2022 System Strength Report

December 2022

A report for the National Electricity Market

Important notice

Purpose

The purpose of this publication is to report on the system strength nodes and system strength standards (minimum and efficient levels) for the coming decade, and AEMO's assessment of any identified system strength shortfalls before December 2025, for the National Electricity Market. AEMO publishes this 2022 System Strength Report in accordance with clause 5.20.7 of the National Electricity Rules (NER), as amended by the National Electricity Amendment (Efficient management of system strength on the power system) Rule 2021 in accordance with clause 11.143.2(b) of the NER. 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.

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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 strength services will be crucial for ensuring a secure power system.

A new framework is now in place to drive proactive system strength solutions at scale

In October 2021 the Australian Energy Market Commission (AEMC) made its final rule determination on efficient management of system strength on the power system. This new system strength framework is intended to enable a more rapid connection of inverter-based resources (IBR) such as solar and wind, with solutions that achieve economies of scale. Under this framework, jurisdictional planning bodies for transmission will be responsible for proactive provision of system strength services, as System Strength Service Providers (SSSPs), to facilitate efficient generator and storage connections.

Under the new framework, AEMO must provide an annual assessment of system strength requirements in the NEM for the coming decade, against a new power system standard comprising:

- A minimum fault level requirement for power system security at each system strength node.
- A requirement for stable voltage waveforms at connection points to host AEMO's forecast levels of IBR (also known as the efficient level of system strength) at each system strength node.

Each NEM region's SSSP must plan to meet the standard (both minimum and efficient levels) from December 2025 onwards, in their role as SSSP. This 2022 System Strength Report provides the first of AEMO's assessments under the new framework.

AEMO is declaring system strength shortfalls and ongoing system strength standards

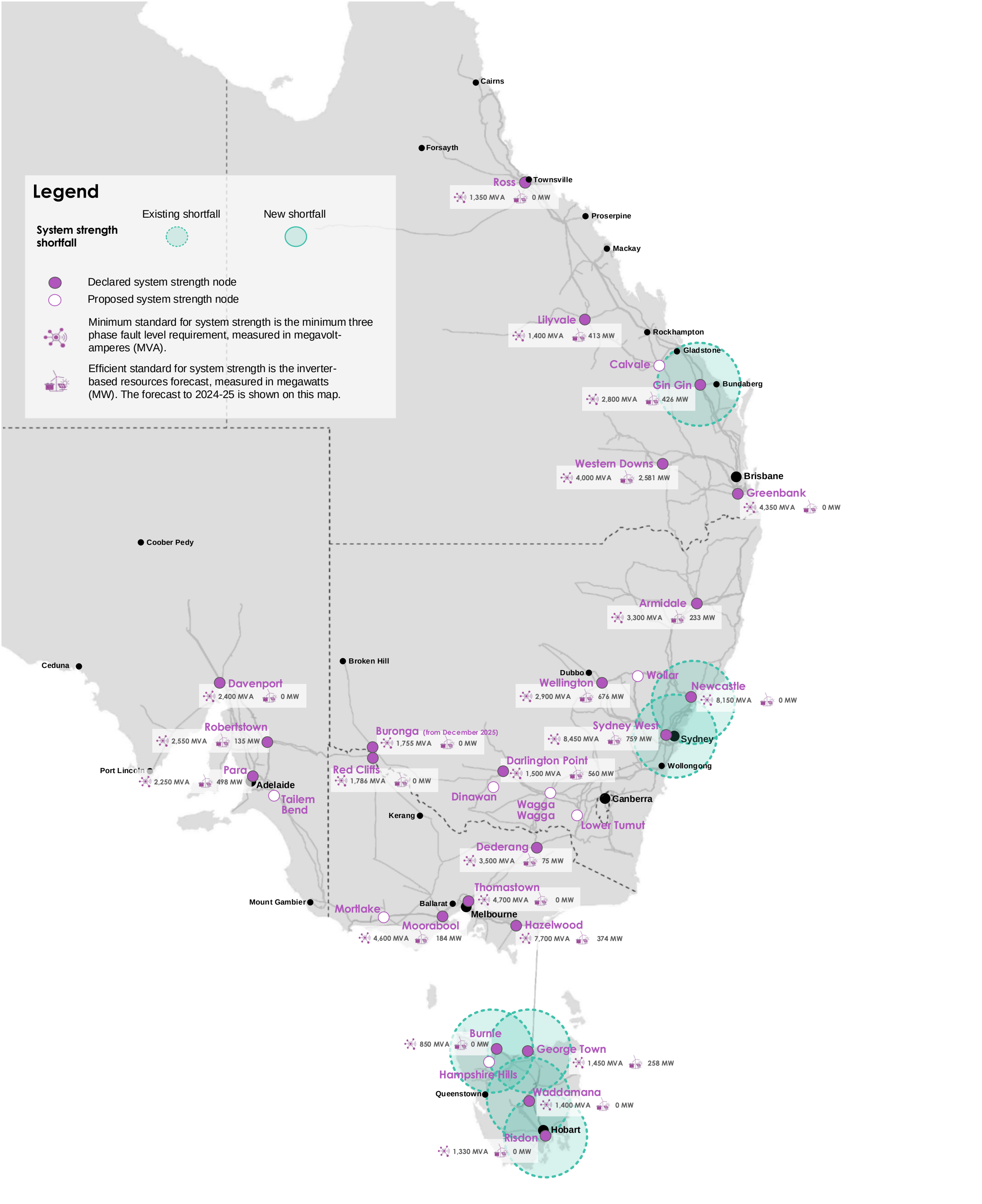
AEMO's most likely scenario is currently the *Step Change* scenario[1], which is considered by energy industry stakeholders to be the 'most likely' plausible future operating environment for the energy sector. *Step Change* sees 40% of coal-fired generation capacity in the NEM withdrawn over the next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

In this report, AEMO applies the new system strength rules framework to the generation and transmission network outcomes in the *Step Change* scenario. AEMO declares system strength nodes across the NEM, and then sets system strength standards at each node, critical planned outages affecting system strength for each region, and

[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.

some system strength shortfalls which must be met in the interim period before the full provision of services is required from December 2025. Figure 1 summarises the system strength declarations made in this report.

Figure 1 A map of the NEM showing system strength nodes, proposed new nodes, and shortfalls and standards



Significant industry effort is needed to deliver system strength

The scale of work required to deliver the system strength standards set in this report should not be underestimated. AEMO and SSSPs, as well as many other organisations across the Australian electricity sector, will need to apply concentrated effort to obtain the necessary system strength services and ensure power system security for the east coast of Australia.

The shortfalls and standards set 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. This report includes the results of a study of a 100% renewables scenario, under which the equivalent of up to 40 new synchronous condensers could be needed to meet system strength requirements.

Multiple system strength solutions are expected to be feasible as technology continues to evolve. Synchronous condensers are a proven technology today, however there are a range of other solutions which could be considered, including grid-forming inverter technologies, agreements with market participants, and conversion of existing power stations to be able to operate as synchronous condensers.

Severe supply chain limitations present risks for delivery of a range of infrastructure options. The scale of system strength needs in the future and the potential for long lead times make it clear that early engagement on system strength services will be crucial for ensuring a secure power system.

AEMO is seeking feedback on key inputs for the 2023 system strength assessments

AEMO will take a consultative approach to setting the system strength standards each year. AEMO intends for the annual System Strength Report to be used to inform future reports. Stakeholders are welcome to provide feedback to planning@aemo.com.au on the matters considered in this report. This may include feedback on:

- Proposed future system strength nodes.
- Whether planning margins should be included in minimum fault level requirement assessments.
- The criteria used to select critical planned outages.

Planning for provision of system strength services across the NEM will be one of the highest priority matters in the Australian electricity sector for the next few years. AEMO looks forward to working with SSSPs and other industry stakeholders on this matter to ensure power system security in the NEM.

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1 Introduction

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[2].

This section outlines the context for the 2022 System Strength Report:

- Trends impacting system strength assessments (Section 1.1).
- Ongoing regulatory reforms (Section 1.2).
- Relationship to other AEMO documents (Section 1.3).
- Information provided in this report (Section 1.4).

1.1 Trends impacting system strength 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[3]. This section describes how a number of these trends are relevant for the provision of system strength.

Accelerated uptake of inverter-based resources (IBR) and withdrawal of synchronous generators is creating a need for new system strength solutions

Australia is currently installing utility-scale 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 system strength has traditionally been provided by synchronous generators, and IBR generally require additional remediation to prevent adverse system strength impacts on the power system, there is an urgent need to plan for the provision of system strength services to facilitate this once-in-a-generation transformation of the power system.

[2] 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.

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

Planning is required to ensure system strength services will be available during network outages

Under the previous system strength framework, AEMO declared system strength shortfalls to be addressed by local transmission network service providers (TNSPs) for instances when fault level availability (as a proxy for system strength) was forecast to fall below minimum requirements for more than 1% of time. It was assumed that operational mechanisms, such as constraints or market interventions, could be used to ensure system strength (and system security) for the remainder of the time.

However, the assumption that operational mechanisms will be available when required can no longer be taken as a given. The NEM events in June 2022 were a stark example of the challenges of managing many concurrent directions activities in the real-time operation of the NEM. In addition, as the power system transition progresses, it can be expected that increasingly long equipment outage periods will need to be navigated and planned for as aging generators require more maintenance time and as outage periods are taken to facilitate integration of new power system elements.

Supply chain difficulties and a rapidly evolving power system will necessitate early and urgent planning for provision of system strength services

Global supply chains have been under pressure for several years, with this situation only exacerbated by the COVID-19 pandemic. Freight prices have reached unprecedented levels, with prices on key global trade routes around seven times higher than they were about two years ago. Australian importers and exporters are struggling with rising prices and a lack of space on ships[4]. In addition, worldwide demand for many key resources for electricity infrastructure has increased markedly and this trend is expected to continue[5]. Anecdotal reports indicate that queuing times for manufacture of high-voltage equipment have doubled.

It is reasonable to assume that some system strength services will include import of synchronous condensers from overseas manufacturers. To facilitate an efficient energy transition, it will be prudent to start these infrastructure projects as soon as possible.

However, it is unlikely that synchronous condensers will form the only system strength service provision mechanism. A variety of innovative solutions will be required, including grid-forming inverters, retrofitting existing generators to operate in synchronous condenser mode, and contractual arrangements with market participants. To enable the ongoing energy transformation, a variety of system strength solutions across all NEM stakeholders will need to be facilitated.

1.2 Ongoing regulatory reforms

AEMO has prepared this report consistent with the new system strength framework, in accordance with transitional rules. Two key regulatory reforms are relevant for the system strength assessments – the new system strength rules framework in effect from 1 December 2022, and the ongoing rule change consideration by the AEMC for an operational security mechanism in the NEM.

[4] Australian Industry Group, Supply chains state of play, at https://www.aigroup.com.au/globalassets/news/reports/2021/supply_chains_state_of_play_dec2021.pdf.

[5] Minerals Council of Australia, Commodity demand outlook 2030, at https://www.minerals.org.au/sites/default/files/Commodity%20Outlook%202030.pdf.

A new system strength rules framework is now in place

This report is the first of AEMO's annual system strength reports published under the new system strength framework which came into effect on 1 December 2022[6]. AEMO has prepared this report consistent with the new rules framework, and with version 2.0 of the System Strength Requirements Methodology released by AEMO in September 2022 in response to the new rules framework following extensive industry consultation[7]. This report covers the new system strength standard required for system strength nodes in the NEM.

AEMO is continuing to consult on amendments to the System Strength Impact Assessment Guidelines to complete the updates required to AEMO's system strength instruments to implement the new rules framework. These guidelines will include, among other things, new minimum access standards for relevant generators, loads and market network service providers, and arrangements for a new system strength charging mechanism.

AEMO expects that as System Strength Service Providers (SSSPs) develop and implement system strength services across the NEM, updates will be required to the system strength assessments provided in these reports in order to reflect the most up to date state of system strength in the power system.

Market bodies are consulting on an operational security mechanism for the NEM

In September 2022 the AEMC released its draft determination on a rule to establish an 'operational security mechanism' to value, procure and schedule security services in the NEM in the operational timeframe. Among other elements, the mechanism would improve the process for scheduling system security service provision. This could include scheduling of service arrangements made by SSSPs when delivering system strength services to meet the new system strength standards.

AEMO and the AEMC are continuing to consult on design and implementation for the mechanism, including through consultation with transmission network service providers and market participants. It is expected that the mechanism would begin operation on 1 October 2025.

1.3 Relationship to other AEMO documents

The annual system strength 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 TNSPs.

In 2020 the annual system strength report was published as part of the 2020 System Strength and Inertia Reports. In 2021, it was published in the 2021 System Security Reports, which also incorporated the inertia report and the Network Support and Control and Ancillary Services (NSCAS) report.

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

Table 1 shows the AEMO reports and processes which are related to the system strength reports.

[6] AEMC. Rule determination. National Electricity Amendment (Efficient management of system strength on the power system) Rule 2021. October 2021, at https://www.aemc.gov.au/rule-changes/efficient-management-system-strength-power-system.

[7] AEMO. System Strength Requirements Methodology version 2. September 2022, at https://aemo.com.au/consultations/current-and-closed-consultations/ssrmiag.

Table 1 AEMO reports and processes related to the System Strength 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
Network Support and Control Ancillary Services (NSCAS) Report	Annual assessment of system security needs and gaps for each NEM region, excluding system strength and inertia.	5	https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/system-security
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 conditions, including 100% instantaneous penetration of renewables.	10	https://aemo.com.au/en/initiatives/major-programs/engineering-framework
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

1.4 This report

The following system strength assessment information can be found in this report:

- Regulatory requirements for this report (Section 2).
- Method and inputs applied to prepare the system strength assessments in this report (Section 3).
- System strength outcomes for each region, comprising system strength nodes, minimum fault level requirements, IBR forecasts, fault level projections and system strength shortfalls declared before December 2025, and critical planned outages for system strength (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, network and market modelling assumptions (Appendix A1).
- Details for electromagnetic transient analysis (EMT) assessments completed for minimum fault level requirements (Appendix A2).
- A description of the translation of the minimum fault level requirements to real time operations (Appendix A3).

2 Regulatory requirements

Under the new regulatory framework[8], AEMO must publish the system strength requirements annually by 1 December. These requirements set the system strength standard, under National Electricity Rules (NER) 5.20C.1(c), for each system strength node and include:

- The minimum three phase fault level for the upcoming year commencing 2 December, to be used for the purposes of maintaining power system security.
- AEMO's forecast for each of the next 10 years of:
  - the minimum three phase fault level; and
  - the projected level and type of IBR and market network service facilities, to be used by SSSPs for the purposes of meeting the system strength standard specification under NER S5.1.14.

The minimum fault level requirement should be set such that:

- There is sufficient fault level to enable protection systems of transmission networks, distribution networks, Transmission Network Users and Distribution Network Users to operate correctly (NER S5.1a.9(a)).
- There is sufficient fault level to enable stable operation of voltage control devices, such as capacitor banks, reactors and dynamic voltage control equipment in accordance with the applicable Australian Standard (AS/NZ 61000.3.7:2001) which provides voltage step change limits for switching of capacitor banks or reactors while remaining stable.
- There is sufficient fault level at the system strength node for the power system to remain stable following any credible contingency event or protected event.

AEMO interprets the phrase 'power system to remain stable' in NER S5.1a.9(a)(3) to mean 'stable conditions' consistent with the definition of a satisfactory operating state under NER 4.2.2(f), which must be maintained following any credible contingency event or protected event. This element of the minimum fault level requirement includes the fault level required for the present level of IBR to operate[9] without succumbing to converter-based instability[10]. Over the coming years, it is envisaged that the efficient level of system strength (NER S5.1a.9(b)) will be the primary vehicle for system strength to support IBR.

For existing system strength nodes, AEMO will take the existing requirement as a starting point for the minimum three phase fault level assessment. Any material changes[11] to the power system for each region are considered and may impact the fault level requirements. New nodes will be assessed under all elements of the minimum fault level requirement criteria.

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[8] The AEMC's rule change National Electricity Amendment (Efficient management of system strength on the power system) Rule 2021 No.11, introduced clause 11.143.2(b).

[9] Operate should not be taken to mean operate at full capacity all times.

[10] Power System Stability Guidelines section A.1.6, AEMO, at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/power-system-stability-guidelines.pdf?la=en.

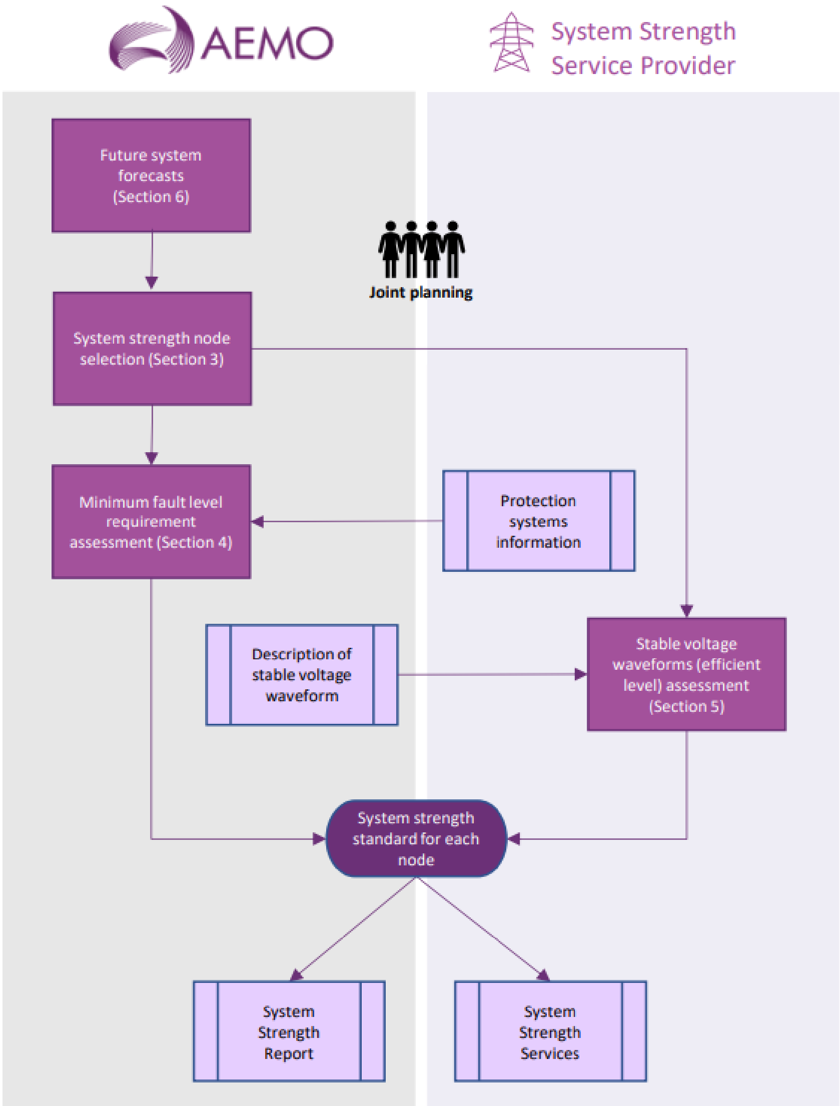
[11] 2022 System Strength Requirements Methodology section 4.1, AEMO, at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-strength-requirements/system-strength-requirements-methodology.pdf?la=en.

AEMO must also publish a 10-year IBR forecast for each system strength node declared. This forecast is to be used by the regional SSSP for the purposes of meeting the system strength standard specification under NER S5.1.14 to ensure stable voltage waveforms at connection points (also known as the efficient level of system strength) as outlined in the System Strength Requirements Methodology (SSRM).

Consistent with the new framework, in the 'transition period' between 1 December 2022 and 1 December 2025, AEMO will continue to publish fault level projections and declare shortfalls as necessary for each node out to 1 December 2025[12]. SSSPs must provide solutions to AEMO to any declared shortfalls in this period.

All information relevant to the system strength standard for each node is provided in this report. In September 2022 AEMO published an amended SSRM incorporating the new system strength framework. Figure 2 shows the division of responsibility between AEMO and the SSSP under the rules for preparation of the assessments provided in the annual System Strength Report.

Figure 2 System Strength Requirements Methodology overview



[12] See clause 11.143.14, outlining the transitional arrangements for declaration of shortfalls before December 2025, introduced by National Electricity Amendment (Efficient management of system strength on the power system) Rule 2021 No.11.

3 Method and inputs

This section details the method applied to perform the analysis for the 2022 System Strength Report. It also provides the key inputs and assumptions applied, such as *Integrated System Plan* (ISP) scenario selection, committed and anticipated projects, and period of declarations.

AEMO has prepared this report consistent with the System Strength Requirements Methodology v2.0 (SSRM). The SSRM was released in September 2022 following extensive consultation with stakeholders, and incorporates the requirements of the new system strength framework[13].

3.1 Method

System strength node selection

AEMO has maintained the existing system strength nodes in the 2022 System Strength Report, except for the New South Wales region where the Buronga 220 kilovolts (kV) node is formally declared, with a start date of 2 December 2025.

AEMO is seeking feedback from all stakeholders on possible declarations of future nodes such as Calvale in Queensland, Mortlake in Victoria, Tailem Bend in South Australia and Hampshire Hills in Tasmania. These nodes are suggested by the SSSPs for better application of the system strength standard set out in the 2022 SSRM.

The system strength standard is applied to each system strength node. Minimum fault level requirements are to be determined and projected as well as forecast IBR associated with each node for a 10-year horizon. Additionally, fault level shortfalls may be declared until 1 December 2025.

Minimum fault level requirement projections

AEMO has maintained existing minimum fault level requirements across the NEM (except for the new Buronga node). For each region, the timing of material changes is identified and their potential effect on the requirement is flagged. This allows the SSSP to plan for any changes to the requirements at the node necessary to ensure power system security. Additional information such as protection scheme operation and design, requirements for voltage control equipment operation, and any fit for purpose power system analysis required to respond to material changes on the power system, may also be required to assess any future changes to the minimum fault level requirements.

IBR forecast

AEMO projects the forecast IBR associated with each node (electrically closest) for the 10-year horizon to allow the SSSP to plan for delivering the efficient level of system strength required to host this IBR. The forecast is broken down into technology types. The forecast is consistent with the 2022 ISP *Step Change* scenario results and the Central scenario demand forecast from the 2022 *Electricity Statement of Opportunities* (ESOO), but has

[13] Version 2.0 of the SSRM is available on AEMO's website at https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/system-security-planning. The consultation materials for the amendments made to incorporate the new system strength framework and are accessible at https://aemo.com.au/consultations/current-and-closed-consultations/ssrmiag.

been updated to include committed and anticipated projects from the 22 July 2022 Generation Information page[14]. Consistent with the ISP, the IBR forecast includes the majority of new generation being forecast to connect in designated renewable energy zones (REZs) across the NEM. In some cases, post-model adjustments have been made to incorporate information provided by the relevant SSSP.

Shortfall declarations out to December 2025

As part of the transition to the new rules framework, AEMO must continue to project fault levels for each system strength node and declare any shortfalls out to 1 December 2025[15]. To determine if a fault level shortfall is present, AEMO forecasts the fault level typically available at each system strength node of the NEM against their respective requirements for every 30-minute dispatch interval. AEMO has assessed shortfalls based on the 99th percentile results of the selected market modelling projection.

Although required to project fault levels and shortfalls to 1 December 2025, consistent with the 2021 System Security Reports, AEMO has completed these projections out to 1 July 2028 (a five-year horizon) for this report. The projections beyond December 2025 are provided for information purposes only.

3.2 Key inputs and assumptions

Demand outlook

The system strength assessments are prepared[16] using the latest 2022 ESOO Central scenario 50% probability of exceedance (50POE) minimum demand projection[17].The 2022 ESOO projects declining minimum demand values for many regions of the NEM. However, the 2022 Central scenario has a higher underlying demand than the previous year forecast.

Figure 3 below shows the differences in the minimum demand projections used in the 2021 and 2022 system strength assessments[18].

[14] AEMO. NEM Generation Information, at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information.

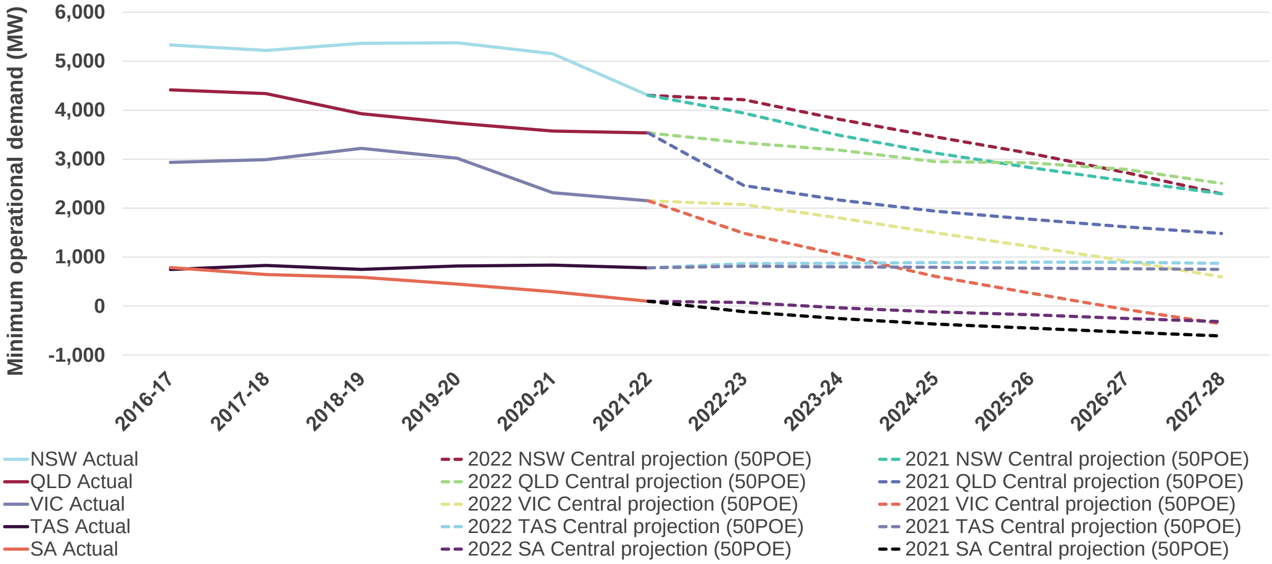
[15] AEMC. National Electricity Amendment (Efficient management of system strength on the power system) Rule 2021 No.11, including clause 11.143.14 outlining the transitional arrangements for declaration of shortfalls before December 2025.

[16] 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.

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

[18] No min demand assessment was performed in Tasmania and hence it is not included in this figure. See Section 4.4 for details.

Figure 3 Minimum demand projections used in 2021 and 2022 system strength reviews



Generation outlook

Building on the 2022 ISP outcomes, the projected generation dispatch in this report follows the *Step Change* scenario and is the basis for projections of minimum fault level requirements, IBR forecasts and shortfall declarations. The majority of new generation is forecast to connect in REZs across the NEM. In addition to this assessment, AEMO has conducted a 100% renewable energy sensitivity for a minimum demand snapshot of the system, the results of which are used to highlight potential system security issues in the event the NEM transitions faster towards 100% instantaneous renewable energy penetration.

Table 2 summarises the use of key inputs for market modelling projections prepared for this report. Appendix A1 has further details.

Table 2 Key inputs for market modelling projections

Input	*Step Change* assessment for this report
Generator withdrawal and operation	Generator withdrawal consistent with the 2022 Final ISP *Step Change* scenario results.
New generation connections	Committed and anticipated generation per the latest NEM Generation Information. IBR projections from *Step Change* results were added into the time-sequential modelling used to project fault levels for the 5-year horizon and the 10-year forecasts.
Transmission network projects	Committed, anticipated and actionable ISP transmission network augmentation projects were included consistent with 2022 ISP commissioning dates. See Appendix A1.2 for further detail. The recently announced Victorian Renewable Energy Zone Development Plan projects in Western Victoria were committed post analysis and could not be included this year.
Minimum unit requirements for system security	All minimum unit requirements were removed, to allow the projections to be assessed, except for the South Australia assumption that two units will be kept on until Project EnergyConnect (PEC) is commissioned.
Demand forecast	Apply 2022 ESOO Central projection for the *Step Change* scenario for demand (which differs from the 2022 ISP *Step Change* scenario for demand).

A. AEMO's NEM Generation Information, at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information.

4 System strength requirements

This section defines the system strength standard specification applicable to each node, in each region of the NEM for the 10-year planning horizon, as well as any shortfalls before December 2025.

For each region, this section details:

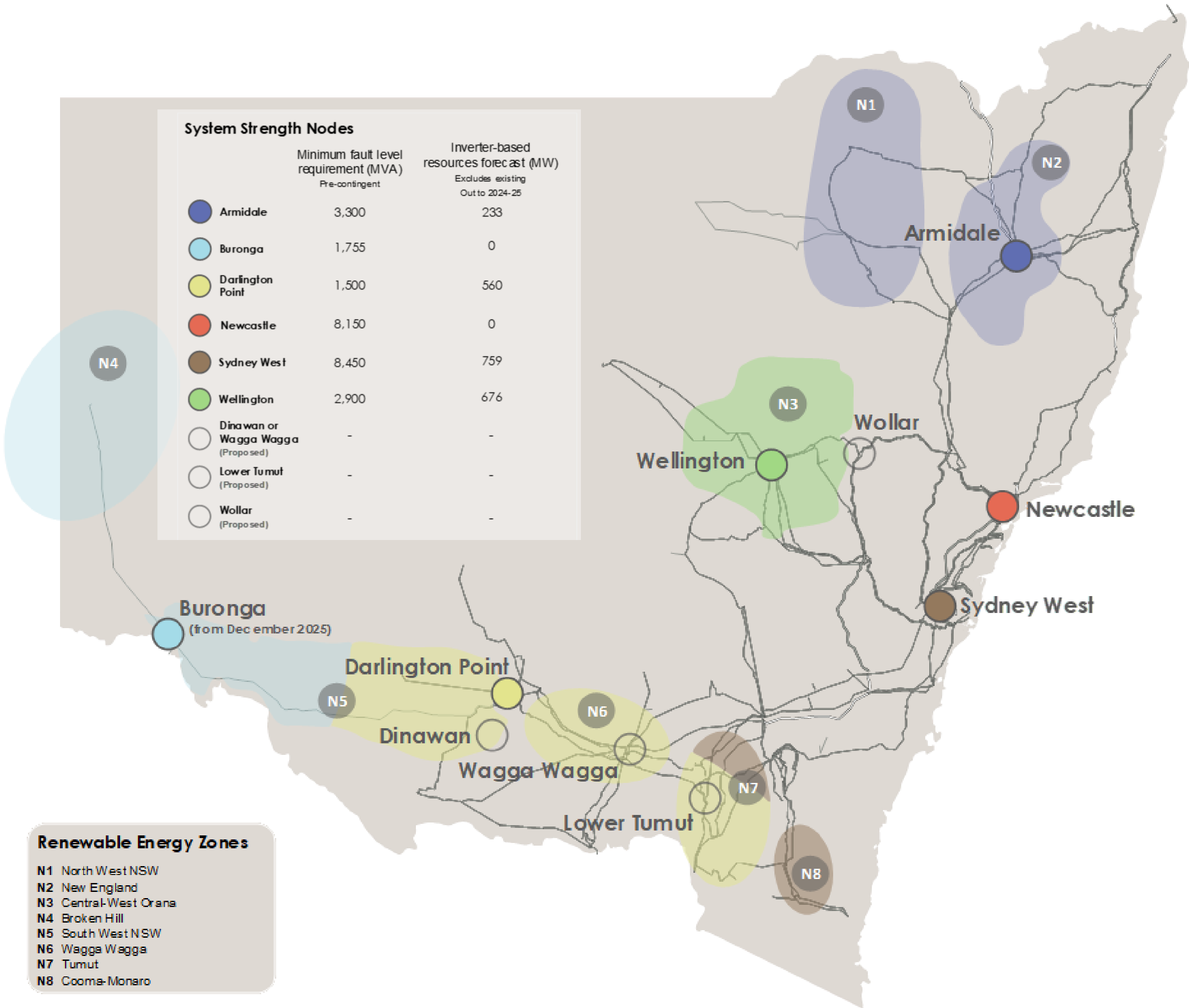
- Supply and demand outlook for the region.
- Existing minimum fault level requirements for each system strength node.
- A 10-year minimum fault level requirement forecast for each region.
- A 10-year IBR forecast for each region.
- Five-year fault level projections for each system strength node, and shortfall assessment to December 2025.
- Defined critical planned outages for each region.

