Reduction of Minimum Synchronous Generators in South Australia

August 2025

Assessment for system security

A summary report on the technical feasibility of reducing minimum synchronous generators in South Australia

We acknowledge the Traditional Custodians of the land, seas and waters across Australia. We honour the wisdom of Aboriginal and Torres Strait Islander Elders past and present and embrace future generations.

We acknowledge that, wherever we work, we do so on Aboriginal and Torres Strait Islander lands. We pay respect to the world's oldest continuing culture and First Nations peoples' deep and continuing connection to Country; and hope that our work can benefit both people and Country.

'Journey of unity: AEMO's Reconciliation Path' by Lani Balzan

AEMO Group is proud to have launched its first Reconciliation Action Plan in May 2024. 'Journey of unity: AEMO's Reconciliation Path' was created by Wiradjuri artist Lani Balzan to visually narrate our ongoing journey towards reconciliation - a collaborative endeavour that honours First Nations cultures, fosters mutual understanding, and paves the way for a brighter, more inclusive future.

Important notice

Purpose

AEMO has prepared this report to inform those with an interest in the South Australian electricity system, including market participants, new investors, and jurisdictional bodies.

This report provides a summary of various technical assessments conducted that investigate the feasibility of a reduction from the current requirement for a minimum of two synchronous generators to be kept online in South Australia.

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Version control

Version	Release date	Changes
1.0	15/08/2025	Initial Release
1.1	25/08/2025	Revision of sustainable IBR generation

Executive summary

AEMO presently dispatches a minimum of two large synchronous generators[1] or its electrical equivalent in South Australia, a reduced number enabled by the commissioning of four synchronous condensers in Q4 of 2021 and detailed analysis.

AEMO and ElectraNet have now undertaken a program of work to reassess this requirement with current network conditions.

Reduction of minimum synchronous generators

This program of work between AEMO and ElectraNet assessed system security aspects that affect the transition towards reducing the minimum number of synchronous generators that must be kept online in South Australia, in addition to the existing four synchronous condensers.

This report provides a summary of various technical assessments conducted by AEMO and ElectraNet. These assessments investigated the feasibility of reducing the number of synchronous generators from the existing minimum requirement of two large synchronous generators, along with four synchronous condensers. Depending on power system conditions and specific system considerations[2], varying amounts of system security services are required within South Australia. AEMO and ElectraNet assessed the likely impact on various aspects of system security services as outlined below with a reduced number of synchronous generators in South Australia and assuming four synchronous condensers online. The assessments were generally conducted under system normal conditions and some further sensitivity analysis was conducted considering the possibility of prior outage of critical network elements.

AEMO and ElectraNet determined that the power system can be securely operated with a single 275 kilovolt (kV) network connected large synchronous generator or its electrical equivalent in service, under specific conditions when the power system is intact and the operational demand in South Australia is above 600 megawatts (MW). Key technical details are listed below:

- Frequency control – when South Australia is interconnected to the rest of the National Electricity Market (NEM), the required frequency control can be procured and a potential reduction in synchronous generators in South Australia would not have a detrimental effect on overall frequency control. When South Australia is at a credible risk of separation from the NEM or operating as an island, additional frequency control measures including interventions are likely to be in place.
- Ramping management – this refers to the need to maintain reserve to manage large changes in output of wind and solar plants (both transmission-connected and distributed photovoltaics [DPV]) over a relatively short timeframe due to wind and cloud conditions. When South Australia is interconnected to the rest of the NEM, ramping requirements can be met with at least one large synchronous generator in service. When South Australia is at a credible risk of separation or operating as an island, AEMO may require two large synchronous generators online to maintain sufficient ramp capability.

[1] Synchronous generator and synchronous generating unit have been used interchangeably in this document and are intended to have the same meaning.

[2] A list of possible system considerations is included in Figure 1 of the report.

