04

Power system security services planning

The transformation of Queensland's power system from synchronous generation to Variable Renewable Energy (VRE) is changing the way essential system services are planned for, procured and managed. This chapter discusses the planning and development of system security services in Queensland.

Key highlights

- Power system security services have traditionally been provided as a by-product of synchronous generation.
- The transformation of Queensland's power system toward VRE necessitates new approaches to providing system security services.
- Significant changes to power system security frameworks have been made in recent years, with further reforms under active consideration by industry and rule makers.
- Powerlink is seeking to deliver system security services for customers in a cost effective manner.

4.1 Introduction

Queensland's electricity system has historically comprised dispatchable generation such as coal-fired generators, gas turbines and hydro-electric plants[1]. These large synchronous generating units have also provided various services to keep the power system secure. The transformation of the power system to VRE generation necessitates changes to the planning of power system security services. Planning for minimum and efficient levels of system strength and providing minimum levels of inertia in the transmission network are the focus of this chapter.

System strength relates to the stability of the voltage waveform, and is a core electrical quality that must be maintained for the safe transfer of energy from generators to consumers[2]. System strength has traditionally been provided by the electrical characteristics of coal, gas-fired and hydro-electric power generation (synchronous generation) which are electrically coupled to the power system. However, many non-synchronous generation technologies, such as large-scale solar and wind, do not inherently provide system strength because the majority to date have used grid-following inverter technology to generate electricity.

Inertia is an instantaneous rapid and automatic injection of energy to suppress sudden frequency deviations and slow the rate of change of frequency. Inertia allows a power system to resist large changes in frequency arising from an imbalance in power supply and demand due to a contingency event. Like system strength, inertia has traditionally been provided by synchronous generators, and additional remediation is needed to ensure the power system has sufficient inertia to remain secure as the power system transforms[3].

This chapter provides an overview of the frameworks for providing system strength and inertia in the National Electricity Market (NEM), and addresses requirements in the National Electricity Rules (NER)[4] 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
- the modelling methodologies, assumptions and results used by Powerlink to plan activities to meet the system strength standard
- Powerlink's forecast of the available fault level at each system strength node
- the system strength locational factor and corresponding system strength node for each connection point for which Powerlink is the Network Service Provider.

1 Queensland Government, Queensland SuperGrid Infrastructure Blueprint, September 2022, p. 9.
2 AEMC, Efficient Management of System Strength on the Power System, Final Determination, October 2021, page i.
3 AEMO, 2021 System Security Reports, December 2021, p. 18, AEMO, 2022 Inertia Report, December 2022, p. 8.
4 NER, clause 5.12.2(c)(8)(ii).

4.2 Inertia and system strength frameworks

4.2.1 Inertia

In September 2017, the Australian Energy Market Commission (AEMC) made the Managing the Rate of Change of Power System Frequency Rule (Inertia Services Rule)[5]. The Inertia Services Rule requires the Australian Energy Market Operator (AEMO) to assess whether shortfalls in inertia exist (or are likely to exist), and obliges Transmission Network Service Providers (TNSPs) to make continuously available minimum levels of inertia[6].

In June 2018, AEMO published its methodology for determining minimum and secure inertia levels, and at the same time reported that it had not identified any inertia shortfalls across the NEM for 2018[7].

In March 2023, the AEMC initiated a rule change request from the Australian Energy Council (AEC) that proposed an ancillary service spot market for inertia in the NEM to address problems arising from declining system inertia and gaps in the inertia framework. The AEMC identified three options – market-based mechanisms, structured procurement, and maintenance of the existing framework – to address the issues identified by the AEC. Given the complexity of the issue, and the potential to interplay with other critical system service reforms, the AEMC extended the timeframe for a draft determination to February 2024[8].

4.2.2 System strength

In October 2021, the AEMC introduced the Efficient Management of System Strength on the Power System Rule (System Strength Rule)[9]. The System Strength Rule:

- 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
- established a new framework for the supply, demand and coordination of system strength in the NEM.

The System Strength Rule established Powerlink as the System Strength Service Provider (SSSP) for Queensland[10]. Under the new framework, parties who submit an application to connect on or after 15 March 2023 are able to choose to remediate their system strength impact, or pay for their use of system strength resources procured by Powerlink. From 1 July 2023, system strength charges apply to connecting parties who come under this new framework and use system strength but choose not to remediate their system strength impact on the network. In March 2023, Powerlink published its 2023/24 system strength unit prices (SSUP) for each declared system strength node. The SSUPs for each node are based on long run average costs. The unit prices apply for a five year period and are indexed by the consumer price index in each of the four remaining years.

