2019 Network Support and Control Ancillary Services (NSCAS) Report

December 2019

A report for the National Electricity Market

Important notice

PURPOSE

The Australian Energy Market Operator (AEMO) publishes this 2019 Network Support and Control Ancillary Services (NSCAS) Report pursuant to its functions under section 49(2) of the National Electricity Law (which defines AEMO's functions as National Transmission Planner) and its broader functions to maintain and improve power system security. In addition, AEMO has had regard to both the requirements of rule 5.20 of the National Electricity Rules and to the Draft ISP Rules published by the Energy Security Board[1].

This publication has been prepared by AEMO using information available at 3 December 2019. Information made available after this date may have been included in this publication where practical.

DISCLAIMER

This document or the information in it may be subsequently updated or amended. This document does not constitute legal or business advice, and should not be relied on as a substitute for obtaining detailed advice about the National Electricity Law, the National Electricity Rules, or any other applicable laws, procedures or policies. AEMO has made every effort to ensure the quality of the information in this document but cannot guarantee its accuracy or completeness.

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

- make no representation or warranty, express or implied, as to the currency, accuracy, reliability or completeness of the information in this document; and
- are not liable (whether by reason of negligence or otherwise) for any statements or representations in this document, or any omissions from it, or for any use or reliance on the information in it).

VERSION CONTROL

Version	Release date	Changes
1.0	20/12/2019	Initial release

[1] See in particular, draft rule 5.20.2 - COAG Energy Council, *Integrated System Plan Rule Changes Consultation Version – 19 November 2019*, available at http://www.coagenergycouncil.gov.au/sites/prod.energycouncil/files/publications/documents/Actionable%20ISP%20-%20Draft%20ISP%20Rules_0.pdf

Executive summary

Network Support and Control Ancillary Services (NSCAS[2]) are non-market ancillary services that may be procured to maintain power system security and reliability, and to maintain or increase the power transfer capability of the transmission network. There are three types of NSCAS: Network Loading, Voltage Control, and Transient and Oscillatory Stability Ancillary Services. AEMO has assessed whether there could be any NSCAS need over the next five years that is not presently being addressed by Transmission Network Service Providers (TNSPs). These are called 'NSCAS gaps' under the National Electricity Rules (NER).

Managing Power System Security

AEMO's assessment found that there is a need for a range of measures to be implemented over the next five years to ensure that the system can be operated securely and reliably. These measures include:

- Operational measures:
  - Maintaining existing operational practices, including dispatch of reactive plant, line switching and/or re-configuration, use of non-market ancillary service contracts, and in the extreme, direction by AEMO of specific equipment.
  - Reviewing limit equations to ensure that constraint equations continue to capture the full range of system conditions as generation dispatch patterns change.
- Investment:
  - Commissioning of planned investments in new reactive plant.
  - Ensuring appropriate staging of future assets.

AEMO is working closely with the TNSPs to implement and review these measures. Because these activities are currently on track to address the emerging power system security needs, AEMO has not identified any NSCAS gaps over the next five years.

Delivering Market Benefits

AEMO's assessment also considered whether there are network constraints that could be relieved to maximise market benefits. AEMO reviewed system normal constraints with a market impact[3] of at least $50,000, as identified in the 2018 NEM constraint report summary[4], reviewed proposed actions by TNSPs that address these constraints, and proposed further investigations where necessary. Accordingly, AEMO has not identified any NSCAS gaps for maximising market benefits in the NEM.

Reviewing the NSCAS framework

It is important that the regulatory framework continues to evolve to keep pace with the rapidly changing power system. AEMO is currently reviewing the current NSCAS framework including the NER and relevant procedures. Any recommendations from this review will be progressed through a formal consultation process. AEMO welcomes input to this review and encourages stakeholders to provide feedback on the existing NSCAS framework to Planning@aemo.com.au by 29 February 2020.

---

[2] NSCAS information, procedures, and guidelines are available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Ancillary-services/Network-support-and-control-ancillary-services-procedures-and-guidelines.

