2022 Network Support and Control Ancillary Services (NSCAS) Report

December 2022

A report for the National Electricity Market

Important notice

Purpose

The purpose of this publication is to provide the annual Network Support and Control Ancillary Services Report for the National Electricity Market. AEMO publishes this report in accordance with clause 5.20.3 of the National Electricity Rules. This publication is generally based on information available to AEMO as at November 2022 unless otherwise indicated.

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Version control

Version	Release date	Changes
1.0	1/12/2022	Initial release.
1.1	13/12/2022	Minor updates for consistency including: appendix title update in Section 1.3, footnote 13 link update in Section 2, footnote 18 update in Section 3, Table 6 update in Section 4.2,Table 9 footnote update in Section 4.3 and footnote linkage in Appendix A1.

AEMO acknowledges the Traditional Owners of country throughout Australia and recognises their continuing connection to land, waters and culture. We pay respect to Elders past and present.

Executive summary

Proactive provision of system security services is crucial for Australia's energy transition

The National Electricity Market (NEM) is continuing to see a once-in-a-century transformation in the way electricity is generated and consumed in eastern and south-eastern Australia. Legacy assets will be replaced with low-cost renewables, energy storage and other forms of firming capacity, and the grid will need to be reconfigured to support two-way energy flow.

Many power system security services have traditionally been provided by thermal synchronous generating units. In the context of changing synchronous generator behaviour, declining minimum operational demand, and rapid uptake of variable renewable energy (VRE) sources connected to the power system through inverters, proactive provision of system security services will be crucial for ensuring a secure power system.

AEMO forecasts a *Step Change* in the energy transition over coming five years

AEMO's most likely scenario is currently the *Step Change* scenario[1]. *Step Change* is considered by energy industry stakeholders to be the 'most likely' plausible future operating environment for the energy sector. *Step Change* sees 40% of coal-fired generation capacity in the NEM withdrawn over the next five years, 60% by 2030, 87% by 2035 and about 96% by 2040.

The Network Support and Control Ancillary Services (NSCAS) framework is a last-resort planning power used by AEMO to consider any system security and reliability needs in the NEM over the coming five years. In this report, AEMO considers NSCAS needs for each jurisdiction in the NEM under the *Step Change* scenario. This includes modelling the impact of projected synchronous generator decommitments in each region alongside the projected commissioning of new transmission network projects, generators, and batteries. In total, 7,750 megawatts (MW) of coal-fired generation is expected to be unavailable for system security purposes in 2027-28. Over the same period, 23,500 MW of new generation capacity and 4,100 MW of storage capacity is expected to connect to the network.

Emerging transmission and renewable energy projects will improve power system security

AEMO has not declared many NSCAS gaps in this report, as summarised in Table 1. This is because announced transmission, generation, battery and system strength projects are expected to provide a range of essential system security services. Any delays to major projects could, however, expose system security gaps, particularly in Queensland, New South Wales and Victoria.

The NSCAS assessments in this report prepare for the *Step Change* scenario. Should industry need to plan for a high or 100% renewable energy penetration scenario in the very near term, or if any new earlier-than-expected generator retirements are announced, additional services will be required more urgently.

AEMO looks forward to working with the jurisdictional transmission network service providers (TNSPs) and other industry stakeholders over the coming years to ensure that emerging projects are introduced in a timely manner to support power system security in the NEM.

[1] AEMO. 2022 *Integrated System Plan* (Section 2.2), at https://aemo.com.au/-/media/files/major-publications/isp/2022/2022-documents/2022-integrated-system-plan-isp.pdf?la=en.

Table 1 Summary of new and existing NSCAS gaps

Region	NSCAS gap
New South Wales 	**Voltage control gap at Coleambally** – AEMO has confirmed the reliability and security ancillary services (RSAS) gap of 2 megavolt amperes reactive (MVAr) reactive power absorption in the Coleambally region declared in the 2021 System Security Reports. Transgrid currently has operational measures in place to manage this issue, and AEMO will continue to receive updates from Transgrid on the resolution of this matter.
Queensland 	**Voltage control gap in southern Queensland** – AEMO has confirmed the RSAS gap of 120 MVAr reactive power absorption in Southern Queensland declared in the 2021 System Security Reports. Powerlink is finalising a near-term solution for this gap. For the latter end of the five-year NSCAS assessment period, AEMO is not declaring a gap. However, re-assessment may be needed in 2023 as more information becomes available. Committed and anticipated generation and storage projects are expected to provide reactive support, along with Powerlink's ongoing project to manage voltages in South East Queensland, but uncertainty remains about the impact of synchronous generation dispatch and system strength services. AEMO will continue to receive updates from Powerlink on this matter, and Powerlink is continuing to pursue measures to maintain voltages in southern Queensland.
South Australia 	**No gap declared in 2022** – AEMO has not identified an NSCAS gap in South Australia over the coming five years. Newly committed and anticipated transmission, generation, and storage projects have improved voltage control in the region. These power system changes also have closed the gap declared in 2021 for 40 MVAr reactive power absorption at Blyth West. Minimum demand projections continue to decline for South Australia, and ElectraNet and SA Power Networks are investigating measures to control voltages across the distribution and transmission systems, including proposed installation of reactors.
Tasmania 	**No gap declared in 2022** – AEMO has not identified any NSCAS gap in Tasmania over the five-year period because system strength and inertia services contracts support a range of security services.
Victoria 	**No gap declared in 2022** – AEMO has not identified any NSCAS gaps in Victoria because operational arrangements are in place to switch 500 kilovolts (kV) transmission lines for voltage control.

Contents

Tables

Figures

1 Introduction

Network support and control ancillary services (NSCAS) are non-market ancillary services that may be procured to maintain power system security and reliability of supply of the transmission network[2] and maintain or increase power transfer capability of the transmission network to maximise the present value of net economic benefit to all those who produce, consume or transport electricity in the market[3].

This section outlines the context for the 2022 NSCAS Report:

- Trends impacting NSCAS assessments (Section 1.1).
- Relationship to other AEMO documents (Section 1.2).
- Information provided in this report (Section 1.3).

1.1 Trends impacting NSCAS assessments

The National Electricity Market (NEM) is in the midst of a transformation, replacing its traditional energy resources with variable renewable energy (VRE) largely based on inverters[4]. This section describes how a number of these trends are relevant for the provision of NSCAS.

Inverter-based resources can provide reactive power capability which can help control network voltages

Australia is currently installing utility-scale inverter-based resources (IBR) faster than at any time in history, and the trend is projected to increase. At the same time, the NEM's transformation will be influenced by the generation and feed-in capability of millions of individual consumer-owned solar photovoltaic (PV) systems. From 2025, there are forecast to be times when the NEM will have enough renewable energy resources to meet 100% of its demand.

AEMO and key industry stakeholders currently consider that AEMO's *Step Change* scenario is the most likely scenario for the purposes of electricity system planning and investment. *Step Change* modelling completed for the 2022 *Integrated System Plan* (ISP) suggests that 14 gigawatts (GW) of synchronous generation resources will withdraw from the market by 2030. While this level of withdrawal has not been formally announced, coal-fired generators are continuing to bring forward their withdrawal from the market.

As IBR displace synchronous generators, IBR must help provide reactive capability. It is important the capability inherent in IBR is utilised as it has an important role in ensuring the future network is stable.

A new system strength framework comes into effect on 1 December 2022

In October 2021, the Australian Energy Market Commission (AEMC) made changes to the system strength framework in the National Electricity Rules (NER), to be progressively implemented from December 2022[5].

[2] In accordance with the power system security standards and the reliability standard, NER Version 174, Clause 3.11.6 (a)(1).

[3] NER Version 174, Clause 3.11.6 (a)(2).

[4] AEMO. 2022 ISP. At https://aemo.com.au/-/media/files/major-publications/isp/2022/2022-documents/2022-integrated-system-plan-isp.pdf?la=en.

[5] See https://www.aemc.gov.au/rule-changes/efficient-management-system-strength-power-system.

System strength is an essential power system security service which ensures the ability of the power system to maintain a stable voltage waveform at any given location, both during steady state operation and following a disturbance[6].

Each NEM region's jurisdictional planning body for the transmission network, known as the System Strength Service Provider (SSSP), must plan to meet the standard, based on the system strength standards set by AEMO, for each year from 2 December 2025.

There is some expectation that synchronous machines will form part of a range of technologies utilised to meet these system strength requirements. These technologies are typically capable of providing other services, such as reactive support, and can be expected to reduce the need for additional NSCAS.

1.2 Relationship to other AEMO documents

The annual NSCAS report draws inputs from a number of related AEMO reports and processes, and in turn informs and underpins a range of reports and processes owned by AEMO and transmission network service providers (TNSPs).

In 2021 the annual NSCAS report was published as part of the 2021 System Security Reports, which also incorporated the inertia report and the system strength report.

In 2022, AEMO is publishing the NSCAS report as a standalone document, given that it covers a five-year horizon rather than the new 10-year horizon considered by the system strength report, and to facilitate separate publication of the reports when required.

Table 2 shows AEMO reports and processes which are related to the NSCAS reports.

Table 2 AEMO reports and processes related to the NSCAS Report

Report or process	Frequency and contents	Time horizon considered (years)	Reference
Inertia Report	Annual assessment of inertia requirements and shortfalls for each NEM region.	5	https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/system-security-planning
System Strength Report	Annual assessment of system strength requirements and shortfalls for each NEM region.	10	https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/system-security-planning
General Power System Risk Review	Annual review of major power system risks in the NEM.	5	https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/general-power-system-risk-review
Electricity Statement of Opportunities (ESOO)	Annual assessment of 10-year supply, demand and reliability outlook for the NEM, that may trigger the Retailer Reliability Obligation.	10	https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-reliability/nem-electricity-statement-of-opportunities-esoo
NEM Engineering Framework	A toolkit to define the full range of operational, technical and engineering requirements needed to prepare the NEM for future operating	10	https://aemo.com.au/en/initiatives/major-programs/engineering-framework

[6] For definitions and descriptions of system strength and power system security, see AEMO's Power System Requirements, updated in July 2020, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power-system-requirements.pdf.

