Appendix 7. Power system security

December 2021

Appendix to Draft 2022 ISP for the National Electricity Market

Important notice

Purpose

This is Appendix 7 to the Draft 2022 *Integrated System Plan* (ISP), available at https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp.

AEMO publishes this Draft 2022 ISP under the National Electricity Rules. This publication has been prepared by AEMO using information available at 15 October 2021. Information made available after this date may have been included in this publication where practical.

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Version control

Version	Release date	Changes
1	10/12/2021	Initial release.

Draft ISP Appendices

Contents

Figures

A7.1 Introduction

The NEM is becoming increasingly dominated by inverter-based resources (IBR). The Draft 2022 ISP projects that the pace of coal power station closures will increase, and that IBR will dominate the NEM in the future. The proportion of generating capacity that is inverter-based is expected to increase from roughly 45% today to 70% by 2030 and 90% by 2050 (including distributed PV).

As the power system transitions, AEMO is considering the impact of emerging trends on system security services such as system strength and inertia. These trends include the ongoing uptake of both utility and distributed IBR, a decline in commitment of synchronous generation, increasing uptake of DER, and lowering of minimum demands. These changes will permanently change the way in which power system security is maintained.

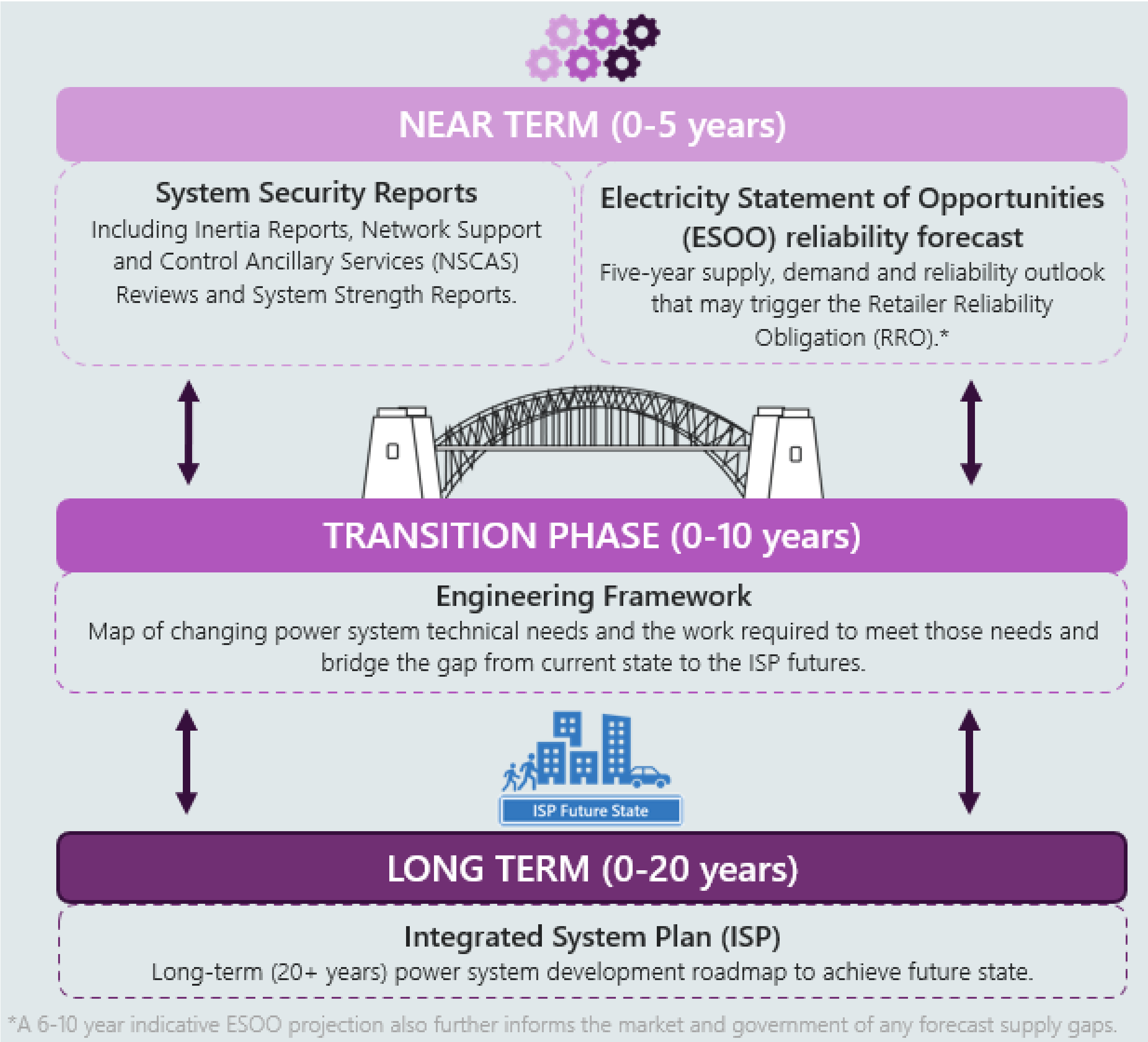
This Appendix 7 provides detail on the power system security needs as the NEM transforms from a power system dominated by large thermal power stations to a system that is more decentralised:

- **A7.2 Relationship to other planning work** – AEMO assesses power system security shortfalls and gaps in the NEM over the coming five years through its annual system strength, inertia and Network Support and Control Ancillary Services (NSCAS) reviews. In addition, AEMO's Engineering Framework will help to provide the right toolkit to meet the operational, technical and engineering requirements to deliver the future power system. This section explains these work areas in the context of the power system security needs described in this report.
- **A7.3 System strength outlook** – AEMO has defined minimum three phase fault level requirements that need to be maintained at specific fault level nodes across the NEM to ensure the network is operated in a stable and secure manner. This section details draft projections and anticipated shortfalls of system strength, as well as the drivers of these shortfalls.
- **A7.4 Inertia outlooks** – AEMO has defined minimum and secure inertia levels that need to be available in each NEM region during periods where separation is classified to being credible. Draft projections and anticipated shortfalls of inertia are detailed, as well as drivers and potential remediation of the shortfalls.

A7.2 Relationship to other AEMO planning work

AEMO is required to annually assess system security for each region of the NEM for the coming five years and declare any shortfalls or gaps to be addressed by TNSPs[1]. AEMO also prepares the Engineering Framework to map the work required to meet the changing power system technical needs and bridge the gap between the current state and the ISP futures. Figure 1 describes the linkage between other planning reports and the ISP, including this Power System Security Appendix.

Figure 1 Linkages between AEMO planning reports



A7.2.1 Near-term power system security assessments

AEMO undertakes annual power system security assessments to identify the need for additional services in relation to inertia, system strength and NSCAS for the next five years.

[1] NER Version 174, Clauses 5.20.3, 5.20.5 and 5.20.7

The 2021 System Security Reports[2], to be released in December 2021, find:

- Declining minimum demand and changing generator dispatch are projected to push our power system to its limits over the coming five years.
- System strength, inertia and NSCAS shortfalls and gaps have been identified across the NEM for the coming five-year period.

AEMO expects further system security needs to be identified as we transition to 100% instantaneous renewable energy penetration and as the regulatory frameworks change.

System strength

System strength is a measure of the ability of a power system to maintain and control the voltage waveform under normal conditions and to return to a steady state condition following a system disturbance[3]. AEMO will publish the 2021 System Strength Report, under the 2021 System Security Reports[4], in December 2021 identifying the system strength requirements and shortfalls over the 5-year horizon. The 2021 System Strength Report focuses on the 5-year outlook and declares shortfalls based on the *Progressive Change* scenario, while also noting the potential system strength impacts from the *Step Change* scenario.

The regional TNSP[5] is required to ensure that system strength services are available to address any fault level shortfall declared by AEMO at a fault level node, in the System Strength Report. Generators subject to the system strength remediation requirements must implement or fund system strength remediation to ensure the generator does not have an adverse system strength impact.

The AEMC's final determination on the 'Efficient management of system strength on the power system' will change these responsibilities for the 2022 System Strength assessment[6].

Inertia

A minimum level of inertia is required in the power system to suppress and slow frequency deviations so that automatic controls can respond to sudden changes in the supply-demand balance[7]. AEMO will publish the 2021 Inertia Report, under the 2021 System Security Reports[8], in December 2021 identifying the inertia requirements and shortfalls over the 5-year horizon. The 2021 Inertia Report focuses on the five-year outlook and declares shortfalls based on the *Progressive Change* scenario while also noting the potential inertia impacts from the *Step Change* scenario.

The regional TNSP[9] is required to ensure that inertia network services or inertia support activities are available to address any inertia shortfall declared by AEMO at an inertia sub-network, in the Inertia Report. Shortfalls

[2] AEMO. *2021 System Security Reports: System Strength, Inertia and NSCAS*, will be available in December 2021 at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/planning-for-operability.

[3] Further information can be found in AEMO's Power System Requirements report, June 2020, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power-system-requirements.pdf.

[4] AEMO, *2021 System Security Reports: System Strength, Inertia and NSCAS*, will be available in December 2021 at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/planning-for-operability.

[5] The jurisdictional planning body is the responsible party if there is more than one TNSP in a region.

[6] AEMC, *Efficient management of system strength on the power system*, at https://www.aemc.gov.au/rule-changes/efficient-management-system-strength-power-system.

[7] Further information can be found in AEMO's Power System Requirements report, June 2020, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power-system-requirements.pdf.

[8] AEMO, *2021 System Security Reports: System Strength, Inertia and NSCAS,* will be available in December 2021 at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/planning-for-operability.

[9] The jurisdictional planning body is the responsible party if there is more than one TNSP in a region.

are assessed against the minimum threshold level of inertia, which is prepared for when the sub-network is islanded or at credible risk of being separated, and for the secure operating level of inertia which is prepared for when the sub-network is islanded. AEMO must consider the likelihood of an inertia sub-network becoming islanded when determining whether there are inertia shortfalls.

The completion of the ESB's Post-2025 electricity market design program[10] and the implementation of the fast frequency response ancillary service[11] can be expected to affect the outcomes delivered under the existing inertia framework.

NSCAS

Network support and control ancillary services (NSCAS)[12] are non-market ancillary services that may be procured to address the following NSCAS needs:

- Maintain power system security and reliability of supply of the transmission network in accordance with the power system security standards and the reliability standard[13].
- Maintain or increase power transfer capability of the transmission network to maximise the present value of net economic benefit to all those who produce, consume or transport electricity in the market[14].

AEMO must, at least annually, identify any NSCAS need forecast to arise in the next five years. The NER give TNSPs the primary responsibility for acquiring NSCAS. If AEMO is required to procure NSCAS under its last resort responsibility, it can only do so to meet the first of the NSCAS needs – for power system security and reliability. AEMO will publish the 2021 NSCAS Report, under the 2021 System Security Reports[15], in December 2021 identifying the NSCAS gaps over the 5-year horizon.

A7.2.2 Enabling transition through the Engineering Framework

AEMO's Engineering Framework[16] is a framework to collaboratively define the full range of operational, technical and engineering requirements needed to deliver the futures envisaged by this ISP, and to inform the market reforms being undertaken by the ESB. The Engineering Framework Initial Roadmap[17] will be used to inform preparation of the NEM for operation under the six identified operational conditions[18], including operation with 100% instantaneous penetration of renewable energy by 2025.

Based on recent stakeholder engagement, the Initial Roadmap finds the following overarching messages emerge:

- Fundamental design decisions are needed.
- Urgent action and alignment is required.

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[10] At https://esb-post2025-market-design.aemc.gov.au/.

[11] AEMC, 'Fast frequency response ancillary service' rule change, at https://www.aemc.gov.au/rule-changes/fast-frequency-response-market-ancillary-service.

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

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

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

[15] AEMO, *2021 System Security Reports: System Strength, Inertia and NSCAS*, will be available in December 2021 at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/planning-for-operability.

[16] AEMO. Engineering Framework at https://aemo.com.au/en/initiatives/major-programs/engineering-framework.

[17] AEMO. Engineering Framework Initial Roadmap will be available in December 2021 at https://aemo.com.au/en/initiatives/major-programs/engineering-framework.

[18] See https://aemo.com.au/newsroom/news-updates/engineering-framework-takes-shape.

- Empower participation in the evolving energy system.
- Scalable risk management approaches are needed.

The potential gaps identified within the Engineering Framework Initial Roadmap will be collaboratively prioritised and actioned with industry through the integration and coordination with new and existing implementation workplans.

A7.3 Draft system strength outlook

Traditionally synchronous machines have provided, and continue to provide a source of system strength, while IBR generally require a level of system strength to be provided at the location they connect to, in order to be able to operate.

This section:

- Notes the importance of system strength and the roles and responsibilities (A7.3.1).
- Discusses the efficient management of system strength rule change (A7.3.2).
- Provides a NEM-wide system strength outlook (A7.3.3).
- Provides a regional system strength outlook (A7.3.4).

A7.3.1 Importance of system strength, roles and responsibilities

A minimum level of system strength is needed for the power system to remain stable under normal conditions and to return to a steady state condition following a system disturbance.

In the NEM, the present division of responsibilities for the provision of system strength is as follows:

- AEMO, in consultation with the TNSP or jurisdictional planning body, is required to determine the location of fault level nodes.
- AEMO is required to determine the minimum three phase fault level at each node and identify whether a shortfall is likely to exist at any node over the five-year horizon.
- The regional TNSP or jurisdictional planning body is required to ensure that system strength services are available to address any fault level shortfall declared by AEMO at a fault level node.
- Generators subject to the system strength remediation requirements must implement or fund system strength remediation to ensure the generator does not have an adverse system strength impact.

