Notice of South Australia Inertia Requirements and Shortfall

August 2020

A report for the National Electricity Market

Important notice

PURPOSE

AEMO publishes this document under rule 5.20B of the National Electricity Rules (NER)..

DISCLAIMER

This document or the information in it may be subsequently updated or amended. This document does not constitute legal or business advice, and should not be relied on as a substitute for obtaining detailed advice about the National Electricity Law, the National Electricity Rules, or any other applicable laws, procedures or policies. AEMO has made every effort to ensure the quality of the information in this document but cannot guarantee its accuracy or completeness.

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

- make no representation or warranty, express or implied, as to the currency, accuracy, reliability or completeness of the information in this document; and
- are not liable (whether by reason of negligence or otherwise) for any statements or representations in this document, or any omissions from it, or for any use or reliance on the information in it.

VERSION CONTROL

Version	Release date	Changes
1.0	27/8/2020	Initial release

Executive summary

Inertia is a fundamental property of power systems that stabilises power system frequency. Power systems with high inertia can resist larger changes in frequency arising from an imbalance in power supply and demand caused by a contingency event. Conversely, lower levels of inertia increase the susceptibility of the power system to rapid changes in frequency.

Under the National Electricity Rules (NER), AEMO is obliged to calculate inertia requirements in each region of the National Electricity Market (NEM). This document determines the inertia requirements in the South Australia region and notifies an inertia shortfall in the region.

Determination of South Australia region inertia requirements

AEMO has applied the Inertia Requirements Methodology[1] to determine the 2020 inertia requirements in South Australia. These replace the 2018 inertia requirements[2]. The updated requirements reflect:

- Findings from the South Australia islanding events in early 20203.
- Anticipated levels of distributed photovoltaics (PV) affecting the potential daytime contingency event size.
- The implications of declining minimum daytime demand in the region[4].

Table 1 summarises the 2020 inertia requirements and compares them to the 2018 requirements.

While the minimum threshold level of inertia remains at 4,400 megawatt-seconds (MWs), the secure operating level of inertia requirement has changed. In current and forecast power system conditions, without more fast frequency response (FFR), the inertia required to operate South Australia securely as an island is calculated to be at least 7,605 MWs in 2020-21 and 14,390 MWs in 2021-22. Installing the quantity of synchronous machines needed within South Australia to meet this requirement is not feasible.

Recognising practical, technical, and economic realities, AEMO has therefore determined the secure operating level of inertia for South Australia based on an assumption that the Inertia Service Provider will undertake inertia support activities involving provision of some level of fast frequency response (FFR), or equivalent amounts of additional FFR will be made available for network support on a basis that enables AEMO to determine a reduced inertia shortfall.

For transparency, in this report, the secure operating level of inertia requirement is expressed as a combination of synchronous inertia and FFR. The possible operating points span a number of combinations of MWs of synchronous inertia paired with megawatts (MW) of FFR.

---

1 AEMO, Inertia Requirements Methodology Inertia Requirements and Shortfalls, July 2018, at https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-security-market-frameworks-review/2018/inertia_requirements_methodology_published.pdf.

2 AEMO, Inertia Requirements Methodology Inertia Requirements and Shortfalls, July 2018, at https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-security-market-frameworks-review/2018/inertia_requirements_methodology_published.pdf.

3 AEMO, Preliminary Report – Victoria and South Australia Separation Event 31 January 2020, April 2020, at https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2020/preliminary-report-31-jan-2020.pdf?la=en.

Also South Australia islanded via a credible contingency on 2 March 2020, see Market Notice 74613, at https://aemo.com.au/en/market-notices?marketNoticeQuery=74613&marketNoticeFacets=.

4 AEMO, Renewable Integration Study Stage1 Appendix A: High Penetrations of Distributed Solar PV, p36, April 2020, at https://aemo.com.au/-/media/files/major-publications/ris/2020/ris-stage-1-appendix-a.pdf?la=en.

Table 1 2020 inertia requirements for the South Australia region of the NEM

Requirement specifics	2018 inertia requirements	2020 inertia requirements		
	Secure (MWs)	Minimum (MWs)	Secure (MWs, and MW of FFR)	Minimum (MWs)
Stage 1. Current period with no synchronous condensers in South Australia	6,000	4,400	Combination of synchronous inertia and FFR shown in Figure 2[A].	4,400
Stage 2. After four synchronous condensers are installed in South Australia[B]	-	-	Combination of synchronous inertia and FFR shown in Figure 3[B].	4,400

A. The amount of FFR required is in addition to the minimum synchronous inertia level requirement and can be partially substituted with additional inertial services from synchronous generating units.
B. ElectraNet expects to complete installation of the synchronous condensers (fitted with flywheels) by mid-2021.

Determination of inertia shortfall

AEMO has assessed whether there is, or is likely to be, an inertia shortfall in the South Australia region. As a result of this assessment, AEMO declares an immediate inertia shortfall in South Australia. The shortfall changes between 2020-21 (Stage 1) and 2021-22 (Stage 2), because the inertia requirements are forecast to change as the distributed PV uptake forecast increases and because the minimum number of synchronous generators assumed to be online after synchronous condensers are installed in the South Australian transmission network will reduce, along with associated primary frequency response. .

The Stage 1 and Stage 2 secure operating level of inertia requirements have been expressed as relationships between different levels of FFR and synchronous inertia. Table 2 and Table 3 show the different shortfall levels that exist at different levels of available FFR. Positive numbers in green indicate no shortfall.

Table 2 Inertia shortfalls at different levels of FFR for Stage 1 secure operating level of inertia, adjusted for inertia support activities

Year	Secure operating level of inertia (SOLI) adjusted for inertia support activities, FFR/inertia combinations					
	Inertia support activities (FFR) (MW)	40	70	90	115	120
2020-21	Inertia shortfall (MWs)	-2,644	-1,744	-896	No shortfall	No shortfall

Table 3 Inertia shortfalls at different levels of FFR for Stage 2 secure operating level of inertia, adjusted for inertia support activities

Year	Secure operating level of inertia (SOLI) adjusted FFR/inertia combinations							
	SOLI FFR (MW)	70	123	150	175	200	210	211
2021-22	Inertia shortfall (MWs)	-8,190	-4,950	-3,360	-1,900	No shortfall	No shortfall	No shortfall

The calculation of inertia requirements – including the quantity of FFR that would be required to reduce the secure operating level of inertia – is inherently uncertain because the requirements will change as the power system develops. AEMO will actively liaise with ElectraNet, as the Inertia Service Provider, to assess the relative contributions of proposed inertia support activities (or FFR that may be made available for network support on a basis that permits AEMO to determine a reduced shortfall).

AEMO has not determined definitive inertia requirements and inertia shortfalls beyond 2021-22 due to high levels of uncertainty regarding the impact of distributed PV beyond this timeframe. Given new FFR capacity can be built without a long lead time if needed (utility-scale batteries can be built within 12 months), AEMO considers it prudent to continue to monitor the distributed PV situation and calculate inertia requirements and identify any inertia shortfalls beyond 2021-22 in future assessments when inputs are more certain.

AEMO considers it very likely that no inertia shortfalls will be declared in South Australia following any commissioning of a second double circuit AC interconnector to South Australia such as Project EnergyConnect. This is because the likelihood of the South Australia region of the NEM being islanded would be significantly reduced.

Next steps

The NER place the responsibility to procure services to address shortfalls in inertia on the local Inertia Service Provider, subject to AEMO determining the requirements and declaring a shortfall, and agreement being reached on when these services must be procured by. ElectraNet is the Inertia Service Provider in South Australia.

