Transgrid

People. Power. Possibilities.

Information for proponents of non-network solutions to meet system strength requirements in NSW

Supplementary to the 'Meeting system strength requirements in NSW' Project Assessment Draft Report (PADR)

Date of issue: 17 June 2024

Contents

1. Introduction

1.1. Background

In December 2022, Transgrid published a Project Specification Consultation Report (PSCR)[1] and called for Expressions of Interest (EOIs) for non-network solutions to meet system strength solutions in NSW[2], as part of the related Regulatory Investment Test for Transmission (RIT-T)[3]. In March 2023 we received EOIs from 25 proponents proposing over 60 individual solutions, including new, existing, upgraded, and converted synchronous generation; pumped hydro; and grid-forming batteries. Over the subsequent months, we engaged with EOI proponents to clarify the technical and cost assumptions that should be applied to their non-network solutions in the RIT-T.

In June 2024, alongside this document, we published the second stage of the RIT-T, the Project Assessment Draft Report (PADR), which identified the type and general location of non-network solutions included in the most credible option portfolios. This market modelling and power system modelling assessment was based on the technical and cost data provided by EOI proponents, and assumed that all solutions are technically feasible (in terms of technical performance) and commercially feasible (in terms of commercial terms and pricing).

Following the PADR publication, we are now seeking to re-engage with EOI proponents to firm up technical and cost information for their projects, and confirm their technical and commercial feasibility. This will inform the final stage of the RIT-T, the Project Assessment Conclusions Report (PACR), which we expect to publish in Q1 2025.

In parallel to the conclusion of the RIT-T, we will run a commercial procurement process, in which we will ask for commercially binding proposals for non-network system strength services. We expect that procurement will run in tranches, commencing in late 2024.

Note that the RIT-T is not a procurement process. Instead, it identifies the quantity, location, and type of preferred system strength options (but not necessarily who should supply them), thereby determining which non-network solutions are eligible to compete for system strength contracts.

Once procurement is complete, the final step before contract execution is to seek an advance determination from the Australian Energy Regulator (AER) on operating expenditure for non-network solutions. The AER will assess whether the proposed system strength contracts meet criteria indicating efficient and prudent expenditure.[4] This determination will provide comfort that Transgrid will be able to recover any payments under these contracts, before they are executed.

[1] https://www.transgrid.com.au/media/dqznf0go/transgrid-pscr_meeting-system-strength-requirements-in-nsw_16-dec-2022.pdf
[2] https://www.transgrid.com.au/media/i2vfgzm1/transgrid_system-strength_eoi_16-december-2022.pdf
[3] https://www.transgrid.com.au/projects-innovation/meeting-system-strength-requirements-in-nsw
[4] Under NER 6A.6.6A(a), which commences on 1 December 2024. Refer https://www.aemc.gov.au/sites/default/files/2024-04/Final%20Rule%20-%20in%20mark%20up.pdf and https://www.aemc.gov.au/sites/default/files/2024-03/ERC0290%20-%20ISF%20final%20determination.pdf section 4.5.4

1.2. Purpose

The purpose of this document and its attachments is to help engage with EOI proponents (**you**) to firm up technical and cost information for your solutions, and confirm their technical and commercial feasibility, as inputs to the final stage of the RIT-T (the PACR).

This document includes updated information about Transgrid's system strength requirements, to help you better understand the opportunity, including:

- An explanation of the RIT-T, procurement, and contracting processes;
- Types of non-network solutions that were identified as part of the preferred option in the PADR;
- Our specific areas of interest for new EOIs;
- Changes to Transgrid's requirements since the December 2022 call for EOIs;
- High-level technical guidance on system strength services;
- Detailed technical performance and power system modelling requirements (in attached documents);
- Data indicating the effectiveness of different locations for system strength provision ('effectiveness factors');

And explains what we need you to do / submit, including:

- How to submit a new EOI proposal;
- What updated information we need you to provide for existing EOI proposals;
- Power system modelling requirements; and
- Consultation on commercial terms and updated pricing.

1.3. Links

Two key documents are referred to frequently throughout this document:

- Meeting System Strength Requirements in NSW - Project Specification Consultation Report (PSCR), link.
- Meeting System Strength Requirements in NSW - Project Assessment Draft Report (PADR), link.

All other documents relating to this RIT-T can be found at the project page on Transgrid's website:

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

1.4. Glossary

The following terms are used frequently throughout this document:

Acronym	Meaning
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
EOI	Expression of Interest
GFM BESS	Grid-Forming Battery Energy Storage System
IBR	Inverter-Based Resources
NEM	National Electricity Market
NER	National Electricity Rules
PADR	Project Assessment Draft Report
PACR	Project Assessment Conclusions Report
PSCR	Project Specification Consultation Report
RIT-T	Regulatory Investment Test for Transmission
STATCOM	Static Synchronous Compensator
SVWSS	Stable Voltage Waveform Support Service

2. RIT-T and procurement process

This section provides an explanation of the RIT-T and procurement process. It is relevant to all proponents of non-network solutions, to provide clarity on where we currently are in these processes, and the pathway to securing a system strength contract.

2.1. RIT-T process

The system strength RIT-T is not a procurement process; rather, it is a cost benefit analysis that determines the optimal quantity, location, and type of preferred system strength solutions. It does not necessarily determine who should supply those solutions.

The RIT-T identifies optimal solution(s) to meet the need, based on an economic cost-benefit analysis test that determines which option (or combination of solutions in the case of this RIT-T) "maximises the net economic benefit to all those who produce, consume and transport electricity in the National Electricity Market"[5]. The cost-benefit analysis does not consider contract pricing – this is because under the RIT-T framework, payments between NEM participants (e.g. from Transgrid to a generator or battery proponent) do not have any net cost or benefit to the NEM as a whole[6]. Instead, net economic benefits are assessed based on NEM participants' underlying capital and operating costs, compared to a state of the world where they do not provide system strength services.

To assess the net economic benefit of the portfolio of solutions used to meet Transgrid's system strength obligations, the RIT-T process consists of three key stages with each stage providing an opportunity for stakeholders to engage with the process.

The initial stage, Project Specification Consultation Report (PSCR), details the need to meet system strength requirements in NSW and describes credible options, including technical characteristics that would be required of a non-network option. Transgrid published the PSCR in December 2022 alongside a call for expressions of interest (EOIs), giving non-network solutions the opportunity to be considered as a potential option to meet Transgrid's system strength requirements.

The Project Assessment Draft Report (PADR), published in June 2024 alongside this report, involves a detailed assessment of the feasible options identified by the PSCR and EOI submissions. This assessment includes developing options comprising portfolios of solutions (portfolio options), and a cost-benefit analysis and an evaluation of each portfolio option's ability to meet our system strength requirements, via market modelling and power system studies.

The RIT-T also includes provisions for re-opening triggers which are triggered if a material change occurs in the NEM that could impact the assessment of the preferred portfolio of options. Given the rapid changes in the NEM occurring in parallel with this RIT-T, Transgrid will subsequently publish another document to consult on additional potential re-opening triggers and allow stakeholders another opportunity to provide input on whether the RIT-T should be re-opened in future to reassess the project under new circumstances.

[5] https://www.aer.gov.au/system/files/AER%20-%20Regulatory%20investment%20test%20for%20transmission%20-%2025%20August%202020.pdf, p5
[6] https://www.aer.gov.au/system/files/2023-10/AER%20-%20RIT-T%20guidelines%20-%20final%20amendments%20%28marked%20up%29%20%20-%206%20October%202023_0.pdf, p60

The Project Assessment Conclusion Report (PACR) outlines the preferred investment options, provides a justification for their selection, and aims to address all stakeholder feedback from the PADR stakeholder submissions. Transgrid expects to publish the PACR in Q1 2025.

Following completion of the PACR, Transgrid will finalise investment decisions and seek the AER's approval via a Contingent Project Application (CPA) for network options and an advance determination on operating expenditure for non-network options.

Throughout the RIT-T process, confidentiality is maintained to protect sensitive information provided by EOI proponents to Transgrid and to ensure a fair and unbiased assessment. Stakeholder engagement is a vital part of the RIT-T process, ensuring that investment decisions are well informed, transparent, and aligned with the broader interests of the energy industry and community.

2.2. Procurement process

The EOIs were assessed through the PADR market modelling to evaluate their economic competitiveness relative to other system strength solutions, based on proponents' underlying capital and operating costs. Now that the results from the PADR have been published, we are asking existing EOI proponents to update their initially submitted EOIs (where appropriate), and welcoming EOIs for new solutions in light of the PADR results.

Additionally, we are asking proponents to provide a power systems modelling package (or consent to using existing models that we already have access to) to facilitate a detailed assessment of the technical feasibility of any new generator / system strength solution. This process ensures that the proposed solutions are robust and capable of meeting the required technical specifications for providing system strength. A power systems modelling package (including PSCAD models) is required for any solution to be considered as part of the optimal portfolio of solutions in the PACR.