[3] The market impact of a constraint is derived by summing the marginal value for each dispatch interval (DI) from the marginal constraint cost (MCC) re-run over the period considered. The marginal value is a mathematical term for the market impact arising from relaxing the RHS of a binding constraint by one MW. As the market clears each DI, the market impact is measured in $/MW/DI. The market impact in $/MW/DI is a relative comparison but is not otherwise a meaningful measure.

[4] AEMO. NEM Constraint Report Summary Data 2018, at http://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Congestion-Information/2018/NEM-Constraint-Report-2018-summary-data.xlsx. Viewed 25 November 2019.

Contents

Tables

1. NSCAS assessment

1.1 Types of NSCAS

NSCAS[5] are non-market ancillary services that may be procured by TNSPs (or by AEMO as a last resort) to maintain power system security and reliability, and to maintain or increase the power transfer capability of the transmission network.

There are currently three types of NSCAS:

- Network Loading Ancillary Service (NLAS).
  - Maintains power flow in transmission lines within capacity ratings following a credible contingency event, and
  - Maintains or increases the power transfer capability of that transmission network, by allowing increased loading on transmission network components.
- Voltage Control Ancillary Service (VCAS).
  - Maintains the transmission network within voltage stability limits, and
  - Maintains or increases the power transfer capability of that transmission network, by improving voltage control and voltage stability.
- Transient and Oscillatory Stability Ancillary Service (TOSAS).
  - Controls power flow into or out of the transmission network, to maintain the transmission network within its transient or oscillatory stability limits, and
  - Maintains or increases the power transfer capability of that transmission network, by improving transient or oscillatory stability.

1.2 Inertia and system strength framework

Inertia and system strength requirements are managed by a separate framework[6] to the NSCAS framework. This report does not investigate inertia or system strength which are reported in separate AEMO publications.

1.3 Planning Assumptions

To maintain the power system within secure levels, the AEMO control room takes operational actions using available options in a hierarchy, with least desirable options used as a last resort. The operational actions AEMO can take are outlined in the Power System Security Guidelines[7].

Operational practices for managing high voltages

High system voltages, particularly during periods of low demand, are an emerging operational challenge and have a focus in this NSCAS assessment. To manage high system voltages, the following steps are taken:

---

[5] NSCAS information, procedures, and guidelines are available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Ancillary-services/Network-support-and-control-ancillary-services-procedures-and-guidelines.

[6] System Security Market Frameworks Review, available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/System-Security-Market-Frameworks-Review.

[7] AEMO. *Power System Security Guidelines*, available https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power_System_Ops/Procedures/SO_OP_3715---Power-System-Security-Guidelines.pdf.

1. Dispatch of reactive power from reactive power devices including static plant such capacitors and reactors, dynamic plant including generating units, STATCOMs and SVCs, and changing transformer tap positions.
2. If voltage security issues are experienced during real time operation, one transmission line per region may be de-energised for voltage control.
3. Activation of Non-Market Ancillary Services (NMAS) contracts for voltage control if any are in place that will assist.
4. If further actions are required, options for power system security direction under section 116 of the National Electricity Law (NEL) will be considered
5. If no power system security direction options are available, multiple transmission lines may be de-energised.

Power system studies completed for this report observed this same hierarchy, including switching up to one transmission line per region if necessary. Line switching to control voltages is not a prudent operational measure in the long-term in the NEM, both in terms of system security and reliability. Where transmission line switching is used, TNSPs should investigate operational solutions with consideration of asset performance and market costs and provide alternative cost-effective solutions if required.

Power system configuration

AEMO conducts its transmission network planning assuming system normal conditions, as required under the existing NSCAS framework. Under system normal conditions all transmission network elements are in service, and all scheduled generating units are available to participate in all markets for which they are registered. The only contingencies that are considered are credible contingencies, which usually means trip of a single transmission element, generating unit or load.