4.1 New South Wales

Existing minimum fault level requirements in New South Wales have remained unchanged in this report. However, a new node and an associated system strength standard have been declared at Buronga, to apply from December 2025. Shortfalls at Newcastle and Sydney West from 1 July 2025 retain the same timing as per the Update to the 2021 System Security Reports, however the magnitudes of the shortfalls are projected to be slightly lower.

Figure 4 shows the system strength nodes and system strength standards for New South Wales.

Figure 4 System strength node location and system strength standard[A,B] in New South Wales



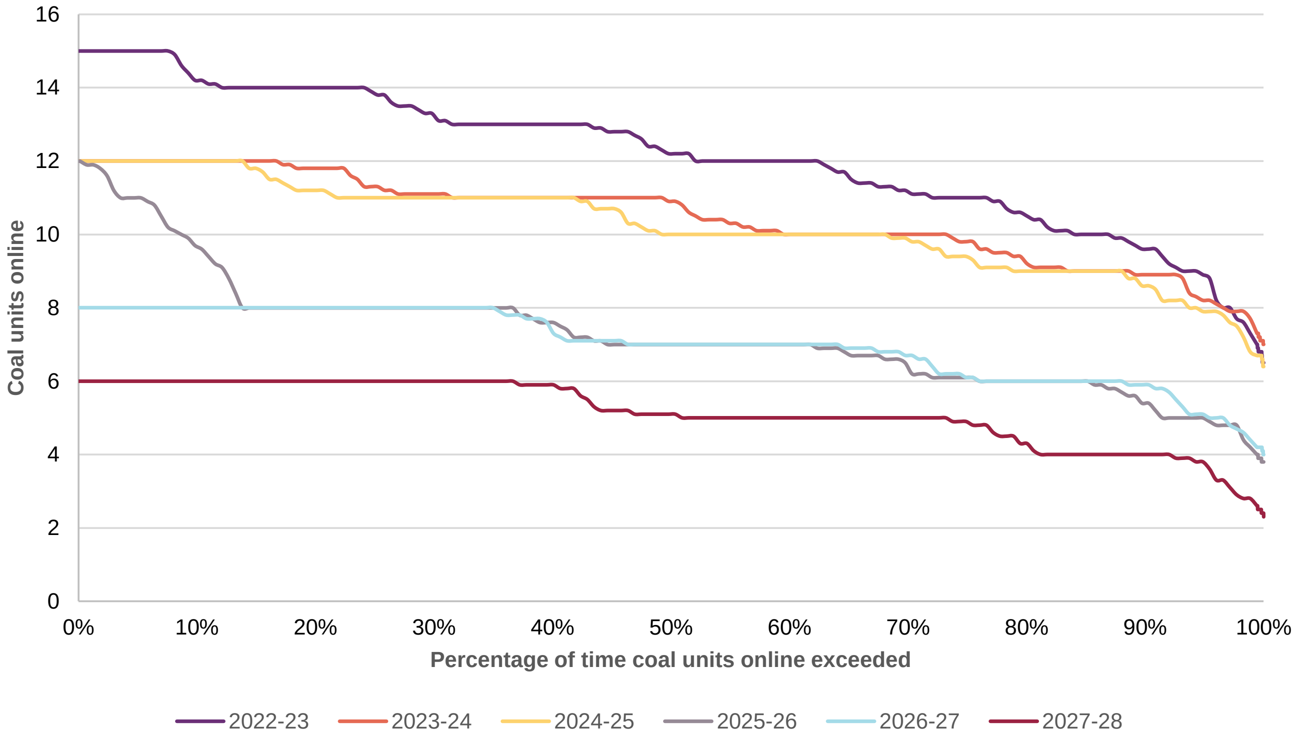
A. Renewable energy zones are mapped to show where the majority of forecast IBR are expected, consistent with the ISP.
B. No offshore wind renewable energy zones have been shown in this figure as projected establishment of these renewable energy zones occurs outside the 10-year forecast in the ISP.

System strength provision is particularly pressured in the context of low demand on the power system and decline of available sources of traditional service provision such as synchronous generators.

Minimum operational demand (sent-out[19]) for New South Wales is forecast to decrease by approximately 2,190 megawatts (MW) between 2022-23 and 2027-28 in the 2022 ESOO Central projection (*Step Change)*. Further details are available in Section 3.2.

The number of coal generators projected to be online in New South Wales across the year is forecast to decline significantly from 2025-26 onwards, as shown in Figure 5.

Figure 5 Number of coal units projected online under *Step Change* scenario, New South Wales



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[19] Refers to power provided by generating units to meet electrical demand, it does not include the power used to operate the generating unit.

4.1.1 System strength nodes

AEMO declares five system strength nodes in New South Wales effective from 1 December 2022, as listed in Table 3. These nodes are the same as the nodes declared in 2021. A new Buronga node has been declared in light of system strength issues present in the Southwest New South Wales region near the West-Murray area, effective 2 December 2025.

AEMO is also considering possible future system strength nodes in New South Wales as noted in Table 3. These nodes may be declared in the 2023 System Strength Report, subject to any feedback received and ongoing transformation of the power system.

Table 3 System strength nodes in New South Wales for the 2022 system strength report

System strength node	Voltage and busbar [A]	Start date	End date
Armidale	330 kV Bus 1	Existing	Not defined
Buronga	220 kV Bus 1	Declared 2 December 2025	Not defined
Darlington Point	330 kV Bus 1	Existing	Possibly upon declaration of another Southwest node
Newcastle	330 kV Bus 1	Existing	Not defined
Sydney West	330 kV Bus 1	Existing	Not defined
Wellington	330 kV Bus 1	Existing	Possibly upon declaration of another Central West Orana Renewable Energy Zone-related node

A. Bus 1 of the system strength node is selected by default. Alternative buses may be selected on a case-by-case basis.

Table 4 Possible future nodes in New South Wales region and closures of existing nodes

System strength node	Voltage and busbar	Start date	End date	Purpose of new node
Dinawan or Wagga Wagga	330 kV Bus 1	Upon completion of PEC	Not defined	This node may provide better locations for location of forecast IBR in Southern New South Wales as it connects. It may also provide a node suitable for assessing critical planned outages on the interconnector with other regions.
Lower Tumut	330 kV Bus 1	May start from post-Eraring Power Station retirement	Not defined	This node may provide a node for major synchronous generation sources in New South Wales as conventional coal units retire. It may also provide a node suitable for assessing critical planned outages on the interconnector with other regions.
Wollar	330 kV Bus 1	Upon closure of Wellington node	Not defined	This node may provide better locations for location of forecast IBR in Central West Orana as it connects.

4.1.2 Minimum three phase fault level requirements

Aside from setting a minimum fault level requirement for the new Buronga node, the New South Wales system strength nodes and their minimum three phase fault level requirements are unchanged from those provided in the 2021 System Security Reports. Table 5 provides the minimum three phase fault level requirements applicable for each system strength node for the coming year, for which the pre-contingent fault levels should be maintained for an intact system-normal power system[20].

Table 5 New South Wales 2022 minimum three phase fault level requirements

System strength node	2022 minimum fault level requirements (MVA)		Comments
	Pre-contingency	Post-contingency	
Armidale 330 kV	3,300	2,800	Existing requirement [A].
Buronga 220 kV	1,755	To be determined.	AEMO has set the pre-contingent value for the Buronga node consistent with 2022 EMT assessment completed for the New South Wales region (details are provided in Appendix A2) and per advice from Transgrid regarding correct operation of protection systems and voltage control equipment. This node start date is December 2025. AEMO will work with Transgrid to finalise both the pre- and post-contingency values with Transgrid before the node start date.
Darlington Point 330 kV	1,500	600 [C]	Existing requirement [A]
Newcastle 330 kV	8,150	7,100	Existing requirement [A]
Sydney West 330 kV	8,450	8,050	Existing requirement [A]
Wellington 330 kV	2,900	1,800	Existing requirement [A]

A. 2020 *System Strength and Inertia Report*, at aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/planning-for-operability.
B. Refer to Appendix 2.2.2 for further details about the EMT analysis. This minimum three phase fault requirement has been informed by not only the EMT analysis, but also protection system and voltage control system advice from the SSSP, consistent with the SSRM.
C. The Darlington Point post-contingency fault level requirement does not include the impact of further network rearrangements needed to re-secure the power system for particular credible contingencies. Secure operation of the power system may require lower fault level values in some situations.

Consistent with the SSRM, AEMO has considered whether material changes to the power system have occurred which would affect the minimum fault level requirement, as well as material changes which may occur over the forecasting period. Table 6 provides the projections for the minimum fault level requirements, including noting potential material changes (denoted by a letter), and Table 7 provides some consideration of those potential material changes.

[20] As per NER S5.1.14(a), page 74, at https://www.aemc.gov.au/sites/default/files/2021-10/ERC0300%20-%20Final%20rule%20-%20in%20mark%20up%20format%20%28%2020.10.21%29%20-%20final.pdf.

Table 6 Pre- and post-contingent minimum fault level requirement projections for the decade ahead (MVA)

		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Armidale 330 kV	Pre-contingent	3,300	3,300	3,300	3,300	3,300[C]	3,300 [C,G]	3,300 [C,G]	3,300 [C,G]	3,300 [C,G]	3,300 [C,G]	3,300 [C,G]
	Post-contingent	2,800	2,800	2,800	2,800	2,800[C]	2,800[C,G]	2,800[C,G]	2,800[C,G]	2,800[C,G]	2,800[C,G]	2,800[C,G]
Buronga 220 kV	Pre-contingent	N/A	N/A	1,755[B]	1,755[B]	1,755[B]	1,755[B,F,G]	1,755[B,F,G]	1,755[B,F,G]	1,755[B,F,G]	1,755[B,F,G]	1,755[B,F,G]
	Post-contingent	N/A	N/A	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC
Darlington Point 330 KV	Pre-contingent	1,500	1,500	1,500[B]	1,500[B]	1,500[B]	1,500[B,D,F,G]	1,500[B,D,F,G]	1,500[B,D,F,G]	1,500[B,D,F,G]	1,500[B,D,F,G]	1,500[B,D,F,G]
	Post-contingent	600	600	600[B]	600[B]	600[B]	600[B,D,F,G]	600 [B,D,F,G]	600 [B,D,F,G]	600 [B,D,F,G]	600 [B,D,F,G]	600 [B,D,F,G]
Newcastle 330 kV	Pre-contingent	8,150	8,150	8,150	8,150	8,150	8,150[EG]	8,150[EG]	8,150[EG]	8,150[EG]	8,150[EG]	8,150[EG]
	Post-contingent	7,100	7,100	7,100	7,100	7,100	7,100[E,G]	7,100[E,G]	7,100[E,G]	7,100[E,G]	7,100[E,G]	7,100[E,G]
Sydney West 330 kV	Pre-contingent	8,450	8,450	8,450	8,450	8,450[H]	8,450[D,F,G,H]	8,450[D,F,G,H]	8,450[D,F,G,H]	8,450[D,F,G,H]	8,450[D,F,G,H]	8,450[D,F,G,H]
	Post-contingent	8,050	8,050	8,050	8,050	8,050[H]	8,050[D,F,G,H]	8,050[D,F,G,H]	8,050[D,F,G,H]	8,050[D,F,G,H]	8,050[D,F,G,H]	8,050[D,F,G,H]
Wellington 330 kV	Pre-contingent	2,900	2,900	2,900[A]	2,900 [A]	2,900 [A]	2,900 [A,G]	2,900 [A,G]	2,900 [A,G]	2,900 [A,G]	2,900 [A,G]	2,900 [A,G]
	Post-contingent	1,800	1,800	1,800[A]	1,800[A]	1,800[A]	1,800[A,G]	1,800[A,G]	1,800[A,G]	1,800[A,G]	1,800[A,G]	1,800[A,G]

Note: Grey shading indicates the time that AEMO determines the fault levels should not change based on the forecast. A letter indicates where a material change may trigger an investigation when appropriate models and parameters are available. Material changes are shown in Table 7 and are linked to the relevant letter in this table.

Table 7 New South Wales material changes which may impact the minimum fault level requirement

Financial year	Letter	Material change	Node primarily affected	Protection requirements	Voltage step change requirement	Power system stability	Comments
2023		-					
2024		-					
2025	A	Central West Orana REZ 500V lines and system strength solution in 2025	Wellington 330 kV	No updated information available at time of writing.	Fault level required for existing static reactive devices, but this requirement should not increase from current requirement.	No comments.	Reduction of network impedance combined with synchronous condensers installed as part of the network upgrade will likely lead to fewer synchronous generators required to meet existing minimum fault level. Fit for purpose studies may be needed to consider the minimum fault level requirement.
2025	B	PEC in service	Buronga 220 kV, Darlington point 330 kV	No updated information available at time of writing.	Fault level required for existing static reactive devices, but this requirement should not increase from current requirement.	No comments.	Reduction of network impedance combined with synchronous condensers installed as part of PEC will likely lead to fewer synchronous generators required to meet existing minimum fault level. Fit for purpose studies may be needed to consider the minimum fault level requirement.
2027	C	New England Renewable Energy Zone 500V lines and system strength solution in 2027	Armidale 330 kV	No updated information available at time of writing.	Fault level required for existing static reactive devices, but this requirement should not increase from current requirement.	No comments.	Reduction of network impedance will likely lead to fewer synchronous generators required to meet existing minimum fault level. Fit for purpose studies may be needed to consider the minimum fault level requirement.
2027	H	Sydney Ring - Northern Loop	Newcastle 330 kV, Sydney West 330 kV	No updated information available at time of writing.	Fault level required for existing static reactive devices, but this requirement should not increase from current requirement.	No comments.	Reduction of network impedance will likely lead to fewer synchronous generators required to meet existing minimum fault level. Fit for purpose studies may be needed to consider the minimum fault level requirement..
2028	D	HumeLink in service	Darlington Point 330 KV, Sydney West 330 kV	No updated information available at time of writing.	Fault level required for existing static reactive devices, but this requirement should not increase from current requirement.	No comments.	Reduction of network impedance will likely lead to fewer synchronous generators required to meet existing minimum fault level. Fit for purpose studies may be needed to consider the minimum fault level requirement.

Financial year	Letter	Material change	Node primarily affected	Protection requirements	Voltage step change requirement	Power system stability	Comments
2028	E	SNW Northern 500 kV Loop	Newcastle 330 kV	No updated information available at time of writing.	Fault level required for existing static reactive devices, but this requirement should not increase from current requirement.	No comments.	Reduction of network impedance will likely lead to fewer synchronous generators required to meet existing minimum fault level. Fit for purpose studies may be needed to consider the minimum fault level requirement.
2028	F	VNI West in service	Darlington Point 330 kV, Buronga 220 kV Sydney West 330 KV	No updated information available at time of writing.	Fault level required for existing static reactive devices, but this requirement should not increase from current requirement.	No comments.	Reduction of network impedance will likely lead to fewer synchronous generators required to meet existing minimum fault level. Fit for purpose studies may be needed to consider the minimum fault level requirement.
2028	G	Synchronous generation retirements	All nodes	No updated information available at time of writing.	Fault level required for existing static reactive devices, but this requirement should not increase from current requirement.	No comments.	Retirement of synchronous generators may mean that system strength in NSW is delivered by other means elsewhere in the region. This may affect minimum fault level requirements throughout the region. Studies are required to ensure power system will remain stable.
2029		-					
2030		-					
2031		-					
2032		-					
2033		-					

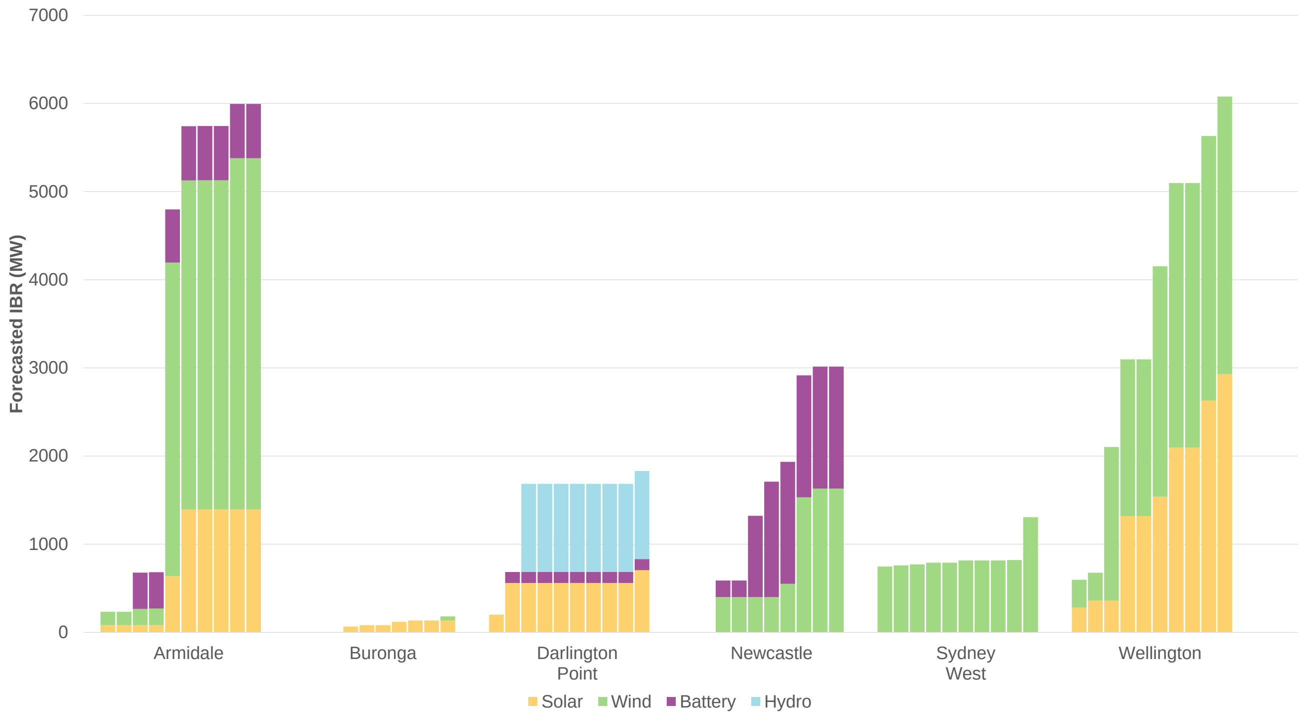
4.1.3 IBR projections

AEMO's 10-year forecast of the level and type of IBR, including IBR-based market network service facilities (MNSF), is listed in Figure 6 and Table 8. This forecast is provided for each system strength node.

AEMO's projection allocates the forecast of utility-scale IBR generation to the nearest system strength node over the coming decade. The data is provided by technology type. The forecast is consistent with the 2022 ISP *Step Change* scenario results[21] and the Central scenario demand forecast from the 2022 ESOO[22] but has been updated to include committed and anticipated projects from the 22 July 2022 Generation Information page[23]. AEMO has also incorporated input from the local SSSP where appropriate.

EnergyCo has been established as the New South Wales Infrastructure Planner for Renewable Energy Zones as part of the New South Wales Electricity Infrastructure Roadmap[24]. AEMO expects that EnergyCo and Transgrid, the SSSP responsible for providing system strength services to meet the system strength standards in New South Wales, will engage in joint planning to provide the efficient level of system strength to host future IBR in NSW.

Figure 6 10-year forecast level and type of IBR[A] and MNSF[B] by system strength node, New South Wales[C]



A. Refer to Table 8 footnote B for why hydro generation is included in this forecast.
B. No MNSFs have been included in this forecast.
C. The near-term years of the forecast may require adjustment by the SSSP when preparing system strength services, as more information becomes available about newly-committed IBR and MNSF.

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21 2022 *Integrated System Plan*, page 9, AEMO, at https://aemo.com.au/-/media/files/major-publications/isp/2022/2022-documents/2022-integrated-system-plan-isp.pdf?la=en.

22 2022 *Electricity Statement of Opportunities*, page 34, AEMO, at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2022/2022-electricity-statement-of-opportunities.pdf?la=en.

23 NEM Generation Information, AEMO, at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information.

24 Electricity Infrastructure Investment Act No. 44 2020 (NSW), at https://legislation.nsw.gov.au/view/html/inforce/current/act-2020-044.

Table 8 Forecast level and type of IBR and MNSF for the next 10 years[A]

System strength node	Technology	Existing IBR	Forecast IBR (MW) [B]										
			Financial year ending										
			2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Armidale	Solar	601	0	80	80	80	80	638	1393	1394	1394	1395	1395
	Wind	442	0	164	164	197	201	3569	3734	3734	3734	3984	3984
	Battery	0	0	0	0	412	412	603	616	616	616	616	616
	Total IBR	**1031**	**0**	**233**	**233**	**677**	**682**	**4798**	**5742**	**5744**	**5744**	**5995**	**5995**
Buronga	Solar	502	N/A	N/A	0	0	65	81	81	120	134	134	134
	Wind	198	N/A	N/A	0	0	0	0	0	0	0	0	45
	Battery	0	N/A	N/A	0	0	0	0	0	0	0	0	0
	Total IBR	**698**	**N/A**	**N/A**	**0**	**0**	**65**	**81**	**81**	**120**	**134**	**134**	**179**
Darlington Point	Solar	1100	0	177	540	540	540	540	540	540	540	540	706
	Wind	0	0	0	0	0	0	0	0	0	0	0	0
	Battery	0	0	0	125	125	125	125	125	125	125	125	125
	VSD Hydro [C]	0	0	0	0	1000	1000	1000	1000	1000	1000	1000	1000
	Total IBR	**1100**	**0**	**177**	**665**	**1665**	**1665**	**1665**	**1665**	**1665**	**1665**	**1665**	**1831**
Newcastle	Solar	0	0	0	0	0	0	0	0	0	0	0	0
	Wind	0	0	0	0	395	395	395	400	550	1531	1631	1631
	Battery	0	0	0	0	188	188	922	1309	1384	1384	1384	1384
	Total IBR	**0**	**0**	**0**	**0**	**583**	**583**	**1317**	**1709**	**1934**	**2916**	**3015**	**3015**
Sydney West	Solar	10	0	0	0	0	0	0	0	0	0	0	0
	Wind	1195	0	774	774	785	804	804	815	815	815	820	1307
	Battery	50	0	0	0	0	0	0	0	0	0	0	0
	Total IBR	**1255**	**0**	**774**	**774**	**785**	**804**	**804**	**815**	**815**	**815**	**820**	**1307**
Wellington	Solar	850	0	285	365	365	1324	1324	1538	2096	2096	2630	2928
	Wind	250	0	316	316	1743	1778	1778	2616	3001	3001	3001	3151
	Battery	0	0	0	0	0	0	0	0	0	0	0	0
	Total IBR	**1100**	**0**	**601**	**681**	**2108**	**3102**	**3102**	**4154**	**5097**	**5097**	**5631**	**6079**

A. The near-term years of the forecast may require adjustment by the SSSP when preparing system strength services, as more information becomes available about newly-committed IBR and MNSF.
B. This forecast includes utility-scale IBR only, consistent with ISP Step Change scenario modelling. Distributed Energy Resources, including rooftop PV, are not included. As per the SSRM, SSSPs may in some cases propose to include system strength to facilitate synchronism of DER as part of assessing what is required to achieve stable operation of projected IBR. For this purpose, DER capacity forecasts are published in AEMO's Inputs, Assumptions and Scenarios Report, available via https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp/current-inputs-assumptions-and-scenarios.
C. VSD Hydro stands for hydrogeneration connected via Variable Speed Drive. Snowy 2.0 power station will consist of six units that can generate 2,000 MW. Three units will be synchronous (fixed) speed and three will be variable speed connected according to Snowy Hydro Project Update, 2020, available at https://www.snowyhydro.com.au/wp-content/uploads/2020/08/Snowy-2.0-booklet_August-2020.pdf.

4.1.4 Fault level projections and shortfalls

AEMO must assess and declare fault level shortfalls until December 2025[25]. Table 9 shows projected fault current levels for each system strength node over the coming five years as well as the shortfalls declared in this report. Results show a strength shortfall at Newcastle and Sydney West due to the projected decline in the number of synchronous machines online. These shortfalls were also declared at these system strength nodes in the 2021 System Security Reports and the Update to the 2021 System Security Reports, and this report confirms their timing and adjusted size of the shortfalls. AEMO understands that Transgrid is continuing to progress its consideration of how to provide services to address the shortfalls.

The fault level duration curves for the New South Wales region are shown from Figure 7 to Figure 12.

Table 9 Projected minimum fault levels, and shortfall declarations, in New South Wales for the next five years

System strength node	Projections (*Step Change*) and shortfalls						
	Projected minimum three phase fault level for 99% of the time						Shortfalls and comments [A]
	2022-23	2023-24	2024-25	2025-26	2026-27 [E]	2027-28 [E]	
Armidale 330 kV	3,272	3,268	3,256	3,240	3,236	5,718	No shortfall.
Buronga 220 kV	N/A	N/A	N/A	2,259	2,392	2,387	No shortfall
Darlington Point 330 kV	696	708	681	723	744	743	No shortfall.
Newcastle 330 kV	8,690	8,827	8,422	6,389 (711 MVA shortfall)	6,795 [B] (305 MVA below requirement)	7,549 (499 MVA below requirement)	A shortfall of 711 MVA is declared from 1 July 2025 to 1 December 2025[C]. This is an adjustment to the existing shortfall declared in May 2022[D]. AEMO will request that Transgrid provide system strength services to address the shortfall by 1 July 2025.
Sydney West 330 kV	9,017	9,132	8,717	7,737 (314 MVA shortfall)	8,392 [B]	7,851 (200 MVA below requirement)	A shortfall of 314 MVA is declared from 1 July 2025 to 1 December 2025[C]. This is an adjustment to the existing shortfall declared in May 2022 [D]. AEMO will request that Transgrid provide system strength services to address the shortfall by 1 July 2025.
Wellington 330 kV	1,902	1,950	1,947	1,921	1,996	1,949	No shortfall

A. The system strength shortfalls for New South Wales are assessed on a post-contingent basis.
B. The shortfalls at Newcastle and Sydney West have changed since previous declarations. A new forecast and set of assumptions about the network have been applied in line with the Step Change scenario augmentations as per Appendix A1.2.
C. From December 2025 no shortfalls will be declared. Should fault levels be projected to fall below the requirement in these years, it is expected the new system strength framework will ensure there is sufficient system strength services.
D. As per May Update to the 2021 System Security reports, at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/operability/2022/update-to-2021-system-security-reports.pdf?la=en.
E. Fault levels projections increase in 2026-27 and 2027-28 due to network augmentation like HumeLink and the Sydney Ring. See Appendix A1.2 for details.

[25] See clause 11.143.14, outlining the transitional arrangements for declaration of shortfalls before December 2025, introduced by National Electricity Amendment (Efficient management of system strength on the power system) Rule 2021 No.11.