- Grid reference – this refers to the need to maintain a balanced three-phase rotating grid voltage phasor universally across the alternating current (AC) power system and enable power system devices to collectively maintain synchronism. An assessment[3] based on desktop modelling and simulations found grid reference to be adequate when South Australia is interconnected to or islanded from the rest of the NEM. AEMO requires at least one large synchronous generator in service until a physical test of this concept is completed or Project EnergyConnect (PEC) Stage 2 is in service.
- Voltage control – ElectraNet's assessment found one 275 kV-connected large synchronous generator to be adequate to meet voltage control requirements in the Adelaide metropolitan area when the operational demand in South Australia is greater than 600 MW and provided essential reactive power equipment is in service. When the operational demand in South Australia is 600 MW or below, two large 275 kV-connected synchronous generators, or its electrical equivalent, are required for voltage control. ElectraNet has further completed a transmission network voltage control regulatory investment test for transmission (RIT-T)[4]. Additional reactors are expected to be commissioned and in service by mid-2026. This will potentially enable operation of South Australia with one large synchronous generator even during periods when operational demand drops below 600 MW.
- System strength – ElectraNet's assessment found that the four synchronous condensers in operation in South Australia provide sufficient system strength[5]. No adverse impact on system strength in the South Australian power system could be identified with transition to a one large synchronous generating unit online under most system conditions.
- Managing inertia and regulation 88A – regulation 88A of the *Electricity (General) Regulations 2012* (SA) requires AEMO to limit the rate of change of frequency (RoCoF) to 3 hertz per second (Hz/s) or less following a non-credible contingency trip of the Heywood Interconnector. Depending on the operational demand and available inertia within South Australia, constraint equations will manage the active power flows on the Heywood Interconnector to meet this requirement.
- Re-securing the power system – AEMO has an obligation under National Electricity Rules (NER) 4.3.1 to maintain power system security in accordance with the general principles stated in NER 4.2.6 and is required to take reasonable actions to return the power system to a secure operating state within 30 minutes of a contingency event. Under certain power system conditions, such as credible risk of South Australia separation from the NEM, unplanned network asset outages or generator outages, AEMO may require two or more synchronous generators online.
- Power system damping – as per ElectraNet's assessment, damping performance was assessed based on the criteria for damping margin to meet the five seconds halving time requirement per NER S5.1a.3. Provided that, under system normal conditions, the inter-area mode damping constants meet certain thresholds, system damping performance is expected to be operationally adequate, following the worst contingency when there is only one large synchronous generator online in South Australia. Further, AEMO will continue working with

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[3] Assessment of grid reference with synchronous condensers and zero synchronous generators (AEMO report published February 2023)

[4] See https://aemo.com.au/consultations/current-and-closed-consultations/electranet-pscr---sa-transmission-network-voltage-control.

[5] See https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/operability/2022/update-to-2021-system-security-reports.pdf?la=en.

ElectraNet on any updates to the system damping limits whilst also monitoring of system damping in real-time. Any system damping performance concerns will be managed in line with existing AEMO processes.

- Heywood Interconnector limit – as per ElectraNet's assessment, a reduction in the synchronous generator requirements from two to one in South Australia was found to have a minimal impact on the existing Heywood Interconnector import or export transfer capability. Heywood Interconnector system normal and N-1 limit advice remains unchanged for power system operation with one large synchronous generator in service. Therefore, the existing limit advice continues to apply.
- Emergency frequency control schemes (EFCS) – based on the available inertia and operational demand, existing Heywood Interconnector constraints will be used to manage the active power flows over the Heywood Interconnector. Therefore, the impact of transitioning to a reduced number of synchronous generators within South Australia on EFCS such as under frequency load shedding (UFLS) and over frequency generator shedding (OFGS) is minimal.
- Protection – as per ElectraNet and SA Power Networks assessments, transmission and distribution system protection operation has been found to be adequate, whether South Australia is interconnected to or islanded from the NEM with one large 275 kV-connected synchronous generator and four synchronous condensers in service.

Based on the assessments conducted, with the exception of:

- the requirement for adequate voltage control when operational demand in South Australia is less than 600 MW,
- the need for adequate ramping resources during South Australia island conditions or when at risk of credible separation, and
- the ability to re-secure the power system

the transition from the present minimum requirement of two synchronous generators to one large 275kV -connected synchronous generator is technically acceptable. Due to the above exceptions, the minimum will often need to be increased to two or more synchronous generators and will need to be based on actual power system operating conditions.

