Power system security services planning

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03. Power system security services planning

The increased share of generation from inverter-based resources (IBR) is changing the way system security services, such as system strength and inertia, are planned for, delivered and managed. Powerlink is actively planning for and procuring system security services to support the stable operation of the power system in Queensland.

Key highlights

- System security services have traditionally been provided as an inherent characteristic of synchronous generation.
- The need for new approaches to system security services arises because most IBR do not inherently provide all these services.
- The provision of system security services is forecast to be most critical at times of low demand, when fewer synchronous generators are online and inherent support is reduced.
- Changes to roles and responsibilities for planning, procuring and delivering power system security frameworks under the National Electricity Rules (NER) have been made in recent years.
- Powerlink is the System Strength Service Provider (SSSP) for Queensland with specific obligations defined in the NER.
- Powerlink is seeking to deliver system security services that support a safe, reliable and cost-effective power system for Queensland customers.

3.1 Introduction

This chapter provides an outline of how Powerlink is meeting the challenges of delivering system security services, and addresses requirements in the NER for the Transmission Annual Planning Report (TAPR) to provide information on:

- the activities Powerlink has undertaken to make system strength and inertia network services available[1]
- Powerlink's response to the Australian Energy Market Operator's (AEMO) most recent system security reports[2]
- proposed network investment to address system strength requirements[3]
- the modelling methodologies, assumptions and results used by Powerlink to plan activities to meet the System Strength Standard[4]
- the available fault level (AFL) at each system strength node[5]
- the system strength locational factor and corresponding system strength node for each connection point for which Powerlink is the Network Service Provider (NSP)[6].

3.2 System security services

Queensland's power system has historically comprised of synchronous generation such as coal-fired power stations, gas turbines and hydro-electric plants. These large generators inherently provide various system security services, such as voltage regulation, inertia and system strength, as an inherent characteristic of their energy dispatch, supporting stable and reliable power system operation.

The increased contribution of IBR generation sources, particularly solar and wind, can reduce the availability of system security services in the National Electricity Market (NEM), prompting the need for new approaches to the planning and delivery of these services.

Table 3.1 outlines the range of system security services which are needed to operate the power system.

1 National Electricity Rules (NER), clauses 5.20B.4(h)(1) and 5.20C.3(f)(1).
2 NER, clause 5.12.1(b)(3).
3 NER, clause 5.20C.3(g).
4 NER, clause 5.20C.3(f)(2).
5 NER, clause 5.20C.3(f)(3).
6 NER, clause 5.12.2(c)(13).

Table 3.1 System security services

Service	Description
System strength	Sufficient ('protection grade') fault current level for protection operation and a stable voltage waveform
Voltage regulation	Maintaining voltages at acceptable levels and sufficient dynamic voltage support to arrest any changes following contingencies
Frequency control	Maintaining system frequency within acceptable range with ongoing natural variations in load and generation, and sudden step-changes following contingencies
Inertia	Limiting the potential rate of change of system frequency following contingencies
Damping	Damping of power system oscillations so that any disturbances decay at an acceptable rate
Power quality	Control of phase unbalance, voltage harmonics, and flicker
Reserves	Availability of generation reserves or demand side resources to restore system security within 30 minutes following contingencies, and for tracking variations in residual demand throughout the day

The provision of system security services is forecast to be most critical at times of low demand, as fewer synchronous generators can remain online. For example, a 350 megawatt (MW) synchronous generator has a minimum stable load of approximately 140MW. Where multiple synchronous generators are needed to be online to maintain system security, minimum demand required needs to be at least as high as the combined minimum stable load of those generators operating (less any interconnector exports). At the same time, market spot prices are typically suppressed (and frequently become negative) at times of low grid-supplied demand, creating a financial incentive to minimise the number of synchronous generators online. Additionally, low market prices provide a strong signal to maximise load (including the charging of storage), increasing the level of demand. If this occurs frequently, it provides an incentive for the development of new energy storage capacity and load.

During very low load periods, non-scheduled generation may be curtailed (resulting in spilling the available energy) to ensure sufficient demand is available to preserve the minimum levels of synchronous generation required to maintain system security. In extreme cases, the Emergency Backstop Mechanism will be activated by Energy Queensland under direction from AEMO. The mechanism switches off inverter-based energy systems (such as rooftop solar PV with capacity of at least 10 kilovolt amperes) for a short time to maintain system security[7].