This report considers the methodology and provisions under the current system strength rules.

A7.3.2 Efficient management of system strength rule change

In October 2021, the AEMC made its final determination on the 'Efficient management of system strength on the power system' rule change[19]. As a result, from December 2022 onwards:

- AEMO will set a system strength standard for each system strength node, including a three-phase fault level required for a secure system and a forecast of future inverter-based connections at the node, and
- Responsible TNSPs will use reasonable endeavours to plan system strength services to meet the standard at each node.

Responsible TNSPs will need to meet the new system strength standard from December 2025 onwards, per the December 2022 declarations, and in the interim the shortfall framework will continue to apply.

[19] AEMC, 'Efficient management of system strength on the power system', accessed in November 2021 via https://www.aemc.gov.au/rule-changes/efficient-management-system-strength-power-system.

In the 2021 System Security Reports, the existing framework is applied, meaning some shortfalls are declared for periods which will ultimately be covered by the system standard under the new framework.

In the ISP timeframe, it can be expected that TNSPs will act consistent with the AEMC's final determination and take reasonable endeavours to fully meet the system strength standard at each system strength node.

A7.3.3 NEM-wide and regional system strength outlook

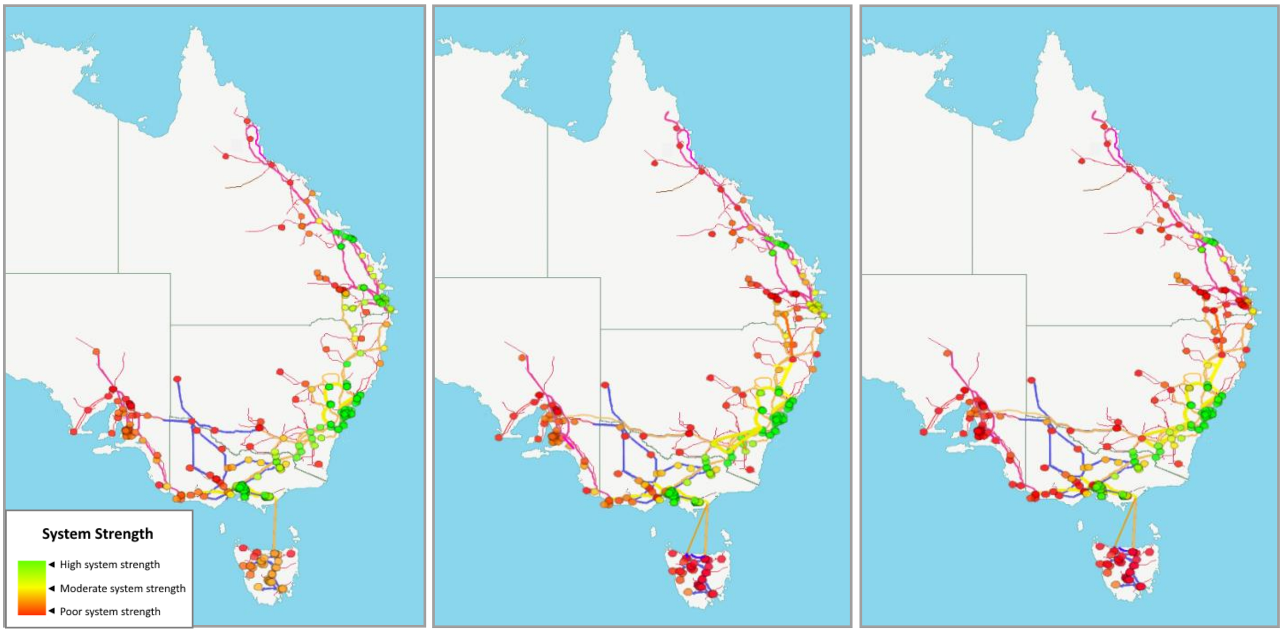
For this Draft ISP, AEMO used the Available Fault Level calculation methodology[20] to perform high level system strength impact assessments. Snapshot periods from the market modelling outputs have been analysed across the NEM. Figure 2 shows areas that already have low system strength, and projects where system strength is expected to decrease unless investments are made:

- In 2021-22:
  - Areas of existing low system strength include Western Victoria, South-West New South Wales, Northern Queensland, and Tasmania.
- In 2031-32:
  - Tasmania system strength is forecast to reduce further, driven by forecast increase in VRE.
  - The Western Victoria Transmission Network project improves the system strength outlook in Western Victoria.
  - Project EnergyConnect improves the system strength outlook in South-West NSW and Northern Victoria.
- In 2036-37:
  - Due to large projections of VRE in nearby REZs, system strength is forecast to further decline in Southern Queensland, South Australia, and South-West Victoria.

This draft assessment is based on the *Progressive Change* scenario. Fault level nodes are held at their requirements. For the final ISP, AEMO will extend the assessment to include the *Step Change* scenario. The *Step Change* scenario has accelerated uptake of VRE and withdrawal of some coal generation and is expected to bring forward the need and increase the size of system strength remediation.

[20] AEMO. System Strength Impact Assessment Guidelines, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/System-Security-Market-Frameworks-Review/2018/System_Strength_Impact_Assessment_Guidelines_PUBLISHED.pdf

Figure 2 NEM-wide system strength outlook 2021-22 (left), 2031-32(centre), 2036-37 (right), *Progressive Change* scenario



A7.3.4 Regional system strength outlook

In 2018, AEMO published the system strength requirements for nodes across the NEM. In determining the requirements, AEMO applied the System Strength Requirements Methodology[21] in each region of the NEM by selecting fault level nodes and then assessing the minimum three phase fault level required at each node. Updates to some regions have been progressively published, considering changes in network conditions. Fault level requirements shown in these ISP projections are based on these latest studies.

To date, AEMO has published[22] fault level shortfalls:

- In **South Australia**, AEMO declared inertia and fault level shortfalls in 2018, which ElectraNet has addressed, mainly by installing major high-inertia synchronous condensers. In 2020, AEMO revised the inertia requirements for the South Australia region to reflect findings from the South Australia islanding event in early 2020, anticipated levels of embedded generation and the implication of declining minimum demand in the region. With the revised inertia requirement, AEMO declared an additional inertia shortfall in South Australia above the shortfall already declared in 2018. ElectraNet is developing a solution to address this shortfall.
- In **Tasmania**, AEMO declared inertia and fault-level shortfalls in November 2019, for which TasNetworks has procured a solution. In May 2021, AEMO declared an additional inertia and system strength shortfall, above those already addressed by TasNetworks to meet the November 2019 shortfall, for which TasNetworks has again procured a solution.

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[21] AEMO, System Strength Requirements Methodology, July 2018, via https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/System-Security-Market-Frameworks-Review/2018/System_Strength_Requirements_Methodology_PUBLISHED.pdf.

[22] AEMO system strength assessments are available via the 'Planning for operability' webpage at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/planning-for-operability.

- In **Victoria**, AEMO declared a fault-level shortfall in north-west Victoria in December 2019. In August 2020 AEMO, in its role as system strength service provider for the Victorian region, secured a short-term solution and is currently developing a further solution for when the current agreements end.
- In **Queensland**, AEMO declared a fault-level shortfall in north Queensland in April 2020, for which Powerlink has developed a solution.

Procurement of system strength mitigation such as large synchronous condensers is expected to take at least two years; there is a risk of being caught out by early generation retirements or failures, as these are aspects not easily forecast. In some locations, network upgrades may also be required to facilitate integration of synchronous condensers due to (local) increases in fault level.

Other technical solutions, such as advanced inverters with grid-forming capabilities at strategic sites in the NEM, have the potential to reduce the system's reliance on synchronous plant, enabling further decarbonisation and delivering benefits to consumers. However, at present this potential is not demonstrated at the necessary scale, and focused engineering development is urgently needed to address the remaining issues and realise the promise of this technology.

The inverters that interface IBR generation with the grid can include advanced functionality to support power system operation, and have the potential to provide some of the stability capability that has previously been delivered by synchronous generators. With sufficient attention, focus, and investment, advanced inverter technology may be able to address many of the challenges facing the NEM today for the integration of renewable (inverter-based) resources[23].

Future fault level nodes definitions and fault level requirements

Projections of fault levels have been assessed using the latest fault level node and minimum fault level requirements for the *Progressive Change* scenario. System strength projections have been provided for the nodes currently defined in each region and compared against the existing requirements. As the generation and transmission systems develop, both the fault level nodes and fault level requirements will change.

Draft results[24] for 2031-32 and 2036-37 are shown in the following sections. The final ISP will further refine these results and extend to include the *Step Change* scenario. For results between 2021-22 and 2026-27, please refer to the 2021 System Security Reports: System Strength, Inertia and NSCAS[25].

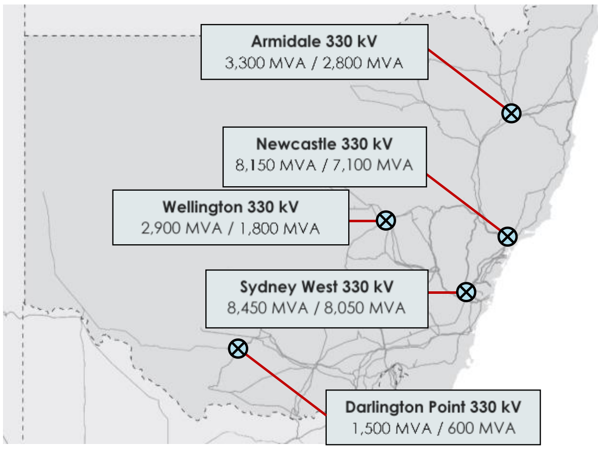
[23] AEMO, *Application of Advanced Grid-scale Inverters in the NEM*, available at https://aemo.com.au/-/media/files/initiatives/engineering-framework/2021/application-of-advanced-grid-scale-inverters-in-the-nem.pdf.

[24] These are early preliminary results which will be refined for the final ISP. Investment decisions should not be made on these draft results.

[25] AEMO, *2021 System Security Reports: System Strength, Inertia and NSCAS*, will be available in December 2021 at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/planning-for-operability.

New South Wales system strength outlook

System strength requirements (pre/post contingent) and summary



A forecast trend of decreasing system strength across New South Wales is due to the accelerated forecast retirements of synchronous generation in the *Progressive Change* scenario.

Network upgrades to facilitate REZ expansions and to facilitate interconnection can increase fault levels at surrounding nodes.

Network expansions include:

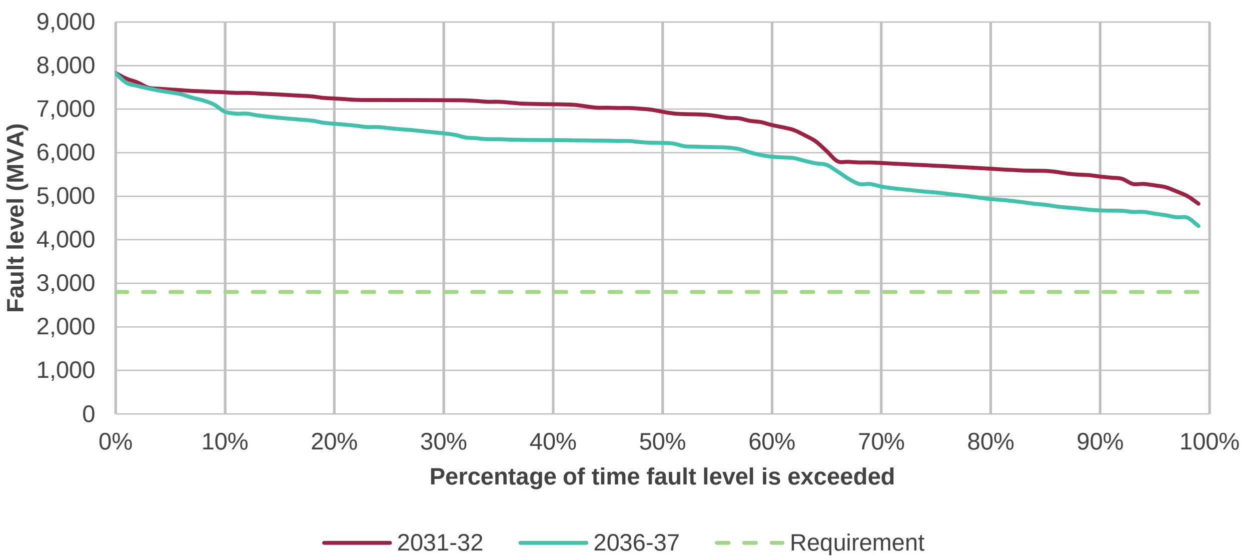
- Project EnergyConnect in Southwest New South Wales.
- Central-West Orana transmission link.
- New England REZ transmission link.
- Reinforcing Sydney, Newcastle, and Wollongong Supply.
- QNI Connect.

