reserve.pdf

[33] Monthly and Annual NEM Constraint reports, for the calendar year are available through the Statistical Reporting Streams page on the AEMO website, at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Congestion-information/Statistical-Reporting-Streams.

Table 4 Equations with persistent market impacts in both 2016 and 2017

ID	Equation ID	Binding hours		Market impact[A]		Description
		2016	2017	2016	2017	
1	V:S_600_HY_TEST_DYN	182	289	$76,535	$659,212	600 MW limit on VIC to SA transfer on Heywood with dynamic headroom.
2	V^SML_NSWRB_2	154	53	$518,333	$441,280	To avoid voltage collapse for loss of Darlington Pt to Buronga (X5) 220 kV line when the NSW Murraylink runback scheme is not available.
3	V::N_NIL_xxx	1054	625	$238,531	$181,973	To prevent transient instability for a trip of a HWTS-SMTS 500 kV line.
4	V>>V_NIL_2A_R & V>>V_NIL_2B_R & V>>V_NIL_2_P	1015	312	$144,342	$143,897	To avoid overloading the South Morang F2 transformer when Yallourn Unit 1 is in 220 kV mode and Hazelwood is operating in radial mode.
5	V:S_600_HY_TEST	48	75	$14,235	$126,093	600 MW limit on SA to VIC transfer on Heywood.
6	V>>V_NIL_5	1	35	$345	$86,009	To avoid overloading either Mount Beauty to Dederang 220 kV lines for any single trip of the parallel lines.
7	V::N_SMF2_xxx	10	184	$4,028	$58,092	To prevent transient instability for a trip of a HWTS-SMTS 500 kV line when South Morang F2 transformer is not available.
8	V::N_HWSM_xxx	34	53	$11,196	$21,877	To prevent transient instability for a trip of a HWTS-SMTS 500 kV line when a HWTS-SMTS 500kV line is not available.
9	V>>V_SMTXF2_6	2	30	$677	$12,604	To avoid overloading of either Thomastown to South Morang 220kV line when South Morang F2 transformer is not available.
10	V::N_BYPASS_HW_SY_xxx	6	14	$2,121	$10,158	To avoid transient instability for trip of a Hazelwood to Sydenham or Hazelwood to South Morang 500kV line.
Total		2,506	1,669	$916,429	$1,741,194	N/A

A. The market impact of a constraint is derived by summarising the marginal value for each dispatch interval from the marginal constraint cost re-run over the period considered.

In 2017, the constraint equation with the largest market impact (constraint equation 1 in 0) restricted export from Victoria to South Australia. Both constraint equations 1 and 5 represent a 600 MW limit to avoid overloading the Heywood Interconnector, and applied as part of the test program for the upgraded Heywood Interconnector. This market impact has increased since 2016, because the constraints were only introduced in mid-2016.

The Victoria – New South Wales interconnector limits are resulting from constraint equations 3 and 4, which prevents higher export flows due to the South Morang F2 transformer and a transient stability limit. This constraint equation is expected to bind less in the short term, due to lower export flows from Victoria resulting from the March 2017 retirement of the Hazelwood Power Station, but more frequently after additional renewable generation is connected to meet the VRET. The proposed augmentations within the Victorian DSN to improve the Victoria – New South Wales interconnection are discussed in more detail in Section 3.8.

It is also noted that the market impact of:

- Constraint equations 7 and 9 increased significantly in 2017. This was due to an extended outage on the South Morang F2 transformer.
- Constraint equation 8 increased in 2017 due de-energisation of the Hazelwood – South Morang 500 kV line associated with managing high voltages in Victoria during light load conditions.
- Constraint equation 2 decreased in 2017, due to a new formulation of the constraint equation which better models the reactive power in north west Victoria.

- Constraint equation 6 increased in 2017, due to higher levels of generation into Mount Beauty Terminal Station.
- Constraint equation 10 increased in 2017, due to Sydenham Terminal Station reconfiguration associated with rebuild works.

2.7 Impact of changing generation mix

2.7.1 Renewable generation uptake

The level of renewable generation penetration in Victoria has increased over recent years and is influencing Victorian network flows. The impact on network flows is expected to become more apparent as more renewable generation connects to the network due to the VRET.

This section reviews network performance under high renewable generation output, and investigates effects on demand from the grid and network operation. It includes:

- A high wind snapshot to assess network performance under high wind generation output.
- Frequency of reverse flow (from the distribution network into the DSN) occurrences as a result of renewable generation directly connected to the distribution system and behind-the-meter (on customers' premises).
- Impact of rooftop PV on regional grid demand, and subsequent challenges it may pose to the network.

High wind snapshot

The high wind snapshot captures the conditions when the Victorian network is subject to high wind generation output. Key summary indicators are provided in Figure 5.

Operational demand at the time of the snapshot was neither high enough to cause risk of thermal overload, nor low enough to develop the potential of over-voltages.

This highlights that there was no significant visible stress on the network during these conditions.

Figure 5 High wind snapshot summary

	High wind snapshot
Date and time	14:30:48 on 24 September 2017
Operational demand at time of snapshot	4,100 MW
Sum of Victorian loads at time of snapshot	3,898 MW
Sum of Victorian generation at time of snapshot	4,306 MW
Sum of Victorian capacity at time of snapshot	5,530 MW
Temperature in Melbourne	17.0 °C
renewable generation Wind Hydro Rooftop PV	 1,172 MW 36 MW 487 MW
System security (N-1)	No system normal or contingency overloads

The level of renewable generation penetration is expected to increase in Victoria, as the generation mix changes due to the VRET. The majority of renewable generation connection interest is in western Victoria where the connection interest exceeds transmission capacity. AEMO is progressing the Western Victoria Renewable Integration Regulatory Investment Test for Transmission (RIT-T), which seeks to increase the capability of the western Victoria power system, and reduce congestion of projected new generation in that region. Details on this RIT-T are presented in Section 3.6.

Reverse flows

The frequency and magnitude of reverse power flows has increased in Victoria over the past few years. The two 220/66 kV Terang transformers have been identified as experiencing the largest duration of reverse flows in Victoria over the 2017-18 year. Table 5 outlines the number of hours that reverse flows occurred through these transformers, categorised into seasons.

Table 5 Number of hours reverse flows occurred at Terang

Year	Autumn	Winter	Spring	Summer	Total[34]
2013-14	11 hrs	4.5 hrs	10 hrs	0 hrs	25.5 hrs
2014-15	14 hrs	0 hrs	7.5 hrs	12 hrs	33.5 hrs
2015-16	27 hrs	11.5 hrs	6.5 hrs	5.5 hrs	50.5 hrs
2016-17	41.5 hrs	8 hrs	46 hrs	25 hrs	120.5 hrs
2017-18	29.5 hrs	8 hrs	20 hrs	24 hrs	81.5 hrs

The table confirms the continuous existence of reverse flow, and thus the impact of distributed generation on transmission planning. It also highlights that the impact varies, depending on the actual availability and timing of DER including output from distribution connected wind generators. This trend of increasing reverse flows will create a more complex network to operate, and may require re-optimisation of asset control schemes to ensure secure and reliable operation.

Strong coordination between transmission network service providers (TNSPs) and distribution network service providers (DNSPs) will be important to monitor and manage these reverse flows and other effects of increased DER.

Impact of rooftop PV on minimum demand

Rooftop PV can reduce the apparent operational demand, allowing it to lessen peak demand and further decrease the minimum demand seen in the network.

Historically, rooftop PV has impacted demand during daylight hours between 08:00 and 17:00. As seen in Section 2.2.3, rooftop PV has started to impact minimum demand, which has historically occurred outside of daylight hours between the hours of 02:00 and 05:00. AEMO's latest forecasts are projecting the time of minimum demand to move from overnight to midday by 2022 in Victoria[35], mostly driven by the increasing penetration of rooftop PV.

As Section 2.2.2 and 2.2.3 show, the Victorian DSN is becoming increasingly reliant on operational measures to manage high voltages within operating limits during minimum demand periods, including de-energisation of 500 kV lines, which are the backbone of the network.

This increases operational risk, due to reduced availability of transmission infrastructure, and has the potential to constrains generation, incurring a market impact. Reduced levels of synchronous generation during minimum demand periods also increase operational challenges, due to reduced plant being available to assist in voltage control.

AEMO is progressing the Victorian Reactive Power Support RIT-T to identify the preferred option to manage high voltages to within operating limits during minimum demand periods. See Section 3.6 for more detail.

2.7.2 Generator retirements

The changing generation mix has materially changed flows on the Victorian DSN, following the closure of the last Hazelwood Power Station unit in March 2017. The remaining coal-fired generators are expected to retire over time, as they reach their technical end-of-life and the power system transitions to a low-carbon future.

AEMO assessed the impact of the Hazelwood Power Station closure on interconnector flows and generated energy mix by fuel type, considering a year before and a year after the Hazelwood Power Station closure.

The major findings for generation, shown in Figure 6, were:

- Generated energy from brown coal decreased, due to reduced capacity after the Hazelwood closure.
- Generated energy from gas increased, likely compensating for the decreased brown coal generation.
- Generation from hydro decreased.

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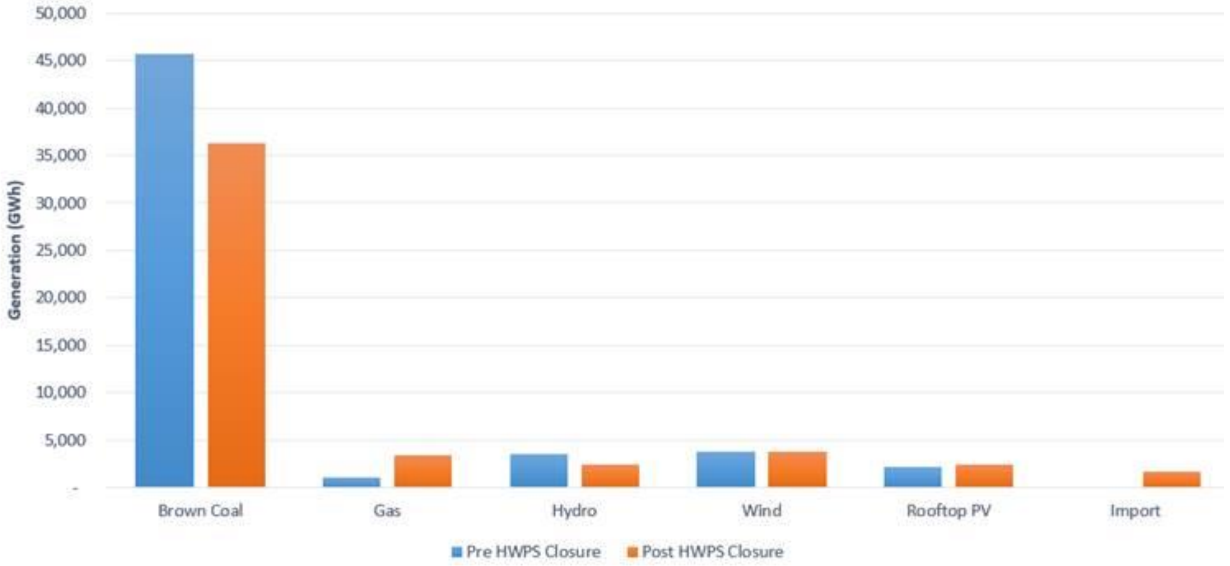
34 The total hours differ from the values published in the 2017 VAPR due to an update to the calculation methodology.

35 AEMO, 2017 *Electricity Forecasting Insights*, available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Electricity-Forecasting-Insights/2017-Electricity-Forecasting-Insights.

- Generation from embedded rooftop PV[36] increased slightly, likely due to additional installations.

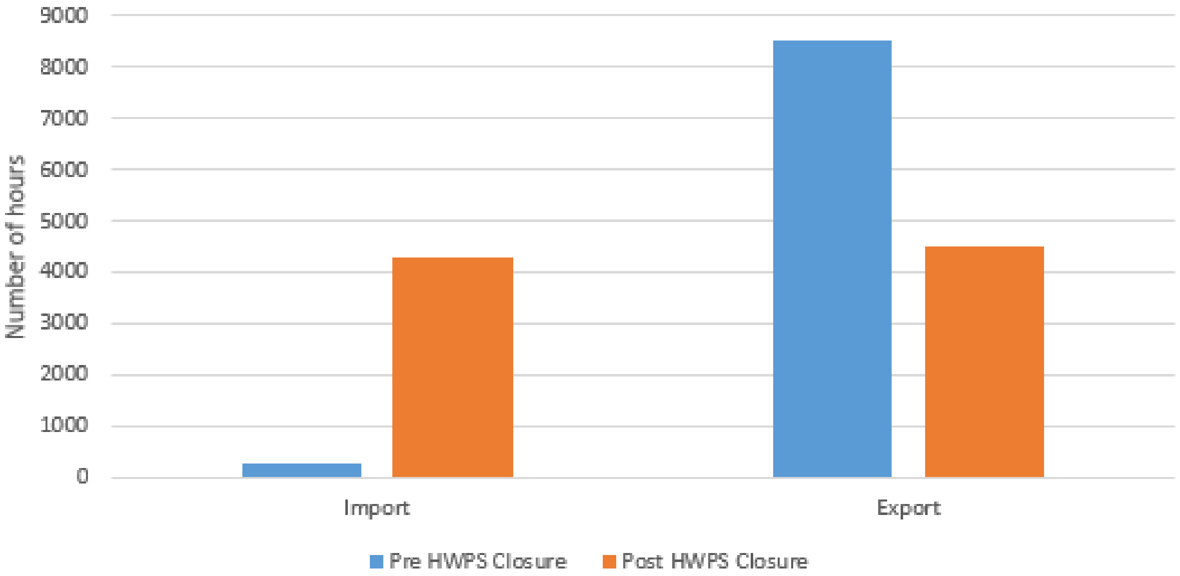
Figure 6 Comparison of Victorian generated energy by fuel type



HWPS refers to the Hazelwood Power Station.