In reality, the transmission network is very often not in a system normal condition. Generating units and transmission elements need to be taken out of service for periodic maintenance. Credible contingencies occur regularly, and it can take time to return the tripped element to service, during which time the network is not in a system normal condition. Non-credible contingencies are less common but also do occur.

As the network rapidly changes due to increased penetration of distributed energy resources (DER), inverter based resources[8] (IBR), and planned major transmission works, the network is and will increasingly operate under conditions with no historical precedent, and for which our understanding is incomplete. In this environment the existing practice of planning for system normal conditions only may no longer be prudent. AEMO is currently reviewing the current NSCAS framework including the NER and relevant procedures. Any revisions to this framework will include a formal consultation process.

1.4 Summary of NSCAS contracts

AEMO, as National Planner, had one NSCAS contract active during 2019. Table 1 shows the costs for this NSCAS over the past five years.

[8] Inverter-based resources are devices that interface with the grid using a power electronic device (called an inverter). Solar PV systems, HVDC converters, and most new wind turbines are all IBR. The inverters digitally synthesize an output to match the power system AC waveform. These devices operate in different ways to conventional generating systems in coal, gas, and hydro plants which interface to the grid with a rotating electro-mechanical generator.

Table 1 NSCAS services in 2019 and their costs from 2015 to 2019

Facility	NSCAS Service	Size (MVAr)	NSCAS Contract End Date	Annual Cost				
				2014-15	2015-16	2016-17	2017-18	2018-19
Combined Murray and Yass substations	VCAS	800	30 June 2019	$9,896,698	$10,055,572	$10,159,498	$10,375,519	$10,572,619

1.4.1 Murray and Yass substations

AEMO had a contract for 800 megavolt amperes reactive (MVAr) absorbing VCAS with TransGrid, including reactors at Murray Switching Station and Yass Substation. The contract commenced from 31 March 2014.

The contract expired on 30 June 2019. TransGrid included the relevant network assets in its regulated asset base. TransGrid continues to provide the required voltage absorbing capability as a prescribed transmission service[9].

1.4.2 Murray and Tumut power stations

In previous years, AEMO reported on a contract with Snowy Hydro for VCAS. This contract expired on 30 June 2018 and was not renewed. In collaboration with TransGrid, AEMO implemented operational solutions to mitigate the need for this service.

[9] AER. TransGrid – Determination 2018-23. https://www.aer.gov.au/system/files/AER%20-%20Final%20decision%20TransGrid%20transmission%20determination%20-%20Attachment%206%20-%20Capital%20expenditure%20-%20May%202018_0.pdf

2. NSCAS Assessment

The following sections present the outcomes from the 2019 NSCAS assessments.

2.1 New South Wales

The reduced availability of synchronous generation across New South Wales will create challenges in controlling voltages across the grid. High bus voltages will be experienced during light load conditions, particularly when there are low power transfers across the network. Voltage management in southern New South Wales will be challenging when Mount Piper generating units and hydro and gas generating units south of Sydney are out of service. The retirement of Liddell Power Station in 2022-23 will remove a source of voltage control for northern New South Wales.

AEMO assessed voltage management in New South Wales with power system studies under the following conditions:

- Forecast minimum demand (minimum demand is forecast to reduce each year from now to 2024).
- Low power transfer on the interconnectors to Queensland and Victoria.
- Mount Piper generating units out of service.
- All New South Wales hydro and gas generating units out of service.
- All Snowy generating units out of service.

Note that both Mount Piper generating units being out of service is unlikely to occur during system normal conditions. It has been investigated here because there have been instances in 2019 of both units being out of service due to maintenance and other reasons.

