electranet

Meeting System Strength Requirements in SA

RIT-T Project Assessment Draft Report

31 MARCH 2025

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Revision Record

Date	Version	Description	Author	Reviewed by	Approved by
31/03/25	1	ElectraNet's System Strength PADR	Wickrama Keerthipala	Various	Brad Harrison

Executive Summary

ElectraNet is responsible for ensuring sufficient system strength services are available in South Australia.

ElectraNet, as the System Strength Service Provider (SSSP) for South Australia under the National Electricity Rules (NER), is responsible for ensuring sufficient system strength services are available to maintain the minimum and efficient levels for the South Australian high-voltage (HV) power transmission system.

An electrical transmission system without adequate system strength will be unreliable. For example, in a system with inadequate system strength:

- Generators may be unable to operate continuously during disturbances on the power system.
- Maintaining power system stability becomes challenging (for example the system voltage and phase angle cannot be kept within safe operating limits).
- Protection systems that ensure safe operation of the network may not operate correctly to protect the system leading to damage to network infrastructure.

Collectively, these issues increase the risk of supply interruptions to end consumers and, as a result, NER obligations have been placed on regional SSSPs like ElectraNet to ensure sufficient system strength and ultimately, reliability.

This Project Assessment Draft Report (PADR) is the second step in the Regulatory Investment Test for Transmission (RIT-T) process to determine the appropriate investments to manage ElectraNet's system strength obligations. It follows the Project Consultation Specification Report (PSCR), and accompanying Expression of Interest (EOI), published on 30 November 2023.

The 'minimum fault level' system strength requirements

Under NER clause S5.1.14, ElectraNet is required to deliver system strength services to the South Australian power system to meet standards set by the Australian Energy Market Operator (AEMO) from 2 December 2025, including for:

- the safe and secure operation of the power system ('minimum level'); and
- to facilitate the stable voltage waveform ('efficient level') of new inverter-based resources (IBRs).

Reference to AEMO's System Strength reports published in 2022, 2023 and 2024, indicates the 'minimum level' system strength requirements are forecast to be sufficient within a three-year period in South Australia without intervention by ElectraNet or AEMO. From the three AEMO system strength reports released to-date, we find that It is likely AEMO does not need to intervene to meet the minimum level (i.e. fault current basis) of system strength in SA prior to December 2027. ElectraNet is not forecasting a shortfall beyond that horizon.

The identified need for this RIT-T is focussed on the provision of stable voltage waveform support for future IBR that AEMO has forecast for South Australia. That is, to meet the 'efficient level' system strength requirements.

Our analysis finds that action is not required to meet the 'efficient level' requirements under the ISP *Step Change* scenario.

We have forecast the stable voltage waveform requirements (i.e. provision of system strength at the efficient level) for South Australia and investigated the additional system strength services required, if any, to support hosting the IBR forecast from AEMO's 2023 System Strength Report.

A detailed PSCAD model including the Project EnergyConnect (PEC) stage 2 interconnector[1] has been used to assess the impact of connecting the forecast IBR volumes in-line with the AEMO 2023 ISP *Step Change* scenario. This assessment finds that the existing network, following the commissioning of PEC stage 2, will have sufficient system strength[2] to maintain stable voltage waveform while hosting the forecast IBR volumes under the AEMO 2023 ISP *Step Change* scenario.

There are some uncertainties with this analysis, including:

- the rate of growth in IBR investments;
- the rate at which IBR generators will improve and contribute to satisfying system strength services; and
- the assumed representation of the forecast generation included in the PSCAD models more than three years ahead.

On balance, we do not consider that there is a requirement to procure additional system strength solutions to meet the 'efficient level' system strength requirements in South Australia under the ISP *Step Change* scenario. We note that this position differs from that in the PSCR and is due to changes in the IBR forecasts since the PSCR was published, as well as a more refined methodology being applied at the PADR stage.

Therefore, we consider that options requiring large capital expenditure such as synchronous condensers should be delayed. However, noting uncertainties in the analysis and potential increases to AEMO's previously advised IBR connection forecast confirmed in the 2024 ISP *Step Change* scenario (particularly after December 2029), it is considered prudent to recommend low cost generic system strength services now as 'low regret' insurance against the system otherwise having insufficient system strength.

Adding clutches to new synchronous generators represents 'low regret' insurance against having insufficient system strength.

ElectraNet is experiencing interest in new Large Industrial Loads (LIL) seeking connection to the transmission network. This raises the potential for a much more rapid increase in IBR connections than forecast in the *Step Change* scenario.

[1] Specifically, 330 kV double circuit line between Bundey, Buronga and Wagga-Wagga to be operational in 2027.

[2] The process and methodology were given in a Technical Note prepared by ElectraNet.

We consider the *Green Energy Exports* scenario (see Figure 2) is a useful proxy for the potential connection of LIL. If this scenario unfolds, and no action is taken to meet the efficient level, there could potentially be significant and rapid investment in further system strength services requirements. It may not be possible to deliver this investment sufficiently quickly, due to the long lead times for some of these investments, which could result in insufficient system strength. Alternatively, while it may be possible to deliver an urgent investment in time, it could come at a significant cost to customers.

Proactively preparing the network with low-cost mechanical clutches to new synchronous generators, enabling them to operate as synchronous condensers, may partially or completely avoid the need for any such 'emergency investment' (as well as any reliability implications for customers).

Based on submissions to the PSCR/EOI and the South Australian Government's development of a Firm Energy Reliability Mechanism (FERM), we think it is likely that new synchronous generators will develop in the next few years.

The use of clutches provides an opportunistic, low cost and 'low regret' insurance against the need to provide additional system strength in South Australia due to a greater volume of IBR connecting (e.g. through LIL connections) in the next three to five years.

Specifically, while these solutions would ultimately be provided by non-network proponents (the costs of which would be recovered via network support contracts with ElectraNet), the incremental capital cost of fitting clutches during construction is estimated to cost in the order of $5 million.

We consider that the addition of clutches to new synchronous generators provides prudent insurance against needing to provide additional system strength in the future, and ElectraNet considers that these contracts should be considered the basis of the preferred option for this RIT-T.

We consider this conclusion to be consistent with the recent AER guidance on managing uncertainty beyond the compliance years (i.e. that SSSPs may procure system strength solutions for beyond the next three years if they demonstrate net economic benefits).[3]

Moreover, we note that the costs of these contracts would only be incurred, and thus recovered from consumers, if clutch proposals can be proven as technically feasible[4] and proponents accept a prudent and efficient price.

At this stage, we consider that new generators adding a clutch could be located anywhere on our 275 kV network, particularly near future IBR clusters, e.g. Cultana.

The PADR has benefitted from stakeholder submissions.

The PSCR and the EOI published in November 2023 were the first step of the RIT-T process and resulted in twelve submissions from proponents.

[3] AER, *The Efficient Management of System Strength Framework*, AER Guidance Note, December 2024, p. 18.

[4] See page 12-14 of draft-transitional-services-guideline.pdf, See also ISF final determination information sheet

The total installations proposed from the twelve submissions can be categorised as follows;

1. 3300 MVA of grid-forming (GFM) Battery Energy Storage Solutions (BESS)
2. 433 MVA of synchronous generator or conversion to synchronous condensers; and
3. 275 MVA of synchronous condensers.

Each type of plant proposed by EOI submissions is used in the PADR to define and assess certain 'generic scalable solutions' with a combination of several such solutions proposed to provide services on a contracted basis.

Submissions

We welcome written submissions on materials contained in this PADR. In particular, we would like to hear from any proponents of new synchronous generators for whom the addition of a clutch to enable operation as a synchronous condenser would be considered.

Submissions are due on 15 June 2025.

Submissions should be emailed to our Planning team via consultation@electranet.com.au

In the subject field, please reference 'Meeting System Strength Requirements in SA RIT-T PADR'.

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Glossary

AACE	The Association for the Advancement of Cost Estimation
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AFL	Available Fault Level, AFL method
AG	Asynchronous Generation
AI	Artificial Intelligence
BESS	Battery Energy Storage System
CESC	Clutch Enabled Synchronous Condenser
CSC	Converted Synchronous Condenser
EDP	Energy Development Plan
EFCS	Emergency Frequency Control Scheme
EOI	Expression of Interest
EMT	Electromagnetic Transients
ESCOSA	Essential Services Commission of South Australia
FERM	Firm Energy Reliability Mechanism
FIA	Full Impact Assessment
GFM	Grid-Forming Inverter
GFL	Grid-Following Inverter
GPS	Generator Performance Standard
GTPS	Generator Technical Performance Standards
HJP	Hydrogen Jobs Plan (including 200 MW H2 Gen)
H2 Gen	Hydrogen Gas Synchronous Generator
HV	High Voltage
IBR	Inverter Based Resources
LIL	Large Industrial Loads
N	System Normal (all transmission elements in service)
N-1	System Normal minus one transmission element
NEM	National Electricity Market
NER	National Electricity Rules
NGM	National Grid Metering
NSP	Network Service Provider (may be a transmission or a distribution entity)
NSCAS	Network Support and Control Ancillary Services
OEM	Original Equipment Manufacturer
OTR	Office of the Technical Regulator
PADR	Project Assessment Draft Report
PEC stage 2	Project Energy Connect stage 2 (800 MW link)
PSCR	Project Specification Consultation Report
PoW	Point on Wave
PSCAD	Manitoba HVDC Research Centre Ltd. Power System Computer Aided Design software
PSS®E	Siemens PTI Power System Simulator for Engineering load flow software
PV	Photo-Voltaic
PVT	Power Voltage Transformer
PWM	Pulse Width Modulation

RIT-T	Regulatory Investment Test for Transmission
RMS	Root Mean Square
RTG-CSC	Repurposed Thermal Generator Converted Synchronous Condenser
SA	South Australia
SC	Synchronous Condenser
SF	Solar Farm
SCR	Short Circuit Ratio
mSCR	Minimum Short Circuit Ratio
SSSP	System Strength Service Provider
SSN	System Strength Node
SSQ	System Strength Quantity
STATCOM	Static Synchronous Compensator
SVW	Stable Voltage Waveform
SVWSS	Stable Voltage Waveform Support Services
TAPR	Transmission Annual Planning Report
TEM	Transverse Electromagnetic Mode of propagation
TIPS	Torrens Island Power Station
TNSP	Transmission Network Service Provider
WAPS	Wide Area Protection Scheme
WF	Wind Farm
X”	Sub-transient Reactance
Xs	Synchronous Reactance

1 Introduction

From 2 December 2025, a new system strength framework[5] will commence under the National Electricity Rules (NER). Under the new framework, ElectraNet is required to act as a System Strength Service Provider (SSSP) and is responsible for planning and operating our network to ensure there is sufficient system strength available in the South Australian (SA) electricity transmission system to meet the standard[6] required by the Australian Energy Market Operator (AEMO).

The 2022 System Strength Report provided the first of AEMO's forecasts and assessments under the new framework, including the 10-year inverter-based resources (IBR)forecast for each system strength node declared (which is to be used by SSSPs for the purposes of meeting the efficient level of system strength)[7]. AEMO's forecasts and assessments have been subsequently updated in AEMO's 2023 and 2024 System Strength Reports[8,9].

ElectraNet is applying the Regulatory Investment Test for Transmission (RIT-T) to options that deliver system strength services to the SA transmission system to meet the efficient standards category set by AEMO from 2 December 2025, as reflected in the AEMO System Strength Report[9] published in December 2023. We are required under the NER to provide these system strength services to maintain the safety, security and reliability of the power system.

1.1 What's in the PADR

This Project Assessment Draft Report (PADR) is the second step in the RIT-T process. It follows the publication of the Project Specification Consultation Report (PSCR)[10] and accompanying Expression of Interest (EOI) published in November 2023.[6] The objective of this PADR is to:

- Summarise the reasons why ElectraNet has determined that investment is necessary.
- Update the description of the identified need for this RIT-T, reflecting developments since the publication of the PSCR (including the publication of AEMO's 2023 System Strength Report and an update to the asynchronous generation feasibility due to improved system strength after commissioning of the PEC stage 2).
- Summarise submissions to the PSCR/EOI, highlighting how these have been addressed in the RIT-T analysis and present generic options derived from of these submissions.
- Recognise the uncertainty in the forecast volume of IBR under the ISP *Step Change* scenario.
- Describe the options being assessed under this RIT-T.
- Set out the basis on which the costs have been estimated at this stage of the RIT-T process.