Figure 7 Armidale node fault level duration curve against the minimum fault level requirement

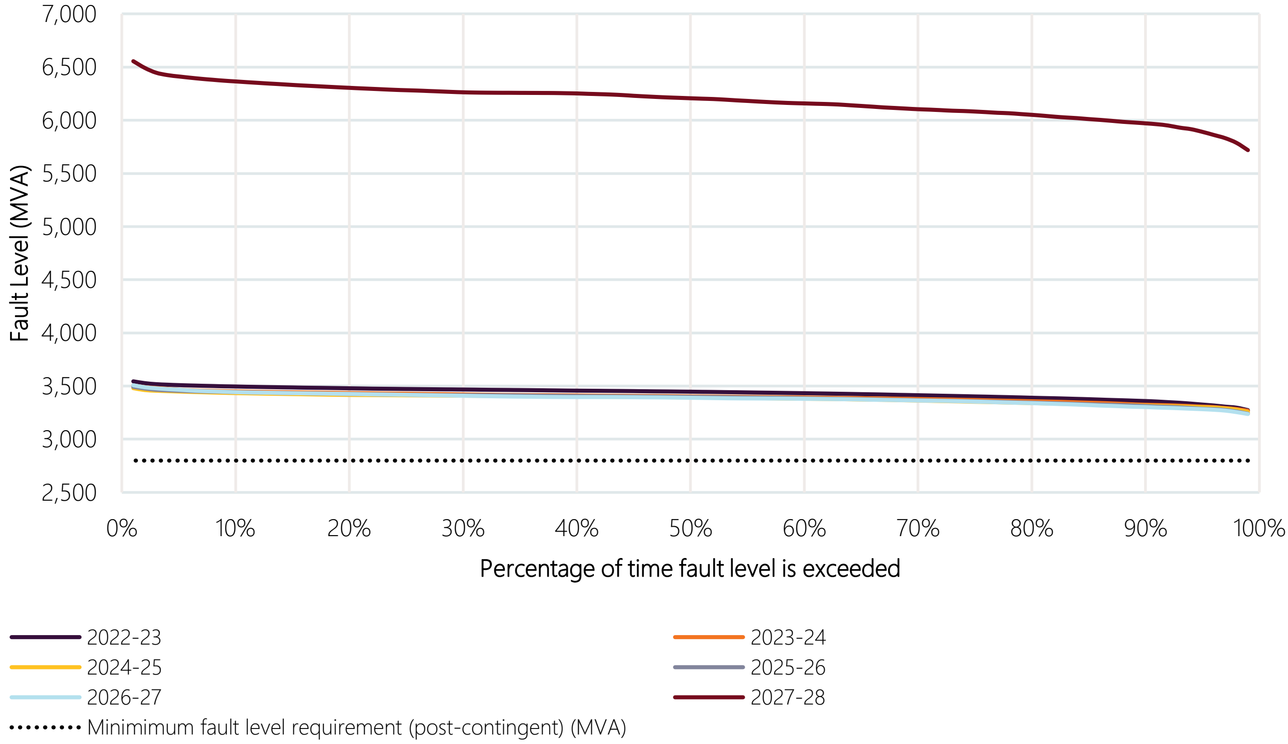
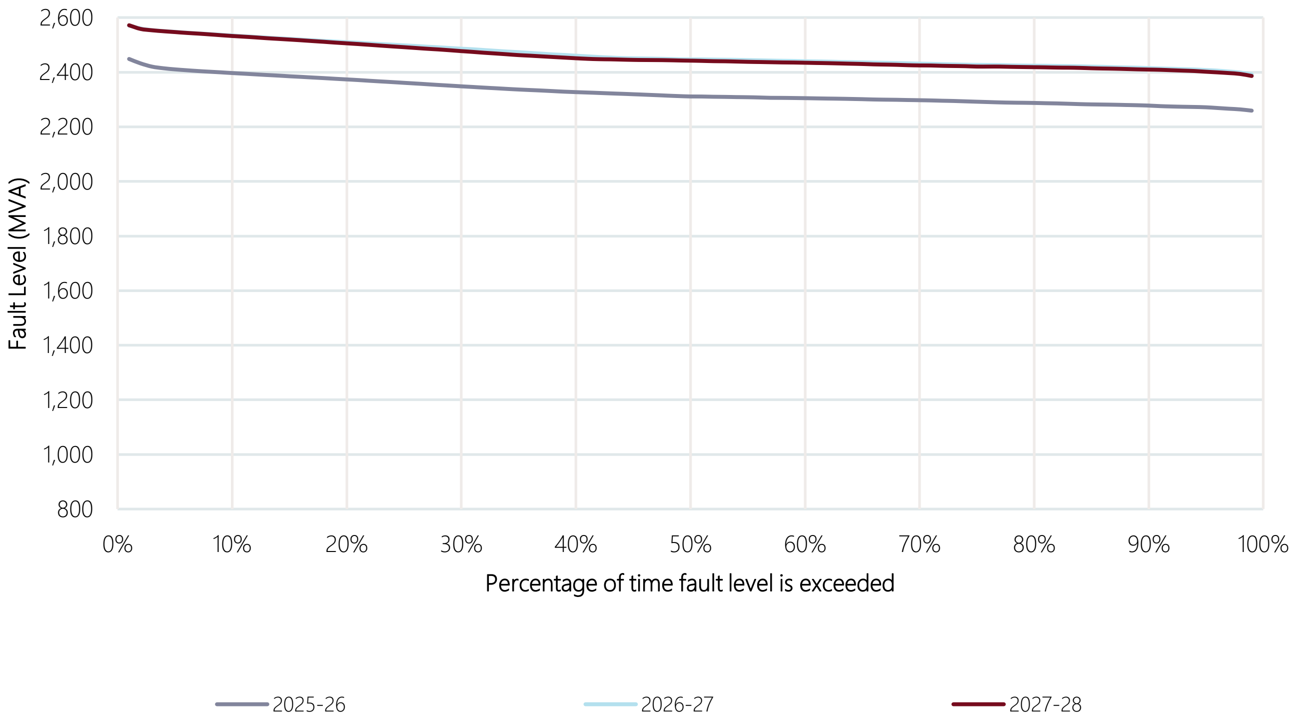


Figure 8 Buronga node fault level duration curve[A]



A. The Buronga node is declared for 2 December 2025 onwards.

Figure 9 Darlington Point node fault level duration curve against the minimum fault level requirement

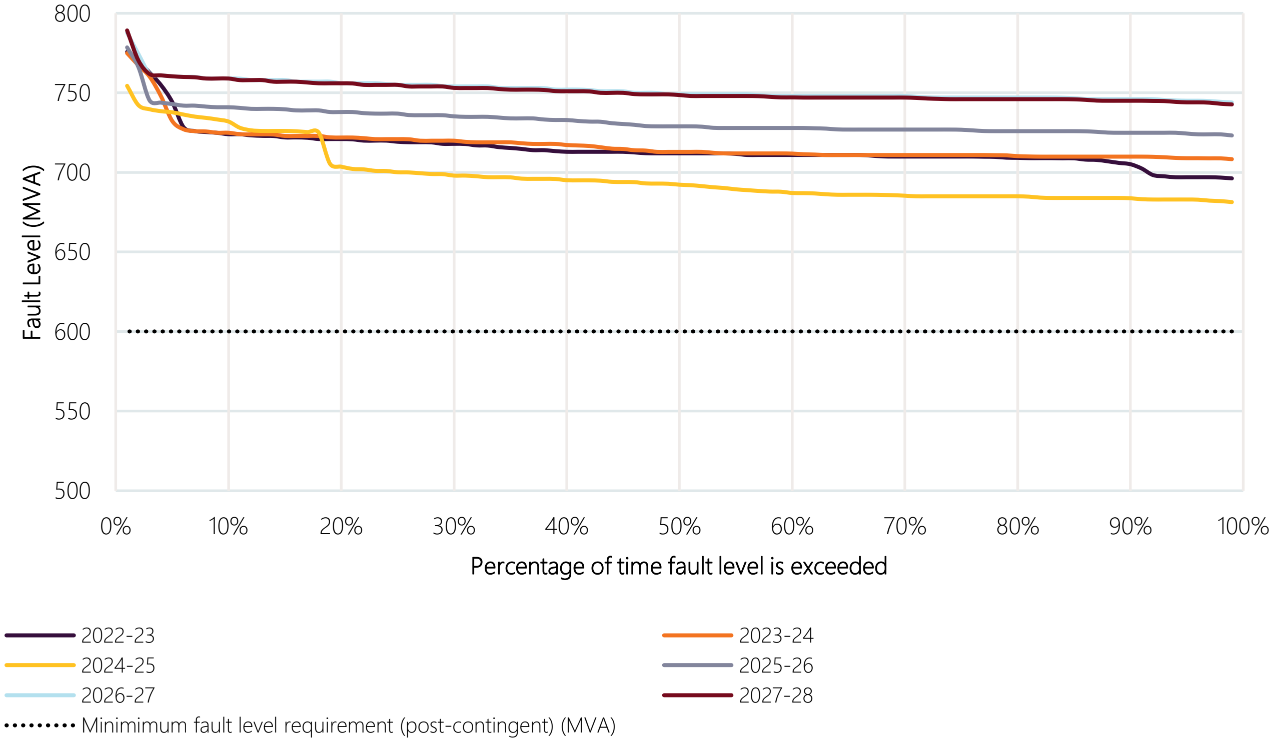


Figure 10 Newcastle node fault level duration curve against the minimum fault level requirement

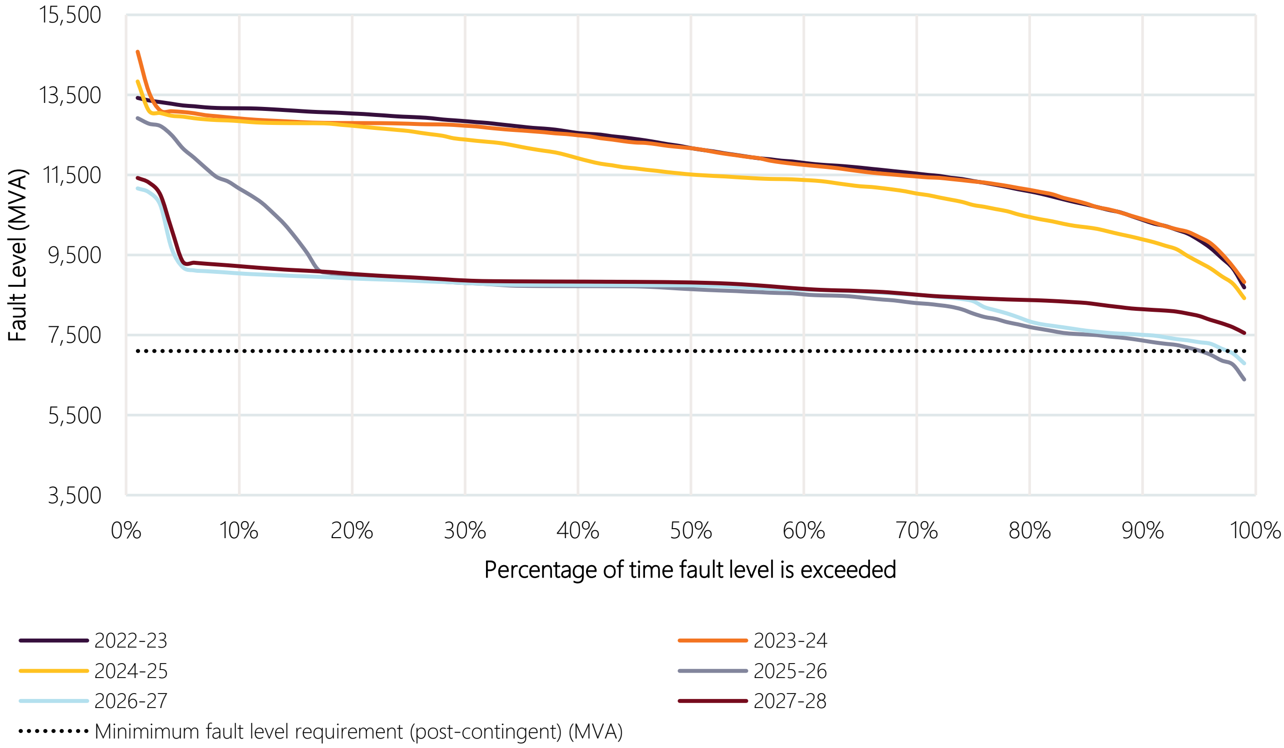


Figure 11 Sydney West node fault level duration curve against the minimum fault level requirement

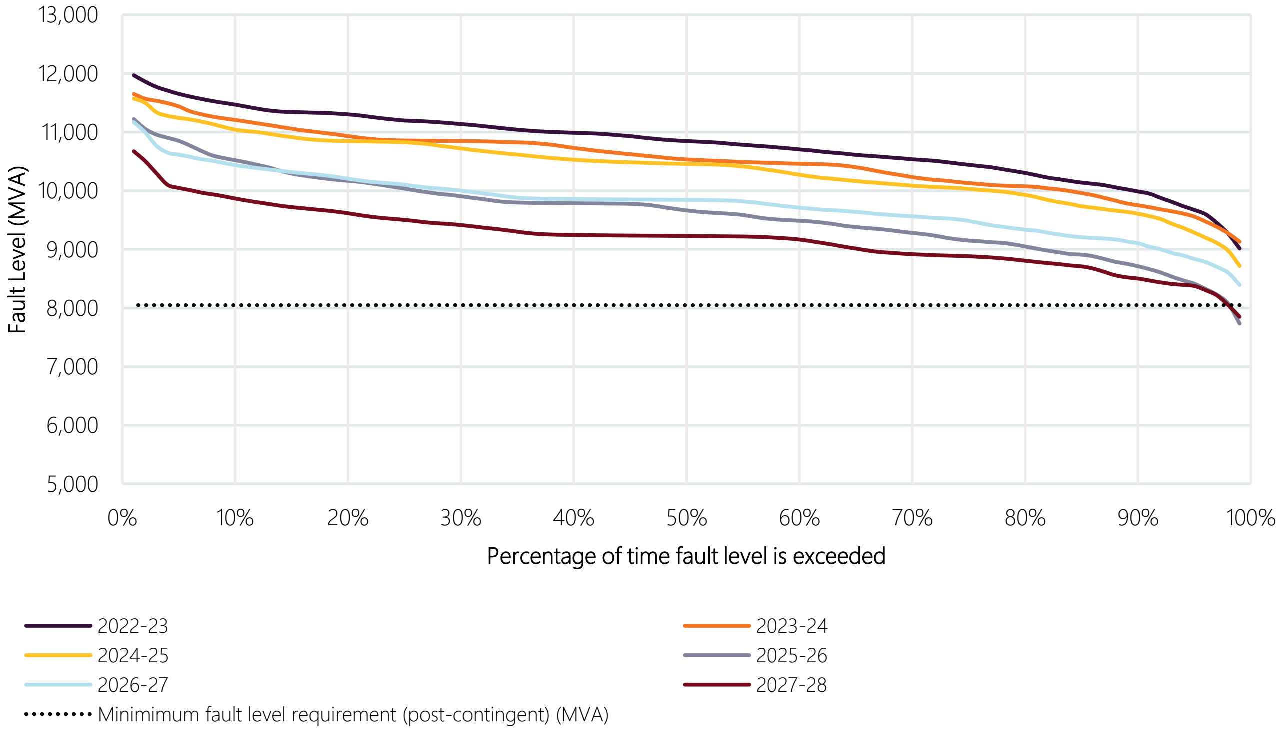
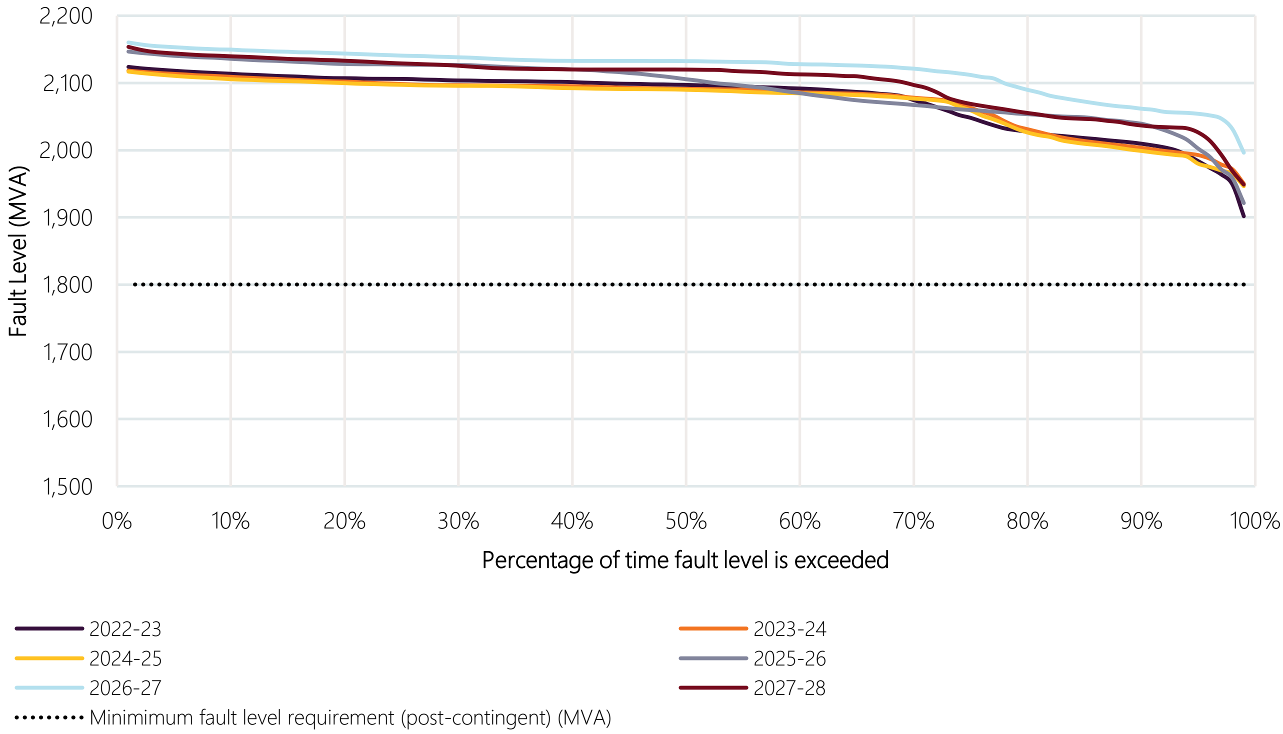


Figure 12 Wellington node fault level duration curve against the minimum fault level requirement



4.1.5 Critical planned outages

AEMO is declaring several critical planned outages which are impactful for maintaining system strength in New South Wales. The identified critical planned outages are given in Table 10.

SSSPs are expected to consider incorporation of critical planned outages into proposed system strength solutions on a case-by-case basis[26]. For example, this may be through ensuring the declared system strength standard for the system strength node is maintained, or through provision of appropriate plans to ensure sufficient system strength in the network for the duration of each relevant outage in accordance with the power system security principles in the rules.

Table 10 Critical planned outages in New South Wales for each system strength node [A]

Affected system strength node	Network outage	Reason for consideration as a critical outage
Armidale **Newcastle**	83 Liddell to Muswellbrook 330 kV line	Loss of another 330 kV line during this outage leaves Armidale connected to Queensland network. Post-contingency fault level at Armidale 330 kV bus depends on southern Queensland generation.
	84 Liddell to Tamworth 330 kV line	As above
	88 Muswellbrook to Tamworth 330 kV line	As above
	85 Tamworth to Uralla 330 kV line	As above
	86 Tamworth to Armidale 330 kV line	As above
	8U Uralla to Armidale 330 kV line	As above
Darlington Point	O51- Lower Tumut to Wagga Wagga 330 kV line	Can lead to a reduction in significant IBR that may have power system consequences. X5, 63 and 996 lines to be opened, Yass to Wagga 132 lines to be opened as necessary.
	62- Jindera to Wagga Wagga 330 kV line	As above
	63- Wagga Wagga to Darlington Point 330 kV line	As above
	X5 – Darlington Point to Balranald 220 kV line	As above.
	O60- Jindera to Wagga Wagga 330 kV line	As above
Newcastle	81 Liddell to Newcastle 330 kV Line [B]	Loss of another 330 kV line will reduce the fault level contribution from Bayswater and Mt Piper significantly.
	82 Liddell to Tomago 330 kV Line [B]	As above

A. AEMO expects that New South Wales and other regional SSSPs will engage in joint planning when critical planned outages may impact system security across different regions of the NEM.
B. Line 81 and 82 contingencies are included as critical planned outages for the potential early retirement of Eraring Power Station in August 2025.

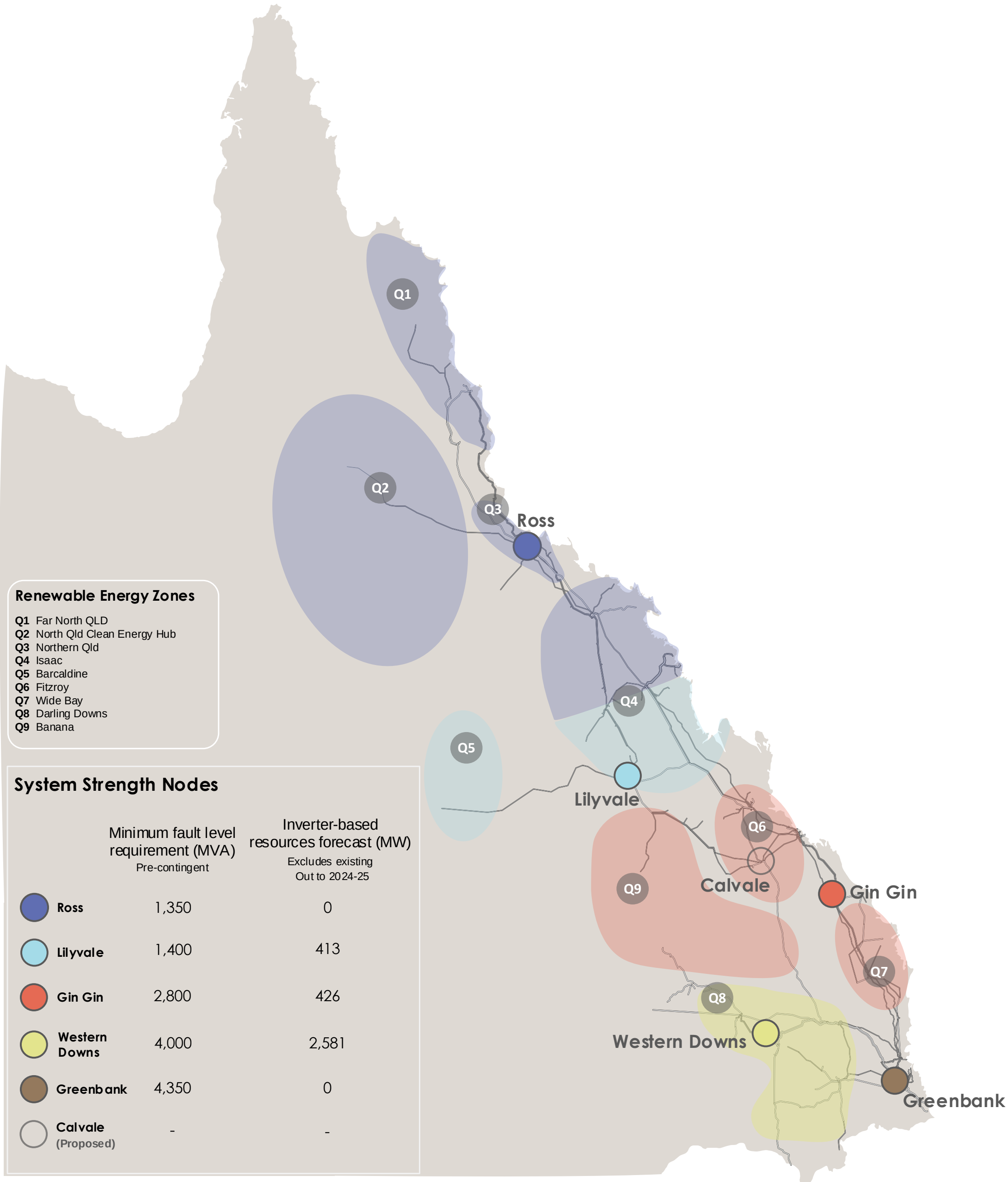
[26] AEMC, 2021, Rule Determination National Electricity Amendment (Efficient Management of System Strength on the Power System) Rule 2021, at https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2021/mass/secondstage/mass-draft-determination-2021.pdf?la=en. Page 98.

4.2 Queensland

Existing minimum fault level requirements in Queensland have remained unchanged in this report. A similar-sized system strength shortfall at the Gin Gin node remains as per the Update to the 2021 System Security report, however the magnitude is projected to be slightly lower. Powerlink is currently identifying solutions for this declared shortfall, and AEMO has requested that services be made available by 31 March 2023.

Figure 13 shows the system strength nodes and system strength standards for Queensland.

Figure 13 System strength node location and system strength standard[A] in Queensland



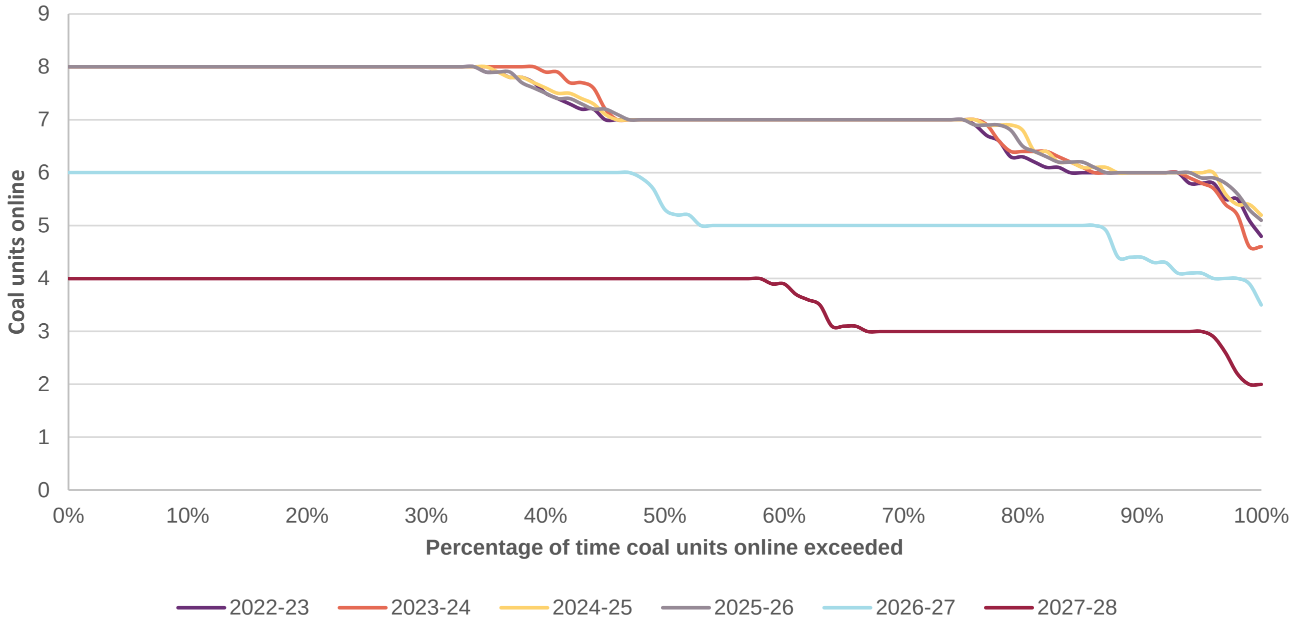
Renewable energy zones are mapped to show where the majority of forecast IBR are expected, consistent with the ISP.

System strength provision is particularly pressured in the context of low demand on the power system and decline of available sources of traditional service provision such as synchronous generators.

Minimum operational demand (sent-out[27]) for Queensland is forecast to decrease by approximately 1,050 MW between 2022-23 and 2027-28 in the 2022 ESOO Central projection (*Step Change)*. Further details are available in Section 3.2.

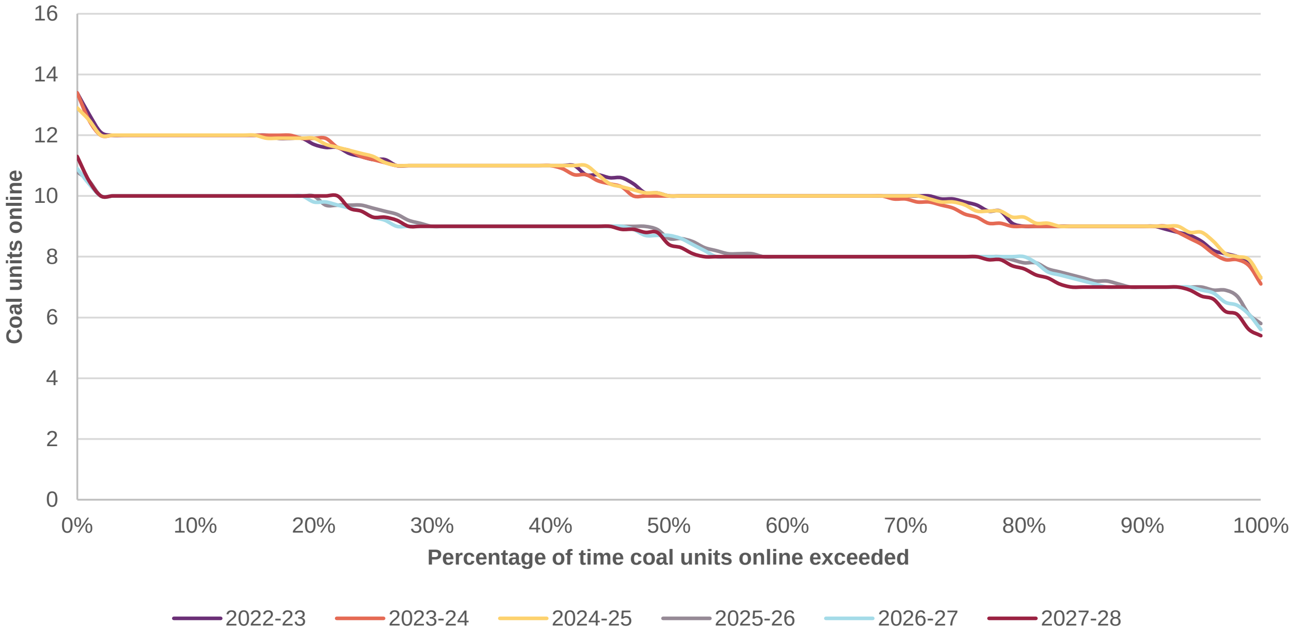
The number of coal generators projected to be online in Queensland across the year is forecast to decline significantly from 2025 onwards, as shown in Figure 14 and Figure 15.

Figure 14 Number of coal units in projected online under *Step Change* scenario, southern Queensland



[27] Refers to power provided by generating units to meet electrical demand, it does not include the power used to operate the generating unit.

Figure 15 Number of coal units in projected online under *Step Change* scenario, central Queensland



4.2.1 System strength nodes

AEMO declares five system strength nodes in Queensland effective from 1 December 2022, as listed in Table 11. These nodes are the same as the nodes declared in 2021. AEMO is also considering possible future system strength nodes in Queensland as noted in Table 12. These nodes may be declared in the 2023 System Strength Report, subject to any feedback received and ongoing transformation of the power system.

Table 11 System strength nodes in Queensland for the 2022 system strength report

System strength node	Voltage and busbar [A]	Start date	End date
Gin Gin	275 kV Bus 1	Existing	Possibly upon declaration of another CQ node [B]
Greenbank	275kV Bus 1	Existing	Not defined
Lilyvale	132 kV Bus 1	Existing	Not defined
Ross	275 kV Bus 1	Existing	Not defined
Western Downs	275kV Bus 1	Existing	Not defined

A. Bus 1 of the system strength node is selected by default. Alternative buses may be selected on a case-by-case basis.
B. Any changes to SSNs will need to be agreed to by the SSSP through the normal joint planning functions.

Table 12 Possible future nodes declared in Queensland region and closures of existing nodes

System strength node	Voltage and busbar	Start date	End date	Purpose of new node
Calvale	275 kV Bus 1	Upon closure of Gin Gin node	Not defined	AEMO is currently testing the plan of moving the Gin Gin node to a bus that is more representative of the Central Queensland generation centre. The current Gin Gin node is particularly sensitive to Gladstone Power station generation behaviour more than other large units in the area. Moving this node to Calvale will help to ensure that no single power station is affecting fault level requirements inequitably.

4.2.2 Minimum three phase fault level requirements

Existing minimum fault level requirements are unchanged from the 2021 System Security Reports. Table 13 provides the minimum three phase fault levels applicable for each system strength node for the coming year, for which the pre-contingent fault levels should be maintained for an intact system-normal power system[28].

Consistent with the SSRM, AEMO has considered whether material changes to the power system have occurred which would affect the minimum fault level requirement, as well as material changes which may occur over the forecasting period. Table 14 provides the projections for the minimum fault level requirements, including noting potential material changes (denoted by a letter), and Table 15 provides some consideration of those potential material changes.

Table 13 Queensland 2022 minimum three phase fault level requirements

System strength node	2022 minimum fault level requirements (MVA)		Comments
	Pre-contingency	Post-contingency	
Gin Gin 275 kV	2,800	2,250	Existing requirement [B.]
Greenbank 275 kV	4,350	3,750	Existing requirement [B.]
Lilyvale 132 kV	1,400	1,150	Existing requirement [B.]
Ross 275 kV	1,350	1,175	Existing requirement [A]
Western Downs 275 kV	4,000	2,550	Existing requirement [B.]

A. 2021 Notice of change to system strength requirement and shortfall at Ross, available via aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/planning-for-operability.
B. 2020 *System Strength and Inertia Report* and 2021 *System Security Reports*, available via aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/planning-for-operability.