Voltages are projected to increase each year as the minimum demand forecast decreases. The assessment found the following:

- Sydney-Shoalhaven area – Existing reactive plant and pre-contingent line switching are projected to remain effective in controlling voltages in the Snowy and Shoalhaven areas as minimum demand declines to 2024. Pre-contingent switching of the 330 kilovolt (kV) Sydney South – Beaconsfield North cable or the 330 kV Haymarket – Sydney South cable will be required at times. AEMO does not consider line switching for voltage control to be a prudent measure in the long-term in the NEM. Because power system security can be maintained, AEMO is not declaring an NSCAS gap in this area. AEMO will review the NSCAS framework and recommends that TransGrid investigate options to procure reactive support to avoid the need to switch transmission lines out of service for voltage control.
- Wagga Wagga area – New reactive support will be required, in addition to line switching, to avoid over-voltages in the Wagga Wagga area from approximately 2023. The precise timing of this need will depend on local factors including levels of demand, DER penetration and 132 kV generation connections. The Darlington Point synchronous condensers proposed as part of Project EnergyConnect[10] are planned for commissioning in 2022-24. These synchronous condensers will provide reactive support to meet this requirement at Wagga Wagga. In staging Project EnergyConnect, it will be prudent to commission the accompanying reactive support, particularly the Darlington Point synchronous condensers, as early as possible. The reactive support will need to be commissioned before the new transmission lines, so that the charging of the lines when lightly loaded does not lead to over-voltages.

[10] ElectraNet & TransGrid. *Project EnergyConnect*, available https://www.projectenergyconnect.com.au/.

Prior to the commissioning of reactive plant included in Project EnergyConnect, extreme dispatch patterns could require intervention from AEMO to maintain voltages in the Wagga Wagga area. AEMO will continue to monitor the likelihood of market conditions that could lead to an NSCAS gap in this area.

- Northern New South Wales and the Hunter Valley area – Voltages in northern New South Wales and the Hunter Valley are projected to be kept within limits with existing reactive plant following the retirement of Liddell Power Station. An upgrade of the Queensland – New South Wales interconnector (QNI Minor), planned for implementation prior to Liddell Power Station's closure[11], includes new Static VAr Compensators (SVCs) at Tamworth and Dumaresq that will provide additional means of managing voltages in Northern New South Wales.
- Central New South Wales to Southern New South Wales – Under the studied conditions, if Mount Piper generating units, New South Wales hydro and gas units, and Snowy generating units are out of service, there may be no dynamic reactive plant between Victoria and Central New South Wales other than the Sydney West SVC. This is a long flow path, and the lack of dynamic reactive plant could lead to stability issues in the future. Due to the increasing penetration of renewable generation in this area, these kind of extreme dispatch patterns will become more likely. AEMO recommends that TransGrid review relevant limit equations in this area to ensure that constraint equations continue to capture the full range of system conditions as generation dispatch patterns change.

AEMO's assessment has not identified an NSCAS gap in New South Wales over the next five years.

2.2 Queensland

Far North, North, Central, and South East Queensland often experience high bus voltages during light load conditions. The Powerlink 2019 Transmission Annual Planning Report (TAPR) identified that high voltages in North and Central Queensland can be mitigated by the installation of a reactor at Broadsound or Nebo substations. This reactor is undergoing final planning and scoping and consultation is expected to commence in 2020.

High voltages in Far North and South East Queensland are presently managed using existing reactive plant and operational measures. However, Powerlink and Energy Queensland are presently involved in joint planning to understand the nature of emerging high voltage issues. This analysis may identify a need for additional reactive plant, both in Far North and South East Queensland, as the minimum customer load continues to decline—due to increasing rooftop photovoltaic (PV) and the capacity of synchronous generating plant to absorb reactive power changes.

Provided that the planned investment at Broadsound or Nebo is completed, AEMO's assessment has not identified an NSCAS gap in North Queensland or Central Queensland over the next five years. AEMO will continue to monitor the situation in these areas and review the findings of Powerlink and Energy Queensland's joint planning studies when they become available.

2.3 South Australia

The South Australian transmission network may experience high voltages during light load conditions. ElectraNet's analysis to date indicates that at forecast levels of minimum demand, transmission voltages can be kept within acceptable limits using the 50 MVAr reactor installed at Templers West in 2018 and the planned synchronous condensers to be installed from September 2020.