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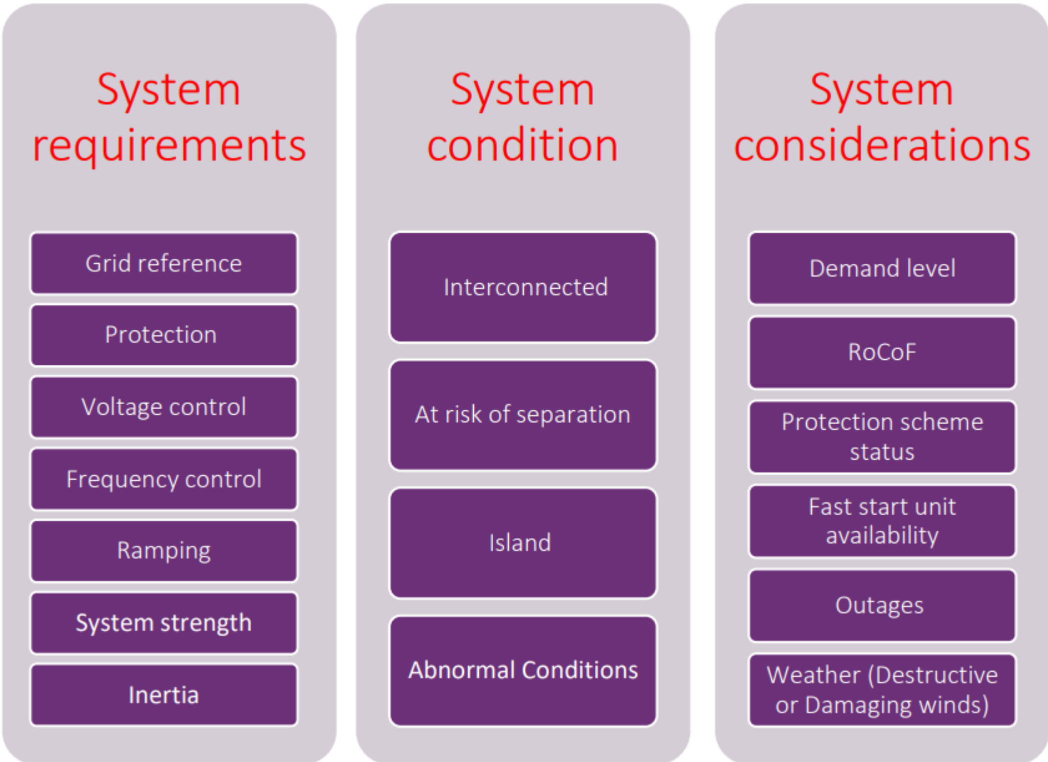
1 Introduction

With four synchronous condensers in operation in South Australia, the requirement for the minimum number of synchronous generators to be kept online was reduced from four to two in Q4 of 2021. Owing to changes in network conditions and instances of high penetration of generation from inverter-based resources (IBR) such as wind farms, solar farms, battery energy storage systems (BESS) and DPV, the requirement to keep a minimum of two synchronous generators online was revisited.

Varying levels of certain system security requirements are needed within the South Australian power system depending on the power system condition and specific system considerations listed in Figure 1 below.

Figure 1 System requirements needed within South Australia, power system conditions and power system considerations



Source: AEMO, South Australia Minimum Generator Requirements, August 2023, at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/2023/sa-minimum-synchronous-generator-requirements-august-2023-update.pdf?la=en.

For example, when South Australia is interconnected to the NEM under system normal conditions, frequency control is unlikely to be a major concern, as adequate frequency control ancillary services (FCAS) can be procured from anywhere in the NEM, so the transition to a minimum less than two synchronous generators is unlikely to result in any adverse impact in this case. It is therefore necessary to assess the requirement for the minimum number of synchronous generating units to be kept online with respect to system requirements, which can vary depending on the system condition and specific system considerations.

This report provides a summary of the assessments undertaken by AEMO and ElectraNet to investigate the technical feasibility of reducing the requirement for minimum number of synchronous generators to be kept online in South Australia along with four synchronous condensers and its likely impact on various aspects of power system security.

While the upgrades associated with different stages of PEC were not explicitly considered in these assessments, the addition of PEC when fully completed (including Stage 2) is expected to improve overall system security in South Australia by adding resilience to the interconnection of South Australia with the rest of the NEM. Further, the findings from this report can form the basis for future assessments when PEC is fully commissioned.

2 Frequency control

This assessment focused on the ability of the system frequency to meet the Frequency Operating Standard (FOS)[6] when the South Australian power system is operating with less than two synchronous generators:

- When South Australia is interconnected to the NEM, FCAS can be sourced globally, so the transition to a minimum less than two synchronous generators does not have a significant impact. For example, the frequency response from an FCAS provider in Victoria will assist with the recovery of system frequency following a generator or load event in South Australia, when South Australia is interconnected to the NEM.
- When South Australia is at credible risk of separation from the NEM, the FOS allows for reliance on emergency frequency control schemes – such as UFLS, OFGS – to maintain frequency within the limits of the FOS. Also, during such conditions, AEMO invokes the necessary constraints to limit the flow on the Heywood Interconnector such that the FOS can be maintained for a trip of the Heywood Interconnector.
- When South Australia is an island, the Very Fast FCAS (VFFCAS) market can be used to achieve desired frequency control. A combination of BESS along with fast start units and interventions can be exercised to achieve adequate frequency control. Fast frequency response (FFR) services[7] are generally not provided by large synchronous generators. Therefore, the transition to a minimum less than two synchronous generators does not materially impact the availability of FFR and thereby frequency control of the South Australian power system.

