Transgrid
People. Power. Possibilities.

Meeting system strength requirements in NSW

Non-network proponent briefing

25 June 2024

Acknowledgement of Country

In the spirit of reconciliation, Transgrid acknowledges the Traditional Custodians of the lands where we work, the lands we travel through and the places we live.

We pay our respects to the people and the Elders past, present and emerging. And we celebrate the diversity of Aboriginal peoples and their ongoing cultures and connections to the land and water.

Agenda

Please note: today's workshop will be recorded (available for 60 days)

No.	Time	Agenda item	Presenter
1.	2:00pm (5 mins)	Welcome	Jesse Steinfeld *Energy Transition Manager*
2.	2:05pm (10 mins)	Outcomes of the system strength Project Assessment Draft Report (PADR)	Jesse Steinfeld
3.	2:15pm (20 mins)	Information for non-network proponents	Li-Wen Yip *Energy Transition Specialist*
4.	2:35pm (20 mins)	Technical performance and power system modelling requirements for synchronous machines and grid-forming batteries	Navid Aghanoori *System Security Analysis Team Lead*
5.	2:55pm (35 mins)	Q&A	

- Q&A initially via Menti (www.menti.com): 8766 8157
- Then opening up for verbal questions via raised hand

Transgrid

Information available from Transgrid's website

'For proponent' information

https://www.transgrid.com.au/projects-innovation/meeting-system-strength-requirements-in-nsw

Document	Description
Information for system strength non-network option proponents	An explanation of the RIT-T, procurement and contracting process, areas of interest for new EOIs and high-level technical guidance for system strength services
EOI response questionnaire	An Excel workbook that gives proponents the opportunity to update or submit new EOIs
Technical performance and power system modelling requirements for synchronous machines	Detailed technical performance and power system modelling requirements for synchronous machines (for consultation)
Technical performance and power system modelling requirements for grid-forming BESS	Detailed technical performance and power system modelling requirements for grid-forming inverters (for consultation)
Effectiveness Factors	An Excel workbook that indicates the effectiveness of different locations for system strength provision

Outcomes of the system strength Project Assessment Draft Report (PADR)

Jesse Steinfeld
Energy Transition Manager

The growing need for system strength

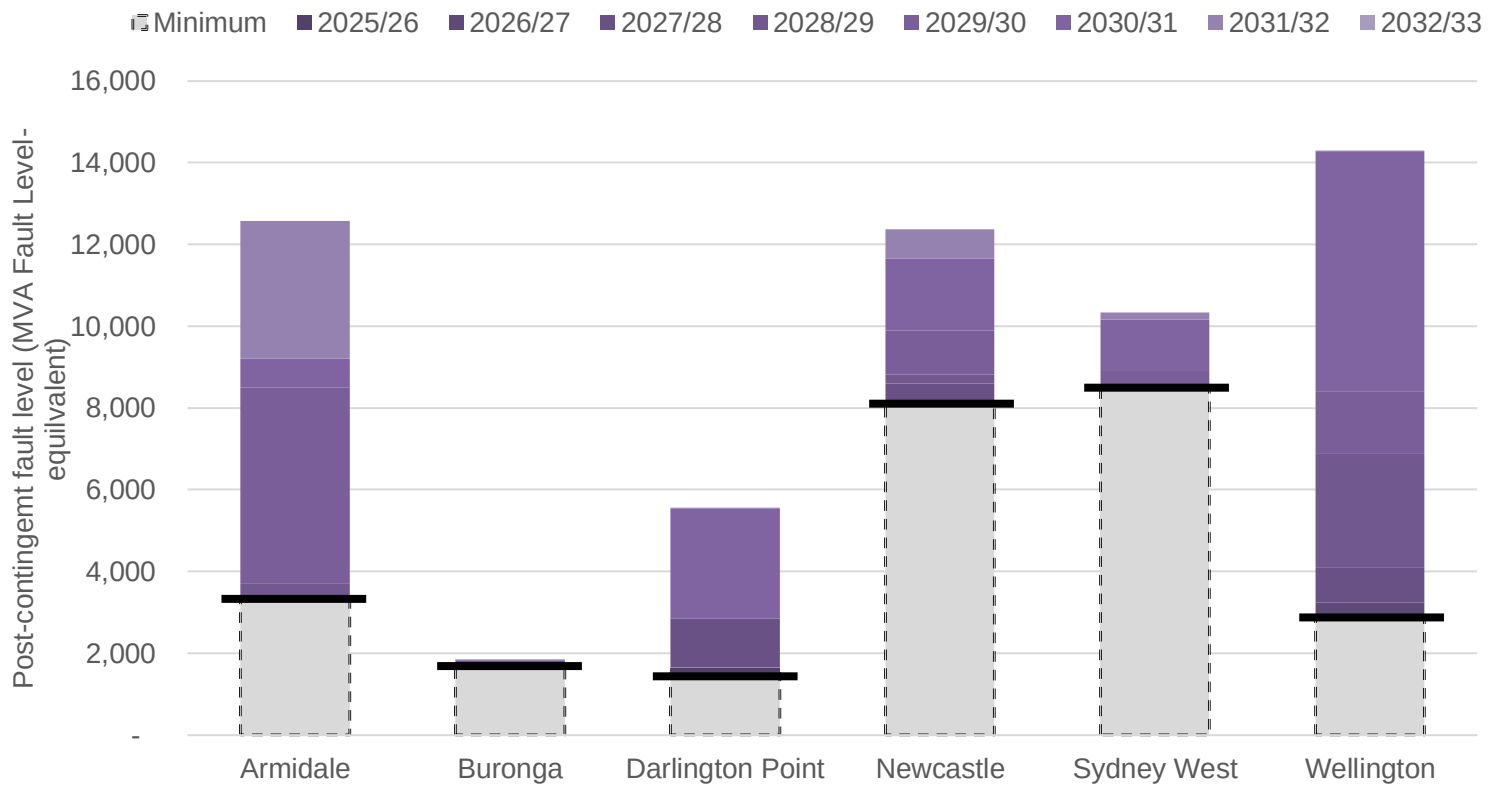
Transgrid's obligations are driven by AEMO's minimum fault level requirements at each system strength node, plus AEMO's annual inverter-based resource forecasts which are driven by the Integrated System Plan, Step Change scenario