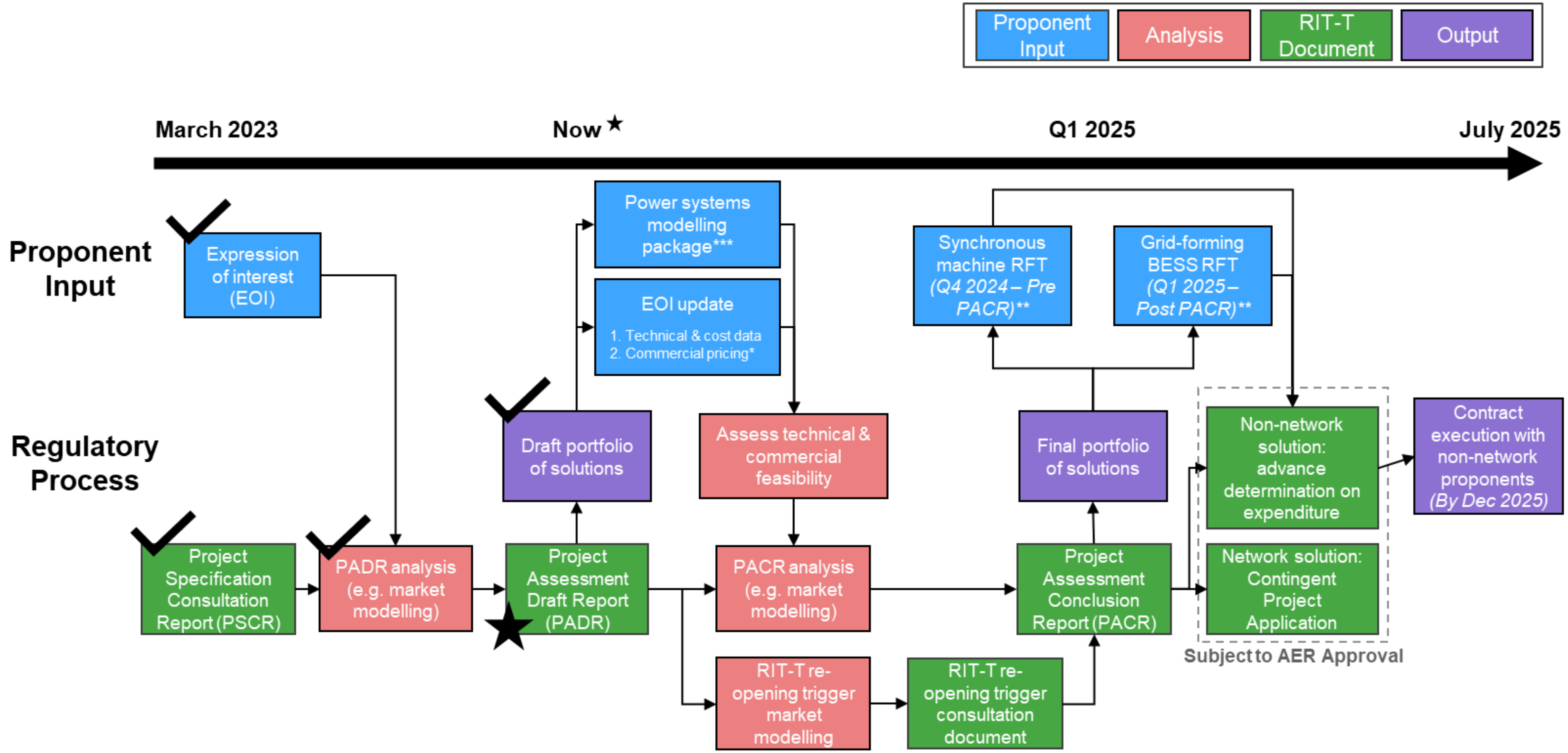
The final portfolio of solutions in the PACR will determine which proponents or types of solutions are eligible to participate in the request for Tender (RFT) process. We expect to initiate the RFT process for synchronous machines before the release of the PACR, allowing for early engagement and procurement of these solutions. We expect to initiate the RFT for grid-forming BESS after the PACR is published. This staggered approach gives us more time to understand the technical capabilities of grid-forming BESS and the optimal makeup of the portfolio of system strength solutions (in particular the quantity of services we require from grid-forming batteries).

Once the contract negotiation is complete, we will seek an advance determination from the Australian Energy Regulator (AER) on whether Transgrid's proposed expenditure on non-network options meets criteria indicating efficient and prudent expenditure. The AER will publish guidelines setting out its process for making these determinations by 1 December 2024.

This will be followed by the execution of contracts between Transgrid and proponents.

Figure 1 provides a flow chart of proponent engagement along the RIT-T process.

Figure 1: Diagram outlining proponent input into the regulatory 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

3. Transgrid’s system strength requirements

This section provides an explanation of Transgrid’s system strength obligations under the National Electricity Rules, and recent updates to Transgrid’s requirements for non-network system strength solutions. It is relevant to all proponents to help understand the opportunity to help meet Transgrid’s system strength needs.

3.1. Background

Under the “efficient management of system strength” rule change[7], From 2 December 2025, Transgrid, as the System Strength Service Provider (SSSP) for NSW and ACT, must meet a system strength standard (NER S5.1a.9) comprising:

*(a) a **minimum three phase fault level** for power system security, expressed in MVA (also known as the **minimum level of system strength**), sufficient to enable:*

(i) correct operation of protection systems of networks and Network Users (both transmission and distribution)

(ii) stable voltage control systems; and

(iii) the power system to remain stable following any credible contingency event or protected event; and

*(b) a requirement for **stable voltage waveforms** at connection points (also known as the **efficient level of system strength**), such that:*

(i) in steady state conditions, plant does not create, amplify, or reflect instabilities; and

(ii) avoidance of voltage waveform instability following any credible contingency event or protected event is not dependent on plant disconnecting or varying active power or reactive power transfers, other than in accordance with performance standards.

Under NER S5.1.14, Transgrid must plan to meet the ‘system strength standard specification’ defined in that clause, for both the minimum and efficient levels of system strength. The system strength standard specification is determined by AEMO under the System Strength Requirements Methodology, and published in the System Strength Report on 1 December each year. The specification comprises 10 year forecasts of:

- pre- and post-continency minimum three phase fault levels (in MVA) at each of the six system strength nodes in NSW; and
- level (in MW) and type of inverter-based resources (IBR) at each of the six system strength nodes in NSW.

3.2. Updates to Transgrid’s requirements

Since the EOI in March 2023, there have been several changes to Transgrid’s requirements for non-network system strength solutions, driven by changes to our obligations (e.g. rule changes and updated inverter-based resource forecasts) and the outcomes of the PADR. In summary:

[7] https://www.aemc.gov.au/rule-changes/efficient-management-system-strength-power-system

- There have been minor changes to the timing and quantity of the system strength requirements – please refer to section 11.3 of this document and section 2 of the PADR for more details. These changes do not materially affect the long term need for system strength solutions, or the evaluation of any of the EOI submissions received.
- Solutions to the system strength need in NSW and ACT must be located within the NSW NEM region (which includes the ACT). System strength contributions provided from other NEM regions via interconnectors will be accounted for via TNSPs' joint planning.
- The Operational Security Mechanism (OSM) has been replaced by the Improving Security Frameworks (ISF) rule change[8]. Under the final rule:
  - AEMO will enable system strength contracts via a simplified scheduling mechanism;
  - By 30 June 2024, AEMO will publish the part of the enablement procedures which provide any minimum or recommended requirements to be included in TNSPs' contracts for system strength services;
  - SSSPs (i.e. Transgrid) will make all payments to system strength contractors; and
  - AEMO is free to enable system strength contracts for the provision of inertia even if that is not their intended purpose, and vice versa[9].
- Grid-forming inverters/BESS are considered technically feasible as a solution to support the stable voltage waveform of new connecting IBRs (for the efficient level of system strength) only, i.e. not for the minimum level of system strength (within the timeframe being contemplated in this RIT-T). This is based on Aurecon's advice on the maturity of grid-forming BESS to provide system strength support[10], and is consistent with AEMO's update to the 2023 Electricity Statement of Opportunities, which stated that minimum fault 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.*"[11] For more details, refer to section 4.1.1 of the PADR, or Aurecon's report accompanying the PADR.
- We have published "effectiveness factors" data, which provide a more granular indication of the locations where system strength solutions can be most effective in providing system strength support to system strength nodes.
- We now intend to procure two types of system strength contract, one for synchronous machines, and one for grid-forming inverters. The differences between the two types of contract are summarised in the table below:

[8] https://www.aemc.gov.au/rule-changes/improving-security-frameworks-energy-transition
[9] https://www.aemc.gov.au/sites/default/files/2024-03/ERC0290%20-%20ISF%20final%20determination.pdf, section 6.3.5
[10] Aurecon, Advice on the maturity of grid forming inverter solutions for system strength, April 2024.
[11] AEMO, *Update to the 2023 Electricity Statement of Opportunities*, May 2024, p. 43.