Report or process	Frequency and contents	Time horizon considered (years)	Reference
	conditions, including 100% instantaneous penetration of renewables.		
Victorian Annual Planning Report (VAPR)	Annual assessment of the Victoria region to inform stakeholders about network performance, planning, challenges and opportunities in the next 10 years.	10	https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/vapr/2022/2022-victorian-annual-planning-report.pdf?la=en
Integrated System Plan (ISP)	A comprehensive roadmap for the NEM, updated every two years, optimising consumer benefits through a transition period of great complexity and uncertainty.	> 20	https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp

1.3 This report

The following NSCAS assessment information can be found in this report:

- Regulatory requirements for this report (Section 2).
- Method and inputs applied to prepare the NSCAS assessments in this report (Section 3).
- For each region of the NEM, AEMO's assessment of NSCAS needs including Reliability and Security Ancillary Services (RSAS) and Market Benefits Ancillary Services (MBAS), and declaration of any NSCAS gaps for the period from December 2022 to December 2028 (Section 4).
- Results from a study of the NEM with 100% renewable penetration at times of minimum demand (Section 5).
- An overview of the next steps to be taken as a result of this report (Section 6).
- Generator and network modelling assumptions (Appendix A1).
- Assumptions for voltage planning studies (Appendix A2).

2 Regulatory requirements

Network support and control ancillary services (NSCAS)[7] are non-market ancillary services that may be procured to address the following NSCAS needs:

- **Reliability and Security Ancillary Services (RSAS)** – maintain power system security and reliability of supply of the transmission network in accordance with the power system security standards and the reliability standard[8].
- **Market Benefits Ancillary Services (MBAS)** – maintain or increase power transfer capability of the transmission network to maximise the present value of net economic benefit to all those who produce, consume or transport electricity in the market[9].

AEMO has conducted the NSCAS review in accordance with the NSCAS description and quantity procedure version 2.2[10].

Reliability and security ancillary services (RSAS)

To identify RSAS needs, AEMO considers the ability to maintain a secure operating state during system normal conditions; that is, the ability of the system to land in a satisfactory operating state following a credible contingency or protected event. On a case-by-case basis AEMO may also assess if the system can be returned to a secure operating state within 30 minutes of a credible contingency or protected event.

AEMO NSCAS studies emulate actions taken by the control room to manage system security issues but also factor in future network changes such as committed generation and transmission projects, generator retirements and forecast change in demand. Use of emergency last-resort responses such as load-shedding are not assumed for planning studies. The operational actions AEMO can take in the control room are outlined in the Power System Security Guidelines[11].

During the 2022 NSCAS assessment, AEMO applied updated voltage management planning assumptions (recorded in Appendix A2) which were an outcome of a planning assumptions review conducted with input from AEMO control room and TNSP planning and operations experts.

Market benefits ancillary service (MBAS)

AEMO's NSCAS assessment considers whether network constraints can be relieved using market benefits ancillary services (MBAS) to maximise net market benefits. AEMO reviews existing constraints for an intact transmission system (no outages) under classical system normal conditions, where those constraints had a binding impact of at least $50,000 and bound for at least one hour, as identified in AEMO's 2022 NEM constraint report summary[12].

[7] The NSCAS definition is in the Chapter 10 Glossary of NER Version 174.

[8] NER Version 174, Clause 3.11.6 (a)(1).

[9] NER Version 174, Clause 3.11.6 (a)(2).

[10] AEMO. NSCAS description and quantity procedure, version 2.2. December 2021. At https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/system-security-planning.

[11] Power System Security Guidelines, 25 May 2022, at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/power_system_ops/procedures/so_op_3715-power-system-security-guidelines.pdf?la=en.

[12] AEMO. NEM Constraint Report 2021 summary data. 17 March 2022, at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/2021/nem-constraint-report-2021-summary-data.xlsx?la=en.

AEMO may also consider, where appropriate, any constraints nominated by participants as inputs into the market benefits assessment process as well as the consideration of possible future binding constraints in alignment with the NSCAS description and quantity procedure[13].

2.1 Division of NSCAS responsibilities

AEMO must, at least annually, identify any NSCAS need forecast to arise in the next five years. AEMO's assessment includes identification of any NSCAS gap for a NEM region, as well as the relevant trigger date for any power system security and reliability gap, a report on any NSCAS acquired by AEMO (in its last resort procurement capacity) in the previous calendar year, and any other information AEMO considers relevant.

The NER give TNSPs the primary responsibility for acquiring NSCAS. If AEMO is required to procure NSCAS under its last resort responsibility, it can only do so to meet the first of the NSCAS needs – for power system security and reliability.

2.2 Summary of NSCAS contracts

AEMO had no active NSCAS contracts during 2022 under the requirement to procure NSCAS for system strength and reliability purposes as a last resort responsibility. Table 3 notes the NSCAS service costs accrued over the past five years by AEMO as part of its NSCAS function.

Table 3 NSCAS services costs from financial year 2017-2018 to 2021-2022

Facility	NSCAS Service	Size (megavolt-amperes reactive [MVAr])	NSCAS contract end date	Annual cost				
				2017-18	2018-19	2019-20	2020-21	2021-22
Combined Murray and Yass substations	Voltage Control Ancillary Service [A] (VCAS)	800 [B]	30 June 2019	$10,375,519	$10,572,619	$0	$0	$0
Murray and Tumut power stations	VCAS	1,650 [C]	30 June 2018	$3,842,236	$0	$0	$0	$0

A. NSCAS procured under the previous NSCAS types developed in 2011.
B. The maximum capacity available from this service.
C. The maximum capacity used at any one time over the years shown.

[13] AEMO. NSCAS description and quantity procedure, version 2.2. December 2021. At https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/system-security-planning.

3 Method and inputs

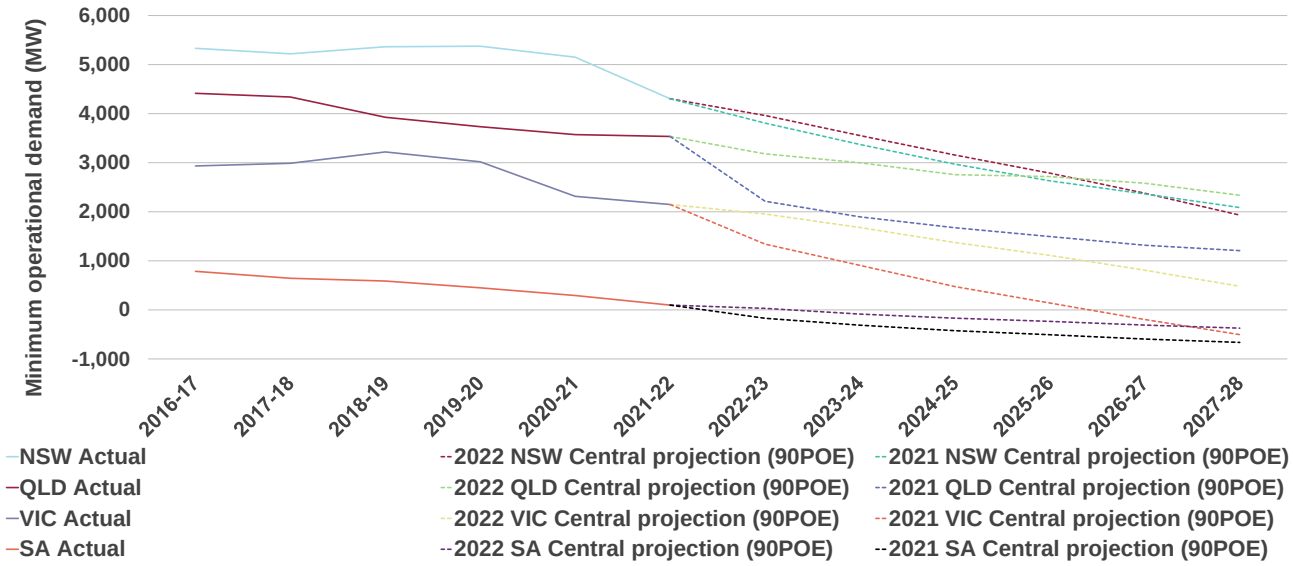
This section details the method applied to perform the analysis for the 2022 NSCAS report, and the key inputs and assumptions applied. This includes ISP scenario selection, committed and anticipated projects, and period of declarations.

Demand outlook

The 2022 *Electricity Statement of Opportunities* (ESOO) projects declining minimum demand values for many regions of the NEM. As such, this 2022 NSCAS report focuses on the impacts of high system voltages which are particularly exacerbated during periods of low or minimum demand. High voltages can lead to equipment damage and cascading failures if no measures are taken to keep within acceptable ranges.

The NSCAS minimum demand assessments were prepared[14] using the 2022 ESOO Central scenario 90% probability of exceedance (90POE) minimum demand projection[15]. The Central scenario for the 2022 ESOO has a higher underlying demand than the previous year's forecast, so the 2022 NSCAS assessment has higher demand scenarios than the 2021 NSCAS assessment. Figure 1 below shows the differences in the minimum demand projections used in the 2021 and 2022 NSCAS assessments[16].