1 July – 1 December 2025:

AEMO-declared fault level shortfalls of 1,420 MVA and 1,165 MVA at Newcastle and Sydney West.

System strength requirements in NSW, from 2 December 2025 to 2032/33

(minimum levels + support for the connection of new inverter-based resources)



Over 100 individual system strength solutions were assessed

Our system strength EOI process resulted in non-network option submissions from 25 parties, covering over 60 individual potential technology solutions. Transgrid has also identified 40 unique network solutions that could help meet the need

Network solutions	Network synchronous condensers	‘Targeted’ grid-forming BESS	Network grid-forming STATCOMs + supercapacitor		
Existing synchronous machines (non-network)	Existing synchronous plant without synchronous condenser mode	Existing synchronous plant with the ability to run in synchronous condenser mode	Existing synchronous plant requiring upgrades to run in synchronous condenser mode		
New synchronous machines (non-network)	Pumped hydro	Gas	Biomass	Non-network synchronous condensers	Compressed air storage (with a clutch to run in synchronous condenser mode)
Batteries (non-network)	Committed and anticipated grid forming-BESS	Committed and anticipated grid-following BESS, converted to grid-forming	EOI-proposed grid-forming BESS	‘Targeted’ (not currently proposed) grid-forming BESS	ISP ‘modelled’ grid-following BESS, converted to grid-forming

Maturity of grid-forming batteries for system strength

AEMO has determined that minimum faut level requirements

- *"must be delivered by devices that can provide protection-quality levels of fault current – such as new synchronous condensers, service contracts with existing hydro or thermal units, or through the retrofit of those existing units themselves"*

(May 2024 update to the 2023 ESOO)

Transgrid also engaged Aurecon to undertake an assessment of the maturity of grid-forming batteries. Aurecon:

Until FY2033

- Concluded that there is insufficient evidence (either at-scale deployments or in modelling) to currently rely on grid forming batteries to support the **"minimum" fault current requirements**.
  - The ability for grid forming batteries to provide a satisfactory fault current response to enable the safe operation of protection equipment in the transmission network has not been confirmed.
  - The performance and stability of grid forming batteries at their rated current limits, when fault current injection is critical, is not yet established, nor has the stability of grid forming batteries been confirmed for strong areas of the grid.

Up to a maximum of 50% of the efficient level solution size

- Concluded grid forming batteries have a key role to play for **"stable voltage waveform" support** for new connecting renewables
  - Transgrid recognises grid forming batteries can provide more "stable voltage waveform" support than as indicated by their fault current contribution (via preliminary PSCAD studies).
  - Our market modelling 'boosts' the contribution of batteries by 3 x fault current contribution

Note, another relevant study by Sandia National Laboratories explores this topic.