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[5] *ElectraNet's obligation is to meet the standard under NER Schedule 5.1.14 from 2 December 2025.*

[6] *The standard in general is two-fold; (1) Minimum standard: minimum fault level (2) Efficient standard: stable voltage waveform to support IBR hosting.*

[7] AEMO, *2022 System Strength Report*, December 2022, p.15. ElectraNet needs to meet efficient level of system strength only.

[8] AEMO, *2023 System Strength Report*, December 2023.

[9] Our technical assessment was performed from April to October 2024 based on AEMO's 2023 System strength report. Later in the year, in December 2024, AEMO published 2024 System strength report.

[10] ElectraNet RIT-T PSCR on System Strength requirements in SA, AEMO | ElectraNet System Strength RIT-T PSCR

- Provide details of the overall proposed preferred option at this stage of the process.

Overall, this report provides transparency into the planning considerations for investment options to ensure that ElectraNet meets its obligations as the SSSP for SA.

1.2 Submissions and next steps

We welcome written submissions on materials contained in this PADR. ElectraNet would particularly like to hear from any proponents of new synchronous generators for whom the addition of a clutch to enable operation as a synchronous condenser would be considered, as outlined in the body of this PADR.

Submissions are due on 15 June 2025.

Submissions should be emailed to our Planning team via consultation@electranet.com.au

In the subject field, please reference 'Meeting System Strength Requirements in SA RIT-T PADR'.

2 The identified need

System strength is a fundamental service required for the power system to operate in a secure state. A power system with inadequate system strength raises the risk of system instability and supply interruptions to end consumers.

Under NER clause S5.1.14, ElectraNet, as the SSSP for South Australia, is required to deliver system strength services to the South Australian power system to meet standards set by AEMO from 2 December 2025, including for:

- the safe and secure operation of the power system ('minimum level'); and
- to facilitate the stable voltage waveform ('efficient level') of new IBR.

As outlined in the PSCR, this is a 'reliability corrective action' RIT-T as it is being undertaken for the purpose of meeting externally imposed regulatory obligations and service standards under the NER.

2.1 Minimum level system strength requirements

To ensure that protection systems operate correctly, and voltage magnitudes stay within acceptable levels, a minimum amount of system strength is required. Three phase fault levels are used to define this minimum system strength requirement, measured in MVA fault level at the system strength nodes in South Australia.

The 'minimum level' system strength requirements do not require addressing at this point in time in South Australia as there is forecast to be sufficient system strength without further intervention by ElectraNet. This conclusion is supported by all three of AEMO's system strength reports released to-date. It is unlikely that AEMO will need to intervene to meet the minimum level (i.e. fault current basis) of system strength in SA prior to December 2027.

2.2 Efficient level system strength requirements

SSSPs must use reasonable endeavours to ensure stable voltage waveforms such that in steady state conditions IBR and market network service facilities do not create, amplify or reflect instabilities.

Avoiding voltage waveform instability following any credible contingency event or protected event should not depend on any of the IBR or market network service facilities disconnecting from the power system. Additionally, there should be no significant variation in the active or reactive power transfer at the connection point, except in accordance with applicable performance standards.

A detailed PSCAD model of the South Australian power system (which includes the PEC stage 2 interconnector)[11] has been used as part of this PADR to assess the impact of connecting the forecast IBR volumes under the AEMO 2023 ISP *Step Change* scenario. This assessment finds that the existing network, following the commissioning of PEC stage 2, will have sufficient system

[11] Specifically, a 330 kV double circuit line between Bundey, Buronga and Wagga-Wagga to be commissioned in December 2026.

strength to maintain stable voltage waveform while hosting the forecast IBR volumes under the *Step Change* scenario.

Specifically, detailed studies[12] conducted on IBR volumes forecast under ISP *Step Change* scenario for the ten-year period (2024-2034) show that the existing system strength plus the contribution from PEC stage 2 are expected to be sufficient to maintain stable voltage waveform at the System Strength Nodes (SSNs) for the forecast IBR volumes.

We consequently do not consider that there is a requirement to procure any additional system strength solutions to meet the 'efficient level' system strength requirements in South Australia considering the AEMO 2023 ISP *Step Change* scenario forecast.

We note that this position differs from that in the PSCR and is due to a necessarily more refined methodology being applied at the PADR stage (as well as updated AEMO IBR forecasts since the PSCR). Specifically:

- The PSCR used the Available Fault Level (AFL) method as a screening tool to estimate the system strength requirements – the required solution based on the AFL methodology was equivalent to a 125 MVAr rated synchronous condenser each at Robertstown and Para for the period from FY26 to FY30; while
- The PADR has employed detailed system studies utilising a wide area PSCAD model of the SA system to evaluate the stability of voltage waveforms at the connection points of the forecast volume of IBR under the ISP *Step Change* scenario – the methodology applied for these studies was consistent with ElectraNet's FIA process and was used to assess this stable voltage waveform requirements to host the forecast volume of IBR.

Despite being a more refined method than the AFL method, PSCAD based models are not typically used more than three years ahead. This is due to the highly detailed inputs required of the model, small changes for which can influence the outcomes. Notwithstanding this limitation, we consider this to be a more appropriate method for the assessment of the efficient level of system strength.

Additional detail on these two processes can be found in Appendix H.

2.3 Rapid growth in load may require additional system strength

ElectraNet is experiencing very high interest in LIL connections to the transmission network. These loads are not included in the AEMO *Step Change* demand forecasts.

ElectraNet first notified the market of this interest in an update to our 2022 Transmission Annual Planning Report in May 2023 and this interest was subsequently included in AEMO's ISP as a sensitivity highlighting the potential for much faster demand growth than the *Step Change*. We consider that, if LIL connections occur, they would increase the system strength requirements in South Australia.

[12] "ElectraNet internal Assessment of efficient system strength requirements under ISP *Step Change* scenario for South Australia to 2034", ElectraNet, 2024 September 30.

The 2024 ISP includes a *Green Energy Exports* scenario, which sees very strong industrial decarbonisation and low-emission energy exports. Under this scenario, the South Australian network would support major new export industries.[13] The *Green Energy Exports* scenario involves a much greater volume of IBR forecast, and thus need for system strength, in comparison to the *Step Change* scenario.

In light of these potential developments, we consider it prudent to consider the *Green Energy Exports* scenario as a proxy for additional LIL connecting (and the expected higher IBR forecast) and so have also referred to this as part of the PADR. This is discussed further in section 2.4.2 below.

2.4 Key assumptions underpinning the identified need have changed since the PSCR

The sections below outline how the key assumptions regarding system strength requirements have changed since the PSCR was published.

2.4.1 *Step Change* scenario from AEMO 2023 System Strength Report

While the overall characterisation of the identified need for this RIT-T has not changed since the PSCR, the detail regarding the amount of system strength required has been refined. This has been driven by the 2024 ISP process resulting in changes to the AEMO IBR forecasts as distinct from forecasts published by AEMO in December 2023.

The analysis in this PADR uses the IBR forecast set out in AEMO's 2023 System Strength Report and so differs from that presented in the PSCR, which was based on the previous 2022 System Strength Report.

The 2023 AEMO System Strength Report reflects several key developments since the 2022 System Strength Report that have had a material impact on the amount of system strength that ElectraNet has to procure. Other factors that may influence IBR forecast in the immediate future may, include:

- the inclusion of latest State and Commonwealth policies, in particular the State government targeting 100% renewable energy in the South Australian electricity grid by 2027; and
- the South Australian Government's Firm Energy Reliability Mechanism (FERM), which, subject to the outcomes of consultation and further refinement of the design, is expected to incentivise investment in synchronous generators that would be suitable for inclusion of a clutch.

While we understand that our system strength requirement for each year is locked in three years in advance (i.e. the three-year binding period), and after that does not change even if AEMO updates the forecast in a later System Strength Report, we have nevertheless updated the IBR forecast underpinning the system strength requirement in all years to align with the

[13] AEMO, *2024 Integrated System Plan*, 26 June 2024, pp. 9 & 59.

2023 System Strength Report. We consider this consistent with the AER's recent guidance on the efficient management of system strength.[14]

Table 1: IBR forecast at Davenport: 2024 ISP *Step Change* scenario against that of 2023

Davenport IBR (MW)	Existing IBR	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
2023R	906	10	10	367	367	367	475	592	680	680	680	680	
2024R	906	10	210	567	567	567	811	1304	1304	1304	1313	1313	1313

Table 2: IBR forecast at Robertstown: 2024 ISP *Step Change* scenario against that of 2023

Robertstown IBR (MW)	Existing IBR	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
2023R	1636	209	727	727	1185	1190	1331	1315	1285	1292	1514	1415	
2024R	1639	724	784	784	1048	1225	1931	1931	1925	2125	2250	2250	2250

Table 3: IBR forecast at Para: 2024 ISP *Step Change* scenario against that of 2023

Para IBR (MW)	Existing IBR	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
2023R	913	71	84	84	356	551	551	551	551	745	745	745	
2024R	869	135	235	235	257	257	257	257	257	331	331	306	306

AEMO's most recent System Strength Report, released in December 2024, indicates a higher volume of IBR at Robertstown and Davenport after FY 2030. For the immediate five years from now, the forecast under the 2024 report is also slightly greater than that of 2023 report. The 2024 report forecasts an increase in IBR beyond the three-year period, i.e. for the years 2027 and 2028 particularly for Davenport.

2.4.2 We have also referred to the *Green Energy Exports* scenario

As outlined above, we expect that the amount of additional system strength needed in South Australia if IBR forecasts increase in the future will be significant (e.g. if future additional LIL connect to our network).

Considering these potential developments, we consider it prudent to refer to the *Green Energy Exports* scenario as a proxy for additional LIL connecting and so have also referred qualitatively to this as part of this PADR.

Under the *Green Energy Exports* scenario, AEMO forecasts a much greater volume of IBR in comparison to the ISP *Step Change* scenario. Specifically, AEMO forecast IBR volume under this scenario exceeding 11 GW of wind, solar and BESS over the next ten years, as shown in the Figure 2 below.

[14] AER, *The Efficient Management of System Strength Framework*, AER Guidance Note, December 2024, p. 15.

Figure 1 shows a breakdown of the solar vs wind IBR forecast from the 2023 ISP *Green Energy Exports* scenario. From 2027 onwards the *Green Energy Exports* scenario forecast exceeds 6,000 MW of IBR in total. We have not tested our power system for stable voltage waveform for a volume of IBR of this size (6,000 MW), which may occur if the *Green Energy Exports* scenario materialises.

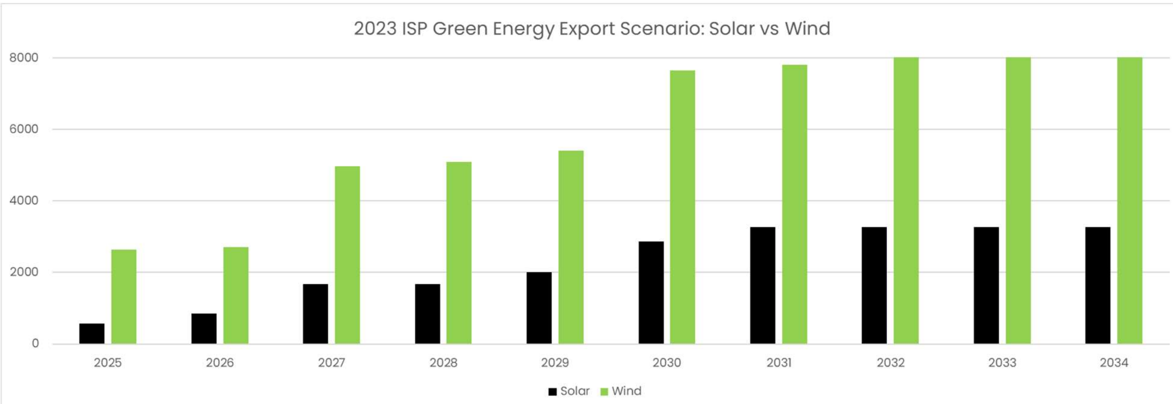

Figure 1: 2023 ISP *Green Energy Exports* scenario: solar and wind IBR forecast volume in MW

Considering the *Green Energy Exports* scenario now, minimises the likelihood that we will need to commence a new RIT-T in a few years' time should IBR forecasts increase due to these types of developments.

AEMO's 2024 System Strength Report includes a greater volume of IBR at Davenport and Robertstown after 2030 than the 2023 (and 2022) System Strength Report. This is consistent with our concerns regarding the *Green Energy Exports* scenario unfolding and/or additional LIL connecting.