The impact on Victorian imports and exports is shown in Figure 7.

Figure 7 Comparison of Victorian import and export hours



Energy imports into Victoria increased, and energy exports out of Victoria decreased. Interconnector flows have changed, from average annual net export hours of 86% in the past five years, to 51% of net export hours in the year since Hazelwood's retirement. Refer to Sections 3.8, 5.2 and 5.3 for further detail on import and export limitations between Victoria and New South Wales as well as options to address the limitations.

[36] Rooftop PV is considered as embedded generation and is not necessarily transmitted through the Declared Shared Transmission (DSN) network.

3. Network development

This chapter describes forecast DSN limitations[37] that are expected to appear over the next 10 years.

Key insights of this chapter

- High levels of renewable generation connections continue to drive the need for augmentation in western Victoria. This chapter includes a new section on opportunities and challenges for connection new generation in Victoria.
  - Several large scale renewable projects became committed in late 2017 and early 2018 in this region.
  - AEMO is progressing the Western Victoria Renewable Integration RIT-T to identify the preferred option for increasing capacity in the area.
- Reducing minimum grid demand is increasing the need for a long-term term solution to address high voltages on the network during light load periods.
  - AEMO is progressing the Victorian Reactive Power Support RIT-T to identify the preferred option to manage high voltages to within operating limits during minimum demand periods.
- Improving interconnection between Victoria and New South Wales will allow sharing of generation between regions, improving competition and reliability of supply to customers.
  - VAPR analysis shows that increasing the export capability of the Victoria - New South Wales interconnector through augmentations within the Victorian DSN is economically justifiable, and AEMO will commence a RIT-T within the next 12 months to identify the preferred option.
  - AEMO is investigating options to increase import capability from New South Wales into Victoria which will help support Victoria during high demand periods.

3.1 Methodology

3.1.1 DSN augmentation planning approach

To identify network augmentation needs, AEMO first investigates transmission network limitations by:

- Reviewing historical network performance over the previous year and the periods that known constraints were binding.
- Reviewing future network performance under a range of demand and generation scenarios considering government policy and economic growth projections.

For any major transmission limitations identified, AEMO performs an exploratory study, using high-level market modelling to identify potential market benefits of relieving the transmission limitations.

Appendix C has more information on AEMO's transmission network limitation review approach.

If positive net market benefits are identified as likely, AEMO initiates a pre-feasibility study, using detailed market modelling to assess the benefits from credible augmentation options. Depending on the scale of costs, if positive net market benefits are projected, this pre-feasibility study may lead to a RIT-T.

This analysis provides signals for potential network and non-network development opportunities, such as localised generation or demand response.

[37] DSN limitations represent network capacity shortfalls which impose constraints on power transfer or result in inability to meet the network performance requirements set out in NER or other relevant legislation or regulations.

Further detail on the DSN planning methodology can be found in AEMO's *Victorian Electricity Planning Approach*[38].

3.1.2 Joint planning

AEMO undertakes active joint planning with other TNSPs and DNSPs to discuss and investigate the challenges and opportunities in addressing transmission limitations via several forums, including those summarised below.

Regular joint planning meetings

For the purpose of effective network planning in Victoria, AEMO conducts regular joint planning meetings with TransGrid, TasNetworks, ElectraNet, and Victorian DNSPs. AEMO also works in close collaboration with the Victorian Government.

Executive Joint Planning Committee

The Executive Joint Planning Committee (EJPC) coordinates effective collaboration and consultation between jurisdictional planning bodies, and AEMO, on electricity transmission network planning issues to:

- Coordinate planning between regions and nationally
- Develop the framework for the Integrated System Plan recommended by the Finkel Review.
- Continuously improve current network planning practices.
- Coordinate on energy security across the NEM.

AEMO chairs the Joint Planning Committee meetings and separately attends as the Victorian TNSP. This is a working committee, supporting the EJPC in achieving effective collaboration, consultation and coordination between TNSPs and AEMO on electricity transmission network planning issues.

Joint planning projects

The outcomes of the joint planning discussions and investigations via the above forums have been incorporated into the VAPR in the context of the following projects:

- ISP (refer to Chapter 5).
- Western Victoria Renewable Integration RIT-T (refer to Sections 3.6, 5.2 and 5.3).
- New South Wales to Victoria export capability (refer to Sections 3.8, 5.2 and 5.3).
- New South Wales to Victoria import capability (refer to Section 3.8, 5.2 and 5.3).
- Distribution network planning and the potential DSN impacts and considerations (refer to Section 3.8).
- South Australia Energy Transformation RIT-T (refer to Sections 3.6, 5.2, and 5.3).
- Marinus Link (refer to Section 5.2 and 5.3).

3.1.3 Scenarios considered

The scenarios considered in this report assess how augmentation needs may be impacted by a range of uncertainties. The scenarios considered sensitivities to factors such as population and economic growth, technology uptake, consumer confidence, and the identification of renewable energy zones (REZs). The scenarios also considered potential changes to the generation mix, including REZs, to meet renewable energy targets at State and Federal Government level.

Specifically, the 2018 VAPR considered the following scenarios over a 10-year outlook:

- Fast change scenario – assumed operational consumption, generation expansion, and retirement plans in line with the 2018 ISP generation outlook for the Fast change scenario. Compared to the central scenario, this scenario has higher load growth, delivers greater emissions reductions, is supported by faster reductions in technology costs and a higher take-up of energy efficiency measures and electric vehicles and has stronger domestic and international gas demand.
- Central scenario – assumed operational consumption, generation expansion, and retirement plans in line with the 2018 ISP generation outlook for the Central scenario. This scenario also assumed a range of central, or mid-point projections of economic growth, future demand growth and fuel costs. The upcoming 2018 ISP models two central cases, 'Neutral' and 'Neutral with storage initiative'. The 2018 VAPR focussed consideration on the Neutral case as

[38] AEMO, *Victorian Electricity Planning Approach*, 2016, available at http://www.aemo.com.au/Electricity/Policies-and-Procedures/Planning/Victorian-Electricity-Planning-Approach.

the proposed Snowy 2.0 initiative is at the end of the VAPR's 10-year outlook. Future work packages on each potential augmentation will explicitly consider the impact of any committed storage developments.

- Slow change scenario – assumed operational consumption, generation expansion, and retirement plans in line with the 2018 ISP generation outlook for the Slow change scenario. Compared to the Central case, this scenario also assumed weaker economic growth, weaker gas demand, and, while current emissions targets would be met, the facilitating technologies not developing as quickly and take-up of energy efficiency measures being lower.

3.2 Completed projects and retirements

3.2.1 Network upgrades

The following projects have been completed since the 2017 VAPR:

- Deer Park terminal station.
  - AEMO, Jemena, and Powercor identified the need for a new terminal station at Deer Park to address limitations at terminal stations servicing Jemena and Powercor's distribution networks in the western Melbourne metropolitan area[39]. The new Deer Park terminal station was completed in August 2017.
- Additional Ballarat – Moorabool 220 kV circuit.
  - This circuit, strung on the vacant side of the existing transmission line towers, was proposed as the second stage of the preferred option from the Regional Victorian Thermal Capacity RIT-T. The continuous rating of the new circuit is 420 megavolt amperes (MVA) at 40° C and was completed in mid-2017[40].

3.2.2 New generator connections

The following generator connections have been completed since the 2017 VAPR:

- The 28.7 MW Yaloak South Wind Farm connected to the Victorian DSN via Powercor's network between Ballarat and Brooklyn in late 2017.
- The 31 MW Kiata Wind Farm connected to the Victorian DSN via Powercor's network at Horsham in late 2017.
- The 55 MW Gannawarra Solar Farm connected to the Victorian DSN at Kerang Terminal Station in early 2018.

Because AEMO is responsible for planning and operating the transmission network, this section does not present connections embedded within the distribution network.

3.2.3 Retirements

There have been no retirements in the Victorian DSN since the 2017 VAPR.

3.3 Committed generation and transmission projects

Information on committed future terminal station projects for connecting load or generation is also presented in this section. This is supported by AEMO's policy and guidelines for establishing new terminal stations in Victoria[41].

3.3.1 Committed generation projects

As at March 2018, the following generation projects meet the criteria for committed projects, having advanced to the point where proponents have secured land and planning approvals, entered into contracts for finance, and either started construction or set a firm date:

- Coal – Loy Yang B (upgrade) (78 MW).
- Solar (DSN connection) – none.
- Solar (distribution connection) – Bannerton Solar Park (88 MW), Gannawarra Solar Farm (55 MW)[42], Swan Hill Solar Farm (15 MW), and Yatpool Solar Farm (81 MW).

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[39] Jemena. Powercor, Jemena, and AEMO joint regulatory test report, available at https://jemena.com.au/industry/electricity/network-planning/western-metropolitan-melbourne-transmission-connec.

[40] AEMO. *Regional Victorian Thermal Capacity Upgrade*, available at http://www.aemo.com.au/Electricity/Planning/Regulatory-Investment-Tests-for-Transmission/Regional-Victorian-Thermal-Capacity-Upgrade.

[41] AEMO. *Guidelines for Establishing Terminal Stations in Victoria, 2011*, available at http://www.aemo.com.au/~/media/Files/Other/network_connections/0174-0018%20pdf.ashx.

[42] This project is complete and connected to the Victorian DSN.

- Wind (DSN connection) – Crowlands Wind Farm (80 MWDSN).
- Wind (distribution connection) – Kiata Wind Farm (31.05 MW)[42], Mt Gellibrand (132 MW), Salt Creek (54 MW), and Yaloak South (28.7 MW)[42].

Because AEMO is responsible for planning and operating the transmission network, this section does not present connections embedded within the distribution network.

More information on committed and potential generation projects for development over the next 10 years can be found on AEMO's generation information page[43]. A register containing information on large[44] generator connections is also published on AEMOs website[45].

3.3.2 Committed transmission network projects

The following projects meet the criteria for committed projects, having advanced to the point where proponents have secured land and planning approvals, entered into contracts for finance, and either started construction or set a firm date:

- Bulgana terminal station.
  - This new terminal station between Ararat and Horsham Terminal Stations, facilitating the connection of Bulgana Wind Farm, is expected to be completed in early 2019. Bulgana Wind Farm was not reported as committed in the March 2018 update of the AEMO generator information page.
- Crowlands terminal station.
  - This new terminal station between Ararat and Horsham Terminal Stations, facilitating the connection of Crowlands Wind Farm, is expected to be completed in late 2018. Crowlands Wind Farm was reported as committed in the March 2018 update of the AEMO generator information page.
- Murra Warra Terminal station.
  - This new terminal station between Horsham and Redcliff Terminal Stations, facilitating the connection of Murra Warra Wind Farm Stage1, is expected to be completed in mid 2019. Murra Warra Wind Farm Stage1 was not reported as committed in the March 2018 update of the AEMO generator information page.
- Haunted Gully Terminal station.
  - This new terminal station between Moorabool and Tarrone Terminal Stations, facilitating the connection of Stockyard Hill Wind Farm, is expected to be completed in late 2019. Stockyard Hill Wind Farm was not reported as committed in the March 2018 update of the AEMO generator information page[Error! Bookmark not defined.].

Refer to Chapter 4 for information on transmission asset retirements.

3.4 Potential generation projects

For large scale generators connecting to the Victoria DSN, AEMO is involved in all stages of the connection process, from pre-feasibility to completion.

For generator distribution connections, the connecting DNSP manages the connection process and is the main point of contact for the connection applicant.

Information on AEMO's processes for network connections[46], network augmentations to cater for new generation connections, and requests for network data[47] can be found on AEMO's website.

3.5 Opportunities and challenges for connecting new generation in Victoria

The high level of renewable generation connection interest in western Victoria, due to favourable wind and solar resources in the area, aligns with the ISP's identification of three REZs in this part of Victoria – Western Victoria, Murray River, and Moyne.

[43] AEMO, Generation Information, available at http://www.aemo.com.au/Electricity/Planning/Related-Information/Generation-Information. Definitions for committed projects are under the 'Background information' tab on each regional spreadsheet.

[44] Generators with a nameplate rating of 30 MW or greater.

[45] AEMO, Register of large generator connections, available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Victorian-transmission-network-service-provider-role/Register-of-Large-Generator-Connections.

[46] AEMO, Network Connections, available at http://www.aemo.com.au/Electricity/Network-Connections.

[47] AEMO, *Policy on provision of network data*, available at: http://www.aemo.com.au/Electricity/Policies-and-Procedures/Planning/Policy-on-Provision-of-Network-Data.

If the volume of new generation active in current connection applications and enquiries connects into the grid, individual generators (both new and existing) may be constrained, mainly due to thermal and system strength limitations of the transmission system in western Victoria. Network limitations outside of western Victoria (including interconnector capability) may also constrain the output of these new generators.

- AEMO is undertaking the Western Victoria Renewable Integration RIT-T to assess the technical and economic viability of increasing transmission network capability in western Victoria, to identify the preferred augmentation option and its optimal timing (see Section 3.6 below).
- The creation of new REZs in remote areas in western Victoria could lead to low system strength issues, as renewable generating units generally contribute much lower fault current and low inertia than conventional synchronous generating units. Generators connecting to areas with low fault levels which are below the generator capability requirements will be required to improve system strength to meet their capability requirements. See Section 5.2.2 of this VAPR and the ISP for more detail on system strength requirements.

