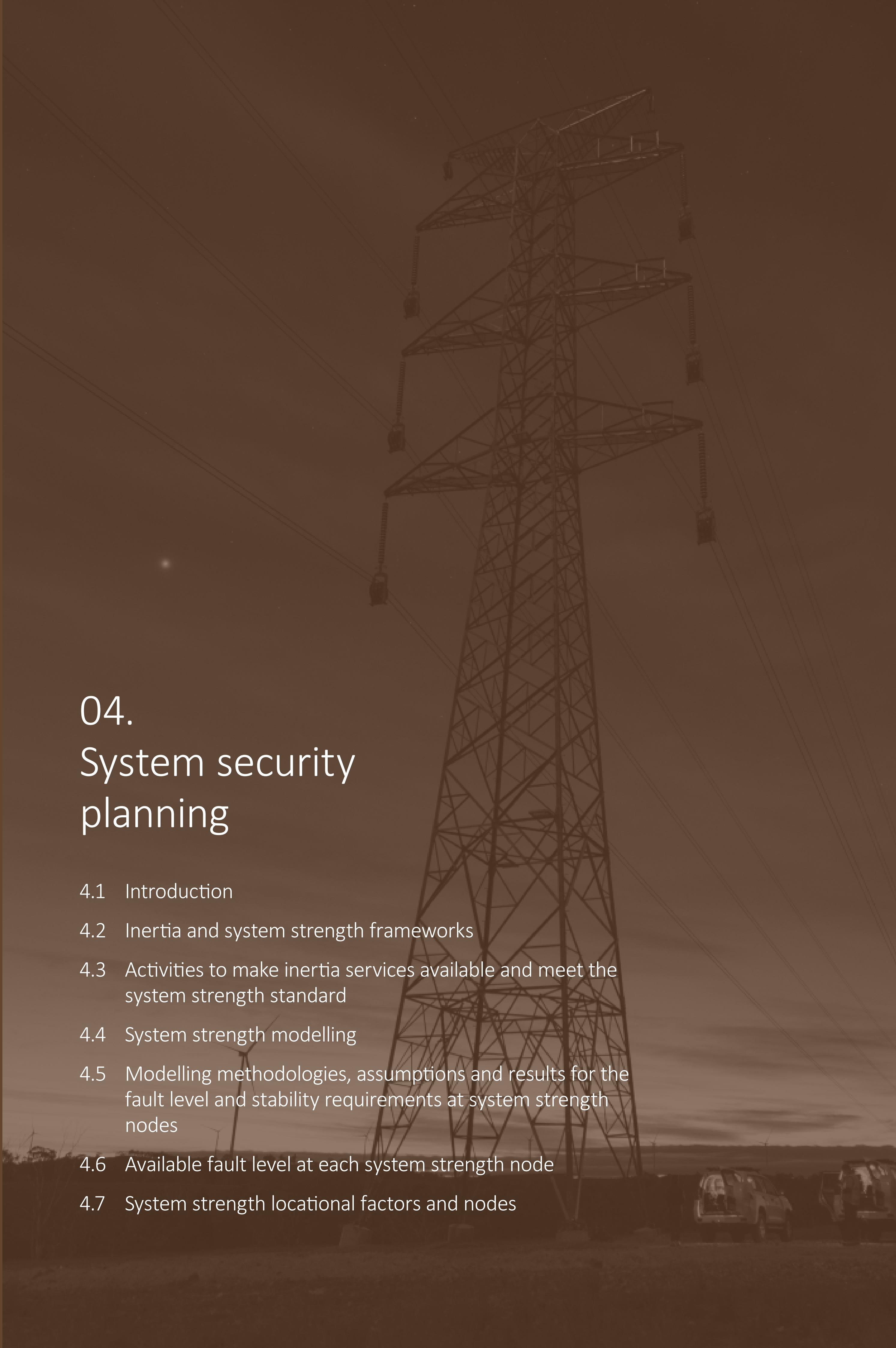

04. System security planning

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 delivery of essential system services in Queensland.

Key highlights

- 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 the planning and delivery of system security services.
- Significant changes to power system security frameworks have been made in recent years.
- Powerlink is seeking to deliver system security services for customers in a cost effective manner.