[6] Revised frequency operating standards, October 2023, at https://www.aemc.gov.au/sites/default/files/2023-04/FOS%20-%20CLEAN.pdf.

[7] This is referring to RAISE1SEC and LOWER1SEC contingency FCAS which is much faster than typical 6 seconds and 60 seconds frequency services provided by large synchronous generators.

3 Ramping and reserve management

AEMO analysed ramping requirements based on historic IBR ramp events[8] in South Australia with durations ranging from five minutes to 4.5 hours. The analysis identified existing operational risks which are dependent upon a number of factors and scenarios, such as the status of gas generators at the commencement of the ramping event, system strength combinations being utilised, magnitude and co-incidence of wind and solar ramping events, and available headroom on the Heywood and Murraylink interconnectors at the start of the ramping event.

The analysis resulted in the following conclusions:

- When South Australia is interconnected to the NEM, all historic ramping events could be successfully managed under all system starting scenarios studied for the ramping assessment (including zero synchronous generators dispatched prior to the ramping event). A further sensitivity test performed based on an assumed co-incidental hypothetical high wind and solar ramp event resulted in a lack of sufficient capacity (Heywood + “cold” start generation) to manage the ramping event. However, this coincidental ramp event was tested as a sensitivity check and does not represent an actual historical event.
- When South Australia is at credible risk of separation from the NEM or when operating as an island, the available generation capacity would likely be insufficient and load shedding may be required to successfully manage large historic ramping events. Hence, it is recommended to maintain the existing requirement of two large synchronous generators or its equivalent in South Australia for this system condition.
- AEMO’s analysis did not consider any market response to the ramping event and assumed that all generators not dispatched were “cold” (yielding longer generator start up times). As such, this represents worst case conditions where a large ramp event is not forecast. Where ramp events are forecast, it is likely a market response will improve the South Australia network’s ability to respond successfully to large ramping events.

When appropriate, AEMO will update industry on ramping and reserve management risks and controls in the General Power System Risk Review (GPSRR).

[8] Only downward ramp events were analysed as part of this assessment, because AEMO assumed large upward ramp events are successfully managed with existing arrangements such as market/dispatch or network constraints.

4 Grid reference

Grid reference is the presence of a balanced three-phase rotating grid voltage phasor that exists universally across the alternating current (AC) power system and enables power system devices to collectively maintain synchronism.

When several synchronous generators are present online, there are numerous sources providing a stable grid reference, hence this service is implicitly assumed available. However, when the number of synchronous generators is reduced, the provision of grid reference must be investigated.

AEMO's assessment resulted in the following conclusions[9]:

- When South Australia is interconnected to the NEM, similar to frequency control, grid reference becomes a "globally" sourced quantity; in other words, Heywood Interconnector would provide the AC grid reference to the South Australian power system and hence grid reference is not an issue.
- When South Australia is at credible risk of separation from the NEM or when operating as an island, detailed electromagnetic transient (EMT) assessment carried out as a proof of concept showed that grid reference can be sustained even with zero synchronous generators online in South Australia.
  - This assessment was based on assumptions of existing power system configuration in South Australia, including four synchronous condensers and grid-following IBR (including BESS).
  - Several credible network contingency events were tested, including prior outage of some critical network elements.
  - No adverse impact was observed, even with zero synchronous generators online in South Australia, on the provision of grid reference. Hence, the transition to a minimum less than two synchronous generators is unlikely to impact the provision of grid reference for this condition.

This assessment for grid reference was carried out based on desktop modelling and simulations as proof of concept. A staged physical test is necessary to verify the findings from this assessment.

[9] See https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/sa-transition-to-fewer-synch-gen-grid-reference.pdf?la=en.