This report constitutes AEMO's notice of these assessments and formal declaration of shortfalls under the NER. AEMO has requested from ElectraNet that the required services for Stage 1 be made available from 1 October 2020. AEMO has agreed with ElectraNet that the required services for Stage 2 will be made available from 31 July 2021.

In the meantime, to the extent possible, operational arrangements will continue to be used to securely operate the South Australia power system if it is islanded.

Contents

Tables

Figures

1. Introduction

1.1 Purpose and scope

This document provides updated inertia requirements and shortfalls for the South Australia region of the National Electricity Market (NEM). AEMO publishes this document under clauses 5.20B.2 and 5.20B.3 of the National Electricity Rules (NER).

1.2 Related documents

AEMO published its Inertia Requirements Methodology and the initial inertia requirements for each region of the NEM in July 2018[5]. The 2018 inertia requirements considered the state of the power system at the time of publication and were not forward-looking.

AEMO subsequently declared an inertia shortfall in South Australia in December 2018, in its 2018 National Transmission Network Development Plan (NTNDP)[6].

ElectraNet is installing four synchronous condensers to meet a system strength (fault level) shortfall in South Australia that AEMO declared in an October 2017 update to its 2016 NTNDP[7], and the synchronous condensers will also be fitted with flywheels in order to provide inertia network services.

1.3 The need for inertia

Inertia is a fundamental property of the interconnected power system that gives stability to power system frequency, especially following a contingency event that affects the supply-demand balance.

In a power system, inertia and frequency deviations are closely related. Power systems with high inertia can resist larger changes in frequency arising from a contingency event leading to an imbalance in supply and demand. Conversely, lower levels of inertia may increase the susceptibility of the power system to rapid changes in frequency.

Synchronous machines, including synchronous condensers fitted with flywheels, inherently contribute to total system inertia. Where suitably designed, non-synchronous generation technology can provide a fast frequency response (FFR) that can reduce the need for inertia. AEMO's Inertia Requirements Methodology published in 2018 explains that available FFR in a region can reduce the inertia requirements[8]. This 2020 Inertia Report accounts for the existing FFR available to support the South Australian network, and specifically considers how additional FFR capability can reduce inertia requirements for the region.

1.4 Operation of South Australia island

When operating as an island, South Australia has to source all its system security needs locally, including voltage control, system strength, inertia, and frequency control. Of these, system strength and voltage control are location-specific, whereas inertia and frequency control can be sourced from anywhere within the islanded system.

---

[5] AEMO, Inertia Requirements Methodology Inertia Requirements and Shortfalls, July 2018, at https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-security-market-frameworks-review/2018/inertia_requirements_methodology_published.pdf.

[6] AEMO, 2018 National Transmission Network Development Plan, at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/ntndp/2018/2018-ntndp.pdf.

[7] AEMO, Second Update to the 2016 National Transmission Network Development Plan, October 2017, at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/ntndp/2017/second_update_to_the_2016_ntndp.pdf?la=en&hash=A9EE910B7DA3C1D88927871630C02B48.

[8] AEMO, Inertia Requirements Methodology and 2018 Inertia Requirements and Shortfalls, Appendix G, at https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-security-market-frameworks-review/2018/inertia_requirements_methodology_published.pdf.

Until recently, synchronous generation has been the key source of frequency control, but grid-scale battery energy storage systems are now being increasingly used for this purpose.

Batteries can provide an FFR service that responds to frequency change several times faster than synchronous generation. On the other hand, the physical inertia provided by a synchronous machine arrests the rate of change of frequency (RoCoF) immediately following a contingency event.

The capabilities provided by synchronous generation and batteries (or other FFR providers) therefore complement each other, collectively assisting to maintain the frequency within the required bands during islanding conditions. AEMO's studies have indicated the need for both synchronous generation and FFR during islanding conditions, as reflected in its current operational practices (for example, when operating South Australia as an extended island between 31 January and 17 February 2020[9]).

To maximise the capability of batteries in responding to frequency disturbances, a battery would need to maintain sufficient state-of-charge and be curtailed in readiness to provide full frequency response following load or generation loss.

Some modern wind and solar farms are capable of providing similar response if they are pre-curtailed under islanding conditions to provide both active power raise and lower services.

1.5 Report structure

In this report, Section 2 provides the updated South Australia inertia requirements for 2020-21 and 2021-22, Section 3 provides AEMO's assessment of inertia shortfalls in South Australia within the period, and Section 4 covers next steps.

[9] AEMO. Preliminary Report – Victoria and South Australia Separation Event, 31 January 2020, at https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2020/preliminary-report-31-jan-2020.pdf.

2. Inertia requirements

AEMO has applied the Inertia Requirements Methodology[10] to determine the updated inertia requirements for the South Australia region. The updated requirements reflect findings from the South Australia islanding events in early 2020[11], anticipated levels of embedded generation, and the implications of declining minimum demand in the region[12].

Table 4 summarises the 2020 inertia requirements and compares them to the 2018 requirements. While the minimum threshold level of inertia remains at 4,400 megawatt-seconds (MWs), the secure operating level of inertia requirement has changed. In current and forecast power system conditions, without more FFR, the inertia required to operate South Australia securely as an island would exceed 7,605 MWs in 2020-21 and 14,390 MWs in 2021-22. Installing the quantity of synchronous machines needed within South Australia to meet this requirement is not feasible.

Recognising practical, technical, and economic realities, AEMO has therefore determined the secure operating level of inertia for South Australia based on an assumption that the Inertia Service Provider will undertake inertia support activities involving provision of some level of FFR, or equivalent amounts of additional FFR will be made available for network support on a basis that enables AEMO to determine a reduced inertia shortfall. For transparency, in this report, the requirement is expressed as a combination of synchronous inertia and FFR. The possible operating points span a number of combinations of MWs of synchronous inertia paired with MW of FFR.

Table 4 2020 inertia requirements for the South Australia region of the NEM

Requirement specifics	2018 inertia requirements		2020 inertia requirements	
	Secure (MWs)	Minimum (MWs)	Secure (MWs, and MW of FFR)	Minimum (MWs)
Stage 1. Current period with no synchronous condensers in South Australia	6,000	4,400	Combination of synchronous inertia and FFR shown in Figure 2[A].	4,400
Stage 2. After four synchronous condensers are installed in South Australia[B]	-	-	Combination of synchronous inertia and FFR shown in Figure 3[B].	4,400

A. The amount of FFR required is in addition to the minimum synchronous inertia level requirement and can be partially substituted with additional inertial services from synchronous generating units.
B. ElectraNet expects to complete installation of the synchronous condensers (fitted with flywheels) in the first half of 2021.

Section 2.1 notes the types of inertia requirements, Section 2.2 describes the current South Australia situation, and Section 2.3 notes the assumptions applied when assessing the 2020 requirements.

The 2020 requirements are provided in Section 2.4.2 for the period before the synchronous condensers are installed, and in Section 2.4.3 for the period after they are installed.

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

[11] AEMO, Preliminary Report – Victoria and South Australia Separation Event 31 January 2020, April 2020, at https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2020/preliminary-report-31-jan-2020.pdf?la=en. Also South Australia islanded via a credible contingency on 2 March 2020; see Market Notice 74613, at https://aemo.com.au/en/market-notices?marketNoticeQuery=74613&marketNoticeFacets=.

[12] AEMO, Renewable Integration Study Stage1 Appendix A: High Penetrations of Distributed Solar PV, p36, April 2020, at https://aemo.com.au/-/media/files/major-publications/ris/2020/ris-stage-1-appendix-a.pdf?la=en.

2.1 Types of inertia requirements

The inertia requirements determined by AEMO must include two different levels of inertia:

1. The **minimum threshold level of inertia** is the minimum level of inertia required to operate an islanded region in a satisfactory operating state.
2. The **secure operating level of inertia** is the minimum level of inertia required to operate the islanded region in a secure operating state.