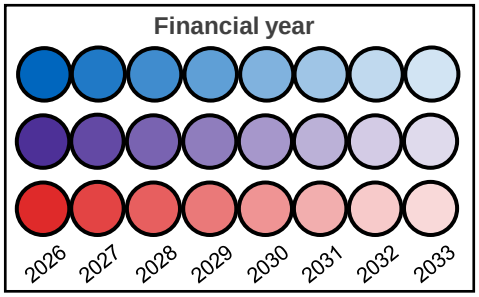
Portfolio of system strength solutions

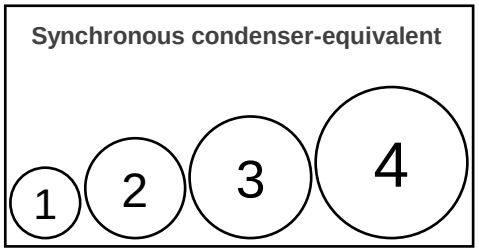
14 synchronous condensers *

>550MW of synchronous machine modifications

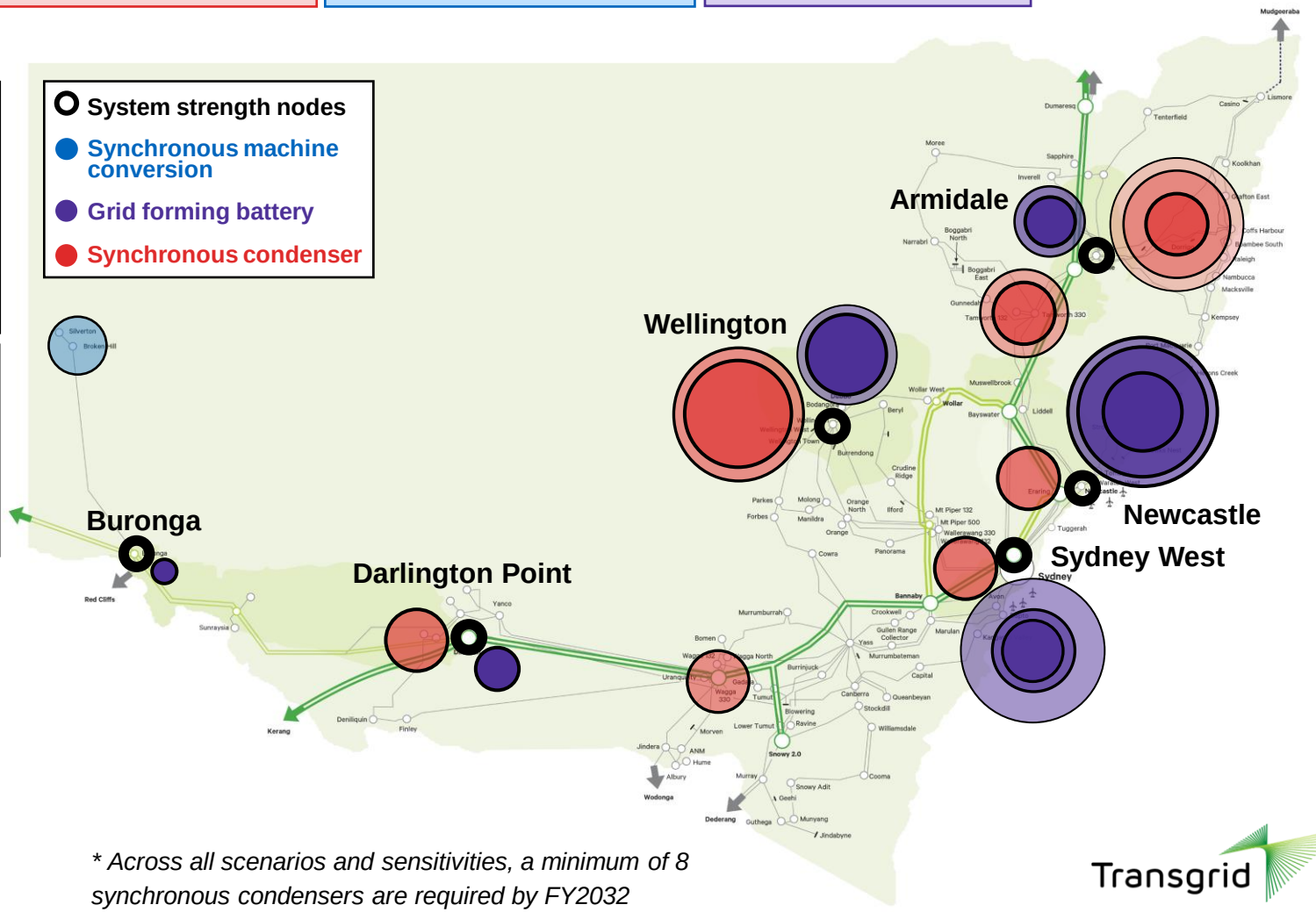
4.8GW of grid-forming batteries

By 2032/33 (under Portfolio option 1)





Note: This figure does not show the redispatch of existing machines, and some new solutions are not displayed for confidentiality.

