AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Notice of Queensland System Strength Requirements and Ross Fault Level Shortfall

April 2020

A report for the National Electricity Market

Important notice

PURPOSE

This report is a notice of AEMO's determination of system strength requirements for the Queensland region and assessment of a fault level shortfall at the Ross fault level node in Queensland, for the purposes of clauses 5.20C.1 and 5.20C.2(c) of the National Electricity Rules (NER). It has been prepared by AEMO using studies performed using information available at 3 April 2020.

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VERSION CONTROL

Version	Release date	Changes
1.0	9/4/2020	Initial release

Executive summary

System strength is a critical requirement for a stable and secure power system. A minimum level of system strength is required for the power system to remain stable under normal conditions and to return to a steady state condition following a system disturbance. System strength relates to the power system voltage waveform and, among other things, can impact the stability and dynamics of control systems used in inverter-based resources[1]. Under the National Electricity Rules (NER), system strength is represented by the three-phase fault level at designated fault level nodes.

This document determines the minimum system strength requirements in the Queensland region of the NEM and notifies a fault level shortfall at the new Ross node.

Determination of Queensland system strength requirements including Ross fault level node

AEMO has applied the System Strength Requirements Methodology[2] (Methodology) to determine the Queensland fault level nodes and their minimum three phase fault levels for 2020. These replace the 2018 system strength requirements for the region, and are listed in Table 1.

The most significant change in the system strength requirements since 2018 is the replacement of the Nebo 275 kilovolt (kV) fault level node with the Ross 275 kV node. In consultation with Powerlink, AEMO has determined that Ross 275 kV is a better representation for system strength conditions in North Queensland compared to Nebo 275 kV, because it:

- is electrically closer to the smaller gas-fired and hydro synchronous generation in North Queensland, and
- has a higher level of inverter-connected generation connections nearby.

Fault level shortfall assessment including Ross fault level node

AEMO has assessed whether there is or is likely to be a fault level shortfall in the Queensland region, and a forecast of the period over which any fault level shortfall might exist.

As a result of its assessment, AEMO declares an immediate fault level shortfall of 90 megavolt-amperes (MVA) at the Ross 275 kV fault level node. AEMO projects that, if not addressed, this fault level shortfall will continue beyond 2024-25.

Addressing the shortfall will allow the network's operational requirements to be met and ensure the stable operation of inverter-connected resources. The declaration of this shortfall does not remove the need for generators (when applicable) to mitigate their impact on system strength.

Next steps

This report constitutes AEMO's notice of a fault level shortfall assessment for the Ross node in Queensland under the NER. The NER places responsibility to ensure that system strength services are available to address the fault level shortfall on the System Strength Service Provider, defined as the transmission network service provider (TNSP) or jurisdictional planning body for the region. Powerlink has this role in Queensland.

[1] AEMO, *System strength in the NEM explained*, March 2020, at https://aemo.com.au/-/media/files/electricity/nem/system-strength-explained.pdf?la=en.

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

In accordance with clause 5.20C.2(c) of the NER, AEMO specifies 31 August 2021 as the date by which Powerlink should ensure that the necessary system strength services to address the fault level shortfall are available.

This report does not address system strength relating to any generation connections, market network service facilities, and alterations to generation systems which are subject to system strength remediation requirements. For those developments, AEMO and the relevant network service provider must consider system strength as part of the connection or alteration process. The System Strength Impact Assessment Guidelines[3] provide more information about treatment of system strength in the NEM.

AEMO is continuing to actively monitor the system strength outlook for Queensland. A number of market and other changes could affect future system strength requirements, such as the operational behaviour of coal-fired power plants in the Queensland region, or any unexpected retirement of synchronous generation units in Queensland.

Table 1 Queensland 2020 fault level nodes, minimum three phase fault levels and fault level shortfalls (megavolt-amperes [(MVA])

Fault level node	2020 minimum fault level (MVA) (Post-contingency)	Projected fault level shortfall
Gin Gin 275 kV	2,250	No
Greenbank 275 kV	3,750	No
Lilyvale 132 kV	1,150	No
Ross 275 kV	1,300	New shortfall declared
Western Downs 275 kV	2,550	No

[3] AEMO, *System strength impact assessment guidelines*, Effective 1 July 2018, at https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/system-security-market-frameworks-review.