4.1 Introduction

Queensland's power system has historically comprised dispatchable generation such as coal-fired generators, gas turbines and hydro-electric plants. These large synchronous generating units have inherently provided various services, such as voltage regulation, inertia and system strength, to maintain power system security. 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. The transformation of the power system to VRE generation necessitates new approaches to the planning and delivery of 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 can broadly be described as the ability of the power system to maintain and control the voltage waveform at any given location in the power system, both during steady state operation and following a disturbance[1]. System strength has traditionally been provided by conventional forms of generation, not because of their fuel source (such as coal, gas and hydro) but because of their 'synchronous' design.

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[2].

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) 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;
- the system strength locational factor and corresponding system strength node for each connection point for which Powerlink is the Network Service Provider[3].

[1] AEMO, System Strength Requirements Methodology, version 2.0, December 2022, p. 6.
[2] AEMO, 2021 System Security Reports, December 2021, p. 18; AEMO, 2022 Inertia Report, December 2022, p. 8.
[3] NER, Clause 5.12.2(c)(8)(ii), which references Powerlink's obligations as the inertia and system strength service provider for Queensland under clauses 5.20B.4(h) and (i), and 5.20C.3(f) and (g), of the NER.

4.2 Inertia and system strength frameworks

The Australian Energy Market Operator (AEMO) and Powerlink are responsible for the planning and delivery of power system security services in Queensland. AEMO's System Security Reports consider the need for services in Queensland, and other regions of the NEM, over a five to ten year horizon. The reports assess system strength requirements, inertia shortfalls and Network Support and Control Ancillary Services (NSCAS) needs. Where AEMO declares a gap/shortfall for a power system security service(s) in Queensland, Powerlink is obliged to make services available within the timeframe stipulated by AEMO.

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). 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[4].

AEMO's most recent Inertia Report, released in December 2023, changed the identified inertia shortfall in Queensland from a range of 8,200 to 10,352 megawatt seconds (MWs) from 1 July 2026, to up to 1,660MWs from 2027/28. The one-year delay reflected updates to the delivery timing of several major generation, transmission and Renewable Energy Zone (REZ) development projects which resulted in utilisation of synchronous generation increasing in the near term. AEMO also indicated that the changed assessment represented a deferred onset of the shortfall, rather than a long-term reduction[5].

Powerlink is taking a prudent approach as to the timing of the commencement of the RIT-T consultation process to meet the declared inertia shortfall. Powerlink is currently progressing a system strength RIT-T (refer to Section 4.3). Given the potential for system strength solutions to contribute to inertia, the preferred option for Powerlink's system strength RIT-T (Section 4.3) may address, either in part or in full, the timing and size of the inertia shortfall.

4.2.2 System Strength

In December 2021, AEMO declared an immediate system strength shortfall of 44 to 65 megavolt-amperes (MVA) at the Gin Gin 275 kilovolt (kV) system strength node for the period 2021/22 to 2026/27, against the minimum (postcontingency) three phase fault level of 2,250MVA at the node[6]. AEMO declared the shortfall as it projected a decline in the number of synchronous generators online in Central Queensland in response to declining minimum demand and increasing VRE and distributed solar photovoltaic (PV) generation[7]. AEMO declared the shortfall on the basis that it forecast system strength services would fall below the minimum requirements for more than 1% of the time under typical dispatch patterns[8].

In May 2022, AEMO updated the declaration to account for its replacement of the Progressive Change scenario with the Step Change scenario for the 2022 Integrated System Plan. The update increased the size of the shortfall at Gin Gin from 33MVA in 2022/23 to 90MVA in 2026/27[9]. AEMO's System Strength Reports released in December 2022 and December 2023 stated that the shortfall at the Gin Gin node was 64MVA until 1 December 2025, at which time new requirements for the provision of system strength services would commence[10].

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4 AEMC, Managing the Rate of Change of Power System Frequency, information sheet, September 2017, p. 2; NER, clauses 4.3.4(j) and 5.20B.4(b).

5 AEMO, 2022 Inertia Report, December 2022, p. 22; AEMO, 2023 Inertia Report, December 2023, p. 14.

6 AEMO, 2021 System Security Reports, December 2021, pp. 42 and 49.

7 AEMO, 2021 System Security Reports, December 2021, p. 42. The declaration was made under Clause 5.20C.2 (Fault Level Shortfalls) of the NER, as in force at the time. Transitional arrangements in Clause 11.143.13(a)(1) of the NER to support the Efficient Management of System Strength on the Power System Rule required Powerlink to continue to comply with the declaration.