4.2.3 Security frameworks for the energy transition

In September 2022, the AEMC released a draft determination to establish an Operational Security Mechanism (OSM) to value, procure and schedule security services across the NEM in operational timeframes. The AEMC intended that AEMO would define the security services to be procured and accredit eligible participants, and that the OSM would commence on 1 October 2025. One of the expected advantages of the OSM was that it would address the over-reliance on directions by AEMO to bring generators online, which would otherwise be offline, to provide essential system services. In May 2023, the AEMC announced that it considered the OSM would be too costly and complex to implement.

In August 2023, the AEMC released a directions paper proposing what it described as a simpler solution to managing power system security. The AEMC suggested greater understanding of the engineering and technical capabilities of the power system were needed before complex market changes could be made. The key elements of the AEMC's proposed improvements to existing security frameworks were:

- improving inertia, network support and control ancillary services and non-market ancillary services (NMAS) frameworks to help ensure system security
- introducing a NEM-wide inertia floor, aligning procurement timeframes with the system strength framework, and removing restrictions on the procurement of synthetic inertia
- introducing an NMAS framework for 'transitional services' that would allow AEMO to procure services to meet system security needs to support the energy transition[11].

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5 AEMC, Managing the Rate of Change of Power System Frequency, September 2017.
6 AEMC, Managing the Rate of Change of Power System Frequency, Information Sheet, September 2017, p. 2.
7 AEMO, 2018 Inertia Requirements Methodology, June 2018, p. 3.
8 AEMC, Efficient Provision of Inertia, March 2023.
9 AEMC, Efficient Management of System Strength on the Power System, October 2021.
10 NER, clause 5.20C.3(a).
11 AEMC, Improving Security Frameworks for the Energy Transition, August 2023.

The AEMC considered its approach would allow for the procurement and scheduling of necessary security services, and avoid reliance on AEMO directing generators to be online to provide services. The AEMC's Final Determination is expected to be released in December 2023.

4.3 Activities to make inertia network services available and meet system strength standard

In December 2021, AEMO published its 2021 System Security Reports. Based on the Progressive Change scenario, AEMO identified:

- an immediate fault level shortfall at the Gin Gin system strength node of 44 to 65MVA
- an inertia shortfall of between 186 and 5,831 megawatt seconds (MWs) until 31 December 2026[12].

AEMO suggested a range of options could address system strength issues, including inverter tuning, synchronous condensers, network augmentations and contributions from existing market participants. AEMO also indicated that a variety of services would be available to meet the inertia shortfall, including inertia support activities such as fast frequency response.

In May 2022, AEMO updated its inertia assessment for the NEM to reflect the identification of the Step Change scenario as the most likely of the development scenarios for the 2022 Integrated System Plan (ISP). The update removed the previous inertia shortfall due to an improved outlook for available fast frequency control ancillary services (FCAS), but noted a potential future shortfall of 8,384 MWs remained a possibility. The update also reaffirmed the fault level shortfall, of 33 to 90MVA, at the Gin Gin system strength node[13].

Immediately following the fault level shortfall declaration, Powerlink commenced an Expression of Interest (EOI) process for short and long-term non-network solutions to the fault level shortfall at the Gin Gin node[14]. Powerlink received a number of responses to the EOI, with parties suggesting various combinations of new installations including pumped storage hydroelectric systems, synchronous generators, plant conversions to hybrid facilities, and batteries with grid-forming inverters. AEMO's 2022 System Security Report, released in December 2022, declared a system strength shortfall at the Gin Gin node of up to 64MVA until 1 December 2025, but did not declare shortfalls at Queensland's four other system strength nodes, being Greenbank, Lilyvale, Ross and Western Downs. AEMO also indicated that Powerlink was identifying solutions for the shortfall at Gin Gin, and that it had requested services be made available by March 2023[15]. Powerlink implemented operational measures to manage the shortfall until a longer term measure is delivered. Powerlink expect to publish the response to the shortfall by December 2023.

In March 2023 Powerlink commenced a Regulatory Investment Test for Transmission (RIT-T) to meet its system strength obligations from December 2025. The technical need for the RIT-T is discussed in Section 4.5, and a summary of the Project Specification Consultation Report (PSCR) is in Section 6.8.2.

