Appendix 7. System Security

December 2023

Appendix to the Draft 2024 Integrated System Plan for the National Electricity Market

Important notice

Purpose

This is Appendix 7 to the Draft 2024 Integrated System Plan (ISP) which is available at https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp. AEMO publishes the Draft 2024 *Integrated System Plan* (ISP) pursuant to its functions under section 49(2) of the National Electricity Law (which defines AEMO's functions as National Transmission Planner) and its supporting functions under the National Electricity Rules. This publication is generally based on information available to AEMO as at 30 October 2023 unless otherwise indicated.

Disclaimer

AEMO has made reasonable efforts to ensure the quality of the information in this publication but cannot guarantee that information, forecasts and assumptions are accurate, complete or appropriate for your circumstances.

Modelling work performed as part of preparing this publication inherently requires assumptions about future behaviours and market interactions, which may result in forecasts that deviate from future conditions. There will usually be differences between estimated and actual results, because events and circumstances frequently do not occur as expected, and those differences may be material.

This publication does not include all of the information that an investor, participant or potential participant in the National Electricity Market might require, and does not amount to a recommendation of any investment.

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

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

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

Copyright

© 2023 Australian Energy Market Operator Limited. The material in this publication may be used in accordance with the copyright permissions on AEMO's website.

Version control

Version	Release date	Changes
1.0	15/12/2023	Initial release.

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

ISP Appendices

Contents

Tables

Figures

Executive summary

AEMO's *Integrated System Plan* (ISP) is a roadmap for the transition of the National Electricity Market (NEM) power system, with a clear plan for essential infrastructure to meet future energy needs. The ISP's optimal development path sets out the needed generation, firming and transmission, which would deliver significant net market benefits for consumers and economic opportunities in Australia's regions.

AEMO has identified a rapidly growing need for coordinated investment in system security services across the NEM. These services are necessary to enable delivery of the development plans considered in the ISP and are crucial to maintaining a secure and resilient power system throughout the energy transition.

This appendix quantifies these emerging requirements, and provides insights into the nature, timing, and geography of the services needed to address them.

AEMO has assessed the emerging need for system strength and inertia in the *Step Change* scenario. This work builds on the existing assessments in AEMO's annual security planning reports[1], and extends their outlook period to cover a 20-year horizon at five-yearly increments. It sets out:

- **A7.1 Recent reforms to the security planning frameworks** - this section provides an overview of recent and ongoing regulatory reforms relevant to the power system security analysis in this appendix. These reforms aim to deliver increasingly efficient and proactive investment in fit-for-purpose services.
- **A7.2 AEMO's approach to system security planning** - this section explains AEMO's overlapping approach to power system security planning across multiple timeframes spanning urgent shortfalls to strategic planning, and across a broad remit of potential security services.
- **A7.3 System security concepts and requirements** - this section describes the technical, economic, and locational drivers for these services in the context of the security assessments presented later in the appendix.
- **A7.4 Projected outlook and opportunities**- this section defines the minimum system security planning standards for each NEM region, the factors that influence how these will evolve, and the expected adequacy of services available to address them. This section is structured geographically to reflect the nature of network investment obligations, and to comment on any potential options for co-optimised investment in multiple security services from a single asset or provider.

[1] At https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/system-security-planning.

Key changes and findings

New South Wales

- Declining utilisation of synchronous generation is expected to reduce synchronous fault levels at some nodes, while major network projects like the Sydney Ring, will provide relief at others. Most associated remediation will be needed over the coming decade, and shortfalls have already been declared for Newcastle and Sydney West from July 2025.
- Substantial growth in IBR generation and storage will drive further investment in system strength over the full 20-year outlook period.
- Projected levels of inertia also decline significantly over the horizon; however strong interconnection with neighbouring regions means New South Wales is not considered sufficiently likely to island.

Queensland

- Similar to New South Wales, decreased utilisation of synchronous generation is expected to reduce synchronous fault levels at all nodes in the region; with most associated remediation investment likely needed over the coming decade. Substantial investment in wind and solar IBR, particularly near the Gin Gin and Western Downs nodes, will drive ongoing investment in system strength services.
- AEMO has declared an inertia shortfall in Queensland from 2027-28; and available inertia levels are projected to decline further over the 20-year horizon.

South Australia

- Four large synchronous condensers in South Australia provide sufficient fault current to meet minimum requirements across the horizon. However, significant IBR build across all three nodes, will require a corresponding investment in system strength services.
- Projected levels of available inertia are already below minimum secure operating levels and are not projected to recover over the study period. However, South Australia is not considered likely to island once Project EnergyConnect (PEC) Stage 2 is commissioned, and protection schemes are in place.

Tasmania

- System strength and inertia shortfalls are projected across the 20-year horizon for Tasmania. The magnitude of these is driven primarily by growth in local IBR and changes in energy exports to the mainland, which combine to impact utilisation of local synchronous hydro generation.

Victoria

- Declining utilisation of synchronous generation is expected to reduce synchronous fault levels at most system strength nodes in Victoria. Most of the investment needed to address these issues will likely be required within the coming decade. However substantial IBR growth will continue to drive investment in system strength services over the longer-term.
- Projected levels of available inertia are already below minimum secure operating levels. However, strong interconnection with neighbouring regions means that Victoria is not considered sufficiently likely to island.

A7.1 Recent reforms to the security planning frameworks

The energy transition is transforming the way electricity is generated, transported, and consumed across the NEM. The pace of this change is still accelerating, and traditional ways of operating are being challenged as system security and reliability become increasingly complex.

The scope of these technological and economic changes must be matched by a supportive and adaptive regulatory framework that can drive action on critical services, remove unnecessary barriers to participation, and streamline investment in least-regret assets and services.

The system security planning frameworks have undergone a series of major overhauls in recent years to ensure they remain fit for purpose, and to continually push for more efficient long-term outcomes.

Changes have been introduced to drive proactive system strength investment

In October 2021, the AEMC amended the system strength framework to drive more proactivity in the provision of system strength services, to deliver a streamlined connection process, and to leverage economies of scale in larger, centralised investments. A new mechanism was also introduced to allow connection applicants to decide between procuring their own system strength assets or contributing towards a fleet of centrally provided services.

The regulatory aspects of the new framework have been progressively finalised over the past twelve months, and implementation activities have now shifted from defining the new standards and guidelines, to coordinating assessment and delivery against them. This process has identified several challenges and friction points in the new framework, and AEMO is continuing to work closely with the AEMC, AER, and market participants to identify and prioritise any potential improvements.

Regulatory Investment Tests for Transmission (RIT-Ts) are already underway in every region to deliver the first round of system strength investment, and the ISP provides a key input into those processes via the IBR investment patterns that underpin the system strength requirements.

New frequency standards, obligations, and markets are now in effect

Inertia services are only one in a portfolio of frequency management tools that are currently in place or are being progressed through regulatory reforms. While inertia has long been an important complement to the FCAS markets, new tools and standards have also been introduced to address needs in the sub 6-second range where inertia was previously the primary tool available:

- **Revised Frequency Operating Standard (FOS)** – the Reliability Panel has introduced a new rate of change of frequency (RoCoF) standard of 1 Hz/s for all mainland NEM regions[2], and retains the existing 3 Hz/s requirement in Tasmania. The revised standard came into effect on 9 October 2023.
- **Mandatory primary frequency response (PFR)** – The AEMC has introduced an enduring set of requirements mandating provision of PFR services from all generation with the capability to do so.
- **Introduction of a very fast (1-second) FCAS market** – AEMO introduced two new FCAS markets (very fast raise and very fast lower) on 9 October 2023.

These new services and reforms improve AEMO's ability to maintain secure frequency levels.

[2] AEMC. Review of the Frequency Operating Standard 2022. At: https://www.aemc.gov.au/market-reviews-advice/review-frequency-operating-standard-2022

Further reforms are underway to improve and align existing security frameworks

The Australian Energy Market Commission (AEMC) is considering options to improve market arrangements for the provision of security services[3]. The AEMC released an initial draft determination for this project in September 2022, however proposed a revised approach in May 2023 to deliver more immediate solutions.

The revised proposal would introduce a new NEM-wide inertia floor to apply at all times, and which would be apportioned to individual regions[4] in addition to the existing islanded inertia requirements. These new requirements would form an inertia specification, with delivery obligations placed on the local TNSP in a similar style to the system strength framework. This may better facilitate co-optimised investment in system strength and inertia services.

This change would be coupled with the re-introduction of last resort planning powers for AEMO to address both inertia and system strength shortfalls under the NSCAS framework, and a new 'transitional' non-market ancillary service would be introduced to facilitate step changes between different operational modes across the energy transition.

The AEMC is currently considering submissions on its second directions paper reflecting this revised approach and expects to publish a final determination in March 2024[5].

[3] See https://www.aemc.gov.au/rule-changes/improving-security-frameworks-energy-transition.

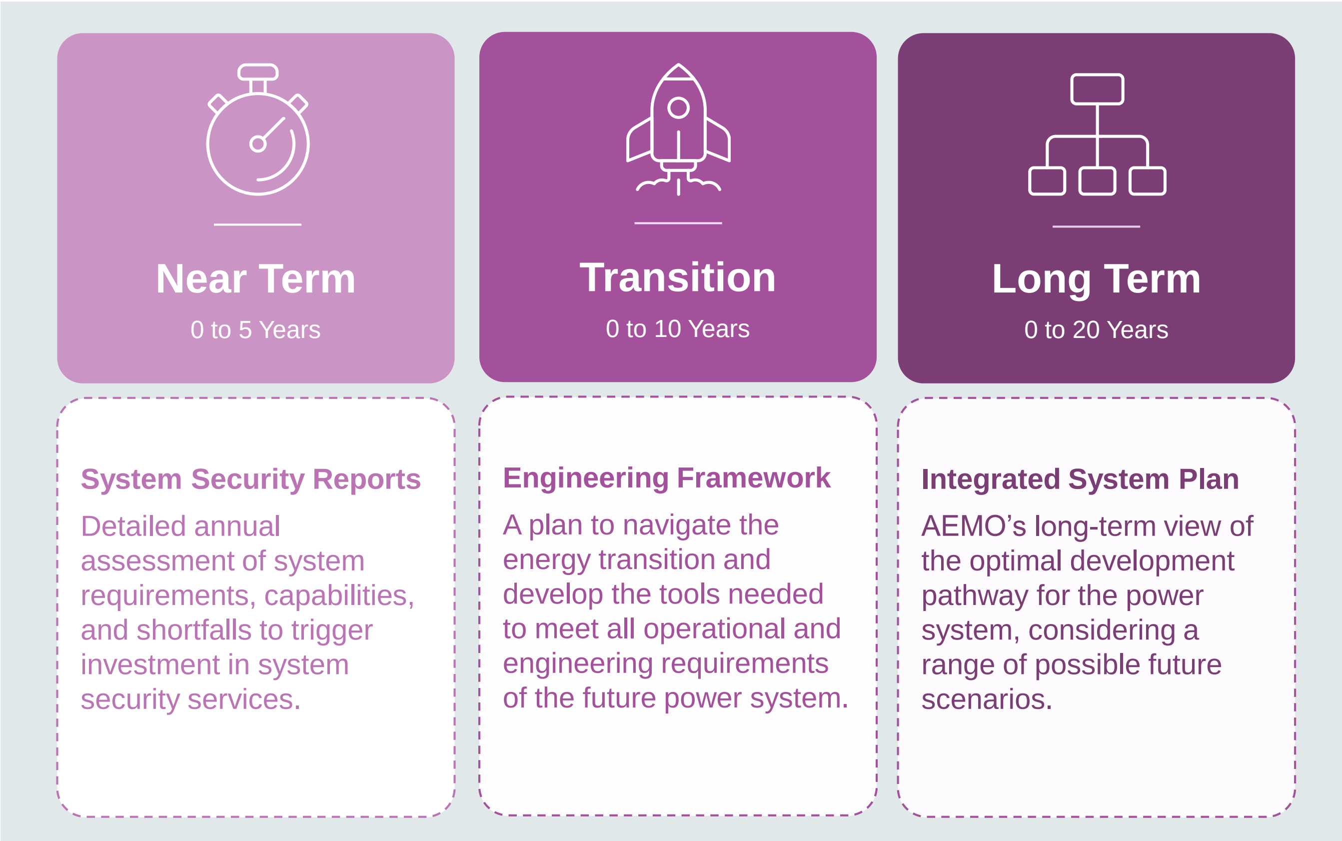
[4] In developing a framework for a NEM-wide inertia floor, it will be important to consider the location and not just the quantity, of system inertia. AEMO is investigating what the implications of different geographic dispersals of inertia across the system could be.

[5] See https://www.aemc.gov.au/rule-changes/improving-security-frameworks-energy-transition.

A7.2 AEMO's approach to system security planning

Effective system security management requires a range of tools and frameworks working in tandem, across multiple timescales, participant types, and geographic areas. Figure 1 summarises AEMO's multilayered approach, and the linkages between the current and future state of the power system.

Figure 1 Overview of key system security planning timeframes and reports



- **In the near-term (0 to 5 years)** - AEMO undertakes detailed power system analysis and market simulation to set system standards, determine security requirements, forecast levels of available system services, and declare any prevailing shortfalls. AEMO has a special planning role in this timeframe, where TNSPs must use all reasonable endeavours to remediate any declared shortfalls, and AEMO may exercise a last-resort planning power to procure services where none would otherwise be forthcoming.
- **In the medium-term (0 to 10 years) -** AEMO is progressing an Engineering Roadmap[6] which aims to prepare the system to operate securely and reliably during periods of 100% instantaneous penetration of renewables. This is part of AEMO's overarching Engineering Framework that seeks to develop tools necessary to meet all operational, technical, and engineering requirements of the future power system.
- **In the long-term (0 to 20 years)** - The ISP provides AEMO's view on the optimal development path for the system as a whole and provides a solid plan for a planning horizon of 20 years on which system security requirements can be identified, quantified, and proactively planned for.

[6] AEMO. Engineering Roadmap to 100% Renewables. At: https://aemo.com.au/initiatives/major-programs/engineering-framework

A7.3 System security concepts and requirements

A7.3.1 System Strength

System strength describes the ability of the power system to maintain and control the voltage waveform at a given location, both during steady state operation and following a disturbance. System strength is often approximated by the amount of electrical current available during a network fault (fault current), however the concept also encompasses a collection of broader electrical characteristics and power system interactions[7].

System strength supports the stable operation of network protection, voltage control devices, and IBR connections. Ensuring that sufficient system strength is available, and in the right locations, is vital to a stable, secure, and reliable power system that supports open and efficient investment.

Historically, system strength has been provided by thermal generators in well-connected parts of the network. As these units are replaced by renewable generation in other locations, it is increasingly difficult to accommodate new IBR investment while maintaining stable power system operation.

In October 2021, the National Electricity Rules (NER) were amended to drive more proactivity in the provision of system strength services, and to leverage the economies of scale and operational benefits of larger, centralised investments. The system strength framework is currently in transition between its previous and new incarnations, both of which apply in parallel until 1 December 2025.

System strength requirements

AEMO publishes a 10-year projection of system strength requirements each year. These requirements are expressed as two distinct components:

- **AEMO's forecast of minimum required three phase fault level** – intended to ensure that network protection and voltage control devices continue to operate correctly, even as traditional fault current sources withdraw from the system. This requirement is specified as a fault current and must therefore be met by devices capable of providing fault current, including synchronous condensers, contracts with existing units to provide synchronous services, or the retrofit of existing synchronous plant to become permanent system strength providers.
- **AEMO's optimised forecast of future IBR investment –** intended to drive sufficient system strength investment in strong, optimised network locations to accommodate or encourage future IBR connections near those locations. This is specified as an accommodated capacity and can therefore be met by any existing or new technology capable of improving the resilience of the local voltage waveform, including dynamic reactive devices or grid forming inverter technology adaptable to the needs of a specific network location.

The System Strength Service Provider (SSSP) in each region has sole responsibility for assessing and delivering the services needed to meet both requirements within a rolling three-year window.

More details on the nature of system strength requirements is available in the System Strength Requirements Methodology[8].

