VICTORIAN ANNUAL PLANNING REPORT

ELECTRICITY TRANSMISSION NETWORK PLANNING FOR VICTORIA

Published: **June 2016**

AUSTRALIAN ENERGY MARKET OPERATOR

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 31 March 2016, although AEMO has incorporated more recent information where practical.

Disclaimer

AEMO has made every effort to ensure the quality of the information in this publication, but cannot guarantee that information, forecasts and assumptions are accurate, complete or appropriate for your circumstances. This publication does not include all of the information that an investor, participant or potential participant in the National Electricity Market might require, and does not amount to a recommendation of any investment.

Anyone proposing to use the information in this publication (including information and reports from third parties) should independently verify and check its accuracy, completeness and suitability for purpose, and obtain independent and specific advice from appropriate experts.

Accordingly, to the maximum extent permitted by law, AEMO and its officers, employees and consultants involved in the preparation of this publication:

- make no representation or warranty, express or implied, as to the currency, accuracy, reliability or completeness of the information in this publication; and
- are not liable (whether by reason of negligence or otherwise) for any statements, opinions, information or other matters contained in or derived from this publication, or any omissions from it, or in respect of a person's use of the information in this publication.

Acknowledgement

AEMO acknowledges the support, cooperation and contribution of all electricity industry participants in providing data and information used in this publication.

Version control

Version	Release date	Changes
1	9/6/2016	

EXECUTIVE SUMMARY

The Australian Energy Market Operator (AEMO) is responsible for planning and directing augmentations 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 future reliability and security needs over the next 10 years, and looks for development opportunities that may deliver net market benefits.

Key insights of the 2016 VAPR

The key driver for network augmentation in the Victorian DSN continues to shift, from supporting peak demand growth, to facilitating inter-regional transfers of energy and ancillary services, and new generation connections. This shift reflects slowing demand growth in Victoria and an increasing focus on the integration of renewable generation.

- Generation connected to areas with limited network capability is at risk of being constrained. Increased certainty around the Large-scale Renewable Energy Target (LRET) has accelerated interest in new generation connections, concentrated in areas with favourable renewable energy sources. In particular, there is a high level of connection interest in North West Victoria (over 1,500 MW). The VAPR analysis indicates that:
  - New generation connections in North West Victoria will likely be limited by network strength[1] or constrained by network capacity.
  - The market benefits of connecting more than 400 MW in the area could justify major augmentation. AEMO will commence a Regulatory Investment Test for Transmission (RIT-T) for augmentation in North West Victoria later this year, and invites stakeholders to engage in discussions about proposed generation projects, as greater certainty around future connections improves the likelihood that major augmentation will be justified.
- Congestion around South Morang is limiting export capability to New South Wales. The benefit of increasing the Victoria – New South Wales export capability is marginally lower than the augmentation cost, even if the current generation surplus in Victoria remains over the next 10 years.
  - AEMO will monitor changes to the Victorian generation mix that could increase market benefits, triggering a RIT-T.
- The need for major augmentation depends on the future of brown coal generation in Victoria. VAPR analysis indicates that potential coal-fired generation retirements would:
  - Increase the market benefits of major augmentation in North West Victoria, as renewable generation facilitated by the augmentation would displace higher-cost generation.
  - Reduce the market benefits of augmenting the Victoria – New South Wales export capability, as there would be less surplus generation to export to New South Wales.
- In response to slowing demand growth, control schemes are proving the most economic and effective means of managing emerging limitations on the network. AEMO is working closely with distribution and transmission businesses to implement control schemes, deferring the need for network augmentation.

[1] Network strength is measured through the fault level and short circuit ratio in an area.

Network opportunities and challenges

The 2016 VAPR does not identify any emerging limitations driven by peak demand, and assesses an opportunity to support generation transfer to New South Wales.

Last year's VAPR assessment of export capability to New South Wales considered congestion on the South Morang F2 transformer. It concluded that the market impact of the constraint did not justify augmentation, but warranted further investigation. This year's assessment has been expanded to consider the market benefits if the transient stability limit[2] and congestion on the South Morang – Dederang 330 kV lines were also alleviated. The 2016 VAPR analysis shows that the gross market benefits of addressing all three limitations are slightly lower than the augmentation costs, under scenarios where surplus generation from Victoria supports New South Wales.

Australia has set a target to reduce carbon emissions by 26–28% below 2005 levels by 2030, which builds on the 2020 target of reducing emissions by 5% below 2000 levels. The Council of Australian Governments (COAG) Energy Council has agreed that the contribution of the electricity sector be consistent with national emission reduction targets, and that a 28% reduction from 2005 levels by 2030 is an appropriate constraint for AEMO to use in its ongoing forecasting and planning processes. This target could lead to coal-fired generation retirements in Victoria.

While this target has not been explicitly modelled in the 2016 VAPR analysis, a scenario including coal-fired generation retirements has been considered.[3] This scenario highlights that the market benefit associated with increasing export capability to New South Wales is sensitive to assumptions around the future of brown coal generation in Victoria.

AEMO will therefore monitor changes to the Victorian generation mix that could increase market benefits, triggering a RIT-T.

Update on previously identified development opportunities

The 2016 VAPR provides an update on the two emerging opportunities identified last year:

- Constraints on the Ballarat–Horsham 66 kV line will be addressed by a committed project to implement an automatic bus splitting control scheme at Buangor 66 kV switching station. This scheme, due for completion in November 2016, will improve export capability to New South Wales and facilitate renewable generation export out of North West Victoria.
- Constraints on the Keilor – Deer Park – Geelong line servicing parts of western Melbourne will be managed in the 10-year outlook using five minute ratings instead of 15 minute ratings. This allows an increase in transmission network capacity to meet modest demand growth in the area without materially affecting security and reliability.

Opportunities and challenges for connecting new generation in Victoria

The 2016 VAPR investigates network capability for new generation connections, highlighting both emerging connection opportunities and risks for proponents.

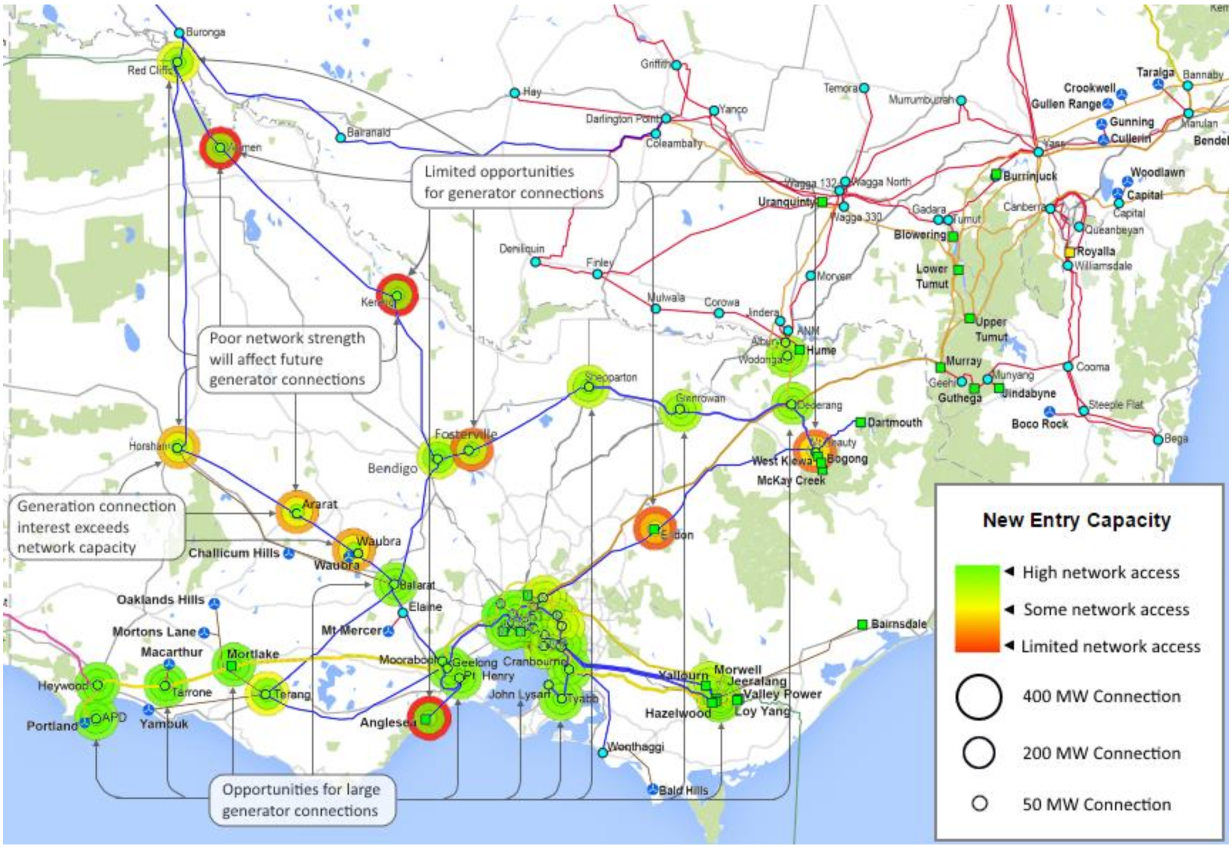
- There are connection opportunities for new generation with access to the 500 kV network between South West Victoria and Latrobe Valley.
  - Connecting to the 500 kV network is more costly than connecting at lower voltages.
- North West Victoria is experiencing a high level of interest for renewable generation connection, primarily due to favourable wind and solar resources. However, the additional connection in the area is expected to exceed network capability. VAPR analysis indicates that:
  - Minor augmentations, such as line upgrades and control schemes, are likely to be beneficial to support the connection of up to 200 MW of additional generation in North West Victoria.

[2] Transient stability is the ability of the power system to maintain synchronism following a severe and sudden disturbance.
[3] Possible retirements have been modelled as a consequence of AEMO's planning scenarios, and do not relate to any specific announcements.

  - Major augmentations, such as new transmission lines, are likely to be economically justified to facilitate the connection of more than 400 MW of generation.
  - If substantial brown coal generation is retired, wind could displace higher-cost generation, increasing the market benefits of augmentation to facilitate connection.
  - Even if network capacity was available, further generation connections could be restricted by network strength. A generator connection which adversely affected power system security may be required to rectify the issue at its own cost. The system security costs of any proposed augmentation would be included as part of a RIT-T.
- More generally, generation connected to areas with low network capability is at risk of being constrained. Proponents with an interest in connecting into such regions should consider that:
  - Connection location plays an important role in determining dispatch merit order, and will often determine who is constrained, regardless of which generator connected first.
  - Existing generation could be constrained off in future due to new connections.

Figure 1 below provides a high level assessment of future generation connection opportunities and risks, and is intended as a guide to assist in the early stages of project feasibility. Proponents are advised to conduct their own due diligence to better understand connection opportunities and risks.

Figure 1 Generation connection opportunities and risks



Asset renewal

While the drivers for network augmentation have changed, there has also been a broader, NEM-wide shift for overall transmission investment towards replacement of ageing assets, as noted in AEMO’s *2015 National Transmission Network Development Plan* (NTNDP).

This trend continues in Victoria with asset renewal expected to comprise at least three quarters of transmission spend in the next three years. In its 2016 asset renewal plan, AusNet Services projects approximately $1.13 billion investment across 53 proposed projects over the coming 10 years.

AEMO has conducted a review of AusNet Services’ renewal plan and has also published AusNet Services’ latest asset renewal plan, as required under the National Electricity Rules.

Recent performance of the DSN

The DSN performed adequately during periods of high stress over 2015–16. The security of the system was maintained and no lines were overloaded, including during times of peak demand and high export.

CONTENTS

TABLES

FIGURES

CHAPTER 1. INTRODUCTION

The Australian Energy Market Operator (AEMO) is responsible for planning and directing augmentation on the Victorian electricity transmission declared shared network (DSN). The VAPR considers the adequacy of the DSN to meet future reliability and security needs over the next 10 years, and looks for development opportunities that may deliver net market benefits.