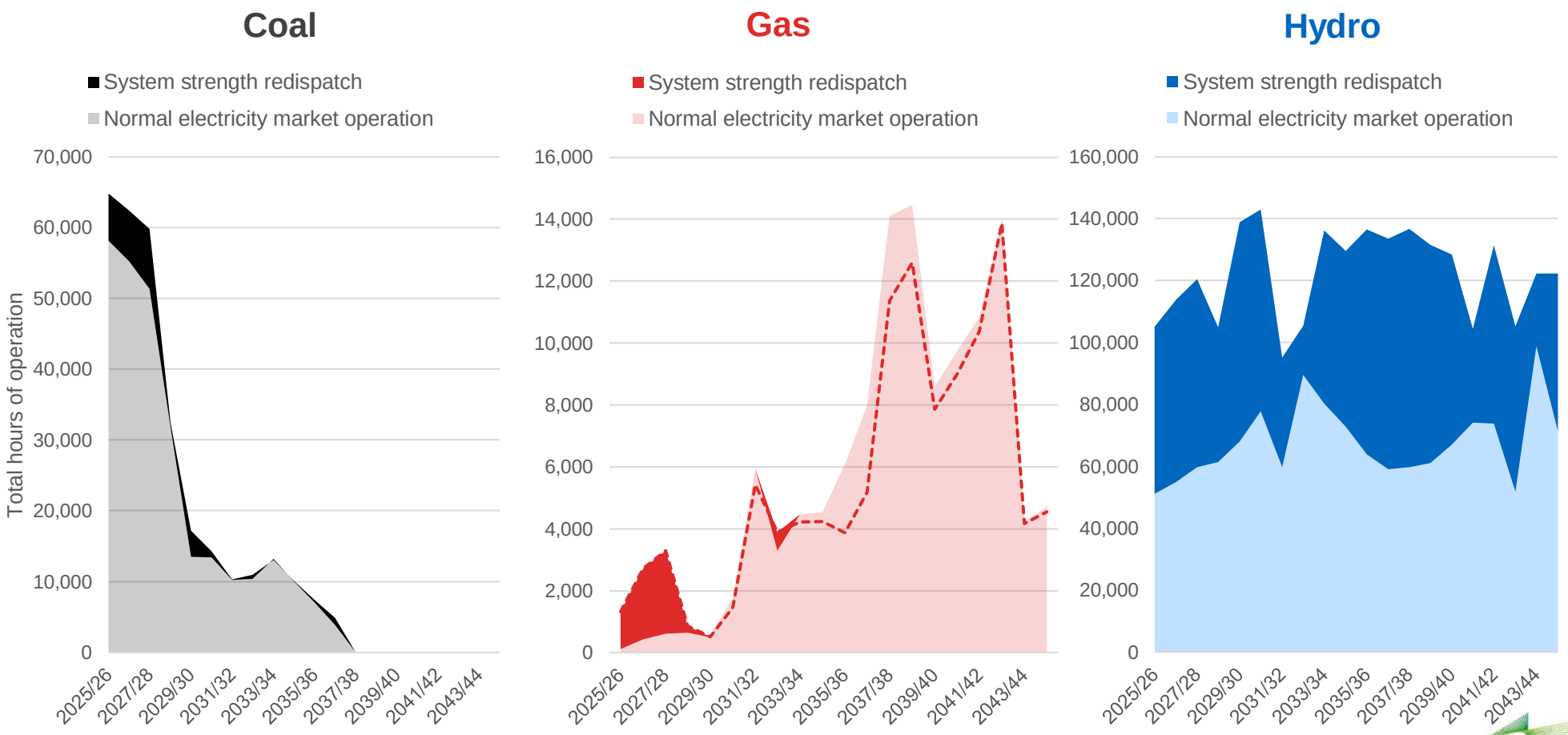


** Across all scenarios and sensitivities, a minimum of 8 synchronous condensers are required by FY2032*

Transgrid

Re-dispatch of existing generators for system strength

Projected hours of operation for synchronous machines in NSW, portfolio option 1
(in normal market operations + co-optimised with system strength constraints)

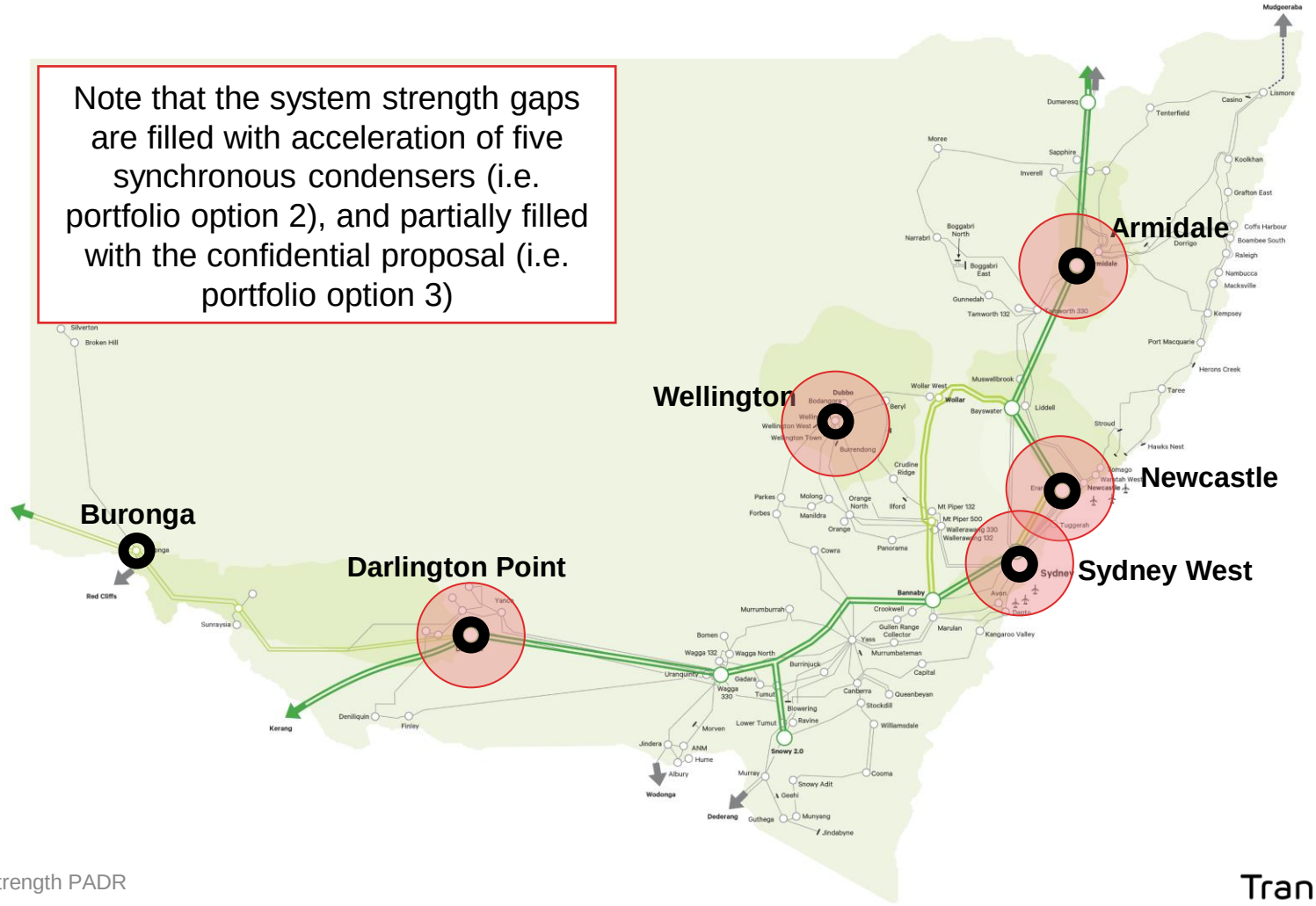


Transgrid

System strength risks prior to new synchronous condensers

Portfolio option 1 - gaps in system strength in 2027/28

Note that the system strength gaps are filled with acceleration of five synchronous condensers (i.e. portfolio option 2), and partially filled with the confidential proposal (i.e. portfolio option 3)



Transgrid

Information for non-network proponents

Li-Wen Yip
Energy Transition Specialist

What's in the document?