Projections – *Progressive Change* scenario

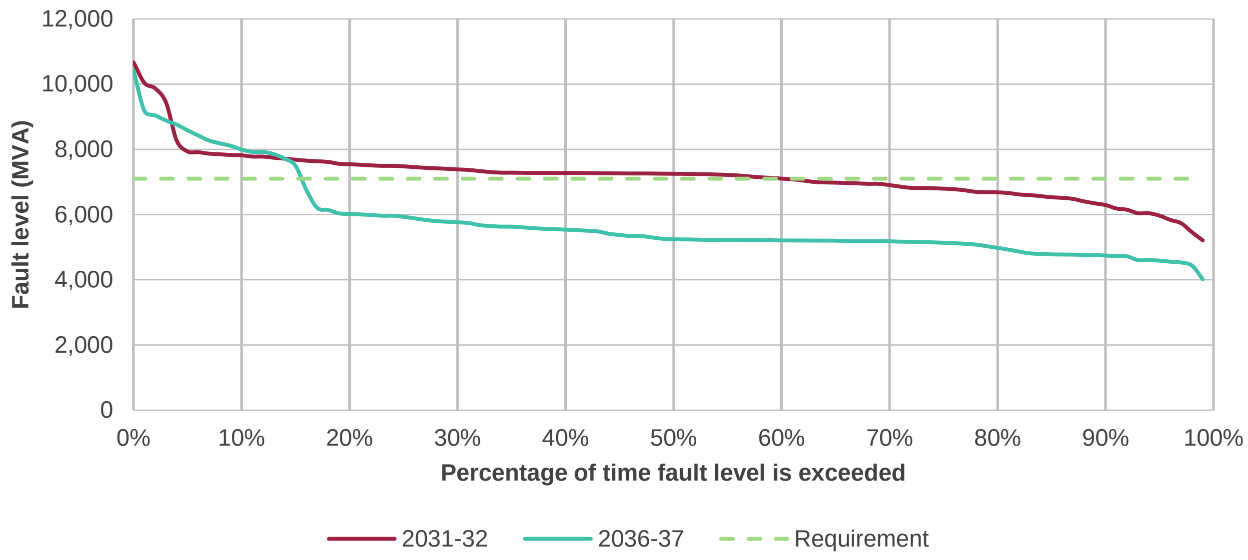
Node	Current requirement met		Comment
	Up to 2031-32	Up to 2036-37	
Armidale 330 kV	Yes	Yes	
Newcastle 330 kV	1,900 MVA potential shortfall†	3,100 MVA potential shortfall†	The closure of Vales Point and Eraring power stations will result in decreased system strength at these nodes. System strength is further reduced with the closure of Bayswater power station.
Sydney West 330 kV	2,750 MVA potential shortfall†	3,800 MVA potential shortfall†	
Wellington 330 kV	Yes	Yes	
Darlington Point 330 kV	Yes	Yes	

† Although AEMO projects that a shortfall may arise, a fault level shortfall is not formally declared.

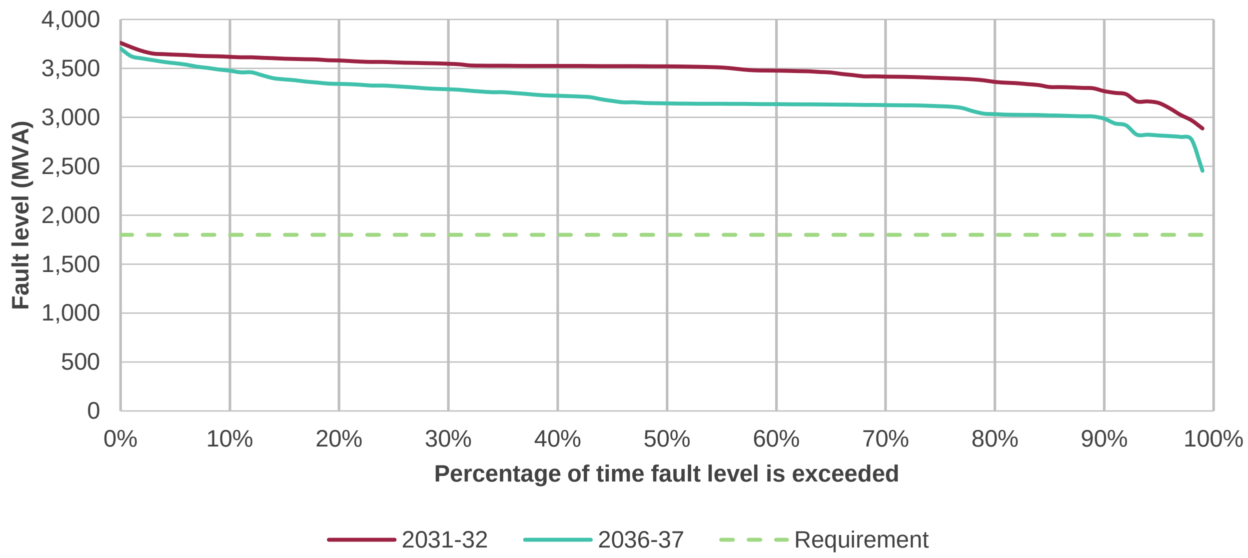
Armidale 330 kV



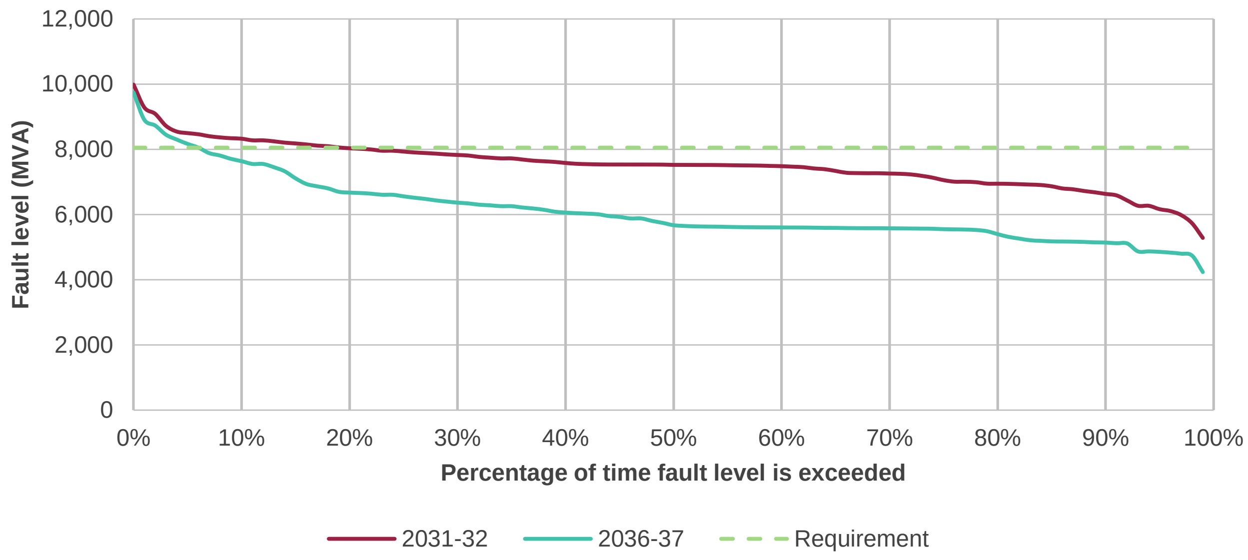
Newcastle 330 kV



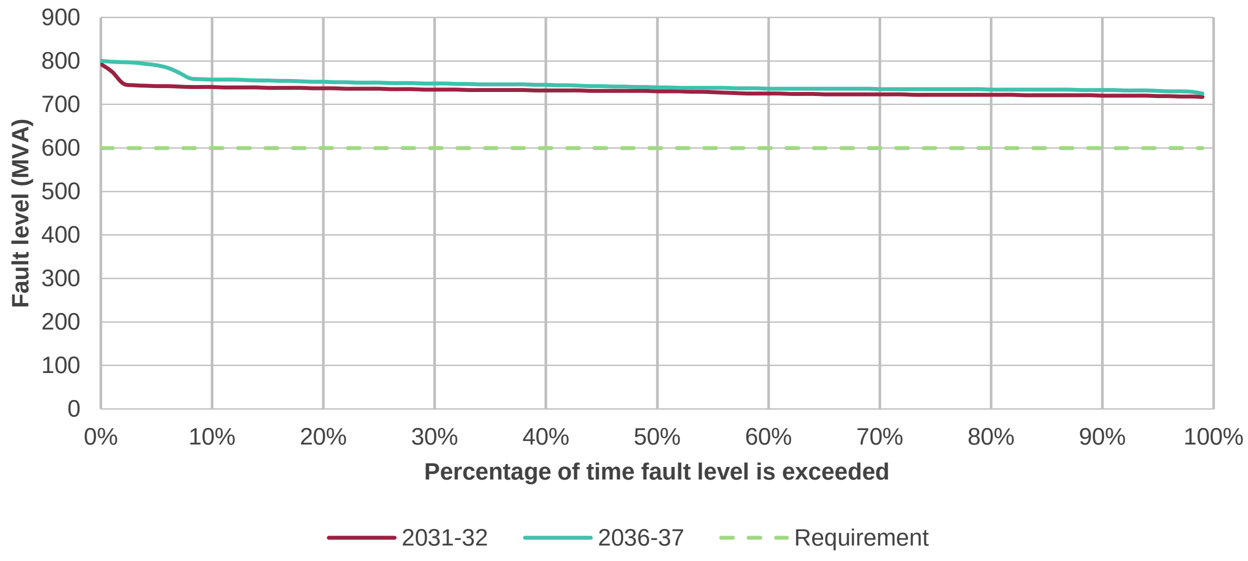
Wellington 330 kV



Sydney West 330 kV

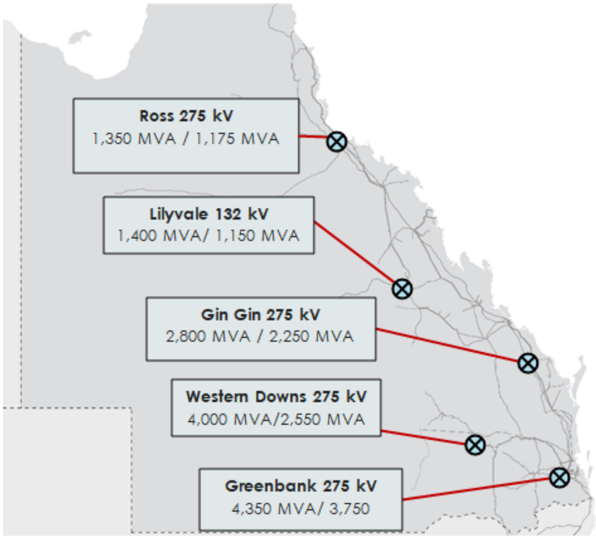


Darlington Point 330 kV



Queensland system strength outlook

System strength requirements (pre/post contingent) and summary



These studies have found that across Queensland, there is a projected trend of decreasing system strength due to the retirement of synchronous generation and the transition to IBR. Future network investments such as QNI Connect increase fault levels at nodes in close proximity to the network upgrades.

Projections – *Progressive Change* scenario

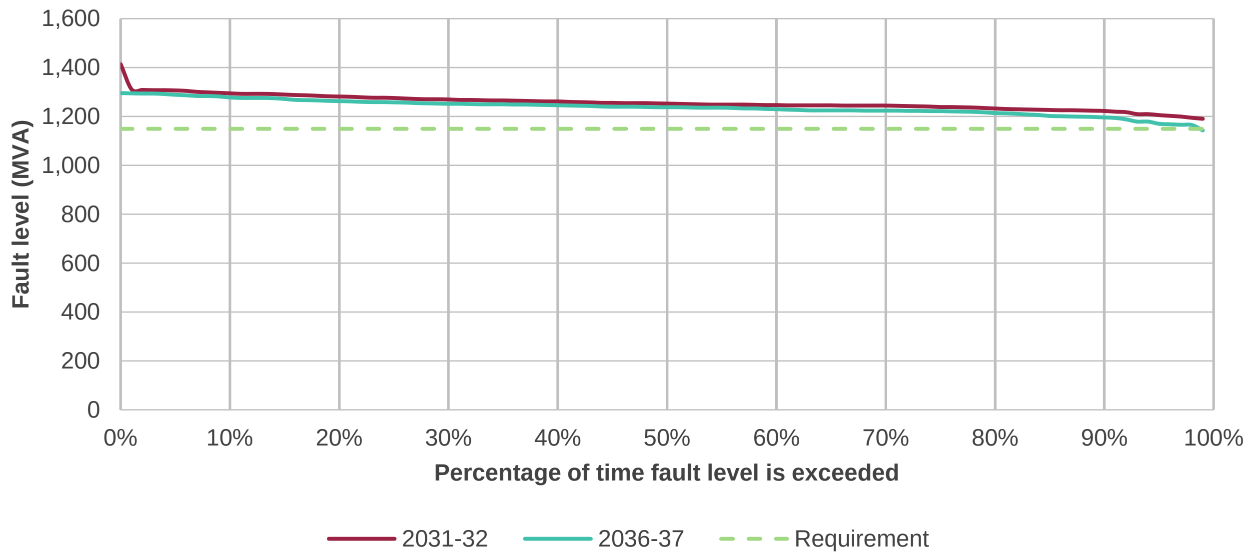
Node	Current requirement met		Comment
	Up to 2031-32	Up to 2036-37	
Gin Gin 275 kV	150 MVA potential shortfall†	200 MVA potential shortfall	Closure of Callide B and Gladstone power stations reduces fault level at Gin Gin.
Greenbank 275 KV	250 MVA potential† shortfall	Yes	Potential closure of Tarong Power Station reduces fault levels at Greenbank and Western Downs[26]. In some cases, closures of generators across Queensland can result in different dispatch patterns in Southern and Central Queensland resulting in changes in forecast fault level at certain nodes.
Lilyvale 132 KV	Yes	Yes	
Ross 275 kV	Yes	Yes	
Western Downs 275 kV	50 MVA potential shortfall†	Yes	Potential closure of Tarong Power Station reduces fault levels at Greenbank and Western Downs. The forecast step increase in fault level at Western Downs between 2031-32 and 2035-36 is due to the projected commissioning of the second 330 kV Queensland to New South Wales interconnector forecast for 2037.