8 AEMO, 2021 System Security Reports, December 2021, pp. 11 and 102.

9 AEMO, Update to 2021 System Security Reports, May 2022, p. 23.

10 AEMO, 2022 System Strength Report, December 2022, p. 41; AEMO, 2023 System Strength Report, December 2023, pp. 28 and 56.

Although the fault level shortfall declared by AEMO 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) type analysis.

Powerlink was required to use reasonable endeavours to make system strength services available to AEMO by 31 March 2023, being the date by which AEMO requested Powerlink provide the services[11]. Immediately following the fault level shortfall declaration, Powerlink commenced an Expression of Interest process for short and long-term non-network solutions to the fault level shortfall at the Gin Gin node[12].

Only one of the four options was able to commence operation by 31 March 2023. However, this solution would not have provided a material increase in system strength at the Gin Gin node to address the required need. Of the three remaining options, Powerlink concluded the addition of a clutch to the shaft between the gas turbine and the synchronous generator at the Townsville Power Station was the least cost option to address the need. The Townsville Power Station is owned by Ratch Australia (Ratch), and Powerlink has entered into a System Strength Services Agreement with Ratch for the provision of system strength services. The addition of the clutch is expected to be delivered by mid-2025. Powerlink expects that operation of the Townsville Power Station as either a generator or as a synchronous condenser will provide sufficient system strength for inverter-based generation facilities in North and Central Queensland to operate stably from mid-2025. In December 2023 AEMO provided its approval of the arrangements to Powerlink, as required under the NER[13]. Powerlink published a final report on the response to the shortfall at the Gin Gin node in January 2024.

In October 2021, the AEMC introduced the Efficient Management of System Strength on the Power System Rule (System Strength Rule). 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 ; and
- established a new framework for the supply, demand and coordination of system strength in the NEM[14].

The System Strength Rule established Powerlink as the System Strength Service Provider (SSSP) for Queensland[15]. 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. The System Strength Unit Prices for each node are based on long run average costs. The prices apply for a five-year period and are indexed by the consumer price index in each of the four remaining years.

In December 2022, AEMO published the first System Strength Report under the evolved framework. The report set out the minimum pre- and post-contingent fault levels, and 10-year forecast of inverter-based resources (IBR) for each of Queensland's five system strength nodes to be used by Powerlink for the purposes of meeting system strength standard specification under Clause S5.1.14 of the NER[16].

4.2.3 Improving Security Frameworks for the Energy Transition

In March 2024, the AEMC made the Improving Security Frameworks for the Energy Transition Rule (ISFET Rule) which aimed to enhance arrangements to value, procure and schedule system security services – which includes system strength, inertia and Network Support and Control Ancillary Services – in the NEM.

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11 AEMO, Update to 2021 System Security Reports, May 2022, page 23. The reasonable endeavours requirement was in Clause 5.20C.3(c)(1) of the NER when the shortfall was declared, and is now in Clause S5.1.14(b) of the NER.

12 National Electricity Rules, Clause 5.20C.3(e).

13 National Electricity Rules, Clause 5.20C.4(e).

14 AEMC, Efficient Management of System Strength on the Power System, Final Determination, October 2021, p. 13.

15 NER, Clause 5.20C.3(a).

16 AEMO, 2022 System Strength Report, December 2022, pp. 37 and 40.

Among other things, the ISFET Rule will align the system strength and inertia procurement frameworks from December 2024, with Powerlink required to ensure sufficient inertia is continuously available to meet projected inertia needs for Queensland from December 2027. The ISFET Rule also included transitional provisions to preserve Powerlink's obligation to address the already-declared shortfall[17].

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

In March 2023, Powerlink commenced a RIT-T to address system strength requirements in Queensland from December 2025. The RIT-T is a key part of Powerlink's implementation of the System Strength Rule. In the Project Specification Consultation Report (PSCR), Powerlink invited submissions from proponents who considered they could offer a potential non-network solution(s) that was both technically and economically feasible by 2030. In response to the PSCR, Powerlink received close to 80 unique non-network solutions from more than 20 proponents.