AEMO can agree adjustments to the minimum threshold level of inertia or the secure operating level of inertia if inertia support activities (such as the provision or procurement of FFR) will result in lower levels of synchronous inertia being necessary to meet system security requirements[13].

2.2 Major projects in South Australia

Two major projects are underway or under consideration which will affect the South Australia inertia requirements or the potential for inertia shortfalls in South Australia over time.

Synchronous condensers with flywheels

ElectraNet is preparing to install four synchronous condensers fitted with flywheels into the South Australia electricity transmission system, which will provide the minimum threshold level of inertia of 4,400 MWs. Two of the synchronous condensers are scheduled for installation in the second half of 2020, and the remaining two by mid-2021.

The four synchronous condensers, fitted with flywheels, were approved[14] to address the system strength shortfall declared in the South Australia region in 2017[15] as well as provide 4,400 MWs of synchronous inertia towards meeting the inertia shortfall declared for the region on 21 December 2018[16].

The flywheels will increase the levels of inertia in the system but, unlike synchronous generation, synchronous condensers are not capable of providing an active power response to correct frequency deviations (which would in turn reduce the overall requirement for inertia).

Interconnection with New South Wales

The proposed new transmission interconnection between the South Australia and New South Wales regions (Project EnergyConnect) is currently pending regulatory assessment as a contingent project, with possible commissioning from 2023. Inertia requirements are calculated assuming islanding is credible or has occurred, and therefore will not be affected by commissioning of Project EnergyConnect.

However, as required by the NER, AEMO must consider the inertia available in adjoining inertia sub-networks and the likelihood of islanding when assessing whether there is an inertia shortfall. The risk of South Australia islanding will be substantially reduced if a second double-circuit AC interconnector is operational. Based on expected system conditions in the next five years, it is therefore likely that no inertia shortfalls would be declared in South Australia following any commissioning of a second double circuit AC interconnector to South Australia such as Project EnergyConnect. This is because the likelihood of the South Australia region of the NEM being islanded would be significantly reduced.

The inertia requirements determined in this report cover two stages – Stage 1 is for financial year 2020-21 with no synchronous condensers installed, and Stage 2 is financial year 2021-22 after the four synchronous

[13] Refer to NER 5.20B.5.

[14] Australian Energy Regulator, Final Decision ElectraNet SA system strength contingent project, August 2019, at https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/contingent-projects/electranet-main-grid-system-strength-contingent-project

[15] AEMO, South Australia System Strength Assessment, September 2017, at https://www.aemo.com.au/-/media/Files/Media_Centre/2017/South_Australia_System_Strength_Assessment.pdf.

[16] AEMO, National Transmission Network Development Plan, December 2018, at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/ntndp/2018/2018-ntndp.pdf.

condensers are installed. Inertia requirements beyond 2021-22 have not been formally determined due to uncertainty of inputs, as discussed in detail in Section 2.4.3.

2.3 Assumptions used to assess inertia requirements

The inertia requirements determined in this report are derived from modelling of the ability to meet the existing frequency operating standards after a large credible contingency event occurs while the South Australia region is islanded.

Section 2.3.1 notes the credible contingency event assumptions applied, and Section 2.3.2 notes the treatment of the emerging role for FFR.

2.3.1 Credible contingency events

The credible contingency events assumed for the South Australia inertia requirements analysis have been updated since the previous assessment in 2018[17].

This assessment considers a fault causing coincident tripping of net distributed photovoltaics (PV)[18] and load as well as trip of the largest generator in the region, during times when distributed PV output is high. The update reflects the impact that disconnection of embedded generation (particularly distributed PV) can have on the network in the daytime at times of low demand on the network.

The ability to operate the South Australian network securely is being challenged with these larger contingency sizes. As part of determining how best to address the inertia requirements in South Australia, AEMO and the relevant South Australian organisations may also consider opportunities to mitigate the size of the contingency events. AEMO and ElectraNet will also continue to analyse the appropriate maximum contingency sizes that can be expected and should be planned for[19].

Contingencies studied to determine secure operating level of inertia adjusted for inertia support activities

Table 5 and Table 6 show the critical contingency events accounted for in determining the 2020 South Australia inertia requirements and shortfall declaration. The most onerous credible contingency during daylight hours is a fault causing disconnection of a synchronous generating unit in Adelaide metropolitan area (metro) and coincident tripping of distributed PV[20] and metro loads. More distributed PV than load trips, causing a net increase in the total loss of generation for the contingency event. Studies assumed all synchronous generating units are dispatched approximately 20 MW above their minimum load requirements, such that they can provide both raise and lower frequency response.

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

[18] The term 'net distributed PV and load' is used to refer to the net impact seen by the grid from PV systems and loads behind the meter.

[19] AEMO, Renewable Integration Study Stage1 Appendix A: High Penetrations of Distributed Solar PV, p36, April 2020, at https://aemo.com.au/-/media/files/major-publications/ris/2020/ris-stage-1-appendix-a.pdf?la=en.

[20] "Distributed PV" includes all grid-connected solar installations that are not part of central dispatch. This includes "Rooftop PV" defined as systems up to 100 kW in size, and "PV non-scheduled generators" defined as systems between 100 kW and 30 MW.

Table 5 Daytime contingency sizes assumed in the 2020 inertia requirements assessment

Stage	Synchronous generator (MW)	Net PV – load disconnection (MW)	Total (MW)
Stage 1. Current period with no synchronous condensers in South Australia	65[A]	100[B]	165
Stage 2. After four synchronous condensers are installed in South Australia	65[A]	150[B]	215

A. Trip of a Torrens Island B unit, generating approximately 20 MW above minimum operating level, to minimise contingency size while having 20 MW of lower frequency control ancillary services (FCAS) available.
B. Amount of distributed PV minus distributed load assumed to trip due to the fault that trips the synchronous generator.

Table 6 Night-time contingency sizes assumed in the 2020 inertia requirements assessment

Stage	Industrial load (MW)
Stage 1. Current period with no synchronous condensers in South Australia	150
Stage 2. After four synchronous condensers are installed in South Australia	150

Synchronous generating unit tripping

In the 2018 assessment, a trip of Pelican Point was modelled to determine South Australia inertia requirements[21]. In the 2020 assessment, a Torrens Island B unit generating 65 MW was chosen as the synchronous generating unit contingency, for the following reasons:

1. Pelican Point has the highest inertia in South Australia and a high minimum operating point, so it would be the most onerous contingency. However, as Torrens Island B units have much lower minimum operating point, they are more likely to be online during time of low demand/high PV output when SA is islanded.
2. A 65 MW operating point, approximately 20 MW above the Torrens B minimum operating level, was modelled. During periods where South Australia is islanded, the units remaining online will be required to maintain headroom to provide, or support via direction, contingency FCAS.
3. A disconnection of other generating units/generating systems outside the metro area will cause a substantially smaller disconnection of distributed PV, and a smaller overall contingency size than the loss of a Torrens Island B unit combined with net PV disconnection.