Figure 1 Minimum demand projections used in 2021 and 2022 NSCAS reviews



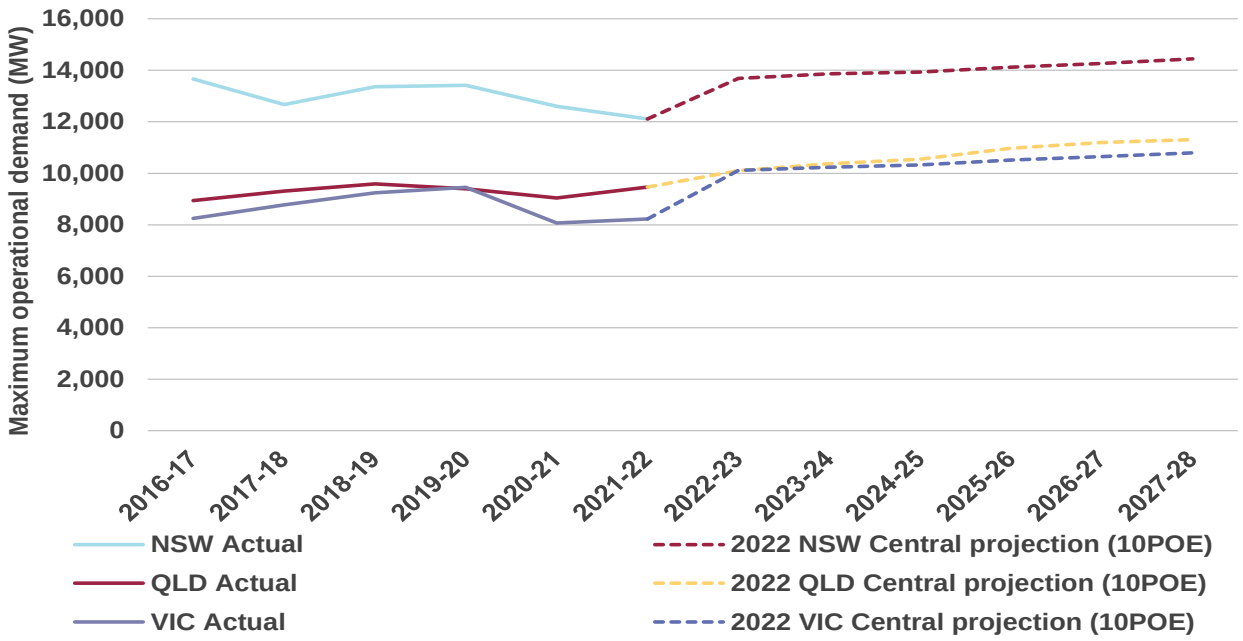
[14] Demand was scaled to 2022 ESOO operational sent-out demand values, however different values for transmission losses and auxiliary loads were used in the load calculations associated with the specific casefiles used for studies.

[15] AEMO National Electricity and Gas Forecasting portal at http://forecasting.aemo.com.au/Electricity/MinimumDemand/Operational.

[16] No NSCAS demand assessment was performed in Tasmania, so minimum demand projections for Tasmania are not included in this figure. See Section 4.4 for details.

Maximum demand analysis was undertaken using the 2022 ESOO Central scenario 10POE maximum demand projections[17] as shown in Figure 2 below[18].

Figure 2 Maximum demand projections used for NSCAS assessments



Network and generation assumptions

AEMO's most likely scenario in the 2022 ISP is the *Step Change* scenario. This is also considered by energy industry stakeholders to be the 'most likely' plausible future operating environment for the energy sector. *Step Change* sees 40% of coal capacity withdrawn over the next five years, 60% by 2030, 87% by 2035 and about 96% by 2040. Aligned with this coal withdrawal, the ISP highlights that urgent investment in transmission and generation infrastructure is needed for the energy transition underway. While some of these critical projects have reached committed status, others are well advanced, priority projects for the NEM but not yet considered committed. Many of these critical projects for the NEM fall within the NSCAS study period, and form a plausible future scenario for AEMO's NSCAS assessments.

AEMO has studied two main scenarios for the NSCAS assessments:

1. Cases with committed transmission and generation projects only. This has been prepared as a base case assessment considering the current system as it stands.
2. Cases with committed, anticipated and ISP Actionable transmission projects modelled, as well as committed, anticipated and forecast generation projects. This aims to include not only the well progressed projects, but those which will plausibly be operational within the NSCAS study period, to be broadly consistent with the *Step Change* scenario considered most likely by AEMO and key industry stakeholders.

[17] AEMO National Electricity and Gas Forecasting portal at https://forecasting.aemo.com.au/Electricity/MaximumDemand/Operational.

[18] No maximum demand assessments were performed in Tasmania and South Australia, so they are not included in this figure. See Sections 4.3 and 4.4 for details.

The NSCAS gaps declared in this report are made against the cases with committed, anticipated and ISP Actionable projects. A summary of transmission and generation projects included in the different scenarios is noted in Appendix A1.

The NSCAS assessment assumes all committed and anticipated transmission augmentations are delivered by dates advised by TNSPs. If any augmentations are delayed, this could lead to new or larger NSCAS gaps arising as demand continues to decline before projects that mitigate the resulting high voltages are in place. If TNSPs believe any relevant projects may be delayed, the TNSP should inform AEMO at the earliest opportunity. Likewise, committed and anticipated generation projects provide valuable reactive support to the network and commissioning delays could lead to more challenging scenarios for voltage control.

AEMO has adjusted the cases to assume that the minimum fault level requirements for system strength purposes for each region are met. For further details about system strength requirements in each region of the NEM, see the 2022 System Strength Report[19].

Declaration period

Although the NSCAS declaration period is from December 2022 to December 2027, to align with AEMO's other internal modelling timeframes, modelling has been undertaken based on financial years and so data from 2022-23 to 2027-28 is presented.

Planning assumptions

The 2020 NSCAS review[20] revealed that the impact of changing generation, network and demand dynamics on operational risk may not be sufficiently accounted for under traditional network planning assumptions. This raised questions as to whether planning assumptions applied in the past remain suitable for future planning, to design the power system appropriately for real-time operation.

In 2021, AEMO investigated its voltage management planning assumptions to ensure the power system is designed appropriately for real-time operation as the power system transitions. Through consultation with TNSPs' planning and operational specialists, updated voltage management planning assumptions are provided in Appendix A2 and applied in this 2022 NSCAS assessment. This includes no longer assuming pre-contingent line-switching for system normal planning studies for the management of high voltages, following consultation on an amendment to the NSCAS description and quantity procedure[21], except in cases where specific agreements have been made with individual TNSPs.

Building on the 2022 ISP outcomes, the projected generation dispatch in this report follows the *Step Change* scenario outcomes and is the basis for shortfall declarations.

In addition to its core scenario, AEMO has conducted a 100% renewable energy sensitivity, the results of which are used to understand potential system security issues in the event of the NEM plausibly seeing 100% renewable energy penetration.

[19] AEMO. 2022 System Strength Report. December 2022. At https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/system-security-planning.

[20] AEMO. 2020 NSCAS Review. December 2020. At https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/planning-for-operability.

[21] AEMO, NSCAS description and quantity procedure consultation, at https://aemo.com.au/consultations/current-and-closed-consultations/network-support-and-control-ancillary-services-description-and-quantity-procedure-consultation.

4 NSCAS assessment

This section provides the NSCAS assessment for each region of the NEM, including RSAS and MBAS needs as well as declaration of gaps.

4.1 New South Wales

AEMO confirms the existing RSAS gap of 2 megavolt amperes reactive (MVAr) reactive power absorption in the Coleambally region as declared in the 2021 System Security Reports remains, and notes that Transgrid has operational measures in place to manage the post-contingent voltages.

Scope of assessment

AEMO assessed voltage control in New South Wales for the five-year outlook period, including transmission projects noted in Table 5, committed[22], anticipated, and forecast new generators[23], announced generator retirements, forecast[24] generator decommitments, and forecast change in demand. This 2022 NSCAS review incorporated changes identified through AEMO's review of planning assumptions for voltage control (more information is provided in Appendix A2). In addition, the minimum synchronous machine requirement associated with the system strength requirements is adhered to for these studies[25].

The studies consider a case with committed projects only, and several sensitivities for minimum demand studies, and a committed project case and sensitivity case for maximum demand.

Results

AEMO confirms the existing RSAS gap of approximately 2 MVAr reactive power absorption at Coleambally 132 kV as declared in the 2021 System Security Reports. This gap is for managing post-contingent high voltages at Coleambally during overnight low demand when nearby solar generation is out of service. The size of the NSCAS gap is not expected to change over the five-year period. The optimal location and solution for addressing this identified gap is to be determined by the TNSP.

AEMO understands that Transgrid is continuing to assess measures to control voltages across southern New South Wales, including through its Regulatory Investment Test for Transmission (RIT-T) to maintain reliable supply in the Deniliquin, Coleambally and Finely area, and through ongoing work to implement the Project EnergyConnect interconnector with South Australia.

[22] Newly committed projects Broken Hill Battery Energy Storage System (BESS) and Queanbeyan BESS from the October 2022 GenInfo were not included in the NSCAS analysis. It is not expected that these generators would materially affect the gap declared.

[23] Forecast new generators and batteries from the 2022 ISP *Step Change* scenario market modelling were modelled to the depth required for a voltage control study.

[24] Forecast generator decommitments from the 2022 ISP *Step Change* market modelling were assumed to be unavailable in the cases which considered committed, anticipated and ISP Actionable projects. If these decommitments meant that minimum synchronous generator combinations required to address system strength requirements could not be met, then alternative generating units were dispatched on in the model.

[25] Seven synchronous units online in 2022-23 casefile, six synchronous units online in 2027-28 casefile.

AEMO has not identified any MBAS gaps to maximise market benefits in New South Wales. Although one high market impact binding constraint was identified[26], AEMO discussed this with Transgrid and understands that a project is under consideration which would address this matter.

Table 4 notes the scenarios assessed and the results of the assessment. Table 5 represents the anticipated and progressing generation and transmission projects modelled in the assessment.

Table 4 New South Wales NSCAS outcomes for scenarios assessed

Time of day	Project assumptions	Financial year ending	Demand (MW)	Pre-contingent line switching assumption	NSCAS gap
Daytime minimum demand	Committed projects only	2028	1,932	No line switching	No NSCAS gap identified.
	Committed, anticipated and progressing projects	2028	1,932	No line switching	No NSCAS gap identified.
Overnight minimum demand	Committed projects only [A]	2023	5,174	No line switching	An NSCAS RSAS gap identified of approximately 2 MVAr reactive power absorption identified at Coleambally 132 kV busbar.
	Committed projects only	2028	5,174	No line switching	An NSCAS RSAS gap identified of approximately 2 MVAr reactive power absorption identified at Coleambally 132 kV busbar.
	Committed, anticipated and progressing projects	2028	5,174	No line switching	An NSCAS RSAS gap identified of approximately 2 MVAr reactive power absorption identified at Coleambally 132 kV busbar.
Maximum Demand	Committed projects only	2028	14,445	Not applicable	No NSCAS gap declared [B].
	Committed, anticipated and progressing projects	2028	14,445	Not applicable	No NSCAS gap identified.