A "one-stop shop" for non-network option proponents:

1. RIT-T and procurement process
2. Transgrid's system strength requirements (already covered)
3. Summary of PADR outcomes (already covered)
4. How to submit new EOIs
5. How to update existing EOIs
6. Commercial terms and pricing
7. Power system modelling package requirements
8. Technical guidance for system strength services
9. Effectiveness factors

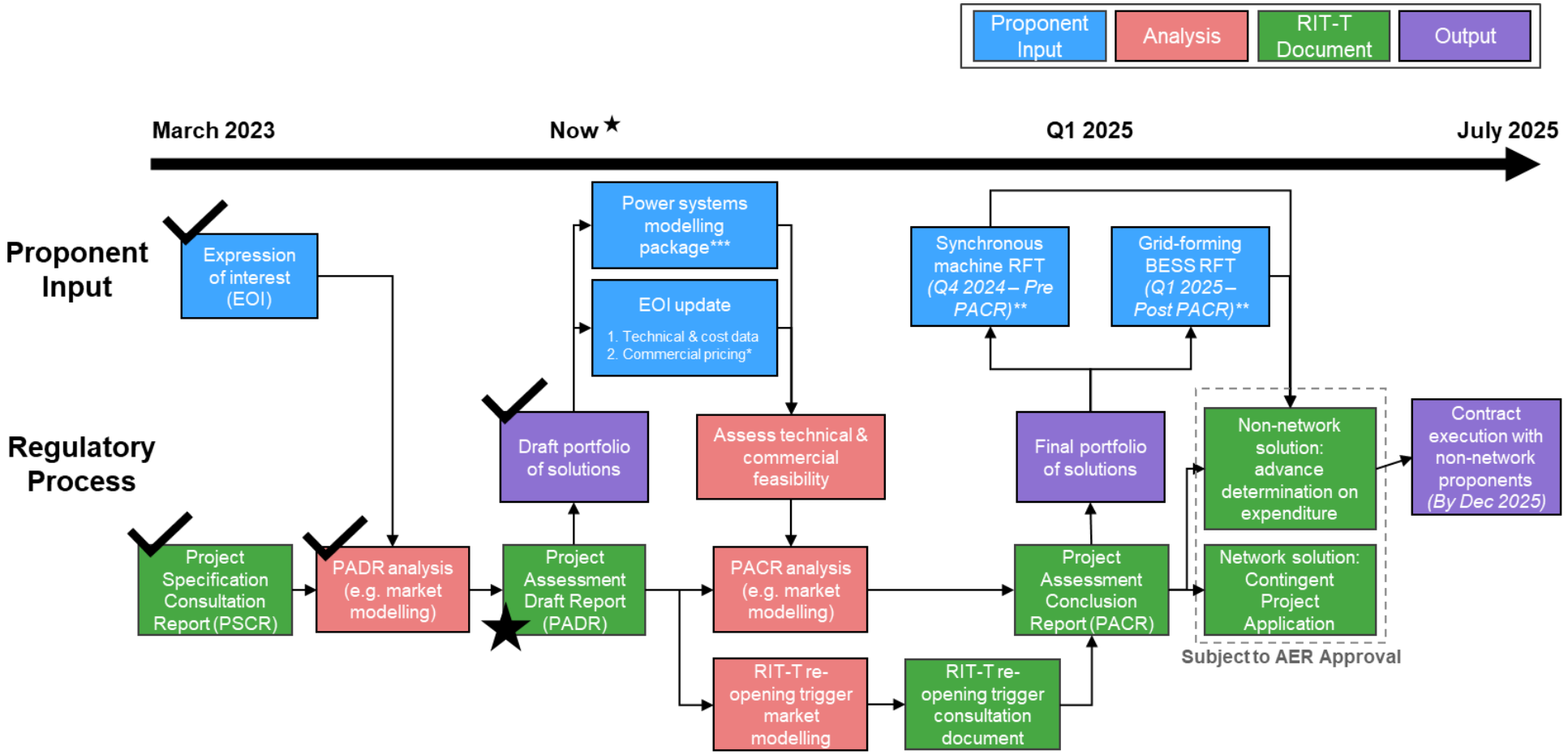
RIT-T and procurement process

The RIT-T is not a procurement process.

It is a cost-benefit analysis that determines the optimal quantity, location, and type of preferred system strength solutions.

In other words, it determines what we should procure, but not who we should procure it from.