Table 14 Pre- and post-contingent minimum fault level projections for the decade ahead (MVA)

		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Gin Gin 275 kV	Pre-contingent	2,800	2,800	2,800	2,800	2,800	2,800[B]	2,800[B]	2,800[B]	2,800[B]	2,800[B]	2,800[B]
	Post-contingent	2,250	2,250	2,250	2,250	2,250	2,250[B]	2,250[B]	2,250[B]	2,250[B]	2,250[B]	2,250[B]
Greenbank 275 kV	Pre-contingent	4,350	4,350	4,350	4,350	4,350	4,350[B]	4,350[B]	4,350[B]	4,350[B]	4,350[B]	4,350[B]
	Post-contingent	3,750	3,750	3,750	3,750	3,750	3,750[B]	3,750[B]	3,750[B]	3,750[B]	3,750[B]	3,750[B]
Lilyvale 132 kV	Pre-contingent	1,400	1,400[A]	1,400[A]	1,400[A]	1,400[A]	1,400[A,B]	1,400[A,B]	1,400[A,B]	1,400[A,B]	1,400[A,B]	1,400[A,B]
	Post-contingent	1,150	1,150[A]	1,150[A]	1,150[A]	1,150[A]	1,150[A,B]	1,150[A,B]	1,150[A,B]	1,150[A,B]	1,150[A,B]	1,150[A,B]
Ross 275 kV	Pre-contingent	1,350	1,350	1,350	1,350	1,350	1,350[B]	1,350[B]	1,350[B]	1,350[B]	1,350[B]	1,350[B]
	Post-contingent	1,175	1,175	1,175	1,175	1,175	1,175[B]	1,175[B]	1,175[B]	1,175[B]	1,175[B]	1,175[B]
Western Downs 275 kV	Pre-contingent	4,000	4,000	4,000	4,000	4,000	4,000[B]	4,000[B]	4,000[B]	4,000[B]	4,000[B]	4,000[B]
	Post-contingent	2,550	2,550	2,550	2,550	2,550	2,550[B]	2,550[B]	2,550[B]	2,550[B]	2,550[B]	2,550[B]

Note: Grey shading indicates the time that AEMO determines the fault levels should not change based on the forecast. A letter indicates where a material change may trigger an investigation when appropriate models and parameters are available. Material changes are shown in Table 15 and linked to the letters in Table 14.

[28] As per NER S5.1.14(a), Page 74, at https://www.aemc.gov.au/sites/default/files/2021-10/ERC0300%20-%20Final%20rule%20-%20in%20mark%20up%20format%20%28%2020.10.21%29%20-%20final.pdf.

Table 15 Queensland material changes which may impact the minimum fault level requirement

Financial year	Letter	Material change	Node primarily affected	Protection requirements	Voltage step change requirement	Power system stability	Comments
2023		-					
2024	A	Lilyvale Transformer Replacement	Lilyvale 132 kV	No updated information available at time of writing. Existing minimum applies	Fault level required for existing static reactive devices, but this requirement should not increase from current requirement.	No comments.	Reduction of network impedance will likely lead to fewer synchronous generators required to meet existing minimum fault level. Fit for purpose studies may be needed to consider the minimum fault level requirement..
2025							
2026							
2027							
2028							
2028	B	Synchronous generation retirements	All nodes	No updated information available at time of writing. Existing minimum applies	Fault level required for existing static reactive devices, but this requirement should not increase from current requirement.	No comments..	Retirement of synchronous generators may mean that system strength in Queensland is delivered by other means elsewhere in the region. This may affect minimum fault level requirements throughout the region. Fit for purpose studies may be needed to consider the minimum fault level requirement.
2030							
2030		Note A					
2031							
2032		Note A					
2033		Note B					

A. The Queensland Energy and Jobs Plan refers to two large hydrogeneration dams that may become operational in 2030 and 2032. The system strength provided by these machines when operational may replace the system strength provided historically from coal-fired generation clustered in Central Queensland (see page 46 of QEJP, at https://www.epw.qld.gov.au/__data/assets/pdf_file/0029/32987/queensland-energy-and-jobs-plan.pdf). As this generation meets the thresholds for anticipated and/or committed status as per AEMO's Generation Information, further fit-for-purpose power system analysis may be required.
B. The Queensland Energy and Jobs Plan describes how the emergence of large new loads on the Queensland electricity system, in particular a renewable hydrogen export industry, will require large-scale renewable energy, storage, firming and transmission developments (see page 49 of QEJP, at https://www.epw.qld.gov.au/__data/assets/pdf_file/0029/32987/queensland-energy-and-jobs-plan.pdf). Renewable hydrogen has the potential to affect the system strength requirements for the entire region depending on the transmission augmentation associated and the technology used to interface the hydrogen load to the power system (e.g. inverter-connected hydrogen load). As this becomes more guaranteed, further fit-for-purpose power system modelling may be required.

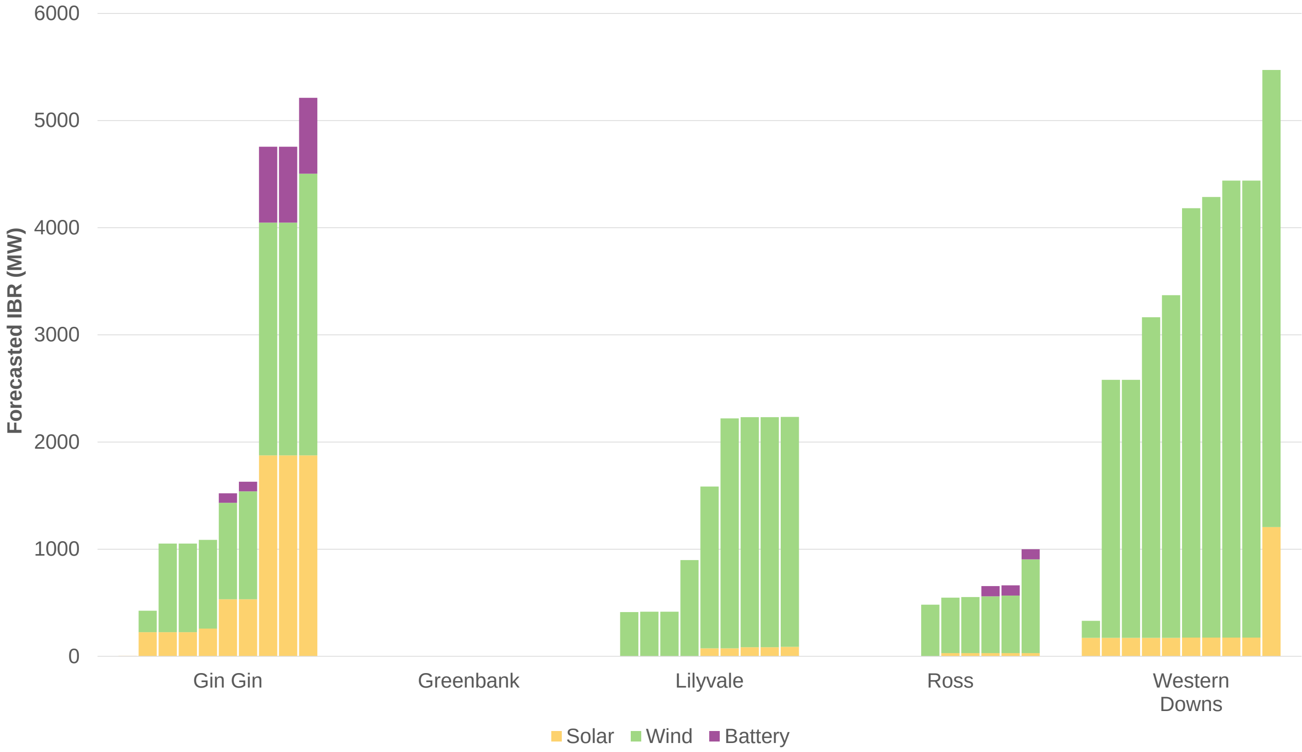
4.2.3 IBR projections

AEMO's 10-year forecast of the level and type of IBR and market network service facilities (MNSF) for the system strength node is listed in Table 16 and Figure 16. This forecast is provided for each system strength node.

AEMO's projection allocates the forecast of utility-scale IBR generation to the nearest system strength node over the coming decade. The data is provided by technology type. The forecast is consistent with the 2022 ISP *Step*

Change scenario results[29] and the Central scenario demand forecast from the 2022 ESOO[30] but has been updated to include committed and anticipated projects from the 22 July 2022 Generation Information page[31]. AEMO has also incorporated input from the local SSSP where appropriate.

Figure 16 10-year forecast level and type of IBR and MNSF[A] by system strength node, Queensland[B]



A. No MNSFs have been included in this forecast.
B. The near-term years of the forecast may require adjustment by the SSSP when preparing system strength services, as more information becomes available about newly-committed IBR and MNSF.

[29] 2022 *Integrated System Plan*, page 9, AEMO, at https://aemo.com.au/-/media/files/major-publications/isp/2022/2022-documents/2022-integrated-system-plan-isp.pdf?la=en.

[30] 2022 *Electricity Statement of Opportunities*, page 34, AEMO, at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2022/2022-electricity-statement-of-opportunities.pdf?la=en.

[31] AEMO. NEM Generation Information, at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information.

Table 16 Forecast level and type of IBR and MNSF for the next 10 years[A]

System strength node	Technology	Existing IBR	Forecast IBR (MW) [B]										
			Financial year ending										
			2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Gin Gin	Solar	385	0	4	225	225	225	260	533	533	1875	1875	1875
	Wind	0	0	0	201	827	827	827	900	1008	2173	2173	2628
	Battery		0	0	0	0	0	0	89	89	708	708	708
	Total IBR	**385**	**0**	**4**	**426**	**1053**	**1053**	**1087**	**1522**	**1629**	**4756**	**4756**	**5212**
Greenbank	Solar	0	0	0	0	0	0	0	0	0	0	0	0
	Wind	0	0	0	0	0	0	0	0	0	0	0	0
	Battery	0	0	0	0	0	0	0	0	0	0	0	0
	Total IBR	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Lilyvale	Solar	319	0	0	0	0	0	0	75	75	86	86	89
	Wind	0	0	0	413	416	416	898	1510	2146	2146	2146	2146
	Battery	0	0	0	0	0	0	0	0	0	0	0	0
	Total IBR	**319**	**0**	**0**	**413**	**416**	**416**	**898**	**1585**	**2221**	**2232**	**2232**	**2235**
Ross	Solar	841	0	0	0	0	0	0	30	30	30	30	30
	Wind	362	0	0	0	0	0	482	518	523	531	537	875
	Battery	0	0	0	0	0	0	0	0	0	95	95	95
	Total IBR	**1204**	**0**	**0**	**0**	**0**	**0**	**482**	**548**	**553**	**656**	**662**	**1000**
Western Downs	Solar	1310	0	173	173	173	173	173	175	175	175	175	1207
	Wind	428	0	159	2408	2408	2992	3198	4007	4112	4265	4265	4265
	Battery	100	0	0	0	0	0	0	0	0	0	0	0
	Total IBR	**1839**	**0**	**331**	**2581**	**2581**	**3165**	**3370**	**4182**	**4287**	**4440**	**4440**	**5472**

A. The near-term years of the forecast may require adjustment by the SSSP when preparing system strength services, as more information becomes available about newly-committed IBR and MNSF.
B. This forecast includes utility-scale IBR only, consistent with ISP Step Change scenario modelling. Distributed energy resources, including rooftop PV, are not included. As per the SSRM, SSSPs may in some cases propose to include system strength to facilitate synchronism of DER as part of assessing what is required to achieve stable operation of projected IBR. For this purpose, DER capacity forecasts are published in AEMO's *Inputs, Assumptions and Scenarios Report*, at https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp/current-inputs-assumptions-and-scenarios.AEMO | Current inputs, assumptions and scenarios.

4.2.4 Fault level projections and shortfalls

AEMO must assess and declare fault level shortfalls until December 2025[32]. Table 17 shows projected fault current levels for each system strength node over the coming five years as well as the shortfalls declared in this report. Results show a strength shortfall at Gin Gin due to the projected decline in the number of synchronous machines online. This shortfall was also declared at this system strength node in the 2021 System Security Reports and the Update to the 2021 System Security Reports, and this report confirms the timing and adjusted size of the shortfall. AEMO understands that Powerlink is continuing to progress its consideration of how to provide services to address the shortfall.

The fault level duration curves for the Queensland region are shown from Figure 17 through Figure 21.

[32] See clause 11.143.14, outlining the transitional arrangements for declaration of shortfalls before December 2025, introduced by National Electricity Amendment (Efficient management of system strength on the power system) Rule 2021 No.11.

Table 17 Projected minimum fault levels, and shortfall declarations, in Queensland for the next five years

System strength node	Projections (*Step Change*) and shortfalls						
	Projected minimum three phase fault level for 99% of the time						Shortfalls and comments[A]
	2022-23	2023-24	2024-25	2025-26	2026-27[D]	2027-28[D]	
Gin Gin 275 kV	2,215 (35 MVA shortfall)	2,219 (31 MVA shortfall)	2,214 (36 MVA shortfall)	2,186 (64 MVA shortfall)	2,163 (87 MVA below requirement)	2,134 (116 MVA below requirement)	A shortfall of up to 64 MVA is declared until from this present year until 1 December 2025[B]. This is an adjustment to the existing shortfall declared in May 2022[C]. Powerlink is currently preparing to make services available. AEMO has requested that services be available from 31 March 2023.
Greenbank 275 kV	4,878	4,872	4,931	4,912	4,373	3,915	No shortfall
Lilyvale 132 kV	1,214	1,214	1,214	1,195	1,190	1,182	No shortfall
Ross 275 kV	1,209	1,209	1,211	1,198	1,193	1,187	No shortfall
Western Downs 275 kV	2,978	2,989	2,962	2,965	2,773	2,535 (15 MVA shortfall)	No shortfall

A. The system strength outcomes for Queensland are assessed on a post-contingent basis.
B. The shortfall at Gin Gin has changed since previous declarations. A new forecast and set of assumptions about the network have been applied in line with the Step Change scenario augmentations as per Appendix A1.2.
C. As per May Update to the 2021 System Security reports, at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/operability/2022/update-to-2021-system-security-reports.pdf?la=en.
D. From December 2025 no shortfalls will be declared. Should fault levels be projected to fall below the requirement in these years, it is expected the new system strength framework will ensure there is sufficient system strength services throughout the region.

Figure 17 Gin Gin node fault level duration curve against the minimum fault level requirement

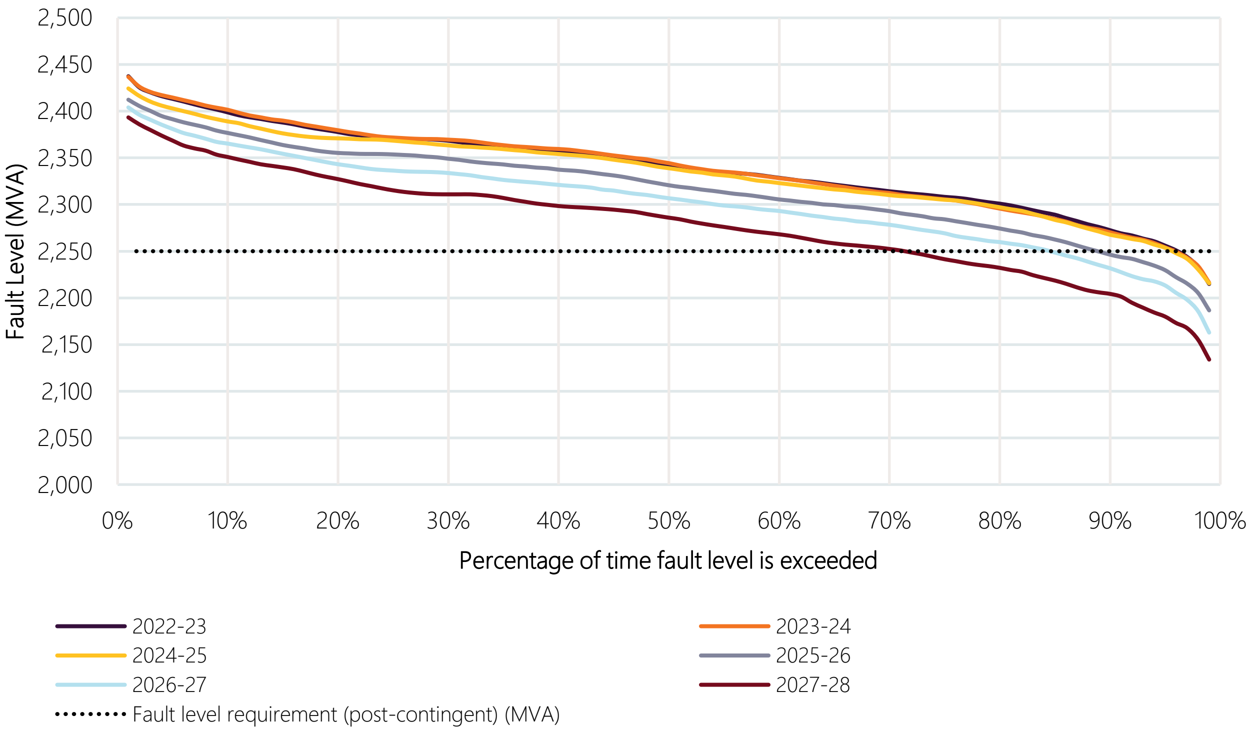


Figure 18 Greenbank node fault level duration curve against the minimum fault level requirement

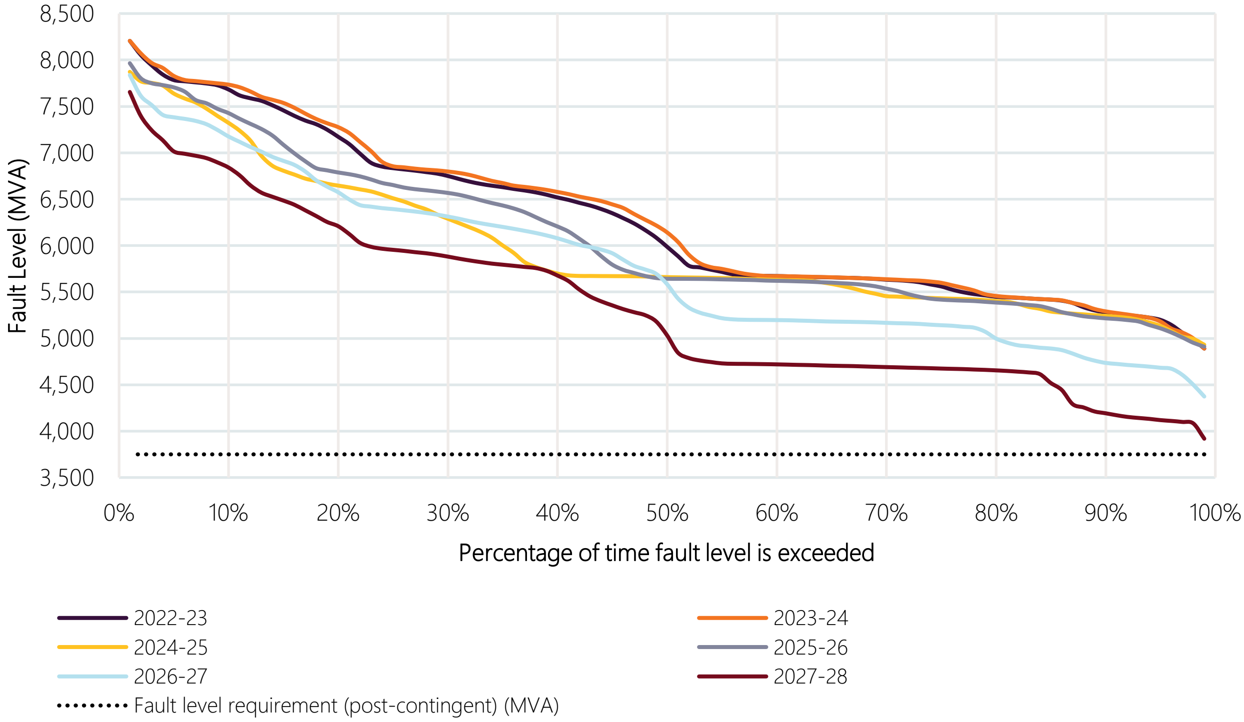


Figure 19 Lilyvale node fault level duration curve against the minimum fault level requirement

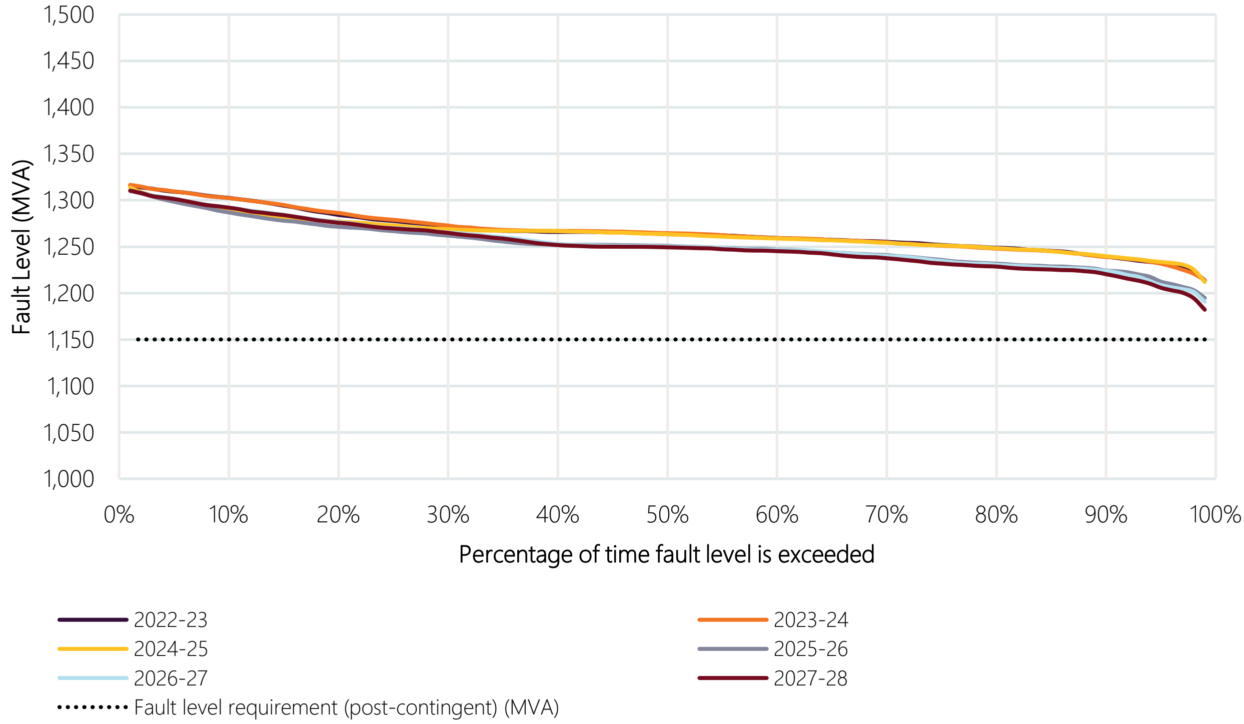


Figure 20 Ross node fault level duration curve against the minimum fault level requirement

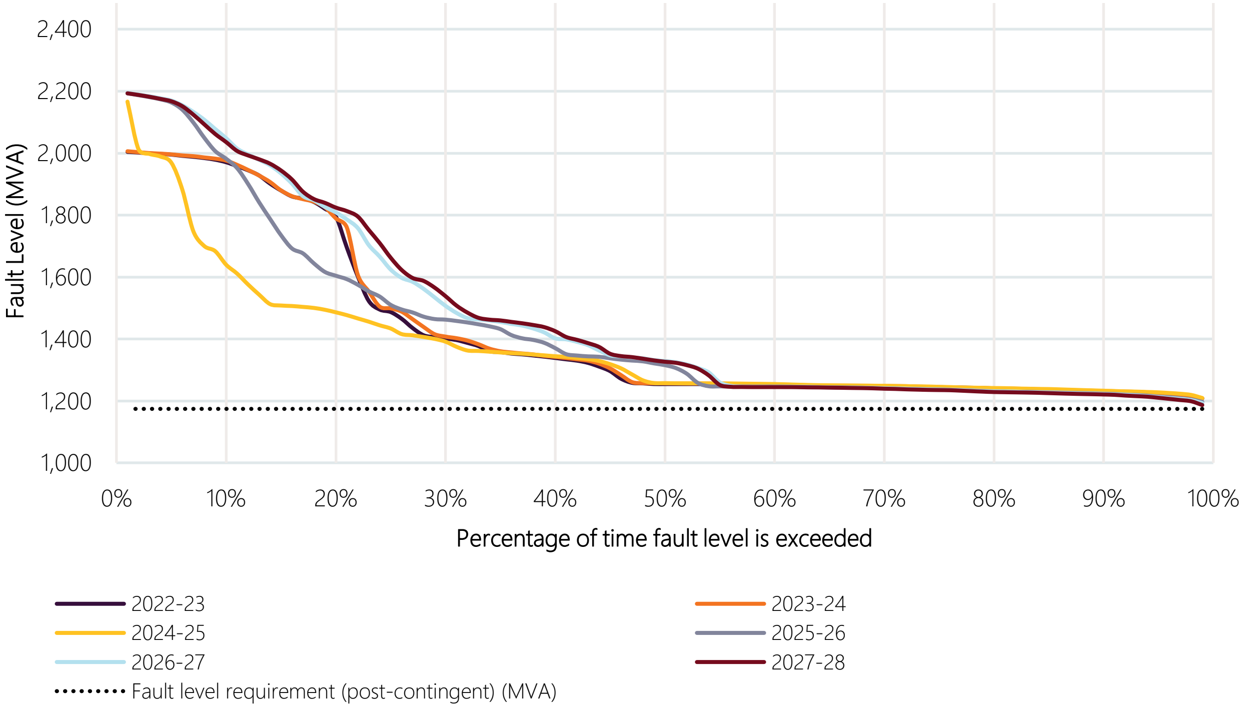
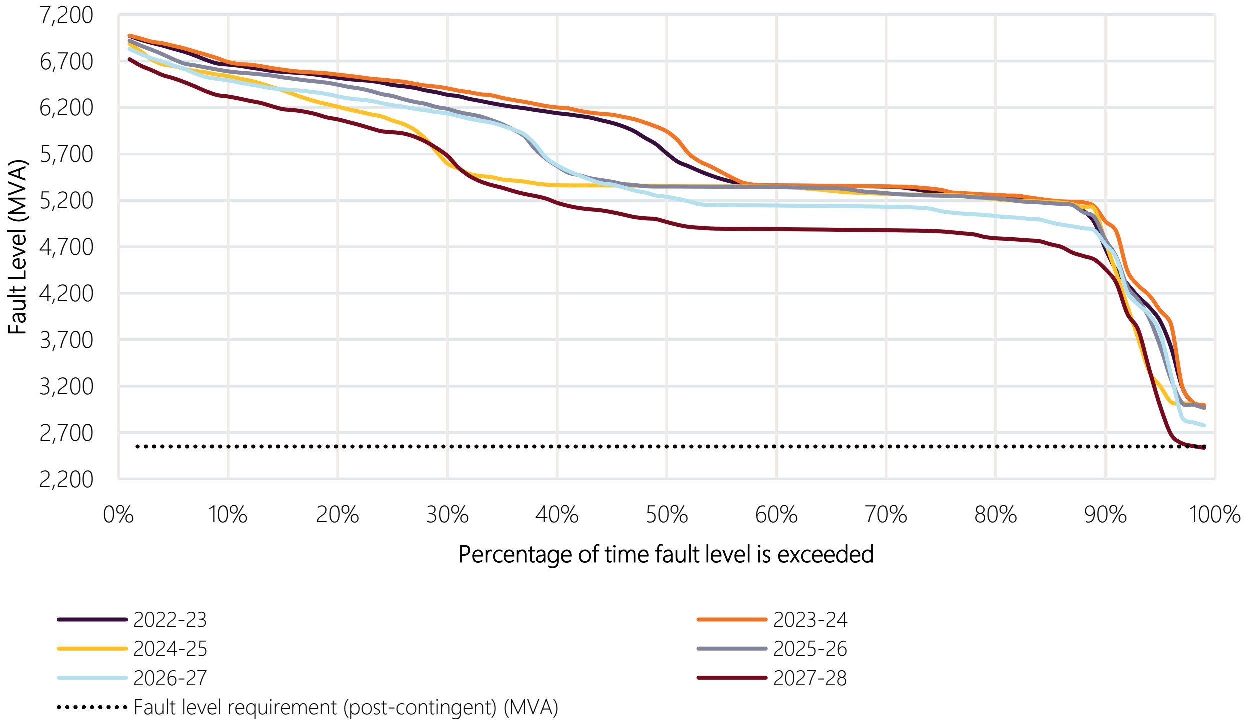


Figure 21 Western Downs node fault level duration curve against the minimum fault level requirement



4.2.5 Critical planned outages

AEMO is declaring two critical planned outages which are impactful for maintaining system strength in Queensland. The identified critical planned outages are given in Table 18.

SSSPs are expected to consider incorporation of critical planned outages into proposed system strength solutions on a case-by-case basis[33]. For example, this may be through ensuring the declared system strength standard for the system strength node is maintained, or through provision of appropriate plans to ensure sufficient system strength in the network for the duration of each relevant outage in accordance with the power system security principles in the rules.

Table 18 Critical planned outages in Queensland for each system strength node

Affected system strength node	Network outage	Reason for consideration as a critical outage
Lilyvale 132 kV	Lilyvale to Broadsound 275 kV line Lilyvale 275/132 kV transformer	Lilyvale 132 kV bus below minimum fault level requirement for another contingency. The outage conditions require radialising the Lilyvale 132 kV network.

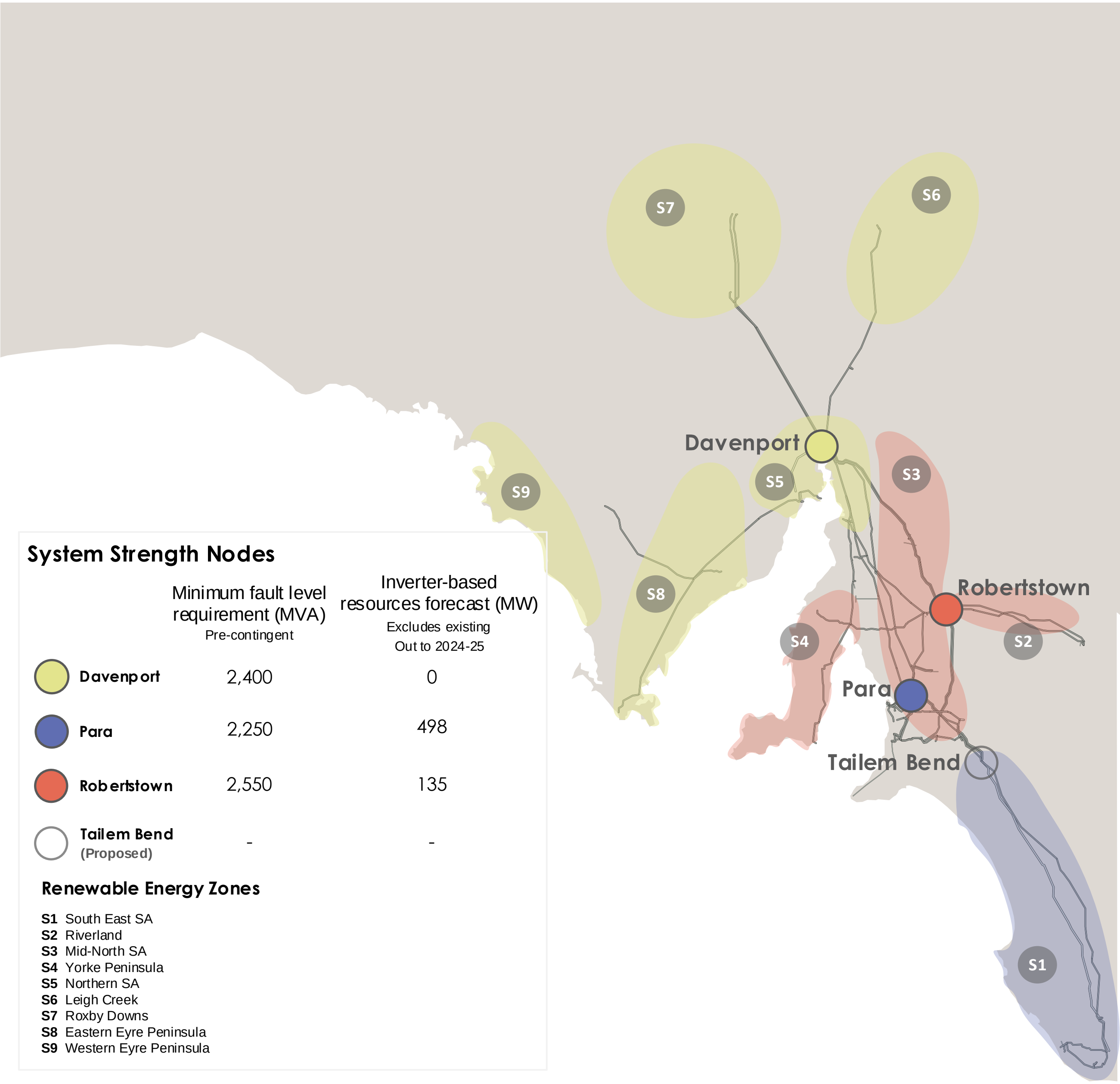
[33] AEMC, 2021, Rule Determination National Electricity Amendment (Efficient Management of System Strength on the Power System) Rule 2021, at https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2021/mass/secondstage/mass-draft-determination-2021.pdf?la=en. Page 98.