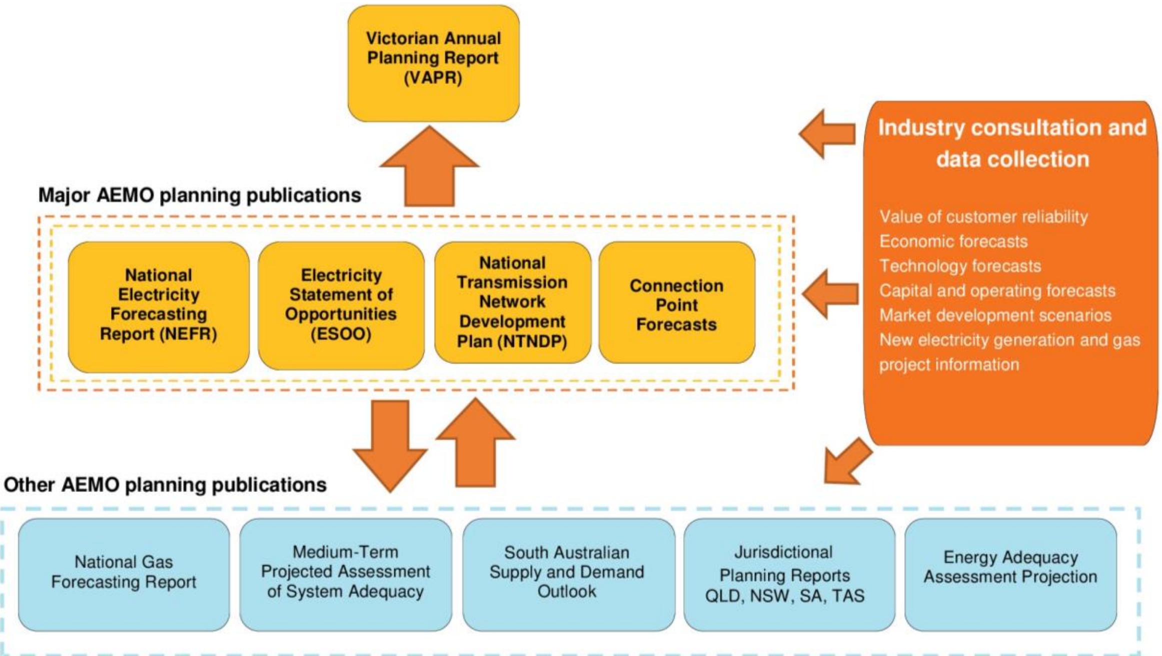
AEMO publishes the VAPR as part of its role as Victorian transmission planner under the National Electricity Law, in accordance with clause 5.12.1 of the National Electricity Rules.

This year's VAPR:

- Introduces a new chapter exploring opportunities and challenges for generator connections in Victoria, highlighting opportunities and risks for proponents wishing to connect to areas with low network capability, such as North West Victoria.
- Provides an update on opportunities identified in last year's VAPR, and presents a new development opportunity in North West Victoria.
- Reviews the performance of the DSN throughout 2015–16, including performance at times of maximum demand and high export to New South Wales.
- Presents AusNet Services' asset renewal plan for the coming 10-year period.

The VAPR is part of a comprehensive suite of AEMO planning publications, an overview of which is shown below.

Figure 2 AEMO planning and forecasting publications



This report is supported by an online, user-friendly interactive map[4] providing data and analysis for a range of National Electricity Market (NEM) topics including emerging development opportunities, transmission connection point forecasts, short-circuit levels, and national transmission plans.

[4] AEMO. Interactive Map. Available at: http://www.aemo.com.au/electricity/planning/interactive-map.

1.1 Supporting Material

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

Resource	Description and links
Interactive NEM Map	The interactive NEM 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	The historical DSN ratings workbook presents ratings and loadings for the 2015–16 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 2016 asset renewal plan	This plan outlines AusNet Services' transmission asset renewal process and provides a list of its planned asset renewal projects 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
Independent planning review of AusNet Services' 2016 asset renewal plan	This report presents the findings from AEMO's independent technical review of AusNet Services' 2016 asset renewal plan. http://www.aemo.com.au/Electricity/Planning/Independent-Planning-Review-VIC-Transmission-Network
Short-circuit levels report and workbook	This material provides information on the capability of Victoria's electricity transmission network to withstand short-circuit currents over a five-year outlook period from 2016 to 2020. 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/Market-Operations/Dispatch/Annual-NEM-Constraint-Report http://www.aemo.com.au/Electricity/Market-Operations/Dispatch/Monthly-Constraint-Report
Demand Forecasts	AEMO's independent connection point forecasts for Victoria are provided on AEMO's website. http://www.aemo.com.au/Electricity/Planning/Forecasting/AEMO-Transmission-Connection-Point-Forecasting/Transmission-Connection-Point-Forecasting-Report-for-Victoria

CHAPTER 2. NETWORK PERFORMANCE

The Victorian electricity transmission declared shared network (DSN) performed adequately over the year 2015–16, with:

- Load at times of peak demand being supplied within the technical limits of the network.
- No lost load due to transmission limitations.

Constraints involving the Victoria – New South Wales Interconnector and Heywood Interconnector bound more than in previous years. Constraints on the Heywood Interconnector will be addressed by the third Heywood 500/275 kV transformer (see Section 3.3.1) and constraints on the New South Wales Interconnector have been investigated further (see Section 3.4.4).

The network experienced higher maximum operational demand in 2015–16 (9,280 megawatts (MW)) compared to 2014–15 (8,564 MW). Despite this, Victoria still exported 160 MW to New South Wales during maximum operational demand.

There were two security violation events that occurred during 2015–16 (see Section 2.8) which were successfully managed operationally without load shedding. A review of these events found that the level of network investment required to minimise the impact of these events was not economically justified given their low probability. There were no load interruption events caused by Victorian transmission outages between 1 April 2015 and 31 March 2016.

2.1 How does AEMO assess performance?

To evaluate the adequacy and performance of the Victorian DSN over 2015–16, this chapter investigates a number of network characteristics, including:

- **The loading of transmission network elements at times of high network stress.** This shows whether the transmission network has enough capacity to supply the load.
- **The reactive power adequacy at times of high network stress and low load periods.** This shows the network's ability to maintain acceptable voltages throughout the network.
- **The impact of constraint equations within Victoria over the 2015–16 period.** This shows how much impact the transmission network had on generation dispatch.
- **The interconnector capability.** This indicates the extent to which the interconnectors' physical limits restricted the import or export of generation.

2.2 Network loading at times of high network stress

AEMO reviewed the loading of network elements to provide insight to how stressed the network was during 2015–16.

The Victorian DSN tends to have two distinctive drivers of network stress:

- Maximum demand conditions (which typically occur on hot summer days) stress the network as high power transfers are required when network ratings are lower than average.
- High network stress can also occur at times where high levels of Victorian generation are being exported to other regions, typically New South Wales.

To understand how the network is performing at these times of high stress, AEMO uses two 'snapshots'[5] to capture network conditions[6] for the maximum demand period and the highest export period.[7]

Table 1 Maximum demand and high export from Victoria snapshot summaries

	Maximum demand snapshot	High export from Victoria snapshot
Date and time	23 Feb 2016 15:30	29 Jan 2016 19:30
Sum of Victorian loads at time of snapshot*	8,884 MW	5,054 MW
Operational demand during snapshot**	9,280 MW	4,985 MW
Temperature in Melbourne	40 ºC	15 ºC
Power flow on Heywood	143 MW (SA to VIC)	282 MW (SA to VIC)
Power flow on Murraylink	60 MW (SA to VIC)	78 MW (SA to VIC)
Power flow from Tasmania	0 MW	0 MW
Power flow to New South Wales	160 MW	1,500 MW
Murray generation	1,506 MW	459 MW

* The loads are the instantaneous values at the exact time of snapshot. Network losses are not considered as part of Victorian load.
** Operational demand is the sum of Victorian scheduled, semi-scheduled, non-scheduled wind greater than 30 MW, and net interconnector flow, for a half-hour trading interval. It typically represents when the DSN is most stressed.

2.3 Maximum demand snapshot

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

[5] All DSN outages are restored (power flow is returned to major transmission lines out of service) when assessing network adequacy at the time of the snapshots.
[6] These snapshots do not necessarily represent the maximum load 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.
[7] The 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).

Figure 3 Maximum demand snapshot: generation, load, and interconnector flow

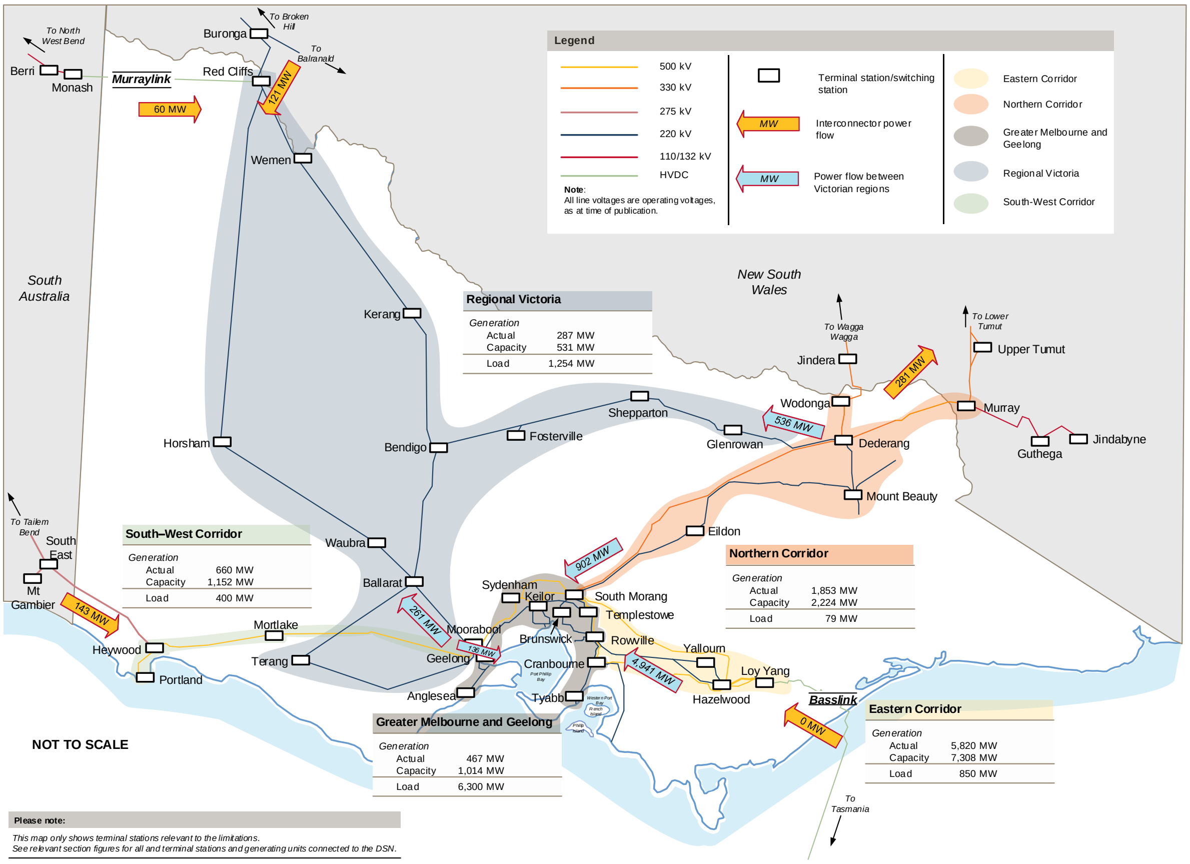


Figure 3 reflects the prevailing conditions at the time of Victorian maximum demand. It shows the electrical regions and their interconnectors, and the transmission lines and their voltages. The arrows indicate power flow from one Victorian electricity region to another, and the lines represent single or multiple transmission lines, depending on the region.

The figure shows that at the time of the maximum demand snapshot:

- Two-thirds of Victorian load was concentrated in Greater Melbourne and Geelong.
- The majority of Victorian generation originated from the Eastern (around 64%) and Northern corridors (around 20%), with power flowing from these regions to Greater Melbourne, Geelong, and Regional Victoria.
- There was no power flow between Tasmania and Victoria, due to an unplanned outage of Basslink that started in December 2015.
- Net power flow from Victoria to New South Wales comprised an export of 281 MW via the Northern Corridor, and an import of 121 MW from Buronga.
- Net power flow from South Australia to Victoria comprised 143 MW via the Heywood Interconnector and 60 MW via the Murraylink Interconnector.
- All Victorian interconnector flows were well below their limits and Basslink was out of service.