Other factors that also affect the provision of system security services relate to the location of synchronous generation plant being online, and include (but are not limited to):

- Network outages, especially those that disconnect Queensland from the NEM, or make this a credible possibility, may require additional system security services to be procured within Queensland.
- Particular generation patterns can cause localised gaps in the availability of system security services in real-time.

There are opportunities for new technologies and non-network solutions to assist with addressing power system security requirements and reduce the need for additional transmission network investment. For example, incentives such as time-of-use tariffs for residential batteries and electric vehicles have the potential to help smooth daily demand profiles and improve the utilisation of the network.

3.3 System security framework

AEMO has responsibility for the forecasting of power system security services. AEMO's annual system security reports assess the need for services across all regions of the NEM, and evaluate requirements for system strength, inertia and Network Support and Control Ancillary Services (NSCAS).

In March 2024, the Australian Energy Market Commission (AEMC) made the Improving Security Frameworks for the Energy Transition Rule which aimed to enhance arrangements to value, procure and schedule system security services in the NEM[8].

7 Queensland Government, Emergency Backstop Mechanism, viewed September 2025.
8 AEMC, Improving Security Frameworks for the Energy Transition, final determination, March 2024, pages 35-37. Prior to the rule change, system strength and inertia services were excluded from the definition of NSCAS under the NER.

3.3.1 Inertia

Inertia is the ability of the system to resist sudden frequency deviations and slow the rate of change of frequency. The energy required to counter significant frequency deviations caused by an imbalance in power supply and demand during a contingency event can come from either the kinetic energy stored in the momentum of synchronous machines or from an instantaneous, rapid and automatic injection of energy from another source (such as synthetic inertia from a battery). Similar to system strength, inertia has traditionally been provided by synchronous generators, and additional remediation is now needed to ensure the power system has sufficient inertia to remain secure.

AEMO is required under the NER to assess whether shortfalls in inertia exist (or are likely to exist) and Transmission Network Service Providers are obliged to use reasonable endeavours to make minimum levels of inertia continuously available[9].

In December 2024, AEMO decreased the previously declared inertia shortfall in Queensland from (up to) 1,660 megawatt seconds (MWs) to 256MWs, in 2027/28[10]. Powerlink understands the primary change in 2024 was an increase in registrations for the one-second Frequency Control Ancillary Services market over the year, which reduces the amount of inertia required during islanded operation of Queensland.

Given the potential for system strength solutions to contribute to inertia, the preferred option for the System Strength Regulatory Investment Test for Transmission (RIT-T) (refer to Section 3.4) may address, either in part or in full, the timing and size of the inertia shortfall.

3.3.2 System strength

System strength is a measure of the ability of the power system to maintain and control a stable voltage waveform at a given location, both during steady state operation and following a disturbance, such as a sudden change in generation or load, or fault on the network[11].

The Efficient Management of System Strength on the Power System Rule, made in October 2021:

- established Powerlink as the SSSP for Queensland
- evolved the 'do no harm' framework which required connecting generators to self-assess their impact on the local network's system strength levels, and self-remediate any adverse impacts
- introduced the System Strength Standard, which requires Powerlink to use reasonable endeavours to plan, design, maintain and operate its network, or make system strength services available to AEMO, from December 2025[12].

Under the new framework, two measures of system strength are defined:

- Minimum level system strength – which maintains the minimum fault level requirements for power system stability (refer to Section 3.5.1)
- Efficient level system strength – which maintains stable voltage waveforms to support future IBR (refer to Section 3.5.2).

3.3.3 Investment drivers

Powerlink is seeking to balance the cost to customers of investing in alternative sources of system security services (such as synchronous condensers) against the potential consequences of insufficient services being available across all operating conditions.

While the costs of these investments may be significant, rapid technological changes such as expanding capabilities of grid-forming Battery Energy Storage Systems (BESS), and procuring services from Pumped Hydro Energy Storage (PHES) systems and gas turbines with clutches, may reduce the need for some solutions over time. In particular, if grid-forming BESS prove to be technically and commercially viable providers of (protection grade) system strength, and are widely deployed, this could reduce the need for Powerlink to invest in other solutions.