Coincident distributed PV tripping

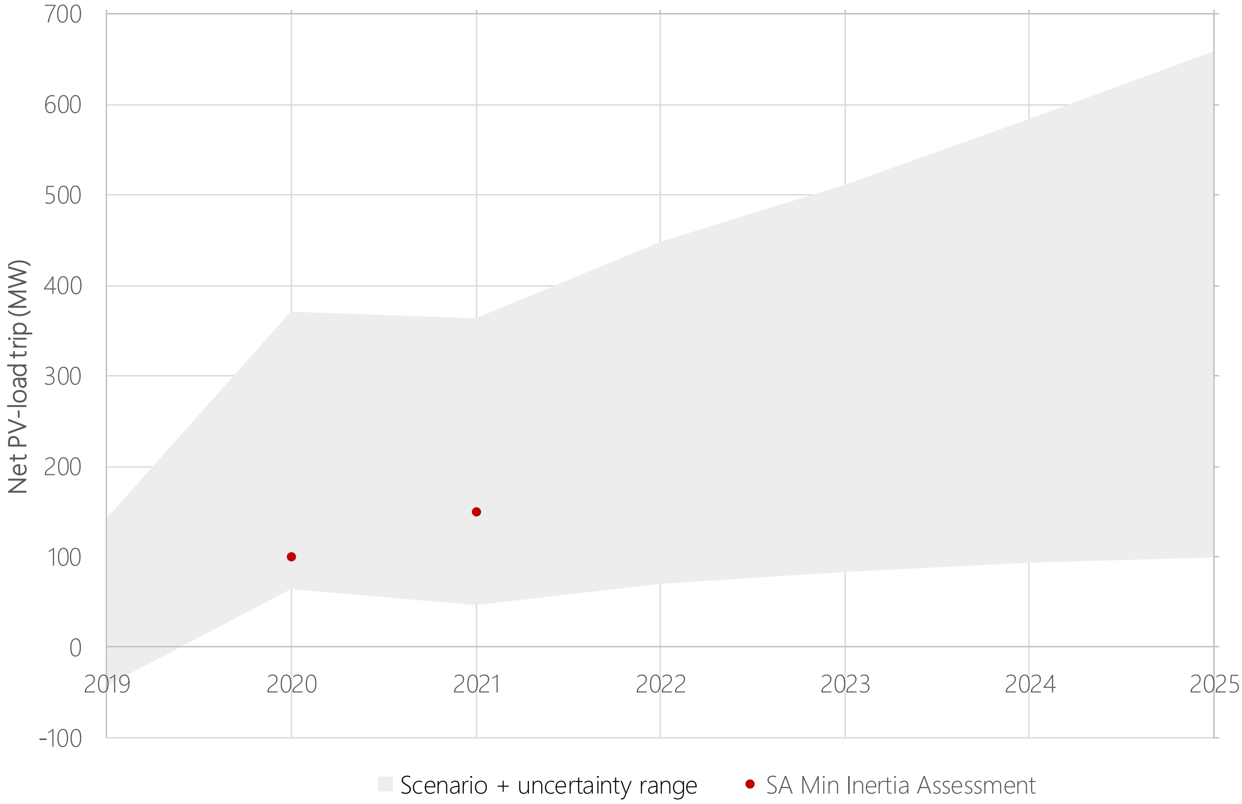
Through power system modelling and monitoring, AEMO has demonstrated that large amounts of distributed PV can disconnect following a credible fault that also disconnects a large synchronous generator. As distributed PV penetration continues to increase, the size of this contingency will grow. Beyond 2022, the growth is expected to continue at a slower rate, assuming the application of improved voltage ride-through compliance testing, and a proposed changes to the existing standard (AS/NZS 4777), over the coming years.

Figure 1 shows AEMO's projections of net distributed PV and load that could trip in South Australia during a high distributed PV output period. These have been calculated across the five 2020 Integrated System Plan (ISP) scenarios[22] and include error margins to account for the uncertainty in the modelling. In the inertia requirements assessment, AEMO assumed a 100 MW net PV load trip in 2020 and 150 MW in 2021, which fall within the range of projections.

[21] AEMO, Inertia Requirements Methodology Inertia Requirements and Shortfalls, July 2018, p31, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/System-Security-Market-Frameworks-Review/2018/Inertia_Requirements_Methodology_PUBLISHED.pdf.

[22] See https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp/2020-integrated-system-plan-isp.

Figure 1 Projected amount of net PV load trip during a high PV period for a credible contingency that also trips a synchronous generating unit in the Adelaide metro area



Therefore, the studied contingencies constitute the largest uncontrolled loss of generation in the South Australian power system, during periods when a moderate net PV load trip is credible and taking account of AEMO's ability to redispatch to minimise contingency size.

Larger contingencies are possible. It may not always be possible to minimise the synchronous generator contingency size. For example, it may be necessary to generate at higher levels to meet demand. Also, larger levels of net PV load trip are possible. In this situation, even if the inertia shortfall is met, the frequency operating standard (FOS) would not be achieved following the contingency.

Accordingly, AEMO wishes to be very clear that providing the inertia and FFR needed to reach the secure operating level of inertia will not ensure system security at all times and in all power system conditions.

2.3.2 Role of fast frequency response

In this 2020 assessment, for practical, technical, and economic reasons, AEMO has expressed the secure operating level of inertia for South Australia with assumed levels of additional FFR. This recognises the demonstrated[23] benefits of FFR in ensuring secure operation of the system and significantly reducing the inertia requirement.

An increasing amount of inverter-based distributed energy resources, such as rooftop solar systems, are affecting the scale and frequency of minimum demand conditions on the network. The current inability of these embedded resources to ride through network faults can lead to challenges in maintaining system security. In addition, the practices used to operate large-scale synchronous generators are changing.

[23] AEMO, Preliminary Report non-credible separation event South Australia – Victoria on 16 November 2019, at https://www.aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2019/preliminary-incident-report---16-november-2019---sa---vic-separation.pdf?la=en&hash=F26C20C49BD51164AE700A30F696A511.

These changes have interrelated impacts on system security. For example, during islanded conditions, lower midday demand also has the impact of reducing the amount of synchronous generation online. As a result, the available inertia and frequency control services to support the system are reduced.

Batteries can provide an FFR service that responds to frequency change several times faster than synchronous generation. Some modern wind and solar farms are capable of providing similar response if they are pre-curtailed under islanding conditions to provide both active power raise and lower services.

In the existing network, FFR is already crucial in ensuring secure operation of the South Australia region when islanded. The South Australian government has procured 70 MW of FFR to be available to assist in maintaining system security, and this is accounted for in AEMO's assessment of the inertia requirements.

AEMO considers that there is an emerging need for FFR distinct from synchronous inertia services. Although synchronous inertia services can assist in addressing some of these issues as they are emerging, some form of fast active power response, such as FFR, is also needed. This became evident during the recent prolonged operation of the South Australia region as an island, when utility-scale batteries were dispatched to provide frequency control to maintain system security[24].

A requirement for FFR to replace purely synchronous inertia is expected to become an important consideration in determining requirements for securing the system going forward, including inertia requirements. This report incorporates analysis of these issues, and this is a continuing area of investigation for AEMO.

2.3.3 Updated operational assumptions

The 2020 assessment includes updated assumptions based on recent experience from operating the South Australia region as an island, including:

- Modelling a range of utility-scale batteries' capacities as available for fast frequency response, when the South Australia region is islanded. In the Stage 1 assessment, different proportions of existing battery capacity are modelled as available, up to the full capacity of all batteries. In the Stage 2 assessment, different proportions of existing battery capacity plus the 50 MW Hornsdale Power Reserve Expansion capacity are modelled as available, up to the full capacity of all batteries.
- Updated assumptions about generating units' governors restricted to a response of not more than 20 MW of frequency response per contingency event.
- Reduced 'load relief' assumptions after the occurrence of a contingency event, to reflect the changing behaviour of loads in response to contingencies with the increasing penetration of power electronics-based equipment[25].

These assumptions are consistent with the current status of the South Australian network. In June 2020, new obligations for generators to provide primary frequency response were included in the NER[26]. These capabilities are expected to be progressively enabled in tranches across all technically capable generating systems. These obligations will require generators to provide frequency response with a narrow deadband, and to disable any control features that act to suppress a generating unit's active power response to a frequency disturbance within the range that the plant is capable of safely and stably responding (for example to cap response to a certain MW level). However, they do not oblige a generator to reserve headroom (or 'foot room') to provide a frequency response. Reservation of the capacity to respond to contingencies will continue to be purchased via the FCAS market.