We consider that our approach of considering the *Green Energy Exports* scenario to be consistent with the principles included in recent guidance provided by the Australian Energy Regulator (AER) for system strength RIT-T in terms of managing uncertainty beyond the binding three compliance years and taking into account the best information available to the SSSP at the time of the RIT-T.[15]

[15] AER, *The Efficient Management of System Strength Framework*, AER Guidance Note, December 2024, p. 15 & 18-19.

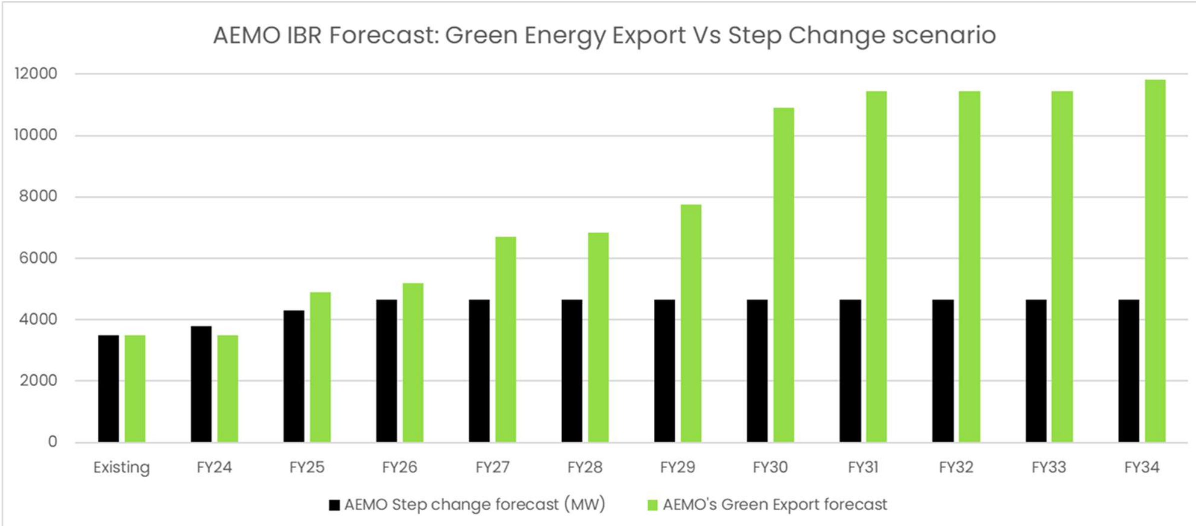

Figure 2: *Green Energy Exports*[16] vs *Step Change* scenario

Considering any greater volume of IBR above and beyond the ISP *Step Change* scenario (i.e. the gap between the green column and the black column in each year after 2027 shown in Figure 2) is not mandatary at the PADR stage. Nonetheless we have calculated an incremental cost ($ per MW of IBR rate of increase) just above the *Step Change* scenario within the PADR analysis (see sections B.1 and B.2) to provide an opportunity to consider proactive application of low-cost (generic) options for any incremental need beyond the *Step Change* scenario if it ever occurs.

[16]From AEMO 2023 System Strength report.

3 Non-network solutions

In conjunction with the PSCR, ElectraNet called for expressions of interest to provide non-network solutions to meet the identified need. This resulted in submissions from 12 parties. These submissions related mainly to BESS plants operating in grid-forming (GFM) mode. Other proposals were either synchronous condensers or conversions of existing gas synchronous generators into synchronous condensers.

BESS plants proposed vary in size (30 MVA to 1200 MVA) and location.

3.1 Submissions in response to EOI and PSCR

Table 4 summarises the statistics of the submissions in response to the EOI and PSCR. Four of the submissions also provided generic PSCAD models and some submissions were later withdrawn.

Table 4: Response to EOI and PSCR (March 2024) – Statistics

Solution type	Number	Minimum rating (MVA)	Maximum rating (MVA)	Remarks
GFM BESS	9	54	1200	Including conversion of existing BESS in GFL to GFM mode
Synchronous generator[17]	4	51	250	Some proposals withdrawn[18] later in 2024
Conversion of synchronous generator to condenser	1	250	250	Withdrawn late in 2024
Synchronous condenser	3	125	250	Including original equipment manufacturer (OEM) submissions
GFM Plant (OEM)	3	0	300	BESS and STATCOM included

3.1.1 Potential incremental need beyond the *Step Change* scenario

In the background of ElectraNet's latest assessment (as explained in section 2.2) there is no additional system strength required for connecting future volume of IBR forecast from AEMO's 2023 System Strength Report under the ISP *Step Change* scenario. The ISP *Step Change* scenario is considered as the baseline in our assessment.

[17] One of the proposals was a hybrid synchronous generator facilitating dual operation of condenser and generator mode possibly through a mechanical clutch mechanism.

[18] Two of the generator proposals were withdrawn within days after announcing the urgency in timing to respond in terms of a detail PSCAD model to TNSP for technical assessment. They may well be willing to resubmit proposals to this PADR knowing that circumstances are different and no urgency at this time around.

However, this gives an opportunity to consider proactive application of low-cost (generic) options for any incremental need beyond the *Step Change* scenario if it ever occurs. This assessment is described in the next section and draws directly on submissions made in response to the PSCR/EOI.

4 Generic options considered

Potential system strength generic solutions may include additional synchronous condensers, conversion of existing synchronous generators to condensers, synchronous machines when operating, synchronous machines with clutches that enables 24/7 provision of system strength services, GFM inverter-based plants (e.g. batteries, static synchronous compensators (STATCOMs)) and network reconfigurations.

Given the finding that there is no requirement for system strength services under the *Step Change* scenario, we have only explored options that have low capital cost and may therefore be a 'low-regret' decision if actioned now.

The following three generic options were examined further due to their low-cost relative to improved hosting capacity ($/MW related indices presented in Appendices B.1, B.2 and B.3) and based on EOIs received from proponents.

4.1 Option 1 - GFM BESS

GFM BESS were a popular proposal (see Table 4) from the proponents of non-network solutions. The total installation proposed across submissions totals 3300 MVA.

The capital cost of construction of a BESS is greater than that of a synchronous condenser. So much so that, although BESS can deliver a range of additional benefits to the system, this is not expected to be sufficient to overcome the higher cost. Further, as discussed above, we have concluded that the need does not warrant investment in high capital cost plant at this stage.

Given the high capital costs of the BESS facility, but the low incremental conversion cost of grid-following (GFL) mode to GFM mode of existing or committed/anticipated BESS plants, we have only considered the incremental cost of upgrading a committed/anticipated BESS to GFM operation. We also found that some existing BESS may potentially be upgraded from GFL to GFM operation at little cost.

We commissioned[19] Manitoba Hydro International to assess the potential of GFM BESS to provide 'efficient level' of system strength services. Based on those results we conclude that it is possible GFM BESS will be capable, under some circumstances, of providing some of the 'efficient level' of system strength services.

We commissioned GHD to assist in understanding the costs of conversion to GFM mode and verify submissions. GHD concluded[20] that the costs are low and estimated the incremental costs at less than $5m. However, it is also our understanding that BESS are increasingly likely to be grid-forming anyway in the future. This will be partly due to many original equipment

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[19] "System Strength contribution from GFM BESS – feasibility study", Manitoba Hydro International (MHI) report submitted to ElectraNet, September 2024 (see Appendix C).
[20] "Cost estimates for mechanical clutches and GFM BESS as enablers of System Strength", GHD report submitted to ElectraNet, October 2024 (see Appendix F).

manufacturers (OEM) offering directly grid-forming inverters without having to convert from grid-following mode.

Despite the low cost of upgrading to GFM operation for either committed/anticipated or existing BESS, we have concluded that this capability will increasingly become a feature of future BESS without intervention from ElectraNet. As a result, we have not considered BESS as part of the preferred option.

4.1.1 Minimum system strength

GFM BESS fault current contribution is not of the same protection grade[21] quality as that of a similar rated synchronous generator. At present, we do not consider that GFM BESS should be relied upon to provide 'minimum level' of system strength services. This opinion may change with experience of GFM BESS over time[22].

4.2 Option 2 - Synchronous clutch

This type of investment is referred to as clutch enabled synchronous condenser (CESC).

The CESC was proposed as part of hybrid synchronous generator (see Table 4) from the proponents of non-network solutions in response to our EOI and PSCR on System Strength Requirements in South Australia. The installation proposed[23] was 150 MVA.

The capital cost of constructing a synchronous generator is greater than that of a synchronous condenser and, although a synchronous generator can deliver a range of additional benefits to the system, this would not be sufficient to overcome the higher cost. Further, as discussed above, we have concluded that the need does not warrant investment in high capital cost plant at this stage.

A low-cost mechanical clutch on a committed/anticipated synchronous generator plant is considered under this generic option. The incremental investment under this option is low cost and incrementally deployable. GHD has estimated the incremental capital cost at less than $5m.

Unlike the GFM BESS, conversion of an existing plant is unlikely to be low cost unless provision for a clutch was made when the plant was built. We do not consider this a low cost option for existing plant and have only considered this option for committed/anticipated new generators.

Further, subject to the outcomes of the SA Government FERM consultation in December 2024, and further refinement of the design, we expect that FERM may incentivise some investment in synchronous generators that would be suitable for inclusion of a clutch.

Given the initial interest in this option through submissions and the development of the FERM, we consider proponents for this option may emerge in the near term, and potentially prior to

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[21] Fault current amplitude of GFM BESS is about 25% of that of a synchronous generator, and it remains with little decaying while that of the synchronous generator decays rapidly within the 100ms sub-transient window.

[22] Maturity of GFM Inverters – Aurecon report

[23] Some of the synchronous generator options including this was withdrawn later in 2024.

publication of the PACR. We have not identified proponents for this option in this PADR, due both to confidentiality and as potential proponents are still emerging.

4.3 Option 3 - Conversion of synchronous generator

This type is generally referred to as repurposed thermal generator converted synchronous condenser (RTG-CSC).

Conversion of a synchronous generator was also proposed (see Table 4) from the proponents of non-network solutions in response to our EOI and PSCR on System Strength Requirements in SA. The total installation proposed across submissions totalled 250 MVA for these solutions.

A gas turbine based synchronous generator can be converted into a synchronous condenser by removal of the gas turbine. The overall cost may depend on the remaining life of the existing generator and associated maintenance and operating costs. However, this option was proposed at $20-$40 million, which is much lower in cost than that of a similar size synchronous condenser.

This option, if not actioned now, may not be available in the future. So, although it is of higher cost than options 1 and 2, we consider it prudent to consider this option as it was proposed as a materially lower cost option than a new synchronous condenser.

This option has not been further considered as part of the preferred option due to the subsequent removal of this option, at the proponent's request, late in the assessment process. Nonetheless, we have continued to present it here as a credible option, albeit without a proponent.

4.4 Options preserved for consideration in the future

A greenfield or new synchronous generator or condenser or a new BESS is not considered necessary now, and therefore not considered any further within this PADR. However, new synchronous condensers are preserved as possible solutions for the future should requirements change.

4.5 Economic analysis

Generic options 1 to 3 are considered in the economic analysis presented in the Appendix B (see sections B.1 to B.3). Based on heuristic assumptions, each generic option is evaluated for its contribution towards system strength on a 'value for cost' basis.

5 Analysis and inferences

Based on the economic assessment (see Appendix B), a priority order for choice of system strength plants was established subject to confirmation of accurate cost estimates and a refined and detail technical assessment of the aforementioned plants.

Referring to Figure 5 and Figure 6 the generic options (solution types) can be ranked for their performance value per investment as shown in Table 5.

Table 5: Ranks 1 to 6 of the solution types

Solution type / rank	System Strength (minimum level)	System Strength (efficient level)
Option 1 – Conversion of GFL BESS to GFM mode (existing and committed/ BESS)	**-**	**2**
Option 2 – Mechanical clutch enablement to synchronous generator (committed/anticipated)	**1**	**1**
Option 3 – Conversion of synchronous generator (existing) to condenser	**2**	**3**
Future (new) synchronous condenser	3	4
Future (new) GFM BESS	-	5
Future (new) synchronous generator	4	6

5.1 Consideration of potential options

Based on the preliminary economic assessment, the three generic options – option 1: GFL to GFM conversion of a committed/anticipated BESS, option 2: Installing a mechanical clutch to a committed gas generator, and option 3: conversion of an existing gas generator into an equivalent inertia synchronous condenser – are recommended for further consideration.

It is our latest understanding that the OEMs can directly build GFM functionality into new inverters thus not having to change over from GFL to GFM.