However, there are strong drivers to support a prudent and timely approach to investing in proven sources of system security services. Some solutions require long implementation lead times, and delay in investment could result in insufficient system security services increasing the risk of degraded system performance and extended supply interruptions for customers.

Powerlink recognises that these uncertainties cannot be fully resolved through analysis alone, as they depend on factors that are either confidential to market participants or subject to future conditions that are inherently uncertain and evolving.

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9 NER, clauses 4.3.4(j) and 5.20B.4(b).
10 AEMO, 2024 Inertia Report, December 2024, page 14.
11 AEMO, System Strength in the NEM Explained, March 2020, page 5.
12 AEMC, Efficient Management of System Strength on the Power System, final determination, October 2021, page 13; NER, clauses 5.20C.3(a) and S5.1.14(b).

Table 3.2 System strength factors subject to significant uncertainty

System strength factor	Nature of uncertainty
Reduction in minimum demand level	The reduction in minimum demand is challenging to forecast because it depends on complex interactions of weather, government policy (e.g. incentivising residential batteries), customer behaviours and timing of new load developments (1).
Timing of coal withdrawal	This includes both generator retirements as well as the possibility some units may modify their operation, reducing the number of units online at any given time. Already, there is a clear trend for fewer units to be available at times of low demand, as generators undertake their maintenance programs.
Location of coal withdrawal	Queensland's transmission network spans a vast geographic area, and certain system services, such as system strength, must be supplied locally. Therefore, there is also a dependency on how operational generators are distributed.
Potential for compound contingencies	Whilst planning focusses on credible contingencies (things that could happen), it is nevertheless important that the system has emergency mechanisms in place to ensure that the power system can recover from non-credible contingencies (rare and severe events).

Note

(1) Refer to Section 2.1.1 for detail on the difficulties of forecasting demand.

To address this need and associated uncertainties, Powerlink's strategy to discharge its responsibilities to plan for and make system security services available includes:

- pursuing a complementary mix of different technologies to address requirements, as outlined in Powerlink's System Strength RIT-T (refer to Section 3.4)
- timing the investment in solutions to anticipate withdrawal of generation, while preserving flexibility to invest in/or procure further solutions over time
- working with the Queensland Government and Energy Queensland (as owner of the Energex and Ergon Energy distribution networks) to explore ways to enhance Queensland's operational tools to maintain system security during periods of low operational demand.

3.4 Activities to meet inertia and system strength requirements

A range of technologies, including synchronous condensers, grid-forming BESS, and PHES systems capable of operating in synchronous condenser mode can deliver system strength services. Gas turbines with clutches, which enable them to operate in synchronous condenser mode, can also provide these services largely without disrupting their energy dispatch.

In June 2025, Powerlink concluded a RIT-T to address system strength requirements in Queensland from December 2025. The preferred option in the RIT-T included:

- nine synchronous condensers across Central Queensland and Southern Queensland by June 2034
- contracting with a range of synchronous generation units in Southern and Northern Queensland for minimum level requirements
- contracting for grid-forming BESS in Southern, Central and Northern Queensland for efficient level requirements[13].

Since finalising the System Strength RIT-T, Powerlink has commenced procurement activities for network synchronous condensers in Central Queensland and is pursuing non-network solutions for Southern, Central and Northern Queensland. The location, timing and expected cost of the network synchronous condensers are still being finalised.

To maintain flexibility, Powerlink has committed to investing in or contracting with a small number of synchronous condensers, while leveraging RIT-T reopening triggers to pivot to new (protection grade) system strength solutions as they become available. Powerlink continues to engage with a range of potential proponents of non-network solutions for system strength and is assessing the potential for grid-forming BESS to address minimum system strength requirements.

[13] Powerlink, Addressing System Strength Requirements in Queensland from December 2025, Project Assessment Conclusions Report, June 2025, page 18.

Indicative costs for non-network solutions were included in the RIT-T cost-benefit assessment. However, these costs did not influence the identification of the preferred option as they are treated as a revenue transfer between energy market participants under the RIT-T framework[14]. Actual costs proposed by non-network proponents during or following the RIT-T process are commercially sensitive and therefore not disclosed by Powerlink.