[24] AEMO, Preliminary Report – Victoria and South Australia Separation Event 31 January 2020, at https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2020/preliminary-report-31-jan-2020.pdf?la=en.

[25] AEMO, Review of NEM load relief November 2019 Update, at: https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/ancillary_services/2019/update-on-contingency-fcas-nov-2019.pdf.

[26] AEMC. Mandatory primary frequency response, at https://www.aemc.gov.au/rule-changes/mandatory-primary-frequency-response.

A sensitivity study was carried out with South Australian generating units' governor deadband settings altered in accordance with the new mandatory primary frequency response obligations. This was found to make no material difference to the levels of inertia services required.

2.4 2020 inertia requirements

AEMO has applied the Inertia Requirements Methodology[27] and the assumptions described in Section 2.3 to find the 2020 inertia requirements for the periods before and after the installation of synchronous condensers in South Australia.

The secure operating level of inertia has changed compared to the 2018 requirements, in part because the studied contingency has changed and FFR has been considered, while the minimum threshold level of inertia remains the same.

In sections 2.4.2 and 2.4.3, Figure 2 shows updated secure operating levels of inertia in the period before the synchronous condensers are commissioned, and Figure 3 shows the requirements after the commissioning. In both figures, the secure operating levels of inertia have been adjusted for inertia support activities provided by FFR.

2.4.1 Minimum threshold level of inertia

The minimum threshold level of inertia remains at 4,400 MWs in both stages, the same as the 2018 requirement, because the minimum threshold level of inertia must consist of only synchronous inertia[28] and because the minimum threshold level of inertia is the level required for the islanded system to remain in a satisfactory state in the absence of a further contingency.

Therefore, AEMO considers that there is no need to change the value of the minimum threshold level of inertia. Rather, AEMO has considered the use of FFR and a different contingency in the assessment for the secure operating level of inertia in order to address the current system conditions.

AEMO is continuing to assess the changing nature of the power system, and the 2020 Inertia Report expected for release by the end of 2020 will cover all regions in the NEM and may include a reassessment of the minimum threshold level of inertia.

2.4.2 Stage 1 – Before synchronous condensers

Figure 2 shows the updated requirements for secure operating levels of inertia adjusted for various levels of inertia support activities provided by FFR, in the period before the synchronous condensers are commissioned. The secure level for daytime is shown in red within the white region, and the secure level for night-time is shown in yellow within the white region.

The areas greyed out in the figure highlight the likely boundaries of secure operation, by removing areas where:

a) Minimum demand conditions may prevent the addition of inertia[29].

b) Inertia is already assumed to be available under system strength requirements[30].

c) The limit of capacity of existing installed utility-scale batteries is reached.

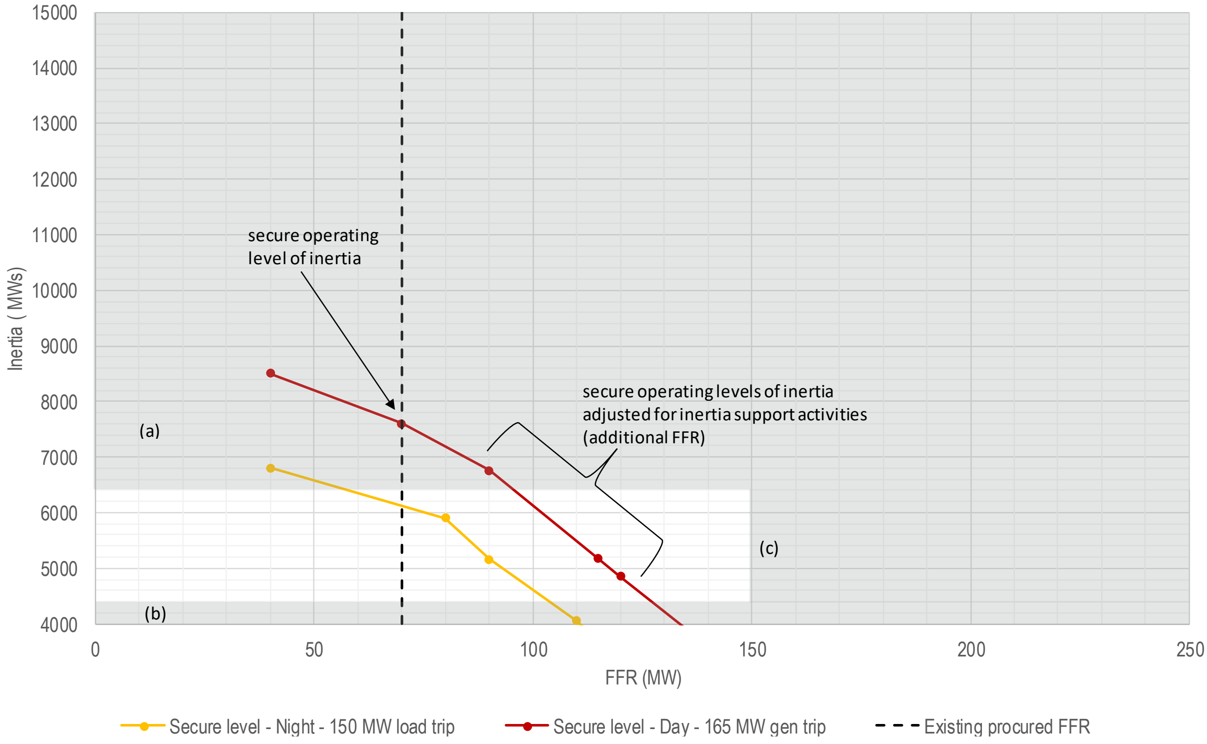
[27] AEMO, Inertia Requirements Methodology Inertia Requirements and Shortfalls, July 2018, at https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-security-market-frameworks-review/2018/inertia_requirements_methodology_published.pdf.

[28] Refer to NER 5.20B.4(d).

[29] For example, with 500 MW of demand in the South Australia region, only 500 MW of synchronous generation can operate. The sum of the minimum generator stable levels then sets a maximum inertia from synchronous generation. The level shown is approximate and will also depend on factors such as synchronous generator availability and Murraylink capacity.

[30] AEMO, Transfer Limit Advice – System Strength, February 2020, at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/transfer-limit-advice-system-strength.pdf?la=en. This advice does not allow generator combinations with a total inertia less than 4,400 MWs when South Australia is operating as an island.

Figure 2 South Australia secure operating levels of inertia adjusted for inertia support activities, pre synchronous condensers



It is expected that each point along the line would be a secure operating point for the studied contingencies, with each point made up of a combination of synchronous inertia (MWs) and FFR (MW). The more FFR is available, the lower the required inertia response. For example, for the daytime contingency, if 100 MW of FFR was provided, then 6,100 MWs of synchronous inertia would be needed, but if 120 MW of FFR was provided, only 4,850 MWs of synchronous inertia would be needed.

Because the daytime requirements are greater than the night-time requirements, the daytime requirements are taken as the Stage 1 secure operating levels of inertia adjusted for FFR.

For contingency sizes above those studied (165 MW daytime, 150 MW night-time), it is expected that the inertia requirements would increase. If larger contingencies occurred at any of the studied inertia/FFR combinations marked in Figure 2, the FOS would not be met.