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

2.4 High Victorian export snapshot

The high Victorian export snapshot shows network conditions when Victoria was exporting the most amount of power to New South Wales, which stresses the network elements in the Northern Corridor. The section is complemented by additional detail in the historical DSN rating and loading workbook (see Section 1.1)

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

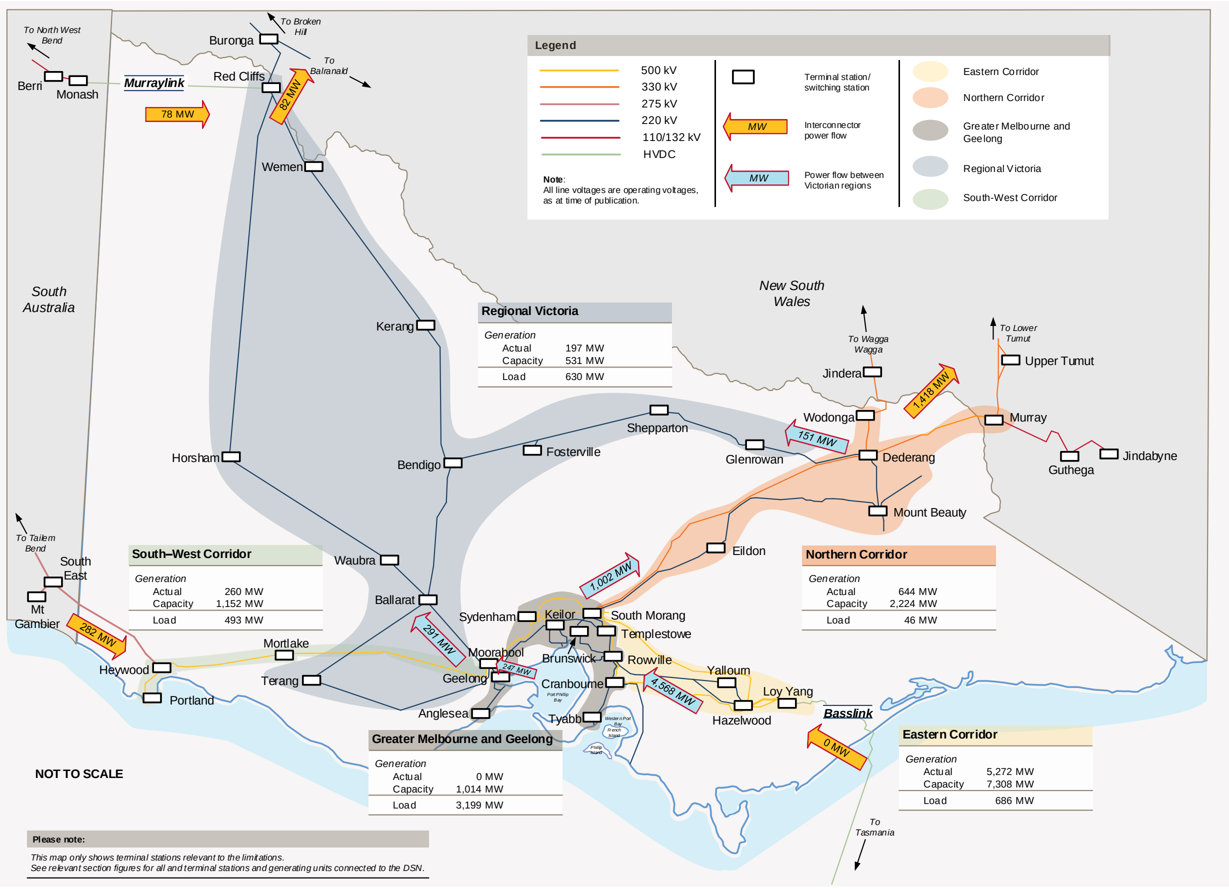


Figure 4 reflects the prevailing conditions at the time of high export from Victoria to New South Wales and shows:

- Two-thirds of the Victorian load was concentrated in Greater Melbourne and Geelong, with the remainder split almost evenly between Regional Victoria, the South-west Corridor, and the Eastern Corridor.
- The majority (over 4,500 MW) of power was from coal-fired generators in the Eastern Corridor which flowed into Greater Melbourne and Geelong. Approximately 1,000 MW subsequently flowed into the Northern Corridor for export to New South Wales.
- All interconnectors were near their limits and Basslink was out of service, with no flow from Tasmania to Victoria due to an unplanned outage.

A review of asset loading at the time of high Victorian export to New South Wales showed that the Victorian DSN performed adequately within the technical network limits. AEMO has investigated the market benefits of increasing the Victorian to New South Wales export capability, and the findings are presented in Chapter 3.

2.5 Network performance at times of low demand

Minimum demand in Victoria has decreased with the closure of industrial sites, such as Point Henry. This decrease, and the recent retirement of reactive power plant, such as the aged synchronous condenser at Fishermans Bend (in September 2015), has created the potential for over-voltages to occur in the South West corridor, typically during periods of low demand.

Since September 2015, there were seven occasions where risks of system over-voltages arose in the South West Corridor. This typically occurred during weekends, when demand is low. AEMO successfully managed the over-voltage risk by operationally switching out transmission lines without compromising system security.

Appendix A has more detail on this over-voltage limitation in the South West Corridor.

2.6 Impact of Victorian transmission constraints

In 2015, the Victorian constraint equation that had the largest market impact limited export to South Australia to prevent overloading the two Heywood 500/275 kV transformers. This limit was improved following the commissioning of a third transformer in December 2015 (see Section 3.3.1). The most significant constraint in 2014 will also be improved following the installation of a third Ballarat–Moorabool 220 kV line in early 2017 (see Section 3.4.1).

Table 2 provides detail on 10 Victorian constraint equations that resulted in a high market impact in 2014 and/or 2015. This is a subset of the top 20 constraint equations that bound consistently during both 2014 and 2015. A comprehensive analysis of constraint equations and their market impact is provided in AEMO's *NEM Constraint Report 2015* (see Section 1.1).

Table 2 Equations with persistent market impacts in both 2014 and 2015

Equation ID	Binding Hours		Market Impact		Description
	2014	2015	2014	2015	
V::N_NIL_xxx	317	1091	$23,304	$117,936	Prevent transient instability for fault and trip of a Hazelwood – South Morang 500 kV line, Victoria accelerates, Basslink Tasmania to Victoria, Yallourn W Unit 1 on 220 kV mode. This equation, when binding, constrains the Victoria – New South Wales Interconnector.
V>>V_NIL_2A_R & V>>V_NIL_2B_R & V>>V_NIL_2_P	844	951	$48,248	$97,980	Avoid pre-contingent overloading South Morang F2 500/330 kV transformer, radial mode, Yallourn W Unit 1 on 220 kV mode. These equations, when binding, constrain the Victoria – New South Wales Interconnector.
V>S_NIL_HYTX_HYTX	474	819	$159,569	$400,859	Limit Victoria to South Australia transfer on Heywood to avoid overloading the Heywood transformers. This equation, when binding, constrains the Heywood Interconnector.
V>S_460	159	261	$43,529	$103,192	Victoria to South Australia (Heywood) upper transfer limit (460 MW).
V>>SML_NIL_7A	43	81	$48,808	$186,019	Avoid overloading Ballarat North to Buangor 66 kV line for loss of the Ballarat to Waubra to Horsham 220 kV line.
V^SML_NSWRB_2	65	73	$147,459	$207,805	With prior outage of New South Wales Murraylink runback scheme, avoid voltage collapse for loss of Darlington Pt to Buronga (X5) 220kV line.
V>>SML_NIL_7B	31	35	$14,455	$129,791	Avoid overloading Buangor to Ararat 66 kV line for loss of the Ballarat to Waubra to Horsham 220 kV line.
V>>V_NIL_5	14	26	$17,039	$16,496	Avoid overloading either Dederang to Mount Beauty 220 kV line (flow to North) for trip of the parallel line.
V>V_NIL_RADIAL_9	52	15	$227,127	$70,503	Avoid overloading the Hazelwood to Jeeralang No. 4 220 kV line for a trip of Hazelwood A4 500/220 kV transformer, while Yallourn unit 1 is in 500 kV mode, Hazelwood is in radial mode, and the Hazelwood 3, 4 busses are split.
V>>SML_NIL_1	29	3	$1,581,992	$17,063	Avoid overloading either Ballarat–Moorabool 220 kV line for loss of the parallel Ballarat–Moorabool 220 kV.

2.7 Interconnector capability over 2015–16

An interconnector's capability depends on the performance of the surrounding network, which varies throughout the year. A detailed summary of the capability and the limits of each interconnector is provided in AEMO's *NEM Constraint Report 2015* (see Section 1.1).

In 2015, Basslink power transfer predominantly consisted of export from Victoria to Tasmania. On 20 December 2015, a fault on Basslink resulted in the separation of Tasmania from the rest of the NEM. Basslink Pty Ltd estimates that Basslink will return to service in late-June 2016.[8]

Northern Power Station was retired in May 2016. AEMO has not yet observed a clear trend indicating the impact of this retirement on interconnector flows.

2.8 Victorian power system reviewable operating incidents

There were two Victorian reviewable power system incidents which resulted in an insecure state in 2015–16, however neither of these incidents resulted in loss of supply in Victoria. A review of these events found major network infrastructure investment that would have prevented the insecure state

[8] Basslink. "Basslink Interconnector Update", 24 May 2016. Available at: http://www.basslink.com.au/wp-content/uploads/2016/05/Media-statement-24-May-FINAL.pdf.

would not be considered economically justified, given the low probability of events. Table 3 presents these reviewable incidents.

Table 3 Significant reviewable power system incidents during 2015–16

Date	Description	Action
13 January 2016	The power system was in an insecure operating state for more than 30 minutes during a heat wave when the Dederang–Glenrowan No.1 and No.3 220 kV lines were reclassified due to a lightning threat. More information is available in AEMO's online pricing event reports.[9]	AEMO is in discussion with AusNet Services on the implementation of a load inter-trip control scheme as an operational measure to avoid future security violations due to the same incident.
18 August 2015	The power system was in an insecure operating state for 48 minutes where, due to a telecommunications failure, Murraylink was unable to follow dispatch targets.	A communication failure detection and automated communication channel changeover has been established at Murraylink to prevent this event from reoccurring.

A comprehensive list of power system operating incidents is provided on AEMO's website.[10] As AEMO is responsible for operating the transmission network, this section does not consider distribution network events that may have resulted in loss of supply.

[9] AEMO. Pricing Event Reports. Available at: http://www.aemo.com.au/Electricity/Resources/Reports-and-Documents/Pricing-Event-Reports.

[10] AEMO. Power System Operating Incident Reports. Available at http://www.aemo.com.au/Electricity/Resources/Reports-and-Documents/Power-System-Operating-Incident-Reports.

CHAPTER 3. NETWORK DEVELOPMENT

This chapter describes network development opportunities in the DSN that are expected to appear in the NEM over the next 10 years. Key points are:

- There is sufficient existing and committed network capacity to meet projected demand growth in the next 10 years.
- An emerging development opportunity has been identified to facilitate generation transfer out of North West Victoria. AEMO will commence a RIT-T for augmentation in North West Victoria later this year.
- Last year's assessment of the South Morang 500/330 kV F2 transformer limitations has been expanded, and now shows that the benefit is marginally lower than the augmentation cost, even if the current generation surplus in Victoria remains over the next 10 years. A lower generation surplus would be expected to lower the benefits.
- AEMO is changing its Victorian electricity planning criteria to consider the use of five minute short-term ratings to manage thermal overloads on transmission lines in Victoria when planning future network requirements. This will allow AEMO to defer more expensive network augmentation in areas with low demand growth, ensuring the network will, over the long term, minimise the total delivered cost of electricity to customers.

3.1 Methodology

To investigate network development needs, AEMO first identifies transmission network limitations by:

- Investigating historical network performance and constraint binding hours.
- Analysing network loading for the forecast maximum demand.

For any major transmission limitations identified, a pre-feasibility study is performed, using high level market modelling to identify the market benefits of relieving the transmission limitations . If net market benefits are identified as likely, the feasibility stage will be initiated, which may lead to a Regulatory Investment Test for Transmission (RIT-T).

This analysis provides signals for potential network and non-network development opportunities such as localised generation or demand side management (DSM). Further detail on the methodology can be found in the *Victorian Electricity Planning Approach*.[11]

3.1.1 Scenarios considered

The 2016 VAPR uses the scenarios described in the latest (2015) NTNDP, as outlined in the National Electricity Rules (NER 5.12.1 (b)). These scenarios consider potential changes to the generation mix, including the retirement of coal-fired generation.