4.3 South Australia

Existing minimum fault level requirements in South Australia have remained unchanged in this report. No system strength shortfalls were identified in the South Australia region, with ElectraNet's four new synchronous condensers now delivering sufficient system strength for South Australia.

Figure 22 shows the system strength nodes and system strength standards for South Australia.

Figure 22 System strength node location and system strength standard[A] in South Australia



A. Renewable energy zones are mapped to show where the majority of forecast IBR are expected, consistent with the ISP.

Minimum operational demand (sent-out[34]) for South Australia is forecast to decrease by 450 MW between 2022-23 and 2027-28 in the 2022 ESOO Central projection (*Step Change)*. Further details are available in Section 3.2.

4.3.1 System strength nodes

AEMO declares three system strength nodes in South Australia effective from 1 December 2022, as listed in Table 19. These nodes are the same as the nodes declared in 2021.

AEMO is also considering possible future system strength nodes in South Australia, as noted in Table 20. These nodes may be declared in the 2023 System Strength Report, subject to any feedback received and ongoing transformation of the power system.

Table 19 System strength nodes in South Australia for the 2022 system strength report

System strength node	Voltage and busbar [A]	Start date	End date
Davenport	275 kV Bus 1	Existing	Not defined
Para	275 kV Bus 1	Existing	Not defined
Robertstown	275 kV Bus 1	Existing	Not defined

Bus 1 of the system strength node is selected by default. Alternative buses may be selected on a case-by-case basis.

Table 20 Possible future nodes in South Australia region and closures of existing nodes

System strength node	Voltage and busbar	Start date	End date	Purpose of new node
Tailem Bend	275 kV Bus 1	Upon connection of forecast IBR in SA region	Not defined	This node may provide better locations for forecast IBR in Southeast South Australia as it connects.

4.3.2 Minimum three phase fault level requirements

South Australia system strength nodes and their minimum fault level and requirements are unchanged from the 2021 System Security Reports. 0 provides the minimum three phase fault levels applicable for each system strength node for the coming year, for which the pre-contingent fault levels should be maintained for an intact system normal power system[35].

Consistent with the SSRM, AEMO has considered whether material changes to the power system have occurred which would affect the minimum fault level requirement, as well as material changes which may occur over the forecasting period. Table 22 provides the projections for the minimum fault level requirements, including noting potential material changes (denoted by a letter), and Table 23 provides some consideration of those potential material changes.

[34] Refers to power provided by generating units to meet electrical demand, it does not include the power used to operate the generating unit.

[35] As per NER S5.1.14(a), Page 74, at https://www.aemc.gov.au/sites/default/files/2021-10/ERC0300%20-%20Final%20rule%20-%20in%20mark%20up%20format%20%28%2020.10.21%29%20-%20final.pdf.

Table 21 South Australia minimum three phase fault level requirements

System strength node	2022 minimum fault level requirement (MVA)		Comments [A]
	Pre-contingency	Post-contingency	
Davenport 275 kV	2,400	1,800	Existing requirement
Para 275 kV	2,250	2,000	Existing requirement
Robertstown 275 kV	2,550	2,000	Existing requirement

A. 2020 *System Strength and Inertia Report*, at aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/planning-for-operability.

Table 22 Pre- and post-contingent minimum fault level requirement projections for the decade ahead (MVA)

		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Davenport 275 kV	Pre-contingent	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400
	Post-contingent	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
Para 275 kV	Pre-contingent	2,250	2,250	2,250	2,250	2,250	2,250	2,250	2,250	2,250	2,250	2,250
	Post-contingent	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Robertstown 275 kV	Pre-contingent	2,550	2,550	2,550	2,550[A]	2,550[A]	2,550[A]	2,550[A]	2,550[A]	2,550[A]	2,550[A]	2,550[A]
	Post-contingent	2,000	2,000	2,000	2,000[A]	2,000[A]	2,000[A]	2,000[A]	2,000[A]	2,000[A]	2,000[A]	2,000[A]

Note: Grey shading indicates the time that AEMO determines the fault levels should not change based on the forecast. A letter indicates where a material change may trigger an investigation when appropriate models and parameters are available. Material changes are shown in Table 23 and are linked to the relevant letters in this table.

Table 23 South Australia material changes which may impact the minimum fault level requirement

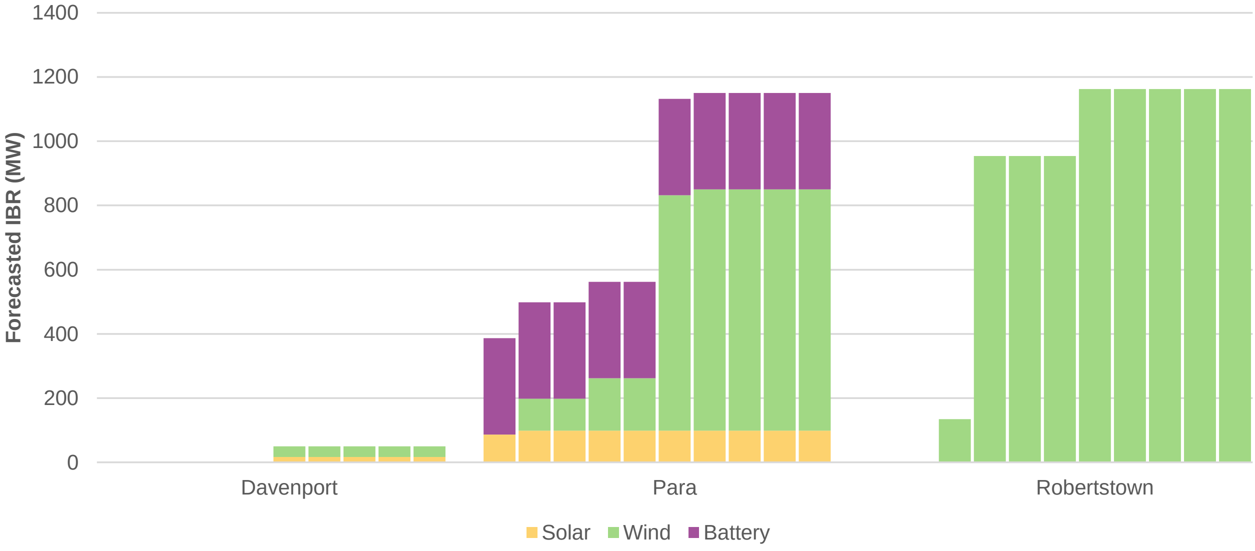
Financial year	Letter	Material change	Node primarily affected	Protection requirements	Voltage step change requirement	Power system stability	Comments
2023		-					
2024							
2025	A	PEC in service	Robertstown 275 kV	No updated information available at time of writing. Existing minimum applies.	Fault level required for existing static reactive devices, but this requirement should not increase from current requirement.	South Australia synchronous generator requirement expected to fall from 2 units to 0 units when PEC is fully commissioned in 2026.	Reduction of network impedance combined with synchronous condensers installed as part of PEC may lead to operation of South Australia with no synchronous generators at times. Fit for purpose studies may be needed to consider the minimum fault level requirement..
2026							
2027							
2028							
2028							
2030							
2030							
2031							
2032							
2033		-					

4.3.3 IBR projections

AEMO's 10-year forecast of the level and type of IBR and market network service facilities (MNSF) for the system strength node is listed in Table 24 and Figure 23. This forecast is provided for each system strength node.

AEMO's projection allocates the forecast of utility-scale IBR generation to the nearest system strength node over the coming decade. The data is provided by technology type. The forecast is consistent with the 2022 ISP *Step Change* scenario results[36] and the Central scenario demand forecast from the 2022 ESOO[37] but has been updated to include committed and anticipated projects from the 22 July 2022 Generation Information page[38]. AEMO has also incorporated input from the local SSSP where appropriate.

Figure 23 10-year forecast level and type of IBR and MNSF[A] by system strength node, South Australia[B]



A. No MNSFs have been included in this forecast.
B. The near-term years of the forecast may require adjustment by the SSSP when preparing system strength services, as more information becomes available about newly-committed IBR and MNSF.

[36] 2022 *Integrated System Plan*, page 9, AEMO, at https://aemo.com.au/-/media/files/major-publications/isp/2022/2022-documents/2022-integrated-system-plan-isp.pdf?la=en.

[37] 2022 *Electricity Statement of Opportunities*, page 34, AEMO, at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2022/2022-electricity-statement-of-opportunities.pdf?la=en.

[38] NEM Generation Information, AEMO, at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information.

Table 24 Forecast level and type of IBR and MNSF at each system strength node for the next 10 years[A]

System strength node	Technology	Existing IBR	Forecast IBR (MW) [B]										
			Financial year ending										
			2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Davenport	Solar	278	0	0	0	0	0	0	17	17	17	17	17
	Wind	526	0	0	0	0	0	0	33	33	33	33	33
	Battery	180	0	0	0	0	0	0	0	0	0	0	0
	Total IBR	984	0	0	0	0	0	0	50	50	50	50	50
Para	Solar	141	0	87	99	99	99	99	56	56	56	56	56
	Wind	351	0	0	99	99	162	162	733	751	751	751	751
	Battery	25	0	300	300	300	300	300	300	300	300	300	300
	Total IBR	517	0	387	498	498	562	562	1089	1107	1107	1107	1107
Robertstown	Solar	0	0	0	0	0	0	0	0	0	0	0	0
	Wind	1414	0	0	135	954	954	954	1163	1163	1163	1163	1163
	Battery	0	0	0	0	0	0	0	0	0	0	0	0
	Total IBR	1414	0	0	135	954	954	954	1163	1163	1163	1163	1163

A. The near-term years of the forecast may require adjustment by the SSSP when preparing system strength services, as more information becomes available about newly-committed IBR and MNSF.
B. This forecast includes utility-scale IBR only, consistent with ISP *Step Change* scenario modelling. Distributed energy resources, including rooftop PV, are not included. As per the SSRM, SSSPs may in some cases propose to include system strength to facilitate synchronism of DER as part of assessing what is required to achieve stable operation of projected IBR. For this purpose, DER capacity forecasts are published in AEMO's *Inputs, Assumptions and Scenarios Report*, at https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp/current-inputs-assumptions-and-scenarios.AEMO | Current inputs, assumptions and scenarios.

4.3.4 Fault level projections and shortfalls

AEMO must assess and declare fault level shortfalls until December 2025[39]. Table 25 shows the projected minimum fault levels for each system strength node declared in this report.

The fault level duration curves for the South Australia region are shown in Figure 24 through Figure 26.

Table 25 Projected minimum fault levels, and shortfall declarations, in South Australia for the next five years

System strength node	Projections (*Step Change*) and shortfalls						Shortfalls and comments[A]
	Projected minimum three phase fault level for 99% of the time						
	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	
Davenport 275 kV	2,029	2,037	2,101	1,983	1,983	1,981	No shortfall.
Para 275 kV	2,952	2,975	3,008	2,307	2,300	2,296	No shortfall.
Robertstown 275 kV	2,442	2,468	2,815	2,863	2,873	2,866	No shortfall.

A. The system strength outcomes for South Australia are assessed on a post-contingent basis.

[39] See clause 11.143.14, outlining the transitional arrangements for declaration of shortfalls before December 2025, introduced by National Electricity Amendment (Efficient management of system strength on the power system) Rule 2021 No.11.

Figure 24 Davenport node fault level duration curve against the minimum fault level requirement

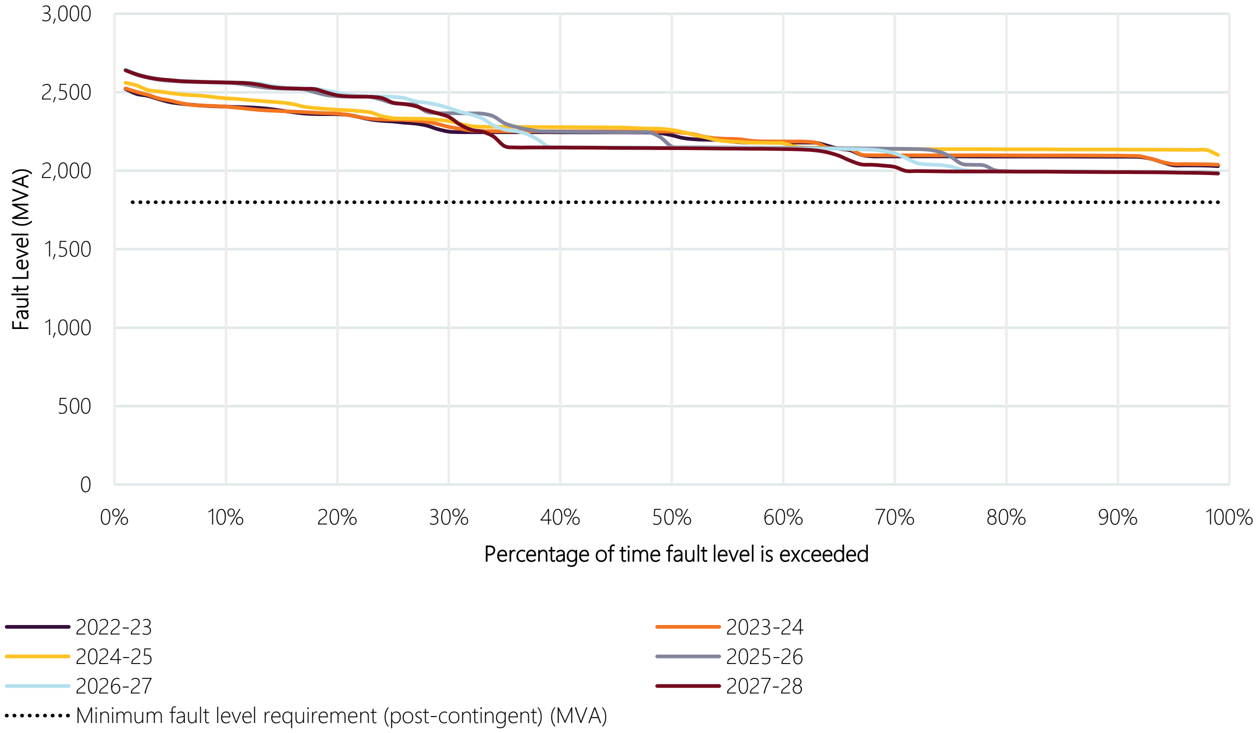


Figure 25 Para node fault level duration curve against the minimum fault level requirement

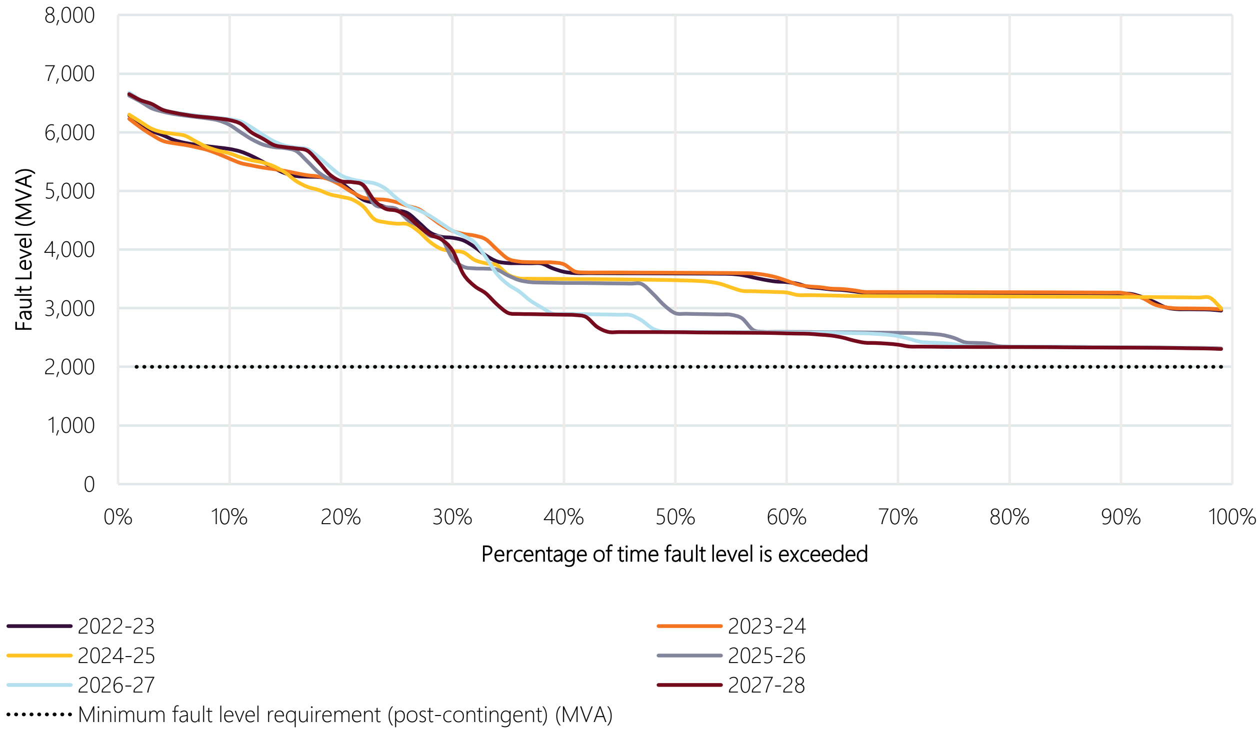
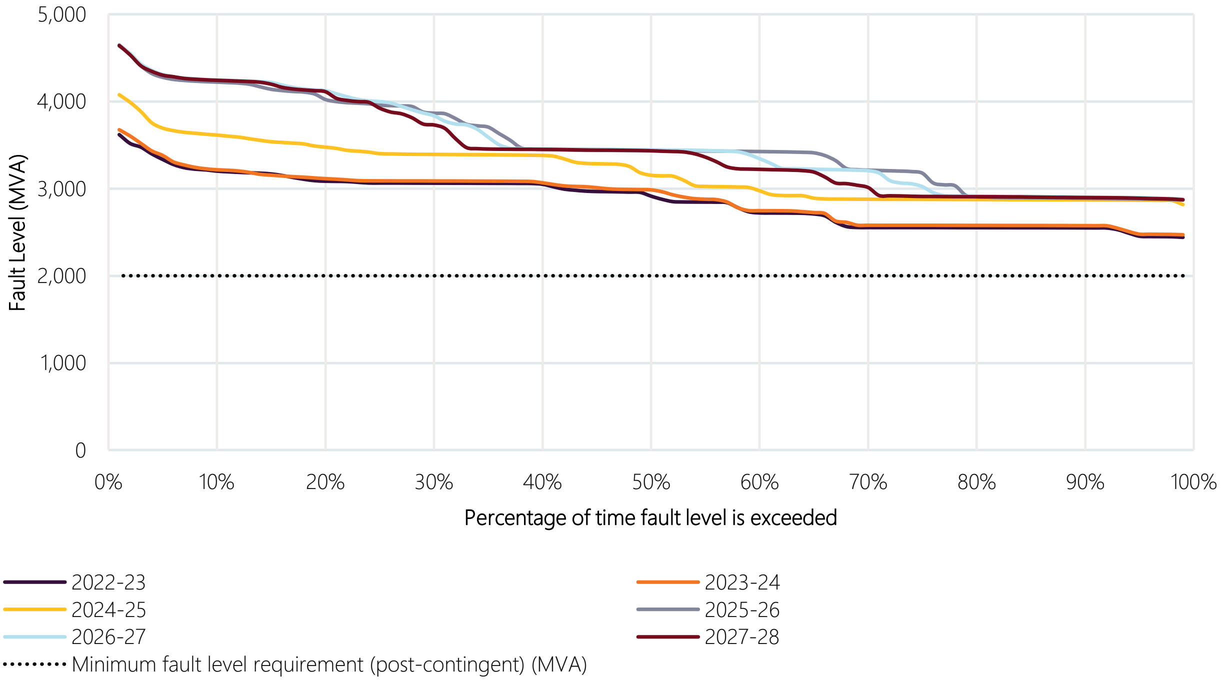


Figure 26 Robertstown node fault level duration curve against the minimum fault level requirement



4.3.5 Critical planned outages

AEMO is declaring several critical planned outages which are impactful for maintaining system strength in South Australia. The identified critical planned outages are given in Table 26.

SSSPs are expected to consider incorporation of critical planned outages into proposed system strength solutions on a case-by-case basis[40]. For example, this may be through ensuring the declared system strength standard for the system strength node is maintained, or through provision of appropriate plans to ensure sufficient system strength in the network for the duration of each relevant outage in accordance with the power system security principles in the rules.

Table 26 Critical planned outages in South Australia for each system strength node [A]

Affected system strength node	Network outage	Reason for consideration as a critical outage
All nodes in South Australia	One synchronous condenser	Significant system strength impact in South Australia for another contingency
	South East to Heywood 275 kV line	As above
	South East to Tailem Bend 275 kV line	As above
	Davenport to Mt Lock 275 kV line	As above
	Robertstown to Mokota 275 kV line	As above
	Robertstown to Tungkillo 275 kV line	As above

[40] AEMC, 2021, Rule Determination National Electricity Amendment (Efficient Management of System Strength on the Power System) Rule 2021, at https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2021/mass/secondstage/mass-draft-determination-2021.pdf?la=en. Page 98.

Affected system strength node	Network outage	Reason for consideration as a critical outage
	Robertstown to Canowie 275 kV line	As above
	Mokota to Willalo 275 kV line	As above
	Belalie to Willalo 275 kV line	As above
	Blyth West to Munno PARA 275 kV line	As above

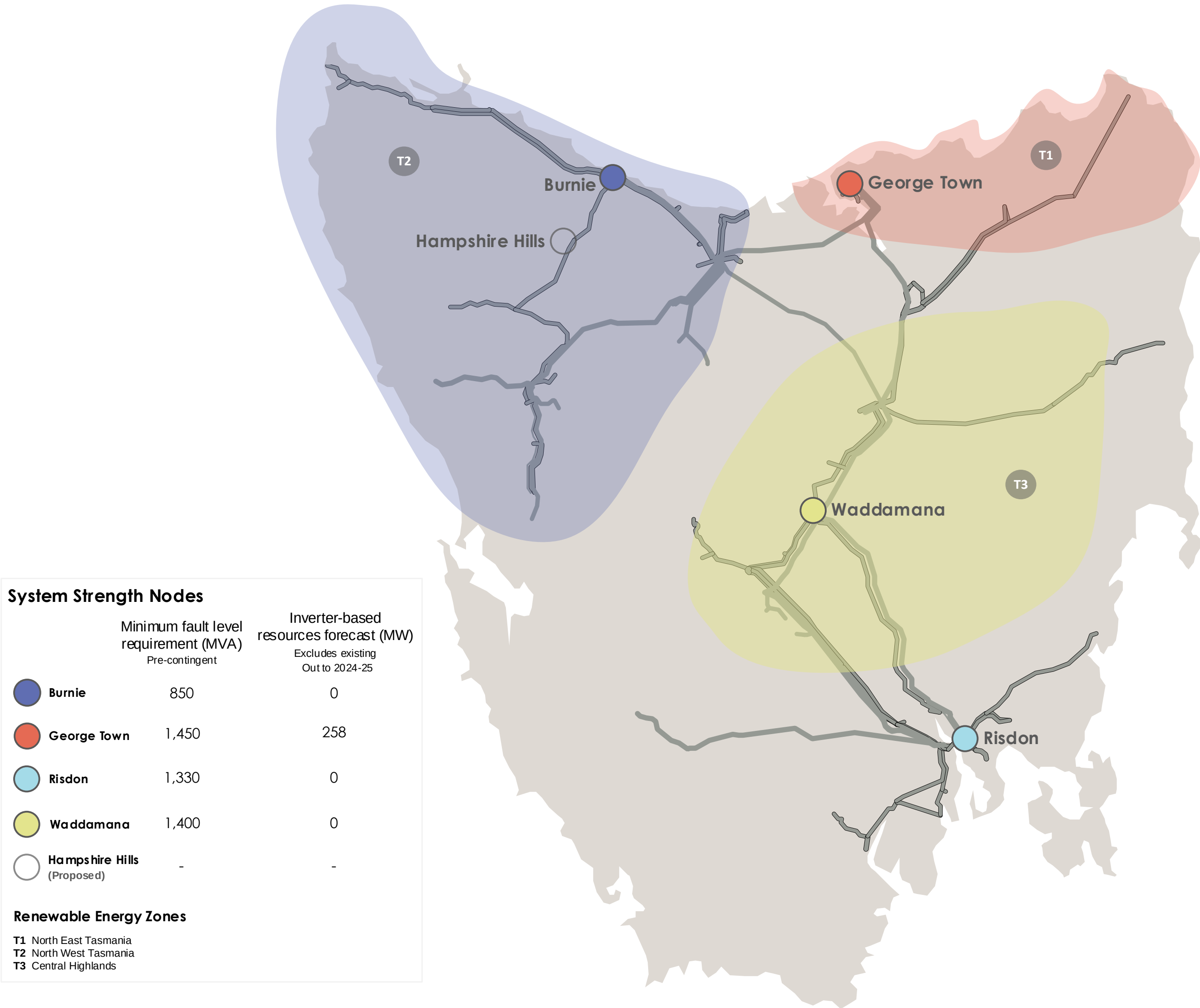
A. AEMO expects that South Australian and other regional SSSPs will engage in joint planning when critical planned outages may impact system security across different regions of the NEM.

4.4 Tasmania

Existing minimum fault level requirements in Tasmania have remained unchanged in this report. The Tasmania outlook for system strength and inertia will continue to rely on the services procured for the 2019 shortfall declaration. AEMO confirms that the system strength shortfall will re-emerge when the existing contract concludes.

Figure 27 shows the system strength nodes and system strength standards for Tasmania.

Figure 27 System strength node location and system strength standard[A,B] in Tasmania



A. Renewable energy zones are mapped to show where the majority of forecast IBR are expected, consistent with the ISP.
B. No offshore wind renewable energy zones have been shown in this figure as projected establishment of these renewable energy zones occurs outside the 10-year forecast in the ISP.

Minimum operational demand (sent-out[41]) for Tasmania is forecast to decrease by approximately 80 MW between 2022-23 and 2027-28 in the 2022 ESOO Central projection (Step Change). Further details are available in Section 3.2.

4.4.1 System strength nodes

AEMO declares four system strength nodes in Tasmania effective from 1 December 2022, as listed in Table 27. These nodes are the same as the nodes declared in 2021.

AEMO is also considering possible future system strength nodes in Tasmania as noted in Table 28. These nodes may be declared in the 2023 System Strength Report, subject to any feedback received and ongoing transformation of the power system.

Table 27 System strength nodes in Tasmania for the 2022 system strength report

System strength node	Voltage and busbar [A]	Start date	End date
Burnie 110 kV	110 kV Bus 1	Existing	Not defined
George Town 220 kV	220 kV Bus 1	Existing	Not defined
Risdon 110 kV	110 kV Bus 1	Existing	Not defined
Waddamana	220 kV Bus 1	Existing	Not defined

A. Bus 1 of the system strength node is selected by default. Alternative buses may be selected on a case-by-case basis.

Table 28 Possible future nodes in Tasmania region and closures of existing nodes

System strength node	Voltage and busbar	Start date	End date	Purpose of new node
Hampshire Hills	220 kV Bus 1	Upon connection of forecast IBR in TAS region	Not defined	This node may provide better locations for forecast IBR in Western Tasmania as it connects.

4.4.2 Minimum three phase fault level requirements

Tasmania system strength nodes and their minimum fault level and requirements are unchanged from the 2021 System Security Reports. Table 29 provides the minimum three phase fault levels applicable for each system strength node for the coming year, for which the pre-contingent fault levels should be maintained for an intact system normal power system[42].

Consistent with the SSRM, AEMO has considered whether material changes to the power system have occurred which would affect the minimum fault level requirement, as well as material changes which may occur over the forecasting period. Table 30 provides the projections for the minimum fault level requirements, including noting potential material changes (denoted by a letter), and Table 31 provides some consideration of those potential material changes.

[41] Refers to power provided by generating units to meet electrical demand, it does not include the power used to operate the generating unit.

[42] As per NER S5.1.14(a), Page 74, at https://www.aemc.gov.au/sites/default/files/2021-10/ERC0300%20-%20Final%20rule%20-%20in%20mark%20up%20format%20%28%2020.10.21%29%20-%20final.pdf.

Table 29 Tasmania minimum fault level requirements

System strength node	2022 minimum fault level requirement (MVA)		Comments [A]
	Pre-contingency	Post-contingency	
Burnie 110 kV [B]	850	560	Existing requirement
George Town 220 kV	1,450	-	Existing requirement
Risdon 110 kV	1,330	-	Existing requirement
Waddamana 220 kV	1,400	-	Existing requirement

A. 2020 System Strength and Inertia Report, at aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/planning-for-operability.
B. Requirements at Burnie may change upon the declaration of a new node at Hampshire Hills 220 kV bus.

AEMO and TasNetworks use the pre-contingency values to inform the operational arrangements for system strength requirements in Tasmania. System strength outcomes in Tasmania are assessed against their pre-contingent levels due to specific local requirements including maintaining Basslink requirements, switching requirements for local reactive plant, and some power quality requirements for metropolitan load centres.

Table 30 Pre- and post-contingent minimum fault level requirement projections for the decade ahead (MVA)

		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Burnie 220 kV	Pre-contingent	850	850 [A]	850 [A]	850 [A]	850 [A]	850 [A]	850 [A]	850 [B]	850 [B]	850 [B,C]	850 [B,C]
	Post-contingent	560	560 [A]	560 [A]	560 [A]	560 [A]	560 [A]	560 [A]	560 [B]	560 [B]	560 [B,C]	560 [B,C]
George Town 220 kV	Pre-contingent	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450	1,450
Risdon 110 kV	Pre-contingent	1,330	1,330	1,330	1,330	1,330	1,330	1,330	1,330	1,330	1,330	1,330
Waddamana 220 kV	Pre-contingent	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400

Note: Grey shading indicates the time that AEMO determines the fault levels should not change based on the forecast. A letter indicates where a material change may trigger an investigation when appropriate models and parameters are available. Material changes are shown in Table 31 and are linked to the relevant letters in this table.