† Although AEMO projects that a shortfall may arise, a fault level shortfall is not formally declared.

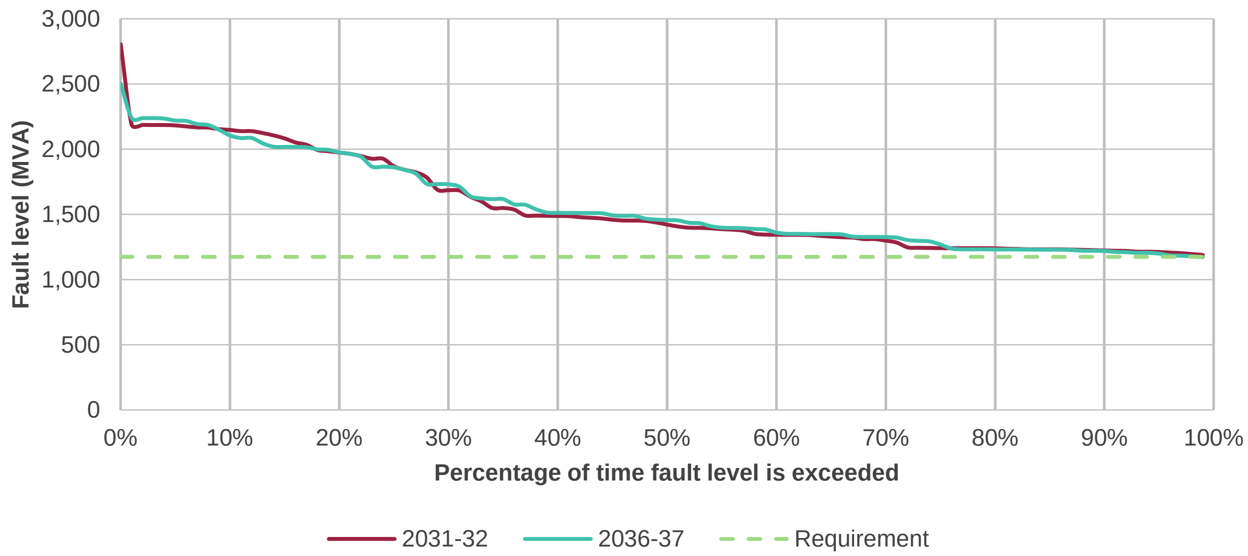
Gin Gin 275 kV

Greenbank 275 kV

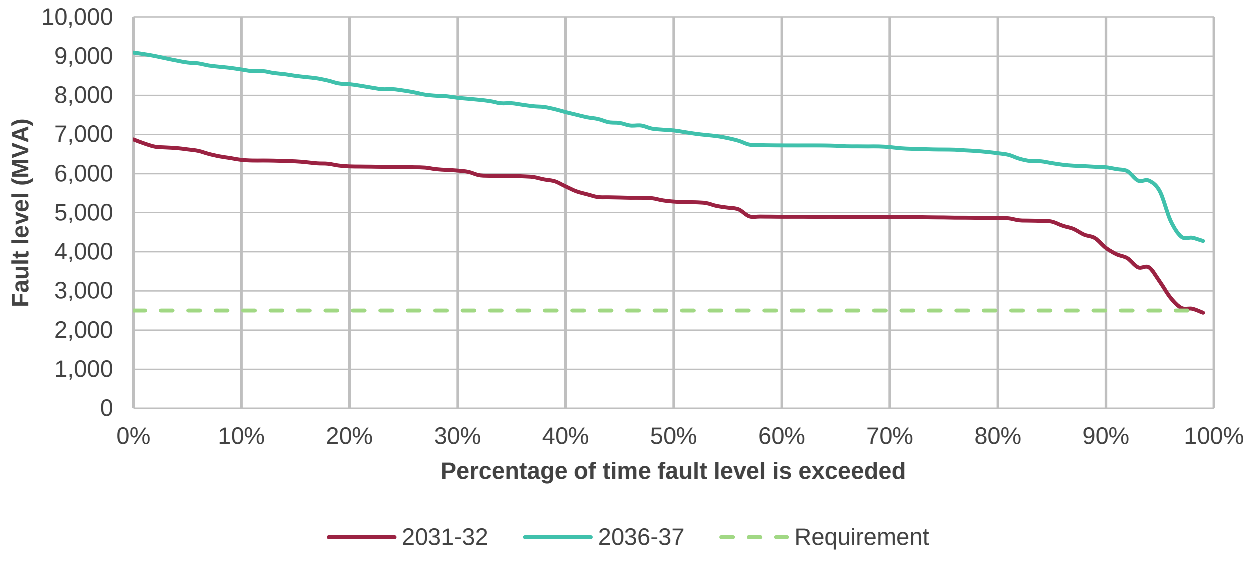
Lilyvale 132 kV



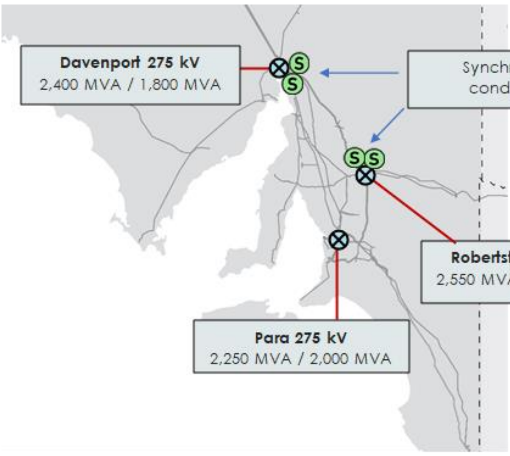
Ross 275 kV

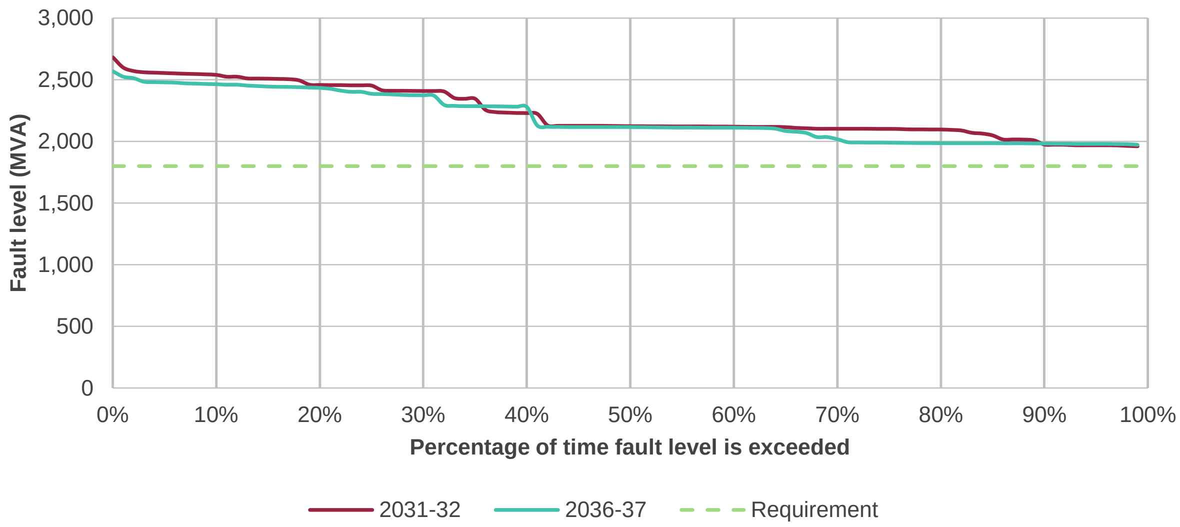


Western Downs 275 kV

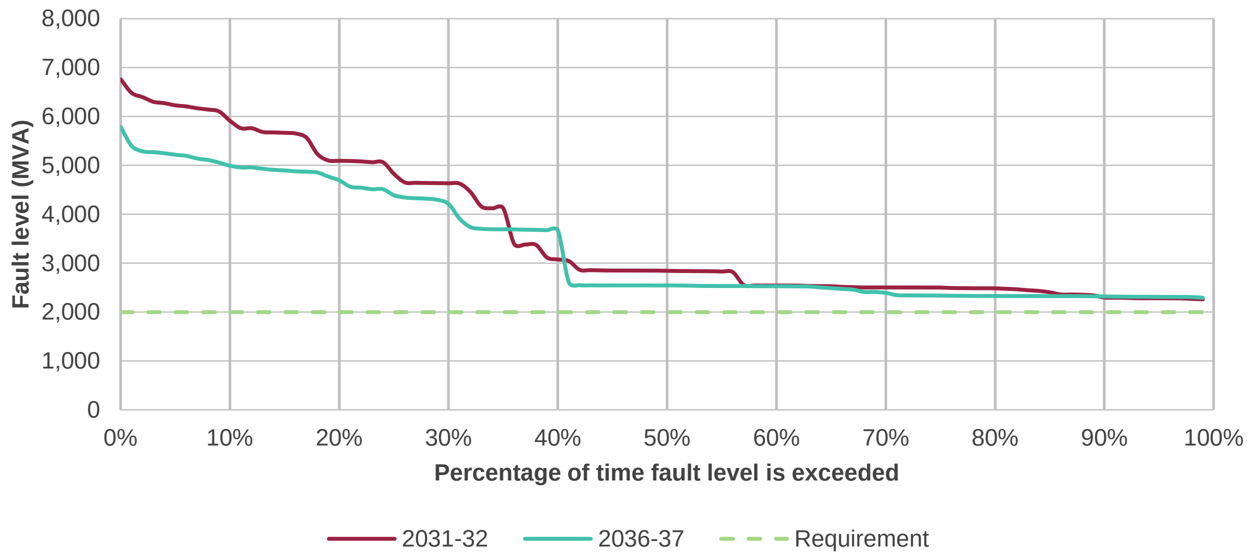


South Australia system strength outlook

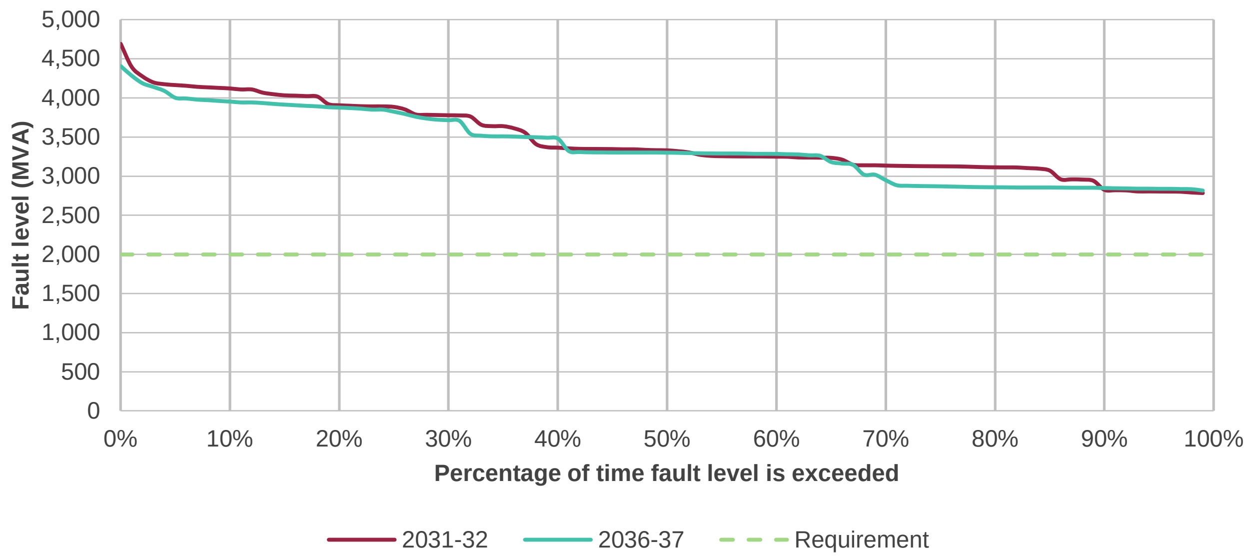
System strength requirements (pre/post contingent) and summary			
			ElectraNet has commissioned four synchronous condensers, two at Davenport and two at Robertstown, to address the fault level shortfall declared by AEMO in October 2017. The synchronous condensers improve system strength and inertia in South Australia.
Projections – *Progressive Change* scenario			
Node	**Current requirement met**		**Comment**
	Up to 2031-32	**Up to 2036-37**	
Davenport 275 kV	Yes	Yes	With the four synchronous condensers installed in South Australia, the projected system strength for all nodes in South Australia is expected to meet the current system strength requirements in the future.
Para 275 kV	Yes	Yes	
Robertstown 275 kV	Yes	Yes	
Davenport 275 kV			