Table 1 - types of system strength contract

	Synchronous system security service	Stable Voltage Waveform Support Service
Eligible technologies	• Synchronous machines only	• Grid-forming inverter technologies only, e.g. - Grid-forming batteries - Grid-forming renewable generators - Grid-forming STATCOMs
Services included	• System strength – fault current and stable voltage waveform support • Inertia	• System strength – stable voltage waveform support (only)
Contributes to	• Minimum level of system strength • Efficient level of system strength	• Efficient level of system strength

Note that the design of system strength contracts may vary in future, to reflect changes in network needs and technology developments.

4. Non-network solution types identified as part of the PADR

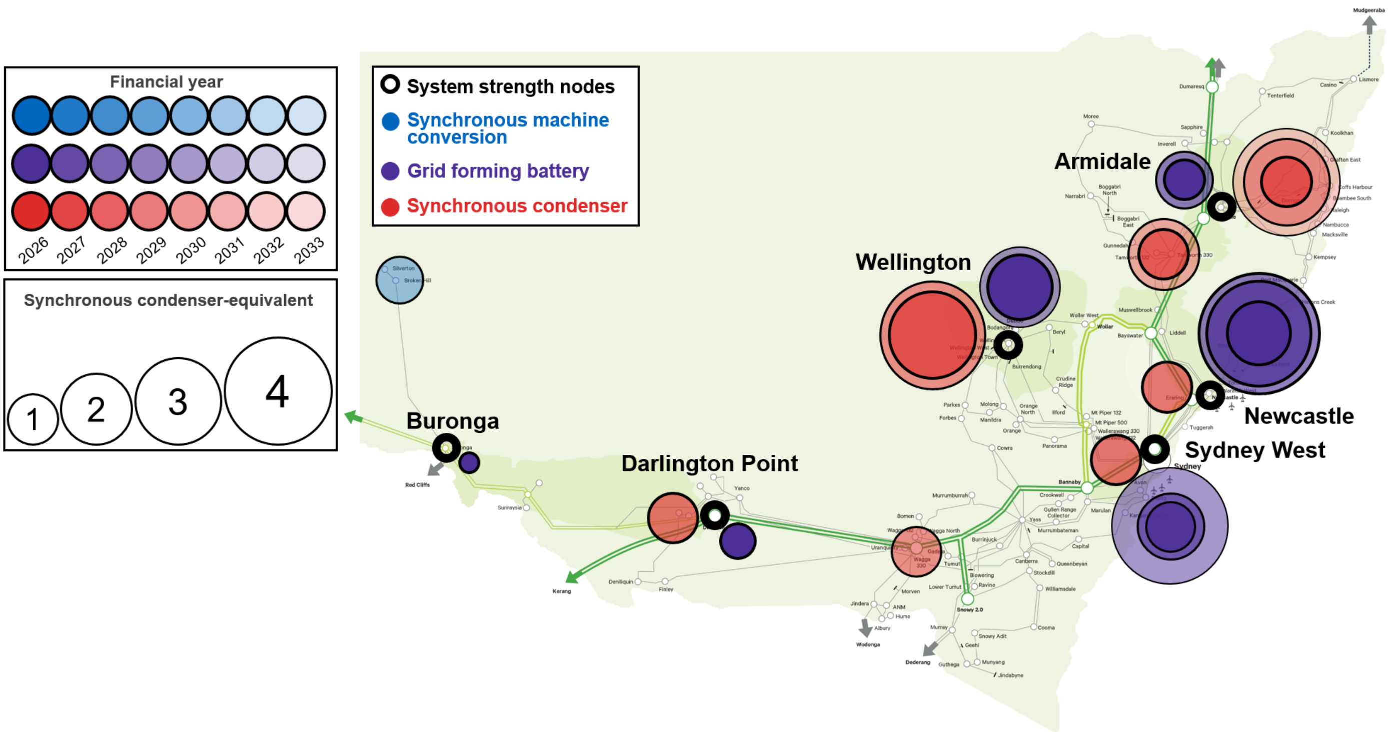
This section summarises the results of the PADR with respect to non-network solutions. It is relevant to all proponents, to help understand which non-network solutions (i.e. types, general locations, and timing) are likely to be selected as part of the preferred option in the PACR.

While it is common for RIT-Ts to identify a 'preferred option' (singular) to meet the need, the scale and complex nature of NSW's system strength requirements necessitated a 'portfolio of solutions' to meet the need. The PADR portfolio optimisation process considered all 100 non-network and network solutions and identified an optimal portfolio of solutions which included:

- 8 to 14 synchronous condensers by 2032/33 (across all portfolio options and sensitivities studied);
- modifications to synchronous hydro generators and the addition of clutches to the Silver City compressed air energy storage facility in Broken Hill, in order to allow system strength provision when the units are not generating, pumping or compressing; in total contributing over 550 MW of generation assets;
- re-dispatching a range of existing hydro generators to ensure they can switch on or operate in synchronous condenser mode where necessary to fill gaps in system strength, as well as a smaller number of gas and black coal units also being re-dispatched; and
- 4.8 GW of new build grid-forming BESS by 2032/33, comprising primarily of upgrading committed and anticipated grid-following BESS with grid-forming capability and ISP 'modelled' BESS included in the IBR forecasts also upgrading to grid-forming capability.

The figure below provides a summary of the magnitude, general location and timing of the new build solutions (or modifications to existing generators) making up the PADR's core 'portfolio option 1'.

Figure 2 – New build prior to 2032/33 under option portfolio 1



Note: This figure does not show the redispatch of existing machines, which are also included in this portfolio. It also excludes selected system strength solutions for confidentiality reasons.

Importantly, under this core option portfolio, market modelling results show that there are gaps in system strength that cannot be filled in 2027/28, which presents risks to the power system and consumers (including expected unserved energy). These gaps in 2027/28 occur at or surrounding Armidale, Wellington, Newcastle, Sydney West and Darlington Point system strength nodes during times when there are low numbers of synchronous machines online due to synchronous generator maintenance or outages (occurring up to 3% of the year). These gaps are exacerbated when individual transmission lines between Newcastle and Armidale are required to be out of service for short periods of time for maintenance or for the connection of new transmission projects.

Additional results and details of the market modelling can be found in section 5 of the PADR.

5. New Expressions of Interest

This section is applicable to any proponents to wish to submit an Expression of Interest (EOI) for a new solution, for which you have not already submitted an EOI in March 2023. It explains what we are looking for, what types of solutions are eligible, and how to submit.

5.1. Areas of interest

We are seeking additional EOIs from all non-network proponents, with a particular interest in solutions which:

- are similar to those included within the portfolio options in the PADR (refer section 4 of this document, and section 5 of the PADR)
- could contribute to meeting system strength gaps at Armidale, Sydney West, Newcastle, Wellington and Darlington Point in 2027/28 and which are capable of providing “protection-quality levels of fault current”[12], such as new synchronous condensers, new synchronous generators or modifications to existing synchronous generating units;
- could provide stable voltage waveform support (e.g. grid-forming batteries, synchronous machines) in:
  - the Broken Hill area from 2026/27;
  - the Parkes area from 2026/27.

5.2. Eligibility criteria

We welcome EOIs for non-network system strength services from assets/projects at any stage of development, including:

- existing assets;
- new projects already under development or construction; and
- proposals for new projects specifically to provide system strength.

Note that proposals for a technology type without a named asset/project can be accepted as submissions to the PADR consultation, but are not eligible for consideration via this EOI process.

Eligible technologies include (but are not limited to):

- To contribute to the minimum and efficient levels of system strength:
  - synchronous generators (with or without capability to operate in synchronous condenser mode);
  - modification of existing synchronous generators to enable operation in synchronous condenser mode;
  - conversion of existing synchronous generators to synchronous condensers;
  - synchronous condensers (with or without flywheels);
  - synchronous motors;
- To contribute to the efficient level of system strength only:

[12] https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2023/may-2024-update-to-the-2023-electricity-statement-of-opportunities.pdf, p43

- grid-forming battery energy storage systems (BESS);
- grid-forming inverter-based renewable generators; and
- grid-forming static var compensators (SVCs) or static synchronous compensators (STATCOMs).

Potential non-network options should meet the following criteria as applicable to the technology type:

- be located within the NSW NEM region (which includes the ACT);
- be commercially and technically feasible;
- provide a material quantity of system strength services;
- be in the name of one contracting party;
- be available for enablement for 95% of each year or part of a year for which the service is offered. We will, at our discretion, consider lower availability measures where significant cost savings can be demonstrated as a result of lower availability measures;
- upon instruction from AEMO or Transgrid to enable the services, proposed services must commit and continuously maintain the service from the time indicated in the enablement instruction;
- once the system strength service is enabled, the service shall remain activated until an instruction to disable is received;
- continue to meet any relevant Generator Performance Standards (GPS) when providing the system strength support services;
- have facilities to transmit specified measured quantities via SCADA to AEMO and/or Transgrid's control room which conform to the required standards of reliability, accuracy and latency as would be applied to a scheduled generating system;
- have metering facilities suitable for resolving any compensation payments associated with the provision of system strength services; and
- if new solutions, be supported by simulation models that comply with the requirements stipulated in AEMO's Power System Model Guidelines. This includes the provision of Electromagnetic Transient (EMT) models for power electronic interfaced equipment, e.g. GFM BESS.