Table 31 Tasmania material changes which may impact the minimum fault level requirement

Financial year	Letter	Material change	Node primarily affected	Protection requirements	Voltage step change requirement	Power system stability	Comments
2023		-					
2024	A	Likely declaration of Hampshire Hills 220 kV node	Burnie 220 kV	No updated information available at time of writing. Existing minimum applies.	Fault level required for existing static reactive devices, but this requirement should not increase from current requirement.	Power system stability requirements may change depending on how requirements are set a new node.	Depending on how requirements are set at a new node, the existing requirements at Burnie (set for power system stability reasons) may change.
2025		-					
2026		-					
2027		-					
2028		-					
2028		-					
2028		-					

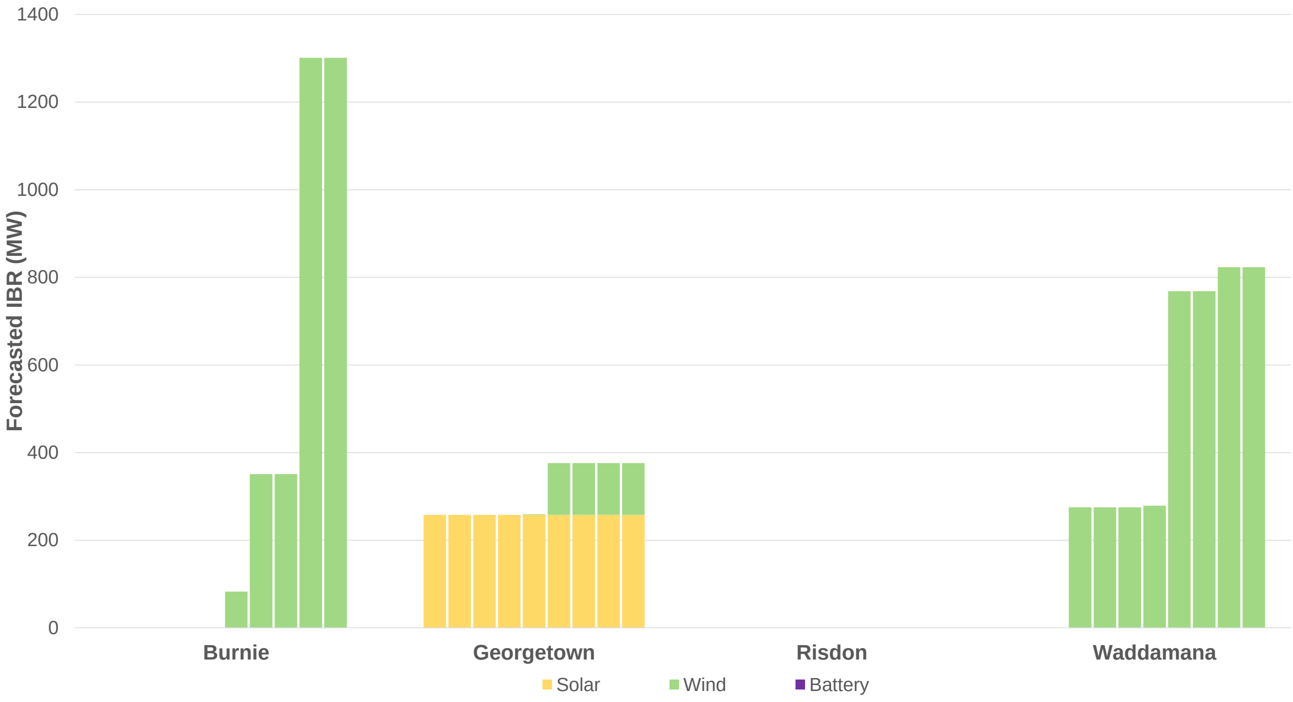
Financial year	Letter	Material change	Node primarily affected	Protection requirements	Voltage step change requirement	Power system stability	Comments
2030	B	MarinusLink Stage 1	Burnie/Hampshire Hills	No updated information available at time of writing. Existing minimum applies.	Fault level required for existing static reactive devices, but this requirement should not increase from current requirement.	Power system stability requirements may change depending on design of Marinus Link DC	Fit for purpose studies may be needed to consider the minimum fault level requirement..
2031		-					
2032	C	MarinusLink Stage 2	Burnie/Hampshire Hills	No updated information available at time of writing. Existing minimum applies.	Fault level required for existing static reactive devices, but this requirement should not increase from current requirement.	Power system stability requirements may change depending on design of Marinus Link DC	Fit for purpose studies may be needed to consider the minimum fault level requirement.
2033		-					

4.4.3 IBR projections

AEMO's 10-year forecast of the level and type of IBR and market network service facilities (MNSF) for the system strength node is listed in Figure 28 and Table 32. This forecast is provided for each system strength node.

AEMO's projection allocates the forecast of utility-scale IBR generation to the nearest system strength node over the coming decade. The data is provided by technology type. The forecast is consistent with the 2022 ISP *Step Change* scenario results[43] and the Central scenario demand forecast from the 2022 ESOO[44] but has been updated to include committed and anticipated projects from the 22 July 2022 Generation Information page[45]. AEMO has also incorporated input from the local SSSP where appropriate.

Figure 28 10-year forecast level and type of IBR and MNSF[A] by system strength node[B], Tasmania[C]



A. No MNSFs have been included in this forecast.
B. The forecast IBR at Burnie is likely to move to new node Hampshire Hills once formally declared. As it is a future node, it has not been included. Additionally, although connected to the network via inverters, MarinusLink has not been included in these forecasts. MarinusLink is not considered as market service facility for the purposes of NER clause S5.1.14(b)(2).
C. The near-term years of the forecast may require adjustment by the SSSP when preparing system strength services, as more information becomes available about newly-committed IBR and MNSF.

[43] AEMO. 2022 *Integrated System Plan*, page 9, AEMO, at https://aemo.com.au/-/media/files/major-publications/isp/2022/2022-documents/2022-integrated-system-plan-isp.pdf?la=en.

[44] AEMO. 2022 *Electricity Statement of Opportunities*, page 34, AEMO, at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2022/2022-electricity-statement-of-opportunities.pdf?la=en.

[45] AEMO. NEM Generation Information, at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information.

Table 32 Forecast level and type of IBR and MNSF at each system strength node for the next 10 years[A]

System strength node	Technology	Existing IBR	Forecast IBR (MW) [B]										
			Financial year ending										
			2023	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**
Burnie	Solar	0	0	0	0	0	0	0	0	0	0	0	0
	Wind	250	0	0	0	0	0	0	83	351	351	1301	1301
	Battery	0	0	0	0	0	0	0	0	0	0	0	0
	Total IBR		**0**	**0**	**0**	**0**	**0**	**0**	**83**	**351**	**351**	**1301**	**1301**
George Town	Solar	0	0	0	258	258	258	258	258	258	258	258	258
	Wind	167	0	0	0	0	0	0	0	118	118	118	118
	Battery	0	0	0	0	0	0	0	0	0	0	0	0
	Total IBR		**0**	**0**	**258**	**258**	**258**	**258**	**258**	**376**	**376**	**376**	**376**
Risdon	Solar	0	0	0	0	0	0	0	0	0	0	0	0
	Wind	0	0	0	0	0	0	0	0	0	0	0	0
	Battery	0	0	0	0	0	0	0	0	0	0	0	0
	Total IBR		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Waddamana	Solar	0	0	0	0	0	0	0	0	0	0	0	0
	Wind	144	0	0	0	275	275	275	279	768	768	823	823
	Battery	0	0	0	0	0	0	0	0	0	0	0	0
	Total IBR		**0**	**0**	**0**	**275**	**275**	**275**	**279**	**768**	**768**	**823**	**823**

A. The near-term years of the forecast may require adjustment by the SSSP when preparing system strength services, as more information becomes available about newly-committed IBR and MNSF.
B. This forecast includes utility-scale IBR only, consistent with ISP *Step Change* scenario modelling. Distributed Energy Resources, including rooftop PV, are not included. As per the SSRM, SSSPs may in some cases propose to include system strength to facilitate synchronism of DER as part of assessing what is required to achieve stable operation of projected IBR. For this purpose, DER capacity forecasts are published in AEMO's *Inputs, Assumptions and Scenarios Report*, at https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp/current-inputs-assumptions-and-scenarios.

Hampshire Hills is not yet a declared node. Until its declaration, IBR associated with Hampshire Hills is assigned to the Burnie node.

4.4.4 Fault level projections and shortfalls

AEMO must assess and declare fault level shortfalls until December 2025[46]. Table 33 shows the projected minimum fault levels for each system strength node and the shortfalls declared in this report. Results show a strength shortfall at all nodes within this horizon. These shortfalls have been addressed through TasNetworks entering into a commercial agreement with Hydro Tasmania for the provision of system strength and inertia services, which expires in 2024. AEMO considers that beyond the end of that agreement, the operation of generation in the market in Tasmania will be insufficient to meet the requirements for system strength and inertia in Tasmania from May 2024.

Table 33 Projected minimum fault levels, and shortfall declarations, in Tasmania for the next five years

System strength node	Projections (*Step Change*) and shortfalls						
	Projected minimum three phase fault level for 99% of the time						Shortfalls and comments [A, B, C]
	2022-23[D]	2023-24[D]	2024-25	2025-26	2026-27[G]	2027-28[G]	
Burnie 110 kV	850	850	476 (374 MVA shortfall)	427 (423 MVA shortfall)	429 (421 MVA below requirement)	429 (422 MVA below requirement)	A shortfall range of 374 to 423 MVA is declared for 15 April 2024 to 1 December 2025[E]. This is an adjustment to the existing shortfall declared in December 2021[F]. AEMO has requested that services be available from 15 April 2024.
George Town 220 kV	1,450	1,450	733 (717 MVA shortfall)	623 (827 MVA shortfall)	627 (824 MVA below requirement)	626 (824 MVA below requirement)	A shortfall range of 717 to 827 MVA is declared for 15 April 2024 to 1 December 2025 [E]. This is an adjustment to the existing shortfall declared in December 2021 [F]. AEMO has requested that services be available from 15 April 2024.
Risdon 110 kV	1,330	1,330	927 (403 MVA shortfall)	819 (511 MVA shortfall)	825 (505 MVA below requirement)	824 (506 MVA below requirement)	A shortfall range of 403 to 511 MVA is declared for 15 April 2024 to 1 December 2025 [E]. This is an adjustment to the existing shortfall declared in December 2021 [F]. AEMO has requested that services be available from 15 April 2024.
Waddamana 220 kV	1,400	1,400	960 (440 MVA shortfall)	806 (594 MVA shortfall)	812 (588 MVA below requirement)	811 (589 MVA below requirement)	A shortfall range of 440 to 594 MVA is declared for 15 April 2024 to 1 December 2025 [E]. This is an adjustment to the existing shortfall declared in December 2021 [F]. AEMO has requested that services be available from 15 April 2024.

A. The system strength outcomes for Tasmania are assessed on a pre-contingent basis due to specific local requirements including maintaining Basslink requirements, switching requirements for local reactive plant, and some power quality requirements for metropolitan load centres.
B. AEMO has confirmed with TasNetworks that the amendments to its services agreement with Hydro Tasmania address the system strength and inertia shortfalls declared in May 2021.
C. AEMO will request that TasNetworks provide system strength services to address the shortfall by 15 April 2024.
D. The values for 2022-23 and 2023-24 reflect the minimum requirement as AEMO assumes that the existing service agreement (refer to note B above) will ensure the minimum requirement is maintained.
E. The shortfalls in Tasmania have changed since previous declarations. A new forecast and set of assumptions about the network have been applied in line with the Step Change scenario augmentations as per Appendix A1.2.
F. As per the 2021 System Security reports, at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/operability/2021/system-security-reports.pdf?la=en.
G. From December 2025 no shortfalls will be declared. Should fault levels be projected to fall below the requirement in these years, it is expected the new system strength framework will ensure there is sufficient system strength services throughout the region.

[46] See clause 11.143.14, outlining the transitional arrangements for declaration of shortfalls before December 2025, introduced by National Electricity Amendment (Efficient management of system strength on the power system) Rule 2021 No.11.

The fault level duration curves for the Tasmania region are shown in Figure 29 through Figure 32. The results have been post-processed to account for the existing system strength services contract for the years 2022-23 and 2023-24. The contract ends on 15 April 2024 and the declared shortfall reflects this.

Figure 29 Burnie node fault level duration curve against the minimum fault level requirement

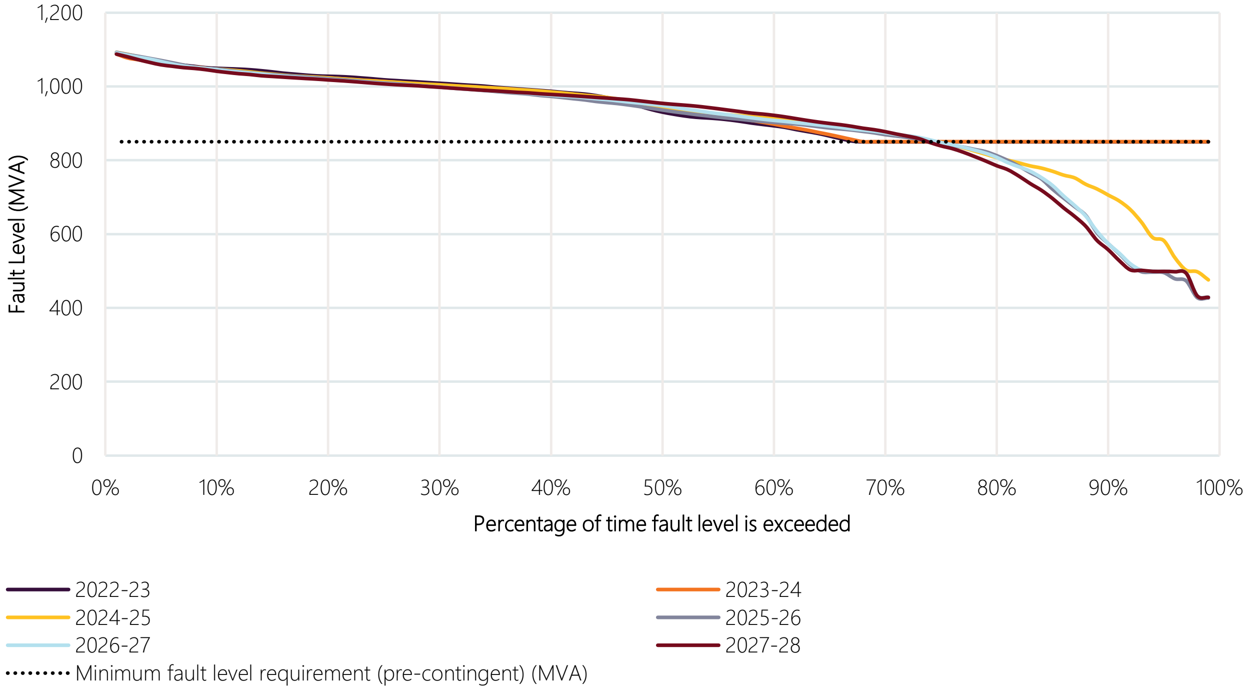


Figure 30 George Town node fault level duration curve against the minimum fault level requirement

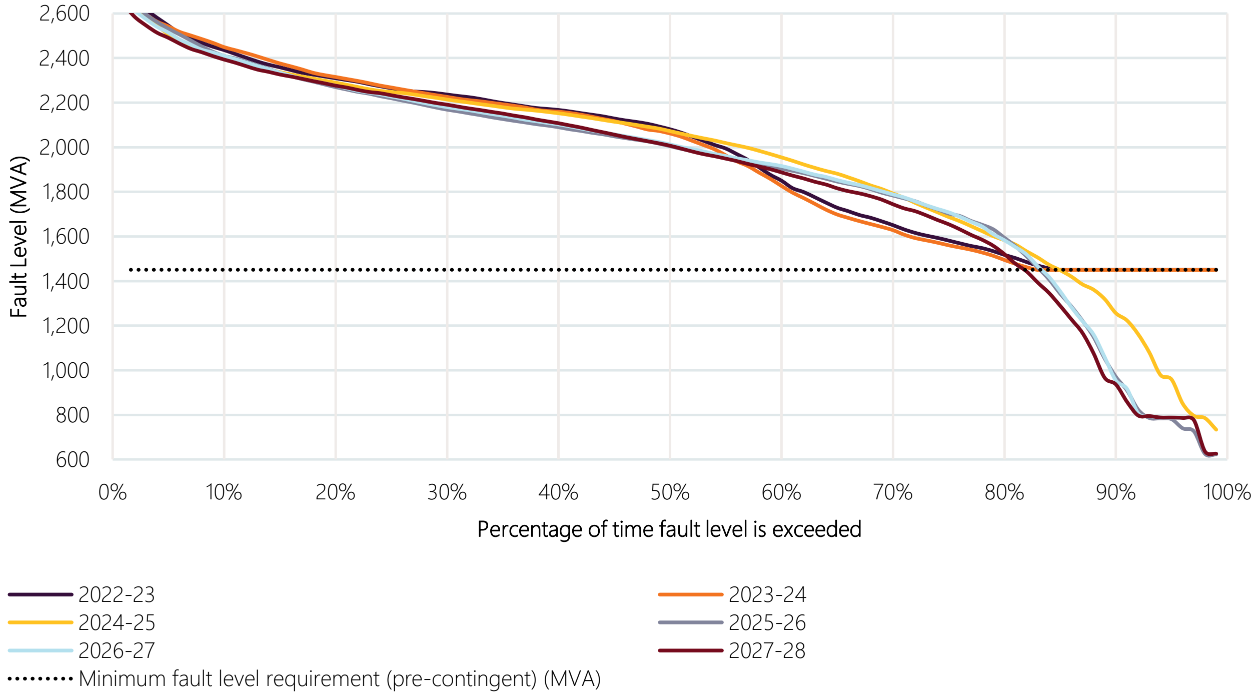


Figure 31 Risdon node fault level duration curve against the minimum fault level requirement

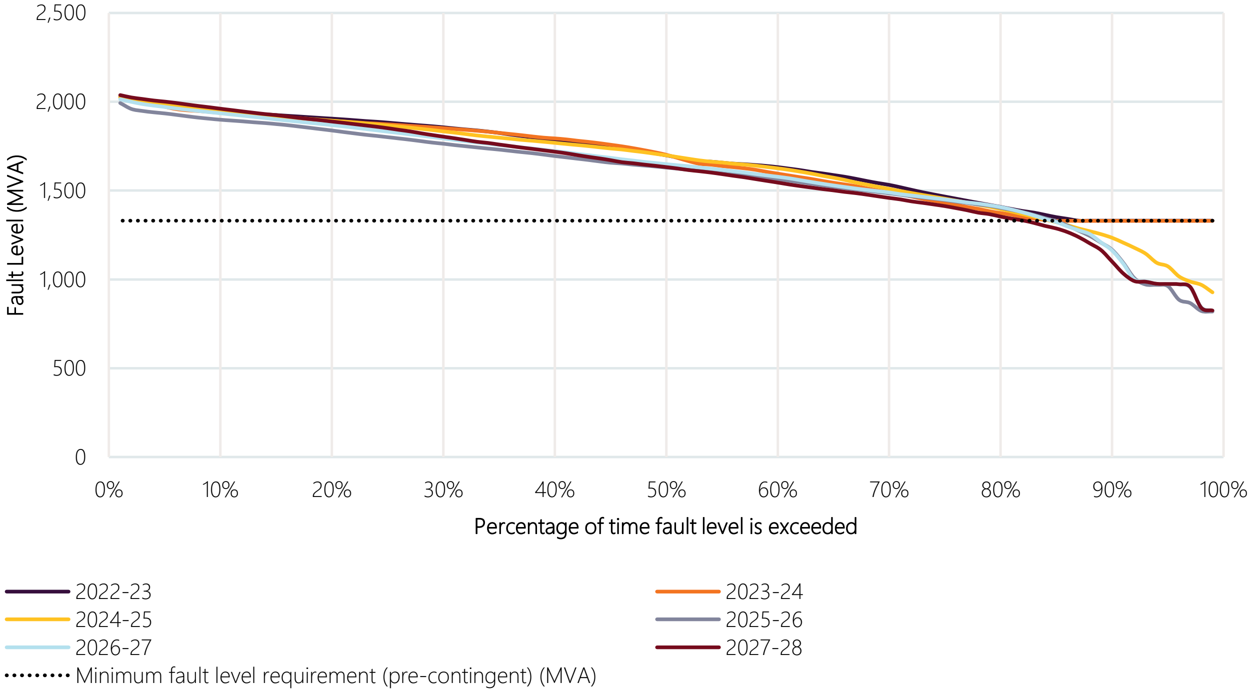
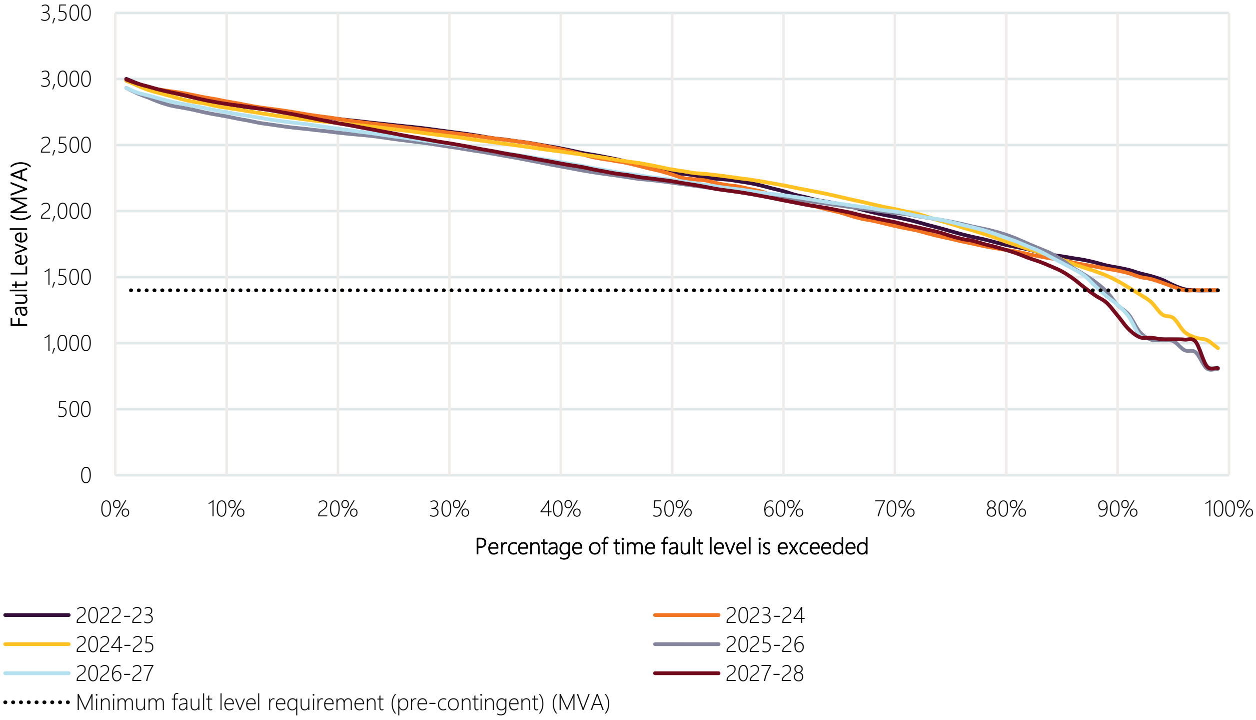


Figure 32 Waddamana node fault level duration curve against the minimum fault level requirement



4.4.5 Critical planned outages

AEMO is declaring no critical planned outages which are impactful for maintaining system strength in Tasmania.

SSSPs are expected to consider incorporation of critical planned outages into proposed system strength solutions on a case-by-case basis[47]. For example, this may be through ensuring the declared system strength standard for the system strength node is maintained, or through provision of appropriate plans to ensure sufficient system strength in the network for the duration of each relevant outage in accordance with the power system security principles in the rules.

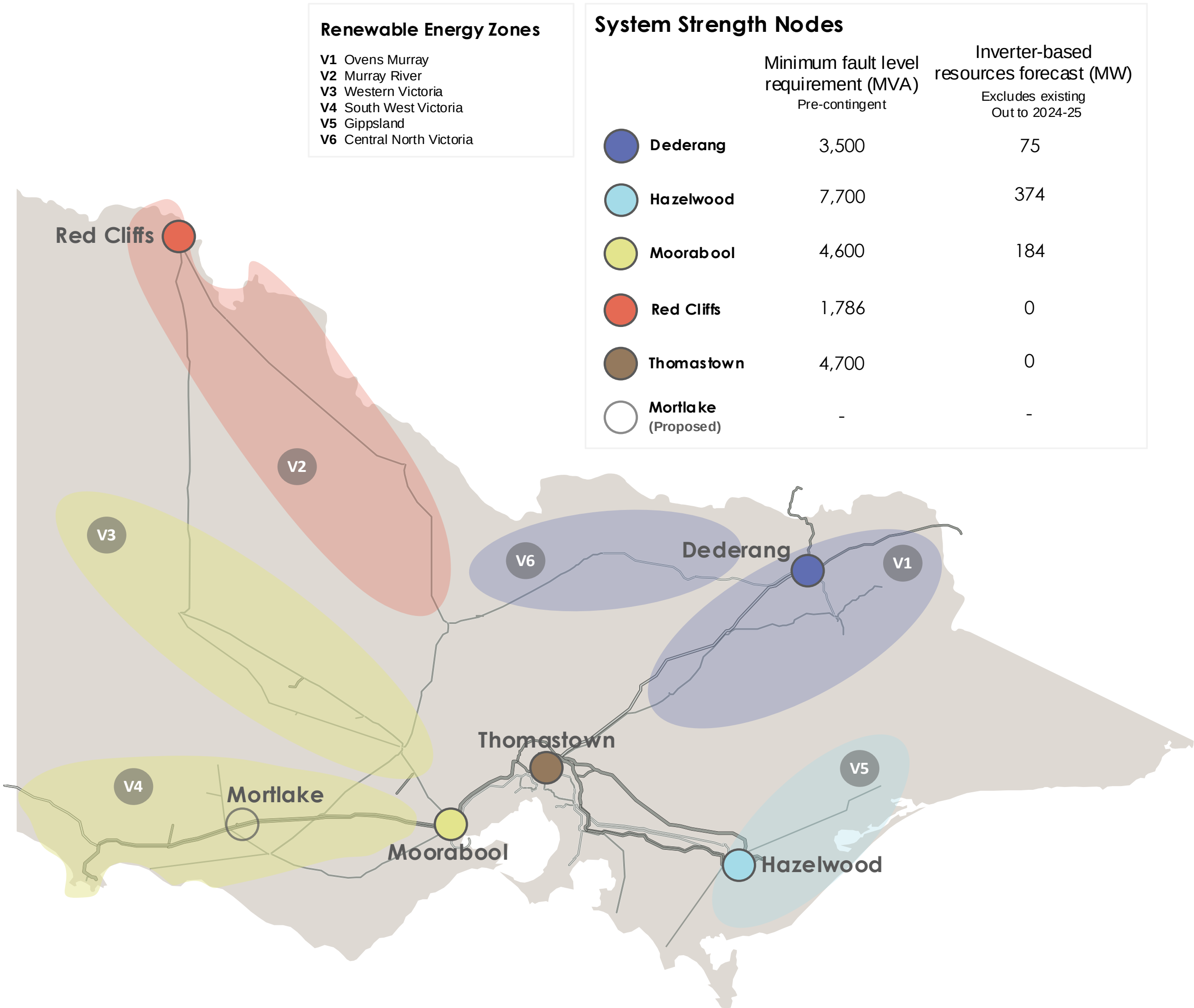
[47] AEMC, 2021, Rule Determination National Electricity Amendment (Efficient Management of System Strength on the Power System) Rule 2021, at https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2021/mass/secondstage/mass-draft-determination-2021.pdf?la=en. Page 98.

4.5 Victoria

Existing minimum fault level requirements in Victoria have remained unchanged in this report. Although potential lack of system strength is projected at Hazelwood, Thomastown and Moorabool from 2026-27 onwards, it is expected that the new system strength standard will be met after December 2025 and formal shortfalls are not declared.

Figure 33 shows the system strength nodes and system strength standards for Victoria.

Figure 33 System strength node location and system strength standard[A,B] in Victoria



System Strength Nodes

	Minimum fault level requirement (MVA) Pre-contingent	Inverter-based resources forecast (MW) Excludes existing Out to 2024-25
Dederang	3,500	75
Hazelwood	7,700	374
Moorabool	4,600	184
Red Cliffs	1,786	0
Thomastown	4,700	0
Mortlake (Proposed)	-	-

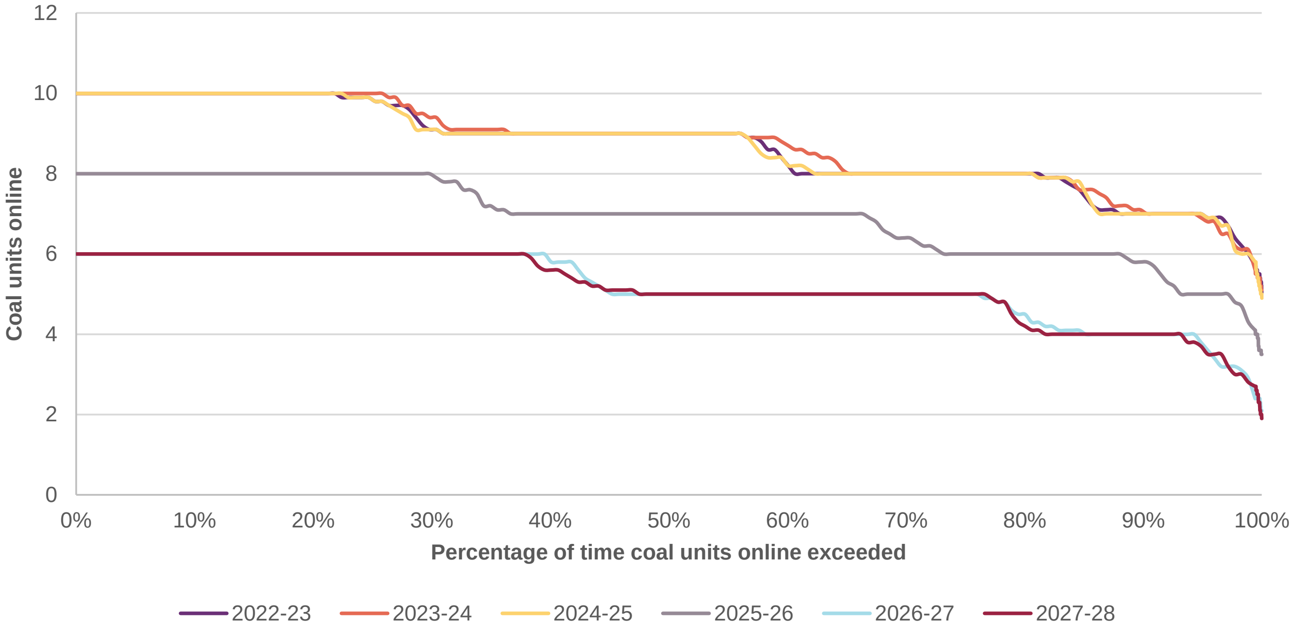
A. Renewable energy zones are mapped to show where the majority of forecast IBR are expected, consistent with the ISP.
B. No offshore wind renewable energy zones have been shown in this figure as projected establishment of these renewable energy zones occurs outside the 10-year forecast in the ISP.

System strength provision is particularly pressured in the context of low demand on the power system and decline of available sources of traditional service provision such as synchronous generators.