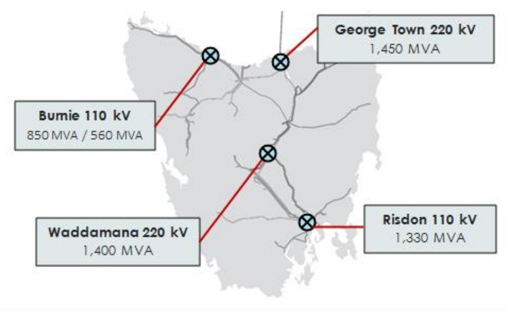
Para 275 kV



Robertstown 275 kV



Tasmania system strength outlook

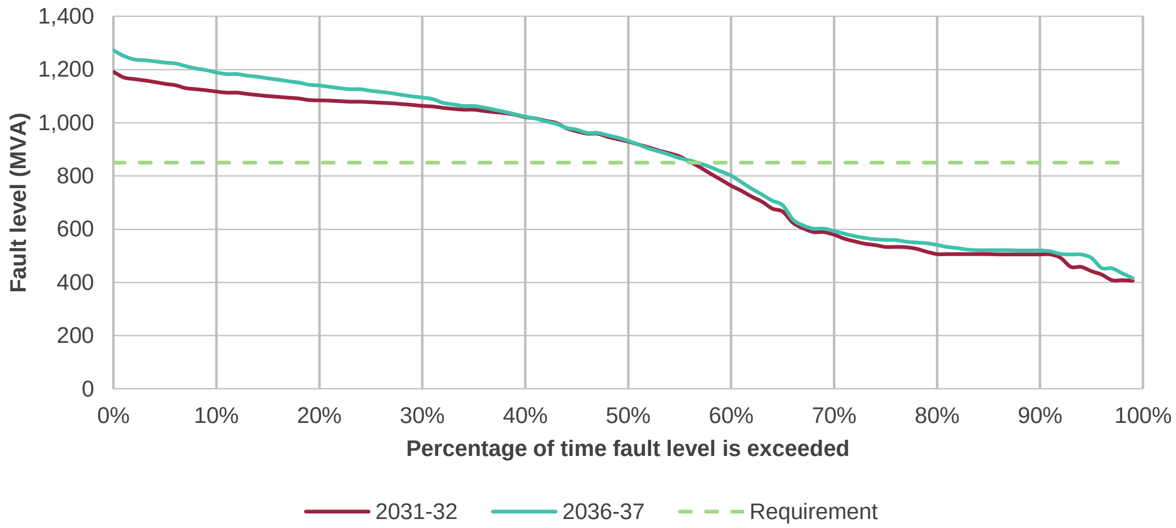
System strength requirements (pre/post contingent) and summary	
	TasNetworks has entered into a contract for system strength and inertia services to address a system strength and inertia shortfall declared in May 2020, which was later revised and increased in May 2021. This contract expires in 2024. Without the continuation of this contract or other system strength services, ISP modelling shows that shortfalls are likely to re-emerge – consistent with findings in the 2021 System Security Reports.

Projections – *Progressive Change* scenario

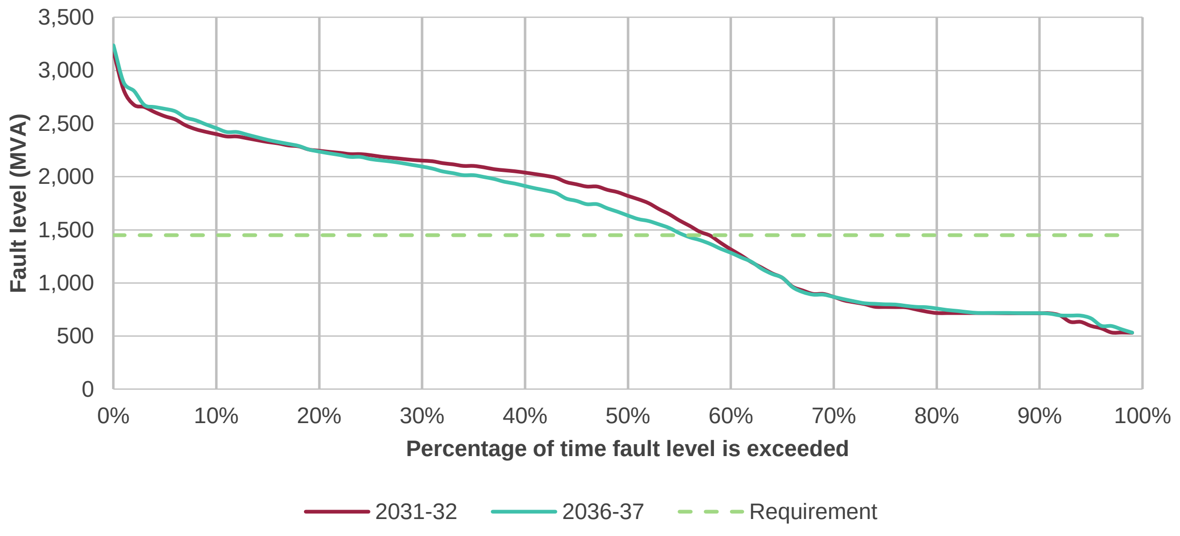
Node	Current requirement met		Comment
	Up to 2031-32	Up to 2036-37	
Burnie 110 kV	450 MVA potential shortfall†	450 MVA potential shortfall†	Consistent with the 2021 System Security Reports, AEMO notes that shortfalls are likely in Tasmania without additional system strength services.
George Town 220 kV	900 MVA potential shortfall†	900 MVA potential shortfall†	
Risdon 110 kV	700 MVA potential shortfall†	700 MVA potential shortfall†	
Waddamana 220 kV	750 MVA potential shortfall†	750 MVA potential shortfall†	

†Although AEMO projects that a shortfall may arise, a fault level shortfall is not formally declared from these results.

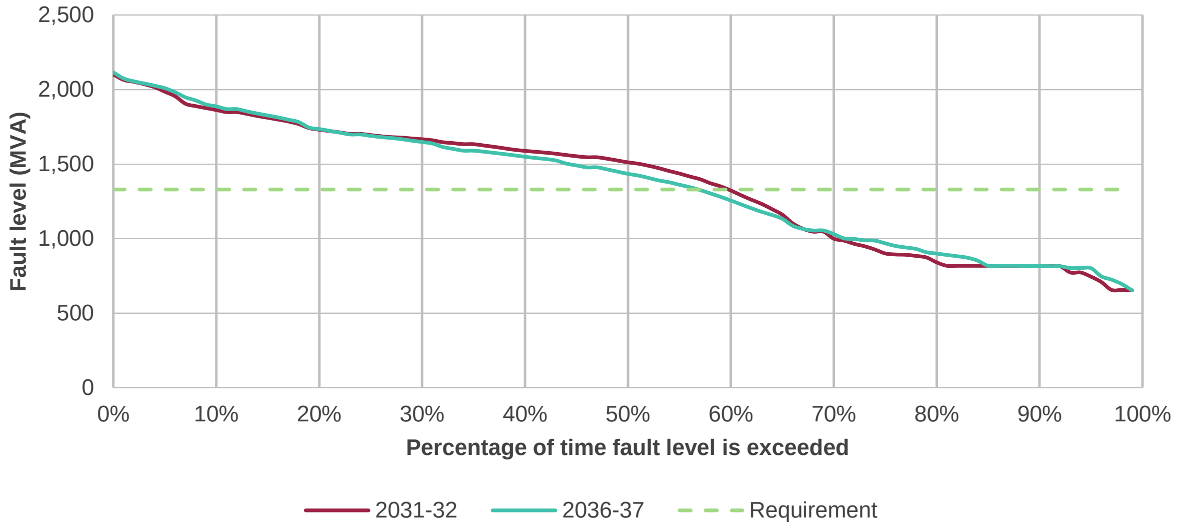
Burnie 110 kV



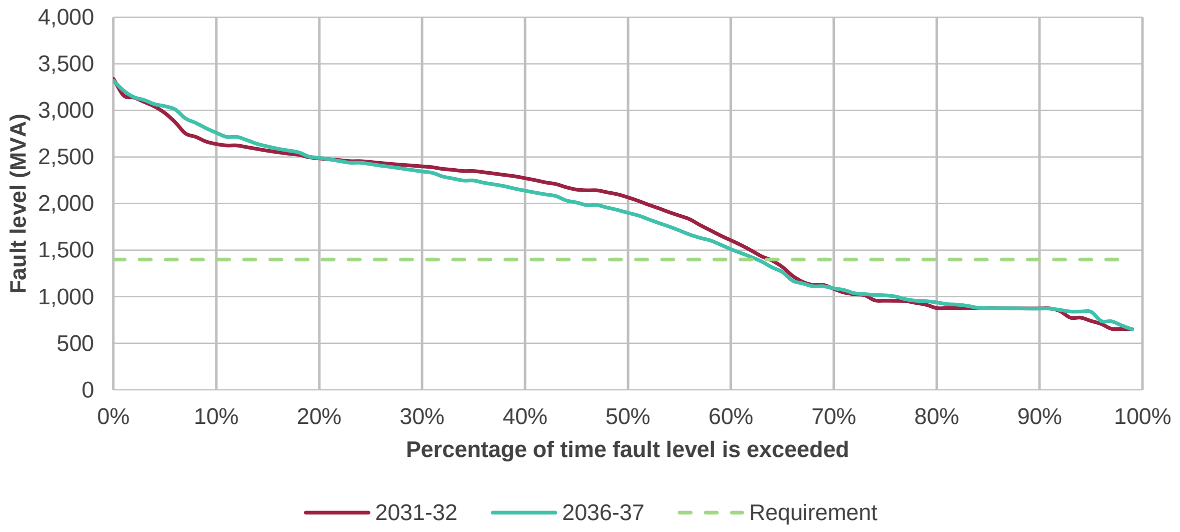
George Town 220 kV



Risdon 110 kV

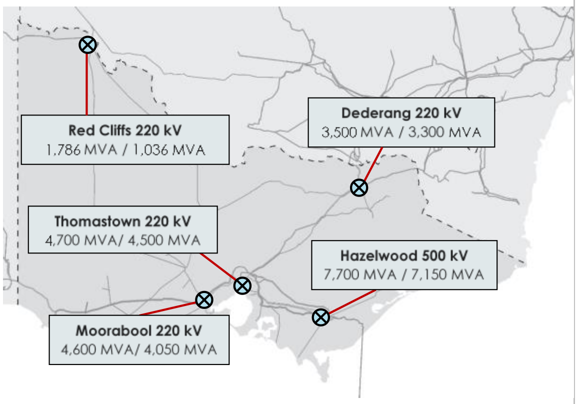


Waddamana 220 kV



Victoria system strength outlook

System strength requirements (pre/post contingent) and summary



The commissioning of Project EnergyConnect is expected to improve the system strength at Red Cliffs. These projections show that Hazelwood 500 kV and Moorabool 220 kV nodes in Victoria fall below the current system strength requirements by 2031-32.

The Hazelwood node represents the synchronous generation centre in Latrobe Valley and is close to Basslink DC link. Retirement of generation in the Latrobe Valley will have a significant impact on the fault level at Hazelwood.

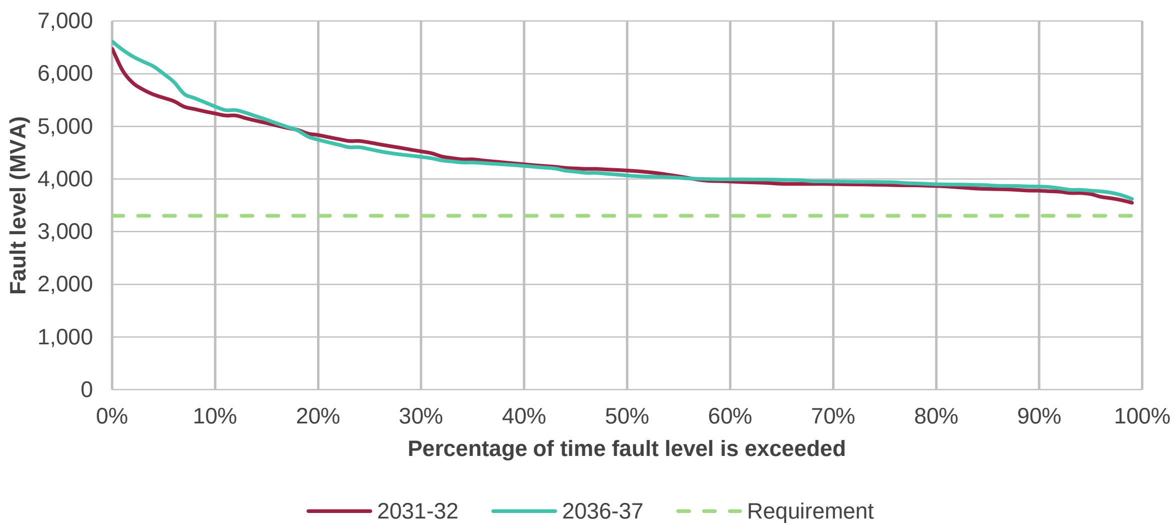
Different generators will have different fault level contributions. The fault level calculated will depend on the units in service. Hazelwood and Moorabool fault level fluctuate between 2031-32 and 2036-37. The number of units in service during these low system strength period remains constant between 2031-32 and 2036-37, however the units in Loy Yang A and Loy Yang B power stations vary under different combinations, resulting in differences in fault level at these nodes.