Therefore, TNSP investments on conversion of GFL into GFM will no longer be urgent, and potentially not warranted, unless for guaranteeing of 24-hour 7-day availability of GFM units. We did not consider that a potential operational guarantee was warranted at this moment.

GHD's report[24] further discusses BESS projects from OEMs (ie, those required for option 1) which need GFM functionality.

[24] "Cost estimates for mechanical clutches and GFM BESS as enablers of System Strength", GHD report submitted to ElectraNet, October 2024.

The mechanical clutch option is possibly subject to agreement with a proponent of a committed generator.

Furthermore, the conversion of an existing gas generator to a synchronous condenser (option 3) is possible subject to assessment of the extra costs involved with conversion. However, a proponent from the EOI recently indicated that the extra costs would prohibit such a conversion.

In this context, the only generic option we recommend for moving forward into the PACR stage is the synchronous mechanical clutch (option 2), which is low cost and contributing well to both aspects of system strength; i.e. minimum fault level and efficient level.

5.2 There is only one potential option at this stage

5.2.1 Adding a clutch to new synchronous generators

As outlined in section 2, analysis undertaken by AEMO and ElectraNet finds that action is not required to meet either the 'minimum' or 'efficient level' system strength requirements under the *Step Change* scenario. However, if the *Green Energy Exports* scenario unfolds, we expect to find that additional system strength is required in order to support the much greater volume of IBR forecast.

If no action is taken now and additional LIL connect, we would expect there to potentially be significant increase in the requirement for system strength services. The long lead times may require expensive investment and/or reduced reliability.

However, and informed by submissions from non-network proponents to the PSCR/EOI, we consider that both of these situations can be avoided if mechanical clutches are added to new synchronous generators pre-emptively.

The use of these clutches is considered to provide an opportunistic, low cost and 'low regret' insurance against the need to provide additional system strength in South Australia due to a greater volume of IBR connecting.

Specifically, while these solutions would ultimately be provided by non-network proponents (the costs of which would be recovered via network support payments from ElectraNet), we note that fitting these generators with clutches during initial construction is estimated to cost in the order of $5 million (which is significantly below that expected to be required if they are to be retrofitted after construction).

We consider that the addition of clutches to new synchronous generators provides prudent insurance against needing to provide additional system strength going forward, and ElectraNet considers that network support contracts to enable this should be the basis of the preferred option for this RIT-T.

Moreover, we note that the costs of these contracts would only be incurred, and thus recovered from consumers, if clutch proposals can be proven as technically feasible and accepted at a prudent and efficient price by proponents.

At this stage, we consider that new generators adding a clutch could be located at most locations on the 275 kV network.

5.3 A quantitative assessment has not been undertaken at this stage

We do not consider that any categories of market benefit (or costs) under the RIT-T are considered material as part of this RIT-T.

This is due to the fact that no investment is expected to be required to meet either the 'minimum' or 'efficient level' system strength requirements under the *Step Change* scenario and there only being one credible option (clutches) for insuring against potentially much higher IBR forecasts in the future.

AEMO's most recent System Strength Report, released in December 2024, indicates a higher volume of IBR at Robertstown and Davenport after FY 2030. For the immediate five years from now, the forecast under the 2024 report is also slightly greater than that of the 2023 report. The 2024 report forecasts an increase in IBR beyond the three-year period, i.e. for the years 2027 and 2028 particularly for Davenport.

A low-cost solution such as clutches on synchronous generators on the 275 kV network would therefore be justifiable for the years beyond 2027 and 2028 to avoid synchronous condenser investment.

6 Proposed preferred option at this draft stage

We consider that the preferred option involves contracting with future non-network proponents who can add mechanical clutches to synchronous generators as part of the initial build costs reflecting the incremental costs of the auxiliary systems and the cost of operation (including energy losses).

While this investment is not required to meet either the 'minimum' or 'efficient level' system strength requirements under the *Step Change* scenario, it is considered a low cost and 'low regret' insurance against the need to provide additional system strength in South Australia if IBR forecasts increase in the future (e.g. in-line additional LIL connecting).

ElectraNet expects that proponents for this option may emerge either prior to the PACR, or shortly after. Notwithstanding that this is a reliability corrective action, given that this option would be progressed as a low cost and low regret insurance option, and is not required to meet the current system strength requirements, ElectraNet considers that the absence of a proponent at this stage does not affect the outcome of this RIT-T.

Importantly, for any clutch solution(s) to be ultimately pursued, they need to be first confirmed as being both technically and commercially feasible. A complete PSCAD model of the plant is required from the proponents in order to assess the technical capability.

The estimated construction timetable and commissioning date of any new synchronous generator including a clutch will be project-dependant and so we do not consider it possible at this stage to provide these details, but will do so in the PACR, if possible, at that stage. Adding clutches to new synchronous generators are also not expected to have a material inter-network impact.

ElectraNet considers that the preferred option at this stage satisfies the RIT-T.

7 References

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Appendix A Compliance checklist

This appendix sets out a checklist which demonstrates the compliance of this PADR with the requirements of the National Electricity Rules version 226.

Table 6: Compliance checklist of PADR with the NER

Rules clause	Summary of requirements	Relevant section(s) in the PADR
5.16.4(k)	**A RIT-T proponent must prepare a report (the assessment draft report), which must include:**	
	(1) a description of each credible option assessed;	3, 4
	(2) a summary of, and commentary on, the submissions to the project specification consultation report;	3
	(3) a quantification of the costs, including a breakdown of operating and capital expenditure, and classes of material market benefit for each credible option;	Appendices B, F, H
	(4) a detailed description of the methodologies used in quantifying each class of material market benefit and cost;	Appendices B, H
	5) reasons why the RIT-T proponent has determined that a class or classes of market benefit are not material;	5.3.
	6) the identification of any class of market benefit estimated to arise outside the region of the Transmission Network Service Provider affected by the RIT-T project, and quantification of the value of such market benefits (in aggregate across all regions);	N/A
	(7) the results of a net present value analysis of each credible option and accompanying explanatory statements regarding the results;	N/A
	(8) the identification of the proposed preferred option;	5
	(9) for the proposed preferred option identified under subparagraph (8), the RIT-T proponent must provide: (a) details of the technical characteristics; (b) the estimated construction timetable and commissioning date; (c) if the proposed preferred option is likely to have a material inter-network impact and if the Transmission Network Service Provider affected by the RIT-T project has received an augmentation technical report, that report; and (d) a statement and the accompanying detailed analysis that the preferred option satisfies the regulatory investment test for transmission.	(a) Appendices C, G (b) may be 2027 (c) N/A (d) 4, 5
5.16.4(l)	If a Network Service Provider affected by a RIT-T project elects to proceed with a project which is for reliability corrective action, it can	All generic solutions assessed either

	only do so where the proposed preferred option has a proponent. The RIT-T proponent must identity that proponent in the project assessment draft report.	have proponents (unless otherwise stated) or are expected to have proponents in the near future (see section 6). Where there are existing proponents, we are not able to state who they are at this stage due to confidentiality.

Appendix B Economic assessment

The costs of each generic option described in section 4 are obtained through quotes provided by the proponents from the EOI process, through public sources such as AEMO's cost data base and through a consultancy report[25] prepared by GHD for ElectraNet. Capital and operating costs for unit sizes of 100MW, 250MW and 600MW of plants for procurement of system strength are considered in the GHD report[25] (see Appendix F). Based on the cost information, a unit cost ($/MVA) of each type of plant or generic option is calculated. Unless otherwise mentioned the costs considered are the minimum values from quotes or references.

The contribution towards system strength by each plant type is defined in terms of additional IBR hosting capacity in MW per each MVA increment of the specific plant type. The contribution towards system strength is two-fold; fault current and stable voltage waveform support. Both these variants of system strength depend on the location on the network, type of the plant, nature of the contingency, degree, depth and pre-fault load flow. There is no detailed assessment particularly on system strength contribution from these plant types towards stable voltage waveform carried out to date that can be relied upon. However, in this PADR heuristic assumptions on fault current and stable voltage waveform are made based on comparative non-related studies on synchronous condensers and GFM BESS including the MHI investigation.[26] Methodologies referred for these calculations are presented in Appendix H.

B.1 Contribution to fault current

It can be seen from Figure 3 that the most economic generic options are (option 2) clutch enabled generator and (option 3) converted synchronous condenser (CSC) on fault current basis. Economic analysis in this section is based on the IBR hosting capacity (MW) on fault current basis. Fault level created due to synchronous condenser, GFM BESS, RTG-CSC and Transmission line tie in are considered initially.

The capital cost of a future gas generator or future GFM BESS is very high compared to other options presented in Figure 3. Therefore, the future gas generator and future GFM BESS are not shortlisted in the search for preferred options within the PADR.

The Brinkworth-Blyth West tie-in at 275kV level brings system strength improvements; however, this option is not competitive against the synchronous clutch option or converted synchronous condenser option. This Brinkworth-Blyth West tie-in may also affect the load flow constraints in the vicinity. Therefore, the Brinkworth tie-in is not shortlisted as a credible option within the PADR. Nonetheless, based on the unit cost information and the contribution towards fault current and stable voltage waveform respectively, a measure is formulated to estimate break even contribution of each type of plant on an economic basis.

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[25] "Cost estimates for mechanical clutches and GFM BESS as enablers of System Strength", GHD report submitted to ElectraNet, October 2024 (see Appendix F).
[26] "System Strength contribution from GFM BESS – feasibility study", Manitoba Hydro International (MHI) report submitted to ElectraNet, September 2024 (seeAppendix D)

Economic break-even contribution against actual contribution

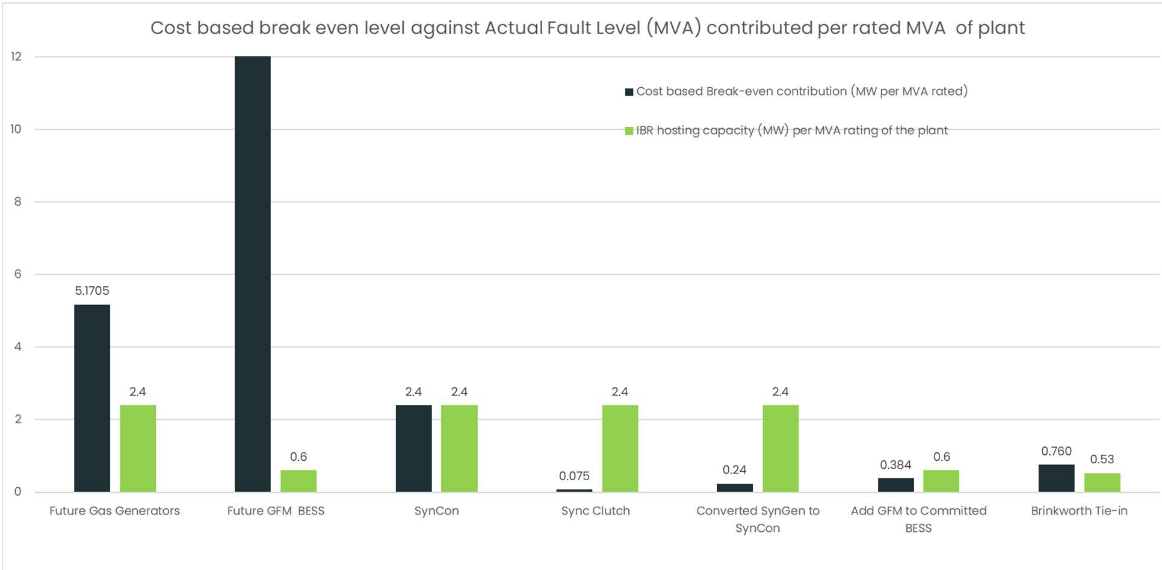

Figure 3: Economic analysis based on EOI minimum costs (fault current basis)

This analysis compares the IBR hosting capacity (MW) per MVA of each system strength plant type in its break-even value against the actual contribution of the same plant type on fault current basis. The analysis uses the minimum costs including the estimates from the GHD report[25].