---

[7] AEMO. *System strength in the NEM explained*. March 2020. At: https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-strength-requirements/ssr/system-strength-explained.pdf?la=en

[8] 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.

A7.3.2 Inertia

In the context of the power system, inertia describes an immediate, inherent, electrical response from connected devices that acts to oppose changes in frequency. Ensuring sufficient levels of inertia are available allows the power system to resist large changes in frequency that can arise following a contingency event, slowing the rate of change of frequency (RoCoF) and providing time for other automated control systems to respond[9].

Inertia is most often associated with synchronous machines, that have large spinning turbines and rotors whose rotation is synchronised to the frequency of the power system. These components are typically heavy, weighing tens or hundreds of tonnes, and are able to readily provide inertia from the kinetic energy associated with the rotating mass[10].

Inverter-based resources (IBR) are typically interfaced with the power system through electronic devices rather than electro-magnetic coupling, and do not typically provide inertia as an inherent characteristic[11]. However, it is possible for some IBR to provide an emulated inertial response through appropriate designs and controls. This is often referred to as fast frequency response (FFR), although FFR is a spectrum of services based on the proportionality of response, and the level of delay between measuring a frequency disturbance and being able to respond to it.

While synthetic inertia could theoretically replace some or all of the synchronous inertia in the NEM, there is not yet sufficient modelling or real-world experience available to quantify the implications and interactions of a system that is fully reliant on synthetic inertia and FFR providers. As such, it is likely that synchronous machines, including synchronous condensers and synchronous generating units, will remain a core component in meeting inertia requirements over time.

Inertia requirements

AEMO publishes a five-year outlook of inertia requirements, projected availabilities, and expected inertia shortfalls each year. These shortfalls are assessed against two distinct inertia requirements:

- **a minimum threshold level of inertia**, being the minimum level of inertia required to operate an inertia sub-network in a satisfactory operating state when the inertia sub-network is islanded; and
- **a secure operating level of inertia**, being the minimum level of inertia required to operate an inertia sub-network in a secure operating state when the inertia sub-network is islanded.

In assessing inertia shortfalls, AEMO calculates the inertia requirements for a given region with reference to maintaining the Frequency Operating Standard. AEMO then undertakes a suite of market modelling studies to estimate the typical levels of inertia expected in the region, where 'typical' refers to a 99th percentile level of availability.

Differences are then declared as inertia shortfalls, and the Inertia Service Provider[12] for each region then has sole responsibility for delivering any required assets or services necessary to address the declared shortfall.

---

[9] For definitions and descriptions of inertia and power system security, please refer to 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.

[10] See https://aemo.com.au/-/media/files/initiatives/engineering-framework/2023/inertia-in-the-nem-explained.pdf?la=en

[11] Note that some variable speed drive hydro units can also be inverter-interfaced and therefore do not provide a synchronous inertial response.

[12] As defined in NER 5.20B.4(a).

A7.3.3 Network Support and Control Ancillary Services (NSCAS)

NSCAS are non-market services with the capability to control the active or reactive power flow into or out of a transmission network. They can be procured to address the following two categories of need[13]:

- **Reliability and security ancillary services (RSAS)** – maintain security and supply reliability of the transmission network in accordance with the power system security standards and the reliability standard.
- **Market benefits ancillary services (MBAS)** – maintain or increase capability of the transmission network to maximise net economic benefits to all those who produce, consume or transport electricity in the market.

AEMO assesses the need for these services annually and declares NSCAS gaps where it identifies an unmet need. Gaps often relate to voltage control, system stability, and thermal limits, but can include other challenges faced in operating a secure power system. The NER give TNSPs primary responsibility for acquiring NSCAS (with or without a declared gap), and AEMO may be required to procure NSCAS under its last resort planning functions.

Reliability and security ancillary services (RSAS)

To identify RSAS gaps, AEMO considers the ability of the power system to maintain a secure operating state during system normal conditions; that is, the ability of the system to land in a satisfactory operating state following a credible contingency or protected event. AEMO may also consider if the system can be quickly returned to a secure operating state following a credible contingency or protected event.

Market benefits ancillary services (MBAS)

To identify MBAS gaps, AEMO considers whether positive net market benefits could be delivered by relieving high-impact network constraints in the annual NEM constraint report summary[14]. AEMO may also consider specific constraints nominated by participants or those forecast to be significant through other power system planning and operational activities, in alignment with the NSCAS description and quantity procedure[15].

A7.3.4 General Power System Risk Review (GPSRR)

AEMO undertakes the GPSRR annually for the NEM in consultation with NSPs. The 2023 review was the first GPSRR[16], and replaces the biennial power system frequency risk review (PSFRR). It includes the following:

- Review of a prioritised set of power system risks, comprising events or conditions that, alone or in combination, would likely lead to cascading outages or major supply disruptions[17]. For each priority risk, the GPSRR assesses the adequacy of current risk management arrangements and (where appropriate) options for future management.
- Overview of risk mitigation measures encompassing Emergency Frequency Control Schemes (EFCSs), operational capabilities and other emerging risks in the context of an evolving power system.
- Review of the arrangements for management of existing protected events and consideration of any changes or revocation.

[13] NER Version 203, Clause 3.11.6 (a)(1), and NER Version 203, Clause 3.11.6 (a)(2)

[14] AEMO. NEM Constraint Report 2022 summary data. 24 May 2023, at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/2022/nem-constraint-report-2022-summary-data.xlsx?la=en.

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

[16] AEMO. *General Power System Risk Review*, July 2023. At: https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2023/draft-2023-general-power-system-risk-review/2023-gpsrr.pdf?la=en

[17] The GPSRR can investigate power system risks that fall outside of the system security framework, such as non-credible contingencies.

A7.4 Projected outlook and opportunities

This section quantifies the adequacy of system security services under the *Step Change* scenario by comparing the expected levels of available services against the associated regional requirements at five-yearly increments.

The section is structured geographically to reflect the largely regional nature of investment obligations for system security services. This structure also makes it easier to identify any potential options for co-optimised investment to deliver multiple system security services from a single asset or provider.

Analysis scope and assumptions

In assessing the adequacy of system security services in this appendix, AEMO has considered the minimum levels of system strength as presented in the 2023 *System Strength Report*[18], and the secure operating levels of inertia as described in the 2023 *Inertia Report*[19].

These requirements are assumed to continue unchanged over the assessment period to 2039-40. In practice, these requirements may change over time.

RIT-Ts are already underway in every NEM region to deliver the first round of system strength investment by 2 December 2025. These may result in investments in new synchronous condensers or other security assets and services that address some of the needs presented in this appendix. However given the quantity, design, timing and location of these possible investments is presently unknown, the underlying needs remain included in full for the projections in this section.

Results are presented for system strength and inertia studies for the 2024-25, 2029-30, 2034-35 and 2039-40. The 2024-25 results come from the 2023 Inertia and System Strength reports. Results for 2029-30 onwards are from ISP modelling. Although AEMO projects that some new and existing shortfalls may arise in future, no inertia or system strength shortfalls are declared on the basis of results in this report.

The market modelling simulations that underpin these projections:

- Are based on the *Step Change* scenario generator, storage and transmission build outcomes for the Draft 2024 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[20].
- Apply bidding strategies that change to reflect greater uncertainties further out into the future. The 2024-25 projections use benchmarked competitive bidding, projections from 2029-30 onwards use short run marginal cost bidding.
- Apply multiple generation outage patterns for the 2024-25 projections, but a single outage pattern for years 2029-30 onwards. This reflects the greater uncertainty in outcomes further into the future.
- Model the Queensland and South Australia regions as islands for the Queensland and South Australia 2024-25 inertia projections, but model the mainland NEM intact for all inertia projections from 2029-30 onwards.

[18] At https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/system-security-planning.

[19] At https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/system-security-planning.

[20] Details for the bidding behaviour model are provided in AEMO’s Market Modelling Methodologies report. AEMO, Market Modelling Methodologies, July 2020, at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/inputs-assumptions-methodologies/2020/market-modelling-methodology-paper-jul-20.pdf?la=en

A7.4.1 NEM-wide outlook

Near term outlook

In the 2023 system security reports[21], AEMO has assessed emerging needs and shortfalls for system strength, inertia, and NSCAS in the near term.

- The 2023 *NSCAS Report* confirmed that existing NSCAS gaps in Queensland and New South Wales have been closed and declared new gaps in Victoria and South Australia. Several marginal or emerging risks were also identified and provided to relevant network businesses for further investigation.
- The 2023 *System Strength Report* confirms the timing of existing shortfalls in Queensland, New South Wales, and Tasmania; but has not identified any new system strength shortfalls within the outlook period to 1 December 2025. Since the 2022 *System Strength Report*, the size of the shortfalls in New South Wales have increased, but the shortfalls in Tasmania have decreased. The size of the Queensland shortfall is unchanged.
- The 2023 *Inertia Report* confirms that all declared inertia shortfalls for 2023-24 are currently being managed appropriately through network support agreements. The analysis has not identified any new inertia shortfalls, but the magnitude and timing of all previously declared shortfalls has been revised. While inertia requirements have generally become more onerous to reflect the latest frequency standards and models; the expected levels of available inertia have improved; resulting in small deferrals or reductions to most shortfalls across the NEM.
- The 2023 *General Power System Risk Review* assessed four priority risks that could lead to cascading outages or major supply disruption. AEMO recommended actions for three of the four risks. These included recommendations concerning plant maintenance on the network in the Tamworth area, investigation and (if found viable) implementation of a new special protection scheme for the Queensland New South Wales Interconnector (QNI), as well as continued collaboration between AEMO and TNSPs to ensure that the future South Australia Interconnector Trip Remedial Action Scheme (SAIT RAS) will operate effectively in conjunction with other protection schemes. AEMO also made a number of other recommendations regarding other risk mitigation measures, and one recommendation regarding the protected events framework.

The changes in shortfall size for both system strength and inertia results are largely driven by updated delivery timing for several major generation, transmission, and REZ development projects. The net result has been a higher modelled utilisation of synchronous generation; resulting in a higher available inertia and fault current.

Long term outlook

In the long term, trends for system security services are driven by the following phenomena:

- **Retiring coal-fired generation** – historically coal-fired generation has been the source of the majority of the system strength and inertia in the NEM and a significant source of voltage control capability. As all coal-fired generation is projected to retire under the *Step Change* scenario by 2037-38, replacement services will need to be procured.
- **Increases in IBR development** – the *Step Change* scenario projects an additional 85 GW of IBR generation by 2039-40. Adequate system strength services will need to be procured to ensure this generation can stably operate. Some of these services will likely need to be provided by established technologies such as synchronous condensers. However, in the longer term AEMO expects that IBR with grid forming inverters will

[21] At https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/system-security-planning.

also contribute system strength. Additionally, IBR generation dispersed across the NEM will provide new sources of voltage control capability.

- **Commissioning of major network augmentations such as new interconnectors** – new interconnectors help system strength and voltage control by lowering the system impedance. They will also reduce the likelihood of regions becoming islanded, which can reduce the need for inertia services.

Figure 2 below shows the projected decline in total inertia online in the mainland NEM to 2039-40 if no new investment in inertia provision were to occur[22]. It illustrates a general sharp downward trend in inertia over time driven by declining coal fired generation utilisation and retirements. The 99th percentile of inertia availability is projected to decline from 63,000 MWs in 2024-25 to 21,000 MWs in 2029-30. Note that currently there are no minimum requirements for inertia online in the mainland NEM as a whole. However, the AEMC is investigating introducing a NEM-wide inertia floor[23], as it is anticipated that very low inertia levels could pose challenges to maintaining system security.

Figure 2 Projected mainland NEM inertia, *Step Change* scenario

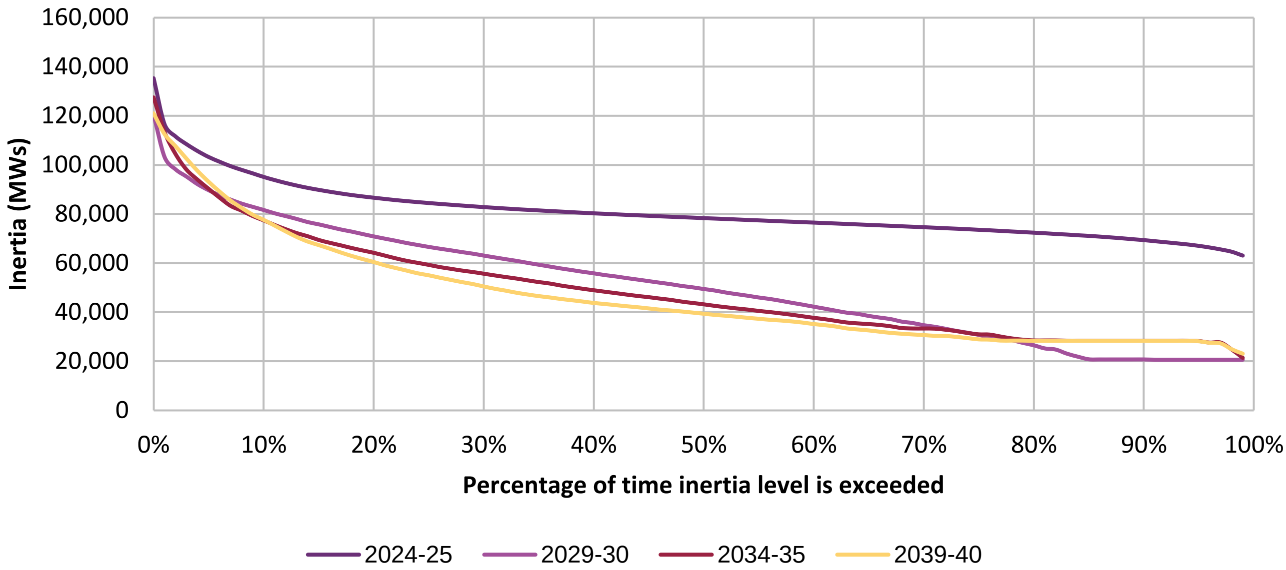


Figure 3 shows the 99th percentile of synchronous fault level projected out to 2039-40 for a representative system strength node in each region, and highlights the following trends:

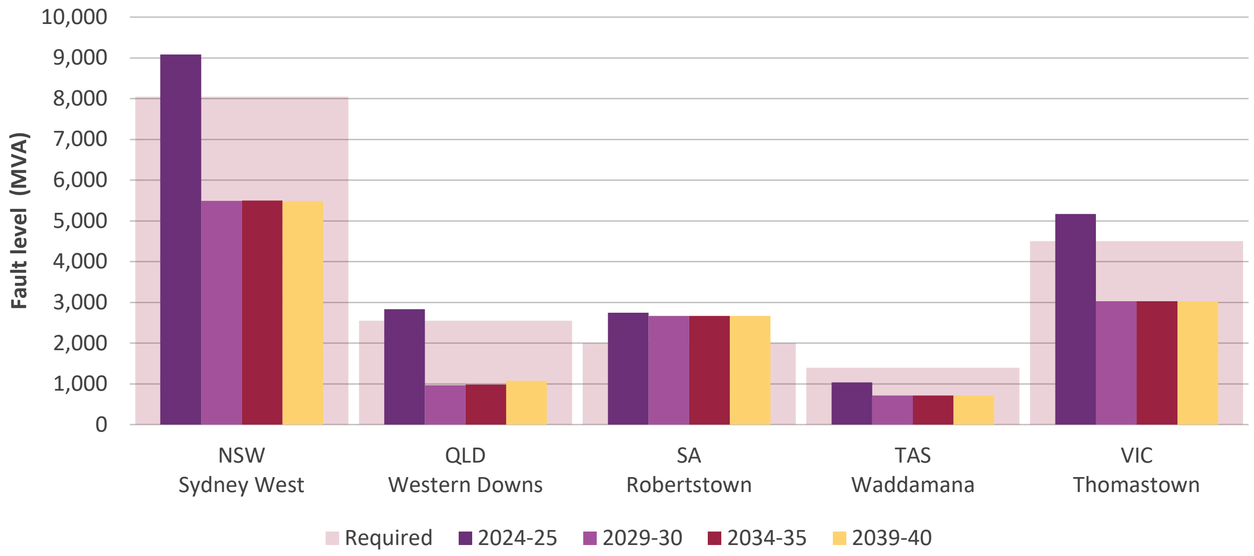
- **New South Wales, Queensland and Victoria** – 99th percentile fault levels generally decline sharply from 2024-25 to 2029-30. This is driven by closures and declining utilisation of thermal generation. The fault level values are generally stable from 2029-30 onwards, despite further plant closures in this period. This is because by 2029-30 there are already considerable periods with limited coal generators online, even before they formally retire.
- **South Australia** – 99th percentile fault levels remain relatively stable from 2024-25 to 2039-40.
- **Tasmania** – 99th percentile fault levels decline from 2024-25 to 2029-30 before remaining stable out to 2039-40. This is driven by a large increase in wind generation capacity out to 2029-30, leading to increased periods

[22] The modelling does account for generation, storage, and transmission built as part of the *Step Change* scenario, which may include some level of associated inherent inertia, but no specific investment for the purpose of inertia provision.