Contents

Tables

Figures

1. Background

On 19 September 2017, the Australian Energy Market Commission (AEMC) introduced new rules in the National Electricity Rules (NER) for managing system strength[4]. Under rule 5.20C:

- AEMO must determine where the fault level nodes are in each region, plus the minimum three phase fault levels and any projected fault level shortfalls at those fault level nodes.
- Transmission network service providers (TNSPs) or jurisdictional planning bodies, as the System Strength Service Providers for each region, are responsible for procuring system strength services to meet a fault level shortfall declared by AEMO.
- These services must be made available by a date nominated by AEMO which is at least 12 months from the declaration of the shortfall, unless an earlier date is agreed with the System Strength Service Provider.

In Queensland, Powerlink is the responsible System Strength Service Provider in its capacity as Queensland transmission TNSP and jurisdictional planning body.

In July 2018, AEMO published the *System Strength Requirements Methodology and System Strength Requirements & Fault Level Shortfalls*[5], followed in December 2018 by the 2018 *National Transmission Network Development Plan* (NTNDP)[6]. These reports included initial assessments of system strength requirements across the National Electricity Market (NEM) and identified no immediate shortfalls for Queensland.

AEMO considers system strength as part of its ongoing national transmission planning work. This work has revealed a need to determine changes to the system strength requirements in Queensland.

In this document, AEMO is publishing these requirements for 2020 and its current assessment of fault level shortfalls in Queensland for the five-year outlook to 2024-25. AEMO publishes this document under clauses 5.20C.1 and 5.20C.2 of the NER. This document has been prepared consistent with clause 5.20.6 of the draft Integrated System Plan (ISP) Rules[7].

Evolving power system needs

In recent years, significant new inverter-based generation resources have been connected to parts of the long and weakly interconnected North Queensland network. Power system security relies on many services that have historically been provided by thermal synchronous generation. New technologies and approaches to these services will be required as the power system continues to transform.

The outlook for system strength is expected to change as the Queensland power system continues to transform. This document declares a fault level shortfall at the newly-determined Ross fault level node in North Queensland. Additional shortfalls may be declared as AEMO continues to study the power system.

Treatment of system strength

System strength is the ability of the power system to maintain the voltage waveform at any given location, with and without a disturbance[8]. This includes resisting changes in the magnitude, phase angle, and shape of the voltage waveform.

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[4] AEMC, *Managing power system fault levels*, accessed March 2020, at https://www.aemc.gov.au/rule-changes/managing-power-system-fault-levels.

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

[6] AEMO, *2018 National Transmission Network Development Plan*, December 2018, at https://www.aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp/national-transmission-network-development-plan-ntndp.

[7] Energy Security Board, *Consultation on Draft ISP Rules*, November 2019, at http://www.coagenergycouncil.gov.au/publications/consultation-draft-isp-rules.

[8] AEMO, *System strength in the NEM explained,* March 2020, at https://aemo.com.au/-/media/files/electricity/nem/system-strength-explained.pdf?la=en.

A strong voltage waveform enables inverter-based resources connected to the power system to remain stable under normal conditions and to return to a steady state condition following a system disturbance.

System strength can be considered low in areas with low levels of available fault current. Presently, areas with increasing volumes of inverter-based generation require more available fault level to enable stable operation to be maintained. It is envisaged that future technology improvements will enhance inverter-based resources' capability in this regard.

The increasing integration of inverter-based resources across the NEM has implications for the engineering design of the future transmission system. As clusters of inverter-based resources connect in proximity, they are now required to remediate their impact on system strength. In addition, TNSPs are required to ensure a minimum level of fault current is always available at each fault level node across their networks, in accordance with the system strength requirements determined by AEMO.

Division of responsibilities for provision of system strength

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

- AEMO is required to determine the location and system strength requirements of fault level nodes across the NEM and identify whether a shortfall is likely to exist at any node in the future. For each fault level node, the minimum three phase fault level is determined and used as the basis for assessing system strength.
- The regional TNSP responsible for planning and directing augmentation of the electricity transmission network is required to ensure that system strength services are available to address any fault level shortfall declared by AEMO at a fault level node. In declaring a shortfall, AEMO nominates the date for which the regional TNSP should make adequate system strength services available.
- Generators subject to the system strength remediation requirements must implement or fund system strength remediation, if necessary, to ensure that its connection (or altered connection) does not have an adverse impact on system strength. This is assessed in accordance with AEMO's *Interim System Strength Impact Assessment Guidelines*[9] and *System Strength Impact Assessment Guidelines*[10] as relevant.

2. Revised system strength requirements

AEMO has applied the *System Strength Requirements Methodology*[11] to determine the system strength requirements for the Queensland region as at March 2020. In summary, a new fault level node is determined at Ross 275 kilovolt (kV) bus, the Nebo 275 kV bus is no longer a fault level node, and an updated set of minimum three phase fault levels are calculated for each node.