Projections – *Progressive Change* scenario

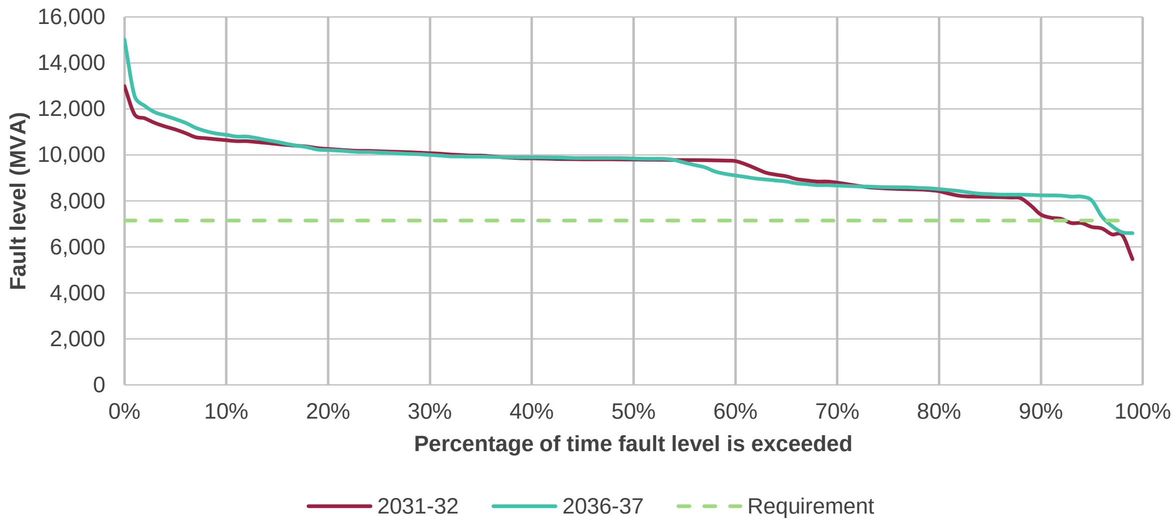
Node	Current requirement met		Comment
	Up to 2031-32	Up to 2036-37	
Dederang 220 kV	Yes	Yes	
Hazelwood 500 kV	1,700 MVA potential shortfall†	550 MVA potential shortfall†	Yallourn Power Station closure results in decreased system strength at these nodes.
Moorabool 220 kV	400 MVA potential shortfall†	150 MVA potential shortfall†	
Red Cliffs 220 kV	Yes	Yes	
Thomastown 220 kV	AEMO is undertaking further investigations and will provide an update in the 2022 ISP.		

†Although AEMO projects that a shortfall may arise, a fault level shortfall is not formally declared.

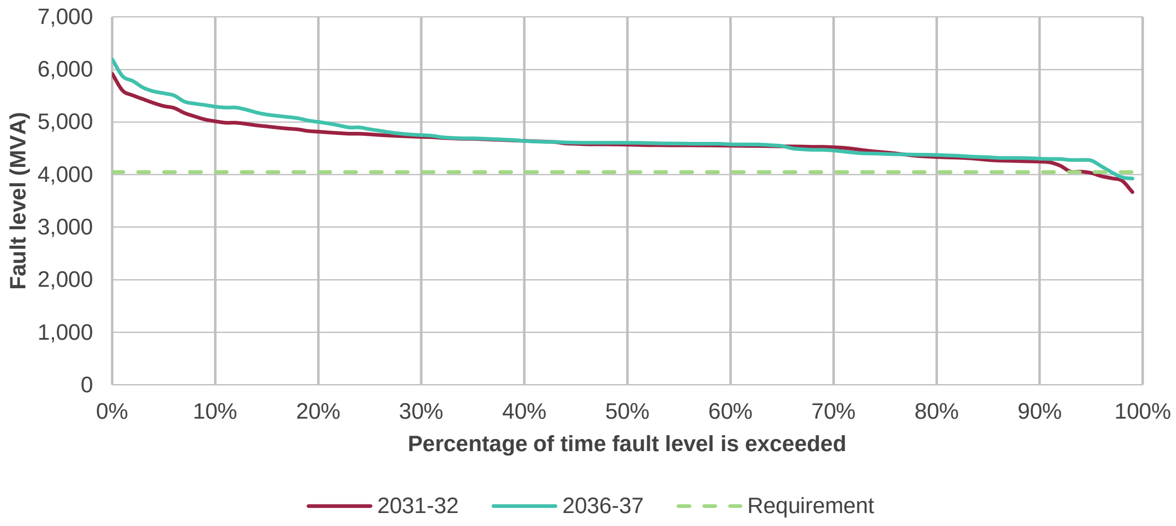
Dederang 220 kV



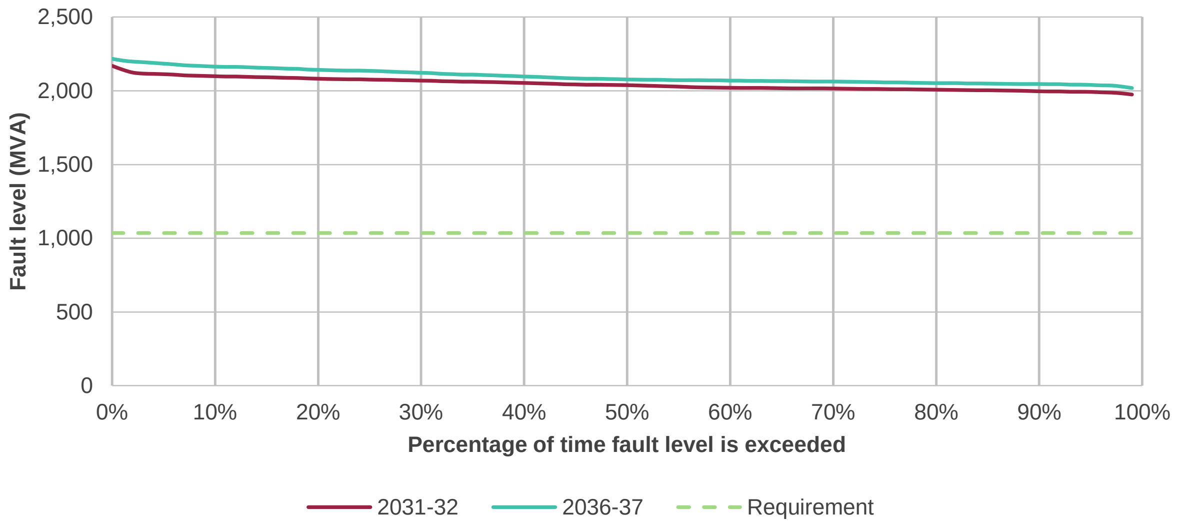
Hazelwood 275 kV



Moorabool 220 kV



Red Cliffs 220 kV



A7.4 Draft inertia outlook

A minimum level of inertia is required in the power system to suppress and slow frequency deviations so that automatic controls can respond to sudden changes in the supply-demand balance. Experience from already declared inertia shortfalls in South Australia and Tasmania has demonstrated the procurement of diverse types of inertia services due to the differences of available services within the two regions:

- In Tasmania, existing synchronous generation (predominantly hydroelectric generation) can be utilised either at low output levels or placed in synchronous condenser mode when required.
- In South Australia, flywheels were added to new synchronous condensers that were initially being installed for system strength remediation. Contracting with proponents for Fast Frequency Response (FFR) can also address or partially address inertia shortfalls.

AEMO will publish the 2021 System Security Reports[27] in December 2021. This report will detail the inertia assessment of the NEM over the five-year outlook. The regional TNSP is required to ensure that inertia network services (or inertia support activities) are available to address any inertia shortfalls identified in the five-year outlook.

A7.4.1 Importance of inertia, roles, and responsibilities

Maintaining an appropriate level of synchronous inertia, or its equivalent, is crucial for ensuring overall power system security.

NER 5.20B sets out the division of responsibilities in the NEM:

- AEMO is required to determine the boundaries of inertia sub-networks (either a region or a sub-region of the NEM), and inertia requirements for each inertia sub-network.
- AEMO must identify whether a shortfall is likely to exist for the inertia sub-region over the five-year horizon. AEMO must consider the likelihood of an inertia sub-network becoming islanded when determining whether there are inertia shortfalls for the sub-network.
- The regional TNSP is required to ensure that inertia network services (or inertia support services) are available to address any inertia shortfall declared by AEMO for the inertia sub-network.

AEMO is required to operate the power system to meet the frequency operating standards (FOS) using services provided by the local TNSP. In 2018, AEMO determined two levels of inertia for each NEM region that must be available for dispatch:

- The Minimum Threshold Level of Inertia is the minimum level of inertia required to operate an islanded region, or a region at credible risk of islanding, in a satisfactory operating state.
- The Secure Operating Level of Inertia (SOLI) is the minimum level of inertia required to operate the islanded region in a secure operating state.

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[27] AEMO, *2021 System Security Reports: System strength, Inertia and NSCAS*, will be available in December 2021 at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/planning-for-operability.

These requirements are solely focused on regional requirements when the region is at risk of islanding or operating as an islanded system. AEMO has from time to time updated the requirements for some regions[28].

A7.4.2 Impact of FFR markets on inertia and requirements

Two key regulatory changes are expected to affect future inertia assessments in the NEM – the post-2025 electricity market design program and the implementation of fast frequency response markets.

Market reforms for essential system security services are under consultation

The AEMC is consulting on rule change requests concerning valuing, procuring and scheduling essential system services to ensure the power system remains secure[29]. These rule changes are being progressed consistent with the broader ESB post-2025 electricity market design program[30].

Any market changes resulting from these rule changes can be expected to affect the five-year outlook for the system strength, inertia and NSCAS assessments, given that the essential system services under review include inertia, frequency control and system strength. AEMO is working closely with the AEMC on the delivery of these rule change requests and will incorporate their final outcomes in future system security assessments and ISP projections.

AEMO will implement a fast frequency response ancillary service market in 2023

In July 2021 the AEMC published a rule requiring that AEMO introduce two new market ancillary services to help control system frequency and keep the future electricity system secure – namely, fast raise and fast lower markets for fast frequency response.

AEMO will implement these markets in 2023. For the purposes of the 2021 System Security Reports, AEMO has chosen to assume that these new ancillary service markets will not necessarily have services available in the near term to meet regional needs for secure operating levels of inertia. It will take time for these new market services to be established and understood. Rather, AEMO is declaring inertia shortfalls where they are identified and where fast frequency response may address these shortfalls AEMO expects that TNSPs will seek to procure those services from providers.

In the longer term, AEMO expects to be able to better project how the existing inertia requirements framework and the future fast frequency response ancillary service markets will interface with one another.

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[28] AEMO inertia assessments are available via the 'Planning for operability' webpage at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/planning-for-operability.

[29] AEMC, 'Capacity commitment mechanism for system security and reliability services', accessed in November 2021 at https://www.aemc.gov.au/rule-changes/capacity-commitment-mechanism-system-security-and-reliability-services, and AEMC, 'Synchronous services market', accessed in November 2021 at https://www.aemc.gov.au/rule-changes/synchronous-services-markets..

[30] Energy Security Board, 'Post 2025 electricity market design', accessed in November 2021 at https://esb-post2025-market-design.aemc.gov.au/.

A7.4.3 NEM Mainland inertia outlook

NEM mainland

The inertia requirements define the minimum levels of inertia required to operate each NEM region as an island. Critically, these defined levels of inertia are only required to be online when a region is at risk of synchronously islanding or is islanded – the concept on which the NEM is based being that synchronous connection to the rest of the NEM provides a strong inertia base. This concept is increasingly being challenged and will require review, as the Draft ISP projects that inertia will fall in most regions as existing coal generation retires.

Substantial amounts of IBR (both VRE and DER) are projected to replace the energy and capacity from synchronous generation such as coal plant when it retires. This will lead to reducing synchronous inertia across the NEM overall. By 2036-37, the inertia across the NEM mainland is projected to fall below the minimum threshold of inertia, which is determined by the sum of each region's threshold of inertia (excluding Tasmania).

While islanded, the frequency operating standards (FOS) allow the frequency to deviate between 49.0 Hz and 51.0 Hz for the largest credible contingency, and the inertia requirements for each region have been calculated on this basis. When NEM regions are interconnected, the FOS require that the frequency be maintained between 49.5 Hz and 50.5 Hz for the largest credible contingency. This can only be maintained with sufficient levels of Frequency Control and Ancillary Services (FCAS) and inertia online. As coal units retire, total inertia reduces across the NEM, and the amount of FCAS required is anticipated to increase.