5.3. Evaluation criteria

The purpose of this EOI process is to enable us to identify and assess credible non-network options for the provision of system strength, including to inform our PACR market modelling. We may elect to supplement, verify or clarify information submitted through this EOI in the preparation of technical and economic assessments for the RIT-T.

Proposals that meet the eligibility criteria in section 5.2 will be evaluated using the following criteria. The criteria are not listed in any specific order and will not be accorded equal weight:

- ability to support Transgrid in meeting its system strength requirements under the NER;
- lead time to deliver system strength services;
- magnitude of system strength services to be provided;

- total expected economic cost, and contract price to Transgrid, which will be calculated using information submitted by proponents and the expected timing, frequency, and probability of enablement. Where there are network costs associated with a proposed non-network option, these costs will form part of the option's economic assessment;
- emissions implications of the proposed solution(s);
- technical feasibility of the proposed solution(s);
- firmness/reliability of the proposed solution(s);
- degree to which the proponent appears capable of delivering the amount of system strength services offered within the desired timeframe for availability for those services; and
- demonstrated track record of the proponent in similar undertakings.

5.4. How to submit

If you intend to submit an EOI for a new project, i.e. if you have not already submitted a EOI for this project in response to our expressions of interest (EOI) in March 2023, please follow these steps:

- Review the information provided in:
  - This document;
  - The PADR;
  - Transgrid's "Technical performance and power system modelling requirements for synchronous system security service" (if applicable); and
  - Transgrid's "Technical performance and power system modelling requirements for stable voltage waveform support service from grid-forming BESS" (if applicable).
- If you have any questions, please submit an information enquiry to systemstrength@transgrid.com.au by 2 August 2024
- Submit the following information to systemstrength@transgrid.com.au by 2 August 2024:
  - The EOI response questionnaire available on Transgrid's website; and
  - Power system modelling package, or consent to use existing models, as per section 8 of this document.
- Do not submit commercial pricing – we will be in contact to request this information following AEMO's publication (on 30 June 2024) of the minimum requirements for system strength contracts.
- We will use submissions to enable an assessment and comparison of network and non-network solutions to meet system strength needs, required as part of the RIT-T process. Please clearly identify any confidential or commercially sensitive information included in your EOI that you do not wish to be disclosed publicly.

Please note:

- We reserve the right to vary the timetable at any time;
- We are not obliged to make an offer to contract with a proponent as a result of this EOI;
- Proponents will bear all costs incurred in responding to this EOI and are not entitled to claim for reimbursement of time, materials or expenses incurred; and

- For full terms and conditions, please refer to the disclaimer at section 12.2.

6. Existing Expressions of Interest

This section applies to all proposed solutions for which an EOI has already been submitted.

6.1. Who needs to provide updates

We welcome updates on all existing EOIs, including confirmation if you wish to withdraw.

There are two exceptions – please do not provide an update if:

- you have already notified us of your withdrawal; or
- we have informed you that your EOI was not eligible for consideration.

6.2. Update your EOI submission

For the PACR, we need to ensure that we have the most accurate and up-to-date information about your proposed solution.

To that end, following the publication of the PADR, we will send you the last clarifications questionnaire you submitted to us (circa mid-2023), and ask you to update it with any new/updated information that may materially affect our market modelling or technical feasibility assessment of your EOI for the PACR.

We will add a new column for you to put your updates in. Please put updated information in this new column (i.e. don't make any changes to existing columns) so that we can clearly identify the updates.

We will ask you to send this back to us at systemstrength@transgrid.com.au within six weeks. We will confirm the submission date when we send it to you.

For the avoidance of doubt, we **don't** need:

- Proposed pricing of system strength services – we will request this separately, after AEMO publishes system strength contacting requirements on 30 June 2024.
- Baseline capital and fixed operating costs for committed, anticipated, and existing projects – the RIT-T treats these as sunk costs and therefore they don't influence the outcome of the analysis.

We **do** need to know about any changes to:

- Commissioning dates and lead times of your solution;
- Incremental costs of providing system strength services, e.g. capital costs of any upgrade / conversion works required solely for provision of system strength, and any consequent changes to operating costs;
- Progress of your project toward the five criteria for "committed" status as per the definition in the RIT-T[13];

[13] https://www.aer.gov.au/system/files/AER%20-%20Regulatory%20investment%20test%20for%20transmission%20-%2025%20August%202020.pdf p13. The five criteria are also explained in the EOI clarifications questionnaire.

- New grant funding, or changes to the amount of grant funding you are likely to receive or repay (which may offset the capital cost of your solution within our PACR assessment).
- Technical specifications of your solution.

6.3. Market modelling input data

If your EOI was modelled in the PADR, we will send you a workbook containing all the technical and cost assumptions that were used for your solution(s).

Please review this workbook and advise of:

- Any updates (e.g. due to changes / developments to your project);
- Any inaccuracies; and
- Any additional information that might help us model your project more accurately.

The information in this workbook is based on your latest EOI clarification questionnaire (which we are also asking you to update), but we do still need you to check this workbook separately to make sure we have correctly interpreted your EOI / clarification responses.

We will ask you to review this workbook within six weeks of receiving it (we will confirm the submission date when we send it to you).

We will update and reflect any new information that you provide in our market modelling for the PACR, which will confirm the preferred portfolio of solutions.

7. Commercial terms and pricing

This section explains why and how we will consult on key commercial terms and firm up pricing, and how these are factored into the RIT-T. It applies to all proponents of non-network solutions.

7.1. Background

As part of the RIT-T assessment, we need to assess each solution's commercial feasibility, before including it in the PACR market modelling.

The RIT-T Guideline says *"An option is commercially feasible under NER clause 5.15.2(a)(2) if a reasonable and objective operator, acting rationally in accordance with the requirements of the RIT–T, would be prepared to develop or provide the option in isolation of any substitute options."*[14]

A reasonable and objective TNSP would only be prepared to develop a non-network option if they are able to recover the associated operating expenditure, which requires an ex-post "network support pass through" determination from the Australian Energy Regulator (AER) under NER 6A.7.2.

As such, prior to non-network contract execution, we will seek an advance determination from the AER on the payments (or payment methodology) under proposed system strength contracts, and the associated operating expenditure, under NER 6A.6.6A. The AER will assess several criteria, including whether the proposed expenditure is "efficient and prudent". This will give us confidence that we will be able to recover the actual operating expenditure via the subsequent "network support pass through" determination.

In addition, before commencing PACR market modelling, Transgrid will assess whether each EOI non-network solution is a commercially feasible option (and will rule them out if not commercially feasible). This assessment will include:

- consulting with proponents on key commercial terms, to identify any issues that may materially impact commercial feasibility for Transgrid or proponents; and
- forming a view on the likely outcome of any AER advance determination on the proposed system strength contracts.

Note that within the RIT-T, contract pricing is only used to assess commercial feasibility. Once a solution is assessed as commercially feasible, its cost-benefit analysis in the RIT-T is based on the underlying capital and operating costs, not contract pricing. Following the RIT-T, contract pricing will be used to assess proposals in the competitive procurement process and subsequent AER determinations.

7.2. Commercial terms and updated pricing

We will publish commercial terms for non-network proponents of system strength solutions, following AEMO's 30 June 2024 publication of minimum and recommended requirements to be included in TNSPs' contracts for system strength services.

Once we have published these commercial terms, we will ask you to make a confidential submission to update the commercial component of your EOI (i.e. proposed payment structure and pricing), based on:

[14] AER - RIT-T guidelines - final amendments (marked up) - 6 October 2023_0.pdf section 3.2.2

- Transgrid's commercial terms;
- AEMO's minimum and recommended contacting requirements (to be published 30 June 2024);
- Information in and attached to the PADR e.g. technical specifications and effectiveness factors;
- the final "Improving Security Frameworks" rule change; and
- any changes to your project or market conditions since your original EOI in March 2023.

We will ask you to submit this within approximately six weeks of us publishing the commercial terms. We will notify you when they have been published, and confirm the submission date.

This updated pricing will be used to assess the commercial feasibility of your proposal; it does not need to be commercially binding.

8. Power system modelling package requirements

This section applies to all proponents of non-network solutions. It explains why we need a power systems modelling package, and what we need you to do or provide.

8.1. Background

For the PADR, we have assumed that all grid-forming batteries and STATCOMs are technically feasible as solutions to the efficient level of system strength, and we used preliminary PSCAD™ studies to develop a generic assumption for the quantity of system strength support that a grid-forming battery or STATCOM could provide.