Fault level nodes

The fault level nodes for Queensland remain the same as those determined in 2018, except for the replacement of the Nebo 275 kV node with the Ross 275 kV node. The fault level nodes are listed in Table 2.

[9] AEMO, *Interim System Strength Impact Assessment guidelines*, November 2017, at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/interim-system-strength-impact-assessment-guidelines-published.pdf.

[10] AEMO, *System Strength Impact Assessment Guidelines*, Effective 1 July 2018, at https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/system-security-market-frameworks-review.

[11] AEMO, *System Strength Requirements Methodology*, July 2018, at https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/system-security-market-frameworks-review.

The Ross 275 kV node is now considered to be a better representation for system strength conditions in North Queensland compared to the Nebo 275 kV node, because it:

- is electrically closer to the smaller gas-fired and hydro synchronous generation in North Queensland, and
- has a higher level of inverter-connected generation connections nearby.

Table 2 Fault level nodes for Queensland region

Fault level nodes class	Fault level node
Metropolitan load centre	Greenbank 275 kV
Synchronous generation centre	Western Downs 275 kV Gin Gin 275 kV
Areas with high inverter-connected[A] (asynchronous) generation	Ross 275 kV Lilyvale 132 kV
Areas electrically remote from synchronous generation	Ross 275 kV Lilyvale 132 kV

A. The 2018 System Strength Methodology refers to this class as 'areas with high asynchronous generation connection/interest'. The term "inverter-connected" is used here for clarity and to align with other AEMO documentation. The meaning and interpretation of the class has not changed since the publication of the 2018 methodology.

Minimum three phase fault levels

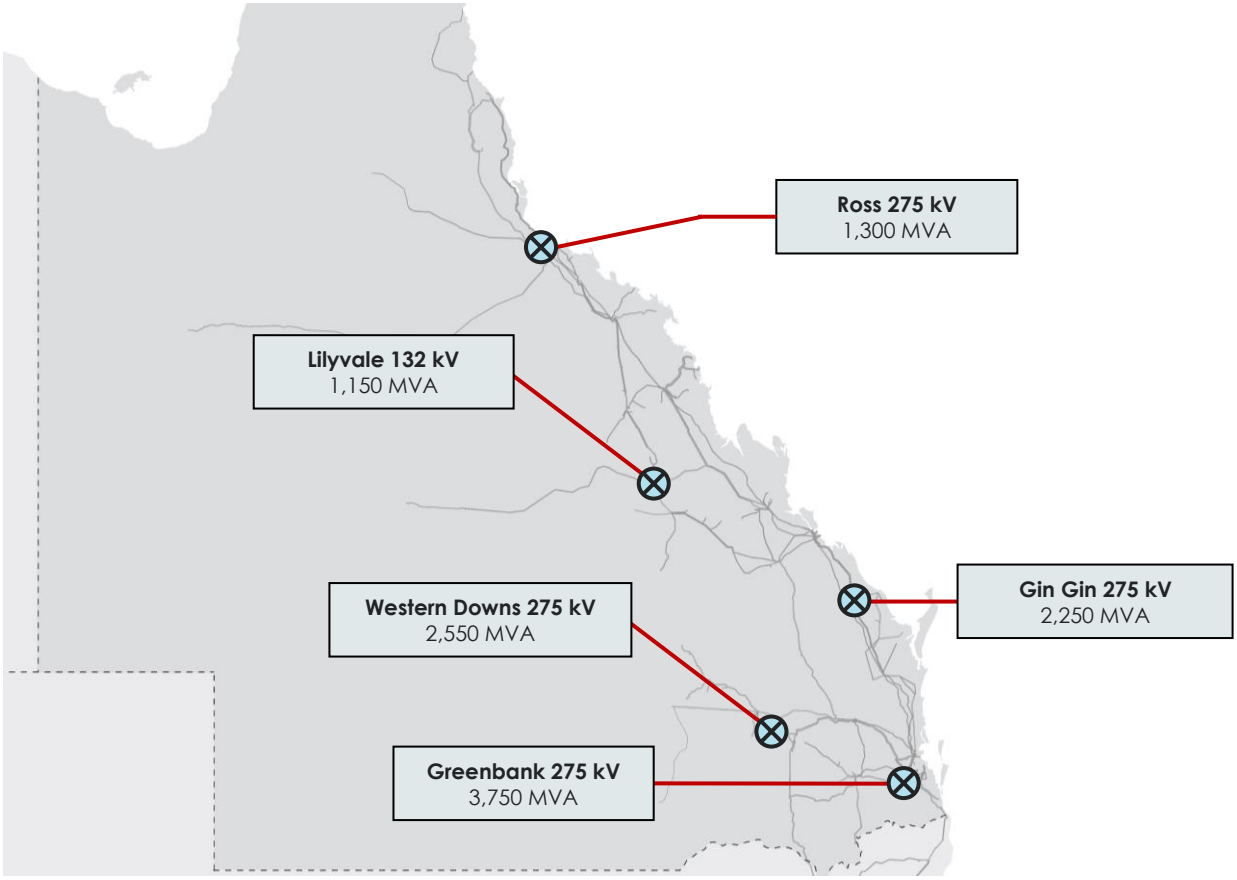
The 2020 minimum three phase fault levels have been determined for all of the Queensland fault level nodes. AEMO carried out detailed electromagnetic transient (EMT) analysis to determine these system strength requirements for the Queensland region, using the study inputs and assumptions detailed in Appendix A1. Using the outcomes from these studies (for example, minimum required synchronous generator combinations), AEMO calculated a new minimum three phase fault level of 1,300 megavolt-amperes (MVA) at the Ross 275 kV fault level node.