5 Voltage control

ElectraNet investigated voltage control requirements in the Adelaide metropolitan area for when South Australia is interconnected to the NEM with the Heywood interconnector in service, and obtained the following conclusions[10]:

- Operation with one large synchronous generator in service is achievable when operational demand in South Australia exceeds 600 MW and sufficient reactive power equipment is in service[11]. The in-service large synchronous generator is connected to the 275 kV transmission network and is either a Torrens Island Power Station (TIPS) B unit or a Pelican Point Power Station unit or a combination of at least eight units at Barkers Inlet Power Station (BIPS). The use of all five units at Snapper Point Power Station is not equivalent to a large generator, and dispatch of units at BIPS in addition is likely to also be required.
- For conditions when the operational demand in South Australia is below 600 MW, switching of Magill – East Terrace 275 kV cable may be necessary for the management of system voltages as a last resort in addition to the availability of two large synchronous generators or equivalent.

ElectraNet has further completed a voltage control RIT-T[12] to ensure sufficient voltage control capability is provided in the Adelaide metropolitan area. The required reactors are expected to be commissioned and in service by mid-2026. Once this additional reactive power equipment is in service, this will potentially enable operation of South Australia with one large synchronous generator even when operational demand drops below 600 MW.

[10] ElectraNet limit advice to AEMO [Internal Document] has the complete list of study assumptions, observations, conclusions and recommendations. The above only lists a summary of the study results as it pertains to operation with one large synchronous generator.

[11] A list of these essential reactive power building blocks is available in the ElectraNet limit advice to AEMO [Internal Document]. Following the loss of an essential reactive power device, an additional large synchronous generator connected to the 275 kV network will be necessary for voltage control to enable the power system to be re-secured within 30 minutes after any contingency event.

[12] See https://electranet.com.au/wp-content/uploads/2024/11/ElectraNet-2024-TAPR-2.pdf.

6 System strength

AEMO publishes system strength limit constraints based on limits advice provided by ElectraNet[13].

Various combinations of generators and synchronous condensers were published previously with a minimum requirement for at least two large synchronous generators or its equivalent to be kept online. This configuration resulted in an IBR hosting capacity of up to 2,500 MW.

ElectraNet carried out an assessment to inform the aggregate limit for hosting IBR generation if the minimum requirement is reduced to one large 275 kV-connected synchronous generator along with the four synchronous condensers kept online.

With South Australia interconnected to the rest of the NEM and Heywood Interconnector in service, the assessment reached the following conclusions:

- Under system normal conditions with no prior outages, the limit for hosting IBR generation remains unchanged at 2,500 MW compared to the limits published with two synchronous generators.
- Under N-1 prior outage conditions (including the outage of a synchronous condenser), a limit of 2,200 MW of IBR generation can be sustained with one large 275 kV-connected synchronous generator in service.
- No adverse system strength impact in the South Australian power system could be identified with transition to one large 275 kV-connected synchronous generator and four synchronous condensers in service.

[13] See https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information-resource/limits-advice.

7 Managing inertia and regulation 88A

Following the introduction of regulation 88A of the *Electricity (General) Regulations 2012* (SA), ElectraNet has provided information to AEMO for transfer limits on the Heywood Interconnector to maintain the expected RoCoF in the South Australian power system to 3 Hz/s or less, following the non-credible contingency trip of both Heywood circuits. The presence of four synchronous condensers with flywheels also provides a certain level of inertia in the South Australian power system.

Depending on other factors – such as the additional inertia available via online synchronous generators, demand, and amount of load available for UFLS – AEMO applies a constraint on the Heywood Interconnector to limit the RoCoF to 3 Hz/s or less. Therefore, the impact of reducing the minimum number of synchronous generators kept online in South Australia can be managed through meeting this requirement for regulation 88A.

AEMO's annual inertia assessment[14] confirmed that the minimum requirements are met for the South Australian power system and no inertia shortfalls have been identified over the three-year assessment horizon, however ElectraNet is required to ensure sufficient supplies are available to meet its inertia sub-network allocation from 1 December 2027.

AEMO has also investigated and proposed preferred management actions for the containment, stabilisation, and recovery of extreme under-frequency for the non-credible loss of Heywood Interconnector leading to islanding of the South Australian power system[15]. These proposed recommendations are expected to minimise the identified power system risks associated with extreme under-frequency to non-material levels, including in scenarios with no minimum requirement for dispatch of synchronous generation within the South Australian power system.

[14] See https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system_security_planning/2024-inertia-report.

[15] See https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/psfrr/non-credible-separation-of-south-australia.pdf?la=en&hash=1F1702974B14DC704FB964C7A25E8645.