[23] Australian Energy Market Commission. *Directions Paper National Electricity Amendment (Improving Security Frameworks for the Energy Transition Rule 2023**, August 2023. At: https://www.aemc.gov.au/sites/default/files/2023-08/ERC0290%20%E2%80%93%20Improving%20security%20frameworks%20for%20the%20energy%20transition.pdf

with fewer hydro units online. The reductions aren't as severe as in other regions because synchronous hydro generation in Tasmania remains sufficiently well-utilised in support of energy exports to the mainland.

Figure 3 Fault level projections and requirements at representative nodes in each region



Estimated cost of security remediation

AEMO has prepared high-level cost estimates for provision of system strength services in each REZ across the NEM. System strength service requirements are based on assessment of existing synchronous generation dispatch, potential network upgrades, and the potential scale of local IBR.

AEMO has estimated costs based on synchronous condenser technology, as an existing, commercially viable, technology that has been demonstrated at scale, and is capable of meeting both the minimum and efficient system strength requirements.

Over time, AEMO expects that alternative technologies such as grid-forming inverters will be become available to provide system strength services following adequate demonstration at scale. The cost estimates presented here are likely to represent an upper bound of system strength cost.

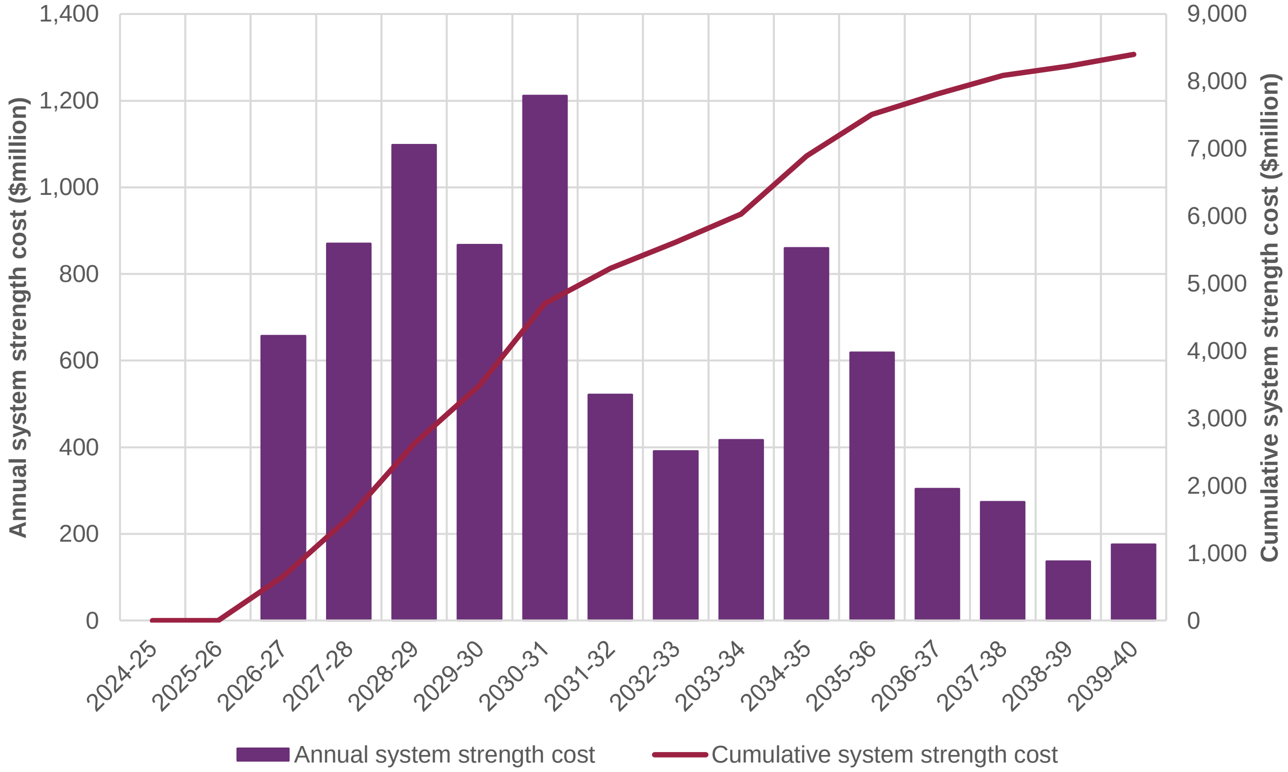
Figure 4 shows the cumulative system strength remediation costs to address system strength remediation for VRE projected under the *Step Change* scenario across the NEM. These estimates assume a cost of $137,000/MW[24]. Approximately $8 billion[25] is required to 2039-40 for system strength remediation for the forecast IBR generation connection in REZs.

---

[24] AEMO. *2023 IASR Assumptions Workbook*, September 2023. At: https://aemo.com.au/-/media/files/major-publications/isp/2023/2023-iasr-assumptions-workbook.xlsx?la=en

[25] The 2022 ISP projected system strength remediation costs of approximately $4 billion out to 2034-35. This assessment projects costs of approximately $7 billion out to 2034-35. The increase is driven by increased remediation costs per MW of IBR ($106,000/MW in the 2022 ISP versus $137,000/MW in this assessment), and an increase in projected IBR build out to 2034-35.

Figure 4 Projected system strength remediation costs by REZ, *Step Change* scenario



AEMO has also considered high level cost estimates for provision of inertia services across the NEM based on deficits identified in each region. AEMO has estimated costs based on the incremental cost of fitting high inertia flywheels to synchronous condensers, as an existing, commercially viable, technology that has been demonstrated at scale. This is estimated at $1,818/MWs[26].

Under the existing inertia framework, inertia services are only procured in regions with projected inertia shortfalls that are determined to be likely to island. This is to enable these regions to maintain system security with respect to frequency while islanded. The *Step Change* scenario projects approximately 17,400 MWs of inertia deficits out to 2039-40 in regions likely to island (Queensland, South Australia and Tasmania). It would cost approximately $32 million to fill these deficits by adding high inertia flywheels to synchronous condensers (where such synchronous condensers were already required to be built for system strength or other purposes).

The inertia framework may be extended in future to enable procurement of inertia services for a broader range of circumstances. For example the AEMC is considering introducing a NEM-wide inertia floor[27]. AEMO has determined a possible cost of inertia services to maintain a hypothetical NEM-wide inertia floor. In the absence of specific regulatory settings at this stage, AEMO has assumed a hypothetical inertia target of the sum all of the regional secure operating level requirements (approximately 55,000 MWs).

By 2039-40, AEMO's regional projections indicate a combined deficit of approximately 36,000 MWs against this hypothetical target. To fully meet this deficit through flywheel investments would cost approximately $65 million, spread across 32 to 36 synchronous condenser investments.

---

[26] Cost based on $2 million per 1,100 MWs high inertia flywheel. See AEMO. *2023 Transmission Expansion Options Report*, September 2023. Section 5.2. At https://aemo.com.au/-/media/files/major-publications/isp/2023/2023-transmission-expansion-options-report.pdf?la=en

[27] Australian Energy Market Commission. *Directions Paper National Electricity Amendment (Improving Security Frameworks for the Energy Transition Rule 2023**, August 2023. At: https://www.aemc.gov.au/sites/default/files/2023-08/ERC0290%20%E2%80%93%20Improving%20security%20frameworks%20for%20the%20energy%20transition.pdf

Not all system strength needs will be met using synchronous equipment, and therefore it is unlikely that the total volume of inertia needs would be met by flywheels-type investments. AEMO notes that other sources of inertia services are also possible, such as contracting with synchronous generators, and a potentially greater role for synthetic inertia from IBR.

Importance of proactive and coordinated planning

AEMO assesses system strength, inertia and NSCAS gaps separately across corresponding annual reports. Each of these reports conducts analysis at a regional level. However, there could be efficiency gains in designing solutions holistically to fill gaps for multiple services or regions.

For example, RIT-Ts are underway in every NEM region to optimise across all available technology options, and to deliver the first round of system strength investment by 2 December 2025. These system strength investments may also provide an opportunity to supplement regional inertia levels using the same technical resource and with minimal incremental cost. For example, flywheels could be added to new synchronous condensers; while fast frequency response services may be available from grid-forming batteries.

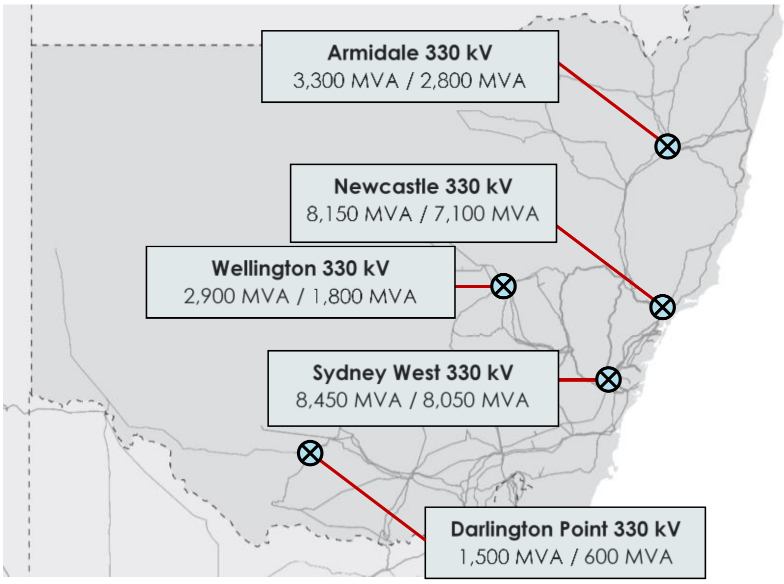
While this type of co-optimisation is possible now, the Australian Energy Market Commission (AEMC) are also considering changes to the inertia framework that may streamline this consideration in future. AEMO will continue to advocate for proactive, efficient, and coordinated investment across all system security services.

Well coordinated joint planning between AEMO, network service providers and jurisdictional bodies will be required to make investments that address identified gaps most efficiently. This joint planning process must recognise that timing solutions to meet identified shortfalls 'just-in-time' carries an inherent risk associated with project lead time uncertainty. Given the critical nature of maintaining system security and reliability, AEMO considers it prudent to plan the delivery of system security infrastructure ahead of when shortfalls are expected to occur.

A7.4.2 New South Wales

System strength outlook – synchronous fault levels

System strength requirements (pre/post contingent)



Key results

Projected closure of coal-fired generation and declining utilisation of others is expected to reduce the synchronous fault level at some nodes.

At other nodes, this decline is offset by network expansions such as the Sydney Ring.

Most projected need for fault current remediation occurs by the end of the decade.

Projected shortfalls against current minimum requirements

Node	Shortfall against minimum requirement				Trends
	2024-25	2029-30	2034-35	2039-40	
Armidale 330 kV	0 MVA	234 MVA	219 MVA	178 MVA	Network expansions are projected to increase maximum fault level and offset decline.
Newcastle 330 kV	0 MVA	1854 MVA	1847 MVA	1865 MVA	Fault levels expected to fall sharply over this decade (shortfalls declared from July 2025 in 2023 *System Strength Report*), with smaller decreases after 2030.
Sydney West 330 kV	0 MVA	2557 MVA	2551 MVA	2568 MVA	
Wellington 330 kV	0 MVA	5 MVA	4 MVA	5 MVA	Increased time spent near minimum.
Darlington Point 330 kV	0 MVA	0 MVA	0 MVA	0 MVA	No significant change.

Projected vs required level of fault current available at least 99% of the time

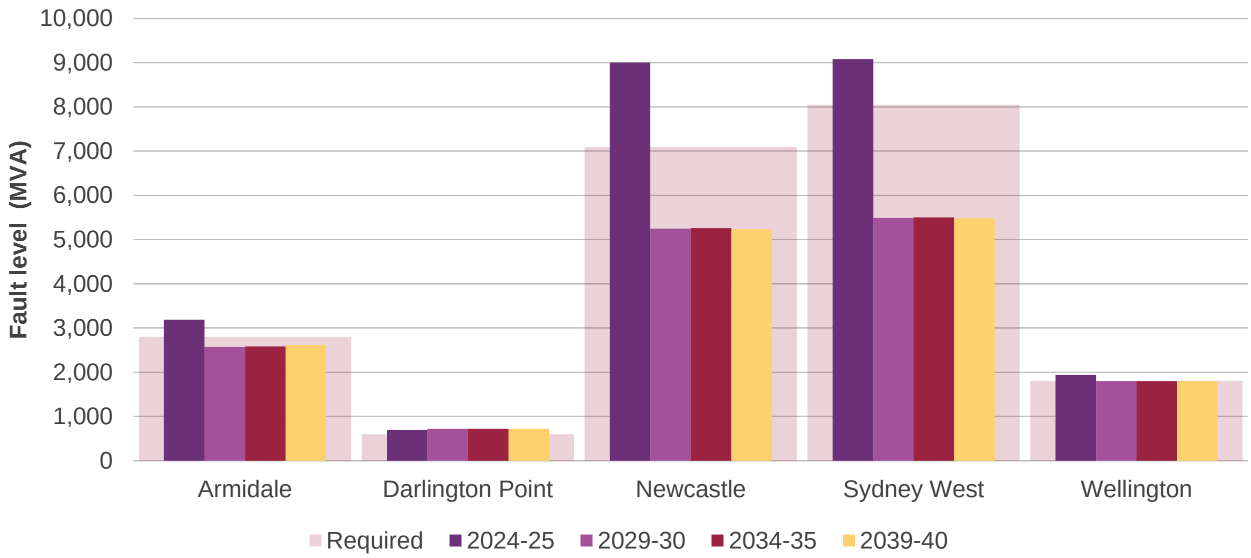
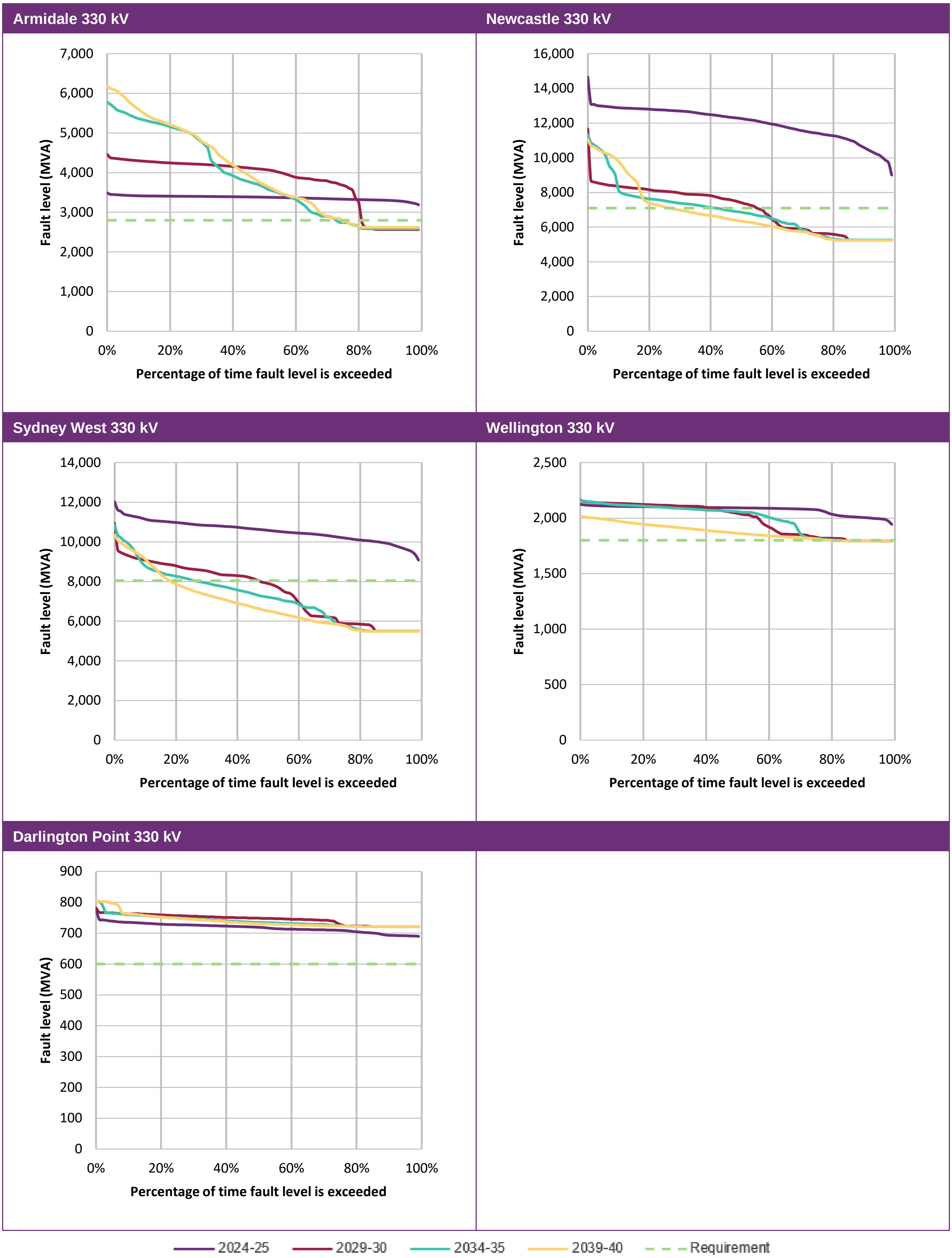