The updated minimum three phase fault levels for the Queensland fault level nodes are provided in Table 3 and Figure 1 below.

Table 3 2020 fault level nodes and minimum three phase fault levels

Region	Fault level node	2020 minimum fault level (MVA) (Post-contingency)
Queensland	Gin Gin 275 kV	2,250
	Greenbank 275 kV	3,750
	Lilyvale 132 kV	1,150
	Ross 275 kV	1,300
	Western Downs 275 kV	2,550

Figure 1 Queensland system strength (fault level) requirements



3. System strength outlook for Queensland

This chapter sets out AEMO's system strength outlook for Queensland. Section 3.1 provides the projected fault levels for each node for the five-year outlook. Section 3.2 provides AEMO's assessment of any projected fault level shortfalls, finding that a new fault level shortfall exists now for the Ross node.

3.1 Projected fault levels

Figures 2 to 6 show the fault level requirement and projected fault levels for each of the fault level nodes in the Queensland region.

Fault levels have been projected by using the dispatch outcomes from the Draft 2020 *Integrated System Plan* (ISP) Central scenario market modelling results[12]. Projections for industrial load consumption, embedded generation uptake, and utility-scale generation operational behaviour are subject to significant uncertainty.

[12] The 2020 draft ISP and supporting documents are at https://www.aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp.