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

- Gradual Evolution scenario. This assumes operational consumption increases in line with the *2015 National Electricity Forecasting Report* (NEFR)[12] medium scenario, and there is a gradual penetration of residential electricity storage on a trajectory to 8 Gigawatt hours (GWh) installed by 2035, as forecast in AEMO's *2015 Emerging Technologies Information Paper*.[13]
- Rapid Transformation scenario. This assumes that operational consumption follows the 2015 NEFR low scenario, and is lowered further by greater rooftop PV uptake (trajectory of 33.3 GW

[11] AEMO. *Victorian Electricity Planning Approach*, 2016. Available at: http://www.aemo.com.au/Electricity/Policies-and-Procedures/Planning/Victorian-Electricity-Planning-Approach.
12 AEMO. *2015 National Electricity Forecasting Report*. Available at: http://www.aemo.com.au/Electricity/Planning/Forecasting/National-Electricity-Forecasting-Report.
13 AEMO. *2015 Emerging Technologies Information Paper*. Available at: http://www.aemo.com.au/Electricity/Planning/Forecasting/National-Electricity-Forecasting-Report/NEFR-Supplementary-Information.

installed capacity by 2034-35, compared to 20.9 GW in the Gradual Evolution scenario) and a 40% penetration of residential battery storage (19.1 GWh installed capacity) by 2035. This scenario also assumes a trajectory in which 20% of households own an electric vehicle (over 2 million electric vehicles) by 2035. This scenario results in more retirement of coal-fired generation within the next 10 years compared to the Gradual Evolution scenario.

Australia has set a target to reduce carbon emissions by 26–28% below 2005 levels by 2030, which builds on the 2020 target of reducing emissions by 5% below 2000 levels. While this target has not been explicitly modelled in the 2016 VAPR analysis, the Rapid Transformation scenario does consider coal-fired generation retirements in Victoria. The 2016 VAPR is based on the 2015 NTNDP scenarios and 2015 Victoria connection point forecasts (see Section 1.1) which were developed before Australia set the 26–28% target. This target will be modelled in AEMO's 2016 NTNDP scenarios, which will be used as inputs into next year's VAPR.

3.2 Changes to the Victoria electricity planning criteria

In response to slowing demand growth and an approximate 40% decrease in the estimated value customers place on their supply reliability[14], AEMO is changing its Victorian electricity planning criteria.[15] Where it is feasible, low-risk, and can defer augmentation costs, the operational impact of control schemes will be considered in planning the future needs of the network. These control schemes allow the use of five minute short-term ratings to manage thermal overloads on transmission lines in Victoria.

Transmission lines can withstand high power flows for short periods of time before overheating, so the adoption of five minute short-term ratings (rather than the usual 15 minute ratings) can be used to increase the line rating – typically by 10%. This option can defer the need for more expensive network augmentation in areas with low demand growth, ensuring the network will, over the long term, minimise the total delivered cost of electricity to customers.

AEMO considers that the adoption of five minute short-term ratings will not materially affect power system security or reliability, as an automatic control scheme to disconnect customer load can be used in the unlikely event of a contingency during periods of high network stress.

Currently, five minute ratings are already available to manage transmission line loading on:

- Rowville–Springvale 220 kV lines (not expected to be used in the coming 10-year period).
- Ballarat–Moorabool No. 1 220 kV line (not expected to be used in the coming 10-year period).
- Ballarat–Bendigo 220 kV line (expected to be used for up to six hours a year, once every 10 years).
- Rowville–Malvern 220 kV lines (expected to be used for up to four hours a year, once every 10 years).

A control scheme to allow five minute short-term ratings will be used to manage loading on the future Keilor – Deer Park – Geelong line. Studies show that five minute short-term ratings may need to be enabled on this line for up to four hours a year, once every 10 years.

3.3 Completed projects

3.3.1 Network upgrades

As a part of the Heywood Interconnector upgrade[16], a third Heywood 500/275 kV transformer and a Heywood 500 kV bus-tie were commissioned in December 2015. This project also includes supporting

[14] AEMO. *Value of Customer Reliability review*. Available at: http://www.aemo.com.au/Electricity/Planning/Value-of-Customer-Reliability-review.
[15] AEMO. *Victorian Electricity Planning Approach*, 2016. Available at: http://www.aemo.com.au/Electricity/Policies-and-Procedures/Planning/Victorian-Electricity-Planning-Approach.
[16] AEMO. Heywood Interconnector RIT-T. Available at: http://www.aemo.com.au/Electricity/Planning/Regulatory-Investment-Tests-for-Transmission/Heywood-Interconnector-RIT-T.

augmentations in South Australia, which have an expected service date of March 2017. The combination of these works is expected to increase the Heywood Interconnector transfer capacity from 460 MW to 650 MW.[17]

3.3.2 Retirements

The Fishermans Bend synchronous condenser was fully decommissioned in September 2015.

3.4 Future projects and opportunities

This section presents findings from AEMO's review of transmission network limitations in Victoria, as well as future committed projects and retirements.

3.4.1 Committed projects and retirements

The following projects have 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:

- Additional Ballarat–Moorabool 220 kV transmission line.
  - This circuit was proposed as the second stage of the preferred option from the Regional Victorian Thermal Capacity RIT-T and is scheduled for completion in early 2017.[18]
- Brunswick terminal station 66 kV connection.[19]
  - This proposed connection is for a new 66 kV supply from the Brunswick Terminal Station comprising three 225 MVA 220/66 kV transformers. The proposed service date is late 2016.
- 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. The proposed service date is late 2017.[20]
  - The 2015 VAPR assessment identified that limitations on the future Keilor – Deer Park – Geelong 220 kV line servicing parts of western Melbourne could be managed in the 10-year outlook using five minute ratings instead of the standard 15 minute ratings. AEMO has progressed this further, and agreements are in place with AusNet Services to implement an automatic load shedding control scheme which will enable the use of five minute ratings. This allows an increase in transmission network capacity to meet modest demand growth in the area. This limitation will continue to be monitored.
- Ararat terminal station.
  - This new terminal station will facilitate the connection of Ararat Wind farm and is scheduled for completion in late July 2016.
- Ballarat–Horsham 66 kV bus splitting control scheme.
  - As outlined in last year's VAPR, the limitation associated with the Ballarat–Horsham 66 kV line servicing parts of regional Victoria will be addressed by an automatic bus splitting control scheme at Buangor 66 kV switching station. This scheme is now committed, and is due to be

[17] AEMO. Interconnector capabilities. Available at: http://www.aemo.com.au/Electricity/Resources/Reports-and-Documents/Network-Operations/Interconnector-Capabilities.
[18] 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.
[19] NERA consulting. Proposed augmentation for Melbourne inner suburbs and CBD supply. Available at: http://www.aemo.com.au/Consultations/Network-Service-Provider/Joint/~/media/Files/Other/consultations/nsp/0179-0255%20pdf.ashx.
[20] Powercor, Jemena and AEMO joint regulatory test report. Available at: http://www.aemo.com.au/Consultations/Network-Service-Provider/Joint/Joint-Consultation-Paper-Western-Metropolitan-Melbourne-Transmission-Connection-and-Subtransmission.

operational by December 2016. The scheme will improve export capability to New South Wales and South Australia, and facilitate renewable generation export out of North West Victoria.

The following retirements are now considered committed:

- AusNet Services proposes to fully decommission the Brooklyn and Templestowe synchronous condensers by no later than 2017.

3.4.2 Current development opportunities

AEMO currently has no open tenders and no active RIT-Ts relating to the Victorian DSN.

3.4.3 Emerging development opportunities

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

An emerging development opportunity is identified to facilitate generation transfer out of North West Victoria.

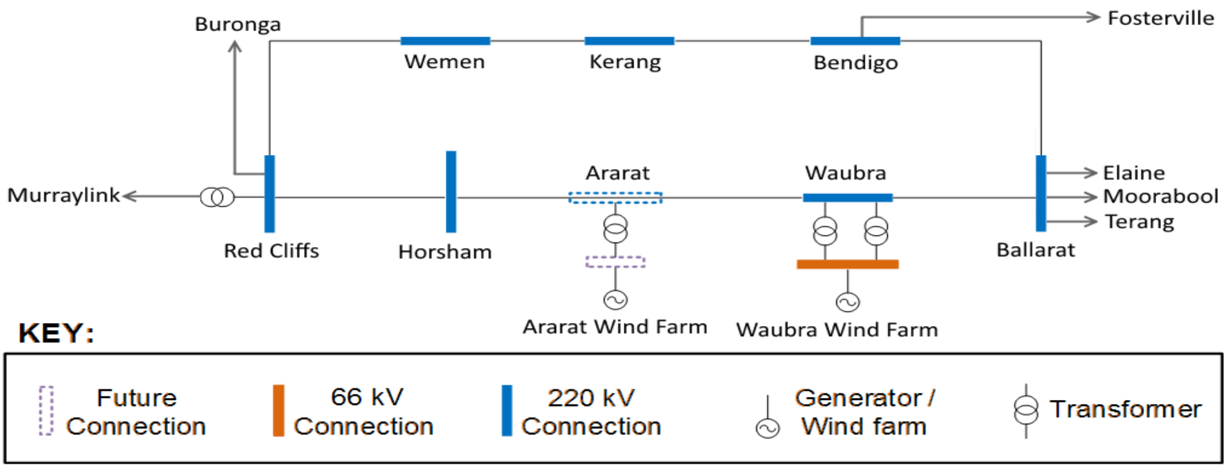
Facilitating generator connections in North West Victoria

North West Victoria is experiencing a high level of interest for renewable generation connection, which exceeds current network capability. AEMO has received applications for over 1,500 MW of new renewable generation in this area, although some projects are more advanced than others. AEMO assessed the market benefits of connecting new generation, and found that major augmentation could be justified if more than 400 MW of new generation connects in this area. Greater certainty from potential generation investors surrounding future generation connections in this area will improve the likelihood that major augmentation will be justified. AEMO will commence a RIT-T later this year to assess potential augmentation benefits in more detail, and invites stakeholders to engage in discussions about proposed generation projects.

Impact on transmission network performance

Following the connection of Ararat Wind Farm, the thermal capacity of the Ballarat–Horsham 220 kV line will limit local generation during peak wind conditions (see Section 4.2). The connection of additional generation in the area will increase network congestion.

Figure 5 220 kV network between Ballarat and Horsham



Forecast market benefits

Alleviating network limitations in North West Victoria is projected to drive gross market benefits of approximately $30 million over a 40-year period, should more than 400 MW of renewable generation be connected in the area. The market benefits are a result of facilitating additional renewable generation, which can displace coal and gas-fired generation that have higher fuel costs. These benefits would further increase if Victorian brown coal generators retire, as the renewable generation could displace even higher-cost black coal or gas-fired generation.

Further, if Australia's LRET target cannot be met without this renewable generation, the penalty price paid for any shortfall would be treated as a resource cost in any RIT-T assessment, as this cost conceptually represents a reduction in environmental benefits. Therefore, the benefits of augmentation would increase in instances where the projected renewable generation curtailment is expected to result in LRET shortfalls.

Development opportunity

The following development opportunities are currently being considered as possible solutions to the emerging network congestion:

- Minor line upgrades – upgrading terminal station line droppers and installing wind monitoring at a total cost of approximately $1.5 million.
- A new 420 MVA single circuit line between Ballarat and Waubra costing about $21 million.
- A new 1,000 MVA double circuit line, replacing the existing Ballarat–Waubra 220 kV line, at a total cost of approximately $37 million.
- Reactive compensation on the Ballarat–Waubra 220 kV lines, costing about $3 million.
- A grid-connected battery to moderate peak generation (see Section 4.2.2 for more details).

The preferred option will depend on how much new generation will connect in the area. See Section 4.2 for discussion on the augmentation options that might be justified at different levels of new generation connection.

Conclusion

AEMO will commence a RIT-T for augmentation in North West Victoria later this year. Given that augmentation may be justified depending on the level of new generation connections, greater certainty on these projects will enable a more robust analysis of augmentation benefits.

3.4.4 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 within the next 10 years.

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.

The full list of monitored transmission limitations can be found in Appendix A.

The South Morang F2 transformer limitation

The assessment of export capability to New South Wales in the 2015 VAPR considered congestion on the South Morang F2 transformer. It concluded that the market impact of the limitation did not justify augmentation, but warranted further investigation.

The assessment in 2016 was expanded to consider the market benefits of the transient stability limit[21] and congestion on the South Morang – Dederang 330 kV lines also being alleviated.

[21] Transient stability is the ability of the power system to maintain synchronism following a severe and sudden disturbance.

Impact on transmission performance

Export capability from Victoria to New South Wales is frequently limited by congestion on the South Morang F2 transformer and South Morang – Dederang 330 kV lines and the transient stability limit.

Forecast market benefit

The forecast market benefit of relieving the limitations impacting Victoria – New South Wales export is approximately $64 million over the next 40 years under the Gradual Evaluation scenario, however this benefit is highly dependent on the future generation mix.