8 Ability to re-secure the South Australian power system

Under NER 4.2.6 (b), AEMO is required to take reasonable action to endeavour to restore the power system to a secure operating state as soon as possible and, at most, within 30 minutes of a contingency event. When South Australia is interconnected to the rest of NEM or at credible risk of separation[16], depending on other power system requirements and system considerations, two large synchronous generators or its electrical equivalent will be necessary in addition to the synchronous condensers to re-secure the power system following a contingency event.

Following a non-credible separation of South Australia from the rest of the NEM, re-securing the system would require the use of BESS or fast start generators and the VFFCAS market. In addition to meeting the RoCoF requirements stated in Section 7 above, it will be critical to manage -post contingency event regulation FCAS, including ensuring sufficient reserves are available, such as BESS headroom.

These resources are needed irrespective of the number of synchronous generators online prior to the contingency event. However, depending on the availability of fast start units and any forced outage of critical equipment, two or more synchronous generators may be required to re-secure the power system.

Where abnormal conditions arise in South Australia while it is islanded, additional measures including use of fast start generators and BESS may be necessary to secure portions of the island or to manage such conditions. This may be needed, whether or not, AEMO has reclassified any non-credible contingency events as credible.

[16] AEMO's requirement that two large synchronous generators should be online in SA during a credible risk of separation is based on the risk assessment completed under the Operations Transition Committee. The transition to a single unit requirement is a significant change to the power system operation which lowers resilience when at credible risk of separation. As such AEMO requires to operate the power system with two large synchronous generators when there is a credible risk of islanding.

9 Power system damping

ElectraNet assessed damping performance of South Australia with one large 275 kV-connected synchronous generator in service based on the criteria in NER S5.1a.3, which require the halving time of any inter-regional or intra-regional oscillation for planning and operational purposes to be less than five seconds. This limit corresponds to a damping limit of σ = -0.139 (Nepers per second [Np/s][17].

ElectraNet assessed the inter-area modes such as I20, I25 and I35 in the NEM, and derived the following conclusions:

- Providing that under system normal conditions (but with one Para static VAR compensator [SVC] out of service) the measured (that is, operational) damping-constant of the I25 mode is better than -0.3 Np/s and that of the I20 and I35 modes is better than -0.14 Np/s, system damping performance is expected to be operationally adequate, following the worst contingency[18], when there is only one large 275 kV-connected synchronous generator unit online in South Australia.
  - This conclusion assumes that the worst-case degradation in damping determined for the export scenarios and outages considered in the investigation is representative of that which is likely to occur in practice.
- Providing that under system normal conditions (but with one Para SVC out of service) the measured (that is, operational) damping-constant of the I35 mode is better than -0.4 Np/s and that of the I20 and I25 modes is better than -0.14 Np/s, system damping performance is expected to be operationally adequate, following the worst contingency, when there is only one large 275 kV -connected synchronous generator unit online in South Australia.
  - This conclusion assumes that the worst-case degradation in damping determined for the import scenarios and outages analysed in the investigation is representative of that which is likely to occur in practice.

AEMO will work with ElectraNet to implement the above system damping limits for Heywood Interconnector transfer, while also continue monitoring of system damping performance via Oscillation Stability Monitoring (OSM) and GE PhasorPoint™. Any system damping performance concerns will be managed in line with existing AEMO processes.

[17] Assuming an exponential decay, exp (-σ.t) = 0.5, for time t = 5 s, the exponential damping constant can be calculated as σ = -0.139 Np/s.

[18] The most onerous contingency for export and import conditions when assessing power system damping is included in the ElectraNet limits advice to AEMO. Further assessments by ElectraNet have also confirmed that the above criteria for damping is met with Heywood Interconnector transfer levels up to +/- 650 MW.

10 Heywood Interconnector transfer capability

ElectraNet assessed the impact to Heywood Interconnector transfer limits with only one large synchronous generator and four synchronous condensers in service in South Australia, and the impact of this arrangement on the existing Heywood Interconnector transient and voltage stability transfer limits for system normal and prior outage operating conditions (including few credible contingencies) for import conditions into South Australia and export conditions from South Australia.