Figure 2 Projected Gin Gin 275 kV fault level duration curves

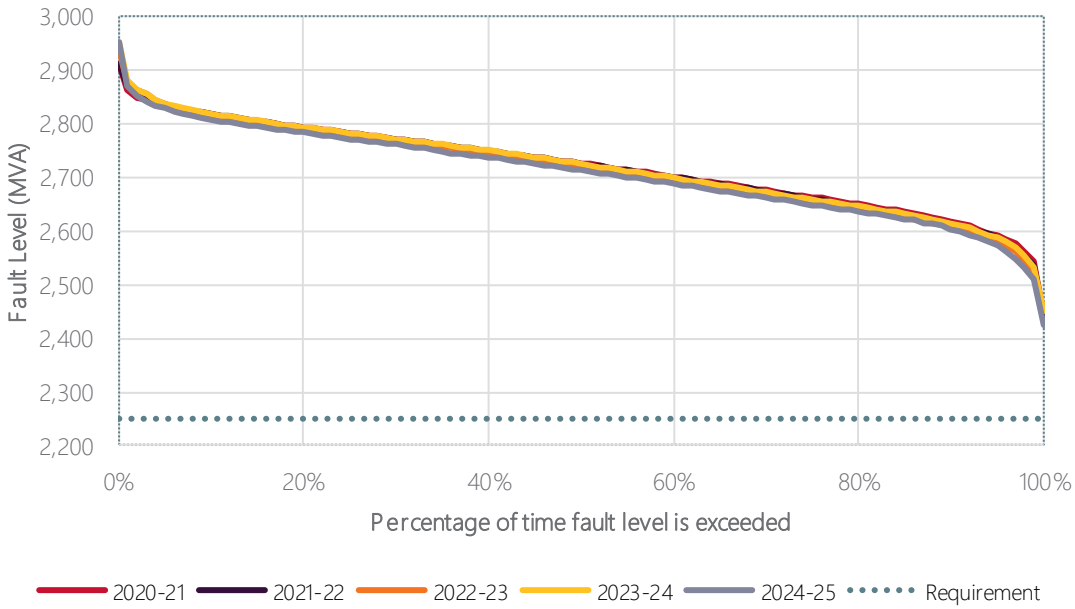


Figure 3 Projected Greenbank 275 kV fault level duration curves

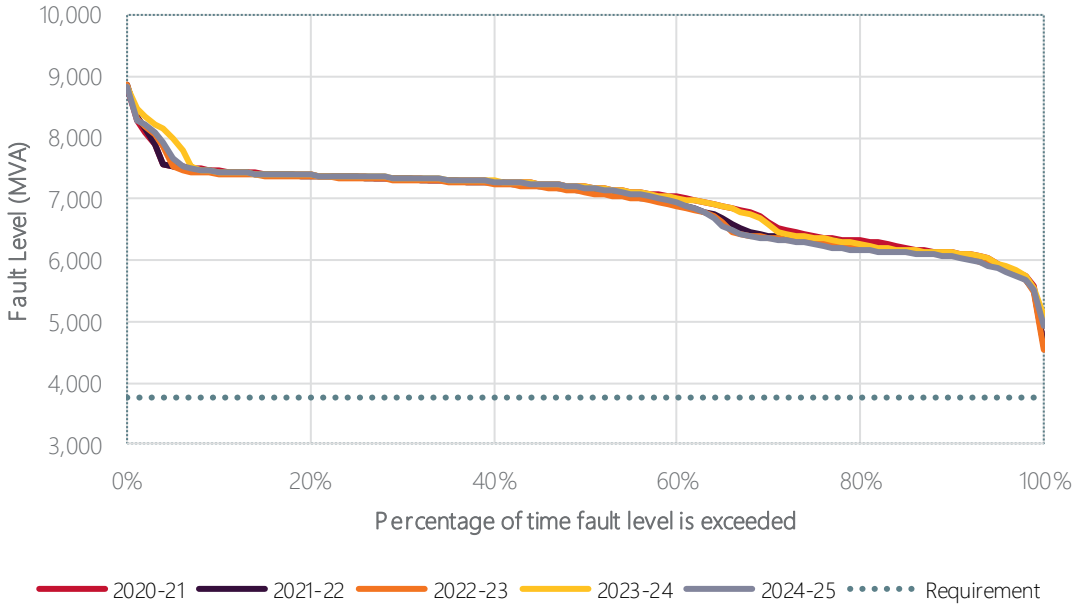


Figure 4 Projected Lilyvale 132 kV fault level duration curves

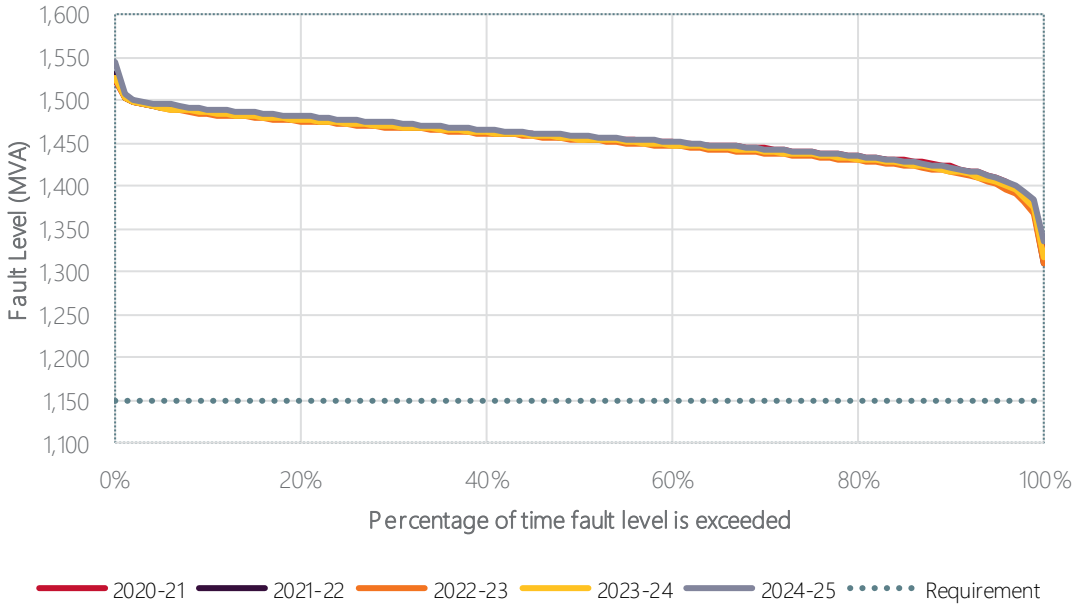


Figure 5 Projected Ross 275 kV fault level duration curves

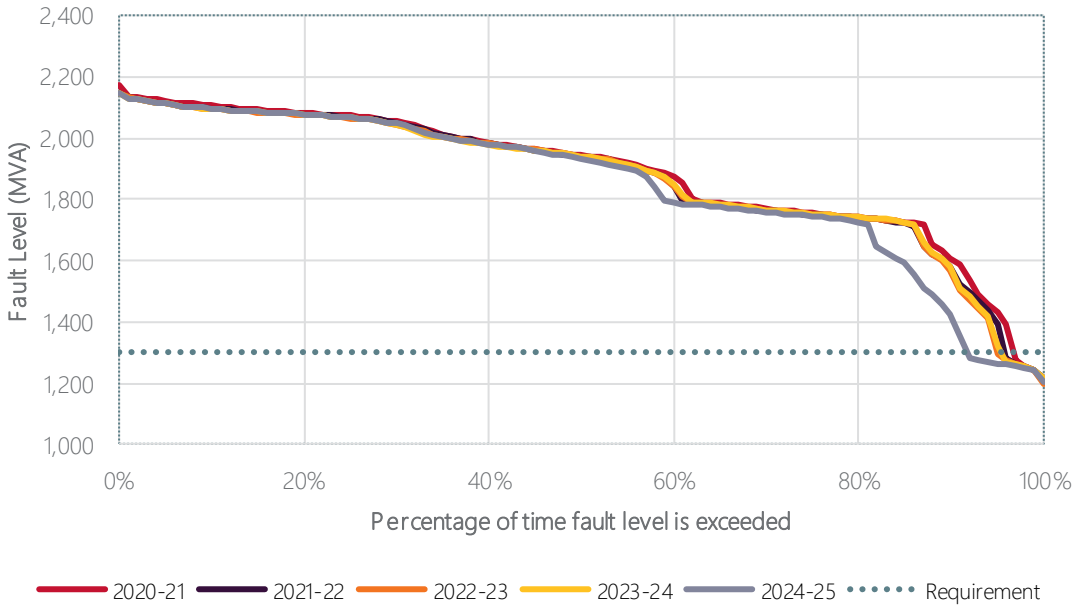
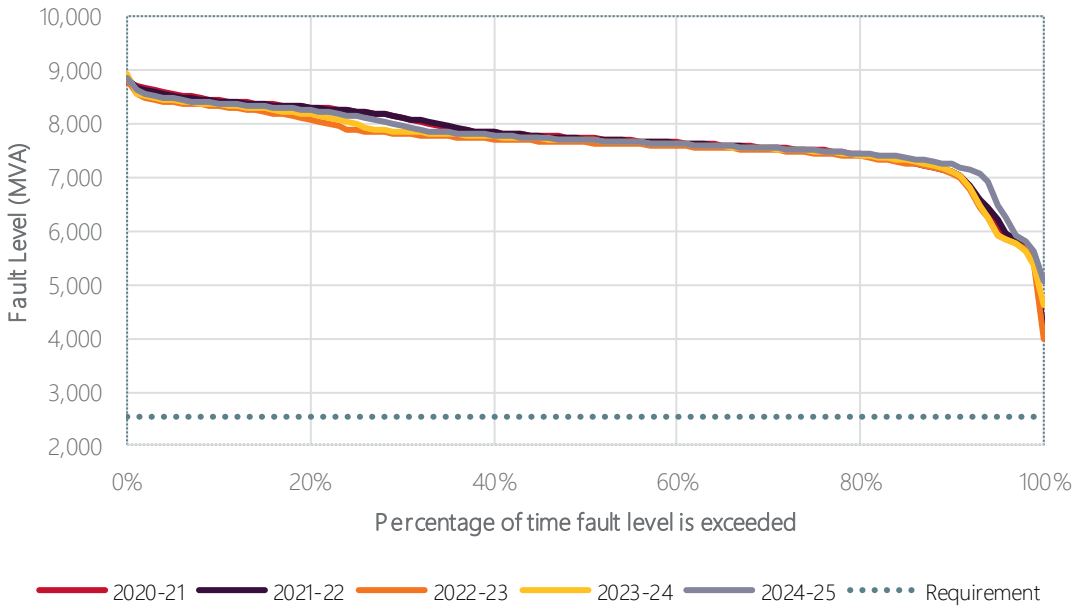


Figure 6 Projected Western Downs 275 kV fault level duration curves



3.2 Fault level shortfall assessment

Ross 275 kV node

Based on the fault level projections in Section 3.1, AEMO assesses there is an immediate 90 MVA fault level shortfall at the Ross 275 kV fault level node in North Queensland. Fault levels at Ross are projected to be lower than the minimum three phase fault level requirement for at least 5% of the time. AEMO projects this fault level shortfall at Ross 275 kV will continue beyond 2024-25.