4.4 System strength modelling

Although the declared shortfall was at the Gin Gin node, the shortfall location does not necessarily capture technical components of the system strength shortfall, or indicate from where the particular problem is most efficiently addressed. That is, options which address the technical power system performance issues elsewhere in Central and North Queensland may reduce or remove the fault level shortfall at the Gin Gin 275kV fault level node. Technical components of the shortfall, and the location from which it should be addressed, can only be informed through system-wide Electromagnetic Transient (EMT) type analysis.

Powerlink has developed an EMT-type model that extends from Far North Queensland to the Hunter Valley in New South Wales. It includes plant specific models for all VRE and synchronous generators (including voltage control systems) and transmission connected dynamic voltage control plant (Static VAr Compensators and STATCOMs). This allows Powerlink to quickly process generator connections and is a comprehensive model with inverter-based plant modelled at the controller level and simulation time steps in micro-seconds.

12 AEMO, 2021 System Security Reports, December 2021, pp. 42, 46.
13 AEMO, Update to 2021 System Security Reports, May 2022, pp. 7, 8, 23, 27.
14 Powerlink, Power System Security Consultations.
15 AEMO, 2022 System Strength Report, December 2022, p. 41.

Powerlink undertakes a Full Impact Assessment (FIA) or stability assessment using the system-wide EMT-type model for all VRE generation applying to connect to the Powerlink network, regardless of the size of the proposed plant. This is because only an EMT-type analysis can provide information on the impact of potentially unstable interactions with other generators and dynamic voltage control plant. Powerlink is exploring a novel method using small signal analysis to understand the impact of potentially unstable interactions with other generators. The FIA or stability assessment is carried out as part of the connection process as per AEMO's System Strength Impact Assessment Guidelines (SSIAG). This ensures that any adverse system strength impact is identified and addressed as part of the connection application.

The SSIAG provides additional details regarding the assessment process and methodology, while AEMO's Power System Model Guidelines provides additional information on modelling requirements.

4.5 Methodology, assumptions and results for the fault level and stability requirements for system strength nodes

In December 2022, AEMO published the assessment of system strength requirements in the NEM for the next 10 years to be used by SSSPs for the purposes of meeting system strength standard specification under clause S5.1.14 of the NER. This includes the minimum fault level requirement at each system strength node and requirement for stable voltage waveforms with AEMO's forecast level and type of inverter-based resources (IBR) and market network service facilities (efficient level of system strength).

As SSSP for Queensland, Powerlink is required to maintain the three phase fault level specified by AEMO for the system strength nodes in Queensland and maintain stable voltage waveforms for the level and type of IBR and market network service facilities projected by AEMO for the relevant year. The relevant year for the 2023 TAPR would be 2 December 2025 to 1 December 2026. Table 4.1 shows the system strength nodes, minimum fault level requirements and IBR forecasts to 2025/26 in Queensland.

Table 4.1 AEMO minimum fault level requirements and IBR forecasts, December 2022

Fault Level Node	Pre-contingent Minimum Fault Level (MVA)	Post-contingent Minimum Fault Level (MVA)	IBR Forecast to 2025/26 (MW)
Gin Gin (275kV)	2,800	2,250	1,438
Greenbank (275kV)	4,350	3,750	0
Lilyvale (275kV)	1,400	1,150	735
Ross (275kV)	1,350	1,175	1,204
Western Downs (275kV)	4,000	2,550	4,420
Total			**7,797**

Note:

(1) Forecast includes 3,747 MW of existing IBR.

Source: AEMO, 2022 System Strength Report, December 2022, pages 37 and 40.

The three phase fault level requirements at each node in Queensland in 2025/26 (the relevant year) is unchanged. At the time of 2023 TAPR, two hydro machines in North Queensland, seven coal-fired synchronous machines in Central Queensland and four coal-fired synchronous machines in Southern Queensland provide the minimum fault level requirements in Queensland, noting that sources of minimum fault level can change as the system evolves.

In March 2023 Powerlink commenced a RIT-T to identify a portfolio of solutions to meet the minimum and efficient levels of system strength (Section 6.8.2). It is expected that non-network solutions will materially contribute to the provision of system strength services through a range of technology solutions. To meet the minimum system strength requirements identified by AEMO the PSCR indicated the following investment would be necessary:

- Seven synchronous machines or equivalent plant online in Central Queensland, in the order of 350MVA each
- Two hydro-electric machines or equivalent plant in North Queensland, in the order of 20MVA each
- Four synchronous machines or equivalent plant online in Southern Queensland, in the order of 400MVA each.