Submissions on the PSCR were due in July 2023, meaning the Project Assessment Draft Report (PADR) was due for publication in July 2024 unless a longer period was agreed by the Australian Energy Regulator (AER). Given the complexity and scale of the System Strength RIT-T, in April 2024 Powerlink requested, and the AER agreed to, an extension of the date by which the PADR was to be published to November 2024.

4.4 System strength modelling

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 is a comprehensive model with inverter-based plant modelled at the controller level and simulation time steps in micro-seconds. The model allows Powerlink to conduct system strength assessments for generator connections.

Powerlink undertakes a Full Impact Assessment (FIA) or stability assessment using the systemwide 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 Modelling methodologies, assumptions and results for the fault level and stability requirements at system strength nodes

In December 2023, AEMO reviewed minimum system strength requirements in each region of the NEM. The report did not change the minimum pre or post-contingent fault levels for system strength nodes in Queensland from the 2022 System Strength Report, but did include estimates of the typical levels of fault level available. In this context, AEMO noted that 'typical' referred to the 99th percentile of availability[18].

17 NER, Clause 11.168.9.
18 AEMO, 2023 System Strength Report, December 2023, p. 10.

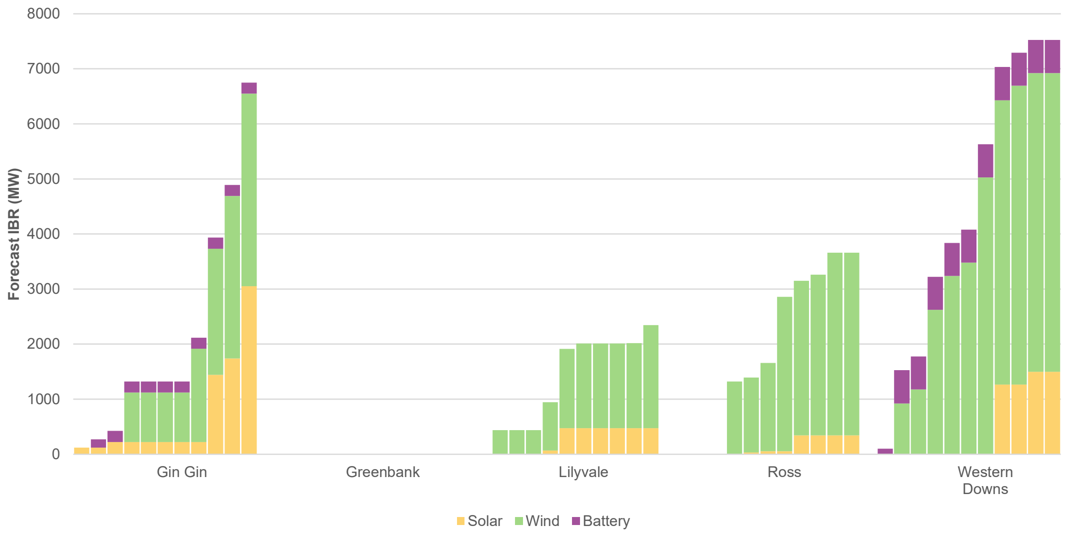
As SSSP for Queensland, Powerlink is required to maintain the three phase fault level specified by AEMO for the system strength nodes in Queensland and maintain stable voltage waveforms for the level and type of IBR and market network service facilities projected by AEMO for the relevant year. The relevant year for the 2023 TAPR would be 2 December 2025 to 1 December 2026. Table 4.1 shows, for each system strength nodes, the pre- and post-contingent minimum fault level, and minimum fault level expected 99% of the time from 2023/24 to 2028/29.

Table 4.1 AEMO minimum three phase fault level expected 99% of the time, December 2023

Node	Pre-contingent minimum fault level (MVA)	Post-contingent minimum fault level (MVA)	Minimum three phase fault current (MVA) expected 99% of the time, financial year ending					
			2024	2025	2026	2027	2028	2029
Gin Gin	2,800	2,250	2,192	2,201	2,201	2,195	2,083	2,093
Greenbank	4,350	3,750	4,642	4,590	4,679	4,626	3,126	3,205
Lilyvale	1,400	1,150	1,172	1,182	1,183	1,179	1,146	1,149
Ross	1,350	1,175	1,327	1,321	1,336	1,332	1,306	1,300
Western Downs	4,000	2,550	2,858	2,830	2,863	2,843	2,112	2,144

The 2023 System Strength Report also included updated IBR projections for Queensland over the 11-year period from 2023/24.