Figure 5 Percentage of time fault level is exceeded in New South Wales



System strength outlook – new IBR investment

Figure 6 IBR projections for New South Wales in 2024-25, 2029-30, 2034-35, and 2039-40

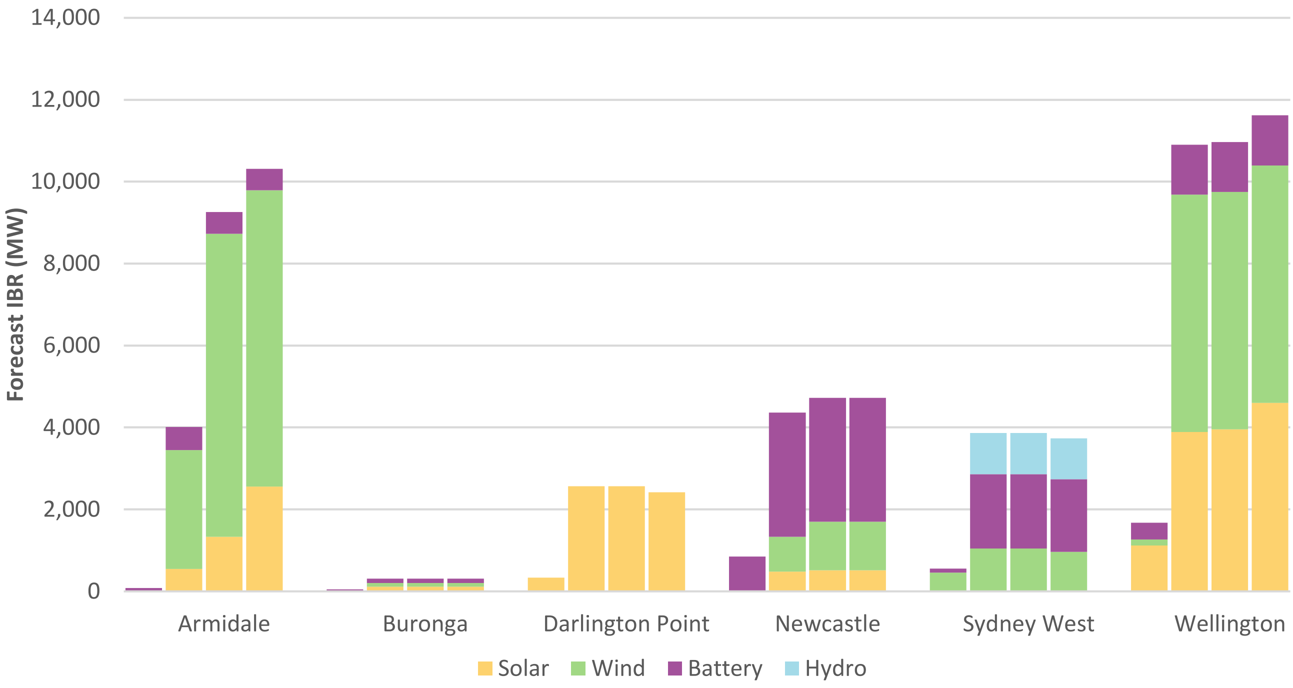


Table 1 IBR projections for New South Wales (MW)

Node	Technology	Existing	2024-25	2029-30	2034-35	2039-40
Armidale	Solar	721	0	544	1,330	2,560
	Wind	442	0	2,907	7,400	7,228
	Battery	0	80	559	529	529
Buronga	Solar	541	0	118	118	118
	Wind	199	0	89	89	89
	Battery	0	50	100	100	100
Darlington Point	Solar	1,458	336	2,567	2,567	2,417
	Wind	0	0	0	0	0
	Battery	150	0	0	0	0
Newcastle	Solar	0	0	484	516	516
	Wind	0	0	847	1,182	1,182
	Battery	0	850	3,029	3,029	3,029
Sydney West	Solar	10	0	0	0	0
	Wind	1,328	454	1,043	1,043	967
	Battery	60	100	1,819	1,819	1,769
	Hydro	0	0	1,000	1,000	1,000
Wellington	Solar	937	1,117	3,887	3,952	4,601
	Wind	255	146	5,794	5,794	5,794
	Battery	0	408	1,224	1,224	1,224

Inertia outlook

Key inertia results

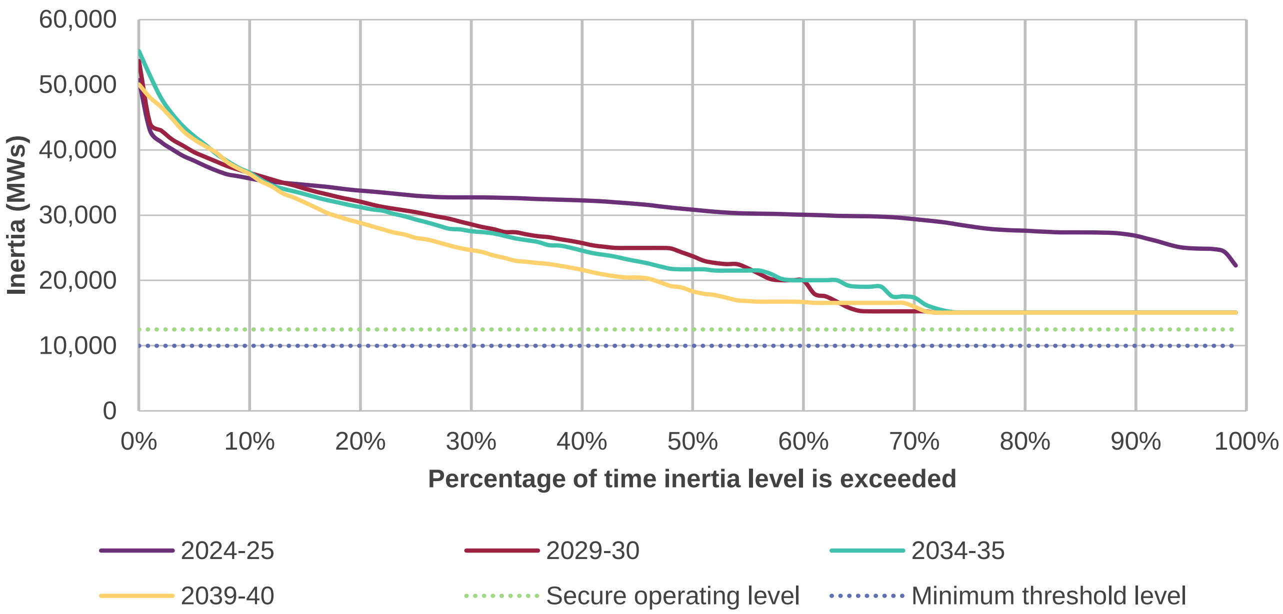
AEMO has not identified any inertia deficits out to 2039-40.

Inertia levels have increased compared with the 2022 ISP. Previously identified inertia deficits are no longer apparent. However, no change in the likelihood of declaring inertia shortfalls, as New South Wales is unlikely to island.

Table 2 Inertia outlook for New South Wales

Inertia projections				
	2024-25	2029-30	2034-35	2039-40
Minimum threshold of inertia (MWs)	10,000	10,000	10,000	10,000
Secure operating level of inertia (MWs)	12,500	12,500	12,500	12,500
Inertia available 99% of the time (MWs)	22,295	15,050	15,050	15,050
Calculated inertia deficit (MWs)	0	0	0	0
Likelihood of islanding	Unlikely	Unlikely	Unlikely	Unlikely

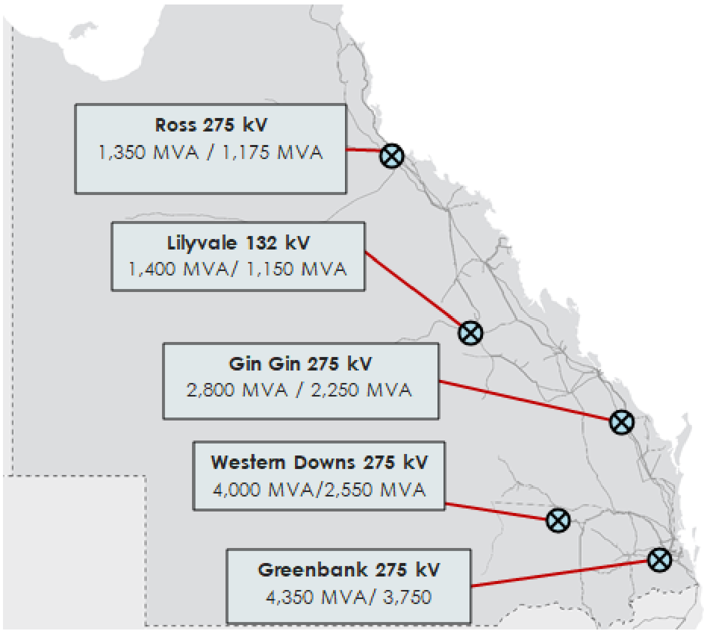
Figure 7 Projected levels of inertia available in New South Wales, *Step Change* scenario



A7.4.3 Queensland

System strength outlook – synchronous fault levels

System strength requirements (pre/post contingent)



Key results

Projected closure of coal-fired generation in Queensland and declining utilisation of the remaining synchronous generators are expected to result in significant reductions in synchronous fault current.

Most of the projected need for fault current remediation occurs by the end of the decade.

Projected shortfalls against current minimum requirements

Node	Shortfall against minimum requirement				Trend
	2024-25	2029-30	2034-35	2039-40	
Gin Gin 275 kV	49 MVA	1427 MVA	1344 MVA	1217 MVA	The synchronous fault current at all nodes is expected to fall sharply over the decade, but further reductions are not expected over the remaining planning horizon.
Greenbank 275 kV	0 MVA	2567 MVA	2554 MVA	2279 MVA	
Lilyvale 132 kV	0 MVA	508 MVA	477 MVA	434 MVA	
Ross 275 kV	0 MVA	378 MVA	343 MVA	400 MVA	
Western Downs 275 kV	0 MVA	1586 MVA	1568 MVA	990 MVA	

Projected vs required level of fault current available at least 99% of the time

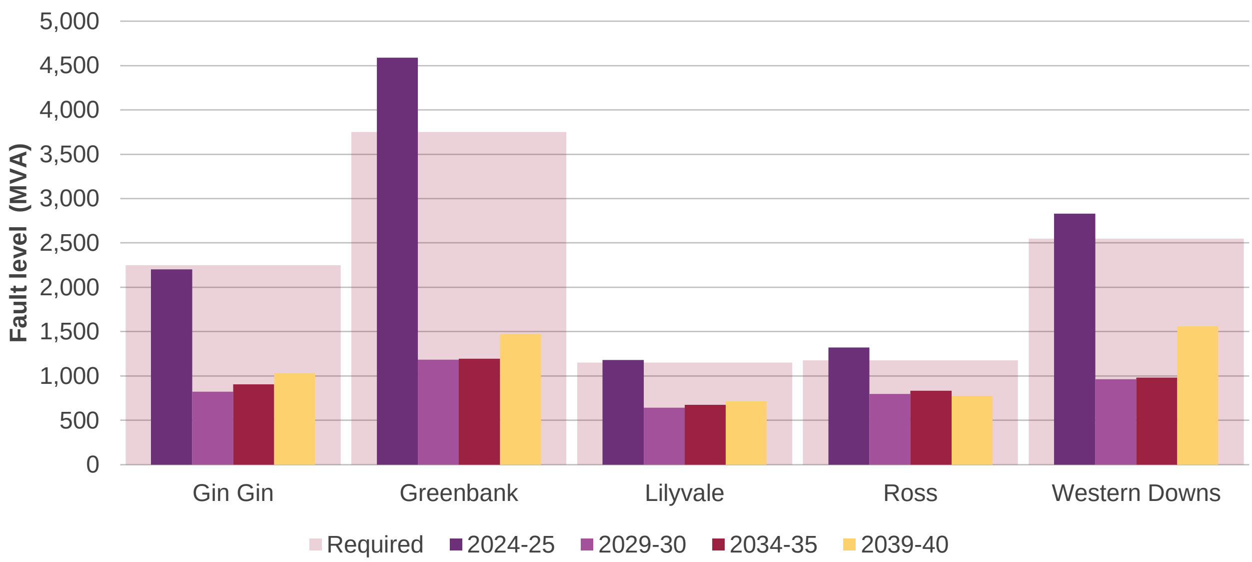
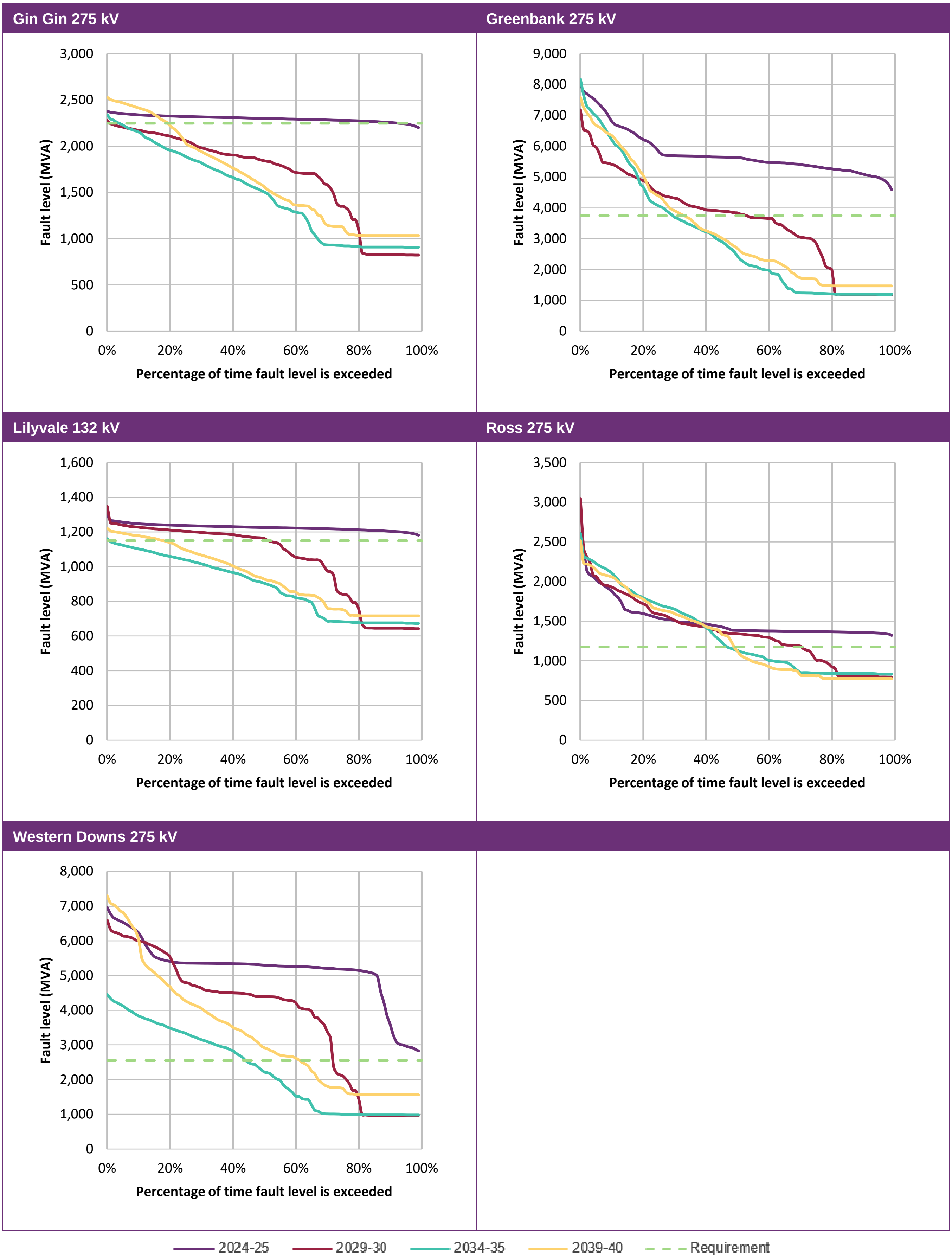