However, ElectraNet has also advised that more detailed analysis is required to determine whether this can be achieved while maintaining sufficient headroom on dynamic reactive plant. AEMO will work with ElectraNet to further explore this issue in 2020. ElectraNet and SA Power Networks are conducting joint studies into

[11] Powerlink & TransGrid, *Expanding NSW-QLD Transmission Transfer Capacity*, available https://www.powerlink.com.au/expanding-nsw-qld-transmission-transfer-capacity.

ensuring distribution voltages can be kept within acceptable limits under forecast minimum demand conditions, and plan to report findings in the 2020 ElectraNet TAPR.

In May 2019, the South Australian transmission system in the north of the state observed high voltages during an outage of one 50 MVAr reactor at Davenport substation. This occurred when wind generation in the area dropped to zero and the reactive power absorption of the wind farms also reduced to zero. To ensure transmission voltages can be kept within acceptable levels before commissioning of the Davenport synchronous condensers in late 2020, AEMO and ElectraNet are currently working with wind farm and solar farm operators to ensure the reactive power support capability of the plant, as described in their Generator Performance Standards, is available when required. AEMO and ElectraNet are also working with wind farm operators to ensure capacitors can be switched in less than 30 minutes.

The South Australian transmission network may experience low voltages during outages across the 275 kV network between Davenport and Adelaide and high generation between Davenport and Robertstown at medium load. This is managed by outage constraint equations that will constrain generation as needed.

AEMO's assessment has not identified an NSCAS gap in South Australia over the next five years. AEMO will continue to closely monitor South Australia minimum demand conditions and the capability of the grid.

2.4 Tasmania

Voltage Management

Voltage control in the Tasmanian network can be challenging in the George Town area. This has been managed to date using control schemes, dispatch limits on Basslink transfer levels and voluntary generator dispatch from Hydro Tasmania.

Voltage control in the George Town area is becoming easier due to reduction in Basslink exports and changes to major industrial load patterns. In its 2019 TAPR, TasNetworks proposed a +/-50 MVAr static synchronous compensator (STATCOM) in the Georgetown area, which was planned to be operational by June 2022. However, TasNetworks has subsequently advised that, due to the decrease in Basslink export, this is unlikely to be economically viable.

Emerging Issues Being Monitored

In November 2019, AEMO identified a system strength gap and an inertia gap in Tasmania[12] under the system security markets framework. Possible solutions to the system strength and inertia gaps, such as Non-Market Ancillary Services (NMAS) contracts with synchronous generators, are also likely to assist with voltage control.

AEMO's assessment has not identified an NSCAS gap in Tasmania over the next five years.

2.5 Victoria

Voltage Management

Victoria experiences high voltages during light load conditions. The worst affected area is the south west transmission corridor around Geelong, Keilor, Moorabool, and Portland. This is presently managed operationally via switching of 500 kV lines and an NMAS contract.

In the Victorian Reactive Support Regulatory Investment Test for Transmission (RIT-T)[13], AEMO has determined the preferred long-term option to manage voltages in Victoria after the NMAS contract expires in March 2021. The Project Assessment Conclusions Report (PACR) for this RIT-T identified a preferred option consisting of three 100 MVAr reactors (one at Keilor in 2022 and two at Moorabool in 2023 and 2025

[12] Notice of Inertia and Fault Level Shortfalls in Tasmania is available at: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/System-Security-Market-Frameworks-Review/2019/Notice-of-Inertia-Fault-Level-Shortfalls-Tasmania-Nov-2019.pdf.

[13] AEMO. *Victorian Reactive Power Support RIT-T*, available https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Victorian-transmission-network-service-provider-role/Victorian-Reactive-Power-Support-RITT.

respectively). A separate Network Capability Incentive Parameter Action Plan (NCIPAP) project by AusNet Services is also underway to install an additional 100 MVAr reactor at Keilor Terminal Station by 2021.

Victoria also experiences high voltages in the north west of the state. The high voltages typically occur during low demand periods when the 220 kV transmission lines in the area are lightly loaded. To date this has mainly occurred during planned outages. However, as the Victorian minimum demand is forecast to decline over the next five years, it is expected that this issue will increase in severity.