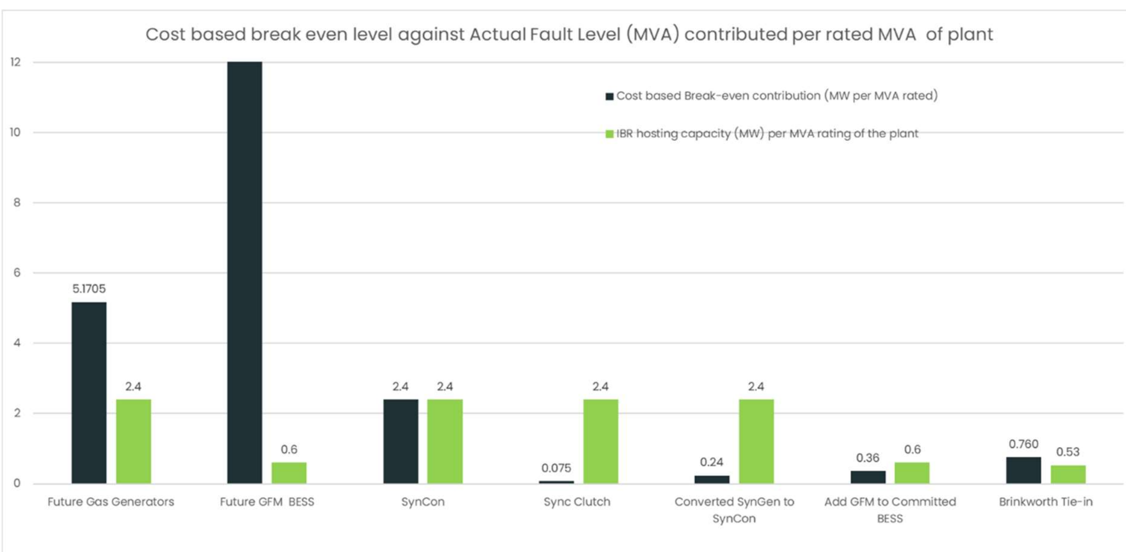

Figure 4: Economic analysis with GHD input data for clutch & GFM conversion (fault current basis)

Figure 3 and Figure 4 show the same analysis with the minimum costs from EOI submissions and the GHD report respectively taken into account. Values in the black columns indicate the economic break-even contribution from each plant type. Lower values indicate better contributing options. From both Figure 3 and Figure 4 it can be seen that the most economic generic options are (option 2) a clutch enabled on a committed/anticipated generator, (option

3) converted synchronous condenser (CSC), and (option 1) GFM on committed/anticipated BESS.

This analysis shows that committed/anticipated BESS, converted synchronous condenser and synchronous clutch are preferred low-cost generic options that can be recommended for fault level contribution.

B.2 Contribution to stable voltage waveform

Economic analysis in this section is based on the contribution to stable voltage waveform in terms of IBR hosting capacity improvement (in MW per MVA) due to the specific plant type.

Taking the contribution from a 125 MVA synchronous condenser connected at Davenport or Robertstown as a standard measure of stable voltage waveform (referred to as efficient level of system strength) contribution, analysis is carried out on assessing new plants for their contribution to system strength. Any of the synchronous machines (repurposed gas generators as synchronous condenser or clutch enabled gas generators) are considered equivalent[27] to a similar MVA rated synchronous condenser in terms of hosting asynchronous generation (IBR volume in MW) for stable voltage waveform. Furthermore, GFM BESS is assumed equivalent[28] to its similar MVA rated synchronous condenser in terms of hosting asynchronous generation (IBR volume in MW) at the node. These heuristic assumptions enable us to undertake an approximate assessment of system strength contribution at the efficient level without going through detailed studies on a wide-area network PSCADTM/EMTDC™ model.

For the PADR stage only approximate analysis is carried out based on heuristic assumptions as explained above.

Economic break-even contribution against actual contribution

Figure 5 compares the IBR hosting capacity (MW) per MVA of each system strength plant type in its break-even value against the actual contribution on the basis of stable voltage waveform.

[27] Contribution towards stable voltage waveform depends on the node location, network impedance, nature of the IBR (e.g GFL or GFM), minimum SCR and requires wide-area PSCAD model simulation to evaluate quantitatively. Reference "Assessment of efficient system strength requirements under ISP *Step Change* scenario for South Australia to 2034", Technical Note prepared by ElectraNet, 2024 September 30.

[28] Contribution towards stable voltage waveform depends on the node location, network impedance, minimum SCR and requires wide-area PSCAD model simulation to evaluate quantitatively. Reference "System Strength contribution from GFM BESS – feasibility study", Manitoba Hydro International report submitted to ElectraNet, September 2024

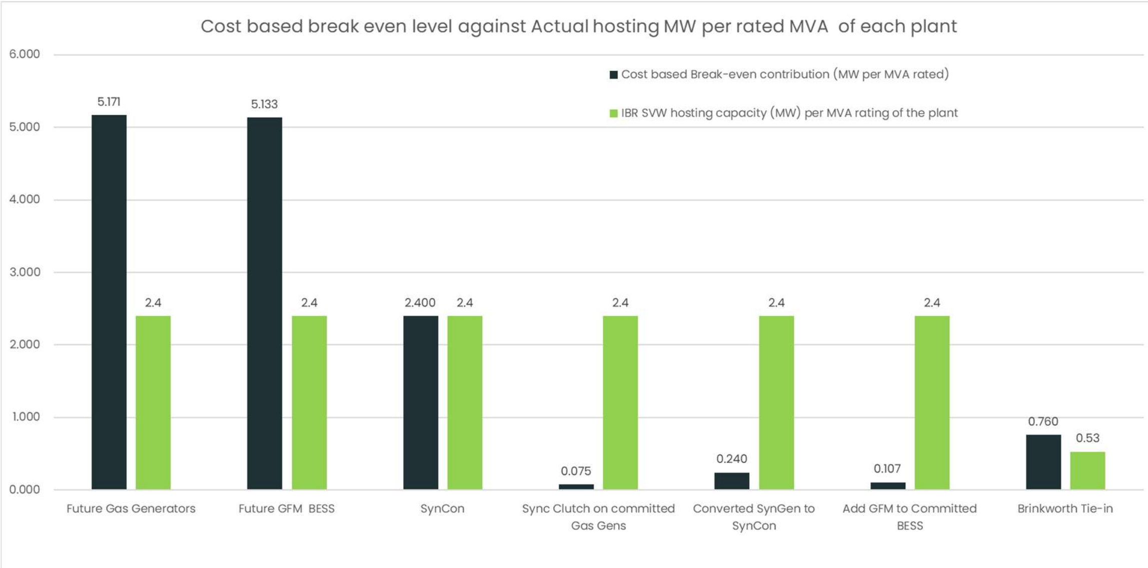

Figure 5: Economic analysis with EOI minimum data (stable voltage waveform basis)

This analysis shows that committed/anticipated BESS, converted synchronous condenser and synchronous clutch are preferred low-cost generic options that can be recommended for the stable voltage waveform support aspect of system strength. The HV network of South Australia may require additional system strength (ie. stable voltage waveform at nodes of IBR) if the actual IBR volume exceeds the forecast under AEMO's 2023 ISP *Step Change* scenario.

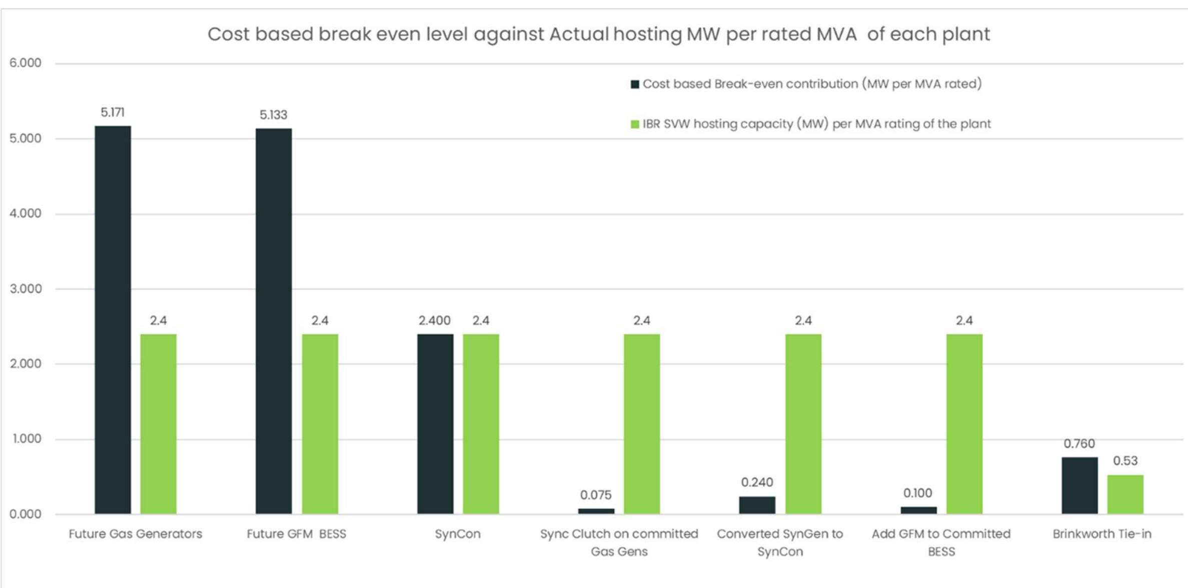

Figure 6: Economic analysis calculation with GHD input data (stable voltage waveform basis)

The low-cost solutions (generic options) identified may be recommended as a proactive measure to prepare for the uncertain forecast of IBR falling in between ISP scenarios of *Green Energy Exports* and *Step Change*.

Figure 6 compares the IBR hosting capacity (MW) per MVA of each system strength plant type taking minimum costs from sources including GHD report into account in its break-even value against the actual contribution on the basis of stable voltage waveform. Figure 6 particularly, and Figure 5, indicate that GFM on a committed/anticipated BESS is the most economic generic option when it comes to the supply of efficient system strength to ensure the maintenance of a stable voltage waveform.

B.3 Estimated contract pricing

Based on GHD's report,[29] approximate annual contract pricing for the generic options are presented in Table 7.

Table 7: Approximate contract pricing (GFM BESS and mechanical clutch)

System utilised	Annual contract cost $ '000s
BESS GFL to GFM	
100MW	$290 minimum to $630 maximum
250MW	$326 minimum to $1,163 maximum
Mechanical clutches:	
100MW / 120MVA	$171 to $490
200MW / 250MVA	$225 to $783
500MW / 600MVA	$354 to $1,389

[29] "Cost estimates for mechanical clutches and GFM BESS" as enablers of System Strength, GHD report submitted to ElectraNet, October 2024.

Appendix C Technical assessment

After receiving responses to the EOI and PSCR on System Strength requirements in SA in April 2024, an assessment of system strength available after PEC stage 2 completion has been initiated.

C.1 Assessment process

The technical assessment was performed as per methodologies described in Appendix H. For stability assessments, ElectraNet's assessment procedure was followed with increasing IBR volumes connected to each of the System Strength Nodes (Davenport, Para and Robertstown) consistent with the ISP *Step Change* scenario. System normal and N-1 outage conditions were tested for critical contingencies.

C.2 Asynchronous generation

Figure 7 shows the increasing asynchronous generation (AG) forecast to 2035. Using AEMO's 2024 ISP *Step Change* scenario as a source of IBR volumes over the next ten years, we analysed increasing volume of total asynchronous generation that can be hosted stably. Results indicated that the total asynchronous generation that can be hosted goes beyond the IBR volume forecast under AEMO's ISP *Step Change* scenario and maintaining stability with support from PEC stage 2.

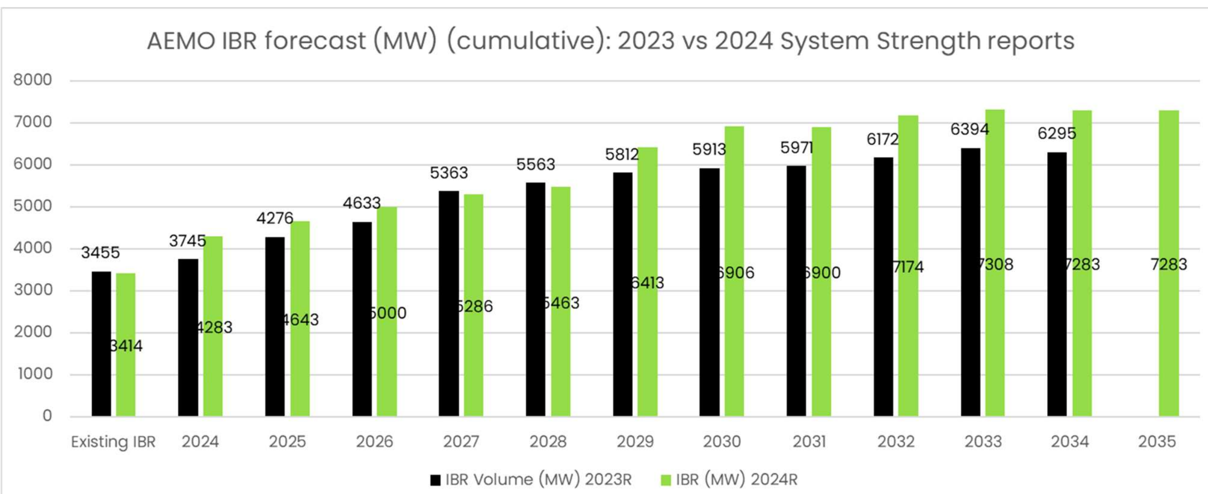

Figure 7: Forecast IBR volume (asynchronous generation)

C.3 Stability assessment outcome

The stability assessment concluded that no voltage waveform instabilities were identified for the years out to 2034 when applying AEMO's *Step Change* forecast as published in the 2024 ISP.