In order to establish that your solution is a technically feasible solution (as an input into the PACR), we will need to model your individual solution in PSS®E, PSCAD™, Small Signal Model, and PowerFactory. This includes:

- Confirming the technical feasibility of individual solutions (i.e. compliance with minimum technical specifications and performance requirements);
- Quantifying the amount of system strength support that each solution could provide, based on its individual technical performance;
- Confirming that the preferred portfolio of solutions is technically feasible, i.e. able to achieve stable voltage waveforms on our network, for the level and type of IBRs forecast by AEMO in the latest System Strength Report.

This means that we require a power systems modelling package for all solutions that are being considered for the PACR (i.e. not ruled out in the PADR).

8.2. General requirements

This section applies to all types of non-network system strength solutions.

If your solution is already connected to our network, or you have already submitted models as part of the connection process, we can use our existing models of your plant to assess your proposed system strength solution, subject to the following:

- Please confirm that you consent to us using these existing models to assess your proposed system strength solution, and that doing so will not put you or Transgrid in breach of any confidentiality or licence agreements relating to these models. Please note that these assessments are separate to the studies required for the connections process, and are carried out by a separate team within Transgrid;
- If you are proposing an upgrade or modification to your plant, please advise whether its technical performance will change, and if so, whether a new/updated model is required to reflect the updated technical performance;
- Please advise if you have recently submitted updated models to AEMO, so that we can make sure we obtain and use the latest version;
- Transgrid and AEMO are currently undertaking upgrades to their modelling platforms, so we may need you to ask you provide updated models to resolve compatibility issues.

8.3. Synchronous machines

This section applies to synchronous machines only.

If providing models to Transgrid, please ensure they comply with the requirements set out in the **"Technical Performance and Power System Modelling Requirements for Synchronous System Security Services"**, which has also been published with the PADR.

If you have not already submitted models to Transgrid as part of the connections process, we will contact you to discuss next steps.

8.4. Grid-forming batteries

This section applies to grid-forming batteries (and other grid-forming technologies) only.

If providing models to Transgrid, please ensure they comply with the requirements set out in the **"Technical Performance and Power System Modelling Requirements for Stable Voltage Waveform Service From Grid-Forming Batteries"**, which has also been published along with the PADR. It is important to note that there are some modelling tests requested in these requirements which are additional to the standard tests involved in the connection process.

If you have not already submitted a power system modelling package to Transgrid, or you have but it doesn't meet the above requirements, we suggest you discuss with your inverter vendor how best to proceed.

9. Technical guidance for Synchronous System Security Service

This section is applicable to synchronous machines. It is provided for information only, based on our current understanding of the minimum fault level requirements. It is subject to the disclaimer in section 12.

Transgrid's "Technical performance and power system modelling requirements for synchronous system security service", published alongside this document, take precedence over anything that conflicts with this section.

Transgrid will contract synchronous machines to provide both system strength and inertia as a single service. This will be called a "synchronous system security service", or a "system security contract".

This is because:

- Synchronous machines enabled under a system strength contract will also provide inertia, regardless of whether the inertia service has been contracted. Therefore a separate inertia contract would not confer any additional obligations or benefits on the synchronous machine.
- Under the "Improving Security Frameworks" (ISF) rule change:
  - AEMO is free to enable system strength contracts for the provision of inertia even if that is not their intended purpose, and vice versa[15]. This means there is no benefit to synchronous machines of having separate contracts for inertia and system strength, i.e. if there were separate inertia and system strength contracts with different prices for the same synchronous machine, AEMO may enable the cheaper one only, regardless of which service is actually required (or if both services are required simultaneously).
  - Transgrid has an obligation to make inertia services available commencing from 2 December 2027[16], or earlier if AEMO declares an inertia shortfall in NSW under the existing inertia framework.

The system strength component of the service will include both fault current (i.e. the minimum level of system strength) and stable voltage waveform support (i.e. the efficient level of system strength).

9.1. Technical assessment

The system strength capability of synchronous machines will depend primarily on their contribution to fault levels at each of the six system strength nodes in NSW (for the minimum level of system strength) or to the connection points of future inverter-based resources (IBR) (for the efficient level of system strength).

We will use PSS®E to determine these fault level contributions (to the minimum level of system strength), and PSCAD™ and small signal modelling to validate their contribution to achieving stable voltage waveforms at IBR connection points (for the efficient level of system strength).

Inertia capability will be assessed, but will not have any impact on the solutions' standing in the system strength RIT-T or procurement process, except to the extent that it affects stable voltage waveform support.

For full details, please refer to the "Technical performance and power system modelling requirements for synchronous system security service" document published alongside this document and the PADR.

[15] https://www.aemc.gov.au/sites/default/files/2024-03/ERC0290%20-%20ISF%20final%20determination.pdf, section 6.3.5
[16] https://www.aemc.gov.au/sites/default/files/2024-03/ERC0290%20-%20ISF%20final%20determination.pdf, section 3.7

10. Technical guidance for Stable Voltage Waveform Support Service

This section is applicable to proponents of grid-forming battery projects, and provides guidance on how best to meet Transgrid's technical requirements for a stable voltage waveform support service (SVWSS). It is provided for information only, based on our current understanding of grid-forming inverters and stable voltage waveform. It is subject to the disclaimer in section 12.

Transgrid's "Technical performance and power system modelling requirements for stable voltage waveform support service from grid-forming BESS" document, published alongside this document, take precedence over anything that conflicts with this section.

This section is written with reference to grid-forming battery energy storage systems (GFM BESS), but it also applies to other grid-forming inverter technologies (e.g. GFM STATCOMs, GFM wind), with appropriate modification or interpretation of any requirements as necessary to achieve the same objectives whilst accounting for the differences in those technologies.

10.1. Background

AEMO's System Strength Requirements Methodology[17] defines four criteria for stable voltage waveforms:

Table 1 - criteria for stable voltage waveform, as defined in AEMO's System Strength Requirements Methodology

Ref	Criterion	Definition
1	Voltage magnitude	The positive-sequence root-mean-squared (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.

To help achieve these criteria, a stable voltage waveform support service (SVWSS) must inject or absorb active (P) and/or reactive (Q) power in response to voltage disturbances, as follows:

[17] https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-strength-requirements/system-strength-requirements-methodology.pdf Chapter 5 Stable Voltage Waveforms

Table 2 - criteria for stable voltage waveform support service

Ref	Criterion	How should a stable voltage waveform service (SVWSS) respond?	Relevant capabilities from AEMO's voluntary specification for grid-forming inverters[18]
1	Voltage magnitude	Provide an almost instantaneous injection/absorption of reactive power (Q) to oppose a sudden change in voltage magnitude (short term voltage stability).	2.3.1 Voltage source behaviour – response to voltage magnitude and phase changes (core capability)
2	Change in voltage phase angle	Provide an almost instantaneous injection/absorption of active power (P) to oppose a sudden change in voltage phase angle (phase angle stability).	
3	Voltage waveform distortion	Provide a "passive, damping response in the harmonic frequency range" thereby reducing harmonic voltage distortion within the power system. **This capability is not required for SVWSS**.	2.4.4 Power quality improvement (additional capability)
4	Voltage oscillations	Provide positive damping to network oscillations in the sub-synchronous frequency range. Responses to small or large disturbances should be adequately damped.	2.3.6 Oscillation damping (core capability)

10.2. Scope

Transgrid will contract GFM BESS to provide stable voltage waveform support (i.e. the efficient level of system strength). This will be called a "stable voltage waveform support service" (SVWSS).

GFM BESS under these contracts will be required to assist with stable voltage waveform criteria 1 (voltage magnitude), 2 (change in voltage phase angle), and 4 (voltage oscillations). Transgrid does not expect any need to procure solutions for criterion 3 (voltage waveform distortion) in the foreseeable future.

Synchronous machines will not be eligible for this type of contract – they will instead be contracted under a "synchronous system security service" contract.

10.3. Technical assessment

The SVWSS capability of GFM BESS will depend primarily on their 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).

We will use PSCAD™ and small signal modelling to assess compliance with minimum technical performance requirements and quantify the SVWSS capability of each GFM BESS. For full details, please refer to the "Technical performance and power system modelling requirements for stable voltage waveform support service from grid-forming BESS" document published alongside this document.

[18] https://www.aemo.com.au/-/media/files/initiatives/primary-frequency-response/2023/gfm-voluntary-spec.pdf

10.4. Guidance on grid-forming battery capabilities with respect to system strength

This section aims to answer some common questions about technical requirements for system strength services that may have material commercial implications for grid-forming battery projects, e.g.