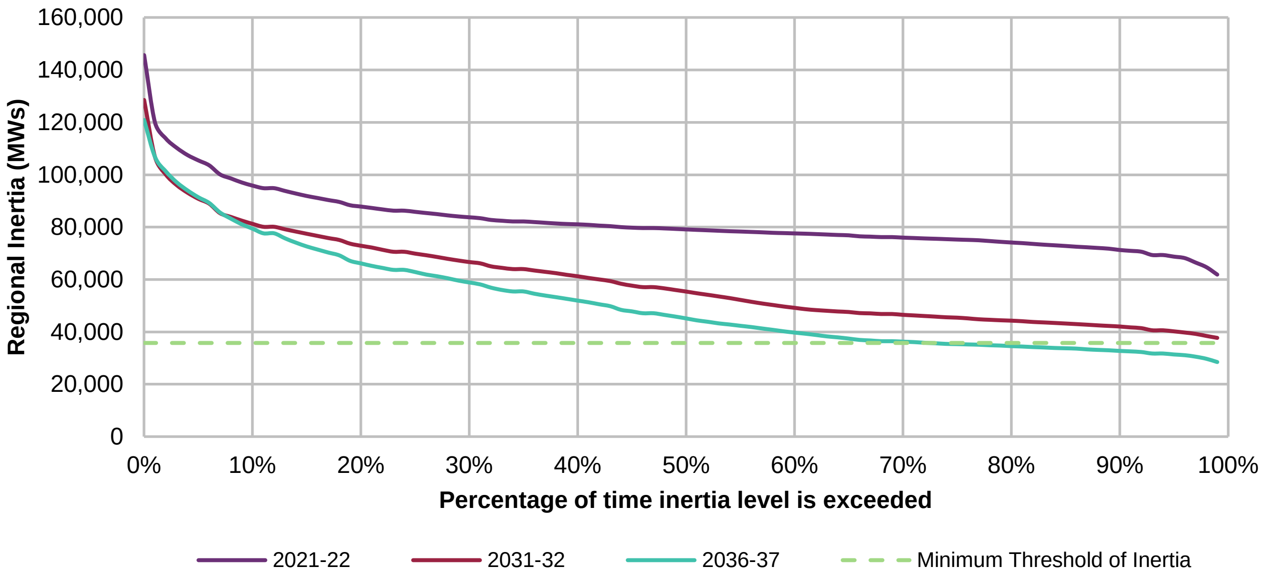
The ability of FFR and grid forming controls to provide a fast injection of active power will increasingly be an important feature for secure operation at lower inertia levels, minimising the need for synchronous inertia and traditional FCAS, and potentially also reducing the proposed minimum inertia requirement.

AEMO is required to design and put in place the new FFR market ancillary service arrangements by October 2023[31].

The current inertia framework does not provide for assessing the inertia requirements and shortfalls across the NEM. AEMO has previously noted consideration of inertia across the NEM is a priority for future years. For this outlook, the inertia requirements of the individual states are summed across the mainland, and mainland inertia projections are plotted for comparison.

Inertia projections (*Progressive Change* scenario)

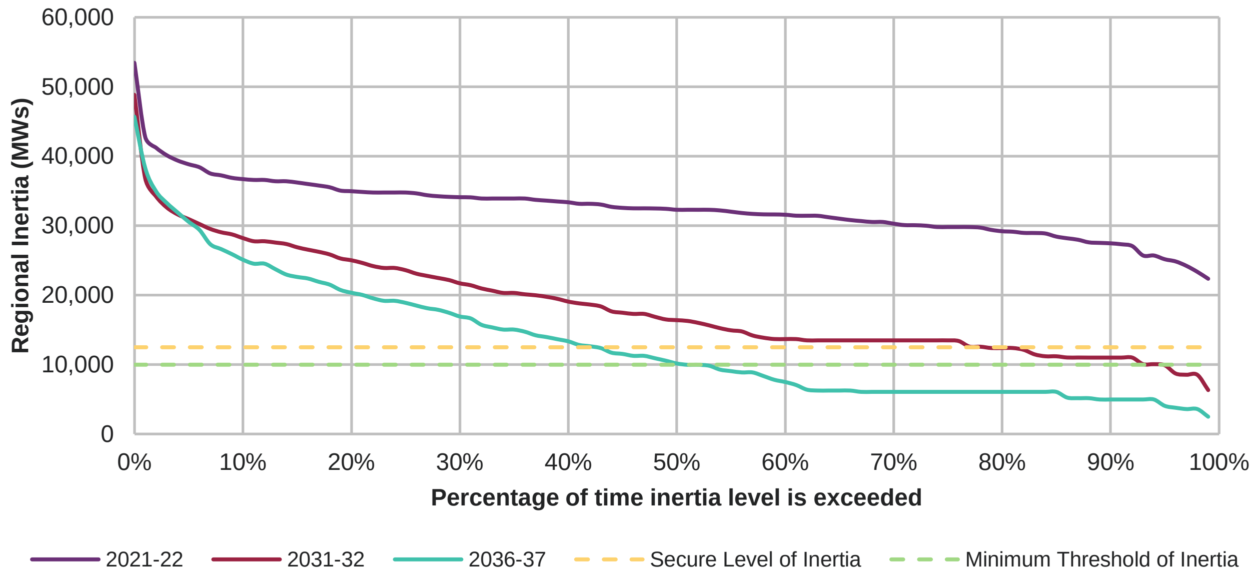
	2031-32	2036-37	Comments
Available inertia 99% of the time (MWs)	37,800	28,450	The projections show that the NEM mainland inertia is projected to decline significantly in 2031-32 when compared to 2021-22. By 2036-37 the inertia on the NEM mainland is forecast to decrease below the minimum threshold of inertia.



[31] AEMC Fast Frequency Response market ancillary service, at https://www.aemc.gov.au/rule-changes/fast-frequency-response-market-ancillary-service.

A7.4.4 New South Wales inertia outlook

New South Wales			
Available inertia is projected to decline below the secure level or inertia and the minimum threshold of inertia in New South Wales due to accelerated forecast in closure of coal stations.			
Inertia requirements†			
	2021 Inertia requirements		The NER only permit AEMO to declare an inertia shortfall for when a region is operating as an island, or during a credible risk of islanding. Even though inertia is projected to fall below both the minimum threshold and secure operating levels of inertia for New South Wales (see chart below), no shortfall can be declared under the framework, as the likelihood of islanding is considered low. This is because of the number of Alternating Current (AC) interconnector circuits to other regions. Islanding of New South Wales therefore remains unlikely.
Secure operating level of inertia (MWs)	12,500		
Minimum operating level of inertia (MWs)	10,000		
Net distributed PV Trip (MW)	Not studied		
Risk of islanding	Not Likely		
Inertia projections (*Progressive Change* scenario)			
	2031-32	**2036-37**	**Comments**
Available inertia 99% of the time (MWs)	6,350	2,500	Retirements of Vales Point and Eraring power stations result in a reduction of available inertia. There is a further reduction projected following the retirement of Bayswater Power Station.
Projected decline below SOLI (MWs)	6,150‡	10,000‡	
‡Unlikely to island although projected below SOLI, shortfalls are not formally declared.			



† Fast Frequency Response from inverter-based devices may reduce the need for traditional FCAS and associated synchronous inertia highlighting alternative options that are now becoming available through the use of advanced inverter control systems. AEMO will continue to explore this relationship.

A7.4.5 Queensland inertia outlook

Queensland
Queensland inertia outcomes are heavily influenced by the potential changes in coal-fired generation operational profiles. Increase in net distributed PV contingency size, due to large uptakes of rooftop PV, has increased inertia requirements in Queensland. The PV contingency size is not expected to increase after the new inverter standard comes into effect 18 December 2021. Due to the physical nature of interconnection with New South Wales, Queensland is still considered to have a 'likely' risk of islanding. This finding is largely driven by Queensland having only one double-circuit AC interconnection to New South Wales via the QNI‡. This however may change with additional interconnection. In this Draft ISP, AEMO has identified a future project to develop a second Queensland to New South Wales interconnector consisting of a 330 kV double-circuit line, strung with one circuit, from the locality of Armidale South to Braemar via Bulli Creek.

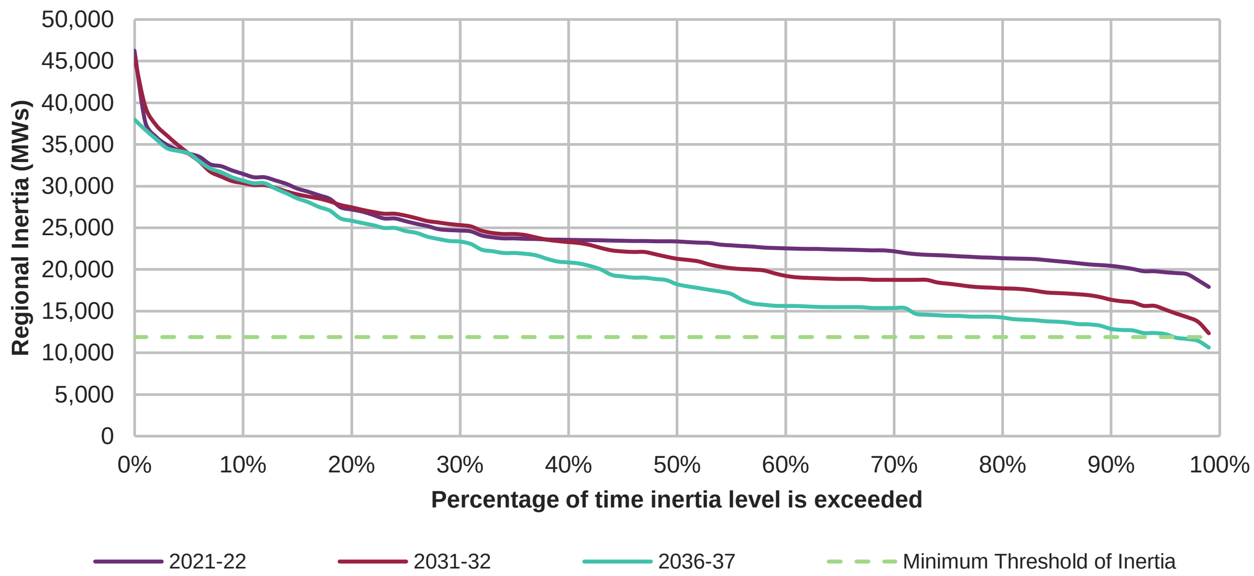
Inertia requirements*

	2021 inertia requirements	
Secure operating level of inertia (MWs)**	24,100 MWs at 390 MW Fast FCAS 16,600 MWs at 455 MW Fast FCAS	In the 2021 System Security Reports, AEMO will revise the secure operating level of inertia requirement for Queensland from 14,800 MWs to a ratio of inertia and Fast FCAS as shown here. This considers the increase in net distributed PV trip contingency size due to the increased forecast uptake of distributed PV, and the relationship between inertia and Fast FCAS.
Minimum operating level of inertia (MWs)	11,900	
Net distributed PV trip (MW)	270	
Risk of islanding	Likely	

Inertia projections (*Progressive Change* scenario)

	2031-32	2036-37	Comments
Available inertia 99% of the time (MWs)	12,350	10,600	Closures of Callide B, Tarong and Gladstone results in the reduction of available inertia in Queensland.
Projected decline below SOLI (MWs)	5,650†	7,400†	

†With additional interconnection, Queensland region may be unlikely to island. Although projected below SOLI, shortfalls are not formally declared. For the purposes of accessing projected decline, available inertia has been compared against a proxy value of 18,000 MWs.



‡ While Directlink converters allow for power transfer between New South Wales and Queensland, as it is HVDC technology, it is not a synchronous interconnection.
* Fast Frequency Response from inverter-based devices may reduce the need for traditional FCAS and associated synchronous inertia highlighting alternative options that are now becoming available through the use of advanced inverter control systems. AEMO will continue to explore this relationship.
** The secure operating level of inertia in Queensland is represented as a relationship between inertia (MWs) required and Fast Frequency Control Ancillary Services (FCAS) (MW) required. Fast FCAS represents 6 second FCAS.

A7.4.6 South Australia inertia outlook

South Australia

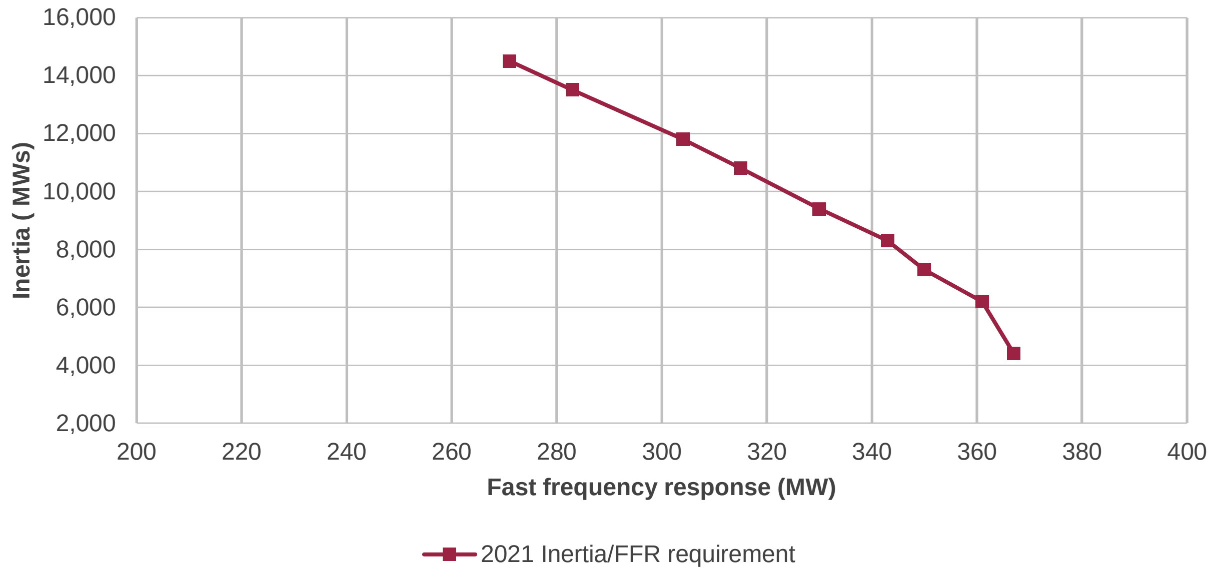
In 2021, ElectraNet commissioned four synchronous condensers to address a system strength shortfall declared by AEMO in October 2017 and the subsequent inertia shortfall declared in South Australia as part of the 2018 National Transmission Network Development Plan (NTNDP). To partially meet this gap, high inertia fly wheels were included in the design of the synchronous condensers.