New generator connections should also consider the impact of lower Marginal Loss Factors (MLFs) at their connection point. In dispatch and settlement in the NEM, the price of electricity is directly influenced by the MLF. Renewable generation in western Victoria is remote from Victorian load centres and, as such, is exposed to higher network losses, represented through lower MLFs. A generator's revenue is directly scaled by its MLF, through both electricity market transactions and revenue derived from large-scale generation certificates (LGCs). The impending ISP has further detail on the impact of MLFs on the REZs.

More information on opportunities and challenges for connecting new generation in Victoria can be found on AEMO's website[48].

3.6 Current transmission development opportunities

Western Victoria Renewable Integration RIT-T

The Western Victoria Renewable Integration RIT-T seeks to increase the capability of the western Victoria power system, and reduce congestion of projected new generation in that region. See the Project Specification Consultation Report (PSCR) of this RIT-T for more information[49].

AEMO is currently progressing a Project Assessment Draft Report (PADR) which will identify the preferred option for augmentation, as well as the optimal timing for investment. AEMO will publish the PADR for this RIT-T in December 2018.

South Australian Energy Transformation RIT-T

ElectraNet is exploring network and non-network options that can facilitate South Australia's energy transformation through the South Australian Energy Transformation RIT-T[50].

AEMO is engaged in joint planning with ElectraNet investigating the feasibility of one of the options being considered, a potential new interconnection between Victoria and South Australia.

Victorian Reactive Power Support RIT-T

The Victorian Reactive Power Support RIT-T seeks to increase the level of reactive power support within Victoria to maintain transmission system voltages within operational limits during minimum demand periods. See the Project Specification Consultation Report (PSCR) of this RIT-T for more information[49].

AEMO is currently progressing a Project Assessment Draft Report (PADR) which will identify the preferred option for augmentation, as well as the optimal timing for investment.

Section 3.7 below discusses AEMO's reactive power management strategy.

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[48] AEMO, Network Connection Initiatives, available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Network-connections/Network-connection-initiatives

[49] AEMO, Regulatory Investment Tests for Transmission, available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Victorian-transmission-network-service-provider-role/Regulatory-investment-tests-for-transmission.

[50] ElectraNet. South Australian Energy Transformation RIT-T, available at https://www.electranet.com.au/projects/south-australian-energy-transformation/.

3.7 Reactive power management strategy

High voltages due to lightly loaded transmission lines in the South-West Corridor around Geelong, Keilor, Portland, and Moorabool have been observed during minimum demand periods, and are expected to worsen with projected reductions in minimum operational demand[51].

Before the closure of Hazelwood Power Station in March 2017, AEMO managed high transmission system voltages with short-term de-energisation of a single 500 kV line when other means of voltage control had been exhausted. Following the closure of Hazelwood Power Station, the frequency of low 500 kV line loading under minimum demand conditions has increased.

AEMO and Victorian DNSPs have also jointly investigated the option of switching off distribution capacitors during light load periods to manage high voltages. As a result of the investigation, a temporary arrangement has been made to switch off up to 350 megavolt amperes reactive (MVAr) of distribution capacitors since December 2017.

However, since March 2017, even with switching off distribution capacitors, the need for de-energisation of 500 kV lines has increased significantly. By March 2018, the de-energisation of 500 kV lines had been implemented more than 40 times during light load periods to manage high voltage, and de-energisation of two 500 kV lines has also been required five times during very light load periods.

With the forecast continued reduction in minimum operational demand, future de-energisation of single and two 500 kV lines may be required to be implemented more frequently, and potentially even de-energisation of three or more 500 kV lines may be required within the next five years.

While de-energisation of 500 kV line(s) can help keep voltages within operating and design limits, it can also potentially constrain generation, incurring a market impact. The de-energisation of multiple 500 kV lines also increases operational risks, due to reduced availability of transmission infrastructure.

AEMO considers de-energisation of single 500 kV lines frequently and two 500 kV lines occasionally undesirable, and de-energisation of more than two 500 kV lines particularly undesirable, considering market impact and reliability risk[52].

AEMO is undertaking the Victorian Reactive Power Support RIT-T[53] to identify the preferred long-term solution to maintain voltages within operational and design limits. The required lead time for major augmentations from a RIT-T can be up to three years, depending on the preferred option.

In the interim, AEMO's reactive power management strategy in the short to medium term is as follows:

- 0 to 6-month timeframe – the use of special operational measures:
  - Lower operational voltage limits at the 500 kV bus connecting Loy Yang Power Station, to allow for full utilisation of the existing generator's reactive power capability.
  - Discuss with DNSP the arrangements for distribution capacitor switching off or transformer tapping.
  - Investigate and implement any network reconfiguration.
  - 500 kV line switching, taking into account Operations Planning Working Group[54]/Power System Security Working Group position on the reasonable use of line switching for voltage control.
- 6-month to 3-year timeframe – implement lower cost (less than $6 million) short lead time solutions once they are economically justified:
  - Negotiate with existing generators to provide additional voltage control support
  - Install additional circuit breakers on existing 500 kV line shunt reactors.
  - Install an additional reactor on the 220 kV network.

The RIT-T will identify the preferred (staged) solutions beyond the 3-year timeframe, which could include network solutions, such as the installation of new static and dynamic reactive plant, and non-network solutions.

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[51] Minimum operational demand is forecast to fall from approximately 2,300 MW in 2016-17 to approximately 900 MW in 2027-28. AEMO is reviewing the methodology for forecasting minimum demand at connection point level to assist in understanding the risks associated with reducing minimum demand.

[52] Increased risk of load shedding should there be an unplanned loss of a single of multiple network assets.

[53] AEMO, Regulatory Investment Tests for Transmission, available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Victorian-transmission-network-service-provider-role/Regulatory-investment-tests-for-transmission.

[54] AEMO, Operations Planning Working Group, available at http://www.aemo.com.au/Stakeholder-Consultation/Industry-forums-and-working-groups/Other-meetings/Operations-Planning-Working-Group.

3.8 Emerging development opportunities

The VAPR identifies opportunities to address transmission network limitations, where credible solutions are likely to deliver positive net market benefits within the next 10 years.

The following emerging development opportunities have been identified:

- Improve Victoria to New South Wales export capability, to transfer surplus generation out of Victoria to New South Wales.
- Improve New South Wales to Victoria import capability.

Improve Victoria to New South Wales export capability

The 2017 VAPR assessment of export capability to New South Wales concluded that the gross market benefits of increasing Victoria to New South Wales export capability was likely sufficient to justify augmenting the associated three limitations within the Victorian DSN.

The 2018 VAPR reassessed the export capability to New South Wales considering the latest available information.

Impact on transmission performance

Export capability from Victoria to New South Wales is frequently limited by thermal capacity limitations on the South Morang F2 transformer, South Morang – Dederang 330 kV lines, and a transient stability limitation. These limitations will constrain generation within Victoria during times of high Victoria to New South Wales export.

Forecast market benefit

Based on preliminary modelling, the forecast gross market benefit of relieving all limitations impacting Victoria to New South Wales export is approximately $220 million and $195 million over the next 40 years under the Slow Change and Central scenarios respectively, and increases to approximately $495 million under the Fast Change scenario. The benefits projected under the Slow Change scenario are greater than under the Central scenario because overall Victorian demand is lower under the Slow Change scenario, resulting in more renewable generation being exported. The projected benefits for the Fast Change scenario are significantly higher, due to significantly higher levels of renewable generation connecting in western Victoria under this scenario, resulting in more renewable generation being exported.

The benefit comes from allowing New South Wales and Queensland customers to increase use of lower cost generation from Victoria. South Australian customers will also benefit, because this augmentation also increases the Victoria to South Australia export limit.

The gross market benefits under all scenarios were calculated assuming that all limitations within the western Victoria areas would be fully removed by the preferred option to be identified by the Western Victoria Renewable Integration RIT-T. As such, the market benefits calculated represent the upper bound of market benefits achievable, and are sensitive to the preferred option to be identified by the Western Victoria Renewable Integration RIT-T.

Development options considered

Any project to improve Victoria to New South Wales export capability will need to collectively address the limitations on the South Morang F2 transformer, South Morang – Dederang 330 kV lines, and the transient stability limit, as they all play a similar role in limiting the transfer from Victoria to New South Wales.

The following three augmentation options may be considered:

1. Installation of a new 500/330 kV transformer at South Morang.
2. Uprating of the South Morang – Dederang 330 kV lines by conductor re-tensioning.
3. Increasing the transient export limit, through network options such as a braking resistor or non-network solutions.

The projected total cost of these augmentation options is approximately $75 million. However, if more substantial upgrades or a new circuit were to be required to address the South Morang – Dederang 330 kV line limitation, this cost could increase.

The augmentation options listed above only present one possible set of options. There may be other options which can also increase the Victoria to New South Wales transfer limit. The above options should be treated as indicative only, and a RIT-T will be required to identify all feasible solutions and the preferred option.

Conclusion

The 2018 VAPR analysis shows that the gross market benefits of alleviating the three limitations are likely sufficient to justify augmentations, under all three scenarios.

The upcoming 2018 ISP also highlights the need for increased interconnection between Victoria and New South Wales. AEMO will commence a RIT-T following the release of the ISP to identify the preferred option for increasing the Victoria to New South Wales export capability. This RIT-T will also consider latest developments, including from the Western Victoria Renewable Integration RIT-T, South Australian Energy Transformation RIT-T, Snowy 2.0 and AEMO's ISP.

Refer to Section 5.3 for detail on how augmentations to the Northern Corridor relates to the long term strategic plan for the NEM.

Improve New South Wales to Victoria import capability

Impact on transmission performance

Import capability from New South Wales to Victoria is limited by thermal limitations on the Murray – Dederang 330 kV lines, the South Morang – Dederang 330 kV lines, and the Dederang – Mount Beauty – Eildon – Thomastown 220 kV transmission path, as well as a voltage stability limitation. Any increase in this import capacity will help support Victoria during high demand periods.

Development options considered

AEMO is considering network and non-network options. These include (but are not limited to) the following possible options, which can be implemented within a short lead time, to increase import capability for the short to medium term:

1. Implement an automatic load shedding scheme to allow for operating the Murray – Dederang 330 kV lines to a higher thermal rating. This measure will increase the thermal import limit to Victoria by about 200 MW.
2. Increase the thermal transfer capability by installing wind monitoring facilities on the Dederang – Mount Beauty – Eildon – Thomastown 220 kV lines.
3. Implement an automatic load shedding scheme to allow for operating the Eildon – Thomastown 220 kV lines to a higher thermal rating.
4. Procure network support services to increase the voltage stability import limit to Victoria from New South Wales. This service may involve the provision of additional reactive support (generating).

Thermal limitations

Thermal limitations on the Murray – Dederang 330 kV lines, the South Morang – Dederang 330 kV lines, and the Eildon – Thomastown 220 kV transmission path can also limit import capability from New South Wales to Victoria. AEMO is investigating the feasibility of the load shedding and wind monitoring options mentioned above to increase the thermal limitations of the lines limiting import from New South Wales to Victoria.

The level of Murray generation influences the import capability from New South Wales to Victoria. If the ambient temperature is 45°C, the Eildon – Thomastown 220 kV line is the binding line for lower levels of Murray generation (less than 1,100 MW), while the Murray – Dederang 330 kV line is the binding line for higher levels of Murray generation (greater than 1,100 MW). If the ambient temperature is 40°C, the binding line would be the Murray – Dederang 330 kV line, regardless of the level of Murray generation. See Figures 8 and 9 for detail.