Zero requirement of system strength

Based on system strength requirements assessed on the PSCAD model, the conclusion is that the IBR volume forecast for 2024 to 2034 under AEMO's 2023 System Strength report can be hosted stably with the existing system strength within the network including PEC stage 2. As a result, none of the EOI proponent options is required to assess in detail within the PSCAD model.

This allows the detailed technical assessment of any of the pro-active solutions (generic options) to be deferred until after the PACR conclusion stage.

However for the PADR, ie. this report, we have used an approximate analysis with heuristic assumptions. Appendices C.4, C.5, H.1, H.2 and H.4 provide background on the approximate analysis of the generic options for their contribution towards system strength.

C.4 Fault current based analysis

Taking a 125 MVA synchronous condenser connected at Robertstown as a standard measure of fault current (fault level as referred to system strength), analysis is carried out to compare options against the standard measure.

Appendix H.4 details the basis of analysis of fault current contributions by various plants including GFM BESS, clutch enabled synchronous machines, repurposed thermal generator converted synchronous condensers or similar sources of fault current.

C.5 Stable voltage waveform based analysis

Taking a 125 MVA synchronous condenser connected at Davenport or Robertstown as a standard measure of stable voltage waveform (referred to as efficient level of system strength), analysis is carried out. Any of the synchronous generators (gas generator or clutch enabled gas generators) is considered equivalent[30] to its similar rated synchronous condenser in terms of hosting asynchronous generation (IBR volume in MW). Furthermore, GFM BESS is assumed equivalent[31] to its similar rated synchronous condenser in terms of hosting stable voltage waveforms for asynchronous generation (IBR volume in MW).

C.6 Assessment under ISP *Step Change* scenario

ElectraNet evaluated the addition of forecast IBR volume under the 2024 ISP *Step Change* scenario for stability in system studies utilising a wide area PSCAD model of the SA power system. The assessment so far indicates a conclusion of zero additional requirement for system strength to achieve the efficient level required for the IBR forecast with the 2024 ISP *Step Change* scenario.

As per AEMO's System Strength reports from 2022 and 2023, the SA HV Transmission network has sufficient system strength for protection operations (minimum fault level). However, the network needs to provide further system strength at an efficient level in order to maintain stable voltage waveform at the nodes of future IBR forecasts under the ISP *Step Change* scenario that may be updated in AEMO System Strength reports in December 2025.

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[30] Contribution towards stable voltage waveform depends on the node location, network impedance, nature of the IBR (e.g GFL or GFM), minimum SCR and requires wide-area PSCAD model simulation to evaluate quantitatively. Refer to "Assessment of efficient system strength requirements under ISP *Step Change* scenario for South Australia to 2034", Technical Note prepared by ElectraNet, 2024 September 30.

[31] Contribution towards stable voltage waveform depends on the node location, network impedance, minimum SCR and requires wide-area PSCAD model simulation to evaluate quantitatively. Refer to "System Strength contribution from GFM BESS – feasibility study", Manitoba Hydro International report submitted to ElectraNet, September 2024.

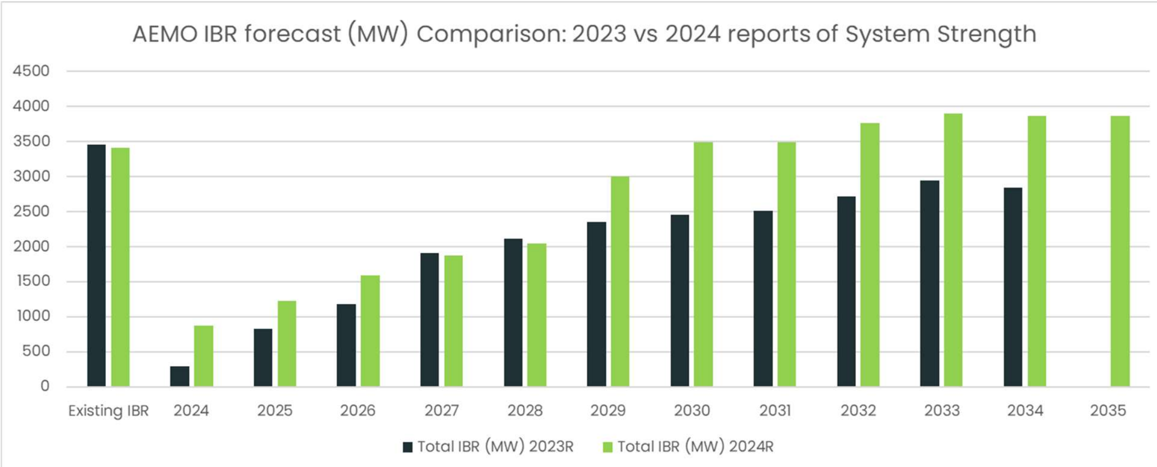

Figure 8: AEMO's latest forecast in 2024 System Strength Report against that of 2023 report

C.7 *Green Energy Exports* scenario

The IBR volume forecast based on AEMO's 2024 ISP *Green Energy Exports* scenario is shown in Figure 9 as a comparison against that of the *Step Change* scenario.

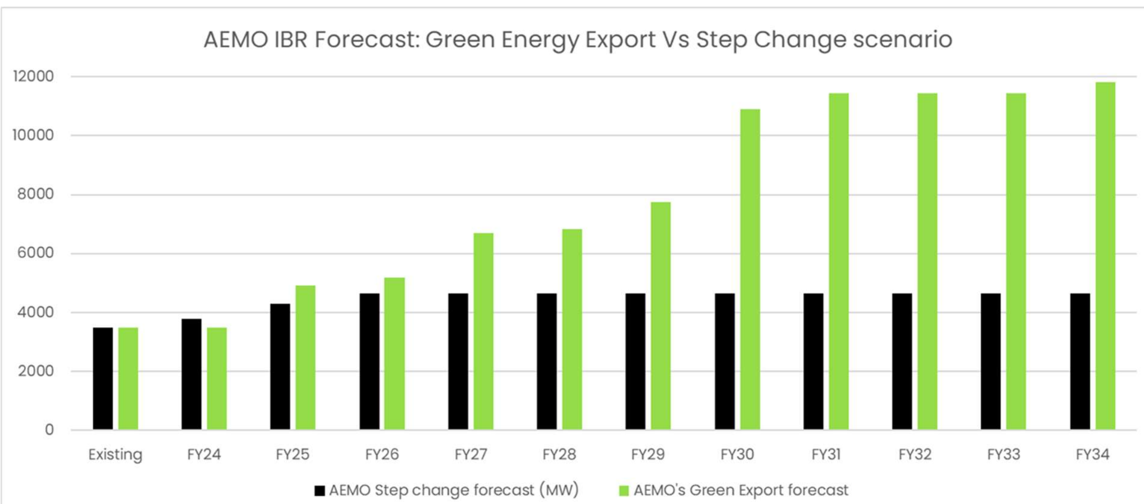

Figure 9: *Green Energy Exports* scenario and ISP *Step Change* (AEMO ISP 2023)

The actual IBR volume finally connected can be something in between these two scenarios (ie. between the green and black columns in Figure 9). In the event that the actual IBR volume realised is close to the higher side (ie. closer to figures of *Green Energy Exports*), then there will be a question of whether the network would have sufficient system strength to host stable voltage waveform for that volume of IBR. Considering these and identified needs from Chapter 2 it is prudent to consider generic options described in the PADR as flexible tools to prepare for uncertain future requirements.

Appendix D Summary from MHI report on "Feasibility of GFM BESS in providing System Strength"

MHI has been engaged by ElectraNet to provide a feasibility assessment on the potential of GFM BESS for contributing to system strength. ElectraNet desires to understand and quantify potential contributions from the BESS plants if operated in GFM mode to determine whether the grid-forming BESS meet the RIT-T threshold as a credible option. The purpose of the MHI report is to demonstrate the technical viability of a generic grid-forming BESS. Failure to demonstrate an improvement in the criteria AEMO have set for measuring system strength (a stable voltage waveform) in this study may lead ElectraNet to determine that GFM BESS is not a viable technical option at this time.

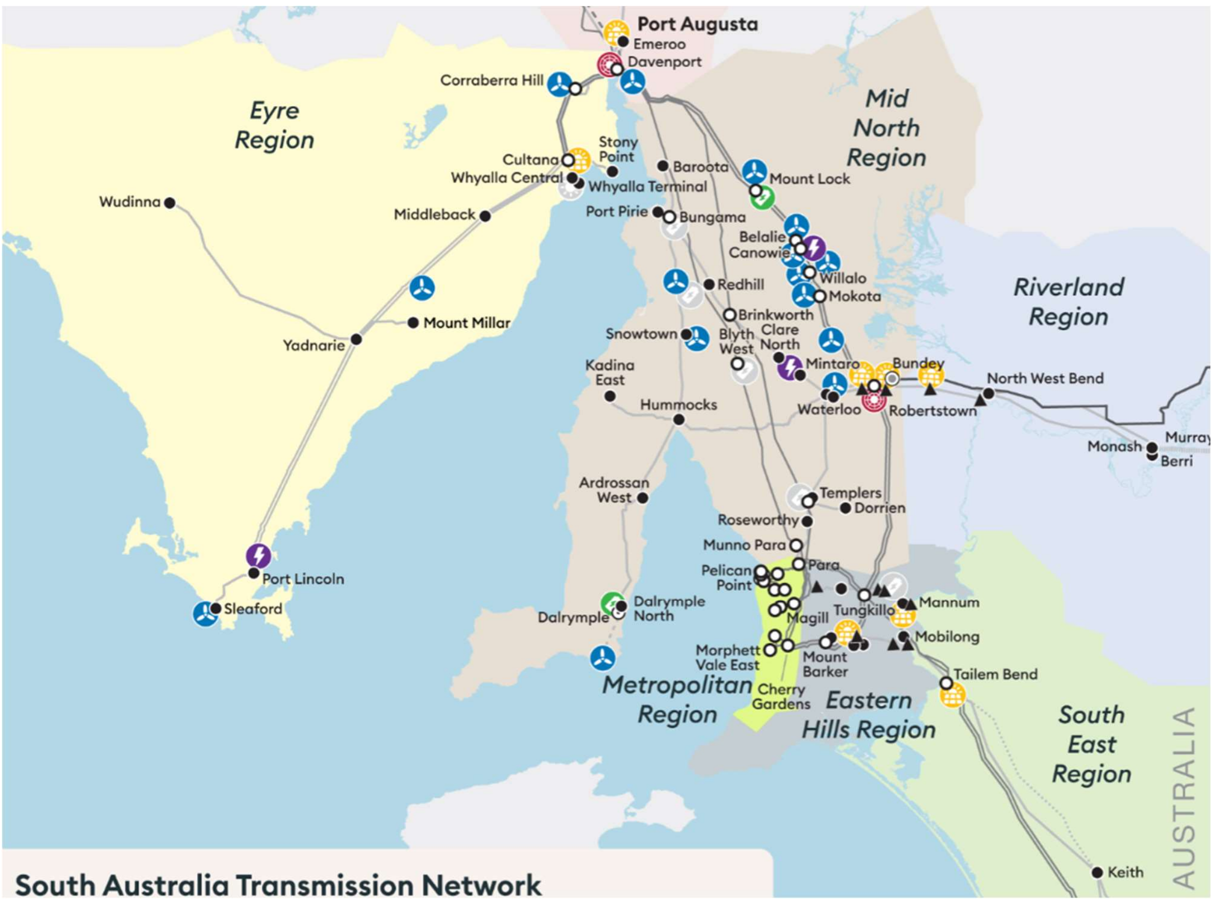

Figure 10: BESS projects were assumed close to Davenport, Para or Robertstown

As the system strength from a GFM BESS cannot be distinctly measured in terms of a tangible unit such as 'MVA' or a proxy 'fault level', this investigation refers to four criteria of stable voltage waveform defined by AEMO[32] in order to calibrate contribution of each BESS towards improvement based on those criteria. For example, the fourth criteria says that the low frequency oscillation at each SSN needs to be kept within the limit of 0.1% (peak-to-peak) for

[32] See page 20 of [2] system-strength-requirements-methodology.pdf (aemo.com.au)

stable voltage waveform. Some contingency scenarios during or post-contingency can lead to induce such oscillations of even higher amplitudes (greater than 0.5% peak-to-peak), and those scenarios were particularly selected for the purpose of initial testing of the GFM BESS model.