Inverter-based resources (IBR) in the north west of Victoria can either help or hinder voltage control, depending on how they are configured and operated. Solar farms connected to the distribution network operate in power factor control mode and generally do not assist in reducing voltages on the transmission system; they can also exacerbate high transmission voltages by offsetting demand.

Most wind farms connected to the transmission network operate in voltage control mode, which can assist to reduce voltages when wind farms are generating. However, the AEMO control room has at times been unable to call upon the full reactive capability of these generators when needed. The Kerang and Horsham SVCs that assist with voltage control in the area are experiencing increasing issues due to aging and increased utilisation (e.g. the Kerang SVC tripped due to a cooling failure in August 2018).

Several proposed projects may assist with managing voltage in north west Victoria, particularly the EnergyConnect interconnector, planned for 2022-24, which will increase the strength of the network and include new synchronous condensers and reactors at Buronga. The Western Victoria Renewable Integration RIT-T, planned for 2024-25 will increase the strength of the west Victoria network with additional transmission lines connecting the area to greater metropolitan Melbourne, and may help to manage voltage issues.

In the interim, AEMO is working collaboratively with intending and registered participants to explore avenues of incorporating reactive equipment in AEMO's Var Dispatch System (VDS), with an aim to ensure that presently under-utilised reactive power support can be made available when needed. AEMO will investigate the north-west Victoria high voltage issue as part of the 2020 Victorian TAPR, to determine if it can be adequately managed into the future by the described projects and measures, or whether specific additional operational measures, non-network solutions, or upgrades are required.

High voltages are also experienced around Eildon during periods of low demand and low power transfer between Victoria and New South Wales. Historically this has been managed by actions including de-energising a 500 kV line in the Latrobe Valley or lowering a 500 kV voltage limit in the Latrobe Valley. AEMO will investigate if additional measures such as non-network solutions or upgrades are required to manage high voltages around Eildon as part of the 2020 Victorian TAPR.

Thermal loading

Thermal limitations on the 330 kV Dederang to South Morang lines contributed to the need to shed Victorian load to maintain system security on 24 and 25 January 2019. AEMO and TransGrid are jointly progressing the Victoria to New South Wales Interconnector upgrade RIT-T[14] to identify a preferred option to increase transfer capability between Victoria and New South Wales in both directions. The PADR for this RIT-T identified a preferred option that includes re-tensioning the 330 kV Dederang to South Morang lines as well as associated works to increase their thermal capability.

Emerging Issues Being Monitored

Other possible future challenges to the ability to maintain acceptable voltage levels in Victoria include:

- Increased likelihood of generator outages due to aging plant. For example, Yallourn and Loy Yang units have experienced extended outages in the last 12 months.

[14] AEMO & TransGrid. *Victoria to New South Wales Interconnector Upgrade RIT-T*, available https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Victorian-transmission-network-service-provider-role/Victoria-to-New-South-Wales-Interconnector-Upgrade-Regulatory-Investment-Test-for-Transmission.

- Aging Latrobe Valley coal power units being unable to provide full reactive power absorption capability when needed.
- Increasingly frequent problems with voltage regulating equipment due to increased utilisation since the retirement of Hazelwood Power Station and Melbourne synchronous condensers.
- Early retirement of Yallourn Power Station or Alcoa Portland smelter would exacerbate high voltage problems.
- Trip of multiple IBR on a single contingency could become the largest generator contingency in Victoria. AEMO will review power system limits to ensure system security is maintained for credible contingencies in Victoria.

AEMO will consider these issues as part of the 2020 Victorian TAPR. AEMO's assessment has not identified an NSCAS gap in Victoria over the next five years.

2.6 NSCAS gaps for maximising market benefits

Table 2 provides a list of historical system normal binding constraints which had market impact[15] in excess of $50,000 in 2018, as identified in the 2018 NEM constraint report summary[16]. AEMO reviewed these constraints and engaged with TNSPs to propose actions to deliver market benefits. As outlined below, a wide range of activities are currently underway to improve the capability of the network. AEMO has not identified any NSCAS gaps for maximising market benefits.