A. No anticipated projects due to be complete by financial year 2023, so only committed projects scenario studied.
B. Reliability and voltage control issues in this scenario, however gaps have not been declared based on this scenario. Consistent with the 2022 ESOO outcomes, reliability gaps are forecast in New South Wales from 2025-26 without additional network investment beyond the present commitments. This has led to challenges developing a stable 2028 load flow case with committed projects only. A gap equivalent to the capability of HumeLink is seen at Bannaby 500 kV, and reactive power gaps in the order of 150 MVAr at Dapto 330 kV, and 70 MVAr at Beaconsfield are also observed.

Table 5 Anticipated and progressing generation and transmission projects

Type of project	Name of project	Delivery date advised by project proponent [A]	Capacity (MW)
Transmission	Project EnergyConnect	Construction and first energisation – end 2024 Full capacity, inter-network testing – July 2026	-
	HumeLink	2026	-

[26] The potential MBAS issue was identified with the following thermal constraint: "N>N-NIL_997_99A Out= Nil, avoid O/L Corowa to Albury 132 kV line (997/1) on trip of Finley to Uranquinty 132kV line (99A), Feedback". More information about constraints is available at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information-resource/constraint-faq.

Type of project	Name of project	Delivery date advised by project proponent [A]	Capacity (MW)
	Central West Orana Renewable Energy Zone (REZ) Transmission Link	2025	-
	New England REZ Transmission Link	July 2027	-
	Reinforcing Sydney, Newcastle and Wollongong supply (Northern 500 kV loop)	July 2027	-
Generation [B]	Waratah Super Battery	Beginning 2025	700
	Quorn Park Solar Farm	December 2023	80
	Walla Walla Solar Farm	December 2023	300
	Yanco Solar Farm [C]	-	60
	N0_WH_Bayswater500	-	396
	N1_SAT_Gunnedah132	-	7
	N2_SAT_Central330_U	-	385
	N2_SAT_South330_U	-	165
	N2_WH_Central330_U	-	1236
	N2_WH_South330_U	-	530
	N2_WL_Central330_U	-	1255
	N2_WL_South330_U	-	538
	N3_SAT_N3North_U	-	480
	N3_SAT_N3West_U	-	480
	N3_WH_N3North_U	-	387
	N3_WL_N3North_U	-	502
	N3_WL_N3West_U	-	502
	N4_SAT_BrokenHill220	-	81
	N8_WH_Cooma132	-	100
	N8_WL_Cooma132	-	200

A. Not applicable for ISP projections.
B. Additional anticipated generators were included in the October 2022 revision of AEMO's Generation Information page, which AEMO did not include in this analysis. It is expected that these additional anticipated generators would generally improve the availability of voltage control in the network, and not affect the NSCAS gap sizing declared for Coleambally 132 kV.
C. Delivery date not advised by proponent.

Next steps

AEMO confirms the existing RSAS gap of 2 MVAr absorbing reactive power in the Coleambally region as declared in the 2021 System Security Reports. AEMO notes that Transgrid has operational measures in place to manage the post contingent voltages at Coleambally. This includes the switching of the 132 kV line between Deniliquin and Finley. AEMO notes that Transgrid has issued a Project Specification Consultation Report (PSCR) for a project to maintain reliable supply in south west New South Wales. AEMO understands that Transgrid is currently preparing a Project Assessment Conclusions Report (PACR) for this project[27].

In other sensitivities, managing voltages remains challenging and urgent progression of anticipated and actionable transmission projects is critical to enable voltage control in the system. Anticipated generation provides valuable voltage support to the system and should also be progressed and connected into the system. Delays to

[27] Transgrid. *Maintaining reliable supply to Deniliquin, Coleambally and Finely area RIT-T PSCR*, at https://www.transgrid.com.au/about-us/regulatory-framework/regulatory-investment-test-for-transmission-rit-t.

generation and or transmission projects could lead to more challenges under certain scenarios, however no NSCAS gap is declared for these scenarios.

4.2 Queensland

AEMO has confirmed the RSAS gap of 120 MVAr reactive power absorption in Southern Queensland declared in the 2021 System Security Reports. Powerlink is finalising a near-term solution for this gap. In the longer term, AEMO is not declaring a gap for the latter end of the five-year NSCAS assessment period, as newly committed and anticipated generation and storage projects are expected to improve power system voltage control, along with Powerlink's ongoing project to manage voltages in South East Queensland. These results are highly sensitive to the impact of synchronous generation dispatch and system strength services, and AEMO may need to re-assess in 2023 as more information becomes available.

Scope of assessment

AEMO assessed voltage control in Queensland over the five-year outlook period, including the minimum demand daytime, minimum demand night-time and maximum demand scenarios.

The study included future committed transmission projects, committed, anticipated, and forecast new generators[28], announced generator retirements, forecast[29] generator decommitments, and forecast change in demand. This 2022 NSCAS review incorporated changes identified through AEMO's review of planning assumptions for voltage control (more information is provided in Appendix A2). In addition, the minimum synchronous machine requirement associated with the system strength requirements was adhered to for these studies[30].

Results

Powerlink's proposed solution[31] for the immediate gap declared in 2021 for the minimum night-time scenario was tested for 2022-23. This solution is expected to close the near-term gap once it is finalised.

For the latter end of the declaration period, a 2027-28 study showed that the gap declared in the 2021 System Security Report will close due to the inclusion of committed and anticipated projects which have progressed since the time the 2021 assessment was undertaken. Powerlink is also progressing a project to manage voltages in South East Queensland. These results are sensitive to assumptions about synchronous generation dispatch and system strength service assumptions.

For this 2022 assessment, AEMO is keeping the initial gap open for 2022-23 pending Powerlink's finalisation of a solution. AEMO considers the gap for 2027-28 to be closed at present but notes that this may require

[28] Forecast new generators and batteries from the 2022 ISP *Step Change* scenario market modelling were modelled to the depth required for a voltage control study.

[29] Forecast generator decommitments from the 2022 ISP *Step Change* market modelling were assumed to be unavailable in the cases which considered committed, anticipated and ISP Actionable projects. If these decommitments meant that minimum synchronous generator combinations required to address system strength requirements could not be met, then alternative generating units were dispatched on in the model.

[30] Seven synchronous units in central Queensland, four, or three in southern Queensland (depending on the sensitivity), and two in northern Queensland.

[31] Powerlink is undertaking actions to address the immediate gap and is progressing a proposed solution.

re-assessment in the near term based on any updated information about progression of committed and anticipated generation and storage projects, or about assumptions regarding synchronous generation dispatch and system strength service provision.

AEMO has not identified any MBAS gaps to maximise market benefits in Queensland.

Table 6 notes the scenarios assessed and the results of the assessment. Table 7 details anticipated and progressing generation and transmission projects considered. This assessment considers maintaining the system in a secure state during system normal conditions and subject to a credible contingency. Restoring the network to a secure operating state within 30 minutes has not been considered in this assessment.

Table 6 Queensland NSCAS outcomes for scenarios assessed

Time of day	Project assumptions	Financial year ending	Demand (MW)	Inter-connector flows	Pre-contingent line switching assumption	NSCAS gap
Daytime minimum demand	Committed projects only	2023	2,336	Medium transfer from Queensland to New South Wales	No line switching	Issues are identified, but no NSCAS gap declared using this scenario. [B]
	Committed projects only	2028	2,336	High transfer from Queensland to New South Wales	No line switching	Issues are identified, but no NSCAS gap declared using this scenario. [B]
	Committed, anticipated, and progressing projects	2028	2,336	High transfer from Queensland to New South Wales	No line switching	No NSCAS gap identified. [C]
Overnight minimum demand	Committed projects only	2023	4,431	High transfer from New South Wales to Queensland	No line switching	An NSCAS RSAS gap identified of approximately 120 MVAr reactive power absorption in Southern Queensland. [A, B]
	Committed projects only	2028	4,431	High transfer from New South Wales to Queensland	No line switching	Issues are identified, but no NSCAS gap declared using this scenario. [B]
	Committed, anticipated, and progressing projects	2028	4,431	High transfer from New South Wales to Queensland	No line switching	No NSCAS gap identified. [C]
Maximum demand	Committed projects only	2028	11,307	High transfer from New South Wales to Queensland	Not applicable	No NSCAS gap identified.
	Committed, anticipated and progressing projects	2028	11,307	Medium transfer from New South Wales to Queensland	Not applicable	No NSCAS gap identified.

A. Powerlink is undertaking activities to address this gap.
B. Issues identified are similar to the gap declared in the 2021 System Strength Report for the night-time case, however outcomes are highly sensitive to different synchronous dispatch conditions and any future system strength services.
C. The absence of a gap is dependent on committed and anticipated projects providing reactive support.

Table 7 Anticipated and progressing generation and transmission projects

Type of project	Name of project	Delivery date advised by project proponent [A]	Capacity (MW)
Transmission	No additional projects		
Generation[32]	Aramara Solar Farm	March 2024	101
	Munna Creek Solar Farm	April 2024	120
	Macintyre Wind Farm	December 2024	890
	Karara Wind Farm	April 2025	103
	Q4_WH_Broadsound275	-	241
	Q4_WH_Lilyvale275	-	241
	Q4_WH_Nebo275	-	241
	Q4_WH_Strathmore275	-	241
	Q6_WH_Bouldercombe275	-	124
	Q6_WH_Calvale275	-	703
	Q8_WH_BulliCreek330	-	676
	Q8_WH_MiddleRidge275	-	676
	Q8_WL_Braemar275	-	158
	Q8_WL_BulliCreek330	-	158
	Q8_WL_Columboola275	-	158
	Q8_WL_MiddleRidge275	-	158
	Q8_WL_Tarong275	-	158

A. Not applicable for ISP projections.

Next steps

AEMO confirms that the initial-year NSCAS gap of 120 MVAr reactive power absorption in southern Queensland declared in December 2021 remains open. It is expected to be closed shortly as Powerlink progress a proposed solution.