Figure 2 also shows the 70 MW of FFR reserves currently available for power system security. Therefore, AEMO defines the baseline Stage 1 secure operating level of inertia as the level of synchronous inertia required when 70 MW of FFR is available. Additional FFR above this 70 MW can be procured by ElectraNet as inertia support activities to lower the secure operating level of inertia requirement, or otherwise made available for network support on a basis that enables AEMO to determine a reduced inertia shortfall.

Stage 1 Secure Operating Level of Inertia = 7,605 MWs

2.4.3 Stage 2 – After four synchronous condensers with flywheels installed

Figure 3 shows the updated inertia requirements for secure operating levels of inertia adjusted for assumed inertia support activities, in the period after the four synchronous condensers are commissioned.

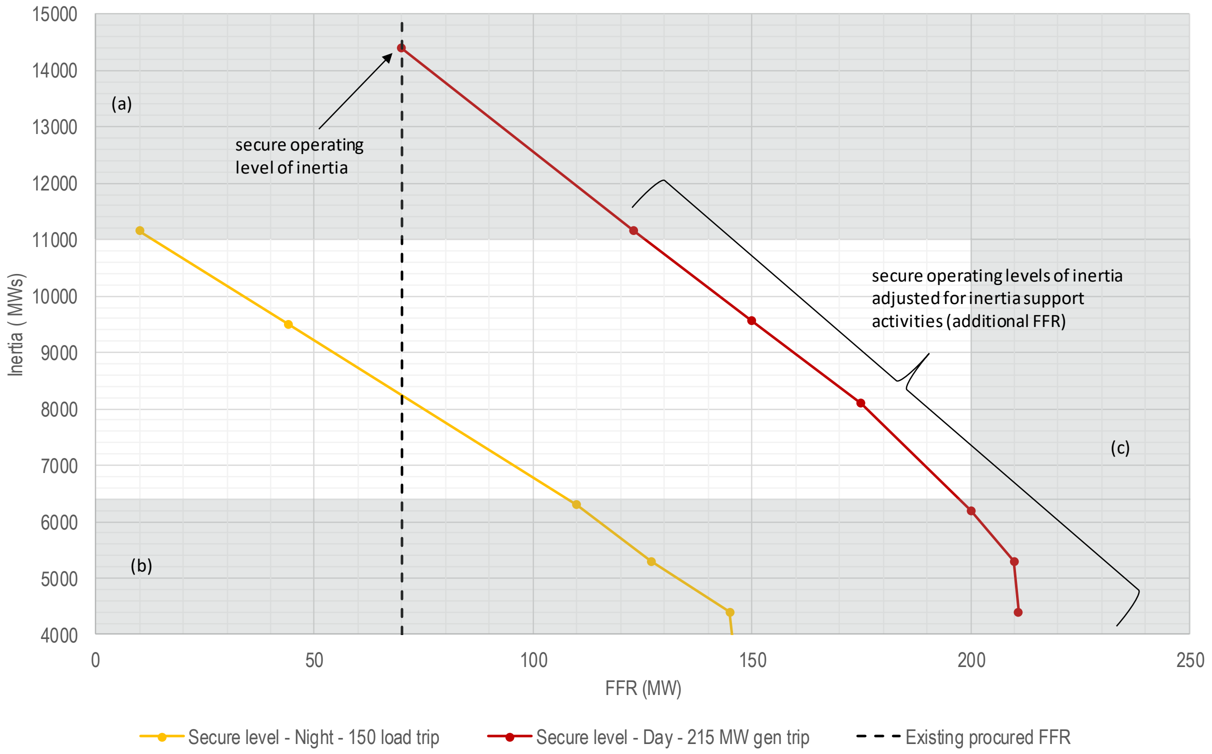
The areas greyed out in the figure highlight the likely boundaries of secure operation, by removing areas where:

(a) Minimum demand conditions may prevent the addition of inertia[31].

(b) Inertia is already assumed to be available under system strength requirements including a planning assumption that at least two synchronous generating units will be online[32].

(c) The limit of capacity of existing/committed installed utility-scale batteries is reached [33].

Figure 3 South Australia secure operating level of inertia adjusted for inertia support activities, with four synchronous condensers with flywheels



It is expected that each point along the line would be a secure operating point for the studied contingencies, with each point made up of a combination of synchronous inertia (MWs) and FFR (MW). The more FFR is available, the lower the required inertia response. For example, at night-time if 100 MW of FFR was provided in the region, then a total of 6,800 MWs of synchronous inertia would be required to remain secure. In the daytime, if 200 MW of FFR was provided then 6,200 MWs of synchronous inertia would be needed. There would be 4,400 MWs provided by the synchronous condensers, with the remaining inertia to be provided by existing synchronous generators which are also able to provide frequency control services.

Because the daytime requirements are greater than the night-time requirements, the daytime requirements are taken as the Stage 2 secure operating levels of inertia adjusted for FFR.

The increased daytime requirements after the synchronous condensers are commissioned is partly driven by the assumption of a larger contingency (215 MW as opposed to 165 MW).

For contingency sizes above those studied (215 MW daytime, 150 MW night-time), it is expected that the inertia requirements would increase. If larger contingencies occurred at any of the studied inertia/FFR

[31] For example, with 500 MW of demand in the South Australia region, only 500 MW of synchronous generation can operate. The sum of the minimum generator stable levels then sets a maximum inertia from synchronous generation. The level shown is approximate and will also depend on factors such as synchronous generator availability and Murraylink capacity. As the synchronous condensers provide inertia with no minimum generation output, the total inertia that can be placed online increases by 4,400 MWs.

[32] Minimum of 6,400 MWs of inertia is assumed for planning purposes to be online due to system strength requirements and at least two synchronous generating units online when all four synchronous condensers are online.

[33] Includes the Hornsdale Power Reserve extension by 50 MW.

combinations marked in Figure 3, the FOS would not be met. It is also noted that if 100 MW of FFR trips (that is, the Hornsdale Power Reserve), returning the power system to a secure operating state within 30 minutes would require significantly more synchronous inertia to come online, which may be challenging operationally.

Figure 3 also shows the 70 MW of FFR reserves currently available for power system security. Therefore, AEMO defines the baseline Stage 2 secure operating level of inertia as the level of synchronous inertia required when 70 MW of FFR is available. Additional FFR above this 70 MW can be procured by ElectraNet as inertia support activities to lower the secure operating level of inertia requirement, or otherwise made available for network support on a basis that enables AEMO to determine a reduced inertia shortfall.