Figure 8 Percentage of time fault level is exceeded at each system strength node in Queensland



System strength outlook – new IBR investment

Figure 9 IBR projections for Queensland in 2024-25, 2029-30, 2034-35, and 2039-40

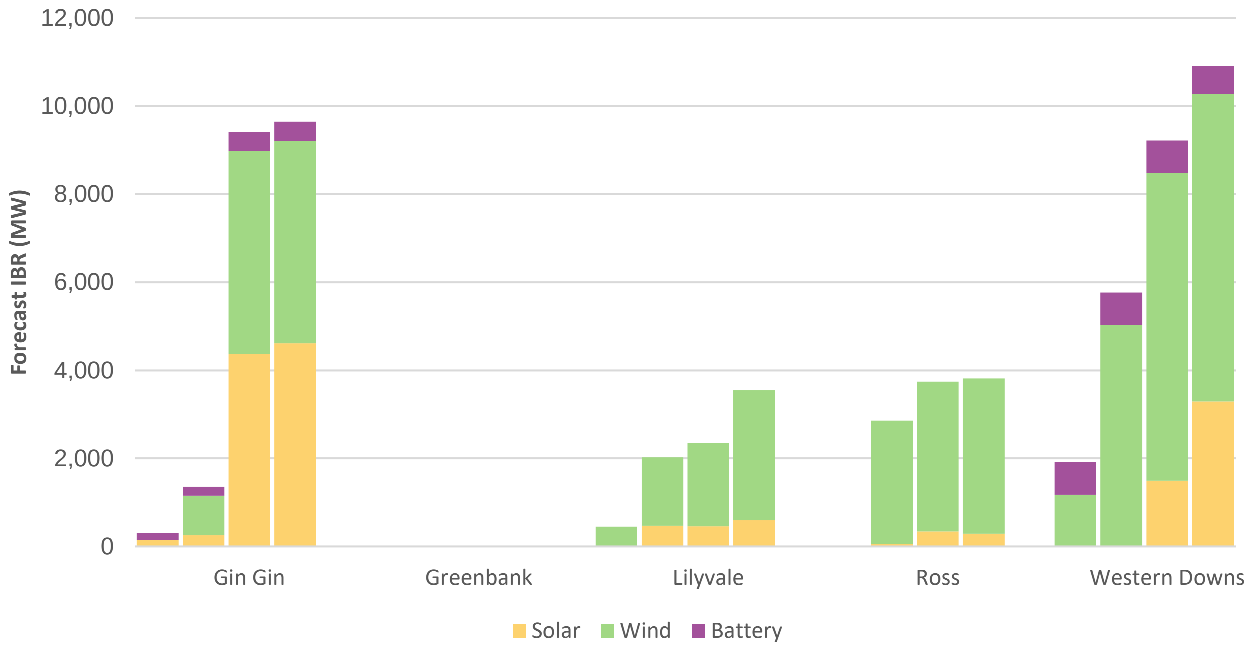


Table 3 IBR projections for Queensland (MW)

Node	Technology	Existing	2024-25	2029-30	2034-35	2039-40
Gin Gin	Solar	471	154	255	4,378	4,612
	Wind	0	0	900	4,600	4,600
	Battery	0	150	200	432	432
Greenbank	Solar	0	0	0	0	0
	Wind	0	0	0	0	0
	Battery	0	0	0	0	0
Lilyvale	Solar	388	0	474	456	599
	Wind	0	450	1,548	1,897	2,950
	Battery	0	0	0	0	0
Ross	Solar	983	0	53	343	293
	Wind	381	0	2,803	3,399	3,526
	Battery	0	0	0	0	0
Western Downs	Solar	1,671	0	0	1,496	3,294
	Wind	626	1,175	5,027	6,981	6,981
	Battery	100	741	741	741	641

Inertia outlook

Key inertia results

In the 2023 *Inertia Report* AEMO declared an inertia shortfall of up to 1,660 MWs from 2027-28. ISP modelling over the 2029-30 to 2039-40 horizon, identified larger inertia deficits throughout this period also.

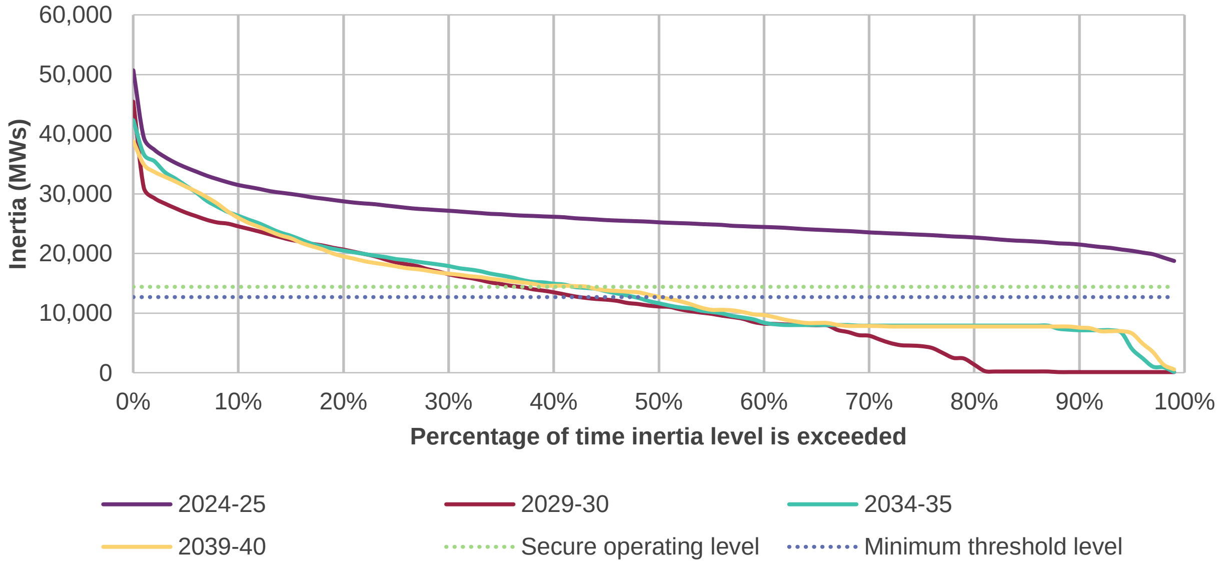
Inertia levels increase slightly in 2034-35 and 2039-40 due to the installation of new pumped hydro generation in Queensland, however this makes little difference at the 99th percentile level. AEMO notes that studies from 2029-30 onward did not model Queensland as an island, which likely leads to lower inertia than would otherwise be the case.

The *Step Change* scenario models the QNI Connect project as commissioning in 2033-34, however AEMO has still classified the likelihood of islanding as "likely" in 2034-35, as there may not be sufficient route diversity with the existing QNI to rule out a plausible event such as flooding or bushfire from separating both flow paths and islanding Queensland. This assessment may change upon more detailed plans for the project being determined.

Table 4 Inertia outlook for Queensland

Inertia projections				
	2024-25	2029-30	2034-35	2039-40
Assumed level of 1-second FCAS (MW)	60	60	60	60
Minimum threshold of inertia (MWs)	12,700	12,700	12,700	12,700
Secure operating level of inertia (MWs)	14,400	14,400	14,400	14,400
Inertia available 99% of the time (MWs)	18,731	132	132	594
Calculated inertia deficit (MWs)	0	14,268	14,268	13,806
Likelihood of islanding	Likely	Likely	Likely	Likely

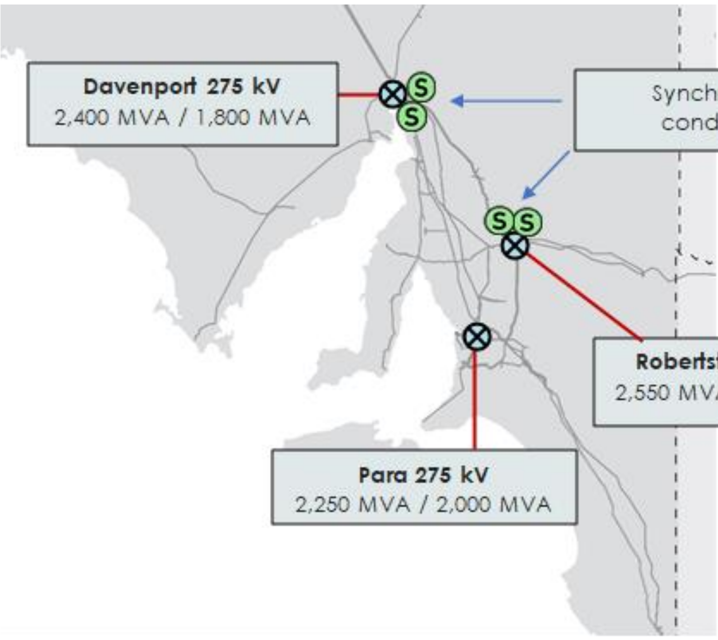
Figure 10 Projected levels of inertia available in Queensland, *Step Change* scenario



A7.4.4 South Australia

System strength outlook – synchronous fault levels

System strength requirements (pre/post contingent)



Key results

With the four new synchronous condensers installed in South Australia, projected system strength remains adequate to meet current minimum fault level requirements.

Projected shortfalls against current minimum requirements

Node	Shortfall against minimum requirement				Trend
	2024-25	2029-30	2034-35	2039-40	
Davenport 275 kV	0 MVA	0 MVA	0 MVA	0 MVA	No significant changes
Para 275 kV	0 MVA	0 MVA	0 MVA	0 MVA	No significant changes
Robertstown 275 kV	0 MVA	0 MVA	0 MVA	0 MVA	No significant changes

Projected vs required level of fault current available at least 99% of the time

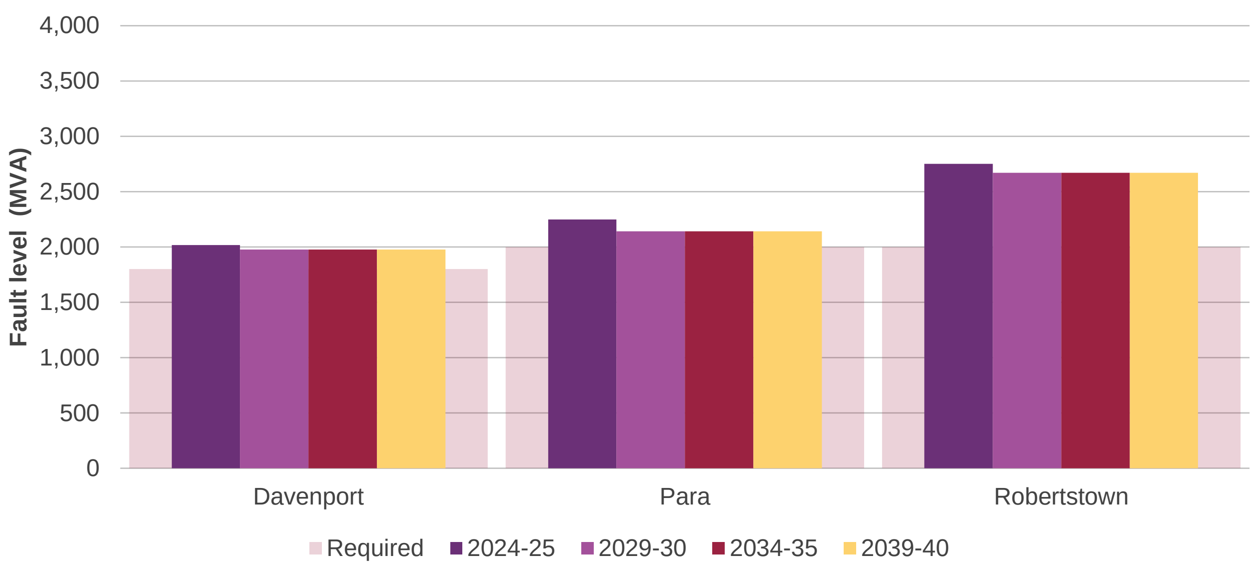
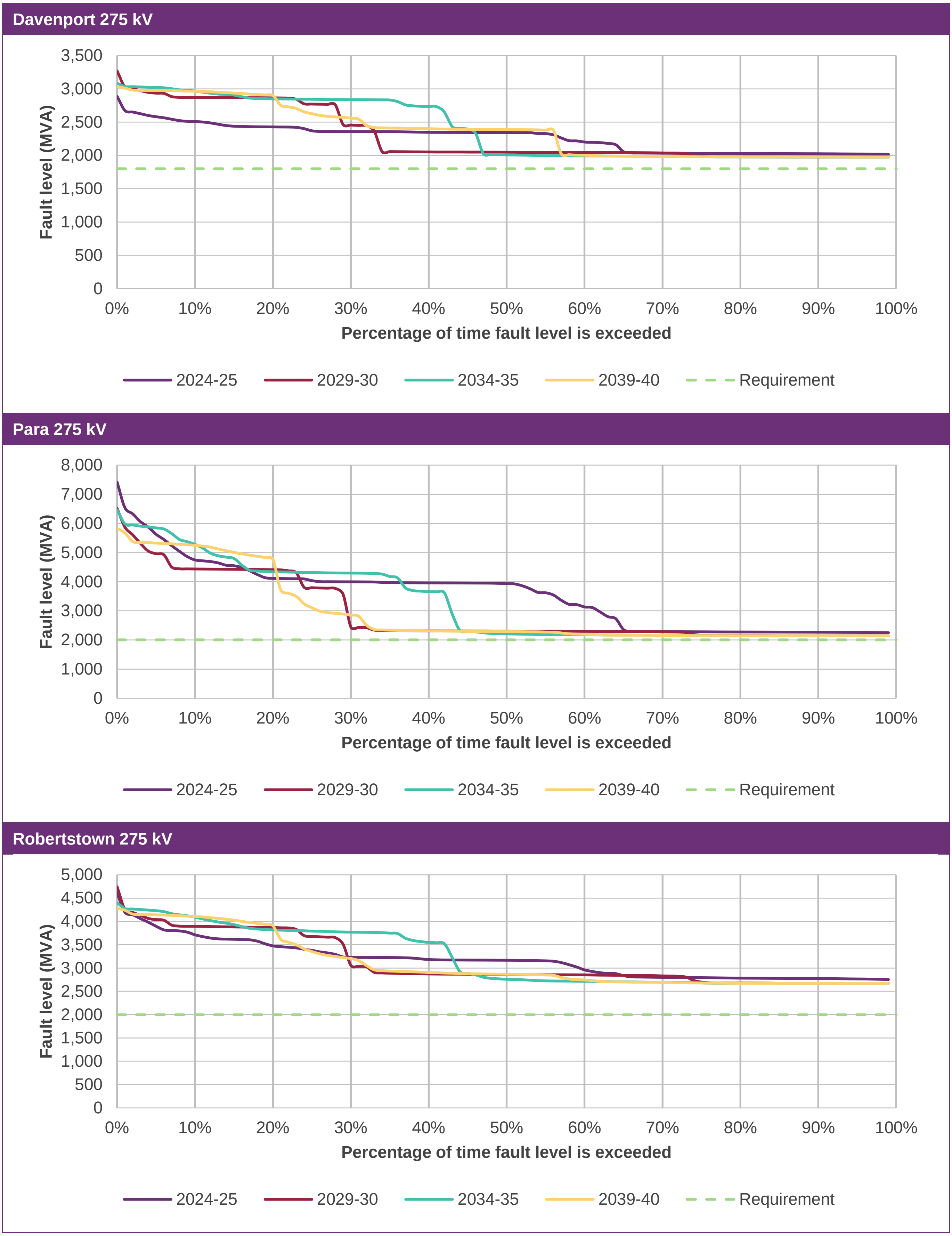