AEMO has closed the final-year gap of 250 MVAr declared in December 2021 but considers that it may need to be re-assessed in 2023 when more information is available. A number of factors could drive the need for re-assessment, including the progression of committed and anticipated generation projects, any further declines in minimum demand projections for the southern Queensland region, measures taken to deliver system strength services, and other risks. AEMO recommends that Powerlink closely monitor the progress of these matters and incorporates the associated risks and uncertainties into the final stage of its RIT-T to manage voltages in South East Queensland (SEQ).

Voltages continue to be challenging, particularly in night-time periods when reactive support from solar farms is unavailable. Additional anticipated projects with reactive support capabilities even at near zero MW output are valuable to control voltage in the network.

[32] Additional anticipated generators were included in the October 2022 revision of AEMO's Generation Information page, which AEMO did not include in this analysis. It is expected that these additional anticipated generators would generally improve the availability of voltage control in the network.

4.3 South Australia

AEMO has not identified an NSCAS gap in South Australia over the coming five years. Newly committed and anticipated transmission, generation, and storage projects are projected to improve voltage control in the region. These power system changes also have closed the gap declared in 2021 for 40 MVAr reactive power absorption at Blyth West.

System security will, however, continue to be a priority issue in South Australia. AEMO understands that ElectraNet is continuing to work with the local distribution network, SA Power Networks, on measures to control voltages across the distribution and transmission systems during low demand periods.

Scope of assessment

AEMO assessed steady state voltage control in South Australia over the five-year outlook period for a zero demand daytime scenario. This is considered to be the most onerous scenario from voltage control perspective because excess power can be exported to Victoria when demand is negative in South Australia, but when demand is at or near zero within South Australia then lower line loadings lead to elevated voltages in the system. Near zero demand is expected to occur in South Australia as rooftop PV systems drive demand seen on the power system downwards after sunrise, and then again as demand picks up with evening peak and sunset. In addition, daily weather events such as significant cloud cover can cause rooftop PV output to reduce, causing demand to fluctuate around near zero demand.

A maximum demand case was not considered because demand in South Australia is not projected to increase over the five-year horizon.

The study included transmission projects noted in Table 9, committed and anticipated generators, announced generator retirements, and forecast change in demand. This 2022 NSCAS review incorporated changes identified through AEMO's review of planning assumptions for voltage control (more information is provided in Appendix A2).

Studies considered zero synchronous generation units in service in South Australia. At present, in the operational context, AEMO applies limit advice requiring that two synchronous generation units remain in service in South Australia for system security purposes during normal operating conditions. Investigations are underway to consider how and when that requirement may reduce to one unit. A minimum synchronous generator requirement in South Australia is not expected to be required under system normal conditions once Project EnergyConnect Stage 2 is operational and ElectraNet implements a scheme to effectively manage the non-credible loss of Project EnergyConnect or Heywood.

Results

No RSAS gaps were identified in South Australia. In the 2021 assessment, with no synchronous generation units in service in South Australia, post-contingency high voltages were observed near Blyth West during periods of near zero demand or low transfers between South Australia and Victoria. However, in the 2022 assessment, contributions from newly committed, anticipated and progressing transmission and generation projects meant that voltages above operational limits were not observed.

AEMO has not identified any MBAS gaps to maximise market benefits in South Australia.

Table 8 notes the scenarios assessed and the results of the assessment. Table 9 details anticipated and progressing generation and transmission projects considered.

Table 8 South Australia NSCAS outcomes for scenarios assessed

Time of day	Project assumptions	Financial year ending	Demand (MW)	Project EnergyConnect status	Dispatch of synchronous units	Pre-contingent line switching assumption	NSCAS gap
Daytime minimum demand	Committed projects only	2028	Near zero	Not included	Two synchronous units online	No line switching	No NSCAS gap declared
	Committed, anticipated, and progressing projects	2028	Near zero	In service	No synchronous units online	No line switching	No NSCAS gap declared

Table 9 Anticipated and progressing generation and transmission projects

Type of project	Name of project	Delivery date advised by project proponent	Capacity (MW)
Transmission	Project EnergyConnect	July 2026	-
Generation [A]	Torrens Island Battery	June 2023	250

A. Additional anticipated generators were included in the October 2022 revision of AEMO's generation information page, which AEMO did not include in this analysis as it was too late to incorporate in the modelling. It is expected that these additional anticipated generators would generally improve the availability of voltage control in the network.

Next steps

AEMO notes that the RSAS gap of 40 MVAr reactive power absorption in South Australia declared in December 2021 has now been closed. AEMO is not declaring an NSCAS gap in South Australia in this 2022 NSCAS assessment.

AEMO acknowledges that under low demand conditions voltage challenges may also exist in the distribution network which would have a flow-on impact on the ability to adjust voltage control set points in the transmission network. These conditions are beyond the extent of what AEMO modelled in this NSCAS assessment, and AEMO understands that ElectraNet and SA Power Networks are investigating measures to control voltages across the distribution and transmission systems during low demand periods.

AEMO notes that ElectraNet has identified, in the 2022 Transmission Annual Planning Report (TAPR)[33], an emerging need to reduce the system's reliance on dynamic reactive power devices to satisfactorily manage steady-state voltage levels at times of low or negative net system demand. ElectraNet's proposed solution is to install a suite of 50-60 MVAr shunt reactors at various locations, expected to be in service in 2024.

[33] ElectraNet Transmission Annual Planning Report 2022, at https://www.electranet.com.au/wp-content/uploads/221031_ENet-TAPR_A4_FINAL-1.pdf.

4.4 Tasmania

AEMO has not identified any NSCAS gap in Tasmania over the five-year period because system strength and inertia services contracts support a range of security services.

Tasmania has a limited forecast change in minimum demand and few committed power system changes in the five-year outlook period. In addition, TasNetworks has an agreement in place for system strength and inertia services until April 2024. That agreement will ensure a minimum number of synchronous units in service at times when system strength or inertia issues are expected to arise – that is, for low demand periods – which will also provide voltage support on the network.

AEMO has not identified an RSAS or MBAS NSCAS gap in Tasmania over the five-year outlook period.

AEMO will continue to work with TasNetworks as the contracts for system strength and inertia services beyond April 2024 are finalised and will monitor how this could affect NSCAS assessments. NSCAS needs may need to be re-assessed in the future if there is a material change to the operating environment in Tasmania.

4.5 Victoria

AEMO has not identified any NSCAS gaps in Victoria because operational arrangements are in place to switch 500 kV transmission lines for voltage control.

Scope of assessment

AEMO assessed voltage control in Victoria for the five-year outlook period, including transmission projects noted in Table 11, committed[34], anticipated, and forecast new generators[35], announced generator retirements, forecast generator decommitments[36], and forecast change in demand. AEMO assessed anticipated and progressing generation and transmission augmentation projects in separate sensitivity scenarios. This 2022 NSCAS review incorporated changes identified through AEMO's review of planning assumptions for voltage control (more information is provided in Appendix A2). In addition, the minimum synchronous machine requirement associated with the system strength requirements is adhered to for these studies[37].

Results

Despite rapid decline in minimum demand and retirement of large thermal machines over the next five years, AEMO has not identified any NSCAS gaps in Victoria because operational arrangements are in place to switch 500 kV transmission lines for voltage control[38].

While no gaps have been identified in minimum demand scenarios, the operation of the Latrobe Valley 500 kV network below surge impedance loading has the potential to exacerbate high voltage issues in the network. This will require available in-service reactors and generation plants to be operating towards reactive absorption limits during these periods. This includes the recently commissioned assets in the Victorian Reactive Power Support RIT-T[39] project. No gaps have been identified in maximum demand scenarios. Issues that were identified are being addressed using existing planning services such as transmission and distribution annual planning.

AEMO has not identified any MBAS gaps to maximise market benefits in Victoria.

Table 10 notes the scenarios assessed and the results of the assessment. Table 11 details anticipated and progressing generation and transmission projects considered.

[34] Newly committed project Hazelwood Battery Energy Storage System from the October 2022 GenInfo was not included in the NSCAS analysis. No gap is declared, and it is expected that this project could assist with voltage control in the Latrobe Valley region.

[35] Forecast new generators and batteries from the 2022 ISP *Step Change* scenario market modelling were modelled to the depth required for a voltage control study.

[36] Forecast generator decommitments from the 2022 ISP *Step Change* market modelling were assumed to be unavailable in the cases which considered committed, anticipated and ISP Actionable projects. If these decommitments meant that minimum synchronous generator combinations required to address system strength requirements could not be met, then alternative generating units were dispatched on in the model.

[37] A maximum of five synchronous generators with least absorbing capabilities near the Latrobe Valley were in service for minimum demand studies.

[38] AEMO. Notice of NSCAS Planning Assumption – Line Switching, Victoria. December 2021. At https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/planning-for-operability.

[39] AEMO. Victorian Reactive Power Support RIT-T, at https://aemo.com.au/initiatives/major-programs/victorian-reactive-power-support-regulatory-investment-test-for-transmission.