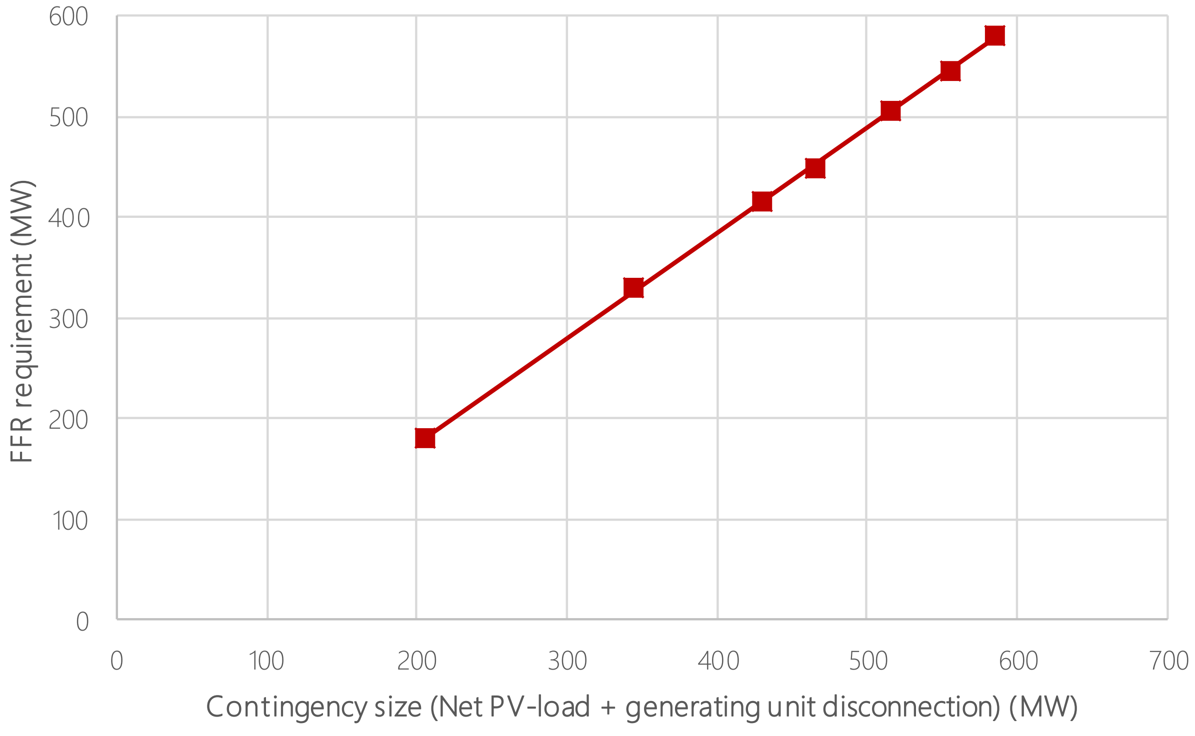
Stage 2 Secure Operating Level of Inertia = 14,390 MWs

Beyond 2021-22, the uncertainty in the level of net PV load trip increases, as shown in Figure 4, so detailed studies to determine secure operating levels of inertia adjusted for inertia support activities have not been completed beyond 2021-22.

Instead, studies were performed at a single inertia level (6,300 MWs) to determine the approximate relationship between contingency size and required FFR as the projected net PV load trip increases, to give an indication of where the inertia requirements may trend in future. Figure 4 shows the results of these studies. The relationship between FFR and contingency size shown here can be approximated by the equation below:

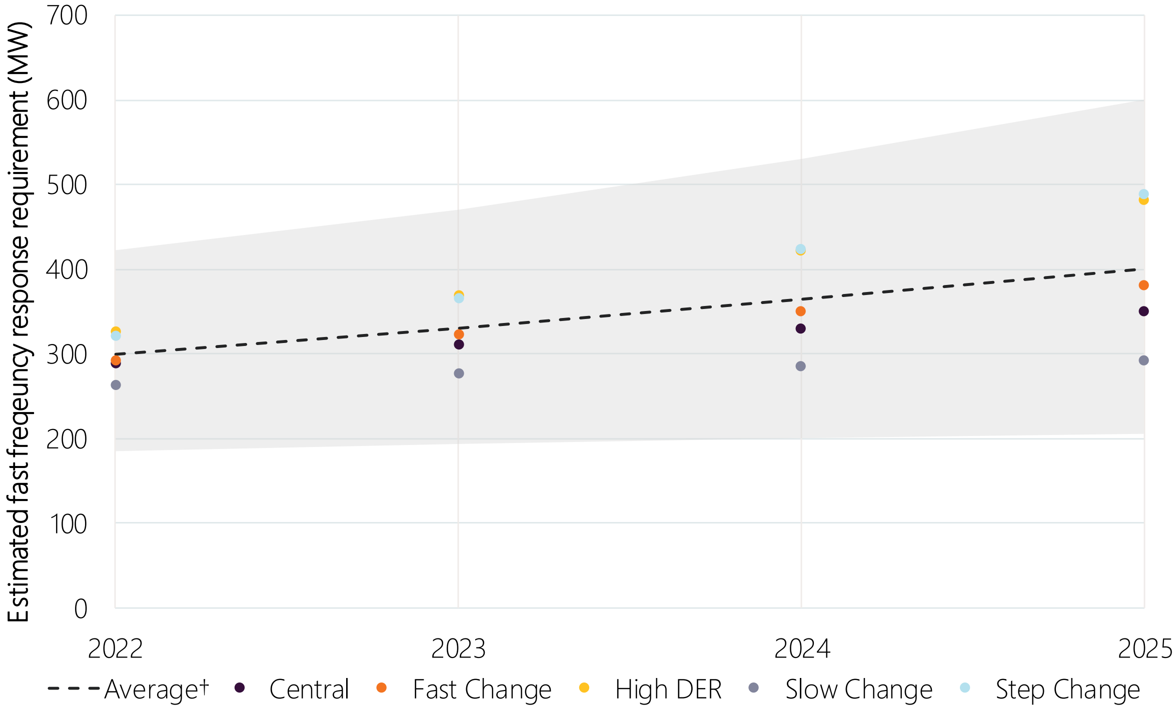
$\text{FFR} \geq 0.95 \times (\text{Metro Generator Size} + \text{Net PV load loss})$

Figure 4 Relationship between contingency size and FFR requirements when 6,300 MWs synchronous inertia online



Applying this equation to the current net PV load trip projections being applied by AEMO, the range of possible FFR requirements when 6,300 MWs of inertia is online was calculated. The results shown in Figure 5 for each ISP forecasting scenario indicate a large uncertainty range which increases over time.

Figure 5 **Estimated FFR requirements when 6,300 MWs of synchronous inertia online assuming 65 MW synchronous generating unit trip + a range of net PV and load trip**



3. Inertia shortfall projections

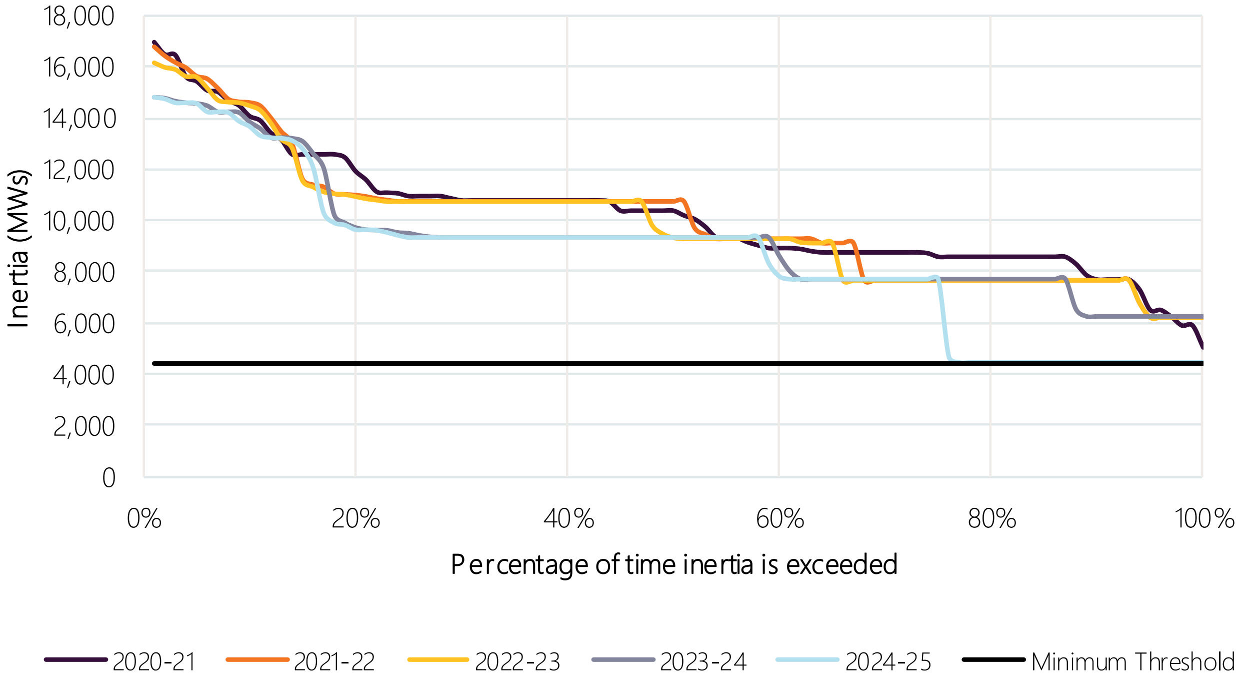
Using the inertia requirements determined in Section 2, AEMO has assessed whether there is likely to be an inertia shortfall in the South Australia region of the NEM, and whether previously-identified shortfalls have been remedied, consistent with clause 5.20B.2 of the NER.