ElectraNet carried out this assessment under system normal operating conditions, varying the South Australia system demand between 1,200 MW and 2,600 MW with a DPV capacity factor between 20% and 80%, and derived the following conclusions:

- The Heywood import and export limits did not change significantly with one TIPS B generator online.
- A further sensitivity demonstrated that tripping of a TIPS B unit or the tripping of Torrens Island Battery Energy Storage System (TIB1) at the same generating output level showed insignificant difference on the Heywood Interconnector import limit.
- When the South Australia network operated with one large 275 kV-connected synchronous generator, results indicate that South Australia import and export stability limits for a TIPS B unit tripping as the contingency are lower compared to when tripping a Pelican Point machine.
- When Quarantine Power Station unit 5 (QPS5) is operated as the single unit in South Australia and is tripped, it results in higher import limits than when tripping either TIPSB or Pelican Point machines. This is an expected outcome, as a fault on the 66 kV network does not cause as significant a DPV shake off as the two 275 kV contingencies. However, this scenario does not meet the voltage control requirements in the Adelaide metropolitan area.
- The N-1 sensitivity study results for the four prior outage operating conditions studied in South Australia indicate that the total Heywood Interconnector transfer limits are not impacted by the number of large synchronous generators online within South Australia.
- It can be concluded that operating with one large 275 kV-connected synchronous generating unit in South Australia will have minimal impact on the existing Heywood Interconnector import or export transfer capability. It was identified that the contingency with the greatest impact on Heywood Interconnector transfers is a 275 kV network fault followed by the tripping of a single online TIPS B machine.
- The existing Heywood Interconnector system normal and N-1 limit advice remains unchanged for power system operation with one large synchronous generator in service. The existing limit advice provided by ElectraNet can continue to be applied. There are constraints[19] in place that manage the flow on the interconnector.

[19] V^^S_NIL_TBSE_2, V^^S_NIL_TBSE_1, V^^S_NIL_SETB_SECP_2, V^^S_NIL_SETB_SECP_1, V^^S_NIL_MAXG_SECP_2, V^^S_NIL_MAXG_SECP_1,V^^S_NIL_MAXG_3, V^^S_NIL_MAXG_2, V^^S_NIL_MAXG_1, V::S_NIL_TBSE_2,V::S_NIL_TBSE_1, V::S_NIL_SETB_SECP_2,V::S_NIL_SETB_SECP_1, V::S_NIL_MAXG_SECP_2, V::S_NIL_MAXG_SECP_1, V::S_NIL_MAXG_3,V::S_NIL_MAXG_2, V::S_NIL_MAXG_1, S::V_NIL_TBSE_2-DS, S::V_NIL_TBSE_1

11 Mid-North generation limit

ElectraNet assessed the dispatch limit for the Mid-North region generation with only one large 275 kV-connected synchronous generator in service in South Australia, and the impact of this arrangement for transient and voltage stability on allowable generation of the existing Mid-North wind and solar farms with system normal and prior outage conditions. The prior outages included contingencies of the synchronous condensers.

The assessment provided the following conclusions:

- Operation of South Australia with one large 275 kV-connected synchronous generator has a minimal impact on the Mid-North region wind and solar farm dispatch limit. As a percentage of total dispatchable capacity, some of the prior outages and contingencies considered had the impact of lowering the dispatch limit by 5-15% compared to operation with multiple synchronous generators in service. Overall, most scenarios remained unaffected by the change.
- The inclusion of TIB1 also had minimal impact on the limit of a couple of scenarios when compared to studies that did not include TIB1.
- Minor amendments are required to the existing transfer capability limits for Mid-North wind and solar farm generation to support power system operation with one large 275 kV-connected synchronous generator in service.

12 Emergency frequency control schemes

As constraint equations are used to manage the requirements for meeting regulation 88A to keep the RoCoF in the South Australia power system to 3 Hz/s or less following the non-credible trip of Heywood Interconnector (see Section 7 above), the impact on UFLS and OFGS schemes is negligible. In other words, active power flows on Heywood Interconnector are managed based on available inertia and load, during periods when UFLS is inadequate.

In addition to constraining the active power flow being imported on Heywood Interconnector during high-risk periods, AEMO along with ElectraNet and SA Power Networks plans to implement or has already implemented the following actions to manage power system response to extreme under-frequency events[20]:

- Restore or increase the amount of emergency under-frequency response available via UFLS.
- Expand the amount of load available for delayed UFLS action to aid in frequency recovery.
- Explore the use of frequency recovery mode using existing and new proportional droop response providers to further aid in frequency recovery and offset detrimental withdrawal as frequency recovers.

AEMO reviewed the existing OFGS schemes in South Australia and found them insufficient for certain conditions and contingencies. AEMO therefore requested ElectraNet increase the OFGS capacity to manage over-frequency events by adding more generators to the scheme and increasing the delay of OFGS trip settings to aid with frequency recovery and reducing the offset with settling frequency. The implementation of updated OFGS settings is being progressed with ElectraNet and is subject to successful testing and commissioning.