Figure 11 Percentage of time fault level is exceeded at each system strength node in South Australia



System strength outlook – new IBR investment

Figure 12 IBR projections for South Australia in 2024-25, 2029-30, 2034-35, and 2039-40

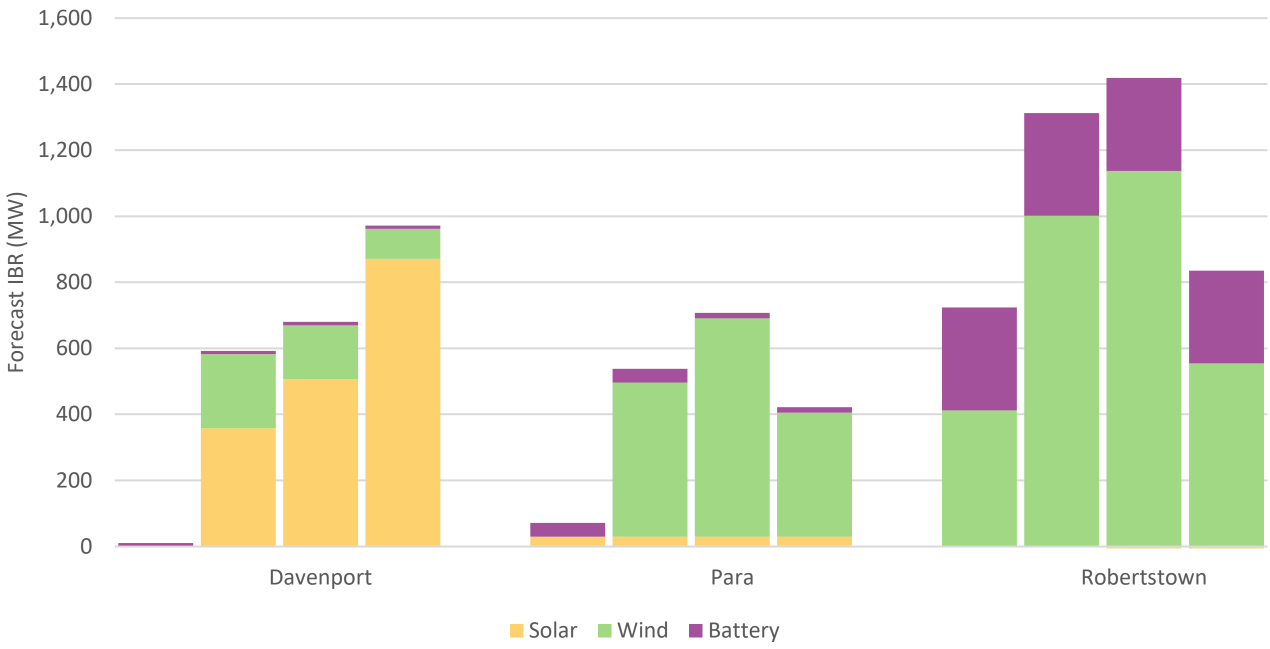


Table 5 IBR projections for South Australia (MW)

Node	Technology	Existing	2024-25	2029-30	2034-35	2039-40
Davenport	Solar	349	0	357	507	871
	Wind	557	0	225	163	91
	Battery	0	10	10	10	10
Para	Solar	286	30	30	30	30
	Wind	358	0	466	661	375
	Battery	282	42	42	17	17
Robertstown	Solar	25	0	0	-6	-6
	Wind	1,434	413	1,001	1,137	554
	Battery	180	311	311	281	281

Inertia outlook

Key inertia results

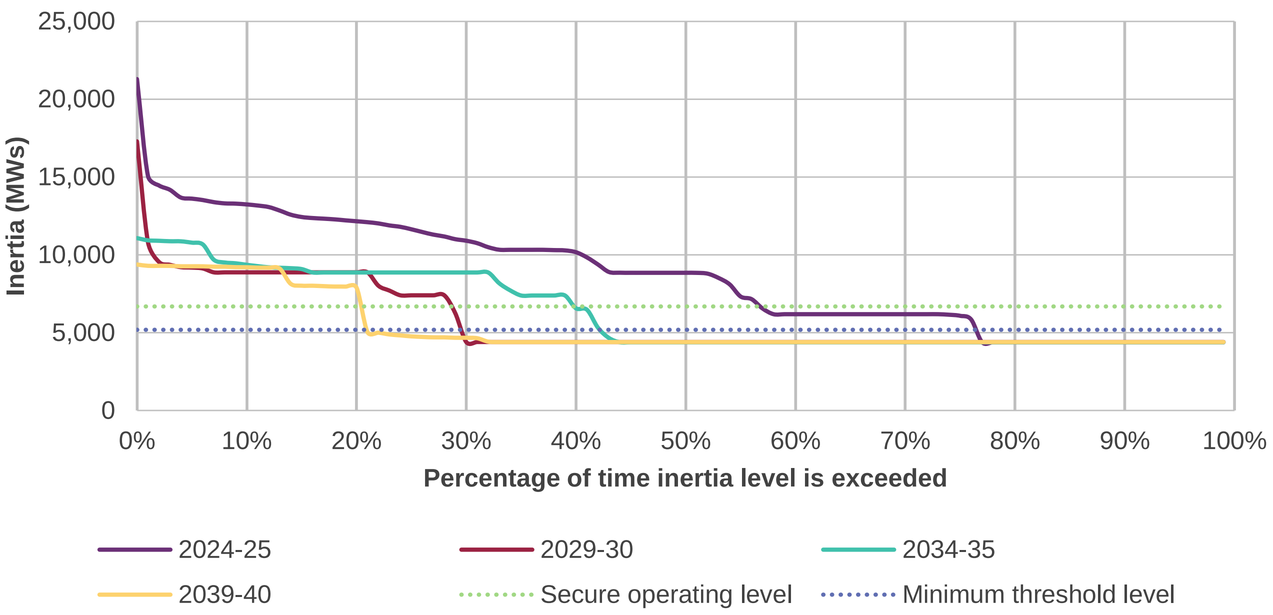
AEMO identified inertia deficits in each of the studied years. In the 2023 *Inertia Report* AEMO declared an inertia shortfall of 500 MWs from July 2024 until PEC Stage 2 is complete with necessary protection schemes in place to manage the non-credible loss of either PEC itself or the Heywood interconnector (expected in 2024-25). After this point AEMO does not anticipate future declarations of inertia shortfalls as South Australia will be unlikely to island.

Table 6 Inertia outlook for South Australia

Inertia projections					
	2024-25 (Early) A	2024-25 (Late) A	2029-30	2034-35	2039-40
Assumed level of 1-second FCAS (MW)	240	240	240	240	240
Minimum threshold of inertia (MWs)	5,200	5,200	5,200	5,200	5,200
Secure operating level of inertia (MWs)	6,700	6,700	6,700	6,700	6,700
Inertia available 99% of the time (MWs)	6,200	4,400	4,400	4,400	4,400
Calculated inertia deficit (MWs)	500	2,300	2,300	2,300	2,300
Likelihood of islanding	Likely[B]	Unlikely[B]	Unlikely[B]	Unlikely[B]	Unlikely[B]

A. A significant transition happens within this year, following the expected commissioning of PEC Stage 2, and associated control schemes. As such, results for 2024-25 have been split into values that apply before and after PEC commissioning.
B. AEMO does not consider South Australia to be sufficiently likely to island following the expected commissioning of PEC Stage 2 in 2024-25 with necessary protection schemes in place to manage the non-credible loss of either PEC itself or the Heywood interconnector.

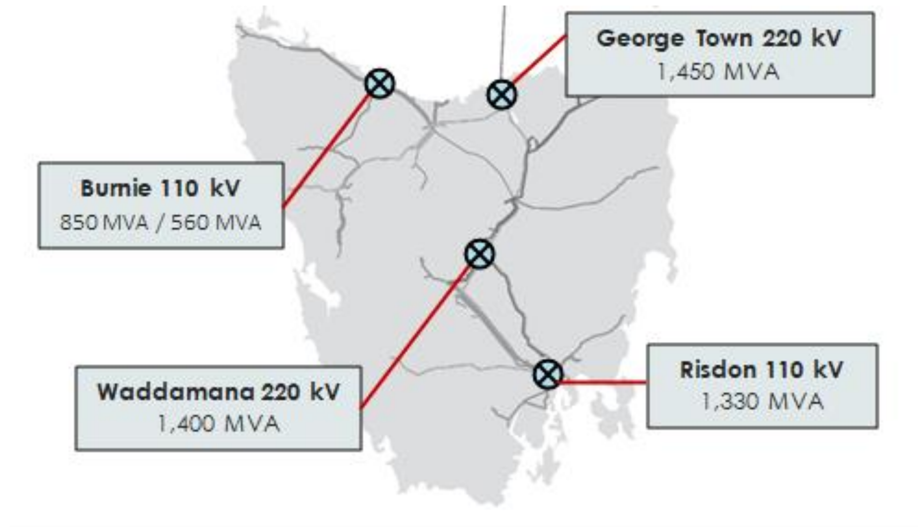
Figure 13 Projected levels of inertia available in South Australia, *Step Change* scenario



A7.4.5 Tasmania

System strength outlook – synchronous fault levels

System strength requirements (pre/post contingent)



Key results

Shortfalls are likely to occur across the outlook period in Tasmania without additional system strength services.

Shortfalls are currently managed through contracted services until April 2024.

Projected shortfalls against current minimum requirements

Node	Current requirement met†				Trend
	2024-25	2029-30	2034-35	2039-40	
Burnie 110 kV	348 MVA	382 MVA	381 MVA	381 MVA	No significant change.
George Town 220 kV	655 MVA	838 MVA	836 MVA	836 MVA	More time spent below minimum.
Risdon 110 kV	346 MVA	607 MVA	605 MVA	605 MVA	More time spent below minimum.
Waddamana 220 kV	359 MVA	683 MVA	680 MVA	680 MVA	More time spent below minimum.

† AEMO and TasNetworks use pre-contingency values to inform the operational arrangements for system strength requirements in Tasmania. These nodes have specific local requirements which must be met for the pre-contingent levels, namely requirements to do with maintaining Basslink requirements, switching requirements for local reactive plant, and some power quality requirements for metropolitan load centres.

Projected vs required level of fault current available at least 99% of the time

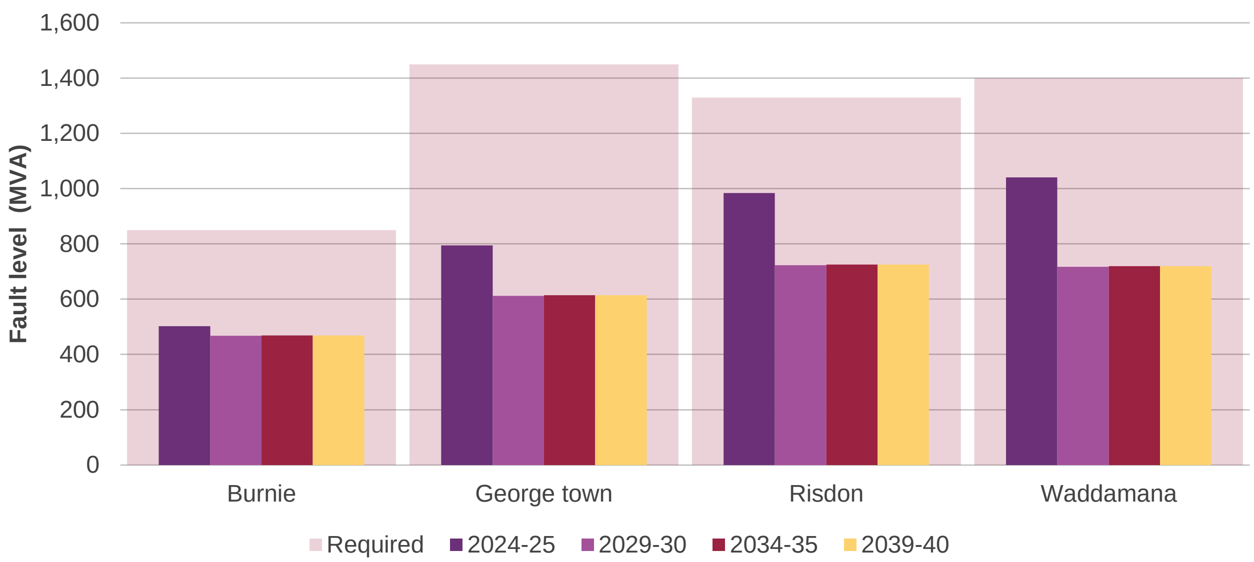
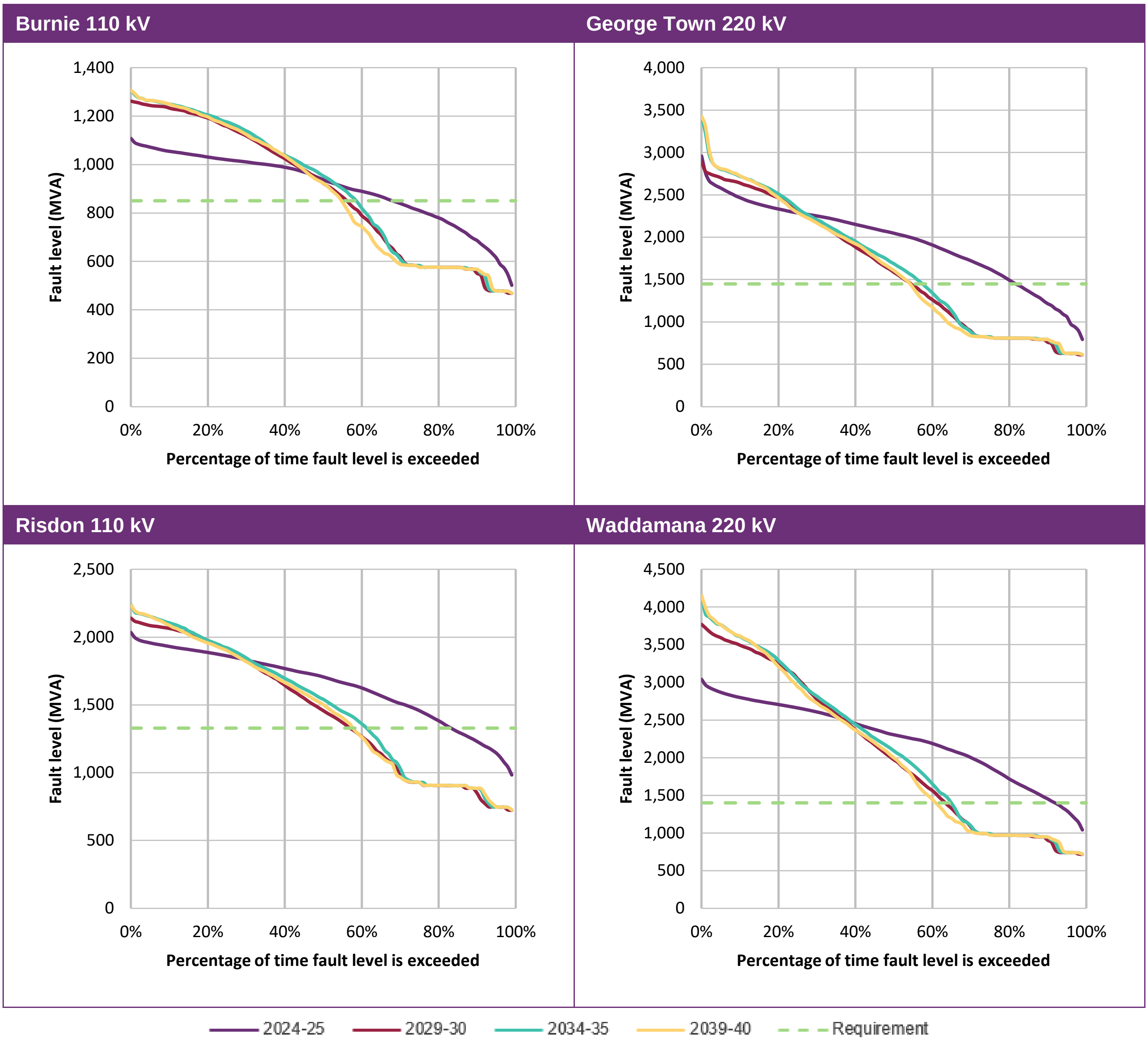