Figure 8 Level of New South Wales import and Murray generation with 45°C line ratings

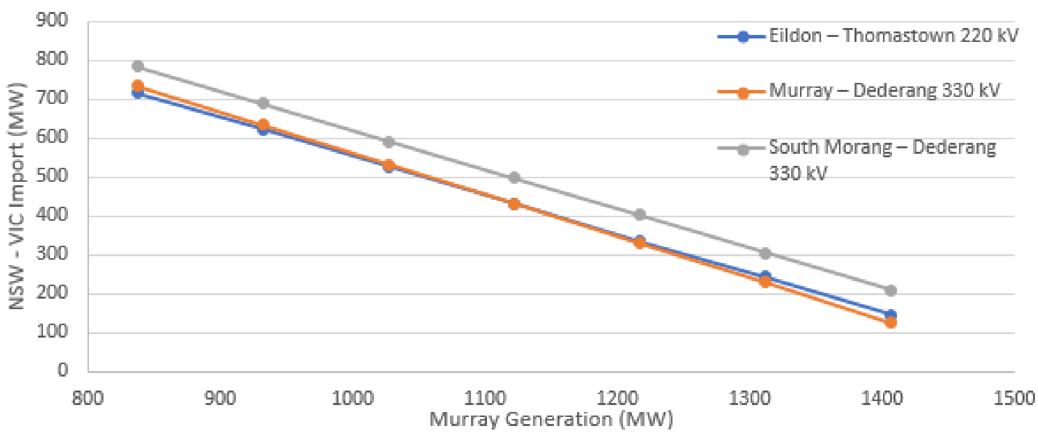
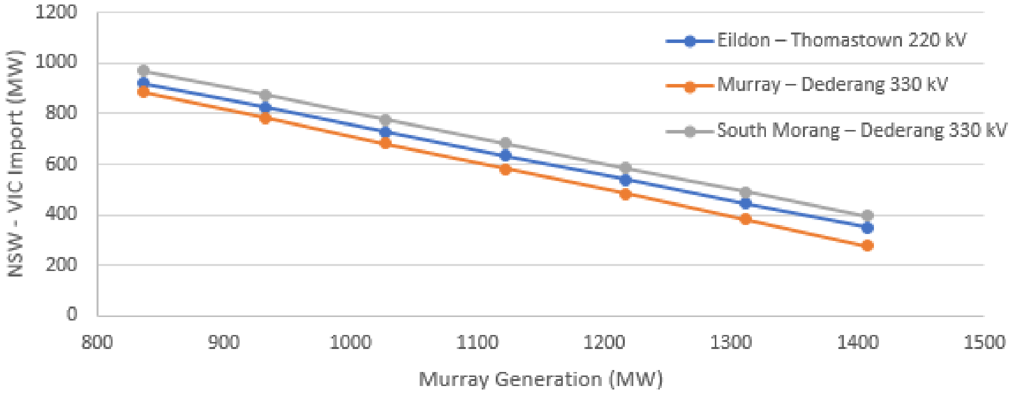


Figure 9 Level of New South Wales import and Murray generation with 40°C line ratings



AusNet Services has received approval for a Network Capability Incentive Parameter Action Plan (NCIPAP) project to install Smart Wires technology at Wodonga Terminal Station (WOTS). This can reduce the reactance on the Jindera – Wodonga 330 kV line, allowing more power to flow through these lines, and reducing loading on the Murray – Dederang 330 kV lines. The Murray – Dederang 330 kV lines can constrain imports from New South Wales to Victoria and, as such, this project has the potential to improve the New South Wales to Victoria import capability by 14.5 MW. This project can also improve the New South Wales to Victoria voltage stability import limit by approximately one-third of the thermal benefit, and is expected to be completed in the first quarter of 2020.

Voltage stability limitation

The operation of generating units in synchronous condenser mode when not generating active power will provide dynamic reactive support that can relieve the existing voltage stability limitation constraining import capability from New South Wales to Victoria.

The voltage stability limitation acts to constrain power transfers into Victoria to a level that will prevent voltage collapse in southern New South Wales if a credible contingency event occurs in Victoria (loss of the largest Victorian generating unit or the Basslink interconnector). As such, generators able to offer synchronous condenser services in southern New South Wales will have the greatest impact, followed by generating units located in northern Victoria near the New South Wales border.

AEMO sought expressions of interest (EOIs) from NEM-registered generators with generating units that have the capability to operate in synchronous condenser mode when instructed by AEMO. These services could be required at times when a generating unit is not dispatched to provide active power, but is available to be run as a synchronous condenser. AEMO has received responses to the EOI and is assessing their technical and economic feasibility.

TransGrid has received approval for a NCIPAP[55] project to install a 100 MVAr capacitor in southern New South Wales to relieve this voltage stability limitation. TransGrid is undertaking detailed studies to identify the optimal location for the capacitor. Further detail can be found in TransGrid's 2018 Transmission Annual Planning Report (TAPR)[56].

Conclusion

AEMO is pursuing minor augmentation options, with relatively low costs and short lead times, to increase the import capability from New South Wales to Victoria.

In addition to the Victorian augmentations, plans are in place to augment the Buronga – Red Cliffs 220 kV line in New South Wales, which will allow the line to operate at its thermal rating.

Future developments impacting the generation mix, such as Snowy 2.0, may require major augmentations and will need to be assessed through a detailed pre-feasibility study.

Refer to Section 5.3 for detail on how augmentations to the Northern Corridor relates to the long term strategic plan for the NEM.

[55] A NCIPAP project is an action plan for improving network capability, put forward to the Australian Energy Regulator (AER) by a TNSP for formal assessment, after it has been independently reviewed by AEMO.

[56] See https://www.transgrid.com.au/publications.

3.9 Monitored transmission limitations

AEMO, through the VAPR analysis, continues to monitor transmission network limitations that may result in supply interruptions or constrain generation periodically, but for which there is currently no known credible solution likely to deliver positive net market benefits.

The full list of monitored transmission limitations can be found in Appendix A. These limitations are not expected to significantly impact the electricity market within the next five years, but may have an impact on the market after this time, depending on changes in generation location, increases in import export, or demand growth.

AEMO invites stakeholders to discuss any monitored transmission limitations where they consider a solution might deliver net market benefits. Otherwise, AEMO does not plan to undertake further detailed assessment on these limitations within the next 12 months, but will continue to monitor triggering conditions.

Relieve Moorabool – Geelong and Geelong – Keilor 220 kV line thermal limitations

The Moorabool – Geelong – Keilor 220 kV corridor delivers generation from western Victoria to Melbourne and is out of the scope of the Western Victorian RIT-T. As such, AEMO had undertaken detailed analysis as part of the VAPR to identify the benefits of increasing the capacity of this corridor.

Impact on transmission performance

The Western Victoria Renewable Integration RIT-T will seek to increase capacity and relieve transmission limitations within western Victoria. To allow additional VRET renewable generation to be transferred from this region to load centres elsewhere in Victoria, the capacity of the Moorabool – Geelong and Geelong – Keilor 220 kV lines may need to be increased. The timing and extent of any potential constraint is sensitive to the amount and location of the VRET generation, as well as the preferred option of the Western Victoria Renewable Integration RIT-T.

Forecast market benefit

The forecast gross market benefit of relieving the Moorabool – Geelong and Geelong – Keilor 220 kV line thermal limitations is approximately $1.5 million over the next 40 years under the Central scenario, under $1 million under the Slow Change scenario, and increases to approximately $165 million under the Fast Change scenario. The gross market benefits under the Fast scenario are significantly higher due to significantly higher levels of renewable generation connecting in Western Victoria under this scenario. This leads to greater market benefits being realised by relieving constraints on Western Victorian generators.

The market benefits under all scenarios were calculated assuming that all limitations within the western Victoria areas would be fully removed by the preferred option to be identified by the Western Victoria Renewable Integration RIT-T. As such, the market benefits calculated represent the upper bound of market benefits achievable, and are sensitive to the preferred option to be identified by the Western Victoria Renewable Integration RIT-T.

Development options considered

The following network development option could address these limitations:

1. Installing a new single circuit Moorabool – Geelong 220 kV line with a rating of approximately 800 MVA at 35°C, with an estimated cost of $11.2 million.
2. Replacing the existing Geelong – Keilor No. 1 and No. 3 220 kV lines with a new double circuit lines rated at 700 MVA at 35°C, with an estimated cost of $75.5 million.
3. Parallel the existing three Geelong – Deer Park – Keilor 220 kV circuits to form a Geelong – Deer Park and Deer Park – Keilor circuit, each rated 810 MVA at 35°C, at an estimated cost of $3.1 million.

There may be other options to address these limitations. The option presented should be treated as indicative only, and a RIT-T will be required to determine the preferred option.

Conclusion

The 2018 VAPR analysis shows that gross market benefits are more than sufficient for investment under the Fast scenario but insufficient under the Slow and Central scenarios to address the Moorabool – Geelong and Geelong – Keilor 220 kV line thermal limitations. AEMO will closely monitor these limitations, taking into consideration the preferred option of the Western Victoria Renewable Integration RIT-T and the level of VRET generation connection.

Refer to Section 5.3 for detail on how augmentations to the Moorabool-Geelong-Keilor line relates to the long term strategic plan for the NEM.

3.10 Distribution planning

In undertaking augmentation planning, AEMO considers DNSP plans for existing and new connection points, and addresses the impact of DNSP plans in its assessment of transmission network limitations.

AEMO addresses the general impact of distribution network modifications (including load changes and network configuration changes) on the DSN by modelling these modifications at connection points. AEMO and DNSPs work together, undertaking joint planning to address connection asset limitations and potential solutions (for example, installing additional transformers at existing connection points or establishing new connection points). This identifies the most efficient solution for both the distribution network and the DSN.

Appendix B lists the preferred connection modifications from Victorian DNSPs' 2017 Transmission Connection Planning Report, and potential DSN impacts and considerations.

3.11 Network Support and Control Ancillary Services

AEMO has not currently identified a Network Support and Control Ancillary Services (NSCAS) gap in Victoria which is not being dealt with.

4. DSN asset retirement, derating, and replacement

This chapter address new NER requirements because of Rules changes related to DSN asset retirement and deratings.

Key insights of this chapter

- AusNet Services has provided a more detailed asset renewal plan for DSN infrastructure, to make network asset retirement, de-rating, and replacement decisions more transparent.
- AEMO has worked with AusNet Services to select DSN assets which – because of their age or performance – may retire in the next 5-7 years. In each case, AEMO has then analysed the future system needs and hence the potential need to replace the assets.
- AEMO's analysis found that a system need would arise if proposed retirements were to occur.

4.1 Rule changes related to DSN asset retirements and deratings

Due to aging transmission assets, changes in technology and slowing demand growth, there is an increasing need to coordinate DSN asset renewal and augmentation programs in Victoria, and to assess the need for asset replacements.

AusNet Services is responsible for assessing the condition of Victorian DSN assets owned, operated, and maintained by AusNet Services and for making asset replacement, retirement, and derating decisions for these assets.

AEMO's involvement, as the Victorian Jurisdictional Planning Body (JPB), has mainly involved providing advice at AusNet Services' request, particularly on the continued need for the service provided by the DSN assets owned, operated, and maintained by AusNet Services, and publishing AusNet Services' Asset Renewal Plan in the VAPR.

A new rule change[57] for the NER, which came to effect in July 2017, requires:

- The Transmission Annual Planning Reports (TAPRs) to include detailed information on all network asset retirements and de-ratings that would result in a network constraint, that are proposed over the planning period.
- AEMO and the Declared Transmission System Operators in Victoria to undertake joint planning in relation to retirement or de-rating of network assets forming part of the DSN.

The new rule also extends the current regulatory investment test framework to include replacement expenditure. This provides opportunities to replace aging assets, and assets no longer suitable for the changing environment, with modern technologies and non-network options.

4.2 Information for inclusion in this VAPR

AusNet Services' 2018 Asset Renewal Plan is published on the AEMO website[58], and provides information aligned with the new NER requirements according to clauses 5.12.2 (1A), 5.12.2 (4)(iv), 5.12.2 (5), 5.12.2 (6), and 5.12.2 (7).

[57] Available at https://www.aemc.gov.au/rule-changes/replacement-expenditure-planning-arrangements.

[58] Available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Victorian-transmission-network-service-provider-role/Victorian-Annual-Planning-Report.

4.3 Joint planning related to asset retirements or deratings

As per NER clause 5.14A and as part of this VAPR, AEMO and AusNet Services have conducted joint planning to determine whether identified needs arise from a selected set of proposed DSN asset retirements.

In the 2017 VAPR, AEMO highlighted the long-term need for the three 500/220 kV transformers at Keilor Terminal Station, which were expected to reach the end of their service life by 2025. The current AusNet Services' 2018 Asset Renewal Plan indicated this retirement is not proposed till 2026, which is outside the assessment time frame for the 2018 VAPR.

The 2017 VAPR also identified the ongoing need for the 500 kV lines in the west out of Hazelwood Terminal Station. Economic replacement strategies will be considered as these lines reach the end of their serviced life.

4.3.1 Methodology

The Australian Energy Regulator (AER) is currently developing a TAPR guidelines which may include guidance for joint planning in relation to retirement or de-rating of network assets. Before the finalisation of these guidelines, AEMO and AusNet Services have agreed on an approach for joint planning to be adopted in this VAPR:

1. AEMO and AusNet Services jointly select a set of assets included in the AusNet Services' Asset Renewal Plan that are likely to create a DSN constraint and possible need for a RIT-T if these assets are not replaced.
2. The selected assets are grouped with their associated network components whenever possible, and a need assessment is conducted by assessing their network impact if retired. For example, circuit breakers and related switchgear and secondary systems are grouped with the associated network components such as transmission circuits, transformers, generators, or reactive plant. If a circuit breaker is retired, then its associated primary network component will be considered as unavailable for service in assessing the system impact of the circuit breaker retirement.
   - Committed projects, transmission assets that do not form part of the DSN, and most secondary equipment were excluded from the network need assessment.
   - Assets proposed for retirement after 2025 were also excluded from the need assessment due to associated uncertainties impacting the retirement decisions.
3. An initial desktop analysis, and if required, further analysis was carried out to assess whether the retirement of the selected asset would result in a network impact (that is, a network need for its replacement).
   - In the case of the retirement causing a disconnection of a generator, a comment on how much generation would be unavailable was considered.
   - If the proposed retirements would cause line, transformer, or static VAr compensator (SVC) outages, the impact of a credible contingency under the worst case operational conditions (normally either maximum or minimum demand conditions) were examined with a prior outage of the respective network element.

Need assessment results

Table 6 below shows the assets included in the need assessment, and the assessment findings.

The assessments were primarily based on maximum demand conditions, except for the Horsham Terminal Station SVC, which was based on minimum demand conditions.

4.3.2 Next steps

The next step in the joint planning for asset retirement and derating is for:

- AEMO, with AusNet Services, to review the current methodology. This review will take into consideration the TAPR guidelines (to be finalised by the AER).
- AEMO, with AusNet Services, to agree on the RIT-T proponent for projects where an identified need arises from an asset retirement or an asset de-rating decision. AusNet Services is expected to be the RIT-T proponent where at least one of the credible options for the RIT-T project is network asset replacement. In other cases, AEMO is expected to be the RIT-T proponent.
- Where AusNet Services is the RIT-T proponent, AEMO to provide high level information to assist AusNet Services to decide whether to proceed with a RIT-T.