Figure 4.1 AEMO 11-year forecast of level and type of IBR at system strength nodes, December 2023



Note: Forecasts excluded existing IBR.

Source: AEMO, 2023 System Strength Report, page 27.

The three phase fault level requirements at each node in Queensland in 2025/26 (the relevant year) is unchanged. At the time of 2024 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. To meet the minimum system strength requirements identified by AEMO, the PSCR indicated that the following sources would be necessary in each region:

- 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 2023, is approximately 16.6GW by 2030 and approximately 25GW by 2034. The 2030 VRE forecast consists of more than 70% of wind farms and less than 30% of solar farms. Existing experience in Queensland indicates that assumptions of system strength requirements based primarily on the three phase fault level calculations can differ from the detailed assessment and therefore can be misleading.

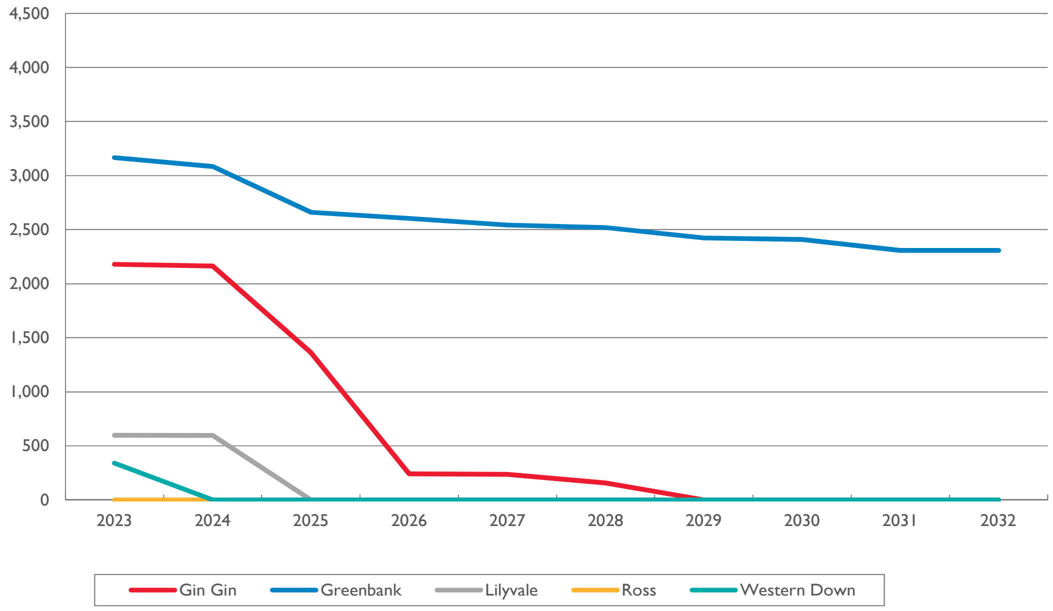
As part of the System Strength RIT-T Powerlink mapped its market intelligence of connection applications and enquiries against the forecast provided in AEMO's System Strength Report. Subsequently, Powerlink performed detailed EMT-type studies to assess system strength requirements, focussing on both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

The findings from the studies indicated that additional system strength resources will be necessary in specific regions of North, Central, and South Queensland to ensure stable voltage waveforms as the integration of VRE into the network increases. The studies also confirmed that grid-forming BESS could provide the efficient level of system strength for future VRE connections. Powerlink anticipates that grid-forming BESS will play a vital role in the future power system to obtain the stable voltage waveform support.

4.6 Available fault level at each system strength node

Figure 4.2 shows the Available Fault Level (AFL) at each system strength node.

Figure 4.2 Available Fault Level



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, 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 System Strength Unit Prices (SSUP) at Western Downs is the lowest in Queensland.

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.[19] System strength locational factors and nodes are included in Appendix H and shown in the TAPR portal.

19 NER, Clause 5.12.2(c)(13).