Figure 14 Percentage of time fault level is exceeded at each system strength node in Tasmania



System strength outlook – new IBR investment

Figure 15 IBR projections for Tasmania in 2024-25, 2029-30, 2034-35, and 2039-40

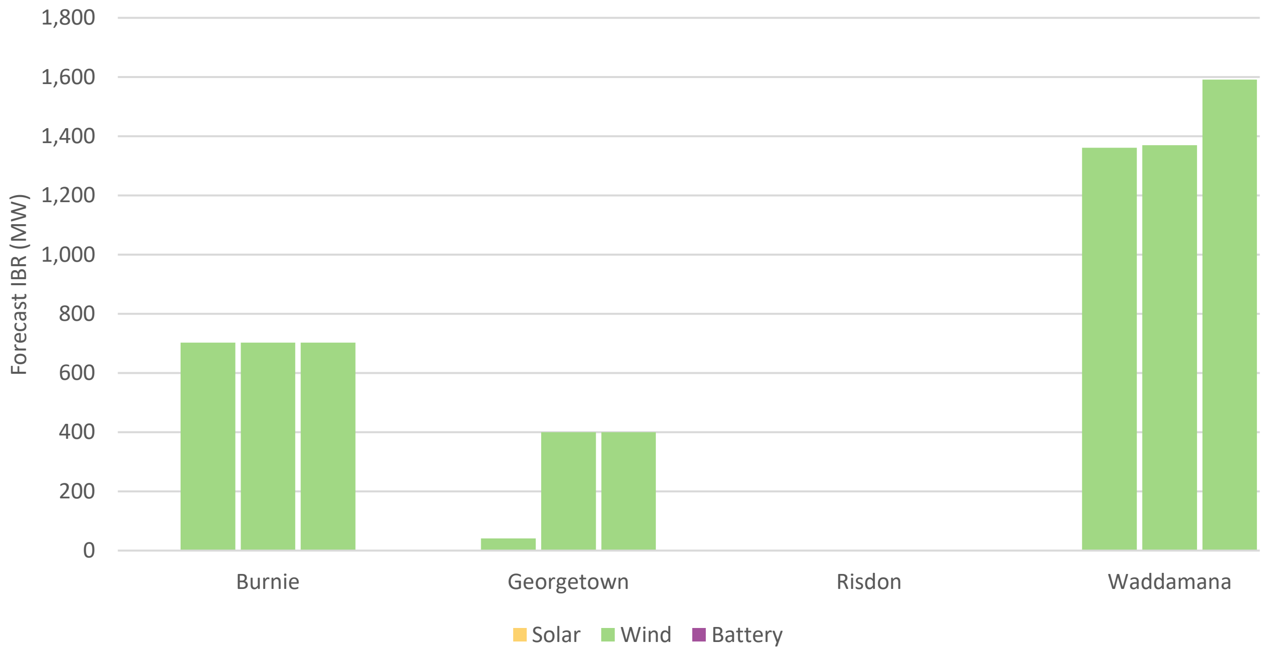


Table 7 IBR projections for Tasmania (MW)

Node	Technology	Existing	2024-25	2029-30	2034-35	2039-40
Burnie	Solar	0	0	0	0	0
	Wind	251	0	703	703	703
	Battery	0	0	0	0	0
Georgetown	Solar	0	0	0	0	0
	Wind	168	0	41	400	400
	Battery	0	0	0	0	0
Risdon	Solar	0	0	0	0	0
	Wind	0	0	0	0	0
	Battery	0	0	0	0	0
Waddamana	Solar	0	0	0	0	0
	Wind	144	0	1,362	1,370	1,592
	Battery	0	0	0	0	0

Inertia outlook

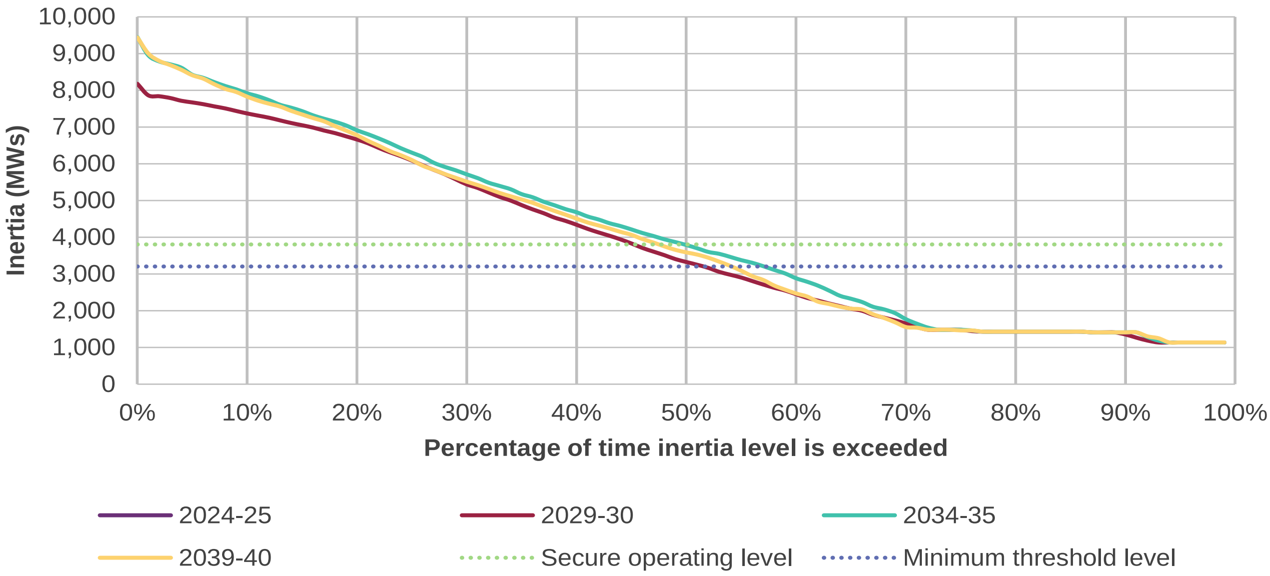
Key inertia results

AEMO identified inertia deficits in all studied years. In the 2023 *Inertia Report* AEMO declared an inertia shortfall of 1,880 MWs in 2024-25. The inertia deficits identified for years 2029-30, 2034-35, and 2039-40 will likely lead to declarations of inertia shortfalls in future Inertia Reports as these years move within the five year Inertia Report assessment window.

Table 8 Inertia outlook for Tasmania

Inertia projections				
	2024-25	**2029-30**	**2034-35**	**2039-40**
Minimum threshold of inertia (MWs)	3,200	3,200	3,200	3,200
Secure operating level of inertia (MWs)	3,800	3,800	3,800	3,800
Inertia available 99% of the time (MWs)	1,926	1,136	1,136	1,136
Calculated inertia deficit (MWs)	1,874	2,664	2,664	2,664
Likelihood of islanding	Always	Always	Always	Always

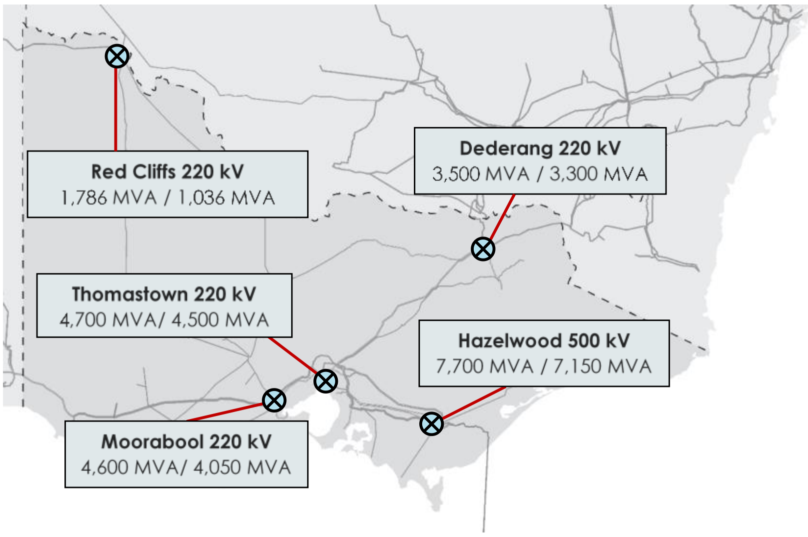
Figure 16 Projected levels of inertia available in Tasmania, *Step Change* scenario



A7.4.6 Victoria

System strength outlook – synchronous fault levels

System strength requirements (pre/post contingent)



Key results

Projected closure of coal-fired generation and declining utilisation of others is expected to significantly reduce synchronous fault current at several nodes within Victoria.

Most of the projected need for fault current remediation occurs by the end of the decade.

Projected shortfalls against current minimum requirements

Node	Potential Shortfall				Trend
	2024-25	2029-30	2034-35	2039-40	
Dederang 220 kV	0 MVA	408 MVA	407 MVA	409 MVA	The synchronous fault current at these nodes is expected to fall sharply over the decade, but further reductions are not expected in the remaining planning horizon.
Hazelwood 500 kV	0 MVA	4215 MVA	4215 MVA	4216 MVA	
Moorabool 220 kV	0 MVA	966 MVA	965 MVA	967 MVA	
Thomastown 220 kV	0 MVA	1473 MVA	1472 MVA	1473 MVA	
Red Cliffs 220 kV	0 MVA	0 MVA	0 MVA	0 MVA	The synchronous fault level at Red Cliffs is expected to increase with commissioning completion of Project EnergyConnect stage 2.

Projected vs required level of fault current available at least 99% of the time

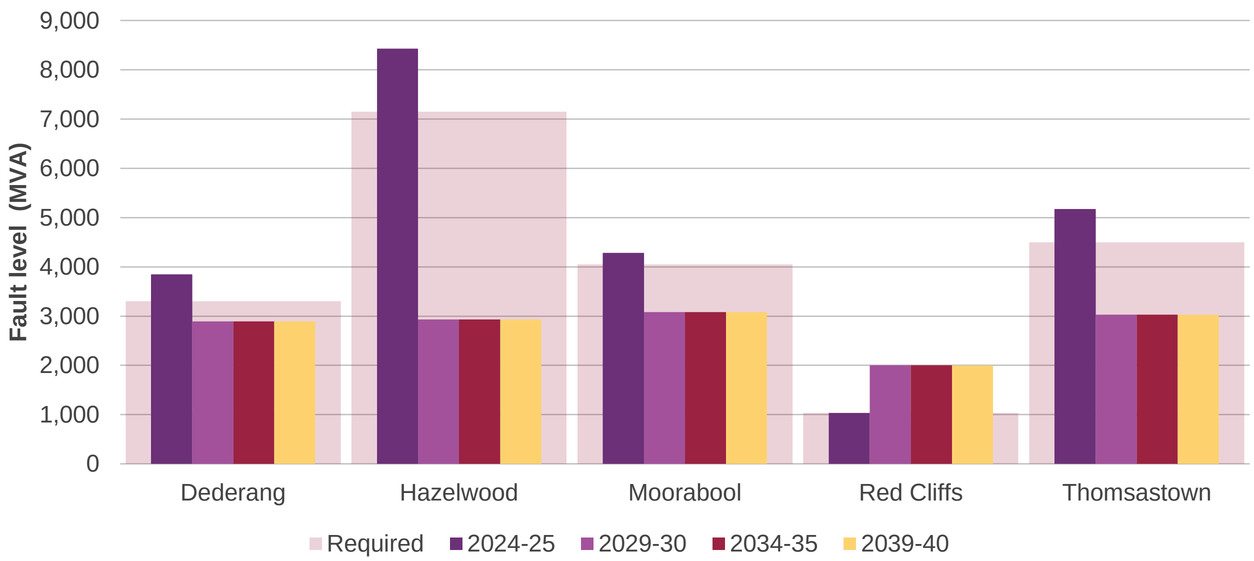
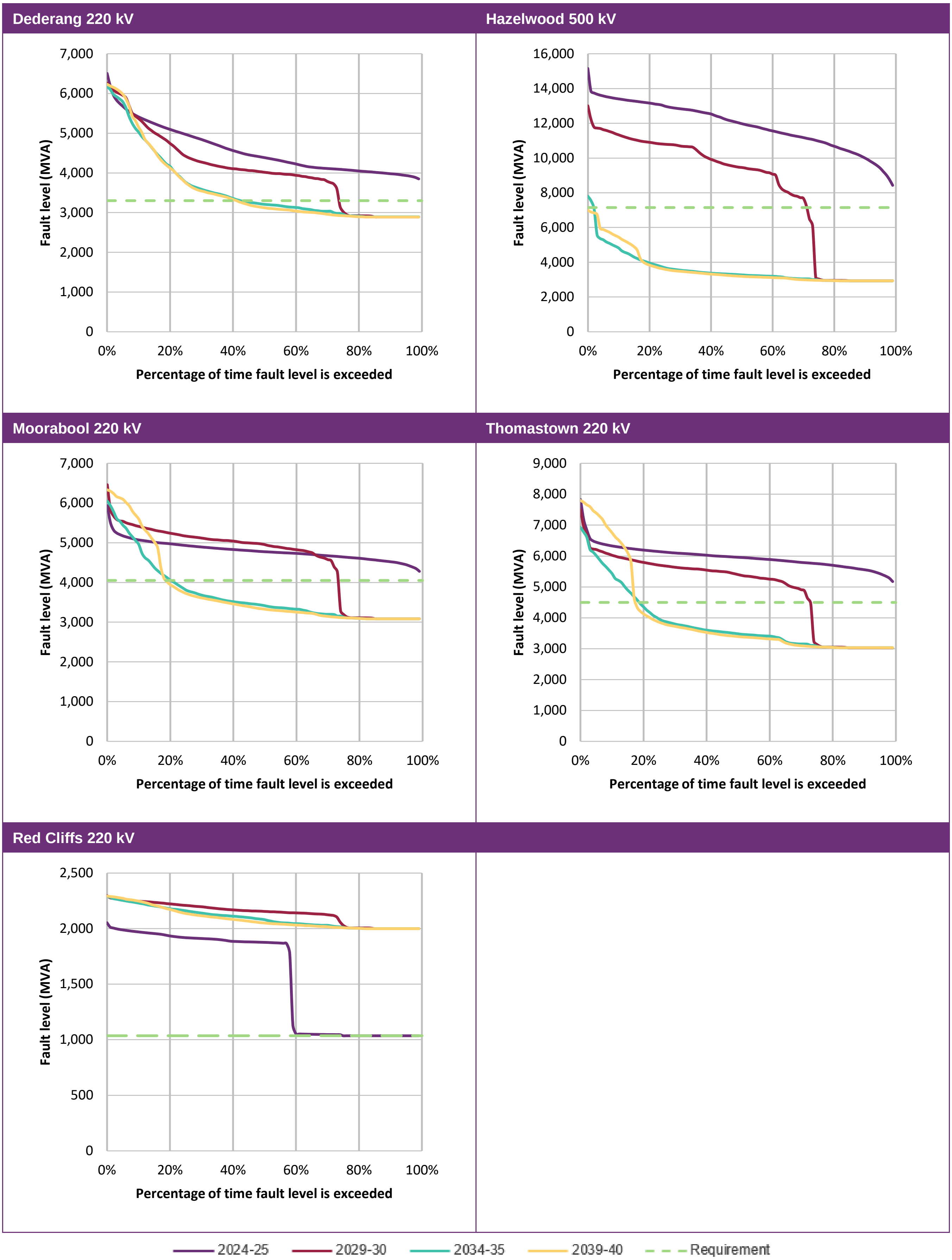