RIT-T and procurement process



* Commercial pricing will be requested after AEMO publishes the minimum contracting requirements on 30 June 2024

** Eligibility to participate in RFT determined by final portfolio of solutions

*** Or consent to use existing models that Transgrid already has access to

New EOIs

We are particularly interested in EOIs for solutions that:

- Are similar to other solutions included in the PADR portfolio options; and/or
- Provide fault current support from 2027/28 – near Armidale, Sydney West, Newcastle, Wellington and Darlington Point; and/or
- Provide stable voltage waveform support from 2026/27 – near Broken Hill and Parkes
- (Full eligibility criteria in Section 5)

How to submit:

- Review all the information provided by Transgrid
- Submit by 2 August 2024:
  - Completed EOI response questionnaire (technical and cost information, no pricing)
  - Power system modelling package, or consent to use existing models.
- Submit later (likely September 2024):
  - Commercial pricing
  - Comments on draft commercial terms (to be published July/August 2024)

Existing EOIs

What we need you to do:

	What	How	When	Why
1	Confirm your EOI is still available (or if you wish to withdraw)	Email us	ASAP	So that we know which solutions are still on the table.
2	Update technical and cost data	We will send you a spreadsheet to update	We will send this to you in the next week or two. You'll have six weeks to return it.	To ensure we have accurate information for the PACR analysis; ensure the market modelling inputs are a correct interpretation of the information you provided.
3	Review and confirm market modelling inputs			
4	Review and comment on draft commercial terms	Email us	We will publish draft commercial terms in July/August. You'll have six weeks to respond.	To assess commercial feasibility (including likely outcome of AER advance determination on non-network expenditure). Draft commercial terms will include AEMO's minimum/recommended contracting requirements which will be published on 30 June 2024.
5	Provide updated commercial pricing	Email us		

Power system modelling package requirements

All solutions must provide a power system modelling package (or consent to use an existing one).

Why?

- To confirm technical feasibility
- To quantify the amount of system strength support that each individual solution can provide
- To confirm that the overall portfolio of solutions meets the overall need

If consenting to use existing model package

- Confirm no issues with existing NDAs or licence agreements
- Confirm existing models will remain valid post any proposed modifications/upgrades
- Advise of any recent model updates

If existing model package not available or suitable

- Synchronous machines – we will contact you to discuss next steps
- Grid-forming batteries – please submit a model package in accordance with Transgrid's technical requirements (discuss with your inverter OEM)

Technical guidance – synchronous machines

Scope

- Synchronous machines can support both the minimum + efficient levels of system strength (fault current + stable voltage waveform), and will also provide inertia regardless of whether it has been contracted.
- Synchronous Machines will contracted under a **"synchronous system security service"** that includes both system strength and inertia.
- Transgrid will need to procure inertia in future, and Transgrid/AEMO can use a system strength contract to provide inertia even if that is not the contract's intended purpose, and vice versa, so we may as well contract them as a single service.*
- Enablement payments will be the same, regardless of the reason(s) the service is enabled.

Technical assessment

- Minimum level of system strength – contribution to fault levels at each of the six NSW system strength nodes
- Efficient level of system strength – contributions to fault levels at connection points of future inverter based resources
- Inertia capability will be assessed, but will only to the extent that it affects stable voltage waveform support (e.g. oscillation damping).
- Full details on Transgrid's "Technical performance and power system modelling requirements for synchronous system security service" – Navid will cover in more detail

**Wherever system strength is contracted in combination with other services, the costs attributable to those other services will be excluded from the System Strength Unit Price.*

Technical guidance – grid-forming inverters

Scope

- Grid-forming inverter technologies can support the efficient level of system strength only (stable voltage waveform). (this may change in future)
- Grid-forming inverters will contracted under a **“stable voltage waveform support service”**
- This service will include support for stable voltage waveform criteria 1 (voltage magnitude), 2 (change in voltage phase angle), and 4 (voltage oscillations).
- This service will not require support for criterion 3 (voltage waveform distortion).
- Inertia capability will be assessed, but only to the extent that it affects stable voltage waveform support (e.g. oscillation damping).

Technical assessment

- System strength capability will depend on inverter rating, design, tuning, and proximity to the grid-following inverter-based resources (IBR) that need to be supported (note, not proximity to the six system strength nodes).
- Assessment will be via PSCAD™ and small signal modelling – details in “Technical performance and power system modelling requirements for stable voltage waveform support service from grid-forming BESS” – Navid will cover in more detail

Technical guidance – grid-forming battery capabilities

Overload / overcurrent capability

- Short-term overload / overcurrent capability is not mandatory, but some technologies may rely on it to meet their technical performance requirements.
- In general, it is helpful for providing stable voltage waveform support, but is less valuable than the equivalent amount of continuous rated capacity.

Headroom (MW)

- Reserving headroom" means reserving a portion of a GFM BESS's active power capacity for a specific purpose, by making it unavailable for other services.
- Whether or not a GFM BESS needs to reserve headroom for stable voltage waveform support will depend on its design.
- Transgrid prefers to contract solutions that are designed so they do not need to reserve headroom.

Energy Buffer (MWh)

- GFM BESS need an energy buffer to ride through and inject/absorb active power in response to network disturbances.
- GFM BESS can meet this requirement by reserving a small amount (less than 5 minutes) of their energy storage capacity.
- Other grid-forming inverter technologies will also require an energy source, e.g. a supercapacitor.

Effectiveness Factors

Definition

- The effectiveness factor for a solution at a certain location, is the ratio between:
  - ✓ The solution's fault level contribution to a system strength node; and
  - ✓ The solution's fault level contribution to its own point of connection.