Sufficient system strength is required to ensure the stable operation of inverter-connected resources. Finding system strength services to address the shortfall will require detailed EMT studies in order to appropriately consider the complex interactions between various power system plant and their impact on system strength. These studies will need to account for uncertainty and variability by identifying an appropriate operating margin to be incorporated in the delivery of the system security services, in line with industry best practice and in agreement with AEMO.

Consistent with the NER this shortfall declaration considers system intact operating conditions. Prior outages of network elements can be dealt with by applying constraints on the output of inverter-based generation.

Table 4 provides the details of the Ross node projected fault level shortfall.

Other fault level nodes

Based on the fault level projections in Section 3.1, AEMO has not identified shortfalls at the other Queensland fault level nodes.

Table 4 Ross node projected system strength shortfall to 2025

Financial year	Ross 275 kV node fault level shortfall (MVA)
2020-21	90
2021-22	90
2022-23	90
2023-24	90
2024-25	90

Notes:

1. This shortfall has been calculated on the assumption that the available fault level at the Ross 275 kV bus will need to be at or above the minimum three phase fault level (post-contingency) for 99% of the time.
2. This shortfall is based on one projection of future fault level requirements over the five-year horizon and a specific set of modelling assumptions, and may not account for the impact of changes in the underlying network.
3. In order to ensure system strength requirements are met at the Ross node, an appropriate operating margin would need to be considered and incorporated, in line with industry best practice and in agreement with AEMO.

4. Next steps

Date for resolution

Under NER clause 5.20C.2(c)(2), AEMO is required to publish and notify the date by which the System Strength Service Provider must ensure the availability of system strength services to address the fault level shortfall.

AEMO has asked Powerlink to make system strength services available to address the fault level shortfall at Ross 275 kV bus at the earliest practicable opportunity. Powerlink and AEMO have agreed that the services should be in place by 31 August 2021.

Responsibility for resolution

The local TNSP, Powerlink, is responsible for ensuring that the system strength services are made available to address the shortfall.

Ongoing monitoring

This assessment of a fault level shortfall at the Ross node has been completed with present models available to AEMO and known parameters as of 3 April 2020.

A1. PSCAD modelling and study setup

AEMO has conducted EMT studies of the Queensland power system using the PSCAD product. This modelling includes detailed models of synchronous generators from major coal-fired, gas-fired, and hydro power stations in Queensland. Only inverter-based plants not subject to the system strength remediation requirements were considered in this requirement determination.

The sections below detail the contingencies considered in the studies, the assessment methodology for the studies and the ultimate finding about minimum three phase fault level at the Ross 275 kV bus.

A1.1 Contingencies considered in the studies

Screening of North and Central Queensland credible contingencies for transmission lines, generators and flexible alternating current transmission devices (FACTS) were performed. From this screen, it was identified that the worst-case contingency could vary, dependent on synchronous machine dispatch. As such, the fault screening was repeated periodically, but the following were the most frequent worst-case contingencies and were the focus of the system strength assessment of the North Queensland network.

- Contingency 1 – Two phase to ground fault (2ph-G) and disconnection of Broadsound – Stanwell 275 kV line, cleared within primary protection time.
- Contingency 2 – Two phase to ground fault (2ph-G) and disconnection of Nebo – Strathmore 275 kV line, cleared within primary protection time.
- Contingency 3 – Two phase to ground fault (2ph-G) and disconnection of Ross Static Var Compensator (SVC), cleared within primary protection time.
- Contingency 4 – Two phase to ground fault (2ph-G) and disconnection of Strathmore SVC, cleared within primary protection time.
- Contingency 5 – Two phase to ground fault (2ph-G) and disconnection of Kareeya Power Station units 2 and 4 due to 132 kV transformer trip, cleared within primary protection time.
- Contingency 6 – Two phase to ground fault (2ph-G) and disconnection of Townsville Power Station line, if Townsville Power Station is in service, cleared within primary protection time.
- Contingency 7 – Two phase to ground fault (2ph-G) and disconnection of Mount Stuart Power Station line, if Mount Stuart Power Station is in service, cleared within primary protection time.