More coal-fired generation retirements have been considered in the Rapid Transformation scenario within the next 10 years, compared to the Gradual Evaluation scenario. It reflects a reduction in the benefits of relieving the congestion on South Morang's F2 transformer, to approximately $18 million. This scenario highlights that the market benefit associated with increasing export capability to New South Wales is sensitive to assumptions around the future of brown coal generation in Victoria and what replaces it.

Development options assessed

Investigations during the 2015 VAPR demonstrated that any project to address the South Morang F2 transformer limit would likely also need to address both transient stability and the South Morang – Dederang 330 kV thermal loading, in order to achieve a positive net market benefit.

The following three projects were considered:

1. Installation of a new 500/330 kV transformer at South Morang.
2. Uprating of the South Morang – Dederang 330 kV line.
3. Increasing the transient export limit, most likely through the implementation of a braking resistor.[22]

The projected total cost of these projects is approximately $72 million. However, if more substantial upgrades or a new circuit were to be required for the South Morang – Dederang 330 kV, this cost could increase several-fold.

Conclusion

The 2016 VAPR analysis shows that the gross market benefits of addressing all three limitations are slightly lower than the augmentation costs, under scenarios where surplus generation from Victoria supports New South Wales. AEMO will monitor changes to the Victorian generation mix that could increase market benefits, triggering a RIT-T.

3.5 Potential locations for new terminal stations in Victoria

This section presents information on the development of the network to accommodate new generation and load connections over the next 10 years. Due to confidentiality, only publicly-available connection information is presented in this section.

AEMO's policy and guidelines for establishing new terminal stations in Victoria[23] streamlines the process for connecting generators and loads. AEMO's objective for Victoria is to develop an economically and technically robust approach to connecting generation and load to the DSN in the long term, while maintaining power quality, security, and reliability of the network.

New terminal stations can be initiated by:

- A Transmission Network Service Provider (TNSP) identifying the need for DSN augmentations to deliver future capacity requirements.

[22] There are other ways of increasing the transient limit, including the installation of synchronous technologies with significant inertia, however these are more expensive than braking resistors. This will be considered in any further studies in consultation with the relevant stakeholders.

[23] 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.

- Applications to connect generation or major directly connected loads to the DSN.
- Plans for new terminal stations necessary to meet distribution network demand, as outlined in the *2015 Transmission Connection Planning Report.*[24]

Table 4 summarises some of the potential generation projects for development over the next 10 years. More information on generation projects and project advancement criteria is available on AEMO's generation information page.[25]

Table 4 Potential generation projects*

Project	Capacity (MW)	Location	Service date
Ararat Wind Farm	241	Approximately 9–17 km northeast of Ararat in Western Victoria	July 2016
Bulgana Wind Farm	189	Within the Joel Joel, Joel South, Bulgana and Great Western districts of south-west Victoria	Not available
Crowlands Wind Farm	82	Approximately 20–25 km northeast of Ararat in Western Victoria	Not available
Dundonnell Wind Farm	312	Approximately 25 km northeast of Mortlake in the Western District of Victoria	Not available
Gannawarra Solar Farm	300	Near Kerang	Not available
Kiata Wind Farm	39	10 km south east of Nhill	Not available
Moorabool Wind Farm	321	South of Ballan and 25–30 km southeast of Ballarat	Not available
Mortlake South Wind Farm	76.5	5 kilometres south of Mortlake in the Moyne Shire of south-west Victoria	Not available
Mount Gellibrand Wind Farm	132	25 km east of Colac and 17 km west of Winchelsea in the Colac Otway Shire on Victoria's Western Plains	Not available
Murra Warra Wind Farm	386	About 25 km north of Horsham	Not available
Salt Creek Wind Farm	30	2.5 km south of Woorndoo, Victoria	April 2018
Stockyard Hill Wind Farm	534	Approximately 35 km west of Ballarat	Not available

* Information provided in this table has been sourced from publicly available information. Where information is not available publicly this has been noted as 'not available'.

To achieve the most cost-effective outcome, AEMO prefers to connect generation developments within the same vicinity (within a radius of approximately 20 km) to a single terminal station.

Table 5 lists some of the proposed terminal station locations selected to support this preference over the next 10 years.

Table 5 Proposed new terminal stations for generation connection*

Terminal station	Line cut-in and location	Project and approximate distance to terminal station	Service date
Ararat Terminal Station (committed)	Ballarat–Waubra–Horsham 220 kV line, approximately 81 km from Horsham.	Ararat Wind Farm (17 km)	July 2016
Stockyard Hill Terminal Station	Near the crossover of the 220 kV Terang–Ballarat and the 500 kV Moorabool–Heywood lines, south of Lismore.	Stockyard Hill Wind Farm (50 km)	Not available

* Information provided in this table has been sourced from publicly available information. Where information is not available publicly this has been noted as 'not available'.

[24] Jemena, CitiPower, Powercor, AusNet Services and United Energy. *2015 Transmission Connection Planning Report.* Available at: http://www.ausnetservices.com.au/CA257D1D007678E1/Lookup/Projects/$file/TCPR%20Report.pdf.
[25] AEMO. Generation Information. Available at: http://www.aemo.com.au/Electricity/Planning/Related-Information/Generation-Information.

Table 6 lists committed terminal station developments to address Victorian peak demand growth over the next 10 years.[26]

Table 6 Committed new terminal stations for connecting load

Project	Driver	Service date
Deer Park Terminal Station	Transfer load from Altona, Brooklyn, and Keilor terminal stations due to increased demand in the area.	Late 2017

3.6 Distribution planning

In undertaking augmentation planning, AEMO considers Distribution Network Service Provider (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 load growth on the DSN by modelling this growth at connection points. AEMO and DNSPs work together, undertaking joint planning to address connection asset limitationsand 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' *2015 Transmission Connection Planning Report*, and potential DSN impacts and considerations.

3.7 Network Support and Control Ancillary Services

AEMO's *2012 National Transmission Network Development Plan* (NTNDP) network support and control ancillary services (NSCAS) assessment identified a potential economic NSCAS gap which presented an opportunity to maximise net economic benefits, by relieving the New South Wales to Victoria voltage stability limitation.

This voltage stability limitation constrains electricity transfer from New South Wales to Victoria. AEMO has been managing this limitation via reactive power support procured through a contract with a generator.

The 2015 NTNDP NSCAS assessment confirmed this ongoing requirement for voltage support. AEMO and TransGrid jointly investigated this voltage stability limitation, the use of the contracted reactive power support, and the effect on the limitation of the newly installed capacitor banks at Canberra and Yass. Based on this investigation, AEMO and TransGrid determined that the current arrangement remains appropriate and will continue to monitor this voltage stability limitation in future.

[26] Jemena, CitiPower, Powercor, AusNet Services and United Energy. *2015 Transmission Connection Planning Report.* Available at: http://www.ausnetservices.com.au/CA257D1D007678E1/Lookup/Projects/$file/TCPR%20Report.pdf.

CHAPTER 4. GENERATOR CONNECTION OPPORTUNITIES

The Victorian transmission network was developed primarily to transfer power from generators in the Latrobe Valley, where coal is abundant, to major load centres and neighbouring states. In recent years, connection interest has focused more on renewable generation, and this interest has accelerated with increased certainty around the LRET. Rather than large generator connections being centralised around the high capacity 500 kV network, smaller connections are now being proposed in weaker areas of the network (such as North West Victoria – see Section 4.3). This decentralisation of generation will test the capability of these weaker areas.

Generator connection interest exceeds grid capability in some areas of Victoria. To assist those who seek to connect generation to the Victorian transmission network, this chapter provides information on:

- The capability of the current transmission network to accommodate new generator connections.
- Potential congestion in North West Victoria, and a case study outlining the conditions under which augmentation can most likely be justified.
- The implications of connection location in a constrained network .
- An overview of AEMO's network connection, augmentation, and data request processes.

4.1 Transmission network capacity

Generation connecting in locations most favourable to resource availability may be at risk of having its output constrained at times due to limited network capacity. Network access is complex, and is influenced by a number of factors, including a wide range of power system technical limits. The likely access level for generator connections varies across the transmission network, and throughout the day. Network access is not guaranteed, and precedence is not given to existing connections (see Section 4.4).

Traditionally, generators have been connected to the transmission network. Due to the growing interest in renewable generator connections, and their relative scale, AEMO has observed that generator applications for connecting into the distribution network are increasing. Some distribution networks will at times supply the transmission network, potentially causing performance issues[27], as the networks were not designed to cope with flow reversal.

4.1.1 Overview of generator connection opportunities

AEMO conducted a high-level assessment of power system limits to determine the risks and opportunities for new generator connections. The results are summarised below to assist in the early stages of project feasibility studies. This assessment:

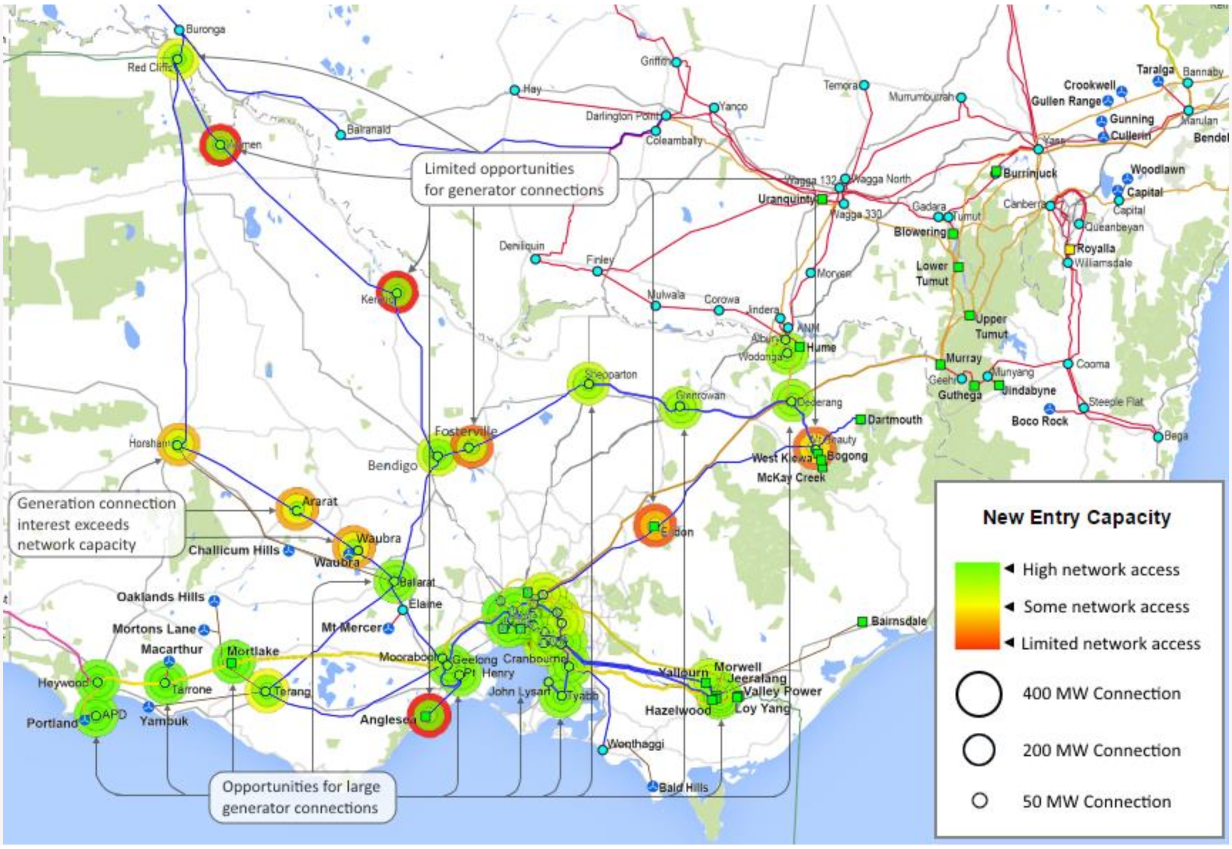
- Simulated congestion on the transmission network that might affect existing and new generation connected to the Victorian DSN.
- Modelled the current capability of the transmission network and included the impact of existing and committed generators (see Section 3.4.1).
- Did not consider future network augmentations or generator projects that are not yet committed, which will influence risks and opportunities for new connections.

Figure 6 provides a high level assessment of future generation connection opportunities and risks. Proponents of new generation connection should conduct their own due diligence, to better understand how technical limitations might influence their connection.