- *Do batteries need to have overload / overcurrent capability to provide system strength?*
- *Do batteries need to reserve active power headroom, i.e. withdraw capacity from the energy and FCAS markets, to provide system strength? How much?*
- *Do batteries need to reserve some of their energy storage capacity for system strength?*

This section is based on our current understanding of grid-forming inverter technologies, and we welcome further consultation and collaboration to improve this understanding. This information should be taken as indicative guidance only: due to the diversity of grid-forming technologies and power system phenomena, it is impossible to provide firm answers to these questions without doing detailed power systems modelling of the specific solution being proposed.

10.4.1. Overload / overcurrent capability

This section aims to answer the question "do batteries need to have overload / overcurrent capability to provide system strength services?".

Summary

Short-term overload / overcurrent capability is not mandatory for a GFM BESS to provide a stable voltage waveform support service (SVWSS), 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.

Grid-forming battery energy storage systems (GFM BESS) and other grid-forming inverter technologies typically have some capability to exceed their nameplate current capability for a short period of time. This capability is defined by a thermal (I^2t) limitation, so smaller overloads can be sustained for longer durations and vice versa, e.g. the same GFM BESS may be capable of 2.0pu overload for 2 seconds, or 1.5pu overload for 30 seconds.

If the continuous rated capacity of a BESS is held constant, increasing its short-term overload capability will increase its stable voltage waveform support service (SVWSS) capability.

However there are several caveats that must be considered when assessing the SVWSS capability of a GFM BESS with overload capability:

- The SVWSS capability of a BESS will depend on its overload capability over tens of seconds, not its maximum overload capability, which may be available only for a few seconds.
- Some aspects of SVWSS may require continuous capability – i.e. a GFM BESS that can inject 100MVA continuously may have greater SVWSS capability than a GFM BESS than can only inject 100MVA for a short duration.
- Short-term overload capability requires the inverters to be operated with some thermal headroom at all times during normal operation. This headroom is normally provided by oversizing the inverters, but depending on how the inverters have been sized, overload capability may be significantly reduced by:

- High ambient temperatures
- Solar gain on equipment enclosures
- Failure of cooling systems
- Operating point prior to the overload event
- Cooldown time since last use of overload capability

- Inverters should be adequately sized so that prolonged operation at rated continuous output does not cause any derating of the overload capability, and an overload event does not cause any subsequent derating of the continuous rated capacity.
- Continuous rated capacity will require more capex than short-term overload capability.
- Continuous rated capacity can also help meet any long-term reactive / voltage support requirements, whereas short-term overload capability cannot.

In summary, for the purpose of SVWSS, continuous rated capacity is more reliable and more useful than short-term overload capability, but requires more capex– so these factors will need to be weighed against each other when optimizing the GFM BESS design.

10.4.2. Headroom

This section aims to answer the question "do batteries need to reserve active power headroom to provide system strength services?". It also applies to any other grid-forming technologies that participate in energy and frequency control ancillary services (FCAS) markets, with appropriate modification or interpretation of any requirements as necessary to achieve the same objectives whilst accounting for the differences in those technologies.

Summary
• Whether or not a GFM BESS needs to reserve headroom whilst providing stable voltage waveform support service (SVWSS) will depend on its design. • Transgrid prefers to contract SVWSS solutions that do not need to reserve headroom.

10.4.2.1. Background

"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. (This is distinct from any reserved energy storage capacity i.e. an "energy buffer", which we discuss in the next section.)

E.g. a 100MW GFM BESS may choose to limit its availability in the energy and FCAS markets to 80MW, thereby reserving 20MW of headroom for provision of network support services.

This 20MW of headroom can be used for continuous delivery of active power outside of the energy and FCAS markets, which in itself is not necessarily helpful for SVWSS. However, depending on the design of the GFM BESS, this may increase its transient capability to inject/absorb active and reactive power in response to voltage disturbances, which may improve its SVWSS capability.

10.4.2.2. Transgrid prefers solutions that don't need to reserve headroom

Transgrid's preference is to contract with solutions that can provide the contracted quantity of SVWSS without needing to reserve headroom, for the following reasons:

- To minimise impacts on the energy and FCAS markets;
- To simplify planning and scheduling of system strength services; and
- To minimise the cost of the service and complexity of the contract (i.e. avoid having to compensate you for the opportunity cost of reserving headroom).

10.4.2.3. Factors that may affect the need to reserve headroom

SVWSS requires a capability to inject/absorb active and reactive power in response to transient voltage disturbances and oscillations.

We expect that most GFM BESS will have some such capability, even when dispatched to their registered maximum charge/discharge capacity, and will hence be able to provide some amount of SVWSS without needing to reserve headroom, due to:

- Capacity that is required for compliance with NER S5.2, but is not fully utilised in our system strength planning scenarios;
- Oversizing inverters' continuous capacity (beyond the requirements of NER S5.2);
- Short-term overload/overcurrent capability (subject to caveats mentioned earlier);
- Other features of the technology that provide SVWSS independent of headroom.

You should discuss these features with your inverter vendor, to the extent they affect the amount of SVWSS your GFM BESS project can provide without needing to reserve headroom.

10.4.2.4. How we will assess whether headroom is required

We will assess the actual SVWSS capability of your GFM BESS via PSCAD™ studies, in which we will assume the GFM BESS is dispatched to its registered maximum charge/discharge capacity.

If we find that it cannot provide an adequate quantity of SVWSS in this scenario, we may suggest options to improve it, including tuning changes, and reserving headroom.

In the event that headroom is required, certain minimum requirements apply – refer to Transgrid's "Technical performance and power system modelling requirements for stable voltage waveform support service from grid-forming BESS" document published alongside this document.

10.4.3. Energy buffer

This section aims to answer the questions "do batteries need to reserve some of their energy storage capacity to provide system strength services?" and "how much is required?".

Summary
Stable voltage waveform support service (SVWSS) requires 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. (NB this is distinct from any need to reserve active power capacity i.e. headroom.) Other GFMI technologies will also require an energy source, e.g. a supercapacitor.

10.4.3.1. Size of energy buffer

GFM BESS (and other grid-forming inverter technologies) must maintain an energy buffer so that they can inject/absorb active power in response to a phase angle jump or rate of change of frequency (RoCoF) event, and keep their DC bus energised before and during the disturbance. In other words, they must be able to deliver sufficient energy to maintain grid-forming behaviour and remain in continuous uninterrupted operation (i.e. ride through) during the disturbance.

The energy buffer must be sized such that the grid-forming inverter can:

- Comply with S5.2.5.5 fault ride through requirements (15 disturbances in 5 minutes);
- Provide active power injection/absorption to fulfil all contracted network support services (e.g. SVWSS and inertia) during all of those disturbances (not just ride through).

10.4.3.2. Energy buffer for a stable voltage waveform support service

GFM BESS must reserve a portion of their energy storage capacity as an energy buffer for SVWSS. (This is also a requirement for some other network support services such as inertia and black start). This means they must impose minimum and maximum limits on the state of charge (SoC) available for market operation:

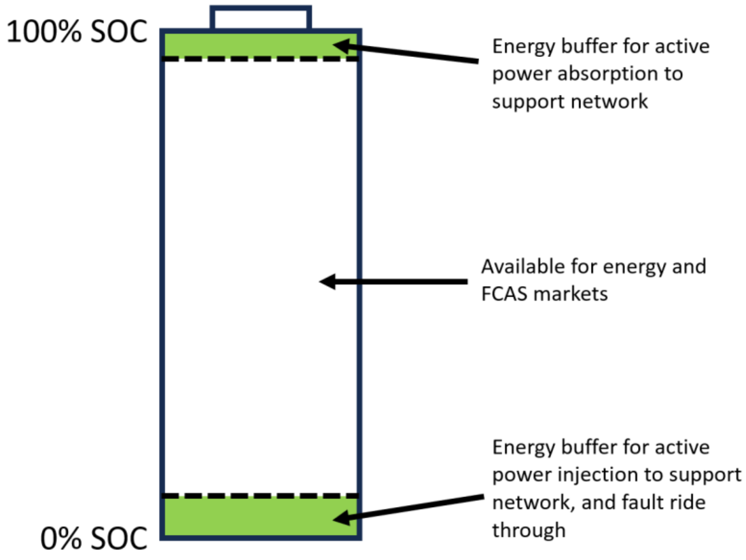


Figure 3 - energy buffers required for network support

These limits should be set using reasonable endeavours to allow for:

- Calibration of SoC range - depending on how the battery management system / SCADA calculates SoC, the available power may drop below 100% before the SoC reaches 0% or 100%, which will reduce the magnitude of network support that can be provided as those limits are approached.
- The GFM BESS will self-discharge whilst idle, due to internal self-discharge of battery cells, and auxiliaries (e.g. fans and pumps) which are powered from the DC bus.
- Frequency response (i.e. Contingency FCAS and primary frequency response) will continue to operate when the GFM BESS is idle, which will cause the GFM BESS to randomly charge and discharge.

- Trading strategy and market conditions may make it commercially undesirable to charge the battery for extended periods, and this cannot be used as a reason for not maintaining the required energy buffers.
- The buffers do not necessarily need to symmetrical, i.e. the upper buffer (near 100%) may not need to be as large as the lower buffer (near 0%).
- Any other relevant factors.