Application

- *Contribution to node = effectiveness factor x fault current contribution at point of connection*
- Reasonably accurate for minimum level of system strength
- May be useful to help understand efficient level of system strength, subject to caveats

Caveats

- These effectiveness factors are based on a solution that contributes 900MVA of fault current at its own point of connection, and the lowest background fault level expected 99% of the time, based on our PADR market modelling.
- Actual fault currents will vary due to actual background fault levels and size of solution.
- Stable voltage waveform solutions are more effective if located close to IBR connection points, not close to the system strength nodes

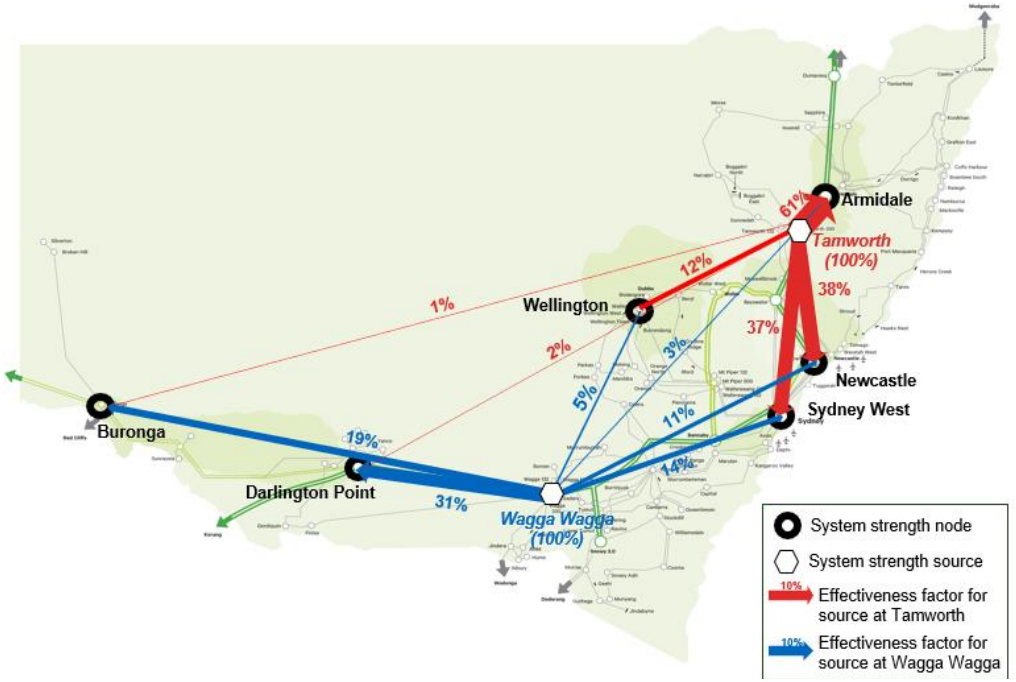


Table 3 - system strength contributions from a 1000MVA (fault level) solution at Wagga Wagga

System strength node	System strength contribution to node		2023 pre-contingent fault level requirement (MVA) [21]	
	Effectiveness factor (%)	Contribution (MVA)	Total need (MVA)	% of need met
Armidale	3%	30	3,300	1%
Buronga	19%	190	1,755	10%
Darlington Point	31%	310	1,500	21%
Newcastle	11%	110	8,150	1%
Sydney West	14%	140	8,450	2%
Wellington	5%	50	2,900	2%

Next steps for non-network option proponents

- We welcome submissions on Transgrid's system strength PADR, due 2 August 2025
- Submit a new or updated Expression of Interest (EOI) for non-network solutions (excluding commercial pricing), due 2 August 2025
- Provide PSCAD and other required models to support Transgrid's assessment of the technical credibility of your solution (in particular for grid-forming batteries), due 2 August 2025
- Await Transgrid's request for you to update the commercial component of your EOI, which will proceed AEMO's publication of minimum scheduling requirements on 30 June 2024

Additional information

https://www.transgrid.com.au/projects-innovation/meeting-system-strength-requirements-in-nsw

Document	Description
Information for system strength non-network option proponents	An explanation of the RIT-T, procurement and contracting process, areas of interest for new EOIs and high-level technical guidance for system strength services
EOI response questionnaire	An Excel workbook that gives proponents the opportunity to update or submit new EOIs
Technical performance and power system modelling requirements for synchronous machines	Detailed technical performance and power system modelling requirements for synchronous machines (for consultation)
Technical performance and power system modelling requirements for grid-forming BESS	Detailed technical performance and power system modelling requirements for grid-forming inverters (for consultation)
Effectiveness Factors	An Excel workbook that indicates the effectiveness of different locations for system strength provision

Technical performance and power system modelling requirements for grid-forming batteries

Navid Aghanoori
System Security Analysis Team Lead

Transgrid

Grid Forming BESS for System Strength Service

- Transgrid is currently only considering GFM BESS for Stable Voltage Waveform support (not for meeting the minimum Fault Level).
- Discusses Transgrid's System Strength Requirement and the relationship with previously published document from AEMO in relation to GFM technology. Table 1 may be found useful for this purpose.
- Explains the Criterion of Stable Voltage Waveform (SVW) and discusses each one briefly:
    - Voltage Magnitude
    - Support in Voltage Phase Angle
    - Voltage waveform distortion
    - Voltage Oscillations
- We then zoom into each of the relevant criteria and explain the expectation from Transgrid. This section is more of a functional specification.
- PSCAD Assessment in both SMIB (done by generator) and PSCAD Wide Area Environment (done by Transgrid) and how each test relates to what SVW.
- General Modelling Package requirement (e.g. PSSE, PSCAD, small signal, PowerFactory, AEMO R1 check list)
    - Compliance, 5.3.9
- R2- Compliance, Commissioning, Ongoing compliance monitoring, R2 validation report.