Table 6 Network need assessment results

Project name	Location	Total cost (real $M)	Target completion date	Major assets components	Retirement outcome
Horsham SVC Controls and Protection Replacement	Horsham	9	2022	Horsham 220 kV SVC	Voltage cannot be maintained within limits
Moorabool Terminal Station Circuit Breaker Replacement (8 circuit breakers)	Moorabool	25	2023	Moorabool – Tarrone 500 kV No.1 line and Moorabool – Sydenham 500 kV No.1line breaker-and-half switch bay	Reduced reliability cause by system separation due to a single credible contingency
				Moorabool – Mortlake 500 kV No.2 line and Moorabool – Sydenham 500 kV No. 2 line breaker-and-half switch bay	Reduced reliability cause by system separation due to a single credible contingency
				Moorabool 500/220 kV A1 transformer double-breaker switch bay	Reduced reliability and capability to meet peak demand
South Morang 330/220 kV Transformer Replacement - Stage 2 (One 700 MVA 330/220 kV transformer)	South Morang	35	2023	South Morang 330/220 kV H1 transformer	Reduced reliability and capability to meet peak demand
Loy Yang and Hazelwood 500 kV Circuit Breaker Replacement Stage 2 (14 circuit breakers)	Loy Yang and Hazelwood	40	2024	Loy Yang – Hazelwood 500 kV No. 1line double breaker switch bay	Generation constraints and reduced reliability
				Loy Yang 500 kV A2 Generator transformer double breaker switch bay	Loss of 530 MW of generation
				Loy Yang 500 kV A3 Generator transformer double breaker switch bay	Loss of 560 MW of generation
				Loy Yang 500 kV B2 Generator transformer double breaker switch bay	Loss of 500 MW of generation
			2024	Hazelwood – Loy Yang 500 kV No.2 Line and Hazelwood – Rowville 500 kV No.3 line breaker-and-half switch bay	Generation constraints and reduced reliability
				Hazelwood – Loy Yang 500 kV No.3 Line and Hazelwood – Cranbourne 500 kV No.4 line breaker-and-half switch bay	Generation constraints and reduced reliability
Brooklyn 220 kV, 66 kV and 22 kV Circuit Breaker Replacement (4 220 kV circuit breakers)	Brooklyn	19	2025	Brooklyn – Altona 220 kV line single switched switch bay	New reliability limitations
				Brooklyn -Keilor 220 kV line single switched switch bay	Reduced reliability and capability to meet peak demand
				Brooklyn – Fishermans Bend 220 kV line single switched switch bay	Generation constraints and reduced reliability
				Brooklyn – Newport 220 kV line single switched switch bay	Loss of generation under an outage and reduced reliability

5. Long-term strategic outlook

This chapter:

- Notes some key Government policies which contribute to the transformational changes, and some initiatives currently under discussion.
- Assesses the potential impacts on the DSN of current and projected changes in generation, demand, and interconnection, consistent with the national development pathway identified in the 2018 ISP from a longer-term strategic perspective.
- Proposes a long-term strategic vision to maintain a secure and resilient network in Victoria.

Key insights of this chapter

- AEMO has analysed the national development pathway identified in the ISP that includes:
  - New generation centres in western Victoria.
  - Generation from Snowy 2.0.
  - A new interconnector between South Australia and New South Wales (Riverlink), connecting into Victoria via the Buronga – Red Cliffs transmission path.
  - Augmentation of the interconnector capacity between New South Wales and Victoria.
  - A new interconnector between New South Wales and Victoria (Sydenham – Wagga via Bendigo, Kerang, and Darlington Point).
- AEMO's analysis shows the following DSN impacts of this scenario, and potential solutions that would manage these impacts in a timely, efficient, and strategic way:
  - Increased renewable generation connections in western Victoria would increase the need for additional capacity on the western Victoria to Melbourne (via Keilor) 220 kV transmission path. The need to facilitate the development of this REZ is aligned with recommendations of the ISP.
  - The proposed South Australia – New South Wales interconnector (Riverlink) connected through Buronga would increase the need for additional capacity on the Western Victoria to Melbourne (via Keilor) 220 kV transmission path, as well as the North West Victoria to Melbourne (via Shepparton and Bendigo) 220 kV transmission path.
  - Additional generation from Snowy 2.0 would impact existing transmission limitations in northern Victoria, and in turn may increase the need for additional capacity of the transmission paths between Snowy and Victorian load centres.
  - A new large New South Wales – Victoria interconnector (Sydenham – Wagga via Bendigo, Kerang, and Darlington Point) would increase inter-regional transfer capacity and relieve transmission constraints between Kerang and Sydenham. It would increase the need for additional capacity on the Sydenham – Keilor 500kV line, and on the Keilor 500/200 kV transformers.

5.1 Government emissions reduction policies

The NEM has been undergoing transformational change, driven by factors including a rapid reduction in costs of new technology and Federal and State Government emissions reduction policies. The changes include an unprecedented increase in DER such as rooftop PV, and grid-connected renewable generation, and the withdrawal of aging synchronous generation.

The key government policies which will contribute to the transformation of the NEM power system and are expected to affect the performance of Victorian DSN include:

- The Victorian Government's VRET [59], which requires that 25% of electricity generated in Victoria will come from renewable energy sources by 2020, and 40 per cent by 2025.
- The Federal Government's Large-scale Renewable Energy Target (LRET)[60], which incentivises the installation of large-scale renewable generation financially through the creation of large-scale generation certificates[61].
- The Federal Government's National Energy Guarantee (NEG)[62]. While specific details on its implementation are yet to be finalised, its the broad objective is to maintain the reliability of the system and achieve Australia's international commitments on electricity sector emissions reductions, at the lowest overall costs.

5.2 Potential impacts of changes to Victoria's interconnection and generation mix

5.2.1 Proposed interconnector developments

The following initiatives, identified in AEMO's ISP, would affect the performance of the Victorian DSN, because they would result in changes in generation mix and interconnection capacity between Victoria and neighbouring regions:

- South Australia Energy Transformation (SAET), which proposes additional interconnection between South Australia and New South Wales which would also link into the Victoria system.
- Hydro Tasmania's proposed Battery of the Nation[63], which would result in additional interconnection between Tasmania and Victoria.
- The proposed Snowy 2.0 project[64] and related transmission network developments will change some of the supply options to Victoria and provide demand for some of the generators in Victoria.
- A new Victoria - New South Wales interconnector through Kerang and central Victoria is also proposed.

The proposed developments and their impacts are described in further detail below.

Additional South Australia interconnector

ElectraNet's SAET RIT-T is currently assessing pathways to increase interconnection to South Australia. AEMO also assessed these pathways independently in developing the ISP and recommends the "RiverLink" pathway, which connects Robertstown in South Australia to Wagga Wagga in New South Wales via Buronga. This pathway could also include augmentation of the Buronga to Red Cliffs 220 kV transmission line, affecting the performance of the Victorian DSN.

Figure 10 gives an overview of the projected impact of RiverLink on network loading outside the western Victoria region. The impact on network loading within western Victoria depends on the capacity and location of additional renewable generation to be installed in the area, and is discussed in Section 5.3.2.

High import from RiverLink, combined with high levels of renewable generation in western Victoria, is projected to exacerbate monitored limitations on the 220 kV system between:

- Moorabool – Geelong – Keilor.
- Bendigo – Fosterville – Shepparton.

High export from RiverLink combined with low levels of renewable generation in western Victoria, would result in increased import from New South Wales. This is projected to exacerbate monitored limitations along Murray – Dederang – South Morang and Dederang – Shepparton – Bendigo, and will drive a need for additional New South Wales – Victoria export capacity. Additional New South Wales – Victoria export capacity is discussed further below in this section.

Figure 10 Impact on network loading – RiverLink

[59] See https://www.energy.vic.gov.au/renewable-energy/victorias-renewable-energy-targets.

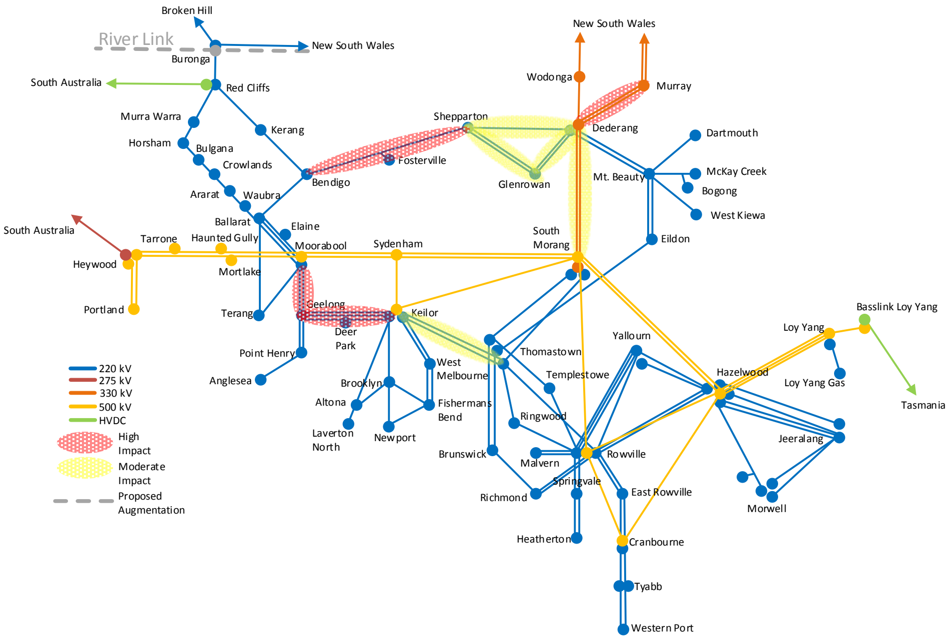
[60] See http://www.cleanenergyregulator.gov.au/RET/About-the-Renewable-Energy-Target/How-the-scheme-works/Large-scale-Renewable-Energy-Target.

[61] Once created and validated, these certificates act as a form of currency and can be sold and transferred to other individuals and businesses at a negotiated price.

[62] See http://www.coagenergycouncil.gov.au/publications/energy-security-board-national-energy-guarantee-consultation-paper.

[63] See https://www.hydro.com.au/clean-energy/battery-of-the-nation.

[64] See http://www.snowyhydro.com.au/our-scheme/snowy20/.

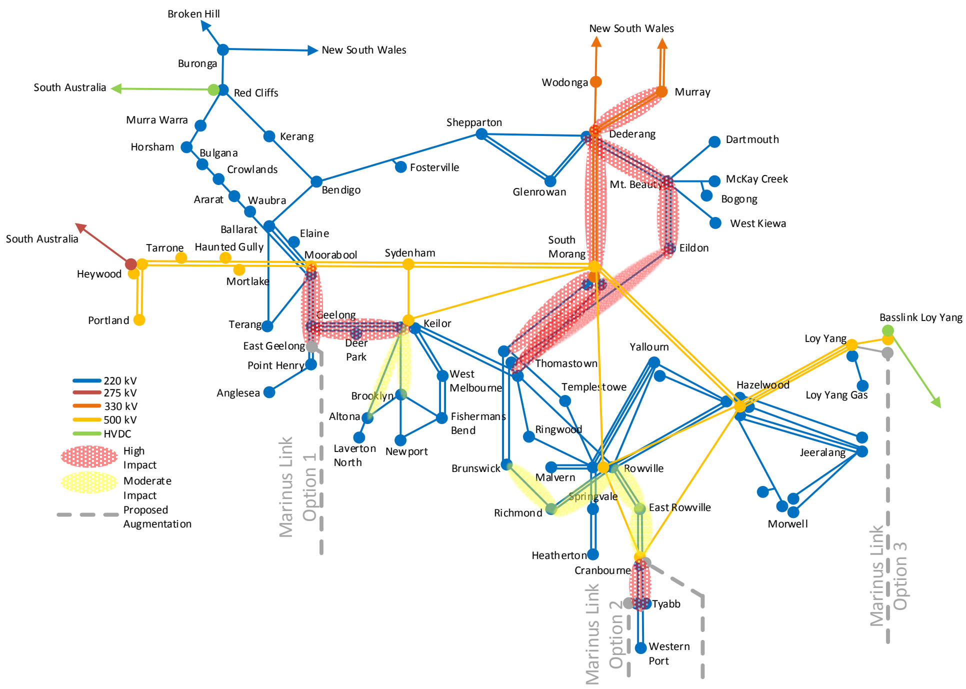


Additional Bass Strait interconnector

The Australian Renewable Energy Agency (ARENA) and TasNetworks are currently assessing options for a second interconnector between Victoria and Tasmania (Marinus Link) as part of Hydro Tasmania's proposed Battery of the Nation project.

AEMO has assessed the impact of Marinus Link on the Victorian DSN, considering four possible connection points. Figure 11 gives an overview of the impact of the Marinus Link on Victorian DSN loading.

Figure 11 Impact on network loading – Marinus Link



In summary:

- The 220 kV system between East Geelong – Geelong, Geelong – Moorabool and Geelong – Keilor could be overloaded under certain operating conditions if Marinus Link was connected to a new terminal station at East Geelong (Option 1).
- The 220 kV system between Tyabb and Cranbourne could be overloaded under certain operating conditions if Marinus Link was connected to the existing Tyabb 220 kV terminal station (Option 2).