Table 10 Victoria NSCAS outcomes for scenarios assessed

Time of day	Projects Considered	Financial year ending	Demand (MW)	Inter-connector flows	Pre-contingent line switching assumption	NSCAS gap
Daytime minimum demand	Committed projects only	2028	481	• High transfer from Victoria to Tasmania • Low transfer from Victoria to South Australia • High transfer from Victoria to New South Wales	Hazelwood – South Morang 500 kV transmission line	No NSCAS gap identified
	Committed, anticipated, and progressing projects	2028	481	• High transfer from Victoria to Tasmania • Low transfer from Victoria to South Australia • High transfer from Victoria to New South Wales	Hazelwood – South Morang 500 kV transmission line	No NSCAS gap identified
Overnight minimum demand	Committed projects only	2028	3,073	• Low transfer from Victoria to Tasmania • Low transfer from South Australia to Victoria • High transfer from New South Wales to Victoria	Hazelwood – South Morang 500 kV transmission line	No NSCAS gap identified.
	Committed, anticipated, and progressing projects	2028	3,073	• Low transfer from Victoria to Tasmania • Low transfer from South Australia to Victoria • High transfer from New South Wales to Victoria	Hazelwood – South Morang 500 kV transmission line	No NSCAS gap identified.
Maximum demand	Committed projects only	2028	10,791	• High transfer from Tasmania to Victoria • High and Low transfer from South Australia to Victoria • High transfer from New South Wales to Victoria	Not applicable	No NSCAS gap identified.
	Committed, anticipated, and	2028	10,791	• High transfer from	Not applicable	No NSCAS gap identified.

Time of day	Projects Considered	Financial year ending	Demand (MW)	Inter-connector flows	Pre-contingent line switching assumption	NSCAS gap
	progressing projects			Tasmania to Victoria • High and Low transfer from South Australia to Victoria • High transfer from New South Wales to Victoria		

Table 11 Anticipated and progressing generation and transmission projects

Type of project	Name of project	Delivery date advised by project proponent	Modelling date (financial year)	Capacity (MW)
Transmission	Project EnergyConnect	July 2026	2028	-
	Western Renewables Link	July 2026	2028	-
Generation [A]	Wunghnu Solar Farm	2028	2028	75

A. Additional anticipated generators were included in the October 2022 revision of AEMO's generation information page, which AEMO did not include in this analysis. It is expected that these additional anticipated generators would generally improve the availability of voltage control in the network.

Next steps

AEMO has not declared an NSCAS gap, so no NSCAS-related next steps are proposed.

AEMO notes that the impact of low demand will have a significant impact on high voltages in the Victorian network particularly around the Latrobe Valley and Melbourne CBD substations. Management of these over-voltages will become reliant on in-service machines with large absorption capability, reactive plant near Melbourne CBD, and the availability of 500 kV pre-contingent line-switching. This will further impact maintenance windows for these assets and any outages should (ideally) be scheduled outside of minimum demand periods, as identified in the 2022 *Victorian Annual Planning Report* (VAPR)[40].

[40] The 2022 VAPR details outage window limitations for 500 kV lines in section 4.5.6, at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/vapr/2022/2022-victorian-annual-planning-report.pdf?la=en.

5 Preparing for 100% instantaneous renewable penetration

From 2025, there are forecast to be times when the NEM has enough renewable energy resources to meet 100% of its demand. However, the realisation of 100% instantaneous penetration of renewables will depend on a range of factors, including provision of widespread system security services.

As part of preparations for higher penetration of renewables, AEMO has undertaken a high-level study of operation of the mainland NEM at 100% instantaneous penetration of renewables[41] during times of low demand. The study assumes transmission network augmentations consistent with the *Step Change* scenario and considers provision of system strength, inertia and voltage control services to ensure a secure power system.

This study is considered to be a first step for assessing power system security needs in the NEM at times of 100% renewable energy penetration, and forms part of Priority Action A2 under AEMO's Engineering Framework[42]. The results presented in this section are indicative only. Further information about measures required for 100% renewable penetration in the NEM can be found in AEMO's *Engineering Roadmap to 100% Renewables*[43].

Selecting a low demand system snapshot for 100% renewable penetration

AEMO selected a power system snapshot to study based on *Step Change* scenario results, with some adjustments. Figure 3 summarises the generation dispatch considered in the study. The system snapshot reflected low NEM-wide operational demand in the middle of the day. It is plausible that this is not the only period where 100% renewables could occur, and AEMO aims to conduct further study of other scenarios at varying levels of demand and generation mixes.

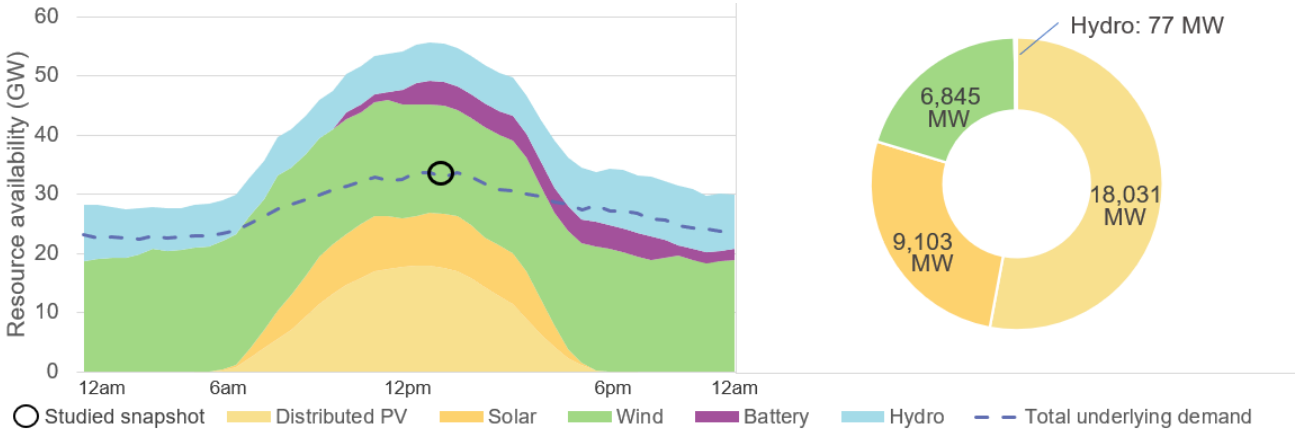
When preparing this study, AEMO made some adjustments in recognition of the need to ensure sufficient renewable energy is available to cover periods leading up to and following the time of low demand, given that many fossil-fuelled generating units having a minimum start-up time of 4 to 6 hours once offline. AEMO did not include Tasmania in the study, as that region has already been operated at 100% renewable penetration due to its high proportion of hydro-powered generation.

[41] Renewables includes wind, solar, distributed PV, batteries, hydro and biofuels.

[42] See https://aemo.com.au/-/media/files/initiatives/engineering-framework/2022/nem-engineering-framework-priority-actions.pdf?la=en&hash=F5297316185EDBD4390CDE4AE64F48BB.

[43] At https://aemo.com.au/en/initiatives/major-programs/engineering-framework.

Figure 3 Resource availability and generation dispatch for low demand 100% instantaneous renewable penetration study



Three cases were assessed for power system security needs

AEMO studied three cases – a case with no mitigation measures to meet system security needs, a case with new synchronous condensers installed, and a case with both new synchronous condensers and retrofit of existing synchronous generators to operate in synchronous condenser mode.

AEMO expects that technological innovation, including but not limited to the use of grid-forming technologies, will be able to contribute to a diverse mix of solutions. AEMO does not consider that synchronous condensers alone would be the only or most efficient way for power system security services to be provided for 100% renewable penetration, but this option has been considered in this study for ease of analysis.

Table 12 provides the initial results of the study emphasising the importance of meeting the new system strength standard from 2025 onwards to facilitate the transition to a 100% renewable energy power system. Figure 4 provides a broad NEM overview of the outcomes of the study.

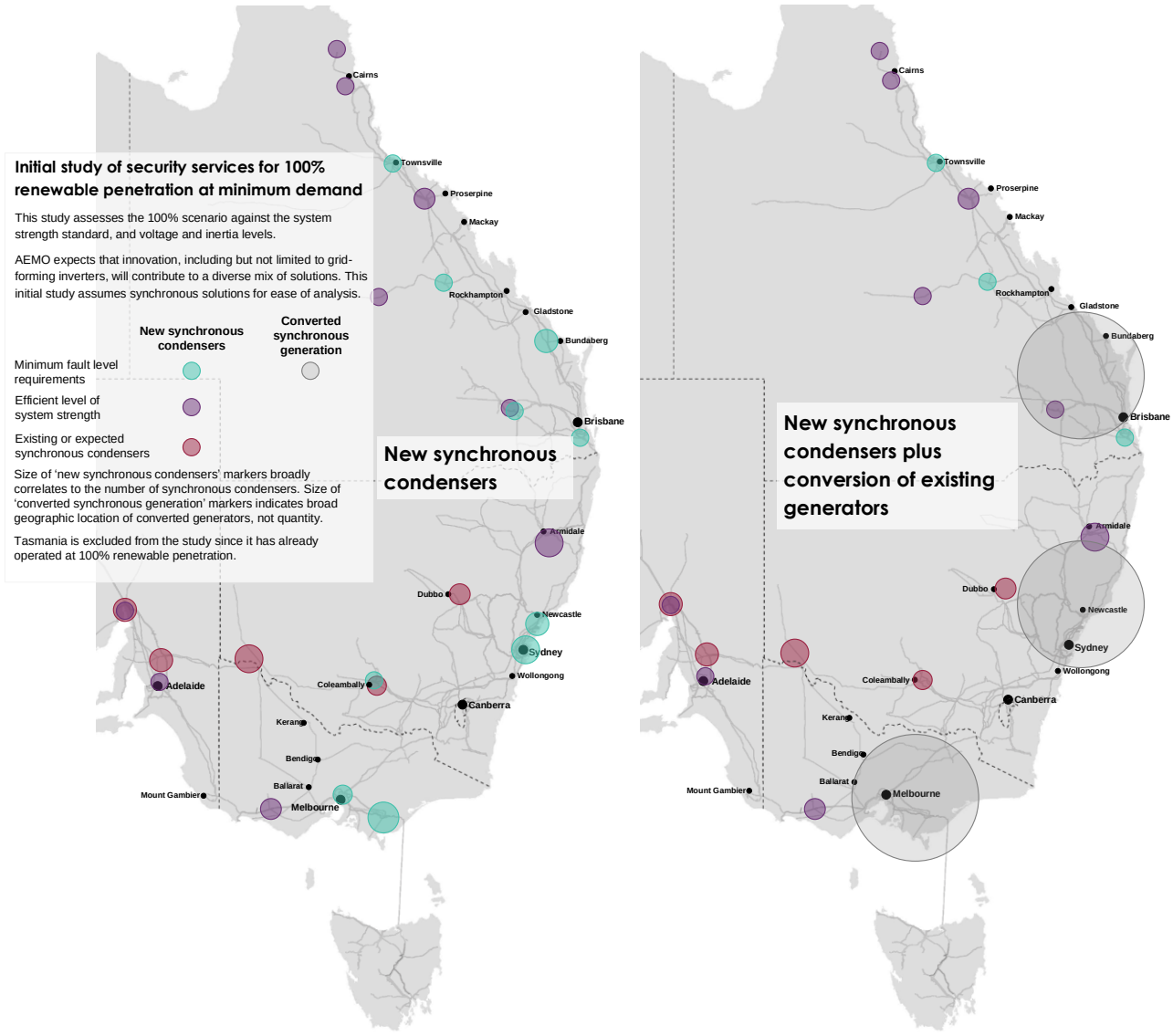
AEMO notes that the results presented in this section are the outcome of a steady-state analysis and are not provided for operational purposes.