If inertia requirements are not met by resources invested in or contracted with through the System Strength RIT-T, a separate RIT-T may be required to procure services, or Powerlink may initiate a new RIT-T to meet system strength and inertia needs concurrently.

3.5 System strength modelling

3.5.1 Minimum level requirements

In December 2024, AEMO updated minimum system strength requirements for the NEM.

Table 3.3 shows, for each system strength node, the pre-contingent minimum fault level, and minimum fault level expected 99.87% of the time from 2024/25 to 2027/28.

Table 3.3 AEMO minimum three phase fault level, December 2024

System Strength Node	Parameter	Minimum three phase fault level current (MVA), financial year ending 2024/25	2025/26	2026/27	2027/28
Gin Gin	Pre-contingent	2,800	2,800	2,800	2,800
	Projected 99.87% of time	3,150	3,155	3,088	2,877
Greenbank	Pre-contingent	4,350	4,350	4,350	4,350
	Projected 99.87% of time	4,513	4,534	4,199	4,473
Lilyvale	Pre-contingent	1,400	1,400	1,400	1,400
	Projected 99.87% of time	1,400	1,400	1,295	1,247
Ross	Pre-contingent	1,350	1,350	1,350	1,350
	Projected 99.87% of time	1,350	1,350	1,350	1,350
Western Downs	Pre-contingent	4,000	4,000	4,000	4,000
	Projected 99.87% of time	4,121	4,150	3,827	4,078

Note:

(1) Source: AEMO, 2024 System Strength Report, December 2024, pages 29-33.

AEMO indicated that shortfalls at the Greenbank, Lilyvale and Western Downs nodes across 2026/27 and 2027/28 were primarily linked to decreased energy exports to New South Wales (NSW) following the delayed retirement of Eraring Power Station in NSW. In AEMO's modelling, the delayed retirement resulted in fewer thermal units expected to be online in Queensland, and lower fault levels than previously projected[15].

The number of coal generating units in service at any point in time in Queensland is a primary consideration for Powerlink's ability to meet minimum system strength requirements. There are currently 22 coal generating units in Queensland, of which 14 are in Central Queensland and eight are in Southern Queensland. To provide sufficient system strength, in Southern Queensland four units are required to be online at all times, and in Central Queensland six units are required to be online at all times. In Northern Queensland two services are required to be online at all times.

For the System Strength RIT-T, Powerlink adopted a probabilistic approach to assess the likelihood of maintaining adequate system strength across the grid. This analysis incorporated coal retirement projections and their impact on fault levels and stability, based on AEMO's 2024 Integrated System Plan forecasts. From 2025 to 2030, existing synchronous generation in Southern, Central, and Northern Queensland is expected to largely meet minimum system strength requirements in the early years. However, in later years, alternative synchronous technologies, such as synchronous condensers, clutched gas turbines, and pumped hydro, will likely be needed to replace retiring generation.

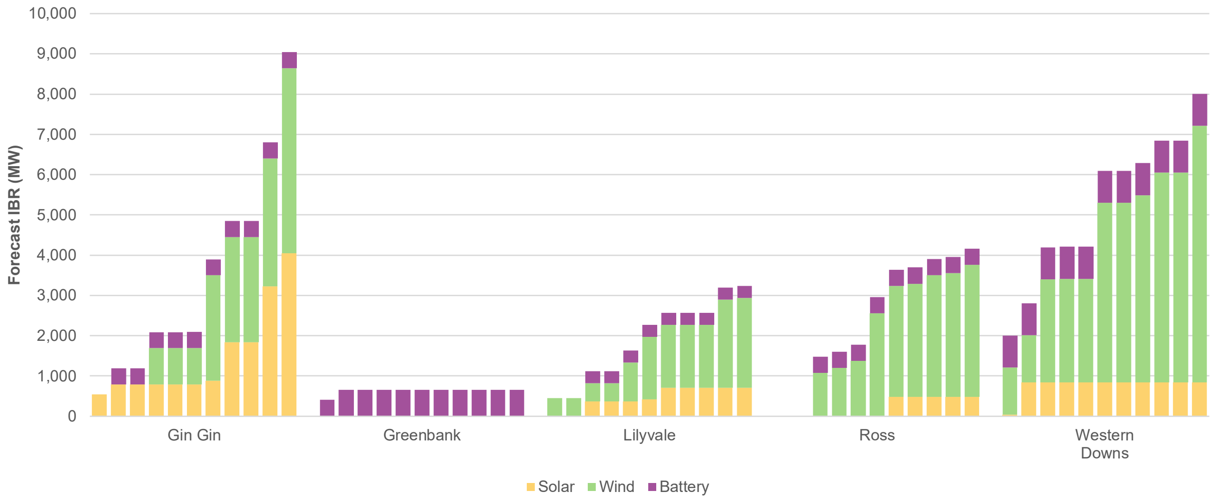
[14] AER, The Efficient Management of System Strength Framework, guidance note, December 2024, page 23.
[15] AEMO, 2024 System Strength Report, December 2024, page 25.