Furthermore, you must have arrangements in place to ensure that the SoC buffers can be maintained during market interventions, e.g.

- During market suspensions - i.e. AEMO must not be allowed to dispatch the GFM BESS to discharge below the SoC buffer, and must allow charging when necessary to maintain the SoC buffer regardless of dispatch price
- Ensure GFM BESS can be charged to maintain the SoC buffer during extended periods where the spot price is at the market price cap (i.e. when the over-constrained dispatch price is higher than the market price cap, which means that scheduled loads, which can't bid higher than the market price cap, are unable to bid a price high enough to get dispatched to charge)

We expect that in total, less than 5% of a GFM BESS's energy storage capacity would need to be reserved for SVWSS. This is an indicative upper limit; the actual requirement is likely to be less and will be confirmed via power systems modelling. (NB the requirement may vary if the same GFM BESS is also providing other network support services that also require an energy buffer.) Refer to the Wallgrove Grid Battery knowledge sharing reports[19] for analysis of how this may affect the commercial/trading strategy of a GFM BESS.

10.4.3.3. Other GFMI technologies

Other GFMI technologies (e.g. GFM STATCOMs) will typically have a dedicated energy source for network support (e.g. a supercapacitor). This supercapacitor should be sized to meet the energy buffer requirement described above.

10.5. Relationship with other network support services

This section explains future network support service opportunities which may become available over time for GFM BESS that are already contracted to provide system strength services.

10.5.1. Relationship with reactive / voltage support

Following a contingency event, voltage instability/collapse may occur at IBR connection points due to a voltage stability transfer limit and/or reactive power shortfall in N-1 conditions. This is not necessarily a system strength issue (i.e. not a result of a fault level shortfall or lack of damping capability) and hence we do not consider this to be within the scope of stable voltage waveform support service (SVWSS). However, GFM BESS may be able to help meet this type of need by providing continuous reactive power capability (above and beyond that required under NER S5.2.5.1) and/or injecting/absorbing active power to reduce loading on the affected transmission line.

Where there is an opportunity for a GFM BESS to provide both SVWSS and reactive/voltage support, we will contract them as a combined service.

[19] https://www.lumea.com.au/projects/wallgrove-grid-battery/

10.5.2. Relationship with inertia

Inertia and stable voltage waveform support service (SVWSS) are two closely related grid-forming capabilities, and in future we intend to contract them as a combined service.

Inertia is an active power response to rate of change of frequency (RoCoF), whereas SVWSS is an active and reactive power response to voltage magnitude/phase angle disturbances and oscillations. But they are interdependent and cannot be considered or provided in isolation. This is because:

- They both arise from the same grid-forming characteristics and are influenced by the same tuning parameters at the voltage or current control loop level;
- They share the same current limits in the inverter;
- RoCoF and voltage disturbances often coincide, requiring simultaneous delivery of inertia and SVWSS;
- Inertia is generally helpful for damping oscillations, which is a component of SVWSS;

Transgrid is currently procuring SVWSS only. However, we may also need to procure inertia in future. When this arises, we may contract GFM BESS to provide SVWSS and inertia as a combined service.

10.6. Alteration of existing performance standards

This section is relevant to any solutions which may require alteration of generator performance standards in order to provide system strength services, e.g. to enable grid-forming capability on a BESS.

Once a performance standard has been agreed, NER 5.3.4A(b)(1A), also known as the “no less onerous” clause, currently prohibits Transgrid from agreeing to a less onerous performance standard when applying to alter a generating system under NER 5.3.9. Transgrid does not currently have any discretion to grant an exemption to this rule, however some flexibility may be introduced as part of the “Enhancing investment certainty in the R1 process” rule change[20].

Please consider this if you are planning to connect your GFM-capable BESS in grid-following mode then subsequently enable GFM capability via a 5.3.9 application.

[20] https://www.aemc.gov.au/rule-changes/enhancing-investment-certainty-r1-process

11. Effectiveness factors

This section provides an explanation of the "effectiveness factors" which we have published with the PADR – how they were calculated, and how they should be interpreted. The effectiveness factors are primarily applicable to synchronous machines, but may also be useful to grid-forming batteries, with some caveats.

11.1. Definition

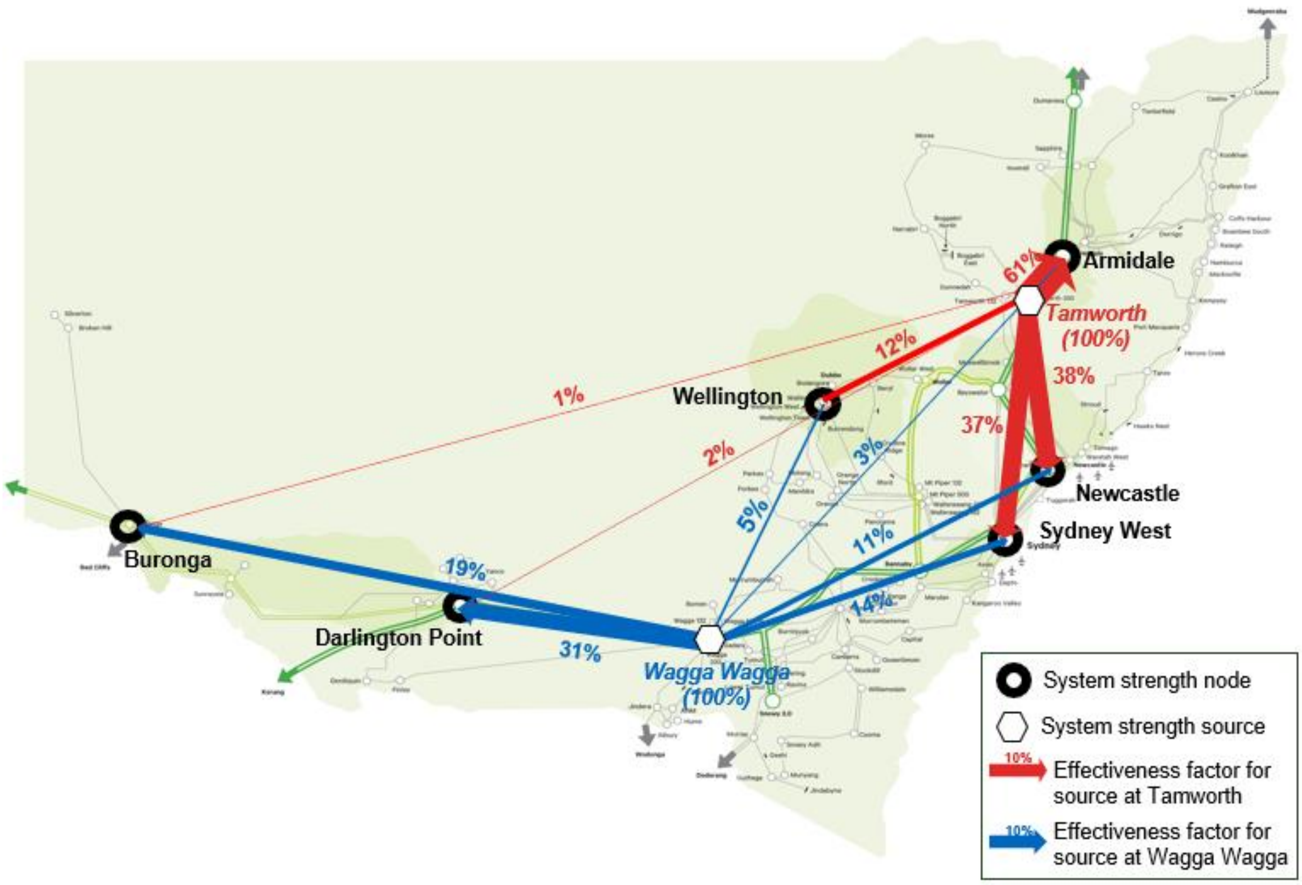
Transgrid has produced 'effectiveness factors' to provide proponents with an indication of the expected system strength contributions of solutions to the six system strength nodes in NSW. Transgrid has published these calculated effectiveness factors as an Excel workbook.

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.

Effectiveness factors were calculated in PSS®E using the benchmark of a solution providing 900 MVA of fault level at its point of connection, during a low system strength period in each year (lowest 99th percentile of NSW fault levels, determined through market modelling for the system strength PADR).In the example below, if a 1000MVA (fault level) solution is located at Tamworth, it would provide a 610MVA fault level contribution to the Armidale node, but only 10MVA at Buronga.

Figure 4: the effectiveness of a system strength solution at Wagga Wagga and Tamworth to all system strength nodes in NSW



11.2. Effectiveness factors for the minimum level of system strength

This section primarily applies to synchronous machines, as other technologies are currently not able to contribute to the minimum level of system strength.