Table 2 Assessment of significant binding constraint equations

Region	Network limitation	Market impact (2018)	Proposed action
NSW	N^^V_NIL_1 Avoid voltage collapse in Southern NSW for loss of the largest Victorian generating unit	$1,000,023	Constraint RHS was increased with 100 megawatts (MW) offset in 2019 raising the level at which it binds. Detailed assessment of the constraint equation is presently underway which may further relieve the constraint. TransGrid plan to install a 330 kV 100 MVAr shunt capacitor bank at Wagga substation in March 2021. AEMO is exploring options to procure NMAS for dynamic reactive support that could further relieve this constraint when Victoria is at risk of load shedding.
QLD	Q>NIL_BI_FB Boyne Island feeder bushing limit on Calliope River to Boyne Island 132 kV lines.	$136,205	In 2016, Powerlink considered addressing this congestion by replacing the Boyne Island transformer feeder bushings under a NCIPAP project. The project was found not to be economically feasible. AEMO has reassessed this limit and did not identify any efficient options to improve it.
	Q:N_NIL_AR_2L-G & Q::N_NIL_AR_2L-G	$70,186	This constraint has been identified and assessed as part of the TransGrid/Powerlink "Expanding NSW-QLD Transmission Transfer Capacity" RIT-T.

[15] The market impact of a constraint is derived by summing the marginal value for each dispatch interval (DI) from the marginal constraint cost (MCC) re-run over the period considered. The marginal value is a mathematical term for the market impact arising from relaxing the RHS of a binding constraint by one MW. As the market clears each DI, the market impact is measured in $/MW/DI. The market impact in $/MW/DI is a relative comparison but is not otherwise a meaningful measure.

[16] AEMO. NEM Constraint Report Summary Data 2018. http://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Congestion-Information/2018/NEM-Constraint-Report-2018-summary-data.xlsx. Viewed 25 November 2019.

Region	Network limitation	Market impact (2018)	Proposed action
	QLD to NSW import limitation due to transient stability limit on QNI for a 2 phase to ground fault at Armidale.		
SA	S_WIND_1200_AUTO & S_NIL_STRENGTH_1 Upper limit (1,460 to 1,295 MW) for South Australian non-synchronous generation for minimum synchronous generators online for system strength requirements.	$13,582,753	S_NIL_STRENGTH_1 replaced the constraint S_WIND_1200_AUTO. The planned installation of synchronous condensers at Davenport and Robertstown during 2020 will alleviate this constraint by raising the level at which it is expected to bind.
	S^NIL_PL_MAX Maximum generation at Port Lincoln due to voltage stability limit.	$264,096	The planned Eyre Peninsula upgrade will alleviate this constraint. The upgrade consists of a new double-circuit line between Cultana and Yadnarie initially energised at 132 kV (but with the option in future to energise at 275 kV) and a new 132 kV double circuit line from Yadnarie to Port Lincoln. Implementation is planned by the end of 2021.
	S_WATERLWF_RB Limit Waterloo WF output to its runback MW capability	$207,404	AEMO has not identified any efficient options to improve this limit.
	S>V_NIL_NIL_RBNW Avoid overloading the North West Bend to Robertstown 132 kV line on no line trips	$195,921	The uprate of the Robertstown to North West Bend No. 2 and North West Bend to Monash No. 2 132 kV lines has alleviated the impact of this constraint by raising the level at which it binds.
	S>NIL_NIL_SETX12 Avoid O/L of either South East 132/275kV TX1 or TX2 on Nil trip (for Transformer SECS assumed I/S or O/S)	$83,169	AEMO has not identified any efficient options to improve this limit.
	S>NIL_WERB_WEWT Avoid O/L Waterloo East-Waterloo 132 kV line on trip of Waterloo East-Morgan Whyalla 4 - Robertstown 132 kV line	$75,482	AEMO has not identified any efficient options to improve this limit.
TAS	T>T_NIL_110_1 Avoid pre-contingent O/L of the Derby to Scottsdale Tee 110 kV line	$1,518,120	Could potentially be relieved by using dynamic line ratings. TasNetworks will investigate following release of the revised Tasmanian frequency operating standard.
	T>T_NIL_BL_110_18_1 Avoid O/L the Lake Echo Tee to Waddamana No.1 line (flow to North) for loss of Tungatinah to Waddamana No.2 110 kV line	$92,736	This constraint binds due to a low circuit rating. AEMO has consulted with TasNetworks and determined that there is currently no economic solution to address this limit. In the long term, lines may be uprated as part of long term strategy for the Upper Derwent 110 kV network.
	T_MRWF_QLIM_xx Limit Musselroe Wind Farm to 150 MW if less than 96% of DVAr capacity online.	$53,844	DVAr assets are part of Musselroe Wind Farm. Wind farm output reduces with reduced DVAr capacity.