Table 12 Preliminary results for system security during 100% renewable energy penetration in the NEM at times of low demand

Solutions considered	System strength	Inertia	Voltage control
No mitigation measures	System strength shortfall identified in New South Wales, Victoria and Queensland	Inertia shortfall in all regions.	Over-voltage issues observed in Victoria and Queensland.
All system strength requirements (minimum and efficient) are addressed with new synchronous condensers [A, B]	The equivalent of up to 40 new synchronous condensers rated at 125 megavolt amperes (MVA) are required across the NEM. This includes assumptions that pumped hydro synchronous generators will be available, and more synchronous condensers (or equivalent) will be required if the pumped hydro is not available.	Inertia requirements are met with the modelled system strength solution, except in some cases where support from frequency control ancillary services (FCAS) markets and/or battery services may also be required.	No voltage range violations with the number of synchronous condensers installed for system strength.
All system strength requirements (minimum and efficient) are addressed with either new synchronous condensers or retrofit of synchronous generators to synchronous condenser mode [A]	15 synchronous generator units are converted to synchronous condensers and up to 25 additional synchronous condensers rated at 125 MVA are added across the NEM to meet the requirement.	Inertia requirements are met with the modelled system strength solution, except in some cases where support from FCAS markets and/or battery services may also be required.	No voltage range violations with the number of synchronous condensers installed and generator conversions completed for system strength.

A. High-level assumptions were made to estimate the services that might be required to address the efficient level of system strength, using fault level as a proxy for system strength. In practice, AEMO expects a diversity of solutions to be delivered, including but not limited to the use of grid-forming technologies.
B. AEMO selected an arbitrary number of units for conversion across the NEM, not based on advice from individual generators or local transmission planning bodies. However, AEMO recognises that efforts are underway within industry to reconsider traditional operating models of existing synchronous generators that may mean a different combination of generators may eventuate in conversion. This includes Priority Action A23 of AEMO's Engineering Framework and the Queensland Energy and Jobs Plan.

Figure 4 NEM outcomes for preliminary study of system security services during 100% renewable energy penetration in the NEM, at times of minimum demand



6 Next steps

AEMO has confirmed NSCAS gaps in New South Wales and Queensland within the five-year declaration period as a result of the 2022 NSCAS assessments. Table 13 summarises the results of the assessment and notes where AEMO will request that TNSPs deliver services to address NSCAS gaps.

If you wish to provide any comments, or ask any questions about this report, please contact AEMO via planning@aemo.com.au. AEMO would be interested to understand from stakeholders what they would consider to be the priority system security matters that should be considered in the 2023 NSCAS assessment.

AEMO and TNSPs will undertake joint planning in 2023 and beyond to ensure that essential power system needs are met as the Australian energy transformation continues at pace.

Table 13 Summary of new and existing NSCAS gaps

Region	NSCAS gap
New South Wales 	**Voltage control gap at Coleambally** – AEMO has confirmed the reliability and security ancillary services (RSAS) gap of 2 MVAr reactive power absorption in the Coleambally region declared in the 2021 System Security reports. Transgrid currently has operational measures in place to manage this issue, and AEMO will continue to receive updates from Transgrid on the resolution of this matter. The trigger date and tender date are unchanged from the 2021 report and have already passed.
Queensland 	**A voltage control gap remains in Southern Queensland** – AEMO has confirmed the RSAS gap of 120 MVAr reactive power absorption in Southern Queensland declared in the 2021 System Security Reports. AEMO will continue to receive updates from the Powerlink on the resolution of this matter. The trigger date and tender date are unchanged from the 2021 report and have already passed. Although a gap is not declared for the latter end of the five-year NSCAS assessment period, re-assessment may be needed in 2023 as more information becomes available.
South Australia 	**No gap declared in 2022** – AEMO has not identified an NSCAS gap in South Australia over the coming five years. Newly committed and anticipated transmission, generation, and storage projects have improved voltage control in the region. These power system changes also have closed the gap declared in 2021 for 40 MVAr reactive power absorption at Blyth West. Minimum demand projections continue to decline for South Australia, and ElectraNet and SA Power Networks are investigating measures to control voltages across the distribution and transmission systems, including proposed installation of reactors.

Region	NSCAS gap
Tasmania 	**No gap declared in 2022** – AEMO has not identified any NSCAS gap in Tasmania over the five-year period because system strength and inertia services contracts support a range of security services.
Victoria 	**No gap declared in 2022** – AEMO has not identified any NSCAS gaps in Victoria because operational arrangements are in place to switch 500 kV transmission lines for voltage control.

A1. Generator and network modelling assumptions

This appendix provides the assumptions used in this report relating to generators, and transmission network augmentations.

A1.1 Generator assumptions

Committed and anticipated generation projects

The casefiles developed for the NSCAS assessments consider existing generators already in service as well as any committed and committed* scheduled and semi-scheduled generation projects from the August 2022 NEM Generation Information[44].

The NSCAS studies also consider anticipated projects captured in the August 2022 NEM Generation Information consistent with the references in the paragraph above, as well as any new generation forecast to be built under the market modelling results for the *Step Change* scenario prepared for the 2022 ISP[45].

Generation withdrawal and operation

The NSCAS assessments in this report are aligned with the generator withdrawals and operation in the *Step Change* scenario of the 2022 ISP[45].

A1.2 Transmission network augmentations

Table 14 provides the details and modelling date for the large committed and anticipated transmission[46] network augmentation projects included in the NSCAS assessments in this report. These projects are modelled consistent with the latest information provided by TNSPs.

[44] AEMO. The August 2022 NEM Generation Information is available under the Archive section of AEMO's Generation Information webpage, at https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information. Criteria for committed and committed* and anticipated are explained in the Background Information tab of the spreadsheet.

[45] See https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp.

[46] Definitions of committed and anticipated transmission network projects can be found in Section 3.10 of AEMO's *2021 Inputs, Assumptions and Scenarios*, July 2021, at https://aemo.com.au/-/media/files/major-publications/isp/2021/2021-inputs-assumptions-and-scenarios-report.pdf?la=en,and Appendix B of the AER*'s Cost Benefit Analysis Guideli*nes, August 202levia https://www.aer.gov.au/system/files/AER%20-%20Cost%20benefit%20analysis%20guidelines%20-%2025%20August%202020.pdf.

Table 14 Large transmission network upgrades included in each assessment

Transmission network upgrade	Augmentation detail	Modelling date (Calendar year) [A]	Included in assessment
South Australia system strength remediation	The South Australia system strength remediation project includes the installation of two high inertia synchronous condensers at Davenport 275 kV substation and two high inertia synchronous condensers at Robertstown 275 kV substation. Each of the four synchronous condensers provide 575 MVA nominal fault current and 1,100 MWs of inertia and were commissioned at the end of 2021.	In service	All scenarios for South Australia
QNI Minor	QNI Minor is the upgrade of the existing interconnector with uprating to increase thermal capacity of the existing transmission lines and installation of additional new capacitor banks and Static Var Compensators (SVCs) to increase transient stability limits on the Queensland – New South Wales Interconnector.	Mid 2023[B]	All scenarios for Queensland and New South Wales
VNI Minor	VNI Minor is an upgrade of the existing Victoria – New South Wales Interconnector with the installation of an additional 500/330 kV transformer, uprating to increase thermal capacity of the existing transmission, and installation of power flow controllers in New South Wales to manage the overload of transmission lines.	2022 [C] (Victoria side) 2023 (New South Wales completion date)	All scenarios for New South Wales and Victoria
South Australia Eyre Peninsula Link	This project will replace the existing 132 kV lines between Cultana and Port Lincoln with a new double-circuit line. This includes a new double-circuit line from Cultana to Yadnarie built at 275 kV but energised at 132 kV and a new double-circuit 132 kV line from Yadnarie to Port Lincoln.	2023	All scenarios for South Australia
Powering Sydney's future	This project is to install a new 330 kV cable between Beaconsfield and Rookwood substations. Derate the existing 330 kV cable and service reactor between Beaconsfield and Sydney South from 330 kV to 132 kV.	Fully completed in 2022	All scenarios for New South Wales
Western Victoria transmission network	The Western Victoria transmission network project is split into two stages. Parts of stage 1 are already complete. **Remainder of Stage 1:** • Uprate Bendigo – Kerang 220 kV line and Kerang- Wemen – Red Cliffs 220 kV lines. **Stage 2:** • A new substation north of Ballarat. • Cut-in the Ballarat – Bendigo 220 kV line at new substation North of Ballarat. • A new 220 kV double-circuit transmission line from substation north of Ballarat to Bulgana (via Waubra). • Moving the Waubra Terminal Station connection from the existing Ballarat – Ararat 220 kV line to a new 220 kV line connecting the substation north of Ballarat to Bulgana. • Cut-in the existing Ballarat – Moorabool No.2 220 kV line at Elaine Terminal Station. • A new 500 kV double-circuit transmission line from Sydenham to the new substation north of Ballarat. • 2 x 500/220 kV transformers at the new substation north of Ballarat . • 4 x 50 MVAr 500 kV reactors, one at each end of the new 500 kV lines.	Late 2021 (Stage 1) 2026[D] (Stage 2)	Stage 1 in all Victorian scenarios, Stage 2 in anticipated, actionable and progressing projects scenarios for Victoria
Project EnergyConnect	**Stage 1:** • A new Robertstown to Bundey 275 kV double-circuit line strung one circuit initially. • A new Bundey to Buronga 330 kV double-circuit line strung one circuit initially. • A new Buronga to Red Cliffs 220 kV double-circuit line strung one circuit only. • A new 330/275 kV substation and a 330/275 kV transformer at Bundey.	Stage 1 2024 Stage 2 2026 [E]	In anticipated, actionable and progressing projects scenarios for New South Wales, South Australia and Victoria