For GFM BESS the stable operation mSCR value may even be lower than 1.2 which means net provision of system strength towards the wider network. The only way to assess this system strength contribution from a GFM BESS is to evaluate the efforts of the BESS in terms of maintaining stable voltage waveform. For that purpose, a wide-area network PSCAD model is required in the assessment.

D.1 Network boundary

A PSCAD™/EMTDC™ model for SA, with equivalent sources at Bundy 330 kV and Southeast 275 kV was used for the assessment. The equivalent impedance values used to represent the upstream network at these boundary buses that are not included in detail within the network model are derived based on the 3PHG fault level at the respective bus. Table 8 lists the power flows into SA measured at the two boundary buses (Bundy 330 kV and Southeast 275 kV) for this study.

Table 8: Power flow provided by the equivalent source at network boundary buses

Load Flow case / Boundary Bus	Min Import Case		Max Import Case		Max Export Case	
	Active Power	Reactive Power	Active Power	Reactive Power	Active Power	Reactive Power
Bundy 330 kV	68 MW	34 MVAr	600 MW	-159 MVAr	-307 MW	31 MVAr
Southeast 275kV	65 MW	46 MVAr	592 MW	37 MVAr	-357 MW	155 MVAr

Dynamic voltage regulating devices in the study area are listed below:

- Davenport synchronous condensers
- Robertstown synchronous condensers
- TIPS synchronous condenser (a new assumed plant for selected studies)
- Southeast SVC
- Para SVC

D.2 GFM BESS model

A generic GFM BESS model from an OEM was used. As this is an OEM model, specifics about the parameters cannot be shared freely. However, at a high-level the GFM BESS contains the following:

- H constant =2.5 s
- Damping Gain = 0.03

A GFM BESS, is referred to as a battery technology equipped with inverters that operates as voltage source synchronised with the grid frequency and provides power to the grid based on the load angle and voltage magnitude. The stable operation of GFM BESS, in the same manner as conventional synchronous generators, must not be dependent on the system strength of the system. In fact, it increases the system strength of the nearby power system (e.g. voltage waveform stability), by generating a robust voltage waveform at its own terminal comprising the magnitude and angle at the synchronised 50 Hz frequency.

D.3 Strategy to quantify the increased hosting capacity

One of the most difficult aspects of this investigation is to evaluate the exact quantity of increment in system strength due to the application of a particular BESS operated in GFM mode. Early stages of this project adopted traditional gradual introduction of contingencies after the first round of normal operational scenario. On that basis and with N-1 contingency, it was first attempted to add IBR volumes in blocks of 100MW until the system shows characteristic signs of losing strength (typically sub-synchronous oscillations) at the respective SSN. With this approach, it took quite a lot of iterative assessments in order to discover that system weakening level of added IBR; for example, at Davenport node it was necessary to add more than 1500 MW of IBR (GFL mode) and still observing no sign of sub-synchronous oscillations. From that point onwards, the strategy of assessing GFM BESS's contribution towards raising the AG hosting capacity at the SSN (e.g. Davenport) has been changed to a more pragmatic results-oriented approach. The MHI report explains this new strategy.

GFM BESS support at SSNs

A single GFM BESS was placed in-service to obtain an initial idea of how much support it can provide to three different SSNs (Davenport 275 kV, Para 275 kV and Robertstown 275 kV). Only BESS units geographically close to each SSN were considered. Three different network changes were made to evaluate this.

1. to evaluate the effectiveness that GFM BESS A and GFM BESS B have on Davenport 275 kV SSN one line from Davenport – Robertstown was disconnected and one line from Munno Para – Blyth West was disconnected.
2. the network model used for these studies was ill-suited to evaluate the effectiveness of GFM BESS D and GFM BESS E have on Robertstown 275 kV SSN. This is due to the modelling of the ideal source at Bundy 330 kV. This source is too close to the Robertstown 275 kV node to fairly represent the dynamic response within the area. Therefore, using this network, the method (as used to evaluate Davenport and Para) will not provide sufficient accuracy. To fairly assess this SSN, it is recommended to move the boundary bus into NSW.
3. to evaluate the effectiveness of GFM BESS F and GFM BESS G have on Para 275 kV SSN, one line from Para to PGW, one line from Para to TIPS, one line from Para to MAGL and one line from Munno Para to Blyth West were disconnected.

For each case mentioned above a base case was developed. This base case contained only GFL BESS units and asynchronous generation was added at the SSN until the voltage oscillation surpassed the threshold of 0.5%, measured at the associated SSN. Next, a single GFM BESS was placed in-service (putting the GFL BESS with the same name OOS) and generation was added to the SSN until the voltage oscillation surpassed the threshold of 0.5% measured at that SSN. The difference between these two values is an estimate of the additional generation of IBRs that can be hosted with one GFM BESS in-service. This strategy of differential approach helps facilitate the evaluation of extra AG hosting capacity (in MW) of each GFM BESS without having to wait for the establishment of the new absolute limit of AG hosting capacity arriving after PEC stage 2 completion.

D.4 Special notes from results

The MHI report presented an exhaustive set of tests and the corresponding results from PSCAD simulations of the Wide Area Network with new IBR and GFBs included. Those results clearly indicated that the GFM BESS can improve system strength under many different instances within the scenarios (S1 to S5) tested and for many AG dispatch cases (three cases) by application of GFM mode on each of the considered BESS. Some cases with a combined fleet of GFM BESS did not perform any better than the individual performance. This was identified as an interference effect which deserves further investigation.

The individual performance in quantified form of each BESS under GFM operating mode was the main interest of the present investigation. For this purpose, the hosting capacity improvement (in MW) at a given SSN was assessed per each of the eight (8) BESS plants assumed (under committed and anticipated).

In order to assess this special performance, a separate strategy (see section D.3) was developed in this study. Following the new strategy, the GFM BESS plants were assessed at each SSN and a short summary is given in Table 9. The following results / trends were identified from the tests of individual BESS performance.

Table 9: IBR volume (MW) achieving stable voltage waveform at the closest SSN from a GFM BESS

BESS location	GFM BESS Size (MW)	Bus (kV)	Closet SSN	Improvement of Hosting IBR (MW) at the SSN
A	Assumed	275	Davenport	210 MW at Davenport
B	Assumed	275	Davenport	220 MW at Davenport
C	Assumed	132	Davenport	10 MW at Davenport
D	Assumed	132	Robertstown	(N/A)[33]
E	Assumed	275	Robertstown	(N/A)[33]
F	Assumed	132	Para	24 MW (SVC active)
G	Assumed	275	Para	415 MW at Para (SVC active)

Inertial capabilities of GFM BESS:

This study would be conducted to investigate if the GFB could be a suitable replacement for the existing synchronous machines with regards to inertia. It would involve sizing a BESS to a similar size as one existing unit and creating a loss of generation (i.e. trip the remaining existing units). From this, the fast injection of active power (effectively inertia) could be compared to the existing synchronous unit. It is also worthwhile to investigate how the dispatch of the GFB effects this behaviour.

This study (MHI GFM) conclusively demonstrated that the grid-forming BESS improves local network stability. When the fault is applied the grid-forming BESS minimizes the voltage angle

[33] Refer to Appendix 6 of the MHI report, "System Strength contribution from GFM BESS – feasibility study", MHI report submitted to ElectraNet, September 2024.

change, holding the angle to a roughly constant value. When the fault is cleared, the voltage angle closes to its new stability point and therefore the system is able to reach a stable operating point.

Appendix E System strength requirements under ISP *Step Change* scenario for South Australia

E.1 System strength requirements

As the System Strength Service Provider (SSSP) for SA, ElectraNet is obliged to meet system strength requirements (including efficient level for hosting IBR stably) for the SA power system. To assess the efficient system strength requirements of the SA power system, AEMO's ten-year forecast for IBR in South Australia as published in the 2024 ISP *Step Change* scenario has been used as a guide for the capacity and location of future wind farm (WF) connections.

E.2 Assessment process

ElectraNet's standard contingency Impact Assessment procedure was followed with increasing IBR volumes connected to each of the System Strength Nodes (Davenport, Para and Robertstown) consistent with the 2024 ISP *Step Change* scenario. System normal and N-1 outage conditions were tested for critical contingencies. All variables were monitored as if for a standard generator connection undergoing an FIA.

To assess the efficient system strength requirements over a ten-year planning horizon, ElectraNet conducted studies utilising a model of the South Australian power system in PSCAD including all existing and committed Inverter Based Resource (IBR) generating systems as well projects for which System Strength Assessments have already been completed and forecast project connections. AEMO's *Step Change* scenario ten-year forecast for IBR in South Australia as published in the 2024 ISP was used as a guide for the capacity and location of future IBR connections.

Forecast IBR was connected directly to the nearest declared system strength node in the study case and forecast projects were represented using models available from existing projects with appropriate generation technology consistent with the AEMO forecast. The studies were conducted with zero synchronous generation online in South Australia and included the system strength services provided by the four ElectraNet owned synchronous condensers located at Davenport and Robertstown. Contingency scenarios assessed included the unplanned disconnection of one or more of these synchronous condensers too.

E.3 Additional system strength requirements

Based on system strength requirements assessed on the PSCAD model the conclusion was that the IBR volume forecast (ISP *Step Change* scenario) for 2024 to 2034 under AEMO's 2023 System Strength report can be hosted stably with the existing system strength within the network including PEC stage 2. As a result, none of the EOI proponent options is required to be assessed in technical detail within the PSCAD model.

We consequently do not consider that there is a requirement to procure any additional system strength solutions to meet the 'efficient level' system strength requirements in South Australia against the IBR forecast of AEMO 2023ISP *Step Change* scenario.

Appendix F Cost estimates for mechanical clutches and GFM BESS: A summary from GHD report

GHD has been engaged by ElectraNet to provide cost estimates for the non-network solutions (see Table 10), including capital, operating, and incremental costs. This GHD report delivers the necessary financial insights to support ElectraNet's RIT-T process in addressing system strength requirements on the 275kV high-voltage network in South Australia.

Table 10: System Strength generic options considered

Plant type	Description
GFM BESS (committed)	Implementing GFM function to an existing/committed BESS of 100MW connecting to 275kV network including balance of plant
GFM BESS (committed)	Implementing GFM function to an existing/committed BESS of 250MW connecting to 275kV network including balance of plant
GFM BESS (new)	Provision of new 250MW GFM BESS connecting to 275kV network including balance of plant at Robertstown or Para
Mechanical clutch	New mechanical clutch for a synchronous gas generator rated at 200MW, 250MVA
Mechanical clutch	New mechanical clutch for a synchronous gas generator rated at 100MW, 120MVA
Mechanical clutch	New mechanical clutch for a synchronous gas generator rated at 500MW, 600MVA

F.1 Existing BESS incorporating GFM functionality

Both 100MW and 250MW capacities are considered here for estimating costs.

Table 11: Existing BESS incorporating GFM functionality - cost estimate (AUD)

#	Item	BESS 100MW		BESS 250MW	
		Low range	High range	Low range	High rRange
1	Total	**$ 1,285k**	**$2,710k**	**$1,365k**	**$4,875k**
2	Revenue loss	$60k	$210k	$145k	$515k

The total figures above are based on the submissions received from OEMs and on separate costs estimated by GHD.