Minimum operational demand (sent-out[48]) for Victoria is forecast to decrease by approximately 1,500 MW between 2022-23 and 2027-28 in the 2022 ESOO Central projection (*Step Change)*. Further details are available in Section 3.2.

The number of coal generators projected to be online Victoria across the year is forecast to decline significantly from 2025-26 onwards, as shown in Figure 34.

Figure 34 Number of coal units projected online under *Step Change* scenario, Victoria



[48] Refers to power provided by generating units to meet electrical demand, it does not include the power used to operate the generating unit.

4.5.1 System strength nodes

AEMO declares five system strength nodes in Victoria effective from 1 December 2022, as listed in Table 34. These nodes are the same as the nodes declared in 2021.

AEMO is also considering possible future system strength nodes in Victoria as noted in Table 35. These nodes may be declared in the 2023 System Strength Report, subject to any feedback received and ongoing transformation of the power system.

Table 34 System strength nodes in Victoria for the 2022 system strength report

System strength node	Voltage and busbar[A]	Start date	End date
Dederang	220 kV Bus 1	Existing	Not defined
Hazelwood	500 kV Bus 1	Existing	Not defined
Moorabool	220 kV Bus 1	Existing	Not defined
Red Cliffs	220 kV Bus 1	Existing	Not defined
Thomastown	220 kV Bus 1	Existing	Not defined

A. Bus 1 of the system strength node is selected by default. Alternative buses may be selected on a case-by-case basis.

Table 35 Possible future nodes in the Victoria region and closures of existing nodes

System strength node	Voltage and busbar	Start date	End date	Purpose of new node
Mortlake	500 kV Bus 1	Upon connection of forecast IBR in Victoria region	Not defined	This node may provide better locations for location of forecast IBR in Southern Victoria as it connects. It may also provide a node suitable for assessing critical planned outages on the interconnector with other regions.

4.5.2 Minimum three phase fault level requirements

0 provides the minimum three phase fault levels applicable for each system strength node for the coming year, for which the pre-contingent fault levels should always be maintained for an intact system normal power system[49].

Consistent with the SSRM, AEMO has considered whether material changes to the power system have occurred which would affect the minimum fault level requirement, as well as material changes which may occur over the forecasting period. Table 37 provides the projections for the minimum fault level requirements, including noting potential material changes (denoted by a letter), and Table 38 provides some consideration of those potential material changes.

[49] As per NER S5.1.14(a), Page 74, at https://www.aemc.gov.au/sites/default/files/2021-10/ERC0300%20-%20Final%20rule%20-%20in%20mark%20up%20format%20%28%2020.10.21%29%20-%20final.pdf.

Table 36 Victoria minimum fault level requirements

System strength node	2022 minimum fault level requirement (MVA)		Comments
	Pre-contingency	Post-contingency	
Dederang 220 kV	3,500	3,300	Existing requirement [A]
Hazelwood 500 kV	7,700	7,150	Existing requirement [A]
Moorabool 220 kV	4,600	4,050	Existing requirement [A]
Red Cliffs 220 kV	1,786	1,036	Existing requirement [B]
Thomastown 220 kV	4,700	4,500	Existing requirement [A]

A. 2020 System Strength and Inertia Report, at aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/planning-for-operability.
B. 2021 System Security reports, at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/operability/2021/system-security-reports.pdf?la=en.

Table 37 Pre and Post contingent minimum fault level requirement projections for the decade ahead (MVA)

		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Dederang 220 kV	Pre-contingent	3,500	3,500	3,500	3,500	3,500	3,500[B]	3,500[B]	3,500[B]	3,500[B]	3,500[B]	3,500[B]
	Post-contingent	3,300	3,300	3,300	3,300	3,300	3,300[B]	3,300[B]	3,300[B]	3,300[B]	3,300[B]	3,300[B]
Hazelwood 500 kV	Pre-contingent	7,700	7,700	7,700	7,700	7,700	7,700[B]	7,700[B]	7,700[B]	7,700[B]	7,700[B]	7,700[B]
	Post-contingent	7,150	7,150	7,150	7,150	7,150	7,150[B]	7,150[B]	7,150[B]	7,150[B]	7,150[B]	7,150[B]
Moorabool 220 kV	Pre-contingent	4,600	4,600	4,600	4,600	4,600	4,600[B]	4,600[B]	4,600[B]	4,600[B]	4,600[B]	4,600[B]
	Post-contingent	4,050	4,050	4,050	4,050	4,050	4,050[B]	4,050[B]	4,050[B]	4,050[B]	4,050[B]	4,050[B]
Red Cliffs 220 KV	Pre-contingent	1,786	1,786	1,786	1,786[A]	1,786[A]	1,786 [A,B,C]	1,786 [A,B,C]	1,786 [A,B,C]	1,786 [A,B,C]	1,786 [A,B,C]	1,786 [A,B,C]
	Post-contingent	1,036	1,036	1,036	1,036[A]	1,036[A]	1,036 [A,B,C]	1,036 [A,B,C]	1,036 [A,B,C]	1,036 [A,B,C]	1,036 [A,B,C]	1,036 [A,B,C]
Thomastown 220 KV	Pre-contingent	4,700	4,700	4,700	4,700	4,700	4,700[B]	4,700[B]	4,700[B]	4,700[B]	4,700[B]	4,700[B]
	Post-contingent	4,500	4,500	4,500	4,500	4,500	4,500[B]	4,500[B]	4,500[B]	4,500[B]	4,500[B]	4,500[B]

Note: Grey shading indicates the time that AEMO determines the fault levels should not change based on the forecast. A letter indicates where a material change may trigger an investigation when appropriate models and parameters are available. Material changes are shown in Table 38 and are linked to the relevant letters in this table.

Table 38 Victoria material changes which may impact the minimum fault level requirement

Financial year	Letter	Material change	Node primarily affected	Protection requirements	Voltage step change requirement	Power system stability	Comments
2023		-					
2024		-					
2025	A	Project Energy Connect in service	Red Cliffs 220 kV	No updated information available at time of writing. Existing minimum applies.	Fault level required for existing static reactive devices, but this requirement should not increase from current requirement.	No comments.	Reduction of network impedance combined with synchronous condensers installed as part of Project Energy Connect will likely lead to fewer synchronous generators required to meet existing minimum fault level. Fit for purpose studies may be needed to consider the minimum fault level requirement.
2026							
2027		-					
2028		-					
2028	B	Retirement of synchronous generation in Latrobe Valley	All nodes	No updated information available at time of writing. Existing minimum applies.	Fault level required for existing static reactive devices, but this requirement should not increase from current requirement.	No comments.	Retirement of synchronous generators may mean that system strength in Victoria is delivered by other means elsewhere in the region. This may affect minimum fault level requirements throughout the region. Fit for purpose studies may be needed to consider the minimum fault level requirement.
2028	C	VNI West in service	Red Cliffs	No updated information available at time of writing. Existing minimum applies.	Fault level required for existing static reactive devices, but this requirement should not increase from current requirement.	No comments.	Reduction of network impedance combined will likely lead to fewer synchronous generators required to meet existing minimum fault level. Fit for purpose studies may be needed to consider the minimum fault level requirement..
2029		-					
2030		-					
2031		-					
2032		-					
2033		-					

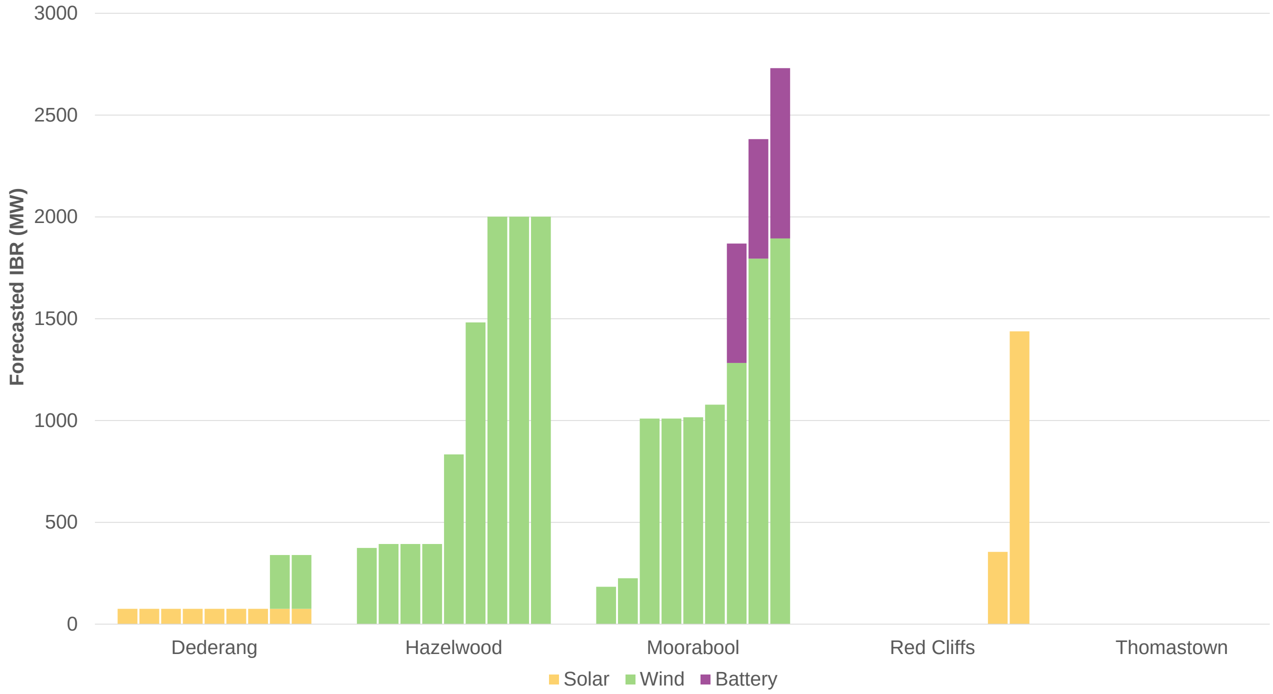
4.5.3 IBR projections

AEMO's 10-year forecast of the level and type of IBR and market network service facilities (MNSF) for the system strength node is described in Figure 35 and Table 39. This forecast is provided for each system strength node.

AEMO's projection allocates the forecast of utility-scale IBR generation to the nearest system strength node over the coming decade. The data is provided by technology type. The forecast is consistent with the 2022 ISP *Step*

Change scenario results[50] and the Central scenario demand forecast from the 2022 ESOO[51] but has been updated to include committed and anticipated projects from the 22 July 2022 Generation Information page[52]. AEMO has also incorporated input from the local SSSP where appropriate.

Figure 35 10-year forecast level and type of IBR[A] and MNSF[B] by system strength node, Victoria[C]



A. Although connected to the network via inverters, MarinusLink has not been included in these forecasts. MarinusLink is not considered as market service facility for the purposes of NER clause S5.1.14(b)(2).
B. No MNSFs have been included in this forecast.
C. The near-term years of the forecast may require adjustment by the SSSP when preparing system strength services, as more information becomes available about newly-committed IBR and MNSF.

50 AEMO. 2022 Integrated System Plan, page 9, at https://aemo.com.au/-/media/files/major-publications/isp/2022/2022-documents/2022-integrated-system-plan-isp.pdf?la=en.

51 AEMO. 2022 Electricity Statement of Opportunities, page 34, at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2022/2022-electricity-statement-of-opportunities.pdf?la=en.

52 AEMO. NEM Generation Information, at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information.

Table 39 Forecast type and level of IBR and MNSF at each system strength node for the next 10 years[A]

System strength node	Technology	Existing IBR	Forecast IBR (MW) [B]										
			Financial year ending										
			2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Moorabool	Solar	0	0	0	0	0	0	0	0	0	0	0	0
	Wind	3625	0	0	184	225	1010	1010	1010	1071	1276	1789	1888
	Battery	300	0	0	0	0	0	0	0	0	586[B]	586	586
	Total IBR	**3695**	**0**	**0**	**184**	**225**	**1010**	**1010**	**1010**	**1071**	**1862**	**2375**	**2474**
Hazelwood	Solar	0	0	0	0	0	0	0	0	0	0	0	0
	Wind	106	0	0	374	394	394	394	833	1482	2001	2001	2001
	Battery	0	0	0	0	0	0	0	0	0	0	0	0
	Total IBR	**106**	**0**	**0**	**374**	**394**	**394**	**394**	**833**	**1482**	**2001**	**2001**	**2001**
Dederang	Solar	302	0	0	75	75	75	75	75	75	75	75	75
	Wind	0	0	0	0	0	0	0	0	0	0	264	264
	Battery	0	0	0	0	0	0	0	0	0	0	0	0
	Total IBR	**360**	**0**	**0**	**75**	**75**	**75**	**75**	**75**	**75**	**75**	**339**	**339**
Red Cliffs	Solar	604	0	0	0	0	0	0	0	0	0	354	1437
	Wind	198	0	0	0	0	0	0	0	0	0	0	0
	Battery	0	0	0	0	0	0	0	0	0	0	0	0
	Total IBR	**802**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**354**	**1437**
Thomastown	Solar	0	0	0	0	0	0	0	0	0	0	0	0
	Wind	57	0	0	0	0	0	0	0	0	0	0	0
	Battery	0	0	0	0	0	0	0	0	0	0	0	0
	Total IBR	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

A. The near-term years of the forecast may require adjustment by the SSSP when preparing system strength services, as more information becomes available about newly-committed IBR and MNSF.
B. This forecast includes utility-scale IBR only, consistent with ISP *Step Change* scenario modelling. Distributed energy resources, including rooftop PV, are not included. As per the SSRM, SSSPs may in some cases propose to include system strength to facilitate synchronism of DER as part of assessing what is required to achieve stable operation of projected IBR. For this purpose, DER capacity forecasts are published in AEMO's *Inputs, Assumptions and Scenarios Report*, at https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp/current-inputs-assumptions-and-scenarios.
C. ISP results do not allocate BESS to specific renewable energy zones but rather to the region as a whole. Allocating this BESS to Moorabool node was performed in post-processing.

4.5.4 Fault level projections and shortfalls

AEMO must assess and declare fault level shortfalls until December 2025[53]. Table 40 shows the projected minimum fault levels for each system strength node and the shortfalls declared in this report. Results show a strength shortfall at Hazelwood, Moorabool and Thomastown due to the projected decline in the number of synchronous machines online in the Latrobe Valley in response to declining minimum demand and increasing VRE and distributed PV. These shortfalls occur post-2025 and as such are not formally declared.

The fault level duration curves for the Victoria region are shown in Figure 36 through Figure 40.

Table 40 Projected minimum fault levels, and shortfall declarations, in Victoria for the next five years

System strength node	Projections (*Step Change*) and shortfalls						
	Projected minimum three phase fault level for 99% of the time						Shortfalls and comments [A]
	2022-23	2023-24	2024-25	2025-26	2026-27[B]	2027-28[B]	
Dederang 220 kV	3,655	3,903	3,814	3,856	3,860	3,788	No shortfall
Hazelwood 500 kV	8,893	8,740	8,693	7,697	6,709 (441 MVA below requirement)	6,638 (512 MVA below requirement)	No shortfall
Moorabool 220 kV	4,533	4,528	4,294	4,166	3,981(69 MVA below requirement)	3,927 (123 MVA below requirement)	No shortfall
Red Cliffs 220 kV	1,042	1,042	1,036	2,007	2,097	2,086	No shortfall
Thomastown 220 kV	5,347	5,312	5,199	4,846	4,300 (200 MVA below requirement)	4,236 (264 MVA below requirement)	No shortfall

A. The system strength outcomes for Victoria are assessed on a post-contingent basis.
B. From December 2025 no shortfalls will be declared. Should fault levels be projected to fall below the requirement in these years, it is expected the new system strength framework will ensure there is sufficient system strength services throughout the region.

[53] See clause 11.143.14, outlining the transitional arrangements for declaration of shortfalls before December 2025, introduced by National Electricity Amendment (Efficient management of system strength on the power system) Rule 2021 No.11.

Figure 36 Dederang node fault level duration curve against the minimum fault level requirement

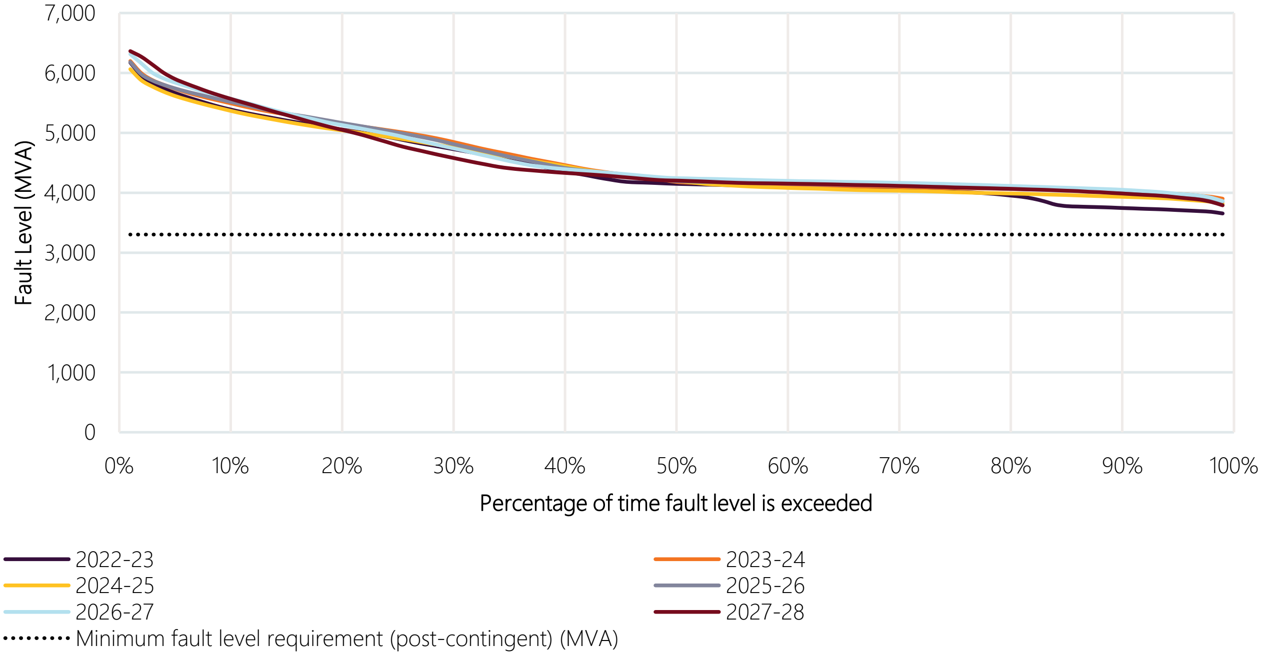


Figure 37 Hazelwood node fault level duration curve against the minimum fault level requirement

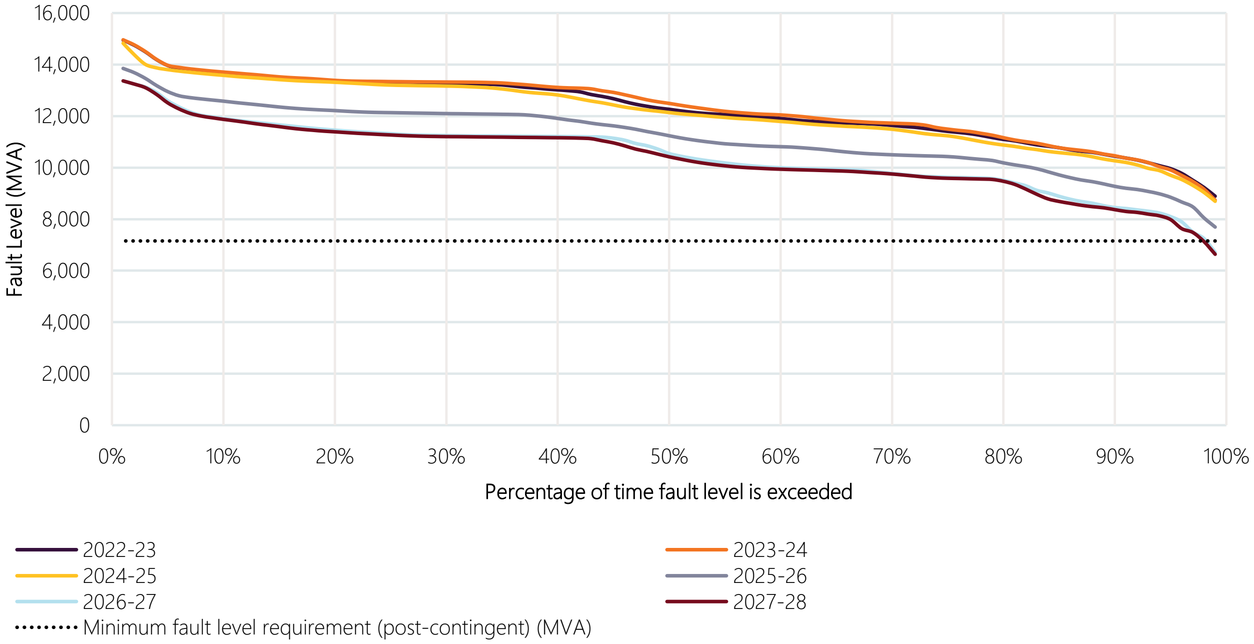


Figure 38 Moorabool node fault level duration curve against the minimum fault level requirement

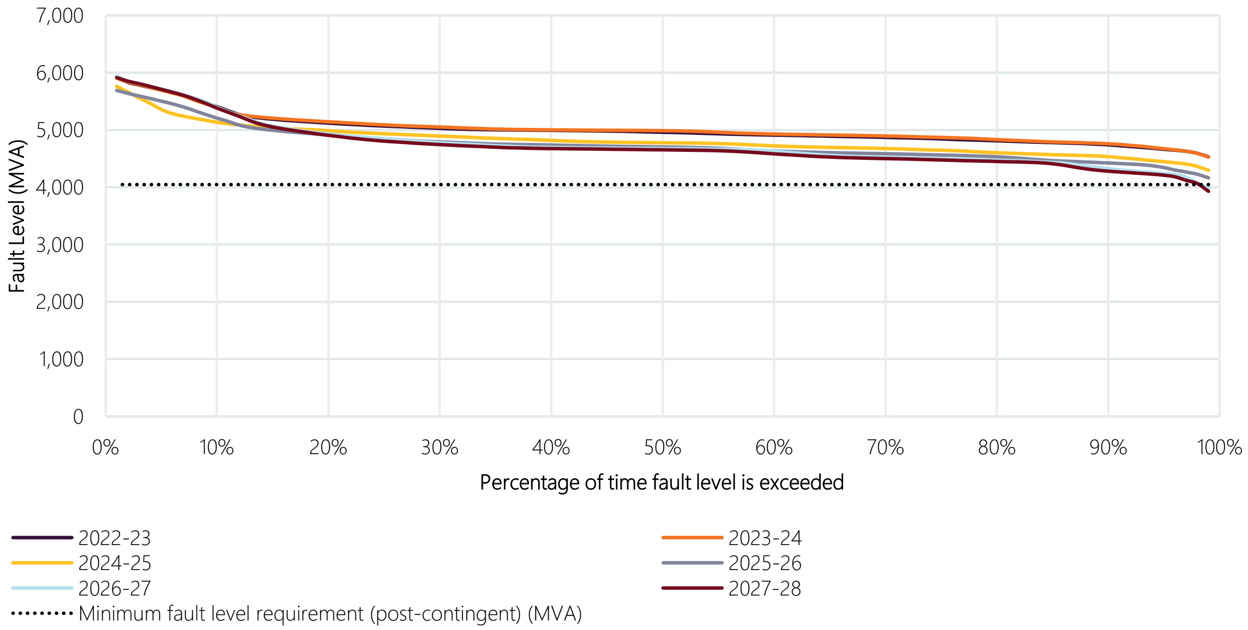


Figure 39 Red Cliffs node fault level duration curve against the minimum fault level requirement

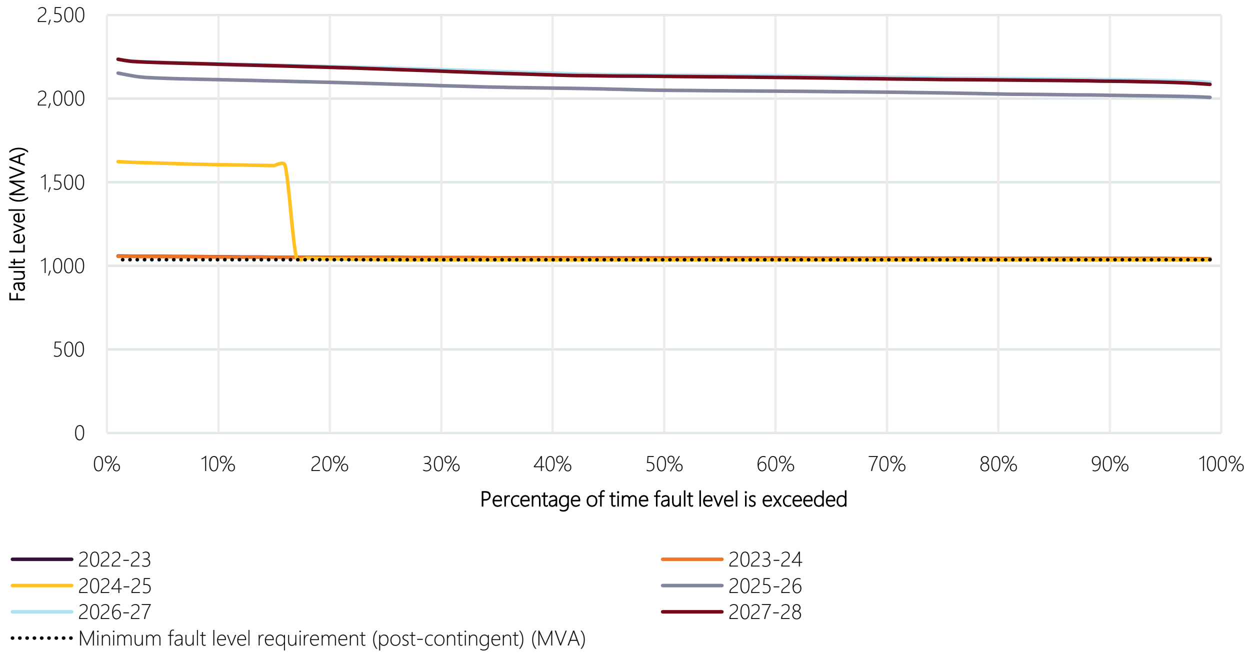
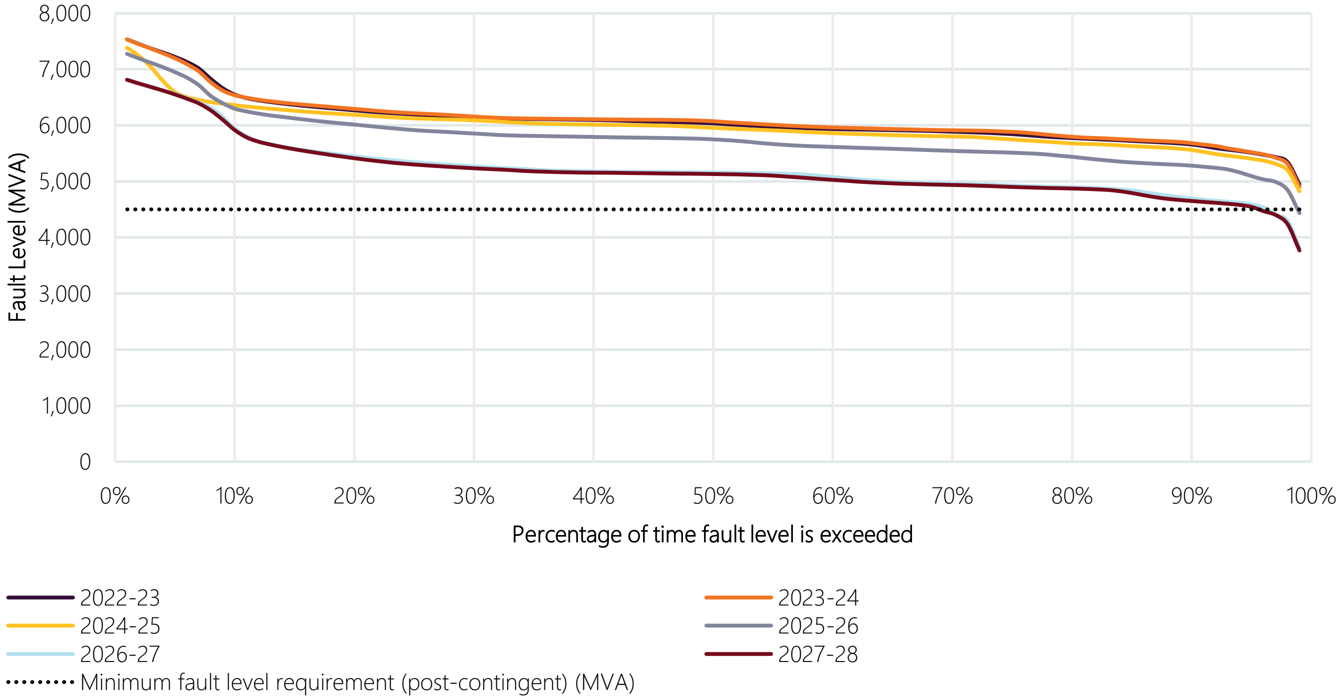


Figure 40 Thomastown node fault level duration curve against the minimum fault level requirement



4.5.5 Critical planned outages

AEMO is declaring several critical planned outages which are impactful for maintaining system strength in Victoria. The identified critical planned outages are given in 0.

SSSPs are expected to consider incorporation of critical planned outages into proposed system strength solutions on a case-by-case basis[54]. For example, this may be through ensuring the declared system strength standard for the system strength node is maintained, or through provision of appropriate plans to ensure sufficient system strength in the network for the duration of each relevant outage in accordance with the power system security principles in the rules.

[54] AEMC, 2021, Rule Determination National Electricity Amendment (Efficient Management of System Strength on the Power System) Rule 2021, at https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2021/mass/secondstage/mass-draft-determination-2021.pdf?la=en. Page 98.

Table 41 Critical planned outages in Victoria for each system strength node [A]

Affected system strength node	Network outage	Reason for consideration as a critical outage
Dederang (Darlington Point in NSW)	Dederang to Wodonga 330 kV line	Fault level at Darlington Point node in NSW drops below requirement for another contingency.
Moorabool **Thomastown**	Hazelwood to Loy Yang Power station 1 or 2 or 3 500 kV line	One of the specified minimum synchronous unit combinations must be dispatched.[B]
	Moorabool to Sydenham 1 or 2 500 kV line	As above
	Hazelwood to Loy Yang Power station 1 or 2 or 3 500 kV line	As above
	Moorabool to Sydenham 1 or 2 500 kV line	As above
	South Morang to Rowville 500 kV line	As above
Moorabool	500/220 kV Transformer at Moorabool	Fault level at Moorabool node drops below requirement for another contingency.
	Mortlake to Moorabool 500 kV line	Significant system strength impact along Victoria to South Australia corridor for another contingency
	Heywood to Mortlake 500 kV line	As above
	Moorabool to Haunted Gully 500 kV line	As above
	Haunted Gully to Tarrone 500 kV line	As above
	Tarrone to Heywood 500 kV line	As above

A. AEMO expects that Victorian and other regional SSSPs will engage in joint planning when critical planned outages may impact system security across different regions of the NEM.
B. As per the dispatches listed in 'Transfer Limit Advice – SA and Victoria', at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/victorian-transfer-limit-advice-outages.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[55] 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[56]. 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 report[57].