[27] Performance issues relating to network flow reversals include, but are not limited to, inefficient protection operation, voltage control difficulty, less effective under-frequency load shedding, and measuring uncertainty.

This figure shows three concentric circles at each transmission terminal station in Victoria. The size of each circle represents the capacity of a possible generator connection, and the colour shading approximates the existing level of grid access that might be achievable without materially affecting the performance of the existing network. These results highlight current opportunities and risks – future generator connections and network changes will affect the illustrated network capability.

Figure 6 Generation connection opportunities and risks



The network access illustrated in Figure 6 shows that:

- There are connection opportunities for new generation with access to the 500 kV network from South West Victoria and Latrobe Valley, given the high level of network access in these areas.
- In contrast, the connection opportunities for new generation in remote areas with long or radial 220 kV lines, such as Wemen, Red Cliffs, Kerang, Glenrowan, Eildon, Mt Beauty, and Anglesea, are limited by network capacity.
- There is currently a high level of generation connection interest in North West Victoria due to its natural resources, however this interest exceeds existing network capacity (see Section 4.2).

Proponents seeking to connect generation within distribution networks should seek advice from the relevant DNSP about the capability of the distribution network.

Although AEMO will allow generator connection in areas with low network capacity, generators in these areas face a high risk of being constrained. More information relating to individual points of interest is available on AEMO's interactive map (see Section 1.1).

4.2 Potential congestion in North West Victoria

The majority of wind farms in Victoria are currently located in the Regional Victoria corridor (West and North West Victoria). Within this area, a significant portion of recent generator connection inquiries relate to a stretch of 220 kV network between Ballarat and Horsham (see Section 3.5).

There is one existing wind farm (Waubra Wind Farm) connected in this area, and another committed project (Ararat Wind Farm – see Section 3.5) planned to connect in July 2016. With the connection of Ararat Wind Farm, the Ballarat–Horsham 220 kV transmission line will be at its thermal capacity under peak wind conditions.

In November 2015, AEMO released a Q & A document[28] highlighting the possibility of future network congestion in the area.

4.2.1 Justifying network upgrades to alleviate congestion

AEMO has performed a case study to assess the network congestion that would result following increasing levels of new connections between Ballarat and Horsham after the commissioning of Ararat Wind Farm. The results of this study are shown in the following table (see Section 3.4.3 for further details about the network solutions listed).

Table 7 Likely solutions to alleviate congestion between Ballarat and Horsham

New generation installed	Congestion time	Wind generation curtailed*	Likely solution to alleviate congestion
200 MW	10%	35 GWh	Minor line upgrades will alleviate 60% of this congestion.
300 MW	12%	80 GWh	The justification for major upgrades, such as new single or double circuit lines, will depend on the future of brown coal generation in Victoria and the degree to which the LRET is achieved from other sources.
400 MW	17%	200 GWh	Major upgrades, such as new single or double circuit lines, can likely be economically justified. At this level of connection, solutions to improve network strength will likely be required (see Section 4.3).

* The specific generation that is constrained will depend on the NEM dispatch process (see Section 4.4).

AEMO will commence a RIT-T for augmentation in North West Victoria later this year. When justifying network upgrades, AEMO considers a range of likely generation expansion scenarios. Greater certainty from potential generation investors surrounding future generation connections in this area will improve the likelihood that major augmentation will be justified. AEMO will commence a RIT-T later this year to assess potential augmentation benefits in more detail, and invites stakeholders to engage in discussions about proposed generation projects.

4.2.2 Battery storage integration

Battery storage may be a credible alternative to network augmentation for alleviating congestion. When connecting to areas with low network capacity, proponents might consider integrating battery storage to moderate their peak generation. AEMO performed an economic assessment to evaluate the merits of large grid-connected battery storage (10–50 megawatt hours (MWh)) as a way to reduce wind curtailment in North West Victoria. This study considered the following benefits:

- Reducing generator fuel costs by storing and releasing renewable energy.
- Reducing wind curtailment, thereby avoiding possible penalties if LRET cannot be met from other sources.

[28] AEMO. *New generator connections to the Victorian transmission system, in particular between the 220kV lines between BATS–WBTS–HOTS and HOTS–RCTS*, November 2015. Available at: http://www.aemo.com.au/Electricity/~/media/5FA06E8ED30F4F6D84355A8D344F0FD0.ashx.

The study assumed that a grid-connected battery will charge whenever wind generation is being curtailed, and discharge during daily price peaks, and found that:

- Battery storage was not found to be justified currently in lieu of network augmentation. The assumed cost of a battery[29] to alleviate congestion in North West Victoria is approximately 2.5 times the market benefits returned, given a 20-year battery lifespan. Benefits are expected to improve as battery costs decrease and lifespan increases.
- Generator proponents could consider the additional benefits of price arbitrage, contracting, and ancillary service provision if they chose to integrate battery storage into a renewable generation project.

The value of large grid-connected battery storage is unique to each location, due to network capacity and generation intermittency. The outcomes of this study are specific to potential congestion emerging in North West Victoria and cannot be applied more broadly.

4.3 Network strength in North West Victoria

A common measure of network strength at a given point in the power system is its fault level.[30] A project-specific measure of system strength for a generator connection is the Short Circuit Ratio (SCR), which is the ratio of the power system fault level at that connection point to the rated local generation. The connection of additional electrically close[31] asynchronous generation (such as wind or solar)[32] will not materially affect the local fault level, but will increase local generation, resulting in a decrease of SCR.

Both the minimum fault level and the minimum SCR are important values for asynchronous generator connection. Insufficient fault level and SCR will challenge:

- The ability of generators to stay connected to the network during faults (see Section 4.3.1).
- Steady state voltage control and transient voltage recovery (see Section 4.3.2).
- Correct operation of control systems during normal operation.

To confirm the correct operation of asynchronous generation under conditions of low network strength, detailed studies using very accurate modelling of turbines and inverters are necessary. Since the specific generator performance will be dependent upon the type and detailed specification of the asynchronous generator in question, and its ancillary plant, it is impossible to provide an exact limitation for the amount of generation that can be installed at any single point of connection.

Figure 7 highlights areas where network strength is most likely to affect new asynchronous generator connections.

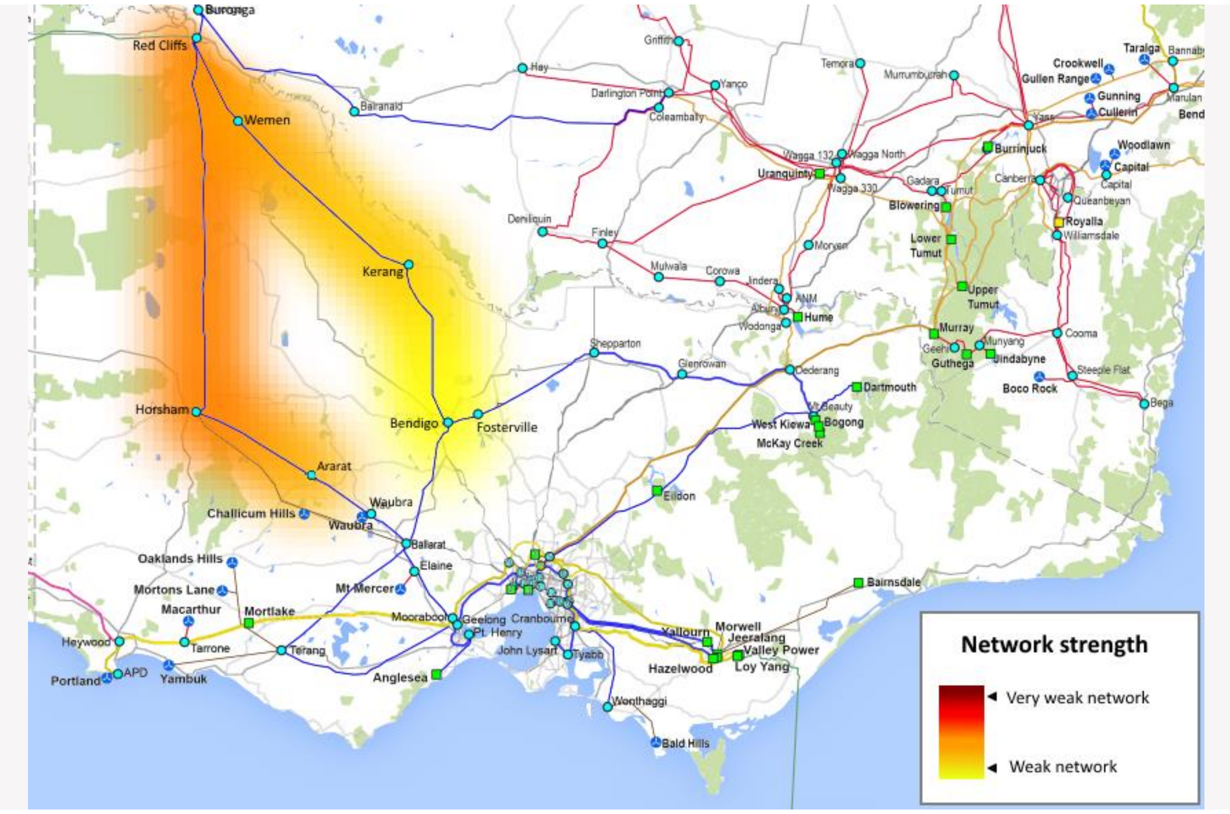
[29] Battery costs have been assumed to be $500 thousand per megawatt hour, based on a forward projection cost from an *Energy Storage for Commercial Renewable Integration* paper. Available at http://arena.gov.au/files/2016/04/ESCRI-General-Project-Report-Phase-1.pdf.

[30] Fault level is the maximum current that is expected to flow in response to a short-circuit at a given point in the power system.

[31] Regardless of their geographical proximity, locations in the power system are considered to be electrically close when the electrical resistence between them is low.

[32] Modern wind turbines and photovoltaic (PV) systems are connected to the power system through the use of power electronic converters and are seen by the grid as asynchronous generation. Synchronous generators (most coal, gas and hydro generators) produce power through directly connected alternating current machines, rotating at a speed synchronised to power system frequency. These generators produce inertia, which dampens the impact of changes in power system frequency, resulting in a more stable system. Power systems with low inertia experience faster changes in system frequency following a disturbance, such as the trip of a generator or load.

Figure 7 Areas with weak network strength



Low network strength is emerging as a potential limitation in North West Victoria, which might restrict future asynchronous generator connections. This limitation is forecast to be most significant at Ararat, Horsham, Red Cliffs, Wemen, and Kerang. Network strength in these areas is expected to further decline as more asynchronous generators connect.

Where network strength is inadequate, new asynchronous generator connections will not be allowed to connect unless synchronous machines (generation or synchronous condenser) can be sourced to improve fault level availability. In some cases, the issues caused by low network strength might be mitigated through modification of converter controls and synchronous dynamic reactive support.

A generator connection which adversely affects power system security may be required to rectify the issue at its own cost. AEMO will consider the potential costs associated with addressing network strength in the RIT-T proposed to facilitate generator connections in North West Victoria (see Section 3.4.3).

4.3.1 Ability of generators to remain connected to the network during faults

A minimum SCR is required to ensure that inverter-connected generating systems (such as wind or solar) can remain connected to the network during nearby faults, and maintain stable operation after the fault is cleared.

For connections with insufficient SCR, asynchronous generator controls may behave unexpectedly during faults. Coordination with dynamic reactive plant will be necessary, and affected wind farms might require turbine control modification.

Fault ride-through requirements are specified within the generator performance standards for all new connections (See S5.2.5.5 of the National Electricity Rules[33]).

[33] National Electricity Rules. Available at: http://www.aemc.gov.au/Electricity/National-Electricity-Rules/Current-Rules.html.

4.3.2 Voltage control

The effects of low network strength on system disturbances are higher voltage drops and slower voltage recovery following network disturbances, such as faults. The geographic spread and the depth of voltage dips increase as the available fault level decreases. This culminates in an increased risk of system instability, even when the asynchronous generation can ride through the fault.

Voltage control requirements are specified within the generator performance standards for all new connections (See S5.2.5.1 in the National Electricity Rules[34]).