Relationship with AEMO Voluntary GFM Specification

Table 1 Summary Table of Transgrid Requirement vs AEMO's Voluntary Specification Requirements

Voluntary Specification Requirement		Required for provision of SVWSS in Transgrid's network
Core capabilities	2.3.1 Voltage source behaviour – response to voltage magnitude and phase changes	Required. • It is critical for the system strength solution not only be able to respond to the voltage disturbance but also be able to operate in different conditions of the voltage. • In addition to the Voluntary Specification [1], Transgrid expects the battery remains grid forming even when operating at the limit; however, it is accepted that the response from battery as a voltage source is only provided up to the current limits. Reaching the current limit thresholds must not be a reason to switch the control mode to grid following current controller including during steady state and Fault Ride Through.
Core capabilities	2.3.2 Frequency domain response	Not required. The Voluntary Specification [1] and Test Requirements Framework [2] propose to use this to illustrate GFMI performance based on the impedance scan of generator; however, Transgrid has not adopted this approach in its

Explained the Criterion of Stable Voltage Waveform and Grid Forming BESS

- The positive-sequence RMS voltage magnitude at a connection point does not violate the limits in the operational guides for the relevant network.
- 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.
- 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.
- Any undamped steady-state RMS voltage oscillations anywhere in the power system should not exceed an acceptable planning threshold as agreed with AEMO.

- We are expecting Reactive Power and Reactive Current Supply but with some specific criteria. (e.g. Response time and dependency on SCR)
- We want the voltage angle of the inverter to be adjusted (through its active power injection), to not only remains synchronised with the network but make the transient voltage angle smoother for GFL IBR's PLL.
- We don’t expect to absorb the harmonics of the network but if the technology could do, it is advantaged. We expect you just to follow our existing assessment guide.
- It is expected that BESS itself will be at least meeting AAS damping and further improve the damping of all sub-synchronous modes, specifically the modes that are likely to be seen from IBRs and inter-connectors. Note there will be small signal modeling and large signal modeling

How to Self-Assess Prior the Submission

Simulation Key Notes:

1- All the tests to be performed at P=0, Pmin and Pmax unless noted otherwise.

2- If SCR is not noted in the test description, the test must be performed under a Short Circuit Ratio (SCR) of 1.2 and SCR of 20 at the POC for SMIB modelling.

3- SMIB studies must be done by the proponent and the results to be presented in a report format (and raw data if requested). It is also recommended that proponent, performs the same or similar tests in a MMIB environment to represent the best performance and effectiveness of GFM technology. In the optional MMIB models, the tests do not need to be limited to the requested tests by Transgrid and can go beyond this.

4- All the wide area tests will be done by Transgrid.

Table 3 Minimum Tests Required to be Performed by GFM BESS proponent and Transgrid

Test No	Description	Purpose of the test	Reference to SVW criteria[3]	SMIB (or MMIB)	Wide Area
1	Cause 3% Voltage drop through a remote fault	• Monitor the response to a small signal voltage disturbance up to 3% (without hitting the limiters). • Correct droop characteristic at the POC and voltage control at the inverter, Fast rise time and adequately damped response are expected. It is also expected that voltage profile of nearby buses will improve by adding BESS.	1,2,4	Y	Y

Grid Forming BESS for System Strength Service

- **Question 1:** If a generator that is called Grid Forming by the OEM, is already Committed, Registered or Operational, does it still need to comply with this specification and go through the testing?
    - Yes. Passing the standard due diligence tests in Connection Application, Registration or Self-remediation does not qualify the technology to provide System Strength to other Asynchronous generators.
- **Question 2**: If a GFM BESS is at the final Holdpoint or full operation, does it need to repeat some or all of the modelling and Holdpoint tests?
    - No. SMIB modelling tests that had been done before do not need to be repeated but all the PSCAD wide area tests by Transgrid will have to be undertaken. The standard Holdpoint tests do not need to be repeated but the specific tests for showing the independency of BESS operation to very low SCR must be undertaken. Additionally, all the R2 and ongoing compliance monitoring conditions still apply.
- **Question 3**: Is every Battery that provides Synthetic Inertia Grid Forming and can provide System Strength Service to Transgrid?
    - No. Please refer to all the requirements in the specification.
- **Question 4:** If we pass all the SMIB tests, does it mean that we will qualify?
    - No. That is the starting point and the minimum. The ultimate decision will be based on the PSCAD wide area studies as well as small signal studies.

Technical performance and power system modelling requirements for synchronous machines

Navid Aghanoori
System Security Analysis Team Lead

Transgrid

Synchronous Machine System Security Service

Technical Performance and Power System Modelling for:

- System Strength
- System Strength- Stable Voltage Waveform Support; and
- Inertia

What we have covered:

- General Requirement (e.g. PSSE, PSCAD etc).
- Compliance and Reporting
- Technical Documentation and Power System Modelling
- Simulation and Results
- Compliance and Reporting in R2

To the best we could we distinguished between a project with fully approved model and technical performance and the one is new or going through 5.3.9.

Q&A