F.2 Information provided by clutch suppliers

Table 12: Mechanical clutch costs – supplier 1

Mechanical clutch - project size	Capital cost (AUD)	Incremental cost	Mechanical clutch - project size	Auxiliary loads (MW)
100MW / 120MVA	Project specific	$2m	$75k	0.7 – 1.4 MW
200MW / 250MVA	Project specific	$3.2m	$120k	2.25 – 4.25 MW
500MW / 600MVA	Project Specific	$5.9m	$150k	4.3 – 8.2 MW

Table 13: Mechanical clutch costs – supplier 2

Mechanical clutch	Capital cost (AUD)	Incremental cost (AUD)	Operation and maintenance cost (annual AUD)	Other remarks/ comments
100MW / 120MVA	Not within scope	$0.75m	Duration per service call approx. 1 week. Cost: see separate hourly rate	Incremental costs budgetary quote +-20%
200MW / 250MVA	Not within scope	$1.0m	Duration per service call approx. 1 week. Cost: see separate hourly rate	Incremental costs budgetary quote +-20%
500MW / 600MVA	Not within scope	$1.9m $1.6m	Duration per service call approx. 1 week. Cost: see separate hourly rate	Incremental costs budgetary quote +-20%

F.3 Approximate contract pricing

The GHD report provides estimates of the annual contact pricing for each option based on a discount rate of 5.0% and profit margin of 15.0%. Based on GHD's report,[34] approximate annual contract pricing for the generic options are presented in Table 7.

[34] "Cost estimates for mechanical clutches and GFM BESS" as enablers of System Strength, GHD report submitted to ElectraNet, October 2024.

Appendix G Technical performance requirements for stable voltage waveform support services

AEMO has developed a Voluntary Grid-forming Inverter Specification[35] in 2023 for TNSPs and OEMs to use as a reference for establishing the minimum performance criteria of GFM BESS in providing stable voltage waveform support services (SVWSS).

Some of the capabilities described in AEMO's Voluntary Specification are essential for provision of SVWSS, but compliance with the Voluntary Specification does not guarantee that a GFM BESS is able to provide SVWSS, or any minimum quantity of SVWSS.

The provision of a "stable voltage waveform support service" is new, provided by a relatively novel technology, grid-forming batteries. ElectraNet's adaptation in a draft document[36] based on best available knowledge and information is planning to seek industry engagement where feasible to help refine it. As such, we may seek your feedback during or after our system strength PADR consultation period (contract: consultation@ElectraNet.com.au).

G.1 Relationship with AEMO's Voluntary Grid-forming Inverter Specification

It is important to note that ElectraNet's adaptation is not a general grid-forming inverter specification, and it does not supersede or replace AEMO's Voluntary Grid-forming Inverter Specification - May 2023 (Voluntary Specification), or Core Requirements Test Framework[37] (January 2024).

Those documents specify the 'core' and 'additional' technical capabilities that power electronic modules should have to be categorised as grid-forming inverters, and a methodology for testing compliance with the 'core' capabilities. Whereas our adaptation draft document specifies the performance requirements for a SVWSS in SA provided by GFM BESS.

G.2 Stable voltage waveform and definition of grid-forming

GFM BESS, is referred to as a battery technology equipped with inverters that operates as voltage source synchronised with the grid frequency and inherently provides power to the grid based on the load angle and voltage magnitude. The stable operation of GFM BESS, in the same manner as conventional synchronous generators, must not be dependent on the system strength of the system. In fact, it increases the system strength of the nearby power system (e.g. voltage waveform stability), by generating a robust voltage waveform at its own terminal comprising the magnitude and angle at the synchronised 50 Hz frequency.

[35] AEMO, "Voluntary Grid-forming Inverter Specification," May 2023. [Online]. Available: http://aemo.com.au/-/media/files/initiatives/primary-frequency-response/2023/gfm-voluntary- spec.pdf

[36] "ElectraNet's technical performance and power system modelling requirements for stable voltage waveform support services from grid-forming BESS", a draft by ElectraNet for consultation, Dec 2024.

[37] AEMO, "Core Requirements Test Framework," January 2024. [Online]. Available: https://aemo.com.au/-/media/files/initiatives/engineering-framework/2023/grid-forming-inverters- jan-2024.pdf.

This performance must be continuously and inherently provided by the GFM BESS unless it is explicitly raised and agreed with ElectraNet otherwise. This inherent behaviour must be consistent with the requirements described in ElectraNet's draft specification.

To best follow the reasoning behind the requirement, some background on system strength which is relevant to the GFM BESS requirement is discussed below.

To assist with system strength in the power system and potential cause of instability, stable voltage waveform requirements comprise of four criterion including voltage magnitude, voltage angle, voltage distortion and voltage oscillation (refer to AEMO's System Strength Requirements methodology[38]), as explained below:

Table 14: Stable voltage waveform criteria, as defined in the System Strength Requirements Methodology

Ref	Criterion	Definition
1	Voltage magnitude	The positive-sequence RMS voltage magnitude at a connection point does not violate the limits in the operational guides for the relevant network.
2	Change in voltage phase angle	Change in the steady-state RMS voltage phase angle at a connection point should not be excessive following the injection or absorption of active power at a connection point.
3	Voltage waveform distortion	The three-phase instantaneous voltage waveform distortion at a connection point should not exceed acceptable planning levels of voltage waveform distortion for pre- and post-contingent conditions.
4	Voltage oscillations	Any undamped steady-state RMS voltage oscillations anywhere in the power system should not exceed an acceptable planning threshold as agreed with AEMO.

Among these criteria, the expectation is that the GFM BESS could assist with:

- Voltage magnitude
- Voltage phase angle
- Voltage oscillations

It is also expected that GFM BESS does not amplify any harmonic emission, voltage fluctuation and material distortion to the voltage waveform unless agreed otherwise with ElectraNet under the agreed performance standard. Being capable of absorbing harmonic current to reduce the harmonic voltage emissions by the GFM BESS will be taken as advantage for competing for system strength contract.

[38] AEMO's System Strength Requirements methodology, December 2022, system-strength-requirements-methodology.pdf

As explained in the section 6 of ElectraNet's draft specification, the performance of the connecting GFM BESS is evaluated as per criteria 1, 2 and 4 - namely voltage RMS magnitude, voltage phase angle and RMS voltage oscillations.

G.3 Technical performance requirements

As given in ElectraNet's draft specification, the performance of the connecting GFM BESS is evaluated prior to offering a system strength contract. PSCAD wide area validation studies must be completed as explained in ElectraNet's draft specification on GFM BESS connections.

Compliance

A GFM BESS that provides SVWSS to ElectraNet must comply with the requirements outlined in ElectraNet's draft specification[39] and must remain compliant with all the National Electricity Rules (NER) clauses and the agreed Generator Performance Standard (GPS) clauses. Should the Proponent suspect any contradictory expectation between the requirement in the draft document and NER, it must be immediately raised with ElectraNet. It must also be noted that providing SVWSS cannot be used as an evidence to support any requests for deviation/s from the formal connection process to to:

- Cause any non-compliance or non-conformance with respect to NER and the agreed Generator Performance Standard.
- Negotiate a lower access standard than it would, using the implemented GFM technology without providing SVWSS.
- Receive exemption to go through NER 5.3.9 process or to propose a negotiated access standard less onerous than the existing agreed performance standard, when applying to alter a generating system under NER 5.3.9. ElectraNet does not have any discretion to grant an exemption to this rule[40].

Additionally, it is expected to meet ElectraNet's requirement of SVWSS using grid-forming BESS, and that the requirements captured in ElectraNet's draft specification are also met.

[39] "ElectraNet's technical performance and power system modelling requirements for stable voltage waveform support services from grid-forming BESS", a draft by ElectraNet for consultation, Dec 2024.

[40] NER 5.3.4A(b)(1A): energy-rules.aemc.gov.au/ner/current/5.3.4A

Appendix H Methodologies referred

H.1 Available Fault Level (AFL) proxy values

Stable voltage waveforms are checked using EMT simulation and the minimum withstand SCR will be recorded. In absence of EMT studies, a proxy AFL method with an SCR requirement for stable operation of 3.0 is used (a different SCR requirement for stable operation can be used where it is known for a given connection). Referring to Appendix A of AEMO's System Strength Assessment Guidelines[41] a proxy value of AFL is calculated at each SSN using the following steps:

- Calculate synchronous fault level at the SSN with all synchronous generators at 1.0 per unit flat voltage.
- Estimate the fault level at the same SSN with additional connected asynchronous generation (IBR) modelled as equivalent sources as per AEMO's guidelines[41] on system strength impact assessment.
- The difference between these two values gives the system strength requirement of the IBR connected to the SSN. If that value is numerically above the synchronous fault level, then there is a shortfall in system strength at that SSN.

The impact of IBR on the required AFL at a given SSN is impacted by the forecast IBR at all SSNs, but is closely proportional to the SSN's own IBR volume forecast.

H.2 Stability assessment

To assess the efficient system strength requirements of the South Australian power system over a ten-year planning horizon, ElectraNet conducted studies utilising a model of the South Australian power system in PSCAD including all existing and committed IBR generating systems as well projects for which System Strength Assessments have already been completed and forecast project connections. AEMO's *Step Change* scenario ten-year forecast for IBR in South Australia as published in the 2024 ISP was used as a guide for the capacity and location of future IBR connections.

Forecast IBR was connected directly to the nearest declared system strength node in the study case and forecast projects were represented using models available from existing projects with appropriate generation technology consistent with the AEMO forecast. The studies were conducted with zero synchronous generation online in South Australia and included the system strength services provided by the four ElectraNet owned synchronous condensers located at Davenport and Robertstown. Contingency scenarios assessed included contingencies on network elements and the unplanned disconnection of one or more of these synchronous condensers.

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[41] https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/ssrmiag/amendment/system-strength-impact-assessment-guidelines-v21.pdf?la=en

H.3 Net present value

As given in ElectraNet's RIT-T Project Specification Consultancy Report (PSCR), the total capital costs and operating costs over a twenty-year period are converted into present value using a discount rate[42] of 7%, consistent with AEMO's 2024 ISP Inputs and Assumptions Workbook and the latest final IASR.[43] Cost comparison between options is achieved through calculation of net present value over the contract period of twenty years.

Each generic option is compared in its cost and value in system strength against a standard synchronous condenser solution.

H.4 Heuristic analysis

Fault level

Taking a 125 MVA synchronous condenser connected at Robertstown as a standard measure of fault current (fault level as referred to system strength), analysis is carried out to compare options against the standard measure (ie. the 125 MVA synchronous condenser). The three-phase fault current from the standard 125 MVA synchronous condenser connected at the 275 kV bus at Robertstown is found to be about 555 MVA using PSSE studies. This amount of fault level (555 MVA) is considered to be the standard unit of contribution from the synchronous condenser.

Comparing a new synchronous generator (say at node A) is achieved through evaluating the fault level due to that synchronous generator at node A. For this example, PSSE simulation gives a fault current contribution of 315 MVA at the local SSN (275 kV level) due to this new synchronous machine at node A. Therefore, in this analysis we consider the fault current contribution by this new generator at the local SSN is of the ratio (315/555) and as a percentage, it is about 56% of the standard synchronous condenser at Robertstown.

This is the basis of approximate analysis of fault current contributions by various plants including GFM BESS, clutch enabled synchronous machines, repurposed thermal generator converted synchronous condensers or similar sources of fault current.

Stable voltage waveform

Taking a 125 MVA synchronous condenser connected at an SSN such as Davenport or Robertstown as a standard measure of the efficient level, analysis is carried out to compare options against the standard measure (ie. the 125 MVA synchronous condenser). Any of the synchronous generators (gas generator or clutch enabled gas generators) is considered equivalent[44] to its similar rated synchronous condenser in terms of hosting asynchronous

[42] Discount rate of 7% is used unless otherwise specifically mentioned in a particular option.

[43] AEMO, 2023 Inputs, Assumptions and Scenarios Report | Final report, July 2023, p 123.

[44] Contribution towards stable voltage waveform depends on the node location, network impedance, nature of the IBR (e.g GFL or GFM), minimum SCR and requires wide-area PSCAD model simulation to evaluate quantitatively. Refer to "Assessment of efficient system strength requirements under ISP *Step Change* scenario for South Australia to 2034", Technical Note prepared by ElectraNet, 2024 September 30.

generation (IBR volume in MW) for stable voltage waveform. Furthermore, GFM BESS is assumed equivalent[45] to its similar rated synchronous condenser in terms of hosting asynchronous generation (IBR volume in MW) for stable voltage waveform.

This methodology is used as an approximation within the PADR where PSCAD simulation was not carried out to assess contribution towards stable voltage waveform from solutions proposed by the EOI process or generic options described in chapters 3 and 4 of the PADR.

[45] Contribution towards stable voltage waveform depends on the node location, network impedance, minimum SCR and requires wide-area PSCAD model simulation to evaluate quantitatively. Refer to "System Strength contribution from GFM BESS – feasibility study", Manitoba Hydro International report submitted to ElectraNet, September 2024.