4.4 Connection location and dispatch merit order

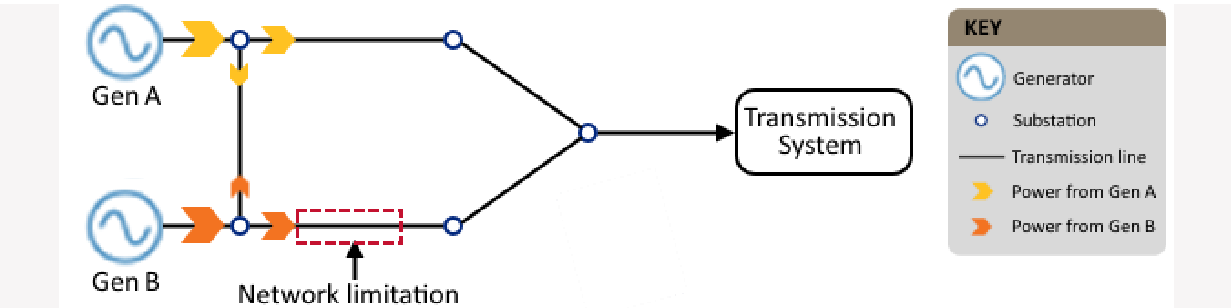
In response to the large number of adjacent connection enquiries, AEMO has included this section to provide transparency on the role of connection location and the method by which new terminal stations are located.

The National Electricity Market Dispatch Engine (NEMDE) optimises the dispatch of generation every five minutes. This economic dispatch process uses mathematical constraint equations to constrain generation when necessary to prevent network limits from being breached. This process is used to maintain the power system secure operating state.

Marginal Loss Factors (MLFs) can influence the offer prices submitted by generators. MLFs are updated annually by AEMO, and estimate the degree that a generator contributes to network losses at the margin. When a generator lodges an offer price at its connection point, that offer is divided by the generator's MLF to translate the price to the regional reference node before being used by NEMDE. Since all generators have the same bidding capability once translated to the regional reference node, the MLF does not provide an advantage that cannot be overcome through competitive bidding.

The following figure represents a fictitious example of two generators connected to a transmission loop.

Figure 8 Generator dispatch example



Since power will flow through the path of least resistance, the majority of power generated by Gen A (say, 60%) will travel through the upper side of the loop, and the majority of the power generated by Gen B (say, 60%) will travel through the lower side.

Given the network limit, a constraint equation will ensure the power flow is kept below the transmission line rating. NEMDE manages this by limiting generation. The constraint equation for this limitation is:

$$0.4 \times \text{Gen A} + 0.6 \times \text{Gen B} \leq \text{Rating} - \text{Operating Margin}^{[35]}$$

If both generators have the same offer price (once translated to the regional reference node by their MLF), then NEMDE will constrain Gen B before constraining Gen A, because decreasing the output from Gen B is a more effective way to alleviate the limitation.

[34] AEMC. National Electricity Rules. Available at: http://www.aemc.gov.au/Electricity/National-Electricity-Rules/Current-Rules.html.
[35] A small operating margin is applied to thermal constraint equations to account for the impact of dispatch and measurement errors.

The offer prices submitted by generators can alter the order of dispatch. If Gen B were to offer power at a price less than 66%[36] the price of Gen A, then the dispatch merit order would be changed, and Gen A would be constrained rather than Gen B. If Gen A were to offer at market floor price, then Gen B would be constrained first, regardless of its offer. For this reason, generator connection location can be crucial to protect generator revenue longer term.

Generators connected in close proximity and having similar impacts on a network limitation will receive the same or similar constraint equation coefficients.

4.4.1 Locating new terminal stations

For connecting new generation, while AEMO will identify a preferred location, the connection applicant will be responsible for selecting a terminal station location to best suit their needs.

In determining the location of a terminal station, the connecting party(s) and/or AEMO must consider the following factors:

- Concentration of energy resources to create a cluster of generation in the area.
- Alignment of the location with AEMO's future development plans for the DSN.
- Reliance on the existing network in the area to support loads and other networks.
- Reduction in the overall costs of potential connections if a single terminal station is established, relative to the establishment of multiple separate connections.
- The most cost-efficient option for terminal station location in relation to connecting entities.
- Availability of suitable land for the construction of the terminal station and the associated easements required for connections to the terminal station.
- Existence of connection enquiries or applications from multiple generators.
- Forecast demand that may require additional connections to the network to meet industrial or distribution demand.

These factors are further detailed in the *Guidelines for Establishing Terminal Stations in Victoria*.[37]

4.5 Online resources

AEMO publishes information on its website about the processes for network connections[38], network augmentations to cater for new generation connections[39], and requests for network data.[40] This section is a high-level summary of each process.

4.5.1 Connections process

For generator transmission connections (typically greater than 30 MW in capacity) in Victoria, AEMO is involved in all stages of the connection process, from pre-feasibility to completion.

For generator distribution connections (embedded generation and typically connections less than 30 MW in capacity), the connecting DNSP manages the connection process and is the main point of contact for the connection applicant.

[36] The price reduction needed for Gen B to gain dispatch priority is calculated as a fraction of their coefficients in the constraint equation. In this example, Gen B must bid at 66% (0.4 / 0.6) of Gen A's bid to ensure that Gen A will be constrained first.
[37] AEMO. *Guidelines for Establishing Terminal Stations in Victoria, 2011*. Available at: http://www.aemo.com.au/Electricity/Network-Connections/Vic_Generator_Transmission_New-Connection/Support/~/media/Files/Other/network_connections/0174-0018%20pdf.ashx.
[38] AEMO. Network Connections. Available at: http://www.aemo.com.au/Electricity/Network-Connections.
[39] AEMO. New Generator Transmission Connections in Victoria. Available at: http://www.aemo.com.au/Electricity/Network-Connections/Vic_Generator_Transmission_New-Connection/Support/Network-Augmentation.
[40] 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.

The connection of a new generator to the transmission network follows six stages:

1. **Pre-feasibility:** Explore the feasibility with AEMO, landowners, and government authorities.
2. **Enquiry:** Submit a connection enquiry to AEMO to determine the most suitable point of connection and clarify the information required for a formal connection application.
3. **Application:** Submit a formal connection application to initiate a new transmission connection.
4. **Contracts:** AEMO prepares an offer to connect for negotiation and execution.
5. **Construction:** Once contracts have been executed, the construction stage begins.
6. **Completion:** Registration, commissioning, and other post-commissioning steps.

4.5.2 Network augmentation process

Network augmentations may be required to connect a new generator project to the Victorian transmission network. Proposals for transmission augmentations to accommodate new connections should be consistent with AEMO's *Guidelines for Shared Transmission Connections in Victoria*.[41]

AEMO's *Guidelines for Establishing Terminal Stations in Victoria*[42] describes the processes for identifying future needs, including the ultimate switching configuration at an existing or proposed terminal station.

To determine the funding mechanism of an augmentation required to accommodate a new generator, AEMO assesses whether the proposed augmentation either meets legislative obligations or delivers system-wide net benefits. A project that passes this test would have its funding recovered from transmission network users through Transmission Use of System (TUoS) charges. A project that does not pass this test would need to be recovered solely from the users requiring the service.

4.5.3 Network data request

Under clause 3.13.3(k)(2) of the National Electricity Rules[43], a registered participant can ask AEMO for information they reasonably require to carry out power system studies (including load flow and dynamic simulations). Participants use a standard request form to request network data.

[41] AEMO. *Guidelines for Shared Transmission Connections in Victoria, 2011*. Available at: http://www.aemo.com.au/Electricity/Network-Connections/Vic_Generator_Transmission_New-Connection/Support/~/media/Files/Other/network_connections/0174-0017%20pdf.ashx.
[42] AEMO. *Guidelines for Establishing Terminal Stations in Victoria, 2011*. Available at: http://www.aemo.com.au/Electricity/Network-Connections/Vic_Generator_Transmission_New-Connection/Support/~/media/Files/Other/network_connections/0174-0018%20pdf.ashx.
[43] AEMC. National Electricity Rules. Available at: http://www.aemc.gov.au/Electricity/National-Electricity-Rules/Current-Rules.html.

CHAPTER 5. AUSNET SERVICES' RENEWAL PROJECTS

This section outlines AusNet Services' transmission asset renewal projects for the next 10-year period. AusNet Services' asset renewal plan is based on asset performance, condition, failure risk, and other operational factors affecting the assets' economic life. Information about how asset renewals are integrated into augmentation planning is available on AEMO's website.[44]

While the drivers for network augmentation have changed, there has also been a broader, NEM-wide shift for overall transmission investment towards replacement of ageing assets, as noted in AEMO's *2015 National Transmission Network Development Plan* (NTNDP). This trend continues in Victoria, with asset renewal expected to comprise at least three quarters of transmission spend in the next three years.

In its 2016 asset renewal plan, AusNet Services projects approximately $1.13 billion investment across 53 proposed projects over the coming 10 years. Approximately 50% of this investment is required for the seven projects detailed below.

Table 8 Large projects proposed for asset renewal

Project	Purpose	Target Completion	Total Cost (sM)
Richmond Redevelopment	Station redevelopment project. Project addresses supply, safety, environmental, and collateral plant damage risk.	2018	175
West Melbourne Redevelopment	Station redevelopment project. Project addresses supply, safety, environmental, and collateral plant damage risk.	2021	119
Springvale Redevelopment	Station redevelopment project. Project addresses supply, safety, environmental, and collateral plant damage risk.	2021	77
Keilor A2 & A4 500/220 kV & B4 220/66 kV Transformer Replacement	Selective replacement of assets based on condition. Project addresses supply, safety, environmental, and collateral plant damage risk.	2025	70
Heatherton Redevelopment	Station redevelopment project. Project addresses supply, safety, environmental, and collateral plant damage risk.	2017	59
Fisherman's Bend Transformer and Circuit Breaker Replacement	Selective replacement of assets based on condition. Project addresses supply, safety, environmental, and collateral plant damage risk.	2020	37
Transmission Line Structure, Conductor and Insulator Replacement	Selective replacement of assets based on condition. Project addresses supply, safety, environmental, and collateral plant damage risk.	2025	35

AusNet Services' complete asset replacement plan is presented on AEMO's website (see Section 1.1). It includes details of alternative options that were assessed, and material changes since the plan's previous publication.

AEMO has independently reviewed AusNet Services' asset renewal plan and published the findings in a separate report (see Section 1.1). The review assessed the extent to which proposed investments are required to address transmission network needs, and considered whether alternative options could better address these needs. Following AEMO's review, AusNet Services revised the asset renewal plan, and the final plan has been published with this VAPR (see Section 1.1).

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

APPENDIX A. DSN MONITORED LIMITATION DETAIL

These details for monitored transmission network limitations are grouped geographically. A number of limitations previously identified as monitored are no longer included in the 2016 VAPR because their triggers are now unlikely to occur. This is due to changes in network loading resulting from committed network projects, projected decreases in demand, or change in generation mix.

A.1 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 the 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 *2015 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 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 ºC and 0.6 m/s wind speed, unless otherwise indicated.[45]
- 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.

[45] For lines with wind monitoring installed, historical wind speed data was analysed to identify the wind speed occurring during the top 5% of demand periods with a 95% confidence interval.

- 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.[46]

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

- 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 according to the 2015 NTNDP generation expansion plan.[47]

For more information about the transmission network limitation review approach, see the Victorian Electricity Planning Approach.[48]

A.2 Eastern corridor – monitored limitations

Table 9 Limitations being monitored in the Eastern corridor

Limitation	Possible network solution	Trigger[49]	2015 NTNDP status	Contestable project status
Rowville–Yallourn 220 kV line loading	A new 500/220 kV transformer at Hazelwood with an estimated cost of $36 million plus any fault level mitigation works. Upgrade the 220 kV Hazelwood–Rowville or Yallourn–Rowville lines.	During period of extremely high temperature and high output from Hazelwood or Yallourn power stations.	The NTNDP did not identify this as a material limitation in the scenarios modelled.	The new transformer is likely to be a contestable project. The line upgrade is unlikely to be a contestable project.
Hazelwood 500/220 kV transformer loading	A new 500/220 kV transformer at Hazelwood with an estimated cost of $36 million plus any fault level mitigation works. Upgrade the 220 kV Hazelwood–Rowville or Yallourn–Rowville lines.	During period of extremely high temperature and high output from Hazelwood or Yallourn power stations.	The NTNDP did not identify this as a material limitation in the scenarios modelled.	The new transformer is likely to be a contestable project. The line upgrade is unlikely to be a contestable project.

[46] AEMO. *Wind Contribution to Peak Demand*, 2012. Available at http://www.aemo.com.au/Electricity/Planning/Related-Information/Wind-Contribution-to--Peak-Demand.
[47] AEMO. *2015 National Transmission Development Plan*. Available at http://www.aemo.com.au/Electricity/Planning/National-Transmission-Network-Development-Plan.
[48] AEMO. *Victorian Electricity Planning Approach*, 2016. Available at http://www.aemo.com.au/Electricity/Policies-and-Procedures/Planning/Victorian-Electricity-Planning-Approach.
[49] Triggers are the operating conditions under which a limitation may result in supply interruptions or constrain generation periodically.