Transmission network upgrade	Augmentation detail	Modelling date (Calendar year) [A]	Included in assessment
	• A new 330/220 kV substation, a 330/220 kV transformer and a 330 kV phase shifting transformer at Buronga. • Static and dynamic reactive plant at Bundey and Buronga. **Stage 2:** • Second 275 kV circuit strung on the Robertstown – Bundey 275 kV double-circuit line. • Second 330 kV circuit strung on the Bundey – Buronga 330 kV double-circuit line. • A new 330 kV double-circuit line from Buronga to Dinawan. • A new 500 kV double-circuit line from Dinawan to Wagga Wagga operating initially at 330 kV. • Two additional new 330/275 kV transformers at Bundey. • A new 330 kV switching station at Dinawan. • Additional new 330 kV phase shifting transformers at Buronga. • Additional new 330/220 kV transformer at Buronga. • Turning the existing 275 kV line between Para and Robertstown into Tungkillo. • Static and dynamic reactive plant at Bundey, Robertstown, Buronga and Dinawan. • A special protection scheme to detect and manage the loss of either of the AC interconnectors connecting to South Australia.		
Central-West Orana REZ Transmission Link [F]	The Central West Orana REZ link includes extension of the 500 kV and 330 kV network in the Central-West Orana region of New South Wales. This REZ will also include some system strength remediation [E] as part of the build.	2025	In anticipated, actionable and progressing projects scenarios for New South Wales
Waratah Super Battery project [G]	The NSW Government is procuring a new network battery – the 'Waratah Super Battery' – dedicated to supporting the electricity transmission grid. This will be a battery energy storage system with a capacity of approximately 700 megawatts (MW); and transmission infrastructure to connect the battery to the existing Munmorah Substation within a former power station.	Beginning 2025	In anticipated, actionable and progressing projects scenarios for New South Wales
Victorian Renewable Energy Zone Development Plan – South West REZ project [H]	A project to connect the existing 500 kV Tarrone-to-Haunted Gully transmission line to the Mortlake Terminal Station. Delivered by AusNet Transmission Group Pty Ltd.	2025	Not considered in 2022 NSCAS report due to short amount of time between project announcement and report finalisation.
Victorian Renewable Energy Zone Development Plan – Western REZ project	A 250 MVA (1,000 MWs) synchronous condenser next to the Ararat Terminal.	2025	Not considered in 2022 NSCAS report due to short amount of time between project announcement and report finalisation. More relevant for System Strength and Inertia Reports, and so considered there.
Victorian Renewable Energy Zone Development Plan – Murray River REZ project	A 125 MW big battery and grid forming inverter technology near Kerang to provide system strength services.	2025	Not considered in 2022 NSCAS report due to short amount of time between project announcement and report finalisation.
HumeLink	A 500 kV transmission upgrade connecting Project EnergyConnect and the Snowy Mountains Hydroelectric Scheme to Bannaby.	2026	In anticipated, actionable and progressing projects

Transmission network upgrade	Augmentation detail	Modelling date (Calendar year) [A]	Included in assessment
			scenarios for New South Wales
Sydney Ring Northern Loop	New 500 kV loop: • A new 500 kV substation near Eraring. • A new 500 kV double-circuit line between substation near Eraring and Bayswater substation. • Two 500/330 kV 1,500 MVA transformers either at Eraring substation or new substation near Eraring.	2027	In anticipated, actionable and progressing projects scenarios for New South Wales
New England REZ transmission link	Transmission network augmentations as defined in the New South Wales Electricity Strategy [I] connecting the REZ to the transmission backbone.	2028	In anticipated, actionable and progressing projects scenarios for New South Wales

A. For some of the nearer-term projects, AEMO is aware of some delays to delivery and commissioning. However, in these cases AEMO does not consider the delays to be impactful for the purposes of system strength assessments and so the modelling dates are unchanged.
B. Consistent with the ISP this timing is when full capacity is expected to be available following commissioning and interconnector testing.
C. Consistent with the ISP this timing is when full capacity is expected to be available following commissioning and interconnector testing.
D. Consistent with the ISP this timing is when full capacity is expected to be available following commissioning and testing.
E. Consistent with the ISP this timing is when full capacity is expected to be available following commissioning and testing. However, construction and first energisation is expected in the second half of 2024, with commissioning activities and inter-network testing scheduled to follow first energisation. It is expected that Project EnergyConnect will progressively release transfer capacity from July 2024 onwards.
F. EnergyCo will build system strength remediation in some form for the CWO REZ. AEMO has included latest information on this remediation.
G. As per NSW Government's announcement at https://www.energyco.nsw.gov.au/waratah-super-battery-munmorah-site.
H. As per Victorian Government's Renewable Development Plan, at https://www.energy.vic.gov.au/__data/assets/pdf_file/0028/580618/Victorian-Renewable-energy-zones-development-plan-directions-paper.pdf.
I. NSW Electricity Strategy, at https://www.energy.nsw.gov.au/nsw-plans-and-progress/government-strategies-and-frameworks/nsw-electricity-strategy.

A2. Assumptions for voltage planning studies

AEMO's 2020 NSCAS review confirmed that in some regions of the NEM the power system is approaching the edge of its design envelope[47] and that traditional network planning assumptions used to consider network investment requirements may no longer be fit for purpose. The planning framework was originally conceived in the context of increasing maximum demand and so may not always provide the levers needed to plan for very low demand periods.

Throughout 2021, AEMO conducted a planning assumptions investigation, including consultation with TNSPs' planning and operations specialists. Table 15 provides the amended assumptions implemented to ensure the system is planned to more efficiently maintain reliability and security within manageable operational risks.

These updated planning assumptions are intended to ensure system security and reliability gaps are appropriately surfaced and allow transparent consideration of the full suite of options to address the gaps. These assumptions do not preclude the use of any particular options to address a gap. For example, pre-contingent line switching may be assessed as a solution to address a gap, along with a range of other technology-neutral options. AEMO anticipates that this assessment by TNSPs would include prudent assessment of operating risks and, as applicable, costs and benefits.

Table 15 Amended planning assumptions for voltage control studies

Topic	Previous assumption (2020 NSCAS)	Updated assumption
1. Line switching for voltage control during system normal and providing for a secure operating state	Assume one line per region can be switched out of service pre-contingent for voltage control.	Assume no pre-contingent line switching for NSCAS assessments unless there is some regionally specific justification which has been agreed with AEMO in its functions as National Planner and Market Operator. AEMO expects that line switching would be considered by the TNSP when assessing solutions to any identified voltage control needs. This assumption has been updated following a public consultation to amend AEMO's NSCAS description and quantity procedure[48].
2. Tuning voltage control plant	Use all available voltage control plant adjustments in desktop planning studies, until a secure solution is reached.	Use AEMO loadflow tuning procedure for planning study voltage control assessments. This procedure incorporates advice from the AEMO control room and from TNSPs' operations specialists. The procedure is intended to limit both "over-tuning" and "under-tuning" in planning study voltage assessments.
3. Pre-contingent reactive headroom on SVCs	Restrict pre-contingent SVC reactive ranges to those stipulated in operating manuals and guides. Where no limits are specified, SVCs can use their full reactive capabilities pre-contingent.	Align pre-contingent SVC reactive ranges applied in planning assessments to those stipulated within the relevant operating manuals and guides. Where pre-contingent SVC reactive ranges have not been specified, either restrict to the lesser of +/-50 MVAr or +/-20% of rating, or to values as advised by the TNSP/RTO. AEMO expects that the TNSP would consider tuning of relevant reactive plant when assessing solutions to any identified voltage control needs.

[47] AEMO. *2020 NSCAS Report*. December 2020, at https://www.aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/Operability/2020/2020-NSCAS-Report.

[48] AEMO. 'Network Support and Control Ancillary Services Description and Quantity Procedure'. December 2021, at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/operability/2021/nscas-description-and-quantity-procedure-v2-2.pdf?la=en.

Topic	Previous assumption (2020 NSCAS)	Updated assumption
4. Post-contingent Reactive headroom on SVCs	Allow SVCs to use full range of reactive capability after a contingency.	Unchanged.
5. Reactive power demand trends	Hold reactive power values steady, using most recent actual value.	Following advice from TNSPs and distribution network service providers (DNSPs) that reactive power demand may be changing at the same time as real power demand declines, AEMO investigated this assumption using as much available data as possible and in consultation with TNSPs, DNSPs and a university. Observed trends include declining day and night time MVAr, and overnight shifts to capacitive reactive demand, particularly for connection points which include high penetrations of residential customers. As a result, AEMO has applied the following process for reactive power projections for the 2021 NSCAS review: • Divide each region of the NEM into sub-regions. • Trend historical demand (MW and MVAr) over the five-year outlook period. • Divide seasonally and by lowest 10% minimum demand days. • Take a regression of the MVAr values to project MVAr demand for the coming five-year outlook period. • Apply projections to sub-regions where these trends show a change, and where these sub-regions are predominantly residential and commercial loads. This is then extrapolated for a further year in the 2022 NSCAS review.