Region	Network limitation	Market impact (2018)	Proposed action
VIC	V>>V_NIL_1x Avoid O/L Murray to Dederang 330kV line (flow MSS to DDTS) for loss of the parallel line.	$525,711	The 2019 VAPR considered a near-term option of relieving this constraint by use of the System Overload Control Scheme (SOCS) and procuring network support services from industrial loads. AEMO will continue to explore this option in the near future and may also consider the use of alternatives.
	V^SML_NSWRB_2 NSW Murraylink runback scheme, avoid voltage collapse for trip of Darlington Point to Buronga (X5) 220 kV line.	$151,776	Implementation of the NSW Murraylink runback scheme will improve this limit. AEMO is working with TransGrid and APA Group to commission this scheme.
	V::N_NIL_xxx Prevent transient instability for fault and trip of a HWTS-SMTS 500 kV line.	$115,464	This constraint has been identified as part of VNI Minor upgrade and TransGrid/AEMO included in the VNI RIT-T. The VNI RIT-T PADR identified that this limit will be cumulatively improved by the preferred options from the VNI RIT-T, Project EnergyConnect RIT-T and the Western Victoria Renewable Integration RIT-T which are planned from 2022 to 2025.
	V^^N_NIL_1 Avoid voltage collapse around Murray for loss of all APD potlines	$57,329	This constraint has been identified as part of VNI upgrade and TransGrid/AEMO included in the VNI RIT-T. The VNI RIT-T PADR identified that this limit will be cumulatively improved by the preferred options from the VNI RIT-T, Project EnergyConnect RIT-T and the Western Victoria Renewable Integration RIT-T which are planned from 2022 to 2025.

3. Next steps

AEMO's assessment found that there is a need for a range of measures to be implemented over the next five years to ensure that the system can be operated securely and reliably. These measures include:

- Operational measures:
  - Maintaining existing operational practices, including dispatch of reactive plant, line switching and/or re-configuration, use of non-market ancillary service contracts, and in the extreme, direction by AEMO of specific equipment.
  - Reviewing limit equations to ensure that constraint equations continue to capture the full range of system conditions as generation dispatch patterns change.
- Investment:
  - Commissioning of planned investments in new reactive plant.
  - Ensuring appropriate staging of future assets.

AEMO is working with the TNSPs to ensure these measures are well coordinated. Because these actions are currently on track, AEMO has not identified any NSCAS gaps over the next five years. AEMO will continue to work with the TNSPs to monitor and assess the issues identified in this report.

Throughout this NSCAS assessment, AEMO has identified potential limitations of the NSCAS framework. It is important that the regulatory framework continues to evolve to keep pace with the rapidly changing power system. AEMO is currently reviewing the NSCAS framework including the NER and relevant procedures. Any recommendations from this review will be progressed through a formal consultation process. AEMO welcomes input to this review and encourages stakeholders to provide feedback on the existing NSCAS framework to Planning@aemo.com.au by 29 February 2020.