The need to ensure sufficient inertia is online only applies when the region is operating as an island for the secure operating level, or during a credible risk of islanding or when islanded for the minimum threshold level. For South Australia this currently occurs during outages of either Heywood Interconnector circuits, or nearby 500 kV circuits in Victoria. AEMO considers that islanding remains likely until the commissioning of Project EnergyConnect (PEC) and the full capacity released*.

Inertia requirements[‡]

	2021 inertia requirements	
Secure operating level (MWs inertia and MW FFR)	6,200 MWs with 360 MW FFR 4,400 MWs with 367 MW FFR	In the 2021 System Security Reports, AEMO will revise the secure operating level of inertia (SOLI) requirements for South Australia. The SOLI in South Australia has been declared relative to the amount of inertia support activities provided, including Fast Frequency Response (FFR). Provision of more FFR (MW) can offset the requirement for synchronous inertia (MWs). The requirements were updated to include the increase in net distributed PV contingency size due to the increased forecast uptake of distributed PV. South Australia's secure level of inertia requirements are represented as a combination of synchronous inertia (MWs) and FFR (MW). Less synchronous inertia is required if more FFR is available.
Minimum operating level of inertia (MWs)	4,400	
Net distributed PV trip (MW)	300	
Risk of islanding	Likely until PEC	

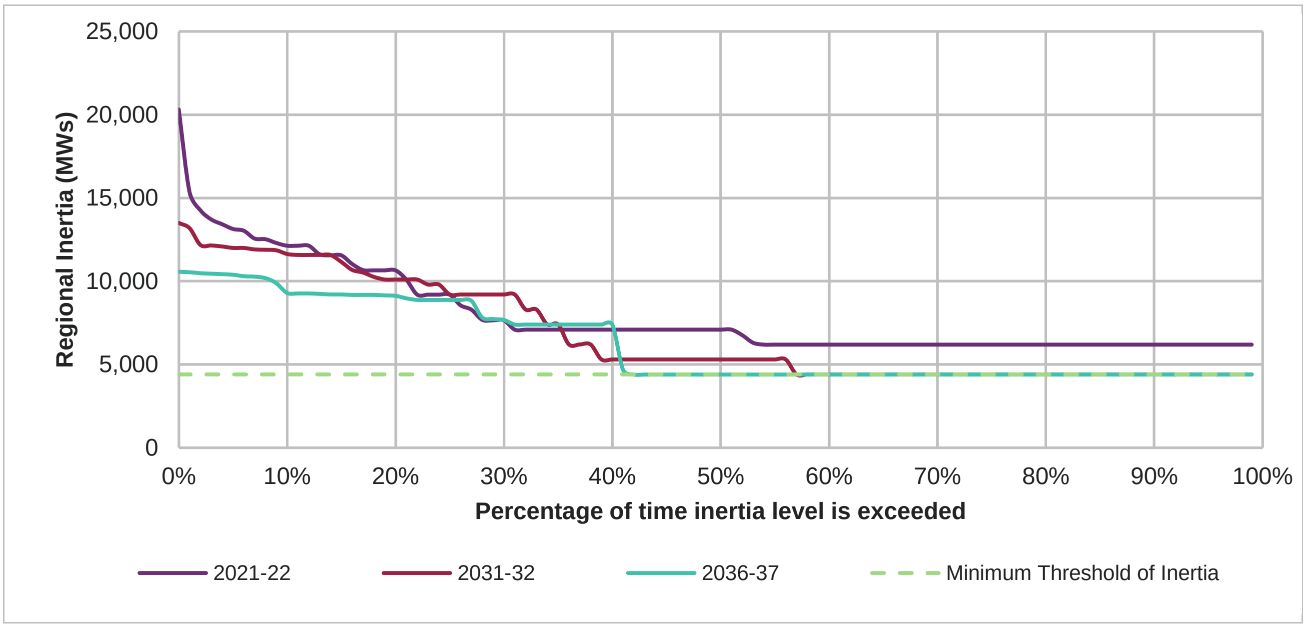
The following chart shows the inertia requirements (MWs) with varying availability of FFR and assumes 4,400 MWs is available from the four synchronous condensers.



Inertia projections (*Progressive Change* scenario)

	2031-32	2036-37	Comments
Available inertia 99% of the time (MWs)	4,400	4,400	367 MW of FFR is required with 4,400 MWs of inertia available from synchronous condensers. If 270 MW of FFR is available, an additional 10,100 MWs of synchronous inertia is required to meet the secure level of inertia in South Australia.
Projected decline below SOLI (MWs)	Depends on FFR available		

[†] After the commissioning of PEC and full release of transfer capacity, Islanding in South Australia is likely to be remote. Unlikely to island although projected below SOLI, shortfalls are not formally declared.

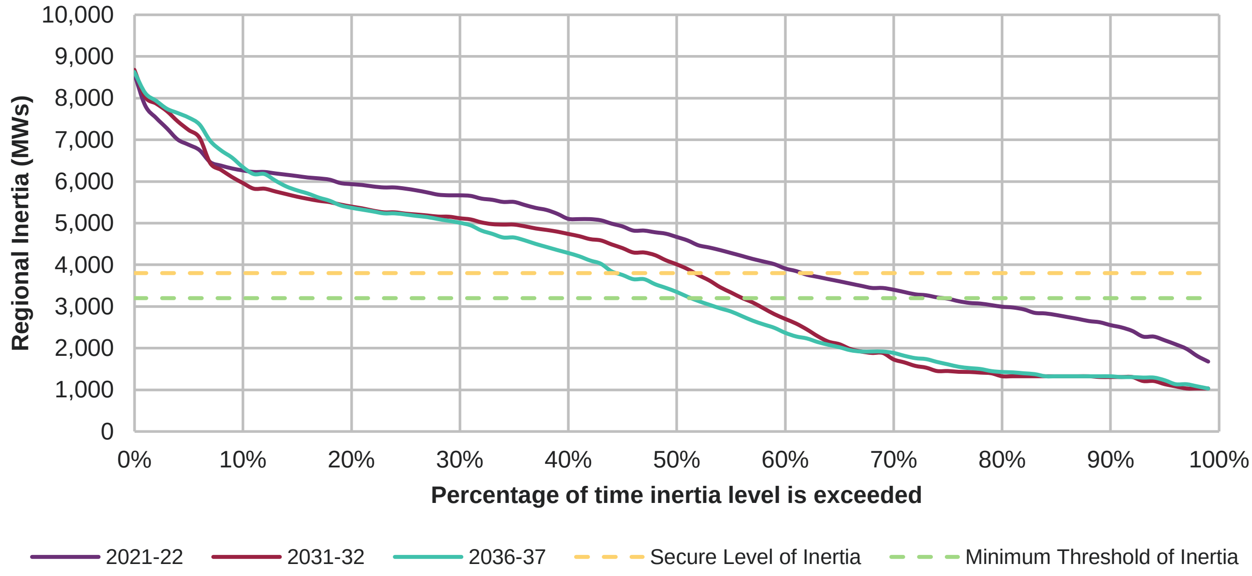


* AEMO Inertia Requirements Methodology and Inertia Requirements and Shortfalls at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-security-market-frameworks-review/2018/inertia_requirements_methodology_published.pdf?la=en.
‡ Fast Frequency Response from inverter-based devices may reduce the need for traditional FCAS and associated synchronous inertia highlighting alternative options that are now becoming available through the use of advanced inverter control systems. AEMO will continue to explore this relationship.

A7.4.7 Tasmania inertia outlook

Tasmania			
In 2020, AEMO declared a system strength and inertia shortfall in Tasmania which was further increased in May 2021. TasNetworks entered a contract for system strength and inertia services which is sufficient to fulfil this identified shortfall. This contract expires in 2024. Without the continuation of this contract or other inertia services, the Draft ISP result under *Progressive Change* scenario projections shows that the inertia available 99% of the time is below the current requirements. These projections show inertia online when dispatched for the energy market and highlight that inertia services are likely to be required in Tasmania for the long term.			
Inertia requirements*			
	2021 inertia requirements		Tasmania is connected to Victoria by an asynchronous High Voltage Direct Current (HVDC) link, so for the purposes of inertia assessments is considered to be operated as an island at all times. This means the inertia requirements also need to be met, at all times.
Secure operating level of inertia (MWs)	3,800		
Minimum operating level of inertia (MWs)	3,200		
Contracted inertia network services until 2024 (MWs)	2,620		
Risk of islanding	Likely		
Inertia projections (*Progressive Change* scenario)			
	2031-32	**2036-37**	**Comments**
Available inertia 99% of the time (MWs)	1,100	1,100	These results are consistent with the inertia projections for Tasmania, to be released in the 2021 System Security Reports‡.
Projected decline below SOLI (MWs)	2,700†	2,700†	

† Although AEMO projects that a shortfall may arise, an inertia shortfall is not formally declared.



* Fast Frequency Response from inverter-based devices may reduce the need for traditional FCAS and associated synchronous inertia highlighting alternative options that are now becoming available through the use of advanced inverter control systems. AEMO will continue to explore this relationship.

‡ AEMO, 2021 *System Security Reports: System Strength, Inertia and NSCAS*, will be available in December 2021 at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/planning-for-operability.

A7.4.8 Victoria inertia outlook

Victoria

Inertia in Victoria is projected to decline below the minimum threshold and secure level of inertia. An increase in available inertia occurs from 2031-2032 to 2036-37, primarily driven by the operation of different combinations of units projected in service in the later period. The number of units in service during these low inertia period remains constant between 2031-32 and 2036-37, however the units in Loy Yang A and Loy Yang B power stations vary under different combinations, resulting in differences to inertia contributions.

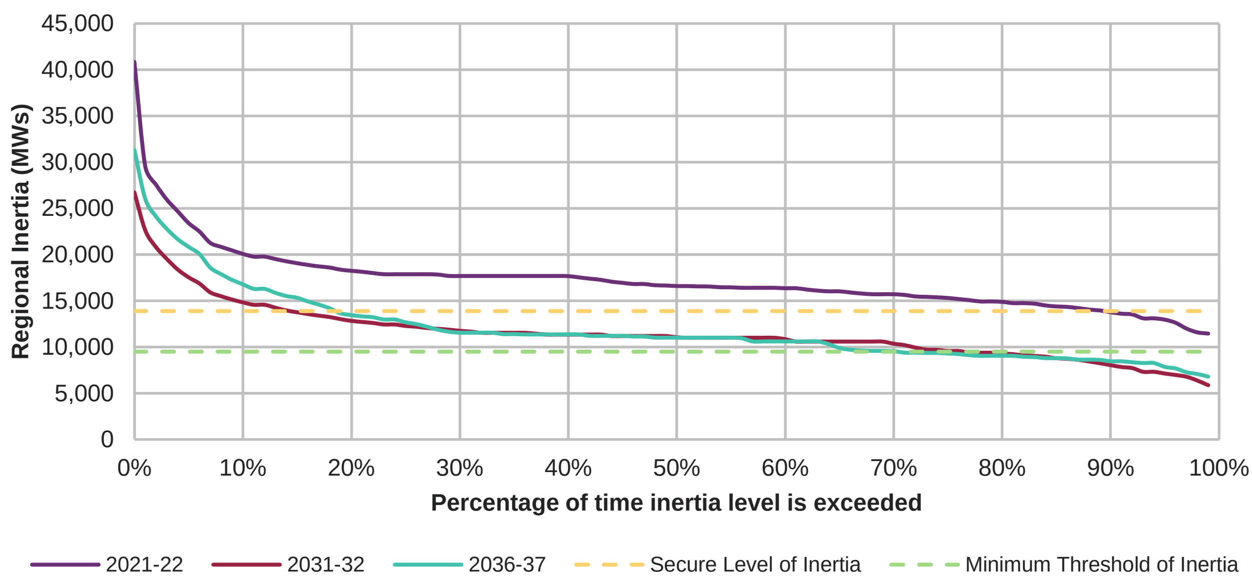
Inertia requirements*

	2021 inertia requirements	
Secure operating level of inertia (MWs)	13,900	The NER only permit AEMO to declare an inertia shortfall for when a region is operating as an island, or during a credible risk of islanding. Even though inertia is projected to fall below the minimum operating level for Victoria, no shortfall can be declared as the likelihood of islanding is considered low. This is because of the number of Alternating Current (AC) interconnector circuits to other regions.
Minimum operating level of inertia (MWs)	9,500	
Net distributed PV trip (MW)	-	
Risk of islanding	Not Likely	

Inertia projections (*Progressive Change* scenario)

	2031-32	**2036-37**	**Comment**
Available inertia 99% of the time (MWs)	5,900	6,800	The retirement of Yallourn Power Station will result in fewer large synchronous units in service and therefore a decline in available inertia in Victoria.
Projected decline below SOLI (MWs)	8,000†	7,100†	

† Unlikely to island although projected below SOLI, shortfalls are not formally declared.



* Fast Frequency Response from inverter-based devices may reduce the need for traditional FCAS and associated synchronous inertia highlighting alternative options that are now becoming available through the use of advanced inverter control systems. AEMO will continue to explore this relationship.