The effectiveness factors for solutions contributing to the minimum level of system strength (i.e. minimum fault level requirements) should be interpreted as follows:

Contribution to node = effectiveness factor x fault current contribution at point of connection

For example, if a synchronous generator is located at Wagga Wagga with a 1000MVA fault current contribution at its point of connection, its system strength contribution to each node is as shown in Table 3 below:

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%

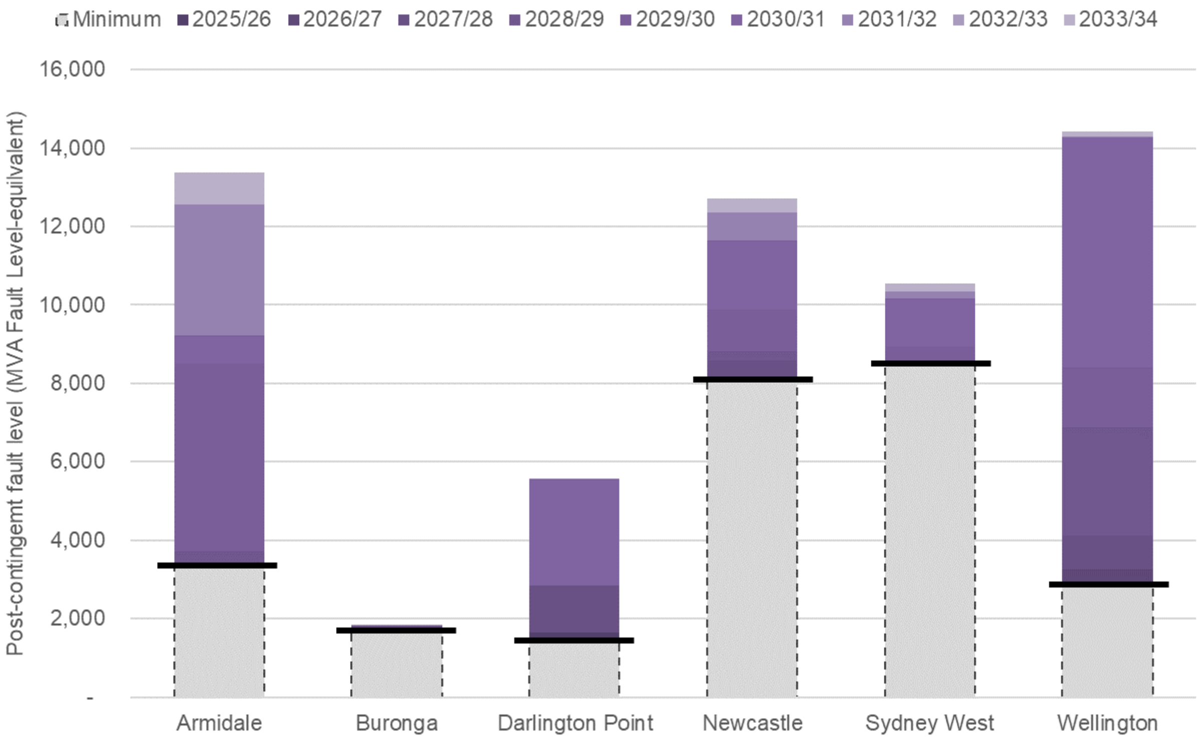
11.3. Location, quantity, and timing of system strength needs

Synchronous machines can contribute to both the minimum and efficient levels of system strength. Transgrid has used the Available Fault Level methodology as per AEMO's System Strength Impact Assessment Guidelines[22] to estimate the efficient level of system strength in terms of equivalent fault level in MVA. Figure 5 below illustrates the need in fault current for the minimum level of system strength (fault level, in grey) and the accumulation of the efficient level need over time at each system strength node (fault level-equivalent, in purple).

[21] https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-strength-requirements/2023-system-strength-report.pdf

[22] https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/ssrmiag/amendment/system-strength-impact-assessment-guidelines-v21.pdf section 3.4

Figure 5: System strength requirements in NSW



11.4. Efficient level of system strength / stable voltage waveform support

This data has been developed on the basis of a synchronous machine providing fault level support to system strength nodes (i.e. to support the minimum level of system strength). However, it may also provide a useful indication of the potential for synchronous machines or grid-forming inverter technology (e.g. grid-forming batteries) to provide stable voltage waveform support (i.e. to support the efficient level of system strength), subject to the following caveats:

- The effectiveness factors were not developed for this specific purpose (rather for fault level contributions from synchronous machines);
- The effectiveness factors show that system strength solutions are more effective if located close to system strength nodes, which is correct for the minimum level of system strength (fault level), but solutions for the efficient level of system strength (stable voltage waveform) are actually more effective if located close to the new IBRs that need to be supported. This means that, all other things being equal, solutions to the efficient level of system strength will be more effective if located near IBRs (e.g. in renewable energy zones), rather than at or close to system strength nodes as suggested by the effectiveness factors.
- The effectiveness of stable voltage waveform solutions is more complex than a fault level assessment – it involves multiple criteria, and is highly dependent on the design and tuning of the solution, and local network phenomena.

11.5. Caveats

Transgrid has published effectiveness factors to provide non-network proponents with a general indication which locations are more effective at providing system strength support than others. This information comes with several caveats.

11.5.1. Changes in background fault levels

Effectiveness factors are dependent on the total fault level in the power system (which changes at any one time). As total fault level in the power system increases, the effectiveness factor of each solution decreases, and vice versa. System strength services are most likely to be required (enabled by AEMO) when fault levels in the power system are low, so in order to keep things simple, we have calculated a single set of effectiveness factors for the lowest fault level expected 99% of the time, based on our PADR market modelling. Our modelling suggests that while changes in the total fault level of the system will change effectiveness factor percentages, it generally does not materially change locations' effectiveness factors relative to each other, e.g. in respect of the Sydney West system strength node, Tamworth (37%) will always have a higher effectiveness factor than Wagga Wagga (14%).

11.5.2. Scaling with size of solution

Effectiveness does not scale linearly with the size of the solution; in other words, the effectiveness factor as a percentage depends on the size of the solution. We have calculated effectiveness factors based on a 900MVA (fault level) solution. Smaller solutions than this will have a slightly higher effectiveness factor, and larger solutions will have a slightly lower effectiveness factor. This effect is more pronounced for lower effectiveness factors (i.e. where the solution is far from the system strength node), however we believe this would not materially change the general indication of the effectiveness of individual network locations for system strength support.

11.5.3. General

These effectiveness factors have been made available subject to the disclaimer in section 12. They should be taken as no more than a preliminary indication of the relative effectiveness of different locations for provision of system strength services. They do not indicate the likelihood of securing a system strength contract, or the amount of revenue that could be earned by a system strength solution.

12. Disclaimers

12.1. General

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12.2. Expressions of Interest (EOIs)

12.2.1. Notice

You must read this section before reading or making any use of this document, including any information contained in this document and any related discussion or information provided as part of, or in connection with, the EOI process contemplated in this document (together "**the EOI material**"). By continuing to read, use or otherwise act on the EOI material, you agree to be bound by the following terms and conditions (including as amended). You consent to submit to the laws and courts of Australia in respect of any proceedings arising out of or relating to the EOI material.

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a. any claim against Transgrid; and
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arising out of, or in connection with:

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d. Transgrid exercising or failing to exercise any discretion or right it has or may in the future have in connection with the EOI or the Project.

12.2.4. Rights

In addition to its rights set out elsewhere in this EOI, Transgrid may at any time and without giving reasons:

a. extend the EOI proposals closure date at any time before the closure date by notice to potential participants;
b. extend the Information enquiries closure date at any time by notice to all potential participants (before the closing time) or all participants (after the closing time);
c. shortlist one or more participants;
d. reject any or all EOI proposals;

e. not accept any EOI proposals;
f. negotiate a private agreement with one or more participants;
g. enter into a contract with one or more participants or any other person at any time;
h. request one or more participants to review, improve and/or enhance any or all part(s) of its EOI proposal;
i. request any participant to submit an offer;
j. amend, suspend, discontinue or terminate the process set out in this EOI by notice in writing to one or more participants whose EOI proposal(s) have been excluded from further evaluation and assessment;
k. provide additional information or clarification to participants;
l. not proceed with this EOI, in the manner set out in clause 2, or at all;
m. terminate a participant's involvement in the EOI process and/or discontinue the evaluation and assessment of an EOI proposal where Transgrid determines that the EOI proposal is unsuitable, unsatisfactory, substantially incomplete or clearly uncompetitive;
n. negotiate with one or more participants or any other person, and enter into transaction documents with any participant or other person;
o. accept or reject any EOI proposal which:
    i. is late;
    ii. is in any way incomplete or irregular;
    iii. does not comply with any requirements of this clause 2;
p. Transgrid's decision to exercise any or none of the rights in this clause 2 is final and Transgrid will not be liable to any participants because Transgrid has exercised any or none of its rights in this clause 2; and
q. Transgrid may exercise its rights in this clause with respect to one participant only or to multiple participants at the same time.