No material impact on the local DSN has been found, in this high-level assessment, if Marinus Link is connected to either Loy Yang 500 kV (Option 3) or Cranbourne 220 kV or 500 kV (Option 4).

However, High Basslink and Marinus Link export from Victoria to Tasmania significantly increases projected flows from New South Wales to Victoria for all four connection options described above, particularly during periods when generation in Victoria is low. Additional New South Wales – Victoria interconnection import capacity is likely to be needed, as discussed further below in this section

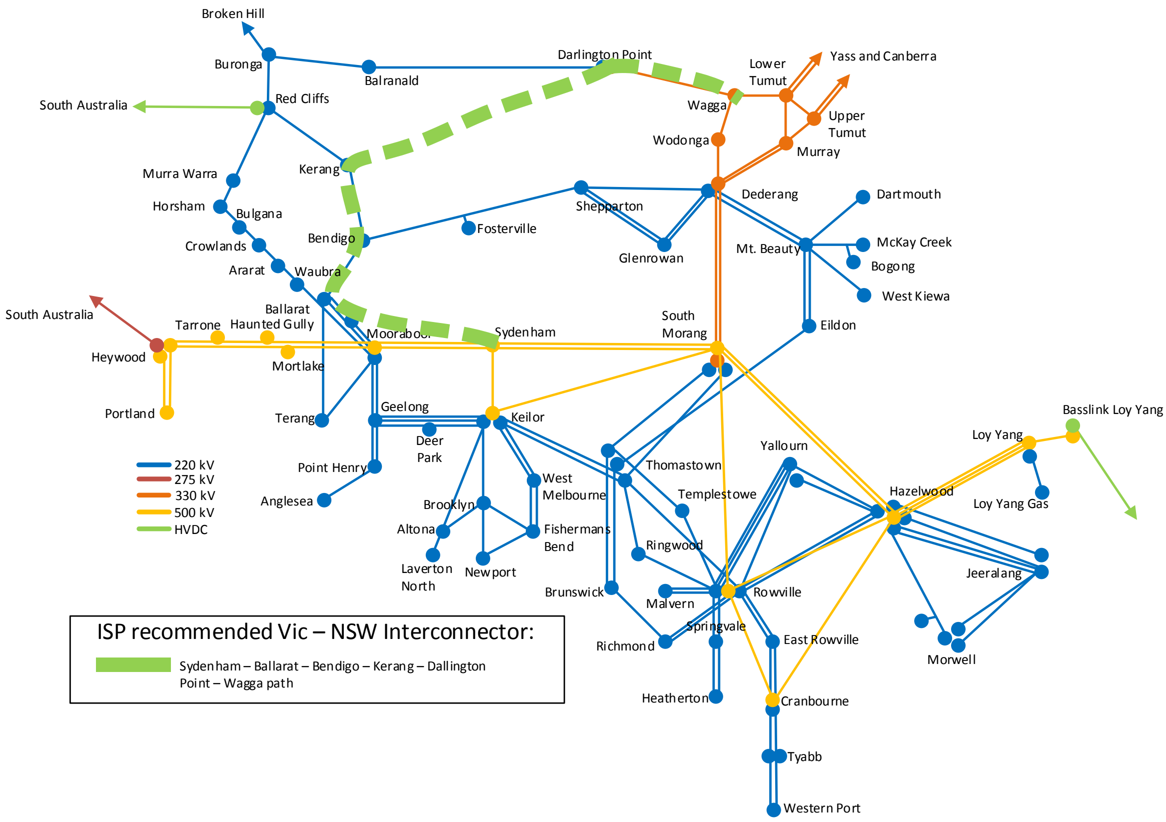
Upgrade to the Victoria - New South Wales interconnector

AEMO, in its role as National Planner, modelled a number of options to upgrade the Victoria – New South Wales interconnector as part of the ISP[65]. A number of options were designed and explored in this work which also considered the resilience of the transmission system.

AEMO's ISP recommends immediate action to upgrade Victoria – New South Wales interconnection to increase Victoria to NSW transfer capacity by 170 MW, through increase thermal capacities of the 500/220kV transformation at South Morang and the existing South Morang – Dederang 330kV line, as well as improve transient stability limit which restricts the Victorian export capability.

In addition to this low capacity augmentation, a high capacity augmentation is proposed through Kerang, as shown in Figure 12

Figure 12 ISP recommended new Victoria – New South Wales interconnector



The proposed Victoria – New South Wales interconnector augmentations would:

- Unlock renewable generation in western Victoria by allowing increased export to New South Wales.

65 See https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan.

- Facilitate the proposed Snowy 2.0 project by relieving constraints in northern Victoria which limit the Victorian import and export capability from/to New South Wales.
- Allow any excess renewable energy in Victoria to be stored in Snowy.

While the augmentation option (shown in Figure 12) would improve the performance of the Victorian DSN by relieving existing constraints, it may also increase loading on the existing network. In particular, it could increase loading on the Sydenham – Keilor 500kV line and Keilor 500/220 kV transformers under certain operating conditions.

Potential augmentation options to address these limitations are discussed in Section 5.4.

5.2.2 Changing generation mix

New renewable energy zones in western Victoria

Since the publication of the 2017 VAPR, about 1,400 MW of new generation (including approximately 400 MW of large-scale solar generation) has become either committed, or with connection agreements signed, in the western Victoria area (see Section 3.3.1 for more details about committed generation projects).

In addition, developing a REZ in Western Victoria and a REZ in the Murray Valley are part of AEMO's ISP pathway for immediate action to provide required capacity and support VRET.

It is projected that about 5,200 MW of new renewable generation will be installed in these zones by 2025[66], including:

- 2,500 MW (primarily wind) on the 500 kV Heywood – Moorabool – Sydenham 500 kV corridor.
- 1,300 MW (primarily wind) on the 220 kV Red Cliffs - Horsham – Ballarat – Terang – Moorabool 220 kV corridor.
- 1,400 MW (primarily solar) on the 220 kV Red Cliffs – Wemen – Kerang – Bendigo 220 kV corridor.

In addition, new generation connections north of the Victoria – New South Wales border can also impact flows in the western Victoria area.

The transmission network in this remote area is weak, and without augmentation, does not have sufficient capacity to allow for full dispatch of the advanced generation projects once they are built.

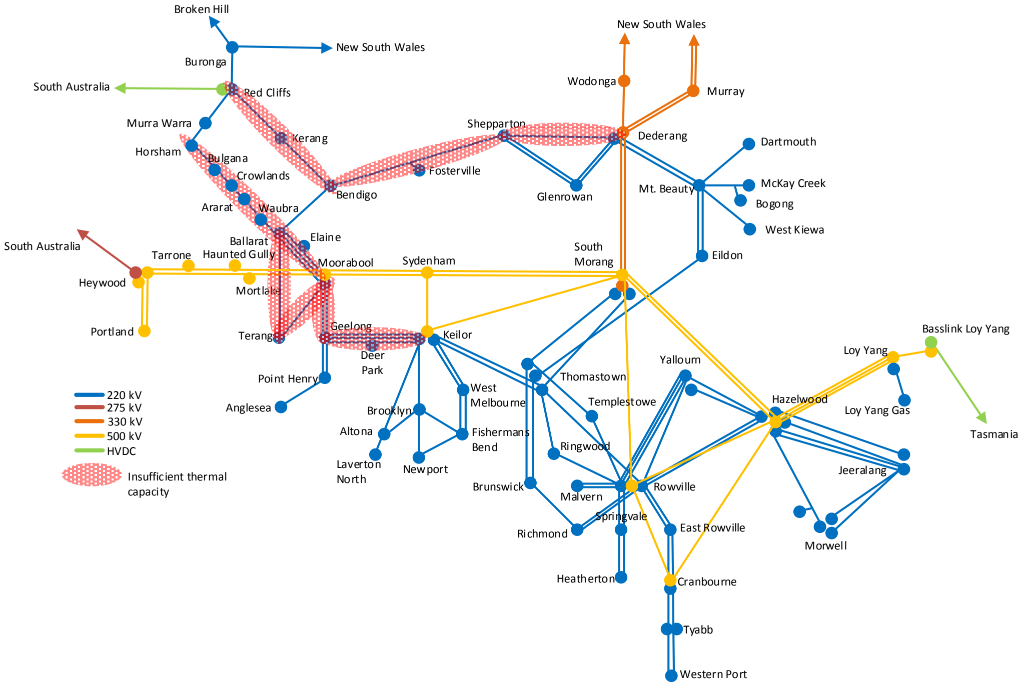
Implications to the DSN as a result include:

- Insufficient thermal capacity on the 220 kV Horsham – Ballarat – Terang – Moorabool corridor for connecting and dispatching the 1,300 MW of new wind generation.
- Insufficient thermal capacity on the Red Cliffs – Wemen – Kerang – Bendigo 220 kV corridor and the 220 kV Bendigo – Shepparton – Dederang path for connecting and dispatching the 1,400 MW of new solar generation.
- Insufficient thermal capacity on the Moorabool – Geelong – Keilor 220 kV corridor to deliver generation from western Victoria to Melbourne load centres.

Figure 13 shows the major transmission paths where loading is projected to significantly increase to deliver the generation from western Victoria to load centres in Victoria and also to New South Wales.

[66] Based on the ISP's Neutral case.

Figure 13 Impact on loading-new renewable generation centres in western Vic area



AEMO may propose network and non-network investments to avoid thermal overloading and other issues on these major transmission paths, if it is economic to do so.

AEMO is currently undertaking the Western Victoria Renewable Integration RIT-T to assess the technical and economic viability of increasing transmission network capability in western Victoria. Refer to the Project Specification Consultation Report (PSCR)[67] of this RIT-T for more information on the identified need of this RIT-T and credible augmentation options. AEMO is currently progressing a Project Assessment Draft Report (PADR) which will identify the preferred option for augmentation, as well as the optimal timing for investment.

Retirement of coal-fired generation

As outlined in Chapter 2, the changing generation mix has begun to materially change flows on the Victorian DSN, following the closure of Hazelwood Power Station in March 2017. Further retirement of coal-fired generators in the Latrobe Valley may:

- For 500 kV connected generation, reduce reactive power capability available to control network voltages during light load periods, increasing the need for additional reactive power support in Victoria. (Section 3.5 discusses this current and emerging issue, and the RIT-T that AEMO has begun.)
- For 220 kV connected generation, increase loading on the 500/220 kV transformers above their capacity in the Melbourne metropolitan area during periods of high demand. The level of the increase in loading would depend on the location and capacity of the replacement generation, as well as the network operational configuration.

New system strength requirements

The creation of new REZs in remote areas could lead to low system strength issues, because renewable generating units generally contribute much lower fault current and low inertia than conventional synchronous generating units.

In the 2017 VAPR, AEMO performed a high-level assessment to locate areas where system strength is an existing or emerging challenge. In that assessment, AEMO identified that network strength in north-west Victoria was already relatively low, and was projected to decline further in future (see Section 4.3.2 of the 2017 VAPR for more information).

To meet the new requirements stipulated in the System Strength Final Rules[68], AEMO, in its role as the system operator, has determined the system strength requirements methodology and the system strength requirements for each region, and identified any fault level shortfall for each region.

[67] Available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Victorian_Transmission/2017/Western-Victoria-Renewable-Integration---Project-Specification-Consultation-Report_FINAL.pdf.

[68] See https://www.aemc.gov.au/sites/default/files/content/38cbd875-6295-4d8d-acd6-52d5adfc3041/System-Strength-Final-Rule-19-Sept-2017-VERSION-FOR-PUBLICATION.PDF.

Given the large amount of renewable generation proposed to be installed in western Victoria, AEMO expects that synchronous condensers or equivalents (including non-network options) will need to be installed in western Victoria, particularly in north-west Victoria, to address emerging system strength limitations. Generators connecting to areas with low fault levels which are below the generator capability requirements will be required to improve system strength to meet their capability requirements.

AEMO will further explore approaches for improving system strength, to identify the most technically and economically effective approach to meet system strength requirements. See Section 3.5 of this VAPR and the ISP for more detail on system strength requirements.

5.3 Long-term strategic plan to address the changing NEM

The Victorian DSN operates as part of a larger, national power system and market. It therefore will be impacted by changes both within and beyond Victoria's borders. The existing Victorian DSN will need to be augmented and re-arranged to accommodate projected changes in generation mix and interconnection between Victoria and neighbouring regions.

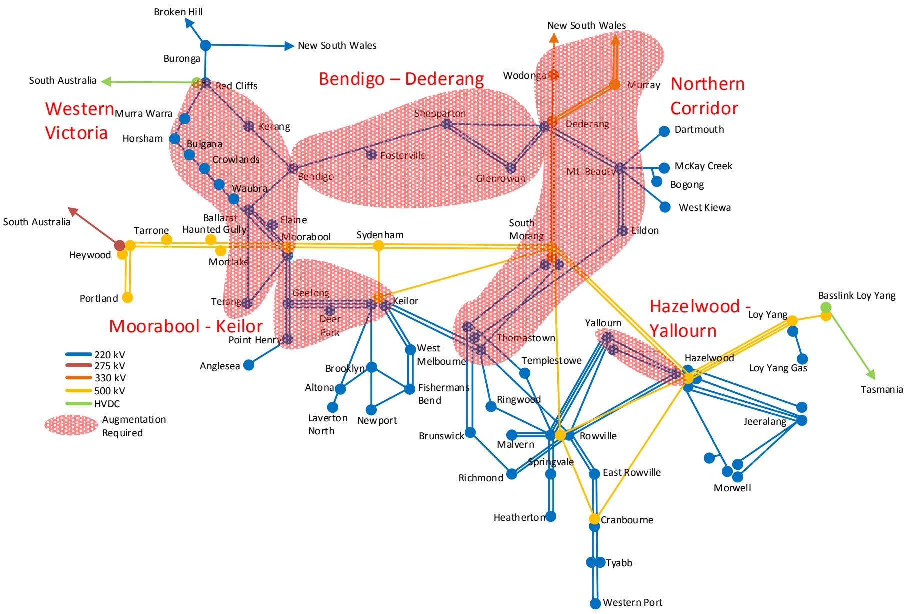
Having analysed a range of possible pathways, AEMO has developed a plausible scenario, aligned with augmentations proposed by AEMO in the 2018 ISP, to highlight potential impacts and provide a long-term strategic vision to maintain a secure and resilient network in Victoria.