Figure 17 Percentage of time fault level is exceeded at each system strength node in Victoria



System strength outlook – new IBR investment

Figure 18 IBR projections for Victoria in 2024-25, 2029-30, 2034-35, and 2039-40

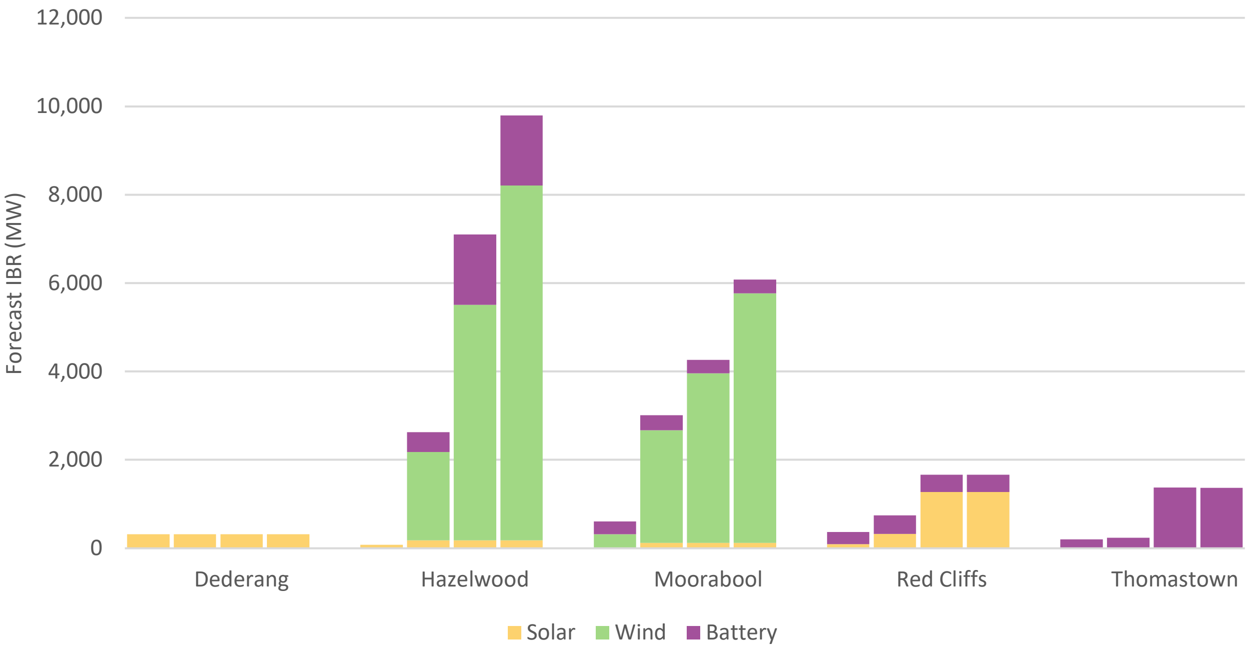


Table 9 IBR projections for Victoria (MW)

Node	Technology	Existing	2024-25	2029-30	2034-35	2039-40
Dederang	Solar	327	313	313	313	313
	Wind	0	0	0	0	0
	Battery	0	0	0	0	0
Hazelwood	Solar	0	77	178	178	178
	Wind	107	0	2,000	5,333	8,030
	Battery	200	0	451	1,587	1,587
Moorabool	Solar	0	0	119	119	119
	Wind	4,126	315	2,553	3,836	5,652
	Battery	350	290	340	310	310
Red Cliffs	Solar	682	95	323	1,271	1,271
	Wind	0	0	0	0	0
	Battery	25	270	420	395	395
Thomastown	Solar	0	0	0	0	0
	Wind	58	0	0	0	0
	Battery	5	200	236	1,372	1,367

Inertia outlook

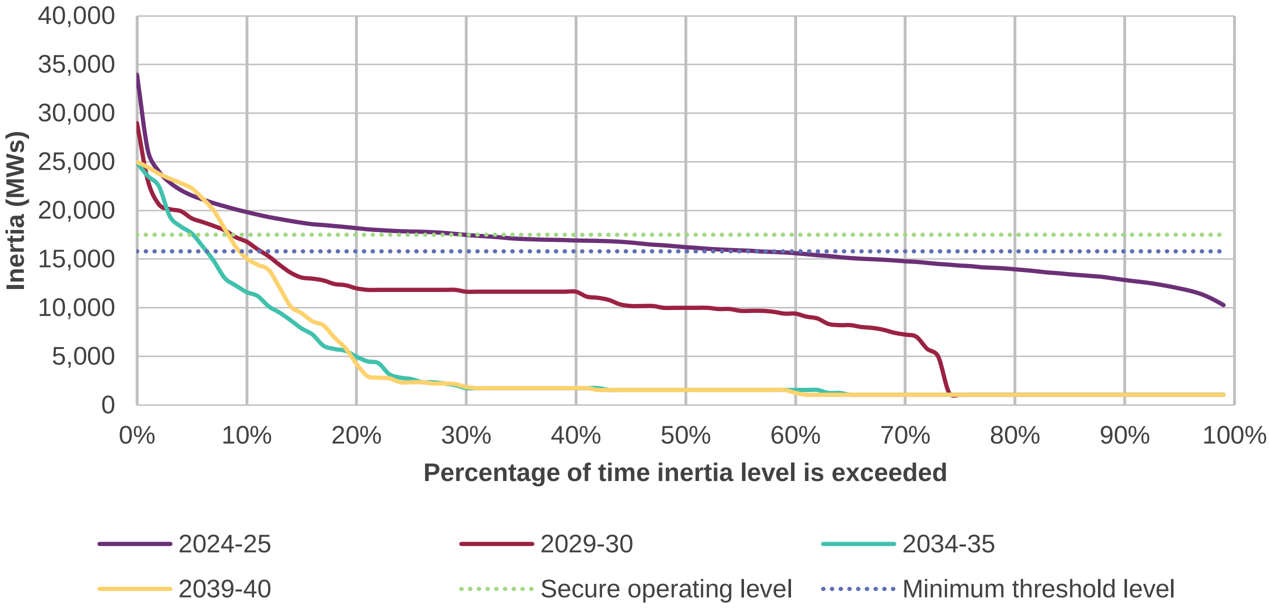
Key inertia results

Lower levels of inertia and increased inertia requirements lead to greater calculated inertia deficits than in the 2022 ISP. AEMO identified inertia deficits in all studied years, however Victoria is not considered sufficiently likely to island due to its strong interconnections with neighbouring regions.

Table 10 Inertia outlook for Victoria

Inertia projections				
	2024-25	**2029-30**	**2034-35**	**2039-40**
Assumed level of 1-second FCAS (MW)	212	212	212	212
Minimum threshold of inertia (MWs)	15,800	15,800	15,800	15,800
Secure operating level of inertia (MWs)	17,500	17,500	17,500	17,500
Inertia available 99% of the time (MWs)	10,259	1,048	1,048	1,048
Calculated inertia deficit (MWs)	7,241	16,452	16,452	16,452
Likelihood of islanding	Unlikely	Unlikely	Unlikely	Unlikely

Figure 19 Projected levels of inertia available in Victoria, *Step Change* scenario



Glossary

This glossary has been prepared as a quick guide to help readers understand some of the terms used in the ISP. Words and phrases defined in the National Electricity Rules (NER) have the meaning given to them in the NER. This glossary is not a substitute for consulting the NER, the Australian Energy Regulator's (AER's) Cost Benefit Analysis Guidelines, or AEMO's *ISP Methodology*.

Term	Acronym	Explanation
Actionable ISP project	-	Actionable ISP projects optimise benefits for consumers if progressed before the next ISP. A transmission project (or non-network option) identified as part of the ODP and having a delivery date within an actionable window. For newly actionable ISP projects, the actionable window is two years, meaning it is within the window if the project is needed within two years of its earliest in-service date. The window is longer for projects that have previously been actionable. Project proponents are required to begin newly actionable ISP projects with the release of a final ISP, including commencing a RIT-T.
Actionable New South Wales project and actionable Queensland project	-	A transmission project (or non-network option) that optimises benefits for consumers if progressed before the next ISP, is identified as part of the ODP, and is supported by or committed to in New South Wales Government or Queensland Government policy and/or prospective or current legislation.
Anticipated project	-	A generation, storage or transmission project that is in the process of meeting at least three of the five commitment criteria (planning, construction, land, contracts, finance), in accordance with the AER's Cost Benefit Analysis Guidelines. Anticipated projects are included in all ISP scenarios.
Candidate development path	CDP	A collection of development paths which share a set of potential actionable projects. Within the collection, potential future ISP projects are allowed to vary across scenarios between the development paths. Candidate development paths have been shortlisted for selection as the ODP and are evaluated in detail to determine the ODP, in accordance with the ISP Methodology.
Capacity	-	The maximum rating of a generating or storage unit (or set of generating units), or transmission line, typically expressed in megawatts (MW). For example, a solar farm may have a nominal capacity of 400 MW.
Committed project	-	A generation, storage or transmission project that has fully met all five commitment criteria (planning, construction, land, contracts, finance), in accordance with the AER's Cost Benefit Analysis Guidelines. Committed projects are included in all ISP scenarios.
Consumer energy resources	CER	Generation or storage assets owned by consumers and installed behind-the-meter. These can include rooftop solar, batteries and electric vehicles. CER may include demand flexibility.
Consumption	-	The electrical energy used over a period of time (for example a day or year). This quantity is typically expressed in megawatt-hours (MWh) or its multiples. Various definitions for consumption apply, depending on where it is measured. For example, underlying consumption means consumption being supplied by both CER and the electricity grid.
Cost-benefit analysis	CBA	A comparison of the quantified costs and benefits of a particular project (or suite of projects) in monetary terms. For the ISP, a cost-benefit analysis is conducted in accordance with the AER's Cost Benefit Analysis Guidelines.
Counterfactual development path	-	The counterfactual development path represents a future without major transmission augmentation. AEMO compares candidate development paths against the counterfactual to calculate the economic benefits of transmission.

Term	Acronym	Explanation
Demand	-	The amount of electrical power consumed at a point in time. This quantity is typically expressed in megawatts (MW) or its multiples. Various definitions for demand, depending on where it is measured. For example, underlying demand means demand supplied by both CER and the electricity grid.
Demand-side participation	DSP	The capability of consumers to reduce their demand during periods of high wholesale electricity prices or when reliability issues emerge. This can occur through voluntarily reducing demand, or generating electricity.
Development path	DP	A set of projects (actionable projects, future projects and ISP development opportunities) in an ISP that together address power system needs.
Dispatchable capacity	-	The total amount of generation that can be turned on or off, without being dependent on the weather. Dispatchable capacity is required to provide firming during periods of low variable renewable energy output in the NEM.
Distributed solar / distributed PV	-	Solar photovoltaic (PV) generation assets that are not centrally controlled by AEMO dispatch. Examples include residential and business rooftop PV as well as larger commercial or industrial “non-scheduled” PV systems.
Firming	-	Grid-connected assets that can provide dispatchable capacity when variable renewable energy generation is limited by weather, for example storage (pumped-hydro and batteries) and gas-powered generation.
Future ISP project	-	A transmission project (or non-network option) that addresses an identified need in the ISP, that is part of the ODP, and is forecast to be actionable in the future.
Identified need	-	The objective a TNSP seeks to achieve by investing in the network in accordance with the NER or an ISP. In the context of the ISP, the identified need is the reason an investment in the network is required, and may be met by either a network or a non-network option.
ISP development opportunity	-	A development identified in the ISP that does not relate to a transmission project (or non-network option) and may include generation, storage, demand-side participation, or other developments such as distribution network projects.
Net market benefits	-	The present value of total market benefits associated with a project (or a group of projects), less its total cost, calculated in accordance with the AER’s Cost Benefit Analysis Guidelines.
Non-network option	-	A means by which an identified need can be fully or partly addressed, that is not a network option. A network option means a solution such as transmission lines or substations which are undertaken by a Network Service Provider using regulated expenditure.
Optimal development path	ODP	The development path identified in the ISP as optimal and robust to future states of the world. The ODP contains actionable projects, future ISP projects and ISP development opportunities, and optimises costs and benefits of various options across a range of future ISP scenarios.
Regulatory Investment Test for Transmission	RIT-T	The RIT-T is a cost benefit analysis test that TNSPs must apply to prescribed regulated investments in their network. The purpose of the RIT-T is to identify the credible network or non-network options to address the identified network need that maximise net market benefits to the NEM. RIT-Ts are required for some but not all transmission investments.
Reliable (power system)	-	The ability of the power system to supply adequate power to satisfy consumer demand, allowing for credible generation and transmission network contingencies.
Renewable energy	-	For the purposes of the ISP, the following technologies are referred to under the grouping of renewable energy: “solar, wind, biomass, hydro, and hydrogen turbines”. Variable renewable energy is a subset of this group, explained below.

Term	Acronym	Explanation
Renewable energy zone	REZ	An area identified in the ISP as high-quality resource areas where clusters of large-scale renewable energy projects can be developed using economies of scale.
Renewable drought	-	A prolonged period of very low levels of variable renewable output, typically associated with dark and still conditions that limit production from both solar and wind generators.
Scenario	-	A possible future of how the NEM may develop to meet a set of conditions that influence consumer demand, economic activity, decarbonisation, and other parameters. For the 2024 ISP, AEMO has considered three scenarios: *Progressive Change*, *Step Change* and *Green Energy Exports*.
Secure (power system)	-	The system is secure if it is operating within defined technical limits and is able to be returned to within those limits after a major power system element is disconnected (such as a generator or a major transmission network element).
Sensitivity analysis	-	Analysis undertaken to determine how modelling outcomes change if an input assumption (or a collection of related input assumptions) is changed.
Spilled energy	-	Energy from variable renewable energy resources that could be generated but is unable to be delivered. Transmission curtailment results in spilled energy when generation is constrained due to operational limits, and economic spill occurs when generation reduces output due to market price.
Transmission network service provider	TNSP	A business responsible for owning, controlling or operating a transmission network.
Utility-scale or utility	-	For the purposes of the ISP, 'utility-scale' and 'utility' refers to technologies connected to the high-voltage power system rather than behind the meter at a business or residence.
Virtual power plant	VPP	An aggregation of resources coordinated to deliver services for power system operations and electricity markets. For the ISP, VPPs enable coordinated control of CER, including batteries and electric vehicles.
Variable renewable energy	VRE	Renewable resources whose generation output can vary greatly in short time periods due to changing weather conditions, such as solar and wind.