AEMO's assessment has been made by using projected demand and supply in the Central scenario of the Draft 2020 ISP to calculate when the expected inertia online will not meet the inertia requirements for more than 99% of the time. In addition, consistent with the NER requirements, AEMO's assessment includes consideration of the likelihood of islanding. Prior to commissioning of a second AC interconnector, islanding of South Australia remains non-remote.

Figure 6 shows the projected inertia in the South Australia region for the five-year outlook.

For the period to 2024-25, AEMO has assessed that the minimum threshold of inertia (4,400 MWs) will be met. However, a shortfall is projected for the secure operating level of inertia in South Australia.

Figure 6 Projected inertia in the South Australia region



Projection for meeting minimum threshold level of inertia

AEMO declared a system strength shortfall for South Australia in 2017[34], resulting in ElectraNet procuring four synchronous condensers for installation in the South Australian region.

[34] AEMO. Update to the 2016 NTNDP, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/System-Security-Market-Frameworks-Review/2019/Second_Update_to_the_2016_NTNDP.pdf.

AEMO also declared an inertia shortfall for the South Australian region as part of the 2018 NTNDP[35]. To meet this gap, high inertia flywheels have been included in the design of the synchronous condensers being procured by ElectraNet. This will meet the minimum threshold component of the inertia gap (4,400 MWs) declared by AEMO.

Projection for meeting secure operating level of inertia

The new requirements determined in Section 2.4 now show a change in the secure operating level of inertia required, due to the potential for a fault tripping a generating unit and triggering co-incident tripping of distributed PV. AEMO is now recommending that FFR from batteries (or another appropriate technology) needs to be incorporated as part of the solution to meet the secure operating level of inertia in South Australia. Depending on the amount of FFR that can be made available, through inertia support activities or otherwise, there may also be a need to increase the amount of synchronous generation online during islanded operation.

As the Stage 1 and Stage 2 secure operating levels of inertia have been expressed as relationships between different levels of FFR and synchronous inertia, the shortfall projections similarly are expressed as a set of values relating back to the relevant levels of FFR and synchronous inertia.

Table 7 and Table 8 compare FFR/inertia combinations of secure operating levels of inertia, for Stage 1 and Stage 2 (taken from Figure 2 and Figure 3), and compare them against the projected 99th percentile inertia for the relevant year. FFR/Inertia combinations for which an inertia shortfall exists are shown in red; those where there is no shortfall are shown in green.

These tables identify combinations for which there would be a shortfall, and therefore identify levels of FFR that could reduce or remove the shortfall.

For example, Table 7 shows that with 90 MW of FFR contracted, the required level of synchronous inertia would be 6,757 MWs – this is greater than the 99th percentile inertia of 5,861 MWs, therefore a shortfall would exist. By contrast, with 115 MW of FFR contracted, the 99th percentile inertia is greater than the required synchronous inertia and there is no shortfall.

A specification of requirements for FFR will need to be prepared and agreed between AEMO and ElectraNet in order to meet the inertia shortfall.

Alternatively, in Table 9 and Table 10, secure operating levels of inertia adjusted for inertia support activities have been subtracted from the 99th percentile projected inertia, showing the shortfall in synchronous inertia for a given FFR level that would need to be filled.

The FFR values in Table 7 to Table 10 include the existing 70 MW of available FFR reserves, so the quantity of FFR needed would be 70 MW lower than any value in these tables.

Given the uncertainties in the determination of inertia requirements discussed in Section 2.3.1 and Section 2.4, ElectraNet should aim to provide levels of FFR consistent with the levels recorded in Table 7 to Table 10. AEMO considers that further modelling by both organisations will be needed to indicate assurance that the shortfall will be addressed with the services that are proposed to be provided.

[35] AEMO. National Transmission Network Development Plan, December 2018, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/NTNDP/2018/2018-NTNDP.pdf.

Table 7 Comparison of 99th percentile projected inertia against Stage 1 secure operating levels of inertia, adjusted for inertia support activities

Year	Projected 99th percentile inertia (MWs)	Secure operating level of inertia (SOLI) adjusted for inertia support activities, FFR/inertia combinations					
		SOLI FFR (MW)	40	70	90	115	120
2020-21	5,861	SOLI inertia (MWs)	8,505	7,605	6,757	5,167	4,850

Table 8 Comparison of 99th percentile projected inertia against Stage 2 secure operating levels of inertia, adjusted for inertia support activities

Year	Projected 99th percentile inertia (MWs)	Secure operating level of inertia (SOLI) adjusted for inertia support activities, FFR/inertia combinations							
		SOLI FFR (MW)	70	123	150	175	200	210	211
2021-22	6,200	SOLI Inertia (MWs)	14,390	11,150	9,560	8,100	6,200	5,300	4,400

Table 9 Inertia shortfalls at different levels of FFR for Stage 1 secure operating levels of inertia, adjusted for inertia support activities

Year	Secure operating level of inertia (SOLI) adjusted for inertia support activities, FFR/inertia combinations					
	SOLI FFR (MW)	40	70	90	115	120
2020-21	Inertia shortfall (MWs)	-2,644	-1,744	-896	No shortfall	No shortfall

Table 10 Inertia shortfalls at different levels of FFR for Stage 2 secure operating level of inertia, adjusted for inertia support activities

Year	Secure operating level of inertia (SOLI) adjusted for inertia support activities, FFR/inertia combinations							
	SOLI FFR (MW)	70	123	150	175	200	210	211
2021-22	Inertia shortfall (MWs)	-8,190	-4,950	-3,360	-1,900	No shortfall	No shortfall	No shortfall

Inertia shortfall projections have not been calculated beyond 2021-22, because the high levels of uncertainty regarding the net distributed PV and load trip in future years (as shown in Figure 1) mean inertia requirements beyond 2021-22 are also highly uncertain (as shown in Figure 5). Therefore, given new FFR capacity can be built without a long lead time if in future it is found it is needed (utility-scale batteries can be built within 12 months), AEMO considers it prudent to continue to monitor the distributed PV situation and calculate inertia requirements and identify inertia shortfalls beyond 2021-22 in future assessments when inputs are more certain.

4. Next steps

The NER place the responsibility to procure services to address declared inertia shortfalls on ElectraNet as the Inertia Service Provider for South Australia.

This report constitutes AEMO's notice of these assessments and formal declaration of an inertia shortfall under the NER. AEMO has requested from ElectraNet that the required services for Stage 1 be made available from 1 October 2020. AEMO has agreed with ElectraNet that the required services for Stage 2 will be made available from 31 July 2021.

This shortfall declaration amends the previous inertia shortfall for the South Australian region declared by AEMO. Importantly, additional fast frequency control services are now required to address the larger contingency sizes anticipated due to the expected disconnection of embedded generation sources and loads during a network disturbance.

In the meantime, to the extent possible, operational arrangements will continue to be used to securely operate the South Australia power system when islanded.