The scenario AEMO has analysed for the 2018 VAPR includes:

- A new REZs in western Victoria and one in the Murray Valley area.
- Generation and pumping load from Snowy 2.0.
- A new interconnector between South Australia and New South Wales (Riverlink), connecting into Victoria via the Buronga – Red Cliffs transmission path.
- A new interconnector between New South Wales and Victoria (Sydenham – Wagga via Bendigo, Kerang, and Darlington Point).
- A new interconnector between Victoria and Tasmania (at east Geelong).

Figure 14 shows the areas in the Victorian DSN where augmentation may be needed as part of the long term strategic outlook in Victoria to complement the above scenario, subject to further technical and economic assessments. The potential augmentations are presented in Figure 15.

Figure 14 Areas in the existing Victorian DSN impacted by studied scenario



The sections below outline the projected impacts in each zone, potential solutions to address the impacts, and how the DSN could be configured to incorporate the range of potential solutions. The preferred solutions to address individual network limitations could include network or non-network options, or a combination of both, which would be identified through respective RIT-Ts.

Western Victoria

Transmission capacity augmentations to address impacts in western Victoria are proposed to be assessed and implemented in stages, depending on the status of renewable generation developments and subject to economic justification. Likely staged developments for the modelled scenario include:

- Stage 1 (5-7 years):
  - 500 kV option: a new Ararat – Ballarat – Sydenham double circuit 500 kV line and a new 220kV Bulgana – Crowlands – Ararat single circuit line. Connecting into Sydenham may reduce loading on the Moorabool – Geelong – Keilor 220 kV transmission line.
  - 220 kV option: a new Ararat – Ballarat – Moorabool double circuit 220 kV line, a new Bulgana – Crowlands – Ararat single circuit 220 kV line and load flow control scheme to reduce loading on the 220 kV Moorabool – Geelong – Keilor path.
  - Combined 220 kV and 500 kV option: a new 220 kV Ararat – Ballarat double circuit line, a new Bulgana – Crowlands – Ararat single circuit 220kV line and a new Ballarat – Sydenham double circuit 500 kV line.
- Stage 2 (beyond 10 years):
  - A new Kerang – Bendigo – Ballarat – Sydenham double circuit 500 kV line (the Ballarat – Sydenham section may have been constructed at stage 1).Some sections of the line could operate at 220 kV initially, to unlock new solar generation in north-west Victoria.

Stage 2 may also include new 220 kV lines between Bulgana – Horsham – Murra Warra and Kerang – Wemen – Red Cliffs. In the nearer term, a new South Australian – New South Wales Interconnector connecting to Buronga may reduce transmission line overloads along the Red Cliffs to Wemen to Kerang 220 kV transmission line, during periods of high local generation in western Victoria, and high export to New South Wales.

Synchronous condensers could also be installed in western Victoria at stages depending on the capacity and location of renewable generation connections, to meet system strength requirements. Generators connecting to areas with low fault levels which are below the generator capability requirements will be required to improve system strength to meet their capability requirements.

Northern Corridor

In Chapter 3 of this VAPR, AEMO has identified a number of limitations in the Northern Corridor of Victoria which impact the import and export capabilities of the New South Wales – Victoria interconnectors. See Section 3.8 for more information on these limitations, and possible options to address the limitations.

Additional New South Wales – Victoria interconnection capacity will be required to ensure the effective utilisation of the additional generation capacity and pumping storage provided by Snowy 2.0 once it is built. This additional interconnection capacity can be provided by a number of options. AEMO's 2018 ISP modelling identified a staged development with the following indicative augmentations[69]:

- Stage 1 (2-5 years) – installation of a braking resistor at Loy Yang, an additional 500/330 kV transformer at South Morang and upgrade to the existing South Morang – Dederang 330 kV circuits.
- Stage 2 (beyond 10 years) – a new Kerang – Darlington – Wagga 330 kV or 500 kV double circuit line to tie into the Stage 2 western Victoria upgrades detailed above.

Moorabool – Geelong - Keilor

If the 220 kV option was found to be the preferred option for stage 1 development of the regional Victoria area, additional augmentation is likely to be required to reduce loading on the Moorabool – Geelong – Keilor 220 kV transmission path. See Section 3.7 for more information on the Moorabool – Geelong – Keilor 220 kV thermal limitation.

If the Western Victoria Renewable Integration RIT-T determines that the 500 kV option is the preferred option for stage 1 development, the Sydenham – Keilor 500 kV line will need to be uprated and additional 500/220 kV transformer capacity or network re-configuration at Keilor may be required to relieve thermal limitations.

To relieve overloads associated with the Sydenham – Keilor 500 kV line, the protection equipment would likely need to be upgraded to remove the existing limitation.

The 2017 VAPR investigated the need for replacing the Keilor 500/220 kV transformers, as they will reach the end of their service life with the next 10 years. One option was to replace the three 750 MVA transformers with two 1,000 MVA units. This may relieve the overload resulting from the stage 1 500 kV option.

[69] The preferred development option will be determined through a RIT-T which will consider other credible augmentations.

Hazelwood – Yallourn

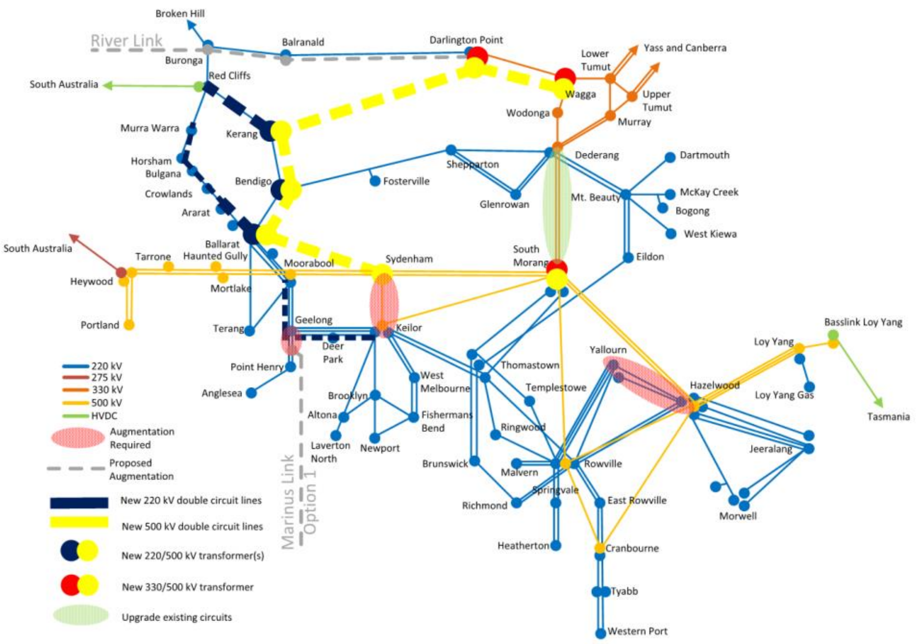
To relieve constraints associated with insufficient 500/220 kV transformer capacity in the Melbourne metropolitan area, the Latrobe Valley – Melbourne 500 kV and 220 kV networks may need to be operated in parallel, with a new double circuit Hazelwood – Yallourn 220 kV line to avoid overloads on the Hazelwood – Yallourn path.

Additional studies will be required to identify the optimal solution for addressing network limitations in the Vic DSN as a result of further coal-fired generation retirement.

Indicative ultimate configuration

Figure 15 shows an indicative ultimate configuration of the Victorian transmission network and interconnectors to neighbouring regions.

Figure 15 Indicative ultimate Victorian DSN impacted by the studied scenario



A comparison of Figure 15 with Figure 14 shows that most of the network limitations associated with the existing DSN would be addressed by:

- Short-term (2-7 years):
  - Upgrade to the existing New South Wales – Victoria interconnector (South Morang – Dederang path).
  - 220 kV upgrades in western Victoria (Bulgana – Ballarat).
  - 500 kV lines between Ballarat and Sydenham and 500/220 kV transformers at Ballarat.
- Longer-term (beyond 10 years):
  - A new 500 kV interconnector between New South Wales and Victoria (via Sydenham, Ballarat, Bendigo, and Kerang).
  - Additional 220 kV lines between Moorabool – Geelong – Keilor.
  - Additional 220 kV lines between Murra Warra – Horsham – Bulgana and Red Cliffs – Wemen – Kerang.

The new Victoria – New South Wales interconnector would likely result in new constraints, which could be addressed by uprating the existing Keilor – Sydenham 500 kV line and optimising Keilor 500/220 kV configuration.

Joint planning will be required to assess augmentation requirements for assets close to the Victoria – New South Wales border.

A1. DSN monitored limitation detail

These details for monitored transmission network limitations are grouped geographically.

Monitored limitations identified in the 2017 VAPR are all included in the 2018 VAPR, but a number of limitations identified prior to 2017 VAPR as monitored are not included in the 2018 VAPR. Because their triggers are now unlikely to occur in the 10-year planning horizon, or they have been addressed as part of emerging development opportunities (see Section 3.8). This is due to changes in network loading resulting from committed network projects, projected decreases in demand, or change in generation mix.

The options presented in the sub-sections below should be treated as indicative only, and a RIT-T will be required to determine the full list of network and non-network options as well as the preferred option. The preferred option may include one or a combination of the options presented in the sub-sections below.

A1.1 Eastern Corridor – monitored limitations

Table 7 Limitations being monitored in the Eastern Corridor

Limitation	Possible network solution	Trigger*	2016 NTNDP status	Contestable project status
Rowville –Yallourn 220 kV line loading	Upgrade the 220 kV Hazelwood–Rowville or Yallourn–Rowville lines.	During period of extremely high temperature and high output from Yallourn power station.	Not identified as a material limitation in the scenarios modelled.	The line upgrade is unlikely to be a contestable project.

* Triggers are the operating conditions under which a limitation may result in supply interruptions or constrain generation periodically.

A1.2 South-West Corridor – monitored limitations

Table 8 Limitations being monitored in the South-West Corridor

Limitation	Possible network solution	Trigger*	2016 NTNDP status	Contestable project status
Moorabool – Heywood – Portland 500 kV line voltage unbalance**	• A switched capacitor with individual phase switching at Heywood or near Alcoa Portland with an estimated cost of $14.2M. • A static VAr compensator (SVC) or a synchronous static compensator (STATCOM) at an estimated cost of $32.9M. • Additional transposition towers along the Moorabool – Heywood – Alcoa Portland 500 kV line at an estimated cost of $37.4M.	New generation connections along the Moorabool–Heywood–Alcoa Portland 500 kV line potentially introduce voltage unbalance along the line. The impact of voltage unbalance levels increases in proportion to power flow magnitude and direction, new generation connection points, and output generated.	Limitation not considered as part of 2016 NTNDP scope as it is related to voltage quality.	• Switched capacitor and static VAr options are likely to be contestable projects. • Line transposition is unlikely to be a contestable project.
Inadequate south-west Melbourne 500 kV thermal capacity	A new Moorabool –Mortlake/ Tarrone – Heywood 500 kV line with an estimated cost of $552.5M.	If significant wind generation and/or gas-powered generation (GPG) (over 2,500 MW in addition to the existing generation from Mortlake) is connected to the transmission network in the South-West Corridor.	Not identified as a material limitation in the scenarios modelled.	The new line is likely to be a contestable project.

Limitation	Possible network solution	Trigger*	2016 NTNDP status	Contestable project status
Moorabool 500/220 kV transformer loading	Install generation inter-trip schemes. Install third Moorabool 500/220 kV transformer costing approximately $24.7M.	Large-scale new generation connected to western Victoria area, and congestion within western Victoria relieved to allow the new generation to be sent out of western Victoria.	Not identified as a material limitation in the scenarios modelled.	The new transformer is likely to be a contestable project

* Triggers are the operating conditions under which a limitation may result in supply interruptions or constrain generation periodically.
** AEMO intends seeking a rule change proposing an increase the negative sequence voltage imbalance levels on the transmission network.