A full-scale EMT model of the entire Queensland network was developed and used to study the North Queensland system strength. As some network phenomena can propagate significant distances, South and Central Queensland network and generation was also represented. This revealed that Central Queensland synchronous generators have a significant impact on system strength and required fault levels at the Ross node.

Success criteria

The success criteria used in the fault level shortfall assessment studies are outlined below.

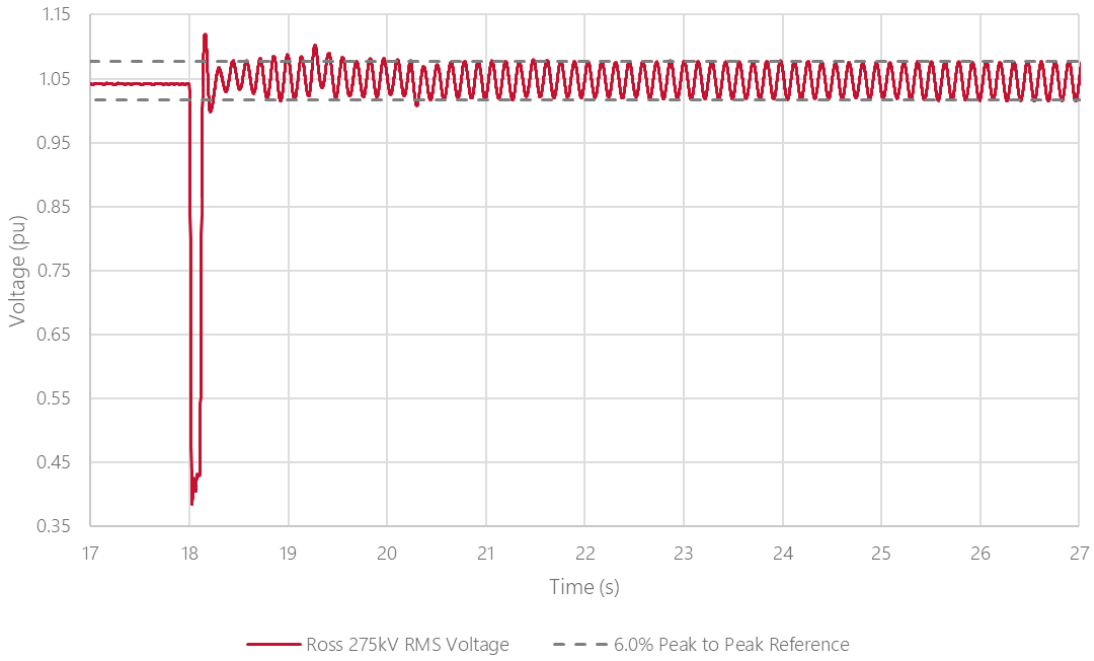
- Generators, as well as Queensland to New South Wales interconnectors, remain online.

- All online generators return to steady-state conditions[13] following fault clearance.
- The power system frequency is restored to within the normal operating frequency band (49.85-50.15 hertz [Hz]).
- Post fault voltage oscillations are adequately damped.

Manifestation of low system strength at Ross

AEMO's large-scale power system stability analysis identified the risk of voltage oscillations following a single credible contingency in North Queensland under system intact conditions. For such a contingency, the magnitude and duration of the oscillations exceed allowable stability limits under the NER and power system stability guidelines, and network standards for quality of supply. An example of these voltage oscillations is illustrated in Figure 7.

Figure 7 Example of North Queensland voltage oscillations



A1.2 Assessment methodology

A1.2.1 Determine minimum synchronous generation

To determine the size of the required fault level and therefore the fault level shortfall, different synchronous machine options were considered in North Queensland, in addition to a combination of synchronous generators in Central Queensland.

A1.2.2 Successful synchronous machine scenarios

The base case system scenario was set up to include different combinations of synchronous generation in Central and North Queensland, comprising units dispatched more than 99% annually. For each scenario, a range of contingencies were tested (as outlined in A1.1).

Building on the base case, several credible scenarios were developed which modelled additional synchronous machine options. The size and location of the additional synchronous machine options was based on

[13] Unless they are tripped as a part of the contingency.

practical considerations and verified in modelling to ensure stable operation for the same range of contingencies. The post-contingent minimum three phase fault level was then determined.

A1.3 Minimum three phase fault level requirement at Ross

Based on these studies, and the present fault level observed in the system, AEMO identified that the minimum three phase fault level (post-contingency) requirement at the Ross 275 kV bus is 1,300 MVA.