A.3 South-west corridor – monitored limitations

Table 10 Limitations being monitored in the South-west corridor

Limitation	Possible network solution	Trigger[49]	2015 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 $13.6 million. A static VAr compensator (SVC) or a synchronous static compensator (STATCOM) at an estimated cost of $31.6 million. Additional transposition towers along the Moorabool–Heywood–Alcoa Portland 500 kV line at an estimated cost of $35.9 million.	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 increase in proportion to power flow magnitude and direction, new generation connection points, and output generated.	This limitation was not considered as part of 2015 NTNDP scope as it is related to voltage quality.	The switched capacitor and static VAr options are likely to be contestable projects. The 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 $530.4 million.	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.	The NTNDP did not identify this as a material limitation in the scenarios modelled.	The new line is likely to be a contestable project.
Over-voltages during low load periods	Installation of additional reactors or other type of reactive plant capable of absorbing reactive power.	Reduction in demand level during low load periods, particularly in the South-west corridor. Retirement of existing reactive plant in or close to the South-west corridor, such as the synchronous condenser at Brooklyn.	The NTNDP did not identify this limitation as this is a localised issue.	Additional reactive support is unlikely to be a contestable project.

A.4 Northern corridor – monitored limitations

Table 11 Limitations being monitored in the Northern corridor

Limitation	Possible network solution	Trigger[49]	2015 NTNDP status	Contestable project status
Murray–Dederang 330 kV line loading	Installing a new (third) 1,060 MVA 330 kV line between Murray and Dederang with an estimated cost of $176.5 million (excluding easement costs) or a new (second) 330 kV line from Dederang to Jindera at an estimated cost of $145.9 million (excluding easement costs).	Increased NSW import and Murray generation.	The NTNDP did not identify this as a material limitation in the scenarios modelled.	These are both likely to be contestable projects.
Dederang – South Morang 330 kV line loading	Up-rating the two existing lines 82 ºC (conductor temperature) operation and series compensation at an estimated cost of $16.2 million. Installing a new (third) 330 kV, 1,060 MVA single circuit line between Dederang and South Morang with 50% series compensation to match the existing lines, at an estimated cost of $234.6 million (excluding easement costs, and subject to obtaining the necessary easement).	Increased NSW import. This constraint will be alleviated by any development to increase the VIC to NSW export limit.	This constraint was identified in the 2015 NTNDP 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	Installing a wind monitoring scheme with an estimated cost of $524.3k or up-rating the conductor temperature of both 220 kV circuits between Dederang and Mount Beauty to 82 ºC, at an estimated cost of $11.9 million.	Increased NSW import and export.	The NTNDP did not identify this as a material limitation in the scenarios modelled.	These are unlikely to be contestable projects.
Eildon–Thomastown 220 kV line loading	Installing a wind monitoring scheme at an estimated cost of $524.3k or up-rating the Eildon–Thomastown 220 kV line, including terminations to 75 ºC operation, at an estimated cost of $42.8 million.	Increased NSW import and export.	This constraint was identified in the 2015 NTNDP during high transfer between VIC to NSW (export or import)	This is unlikely to be a contestable project.
Dederang 330/220 kV transformer loading	Installing a fourth 330/220 kV transformer at Dederang at an estimated cost of $20.8 million.	At times of over 2,500 MW of imports from NSW and Murray generation (with the DBUSS transformer control scheme being active).	The NTNDP did not identify this as a material limitation in the scenarios modelled.	The new transformer is likely to be a contestable project.
Voltage collapse at South Morang, Dederang, Wodonga, and Jindera	Installing additional capacitor banks and/or controlled series compensation at Dederang and Wodonga terminal stations.	Increased NSW import and export.	The NTNDP did not identify this as a material limitation in the scenarios modelled.	These are unlikely to be contestable projects.

A.5 Greater Melbourne and Geelong – monitored limitations

Table 12 Limitations being monitored in the Greater Melbourne and Geelong

Limitation	Possible network solution	Trigger[49]	2015 NTNDP status	Contestable project status
Rowville–Malvern 220 kV line loading[50]	Cut-in the 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 an estimated cost of $10.6 million.	Load growth or additional loads connected to Malvern Terminal Station.	NTNDP did not identify this limitation as it is a localised issue.	The line cut-in is unlikely to be a contestable project.
Rowville–Springvale–Heatherton 220 kV line loading[50]	Connection of a Rowville–Springvale third circuit with an estimated cost of $53 million.	Load growth 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	Installation of a second 500/220 kV 1,000 MVA transformer at Cranbourne with an estimated cost of $39.8 million.	Increased demand in Eastern Metropolitan Melbourne.	The NTNDP did not identify this 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	Replacement of 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.	The NTNDP did not identify this 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	Install an automatic load shedding control scheme to enable the use of five minute line rating. New (third) 500/220 kV transformer at Rowville, with an estimated cost of $39.8 million, plus any fault level mitigation works.	Load growth 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	A new 500/220 kV transformer at Cranbourne Terminal Station with an estimated cost of $38.8 million (excluding easement cost).	Load growth around the Eastern Melbourne Metropolitan area.	The NTNDP did not identify this as a material limitation in the scenarios modelled.	The new transformer is likely to be a contestable project.
Keilor–Deer Park–Geelong 220 kV line loading[51]	Connection of a second 220kV line (Keilor – Geelong No.1) at Deer Park at an estimated cost of $12 million.	Increased demand at Deer Park	NTNDP did not identify this limitation as it is a localised issue.	These are unlikely to be contestable projects.
Victoria – New South Wales transfer limitation	New 500/330 kV transformer at South Morang, a Braking resistor at Loy Yang, and uprating of the South Morang–Dederang 330 kV lines. The total cost of these upgrades is expected to be approximately $72 million. The first two components are expected to be contestable.	Additional export capability from VIC to NSW due to surplus generation in Victoria	This limitation was identified in the NTNDP during periods of high Victorian export	The new transformer is likely to be a contestable project.

[50] 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. See Section 3.2 for detail.
[51] 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. See Section 3.2 for detail.

A.6 Regional Victoria – monitored limitations

Table 13 Limitations being monitored in Regional Victoria

Limitation	Possible network solution	Trigger[49]	2015 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.
Bendigo–Fosterville–Shepparton 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 $45 million, or up-rate the existing conductor from 82 ºC to 90 ºC at an estimated cost of $58.7 million.	Increased demand in Regional Victoria and/or increased import from NSW.	NTNDP did not identify this limitation as it is a localised issue.	The new transformer is likely to be a contestable project.
Dederang–Glenrowan 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 $45 million; or replace the existing Dederang–Glenrowan 220 kV lines with a new double circuit line; or replace the existing Dederang–Shepparton 220 kV line with a new double circuit line at an estimated cost of $258 million.	Increased demand in Regional Victoria and/or increased import from NSW.	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.
Dederang-Shepparton 220 kV line loading	Install an automatic load shedding control scheme to enable the use of five minute line rating. Replace the existing Dederang–Shepparton 220 kV line with a new double circuit line at an estimated cost of $258 million, explore power flow control devices.	Increased demand in Regional Victoria and/or increased import from NSW.	NTNDP did not identify this limitation as it is a localised issue.	The transmission line works are likely to be contestable projects.
Kerang – Wemen – Red Cliffs 220 kV line loading	Install an automatic load shedding control scheme to enable the use of five minute line rating. Replace the existing Bendigo – Kerang – Wemen – Red Cliffs 220 kV line with a new double circuit 220 kV circuit line at an estimated cost of $581.4 million.	When there significant load growth at the Kerang Terminal Station, or new generation at Kerang and Wemen.	The NTNDP identified that this constraint occurs, if high proportion of the new wind generation is built at Red Cliffs or along Red Cliffs – Kerang corridor.	The new transmission line is likely to be a contestable project.
Ballarat–Bendigo 220 kV line loading[50]	Uprating Ballarat–Bendigo 220 kV line to 82 ºC at an estimated cost of $42.5 million.	Increased demand in Regional Victoria.	NTNDP did not identify this limitation as it is a localised issue.	None of the possible network options identified are likely to be contestable projects. However, non-network solutions are also available to address this limitation. Any non-network option is likely to be a contestable project.

APPENDIX B. DISTRIBUTION NETWORK SERVICE PROVIDER PLANNING

This appendix lists the preferred connection modifications from the *2015 Transmission Connection Planning Report*[52] and the potential DSN impacts and considerations.

Table 14 Distribution network service provider planning impacts

Location/terminal station	Preferred connection modification	DSN impacts and considerations
Brunswick 66 kV	Establish a new 66 kV supply point with three 225 MVA 220/66 kV transformers in late 2016. This enables West Melbourne and Richmond Terminal Station off–loading and increases local supply reliability.	The transfer of load from the west and east of the Melbourne Metropolitan Area to its north has been taken into consideration in AEMO's assessment of upcoming constraints.
Cranbourne 66 kV	Install a fourth Cranbourne 150 MVA 220/66 kV transformer by summer 2023–24.	Load growth requiring this transformer will be included in Greater Melbourne and Geelong planning.
Deer Park 66 kV	Establish a terminal station at Deer Park with two 225 MVA 220/66 kV transformation supplied from Keilor–Geelong 220 kV transmission by November 2017.	Offloading from Altona Terminal Station West and Altona Terminal Station/Brooklyn Terminal Station will defer the augmentation from those stations. Load transfer to Deer Park Terminal Station will increase line flows in the Western Melbourne Metropolitan Area transmission loop and has been taken into consideration in AEMO's assessment of upcoming constraints.
Frankston 66 kV	Establish a new 66 kV line from Cranbourne Terminal Station to supply a new 66/22 kV zone substation in the Skye and Carrum Downs area by 2024.	This may impact emergency load shedding groups and will be assessed in detail closer to the proposed installation date.
Red Cliffs 66kV	A distribution reinforcement project to re-conductor part of the Wemen–Robinvale 66 kV line is planned to be completed in 2018. This allows a temporary distribution load transfer from Red Cliffs to Wemen, deferring need for additional Red Cliffs transformation.	This re-conductoring and temporary load transfer won't significantly impact the transmission network.
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 2017. Prior to establishing the Brunswick 66 kV switchyard, emergency load transfers from Richmond 1&2 bus group to the Malvern and Templestowe terminal stations will be available. Subject to availability, installation of AusNet Transmission Group's spare 220/66 kV transformer for metropolitan areas could be undertaken to temporarily replace a failed transformer at Richmond Terminal Station 66 kV.	The impact of the load transfer has been taken into consideration in AEMO's assessment of upcoming constraints. The contingency plan for emergency load transfer and temporary Richmond Terminal Station transformer/s will help to reduce the load at risk.
Springvale 66kV	Replace three of the four Springvale Terminal Station 'B' transformers in 2021, as part of AusNet Transmission Group's asset replacement program. Rebalance the bus group loads by transferring Oakleigh East and Clarinda zone sub from SVTS 12 to 34 66kV bus group coincident with asset renewal project, if economic; otherwise not before 2025. Transfer load off Springvale to the proposed Dandenong Terminal Station shortly after 2025.	Need to extend existing easements to supply Dandenong Terminal Station that United Energy considers may be viable shortly after 2025.
Terang 66 kV	Install a third 220/66 kV transformer, not before 2024, if non-network support unavailable.	Load growth requiring this transformer will be included in Regional Victoria planning.
West Melbourne 66 kV	Transfer load to the proposed Brunswick 66 kV connection point in late 2016.	The impact of the load transfer has been taken into consideration in AEMO's assessment of upcoming constraints.

[52] Jemena, CitiPower, Powercor, AusNet Services and United Energy. *2015 Transmission Connection Planning Report.* Available at: http://www.ausnetservices.com.au/CA257D1D007678E1/Lookup/Projects/$file/TCPR%20Report.pdf.

MEASURES AND ABBREVIATIONS

Abbreviation	Full term
AEMO	Australian Energy Market Operator
DSN	Declared Shared Network
km	Kilometres
kV	Kilovolts
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
WACC	Weighted average cost of capital

GLOSSARY

Glossary 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.
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).
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	Reactive power, which is different to active power, is a necessary component of alternating current electricity. It is predominantly consumed in the creation of magnetic fields in motors and transformers. Management of reactive power is necessary to ensure network voltage levels remain within required limits, which is in turn essential for maintaining power system security and reliability.
Unserved energy	The amount of energy that cannot be supplied because there is insufficient generation or network capacity to meet demand.