A1.3 Northern Corridor – monitored limitations

Table 9 Limitations being monitored in the Northern Corridor

Limitation	Possible network solution	Trigger*	2016 NTNDP status	Contestable project status
Murray – Dederang 330 kV line loading	• Install third 1,060 MVA 330 kV line between Murray and Dederang with estimated cost of $183.9M (excluding easement costs). • Install second 330 kV line from Dederang to Jindera at estimated cost of $152M (excluding easement costs).	Increased NSW import and Murray generation.	Not identified as a material limitation in the scenarios modelled.	These are both likely to be contestable projects.
Dederang – South Morang 330 kV line loading	• Up-rate two existing lines to 82 °C (conductor temperature) operation and series compensation at estimated cost of $16.8M. • Install third 330 kV, 1,060 MVA single circuit line between Dederang and South Morang with 50% series compensation to match the existing lines, at estimated cost of $244.4M (excluding easement costs, and subject to obtaining the necessary easement).	Increased NSW import. This constraint will be alleviated by the development proposed to increase the VIC to NSW export limit.	Constraint identified during high transfer between VIC to NSW (export or import).	The new line is likely to be a contestable project.
Dederang – Mount Beauty 220 kV line loading	• Install a wind monitoring scheme. • Up-rate the conductor temperature of both 220 kV circuits between Dederang and Mount Beauty to 82 °C, at estimated cost of $12.4M.	Increased NSW import and export.	Constraint identified during high export to NSW.	These are unlikely to be contestable projects.
Eildon – Thomastown 220 kV line loading	• Install wind monitoring scheme • Up-rate Eildon–Thomastown 220 kV line, including terminations to 75 °C operation, at estimated cost of $44.6M.	Increased NSW import and export.	Constraint identified during high import from NSW.	This is unlikely to be a contestable project.
Dederang 330/220 kV transformer loading	Install a fourth 330/220 kV transformer at Dederang at an estimated cost of $14.4M.	At times of over 2,500 MW of imports from NSW and Murray generation (with the DBUSS transformer control scheme being active).	Not identified as a material limitation in the scenarios modelled.	The new transformer is likely to be a contestable project.

* Triggers are the operating conditions under which a limitation may result in supply interruptions or constrain generation periodically.

A1.4 Greater Melbourne and Geelong – monitored limitations

Table 10 Limitations being monitored in Greater Melbourne and Geelong

Limitation	Possible network solution	Trigger*	2016 NTNDP status	Contestable project status
Rowville–Malvern 220 kV line loading**	Cut-in Rowville–Richmond 220 kV No.1 and No.4 circuits at Malvern Terminal Station to form the Rowville–Malvern–Richmond No.3 and No.4 circuits at estimated cost of $11M.	Increased demand or additional loads connected to Malvern Terminal Station.	Not identified as it is a localised issue.	The line cut-in is unlikely to be a contestable project.

Limitation	Possible network solution	Trigger*	2016 NTNDP status	Contestable project status
Rowville – Springvale – Heatherton 220 kV line loading	• Connect a third Rowville –Springvale circuit (underground cable) with estimated cost of $55.2M. • Connect a Cranbourne –Heatherton 220 kV double circuit overhead line with estimated cost of $35.7M.	Increased demand or additional loads connected to Springvale and Heatherton Terminal Station.	NTNDP did not identify this limitation as it is a localised issue.	The third circuit is likely to be a contestable project.
Rowville A1 500/220 kV transformer loading	Install a second 500/220 kV 1,000 MVA transformer at Cranbourne with estimated cost of $24.7M.	Increased demand in Eastern Metropolitan Melbourne.	Not identified as a material limitation in the scenarios modelled.	The new transformer is likely to be a contestable project.
South Morang H1 330/220 kV transformer loading	Replace the existing transformer with a higher rated unit in conjunction with SP AusNet's asset replacement program.	Increased demand in Metropolitan Melbourne and/or increased import from NSW.	Not identified as a material limitation in the scenarios modelled.	This is unlikely to be a contestable project.
South Morang – Thomastown No.1 and No.2 220 kV line loading	• Increase the transfer capability by installing wind monitoring facilities on the South Morang to Thomastown line. • Install an automatic load shedding control scheme to enable the use of five-minute line rating. • Install a third 500/220 kV transformer at Rowville, with an estimated cost of $24.7M, plus any fault level mitigation works.	Increased demand around the Melbourne Metropolitan area and/or increased export to NSW.	NTNDP did not identify this limitation as it is a localised issue.	The new transformer is likely to be a contestable project.
Cranbourne A1 500/ 220 kV transformer loading	Install a new 500/220 kV transformer at Cranbourne Terminal Station with an estimated cost of $24.7M (excluding easement cost).	Increased demand around the Eastern Melbourne Metropolitan area.	Not identified as a material limitation in the scenarios modelled.	The new transformer is likely to be a contestable project.
Moorabool – Geelong - Keilor 220kV line loading	• Connect a new single circuit Moorabool – Geelong 220kV line with a rating of approximately 800MVA at 35°C, with an estimated cost of $11.2M. • Replace the existing Geelong – Keilor 1 and 3 220kV lines with a new double circuit line, each circuit rated at 700MVA at 35°C, with an estimated cost of $75.5M.	Large-scale new generation connected to western Victoria area, and congestion within western Victoria relieved to allow the new generation to be sent out of western Victoria.	Constraint identified in the NTNDP during high renewable generation, if large amount of wind and solar generation is connected in north-west Victoria.	This is unlikely to be a contestable project.
Keilor – Deer Park –Geelong 220 kV line loading***	• Installing a new single circuit Moorabool – Geelong 220 kV line with a rating of approximately 800 MVA at 35° C, with an estimated cost of $11.2M. • Replacing the existing Geelong – Keilor No. 1 and No. 3 220 kV lines with a new double circuit lines rated at 700 MVA at 35° C, with an estimated cost of $75.5M. • Parallel the existing three Geelong – Deer Park - Keilor 220 kV circuits to form a Geelong – Deer Park and Deer Park – Keilor circuit, each rated 810 MVA at 35° C, at an estimated cost of $3.1M.	Increased demand at Deer Park	NTNDP did not identify this limitation as it is a localised issue.	These are unlikely to be contestable projects.

* Triggers are the operating conditions under which a limitation may result in supply interruptions or constrain generation periodically.
** This monitored limitation assumes five-minute ratings are already applied – an automatic load shedding control scheme to enable the use of five-minute line ratings is currently available to manage this limitation.
*** This monitored limitation assumes five-minute ratings will be applied – an automatic load shedding control scheme to enable the use of five-minute line ratings will be available to manage this limitation.

A1.5 Regional Victoria – monitored limitations

Table 11 Limitations being monitored in Regional Victoria*

Limitation	Possible network solution	Trigger**	2016 NTNDP status	Contestable project status
Inadequate reactive power support in Regional Victoria	Staged installation of additional reactive power support in Regional Victoria.	Increased demand and/or decrease in power factor in Regional Victoria.	NTNDP did not identify this limitation as it is a localised issue.	Additional reactive support is unlikely to be a contestable project.
Dederang–Glenrowan Shepparton–Bendigo 220 kV line loading	• Install an automatic load shedding control scheme to enable the use of five-minute line rating. • Install a phase angle regulating transformer on the Bendigo – Fosterville –Shepparton 220 kV line at an estimated cost of $46.9 million. • Replace existing Dederang–Glenrowan, Glenrowan–Shepparton and Shepparton–Bendigo 220 kV lines with new double circuit lines at respective estimated costs of $69.4M, $62.2M, and $95.9M (a total of $227.5M).	• Increased demand in Regional Victoria and/or increased import from NSW. • Large-scale new generation connected to western Victoria area, and congestion within western Victoria relieved to allow the new generation to be sent out of western Victoria.	NTNDP did not identify this limitation as it is a localised issue.	The new transformer or new transmission lines are likely to be contestable projects.

* AEMO is conducting a RIT-T to identify the preferred augmentation option to address DSN capacity limitations in the regional Victoria. The outcome of this RIT-T will affect the status of the limitations in this area.
** Triggers are the operating conditions under which a limitation may result in supply interruptions or constrain generation periodically.

A2. Distribution network service provider planning

This appendix lists the preferred connection modifications from the 2017 Transmission Connection Planning Report[70] and the potential DSN impacts and considerations.

Table 12 Distribution network service provider planning impacts

Location/terminal station	Preferred connection modification	DSN impacts and considerations
Cranbourne 66 kV	Install a fourth Cranbourne 150 MVA 220/66 kV transformer by end of 2027.	Increased demand requiring this transformer will be included in Greater Melbourne and Geelong planning.
Richmond 66 kV	Permanently transfer load from Richmond Terminal Station 66 kV to new Brunswick Terminal Station 66 kV, which will be done via sub transmission networks by summer 2019-20.	The impact of the load transfer has been taken into consideration in AEMO's assessment of upcoming constraints.
West Melbourne 22 kV	Transfer load to adjacent stations and retire all the existing WMTS 22 kV systems by the end of 2023.	The impact of the load transfer has been taken into consideration in AEMO's assessment of upcoming constraints.

[70] Jemena, CitiPower, Powercor, AusNet Services and United Energy. 2017 Transmission Connection Planning Report. Available at http://sharedocs/sites/wa/p/vp/Joint_Planning/Joint%20Planning%20Meetings/TCPRs/Transmission%20Connection%20Planning%20Report%202017.pdf.

A3. Transmission network limitation review approach

In assessing the impact of limitations, AEMO considers information from power system performance analysis and market simulations each year for the next ten years regarding:

- The percentage N and N–1 loadings of transmission plant associated with the network loading limitation, based on the continuous and short-term ratings respectively.
- The load and energy at risk. Load at risk is the load shedding required to avoid the network limitation. Energy at risk is the resulting unserved energy (USE).
- Expected USE, which is a portion of the energy at risk after taking into account the probability of forced outage.
- Dispatch cost, which is the additional cost from constraining generation.
- Limitation cost, which is the total additional cost due to both constraining generators and the expected USE.

Power system performance analysis generally uses more conservative assumptions about demand, temperature, and wind speed to capture as many network limitations as possible for later market simulation testing. For this reason, DSN performance analysis results (that is, the percentage loadings) can show more severe impacts than market simulations.

AEMO derives forecast transmission plant loadings using load flow simulations, and develops load flow base cases for these simulations using the following inputs:

- The 10% probability of exceedance (POE) terminal station demand for maximum demand base cases. For more information, see 2016 Transmission Connection Point Forecasting Report for Victoria (see Section 1.1).
- Historical maximum power transfers for a high Victoria to New South Wales power transfer base case.
- Typical generation dispatch and interconnector power transfer patterns under the given operating conditions.
- The system normal operational configuration for the existing Victorian transmission network.
- Committed transmission network augmentation and generation projects, and other projects (or their equivalent), which AEMO considers necessary for maintaining the power system in a satisfactory, secure, and reliable state during summer maximum demand periods.
- Standard continuous ratings and short-term ratings at 45 °C and 0.6 m/s wind speed, unless otherwise indicated.
- Unless indicated, 15-minute ratings are used as short-term ratings for transmission lines. Some transmission lines in Victoria are equipped with automatic load shedding schemes, which, once enabled, will avoid overloading by disconnecting preselected load blocks following a contingency. These schemes allow the lines to operate up to their five-minute short-term ratings.
- Wind generation availability during maximum demand of 6.5% of the installed capacity is assumed. For more information, see the Wind Contribution to Peak Demand study results.

AEMO bases the market impact of each network limitation on probabilistic market simulations that apply:

- Weighted 50% POE and 10% POE maximum demand forecasts (weighted 70% and 30% respectively).
- Historical wind generation availability.
- Historical load profiles.
- Dynamic ratings based on historical temperature traces.
- Non-committed new and retired generation, consistent with latest NTNDP generation expansion plan.

For more information about the transmission network limitation review approach, see the Victorian Electricity Planning Approach.

Measures and abbreviations

Abbreviation	Full term
AEMO	Australian Energy Market Operator
DSN	Declared Shared Network
MW	Megawatts
NEFR	National Electricity Forecasting Report
NEM	National Electricity Market
NEMDE	National Electricity Market Dispatch Engine
NSCAS	Network Support and Control Ancillary Service
NTNDP	National Transmission and Development Plan
RIT-T	Regulatory Investment Test for Transmission
USE	Unserved energy
VAPR	Victorian Annual Planning Report

Glossary

This document uses many terms that have meanings defined in the National Electricity Rules (NER). The NER meanings are adopted unless otherwise specified.

Term	Definition
active power	Active power is a measure of the instantaneous rate at which electrical energy is consumed, generated or transmitted. In large electric power systems, it is measured in megawatts (MW).
annual planning report	An annual report providing forecasts of gas or electricity (or both) supply, network capacity and demand, and other planning information.
black system	The absence of voltage on all or a significant part of the transmission system or within a region during a major supply disruption affecting a significant number of customers.
committed projects	Generation that is considered to be proceeding under AEMO's commitment criteria.
constraint	A limitation on the capability of a network, load, or generating unit such that it is unacceptable to either transfer, consume, or generate the level of electrical power that would occur if the limitation was removed.
contestable augmentation	An electricity transmission network augmentation for which the capital cost is reasonably expected to exceed $10 million and that can be constructed as a separate augmentation (that is, the assets forming that augmentation are distinct and definable).
electrical energy	Average electrical power over a time period, multiplied by the length of the time period.
limitation (electricity)	Any limitations on the operation of the transmission system that could give rise to unserved energy or to generation re-dispatch costs.
maximum demand	The highest amount of electrical power delivered, or forecast to be delivered, over a defined period (day, week, month, season, or year) either at a connection point, or simultaneously at a defined set of connection points.
National Electricity Market	The wholesale market for electricity supply in Queensland, New South Wales, the Australian Capital Territory, Victoria, Tasmania, and South Australia.
reactive power	In an AC (alternating current) power system, like Australia's National Electricity Market, voltage and current oscillate together, very quickly, as they cycle through positive and negative values. This cycling process creates both active (real) and reactive power. Active power moves through the system and is delivered to consumers. Reactive power is predominantly consumed in the creation of magnetic fields in motors and transformers, and regulates voltage to keep them, within required limits, so active power keeps moving and power system security and reliability is maintained.
unserved energy	The amount of energy that cannot be supplied because there is insufficient generation or network capacity to meet demand.