ElectraNet has upgraded the System Integrity Protection Scheme (SIPS) to a more effective Wide Area Protection Scheme (WAPS) to lower the risk of South Australia islanding due to the trip of multiple South Australia generators when South Australia is importing, as recommended by the 2023 GPSRR (and previous Power System Frequency Risk Reviews)[21]. It was anticipated that the protection grading in the SIPS was very tight and sensitive to the number of synchronous generators online. However, this short-term risk has been mitigated with the implementation of WAPS.

In addition to the UFLS and OFGS schemes, the above automated control schemes are available to prevent instability in South Australia following cascading events.

[20] See https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/psfrr/non-credible-separation-of-south-australia.pdf?la=en.

[21] See https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2023/draft-2023-general-power-system-risk-review/2023-gpsrr.pdf?la=en.

13 Protection adequacy

ElectraNet and SA Power Networks assessed protection system adequacy with one large 275 kV-connected synchronous generator in service in South Australia.

This assessment found that:

- Under system intact conditions – that is, when South Australia is interconnected to the rest of the NEM – protection is adequate with one large 275 kV-connected synchronous generator and four synchronous condensers in service.
- For South Australia island conditions (including largest pre-contingent outage) and with no change of existing hardware or relay replacement, protection systems will operate as expected under the most onerous fault level scenarios, with one large 275 kV-connected synchronous generator and four synchronous condensers in service.

ElectraNet completed some setting changes to account for operation with a minimum of one 275 kV-connected synchronous generator kept online in South Australia under island conditions.

14 Summary

ElectraNet and AEMO assessed various impacts on system requirements as part of this program of work, including frequency control, ramping and reserve management, grid reference, voltage control, system strength, re-securing the power system following a contingency event, power system damping, interconnector and Mid-North transfer capability, emergency frequency control scheme, and protection system adequacy. Table 1 summarises the conclusions.

Table 1 Results of the assessment outcome, indicating technical feasibility to transition to a reduced minimum number of synchronous generators

South Australia power system requirements	When South Australia is interconnected to NEM	South Australia at risk of islanding	South Australia islanded
Frequency control	Necessary requirements can be procured from other regions.	Reliance on emergency frequency control scheme.	Reliance on FFR and VFFCAS market, including interventions.
Ramping and reserve management	One or zero synchronous generators found to be adequate to manage historical ramps.	Two large synchronous generators or equivalent may be required, market response likely to aid further.	
Grid reference	One or zero synchronous generators can maintain grid reference along with synchronous condensers, but a physical test is needed to verify this concept if zero synchronous generators are online.		
Voltage control	One large 275 kV-connected synchronous generator with reactive power control devices in Adelaide metropolitan is sufficient provided the operational demand is greater than 600 MW.		
System strength	Four synchronous condensers are installed to provide necessary system strength to the South Australian network.		
Managing Inertia and regulation 88A	Depending on South Australia system inertia and demand, the Heywood Interconnector flow can be controlled to reflect regulation 88A requirements.		Minimum levels for inertia sub-network have been met in the three-year horizon and options for frequency containment have been implemented.
Re-securing the power system	Two large synchronous generators may be required or more depending on availability of fast start units and other operating conditions (such as reclassification of lines, or severe weather warning).		
Power system damping	System damping performance is expected to be operationally adequate, following the worst contingency, when there is only one large synchronous generating unit online in South Australia, provided the inter-area modes have damping below a certain threshold during system normal.		
Heywood Interconnector transfer capability	The existing Heywood Interconnector system normal and N-1 limits advice remains unchanged for power system operation with one large synchronous generator in service.		Not applicable.
Mid-North generation limit	The Mid-North generation limit is not impacted by the further reducing the minimum number of synchronous generators in South Australia.		
Emergency frequency control schemes (EFCS)	System inertia and operational demand is factored in to manage Heywood Interconnector flow such that the EFCS remains adequate. WAPS in addition to EFCS is available to lower the risk of islanding due to trip of multiple generators in South Australia when importing.		
Protection adequacy	Transmission and distribution system protection are adequate with four synchronous condensers and one large 275 kV-connected synchronous generator.		

Note: this table assumes four synchronous condensers are online during system normal in addition to the large synchronous generators in service.
Colour coding: Grey cells indicate that the present minimum requirement of two synchronous generators must continue to be met for the corresponding power system requirement and system condition.