To address uncertainty in emerging technologies, the RIT-T has been designed with flexibility, allowing a shift to solutions such as gas turbines with clutches or grid-forming BESS if they become technically and commercially viable, while still advancing near-term investments to mitigate system security risks.

3.5.2 Efficient level requirements

The AEMO 2024 System Strength Report also included updated forecasts of IBR generation for Queensland over the 11-year period from 2024/25.

Figure 3.1 AEMO 11-year forecast of level and type of IBR at system strength nodes, December 2024



Notes:

(1) Forecasts excluded existing IBR.

(2) Source: AEMO, 2024 System Strength Report, December 2024, page 28.

At an aggregate level, the 2024 forecast shows higher IBR from 2024/25 to 2032/33 than previous forecasts from 2022 and 2023. Consistent with earlier forecasts, the majority of growth (in terms of megawatts) in the 2024 forecast is for wind projects[16].

Powerlink has created an electromagnetic transient modelling (EMT) simulation model that covers Far North Queensland to the Hunter Valley in New South Wales. The model features detailed representations of all transmission connected variable renewable energy, synchronous generators, BESS and dynamic voltage control plant. The model allows Powerlink to conduct system strength assessments for generator connections.

As part of the System Strength RIT-T, Powerlink mapped its market intelligence of connection applications and enquiries against the forecast provided in AEMO's System Strength Reports. Most projects are choosing to self-remediate their system strength impact. Subsequently, Powerlink performed detailed EMT studies to assess system strength requirements, focussing on both the minimum level and efficient level of system strength support needed for the existing and projected IBR generation in Queensland over the 2025 to 2030 planning horizon.

All inverter-based plants connecting to Powerlink's network must undergo a Full Impact Assessment (FIA) or stability assessment using an EMT model. This analysis is essential to identify any unstable interactions with other generators or voltage control equipment. The assessment follows AEMO's System Strength Impact Assessment Guidelines (SSIAG), which ensures any negative impacts on system strength are addressed as part of the connection application process. Further details on the assessment and modelling requirements are available in the SSIAG and AEMO's Power System Model Guidelines.

3.6 Available fault level as indicator of system strength

While AFL has traditionally been used as a proxy for system strength, it is increasingly recognised as insufficient in modern power systems dominated by IBRs. AFL quantifies the fault current available at a node, but does not capture broader system strength attributes such as the ability to maintain and control voltage waveforms during steady-state and post-disturbance conditions.

16 See AEMO, 2022 System Strength Report, December 2022, page 39; AEMO, 2023 System Strength Report, December 2023, page 27.

AFL also does not account for the dynamic behaviour of the system, including transient and small-signal stability, or the operational viability of protection systems and voltage control devices under low fault level conditions.

Moreover, technologies such as grid-forming BESS can provide system strength without contributing high fault current, further decoupling AFL from actual system resilience. Therefore, relying solely on AFL risks overlooking critical aspects of system operability and stability in a high-IBR environment.

Powerlink considers a FIA the only technically prudent method to assess the dynamic performance of connecting plant under a wide range of network conditions and contingencies to ensure compliance with clause 5.3.4A of the NER. As such, a FIA is a necessary part of the application to connect process.

3.7 System strength locational factors and nodes

System strength locational factors are part of the formula for system strength charges. The NER requires Powerlink to list the system strength locational factor for each connection point for which Powerlink is the NSP, and the corresponding system strength node[17]. System strength locational factors and nodes are included in Appendix I and shown in the TAPR Portal.

17 NER, clause 5.12.2(c)(13).