AEMO's forecast of VRE and Battery energy storage systems (BESS), as at December 2022, is approximately 12.5GW by 2030 and approximately 17.5GW by 2033. Powerlink mapped its market intelligence of connection applications and enquiries against the forecast provided by AEMO. The forecast capacity for 2025 and a significant part of 2030 in each system strength node was mapped against the current applications, providing confidence in the forecast size and location of the generation plants. Existing experience in Queensland indicates that assumptions of system strength requirements based primarily on the fault level calculations can differ from the detailed assessment and therefore can be misleading. Powerlink performed detailed EMT studies to understand the required system strength support, in addition to the minimum level, to host the total 12.5GW of VRE generation.

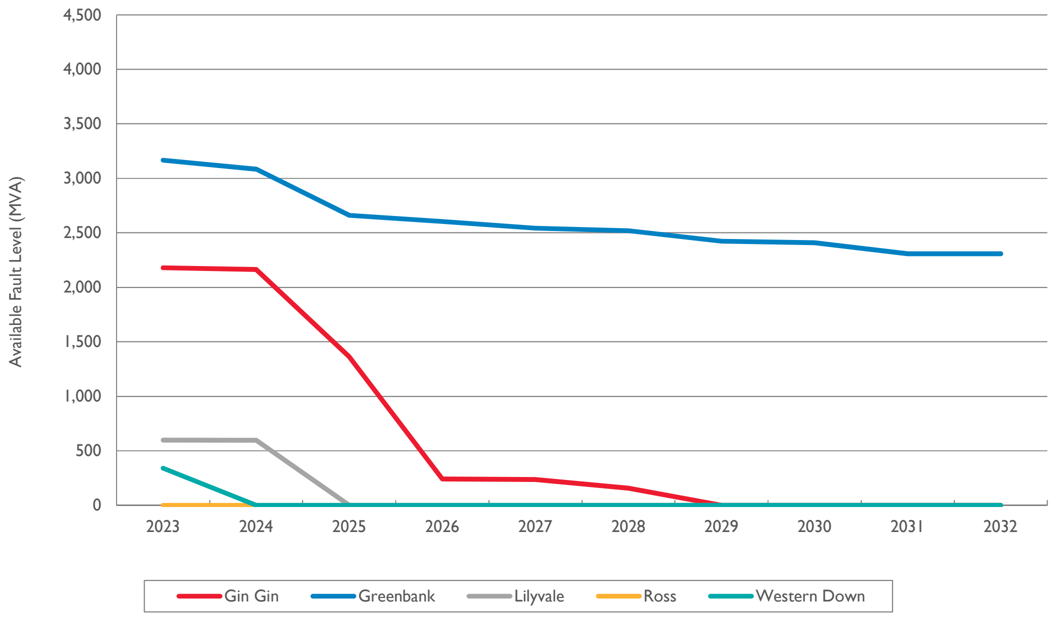
Results from studies indicated that additional system strength support equivalent of four 200MVA synchronous condensers would be required to maintain the stable voltage waveform with 12.5GW of VRE. Studies also confirmed that grid-forming BESS could provide the necessary system strength support to obtain the stable voltage waveform. Experience and studies for stable voltage waveform requirements indicate that required system strength is a function of the inverters connected and also the MW generated by the VRE.

The 2030 VRE forecast consists of more than 80% of wind farms and less than 20% of solar farms. Therefore, system strength requirements for day time and night time were assessed separately. Studies indicated night time system strength requirements were also sufficient during day time.

4.6 Available fault level at each system strength node

Figure 4.1 shows the Available Fault Level (AFL) at each system strength node.

Figure 4.1 Available Fault Level (AFL)



The AFLs at each node were calculated as per the SSIAG. Calculation of AFL works in such a way that it will reduce as more VRE is connected in the region. The above AFL is based on the minimum fault level as the source of the efficient level of system strength for future VRE connection is not confirmed at the time of publication of this report. It should be noted that while it is a requirement of the NER to publish the AFL to provide an indication of available system strength in the region[16], experience in Queensland has been that AFL does not reflect the available quantity of system strength required to maintain stable voltage waveforms. The highest amount of VRE is forecast at Western Downs in AEMO's report and therefore the AFL at Western Downs becomes zero very early. However, the actual requirements for system strength support at Western Downs does not follow the trend of AFL and therefore the SSUP at Western Downs is the lowest in Queensland.

[16] NER, clause 5.20C.3(f)(3).

4.7 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 Network Service Provider, and the corresponding system strength node[17]. System strength locational factors and nodes are included in Appendix H and shown in the TAPR portal.

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