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 41 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.

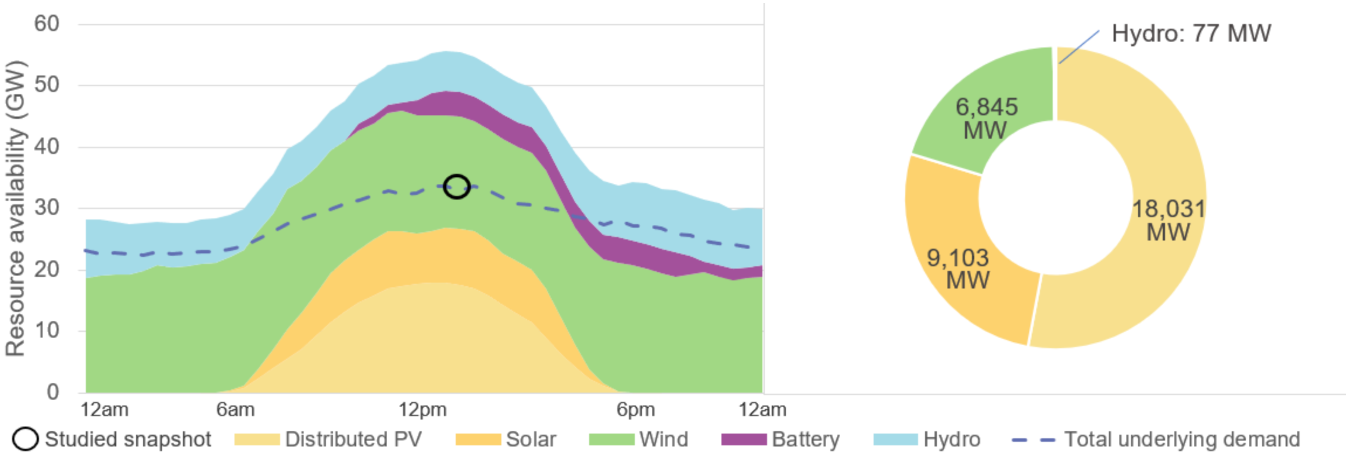
When preparing this snapshot, AEMO made some adjustments in recognition of the need to ensure sufficient renewable energy is available to cover periods leading up to and following the time of low demand, given that many fossil-fuelled generating units having a minimum start-up time of 4 to 6 hours once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

[55] Renewables includes wind, solar, distributed photovoltaics, batteries, hydro and biofuels.

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

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

Figure 41 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 42 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 42 provides a broad NEM overview of the outcomes of the study.

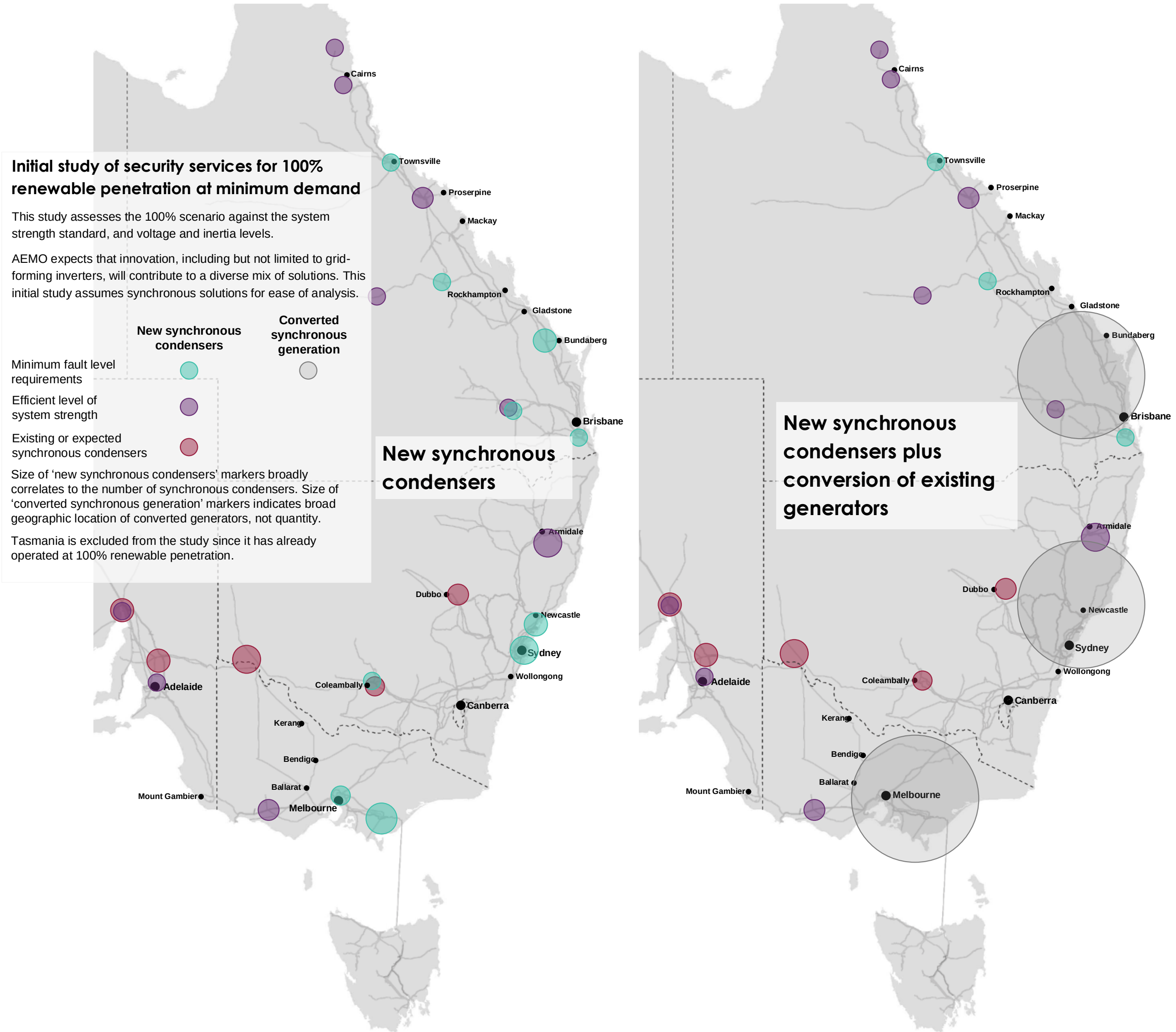
AEMO notes that the results presented in this section are the outcome of a steady-state analysis and are not provided for operational purposes.

Table 42 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 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 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 42 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 identified a number of system strength shortfalls and standards as a result of the 2022 assessments. Table 43 summarises the requests to SSSPs to deliver provide system strength services.

If you wish to provide any comments or ask any questions about this report, please contact AEMO via planning@aemo.com.au.

AEMO and the SSSPs 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 43 Summary of 2022 system strength standards and shortfalls in the NEM

System strength nodes	Minimum fault level requirement from 2 December 2022 (MVA)	IBR projection by 2032-33 (total MW)	Fault level shortfall declared before December 2025 (MVA)
New South Wales			
Armidale	3,300	5995	No shortfall
Buronga	1,755	179	No shortfall
Darlington Point	1,500	1831	No shortfall
Newcastle	8,150	3015	A shortfall of 711 MVA is declared from 1 July 2025 to 1 December 2025. This is an adjustment to the existing shortfall declared in May 2022. AEMO will request that Transgrid provide system strength services to address the shortfall by 1 July 2025.
Sydney West	8,450	1307	A shortfall of 314 MVA is declared from 1 July 2025 to 1 December 2025. This is an adjustment to the existing shortfall declared in May 2022. AEMO has requested that services be available from 1 July 2025.
Wellington	2,900	6079	No shortfall
Queensland			
Gin Gin	2,800	5212	A shortfall of up to 64 MVA is declared until from this present year until 1 December 2025. This is an adjustment to the existing shortfall declared in May 2022. Powerlink is currently preparing to make services available. AEMO has requested that services be available from 31 March 2023.
Greenbank	4,350	0	No shortfall
Lilyvale	1,400	2235	No shortfall
Ross	1,350	1000	No shortfall
Western Downs	4,000	5472	No shortfall
South Australia			
Davenport	2,400	50	No shortfall
Para	2,250	1107	No shortfall
Robertstown	2,550	1163	No shortfall
Tasmania			
Burnie	850	1301	A shortfall range of 374 to 423 MVA is declared for 15 April 2024 to 1 December 2025. This is an adjustment to the existing shortfall declared in December 2021. AEMO has requested that services be available from 15 April 2024.

System strength nodes	Minimum fault level requirement from 2 December 2022 (MVA)	IBR projection by 2032-33 (total MW)	Fault level shortfall declared before December 2025 (MVA)
George Town	1,450	376	A shortfall range of 717 to 827 MVA is declared for 15 April 2024 to 1 December 2025. This is an adjustment to the existing shortfall declared in December 2021. AEMO has requested that services be available from 15 April 2024.
Risdon	1,330	0	A shortfall range of 403 to 511 MVA is declared for 15 April 2024 to 1 December 2025. This is an adjustment to the existing shortfall declared in December 2021. AEMO has requested that services be available from 15 April 2024.
Waddamana	1,400	823	A shortfall range of 440 to 594 MVA is declared for 15 April 2024 to 1 December 2025. This is an adjustment to the existing shortfall declared in December 2021. AEMO has requested that services be available from 15 April 2024.
Victoria			
Dederang	3,500	357	No shortfall
Hazelwood	7,700	2001	No shortfall
Moorabool	4,600	2731	No shortfall
Red Cliffs	1,786	2042	No shortfall
Thomastown	4,700	0	No shortfall

A1. Generator, network and market modelling assumptions

This appendix provides the assumptions used in this report relating to generators, transmission network augmentations, and market modelling for generator dispatch.

A1.1 Generator assumptions

Committed and anticipated generation projects

The fault level projections and IBR forecasts provided in this report consider existing generators already in service as well as any committed and committed* scheduled and semi scheduled generation projects. Projections for 2022-23 to 2027-28 incorporate projects from the July 2022 NEM Generation Information, and projections for 2028-29 to 2032-33 incorporate projects from the January 2022 NEM Generation Information[58].

The fault level projections and IBR forecasts also consider anticipated projects captured in the January and July 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[59].

Further details about how projects have been incorporated in the market modelling results used in this report can be found in Appendix A1.3.

Generation withdrawal and operation

The fault level projections and IBR forecasts in this report are aligned with the generator withdrawals and operation in the *Step Change* scenario of the 2022 ISP[63], including the potential early retirement of Eraring Power Station[60] in August 2025. The minimum fault level requirement projections for the coming decade have also been prepared with respect to the generator withdrawals and operation in the *Step Change* scenario.

A1.2 Transmission network augmentations

Table 44 provides the details and modelling date for the large committed and anticipated transmission[61] network augmentation projects included in the system strength assessments in this report (excluding the preparation of the

[58] AEMO. The January and July 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.

[59] 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.

[60] See https://www.originenergy.com.au/about/investors-media/origin-proposes-to-accelerate-exit-from-coal-fired-generation/.

[61] 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 Guidelines*, August 2021, at https://www.aer.gov.au/system/files/AER%20-%20Cost%20benefit%20analysis%20guidelines%20-%2025%20August%202020.pdf.

near-term minimum fault level requirements). These projects are modelled consistent with the latest information provided by TNSPs, where timing permitted.

Table 44 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 current and 1,100 MWs of inertia and were commissioned at the end of 2021.	In service	Fault level projections, IBR forecasts and minimum fault level requirement forecasts
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 to New South Wales interconnector.	Mid 2023 [B]	Fault level projections, IBR forecasts and minimum fault level requirement forecasts
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)	Fault level projections, IBR forecasts and minimum fault level requirement forecasts
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	Fault level projections, IBR forecasts and minimum fault level requirement forecasts
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	Fault level projections, IBR forecasts and minimum fault level requirement forecasts
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)	Fault level projections, IBR forecasts and minimum fault level requirement forecasts
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.	Stage 1 2024 Stage 2 2026 [E]	Fault level projections, IBR forecasts and minimum fault level requirement forecasts

Transmission network upgrade	Augmentation detail	Modelling date (Calendar year) [A]	Included in assessment
	• 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. • 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 renewable energy zone (REZ) Transmission Link	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 [F] as part of the build.	2025	Fault level projections, IBR forecasts and minimum fault level requirement forecasts
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	Not included in assessments due to timing constraints
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 included in assessments due to timing constraints
Victorian Renewable Energy Zone Development Plan – Western REZ project	A 250 MVA (1000 MWs) synchronous condenser next to the Ararat Terminal Station.	2025	Not included in assessments due to timing constraints
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 included in assessments due to timing constraints
HumeLink	A 500 kV transmission upgrade connecting Project EnergyConnect and the Snowy Mountains Hydroelectric Scheme to Bannaby.	2026	Fault level projections, IBR forecasts and

Transmission network upgrade	Augmentation detail	Modelling date (Calendar year) A	Included in assessment
			minimum fault level requirement forecasts
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	Fault level projections, IBR forecasts and minimum fault level requirement forecasts
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	IBR forecasts and minimum fault level requirement forecasts
Marinus Link	Two new HVDC cables connecting Victoria and Tasmania, each with 750 MW of transfer capacity and associated alternating current (AC) transmission.	Cable 1: 2029 Cable 2: 2031	IBR forecasts and minimum fault level requirement forecasts
VNI West	A new high capacity 500 kV double-circuit transmission line to connect Western Renewables Link (north of Ballarat) with Project EnergyConnect (at Dinawan) via Kerang.	2032	IBR forecasts and minimum fault level requirement forecasts

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.

A1.3 Market modelling of generator dispatch method

AEMO undertakes integrated energy market modelling to forecast future investment in and operation of electricity generation, storage and transmission in the NEM[62].

Projected generation and storage investment and dispatch from the *Step Change* scenario results for the 2022 ISP have been used for system strength assessments in this report, with some updates to reflect the latest information. These market modelling results:

- Cover the financial years from 2022-23 to 2032-33.
- Were updated compared to the 2022 ISP results, to include updated generator statuses, particularly all existing, committed, and committed* generation as of 22 July 2022 from AEMO's NEM Generation Information page.
- Are based on the *Step Change* scenario generator, storage and transmission build outcomes for the 2022 ISP.
- Include generator dispatch projections from a time-sequential model using the 'bidding behaviour model' for realistic generator dispatch results given the generation and build outcomes. The bidding behaviour model

[62] ISP Methodology, AEMO, at https://aemo.com.au/-/media/files/major-publications/isp/2021/2021-isp-methodology.pdf?la=en.

uses historical analysis of actual generator bidding data and back-cast approaches for the purposes of calibrating projected dispatch[63].

- Apply the *Step Change* scenario 50POE demand projection from the 2022 ESOO.
- Apply projections of generation outages based on Monte Carlo simulation.
- Apply projections of planned maintenance. Maintenance events are assumed to be distributed throughout the year such that they minimise planned outages at times when it is most required when consumer demand is high, to avoid exacerbating reliability risks.
- Incorporate a range of market modelling iterations for each year of the study period, capturing multiple generator outage patterns. This better captures the variability in generator outage patterns, and hence gives better regard of typical dispatch patterns.
- When applying the market modelling results to assess the system strength projections, some post model adjustments were made where necessary based on industry knowledge and known operational practices.

Table 45 details the market modelling used in different sections of the report, for fault level shortfall declarations a five-year projection was applied, whereas for the IBR forecasts for ten years utilised the 2022 ISP projections.

Table 45 Market modelling results used in for system strength assessments

System strength assessment	Market modelling results	
	2022-23 to 2027-28 [A]	2028-29 to 2032-33 [B]
Fault level projections for shortfall declaration until December 2025	✓	N/A
Minimum fault level requirement projections for ten years as part of the system strength standard	✓	✓
IBR forecast for ten years as part of efficient level of the system strength standard	✓	✓
Existing minimum fault level requirement determination [C]	N/A	N/A
Critical planned outages	✓	✓

A. Results for 2022-23 to 2027-28 projections for the 2022 system strength report consider all existing, committed, and committed* generation as of 22 July 2022 from AEMO's NEM Generation Information database. Checks and adjustments were made to ensure that no inadvertent overlap or double-counting occurred between the two batches of market modelling results applied across the coming decade.
B. Results for 2028-29 to 2032-33 projections were conducted previously as part of the 2022 ISP and as such only consider all existing, committed, and committed* generation from 22 January 2022. Checks and adjustments were made to ensure that no inadvertent overlap or double-counting occurred between the two batches of market modelling results applied across the coming decade.
C. Minimum fault level requirements for the near-term determinations are not based on market modelling results. See Appendix A2 for further details.

[63] Details for the bidding behaviour model are provided in AEMO's Market Modelling Methodologies report. AEMO, ISP Methodology, August 2021, at https://aemo.com.au/-/media/files/major-publications/isp/2021/2021-isp-methodology.pdf?la=en.

A2. EMT assessments for minimum fault level requirements

This appendix notes what comprises the minimum fault level requirements as well as details for the EMT studies undertaken for the minimum fault level requirements included in this report, consistent with the System Strength Requirements Methodology[64].

The following sections provide details on treatment of minimum synchronous machine dispatch combinations in each region studied, contingencies considered, success criteria, and model setup for the assessment undertaken to investigate minimum fault level requirements in New South Wales and Victoria.

A2.1 Minimum fault level requirements to ensure power system stability

Described in Section 2, the minimum fault level requirement comprises three elements. It should be set such that there is sufficient fault level to:

- Enable protection systems of transmission networks, distribution networks, Transmission Network Users and Distribution Network Users to operate correctly.
- Enable stable operation of voltage control devices, such as capacitor banks, reactors and dynamic voltage control equipment
- Ensure power system stability in the NEM.

The power system stability element of the minimum fault level requirement includes the fault level required for *existing* IBR to operate[65] without converter-based instability[66] occurring.

AEMO has completed wide-area EMT analysis for the New South Wales and Victorian regions to determine the sufficient fault level for the existing power system to remain stable (third element of minimum fault level requirements), however, until AEMO is satisfied the system can operate securely for all three elements of the minimum fault level requirement, current requirements around the NEM are set at their current value.

Importantly, AEMO has not yet received information from relevant SSSPs advising that that fault level requirements can be changed based on any updated information about requirements to ensure protection system operation and the stable operation of voltage control devices. Minimum fault level requirements at a system strength node can only change if there is sufficient evidence that all three elements are addressed.

[64] AEMO. *System Strength Requirements Methodology.* September 2022, at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-strength-requirements/system-strength-requirements-methodology.pdf?la=en.

[65] Operate should not be taken to mean operate at full capacity all times.

[66] AEMO. *Power System Stability Guidelines.* September 2022, at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/power-system-stability-guidelines.pdf?la=en.

A2.2 EMT analysis completed in 2022 for this report

A2.2.1 Detailed EMT analysis case set up

Detailed EMT analysis was completed to consider how and if power system security could be ensured for New South Wales and Victoria under changed or new minimum machine combinations. This analysis informs AEMO and SSSPs' understanding of the state of the system but has not been used to amend the existing minimum fault level requirements. This analysis was, however, used to derive the minimum fault level requirements for the new system strength node at Buronga.

The EMT analysis was completed using the four state NEM PSCAD version 5 model released in July 2022. The case was based on a snapshot of the existing network but tuned in the following ways:

- IBR was dispatched to a high level (at least 70% of maximum output).
- Generation in the case was dispatched to not violate inter or intra connector transfer limits, voltage stability limits or thermal limits on the transmission network.
- A reasonably low demand was applied across the NEM.

This resulted in the following snapshot of demand and generation by region and the interconnector flows for one of the scenarios investigated:

Table 46 Regional generation and demand

Region	Generation (MW)	Demand including losses (MW)
Queensland	4,410	4,560
New South Wales	5,390	6,130
Victoria	4,430	3,580
South Australia	1,570	1,090
Tasmania	635	1,075

Table 47 Interconnector flow between regions

Interconnector	Flow (MW)
QNI	150 to QLD
VNI	890 to NSW
Heywood	500 to VIC
Murraylink	20 to SA
Basslink	440 to TAS

Assumptions

The following assumptions were applied in the analysis:

- Included IBR in the assessment was those that met the criteria of 'existing'[67] as at 1 January 2022.

[67] According to AEMO's NEM Generation information page.

- When the IBR has been dispatched, all its inverters are online, regardless of MW output.
- All synchronous generator dynamics were captured using the higher-order synchronous machine model component in PSCAD including the exciter and governor controls, except as noted below.
- In the PSCAD model, Bayswater units 1 and 2 do not have complete dynamic models represented. Accurate machine dynamic behaviour is very important when performing EMT analysis, so Bayswater units 1 and 2 were disabled. The combinations for synchronous generators in the studies have only considered the Bayswater units which have the full dynamic models.
- Synchronous condensers at Kiamal Solar Farm and Buronga substation associated with Finley and Darlington Point solar farms were online. Additional sensitivity studies were carried out without these solar farms and their synchronous condensers out of service to screen for system strength issues.
- In addition to the IBR plant and synchronous machine models, detailed Static Var Compensator (SVC) models were included and monitored in the assessment.
- Battery Energy Storage Systems (BESS) were included only if they met the threshold criteria of existing as of 1 January 2022.
- Other regions not currently being studied were held at the minimum synchronous dispatch as per limit advice[68].
- The above modelling setup resulted in satisfactory initialisation of all PSCAD components for EMT simulations.

Success criteria

The success criteria applied in the PSCAD assessments are based on the success criteria outlined in section A3 of the 2021 system security reports[69].

A2.2.2 NSW detailed EMT analysis outcomes

The 2021 System Security Reports presented the need for reassessment of existing system strength nodes and whether new nodes should be introduced as the number of coal units online in New South Wales is projected to decline. Previous EMT analysis completed in 2019 found the New South Wales region was stable for seven large synchronous generators online. This is the basis for the existing fault level requirements in New South Wales.

Assumptions

- The following detailed SVC models were included:
  - Armidale SVC.
  - Broken Hill SVC.
  - Lismore SVC.
  - Sydney West SVC.

[68] Limits advice is accessible on AEMO's website at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information-resource/limits-advice.

[69] AEMO. Appendix A3, 2021 System Security Reports. December 2021. At https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/system-security-planning.

- Network limits were preserved (as necessary) by reducing the megawatt output of generators, especially IBR in the Southwest New South Wales region. Parameters such as interconnector flows were monitored to ensure limits were not violated.
- Other regions were held at the minimum synchronous dispatch as per limit advice[70].

Scenarios considered

Due to the announced early retirement of the Eraring Power Station as well as the synchronous generation withdrawal as projected in the *Step Change* scenario, AEMO considered it prudent to determine the stability of the New South Wales region with fewer than seven large units online. Different five-unit synchronous machine combinations were selected for wide area PSCAD assessments.

Contingencies applied in studies

Credible contingencies as listed in Table 48 were identified for study in this assessment.

Table 48 Credible contingencies studied in the EMT assessment

No.	Contingency description
1	Armidale – Tamworth 330 kV
2	Darlington Point – Wagga 330 kV
3	Liddell – Newcastle 330 kV
4	Sydney West – Sydney North
5	Wellington – Wollar 330 kV
6	Mt Piper Unit 1
7	Buronga – Red Cliffs 220 kV
8	Marulan – Yass 330 kV
9	Wagga – Lower Tumut 330 kV
10	Mt Piper – Wellington 330 kV
11	Newcastle – Eraring 330 kV
12	Sydney West – Liverpool 330 kV
13	Wagga – Wagga North 132 kV
14	Darlington Point – Balranald 220 kV
15	Balranald – Buronga 220 kV
16	Mt Piper – Bayswater 500 kV
17	Armidale – Dumaresq 330 kV
18	Murray – Upper Tumut 330 kV
19	Jindera – Wodonga 330 kV
20	Armidale SVC
21	Armidale – Sapphire 330 kV
22	Liddell – Tamworth 330 kV

[70] Limits advice is accessible on AEMO's website at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information-resource/limits-advice.

No.	Contingency description
23	Sydney West – Bayswater 330 kV
24	Wellington 330/132 kV Transformer
25	Sydney West – Bannaby 330 kV
26	Mt Piper – Wallerawang 330 kV
27	Dapto – Sydney South 330 kV
28	KVSS – Dapto 330 kV

All faults were simulated as 2ph-G fault, as an unbalanced fault is likely to impose worst case fault ride-through behaviour for IBR generators.

All faults were cleared and the element listed in the contingency description in Table 48 tripped based on primary fault clearing times for near and far ends in accordance with the NER fault clearance times[71].

Where applicable, the automated tripping and runback schemes associated with each contingency was applied as part of the contingency event.

Conclusions

A five-unit synchronous machine combination in New South Wales was found to be sufficient to meet the success criteria for the system strength assessment at the existing system strength nodes and the new Buronga 220 kV system strength node for both combinations 1 and 2 outlined. The five-unit combinations resulted in generally lower fault levels across New South Wales compared to the existing minimum levels based on the seven-unit combination.

Although the combination results in lower fault levels, fault level requirements are not automatically reduced to these levels, because power system stability is just one of the three elements making up the fault level requirement.

AEMO looks forward to working with Transgrid as the power system evolves to understand whether any amendments to the minimum fault level requirements should be made over time.

A2.2.3 Victorian detailed EMT analysis outcomes

The 2021 System Security Reports presented the need for reassessment of existing system strength nodes as the number of coal units online in Victoria is projected to decline as per the *Step Change* scenario and because the most recent previous EMT analysis in Victoria focused on the Red Cliffs system strength node. Current limit advice states that the Victorian region is stable with five large units online. This is the basis for the existing fault level requirements in Victoria.

Assumptions

- The following SVCs were included:
  - Broken Hill SVC.
  - Horsham SVC.

[71] NER Fault Clearance Times Table S5.1a.2, at https://energy-rules.aemc.gov.au/ner/177/29929#S5.1a.8.

  - Kerang SVC.
  - Rowville SVC.
- One Hazelwood to South Morang 500 kV line was switched out based on normal voltage control operating procedures in Victoria
- Reactors at Moorabool and Keilor terminal stations were assumed switched in.
- Parameters such as interconnector flows were monitored to ensure limits were not violated.
- Other regions were held at the minimum synchronous dispatch as per AEMO's limit advice[72].

Scenarios considered

As previous EMT analysis in Victoria focused on the Red Cliffs system strength node, it was considered prudent to undertake a wide area study with the current five-unit combination in Victoria, but inclusive of all the system strength nodes.

Due to the synchronous generation withdrawal as projected in the *Step Change* scenario, AEMO also considered it prudent to determine the stability of the Victoria region with fewer than five large units online (replacing with smaller gas turbine units).

Contingencies applied in studies

Credible contingencies as listed in Table 49 were identified for study in this assessment.

Table 49 Credible contingencies studied in the EMT assessment

No.	Contingency description
1	32081 Kerang – Bendigo 220 kV
2	32040 Ballarat – Waubra – Ararat 220 kV
3	23082 Buronga – Red Cliffs 220 kV
4	22201 Balranald – Darlington Point 220 kV
5	21200 Darlington Point - Wagga 220 kV
6	30006 Red Cliffs – Kiamal 220 kV
7	30007 Darlington Pt SF Syncon
8	30008 Finley SF Syncon
9	30009 Hazelwood – Loy Yang 500 kV
10	30010 Hazelwood – South Morang 500 kV
11	30011 Dederang – South Morang 330 kV
12	30012 South Morang 500/330 kV transformer
13	30013 Moorabool 500/220 kV transformer
14	32831 Red Cliffs – Wemen – Kerang 220 kV
15	30015 Hazelwood – Rowville 220 kV
16	35488 Moorabool – Haunted Gully 500 kV
17	30017 Bendigo – Fosterville – Shepparton 220 kV

[72] Link to Limit advice homepage

No.	Contingency description
18	30018 Loy Yang B Unit 1 Transformer 500 kV
19	30019 APD 500 kV fault and load trip
20	30020 Dederang – Glenrowan 220 kV

All faults are simulated as 2ph-G fault, as an unbalanced fault is likely to impose worst case fault ride through behaviour for IBR generators.

All faults were cleared, and the element listed in the contingency description in Table 49 tripped based on primary fault clearing times for near and far ends in accordance with the NER fault clearance times[73].

Where applicable, the automated tripping and runback schemes associated with each contingency were applied as part of the contingency event.

Conclusions

Both combinations studied were found sufficient to meet the success criteria for the system strength assessment at the existing system strength nodes. One of the combinations studied resulted in generally lower fault levels across Victoria compared to the current minimum levels based on the five large unit combination.

Although one of the combinations resulted in lower fault levels, fault level requirements are not automatically reduced to these levels, because power system stability is just one of the three elements making up the fault level requirement.

AEMO will consider these issues as the power system evolves to understand whether any amendments to the minimum fault level requirements should be made over time.

[73] NER Fault Clearance Times Table S5.1a.2, https://energy-rules.aemc.gov.au/ner/177/29929#S5.1a.8.

A3. Translation of minimum fault level requirements to real-time operations

AEMO is required to publish minimum fault level requirements for each system strength node applicable for the following year. Maintaining the system strength requirements at each node forms part of the general power system principles to operate a secure network as per NER 4.2.6(g).

The minimum fault level requirements translate to real time operations such that if the operational conditions match the planning assumptions studied then these minimum fault levels are expected to be maintained. This may be, if necessary, through the enablement of system strength services under NER 4.4.5(a).

The minimum fault level requirements have been assessed for pre-contingent system normal conditions given a particular set of planning assumptions. The requirements do not account for planned or unplanned outages or other operational conditions outside of an intact system that might occur in the network. Where these circumstances outside of the planning assumptions may occur, the minimum fault level requirements may not be maintained even with the enablement of system strength services under NER 4.4.5(a). Under those conditions, AEMO and TNSPs will act on the latest limit advice to keep the power system secure as required under NER 4.3.2(a).

Table 50 lists the pre-contingency minimum fault level requirements for each system strength node as at 1 December 2022.

Table 50 Pre-contingency minimum fault level requirements for translation to real time operations

System strength node	Minimum fault level requirement (pre-contingency) (MVA [A,B])
New South Wales	
Armidale 330 kV	3,300
Buronga 220 kV (from December 2025)	1,755 (from December 2025)
Darlington Point 330 kV	1,500
Newcastle 330 kV	8,150
Sydney West 330 kV	8,450
Wellington 330 kV	2,900
Queensland	
Gin Gin 275 kV	2,800
Greenbank 275 kV	4,350
Lilyvale 132 kV	1,400
Ross 275 kV	1,350
Western Downs 275 kV	4,000
South Australia	
Davenport 275 kV	2,400
Para 275 kV	2,250
Robertstown 275 kV	2,550

System strength node	Minimum fault level requirement (pre-contingency) (MVA [A,B])
Tasmania	
Burnie 110 kV	850
George Town 220 kV	1,450
Risdon 110 kV	1,330
Waddamana 220 kV	1,400
Victoria	
Dederang 220 kV	3,500
Hazelwood 500 kV	7,700
Moorabool 220 kV	4,600
Red Cliffs 220 kV	1,786
Thomastown 220 kV	4,700

A. These minimum requirements are three phase fault levels to be maintained by real time operations at the node. They do not include a duration in which these requirements should be maintained.
B. These requirements are calculated to ensure system security for the 'worst credible contingency'. Non-credible events like the inability of synchronous generators to ride through a circuit breaker fail event have not been considered. Events like this and the resulting loss of resilience of the system should be taken into consideration by the SSSP when meeting the system strength standard.