Transgrid

People. Power. Possibilities.

Meeting system strength requirements in NSW

RIT-T Project Specification Consultation Report

Region: New South Wales

Date of issue: 16 December 2022

Disclaimer

This suite of documents comprises Transgrid's application of the Regulatory Investment Test for Transmission (RIT-T) which has been prepared and made available solely for information purposes. It is made available on the understanding that Transgrid and/or its employees, agents and consultants are not engaged in rendering professional advice. Nothing in these documents is a recommendation in respect of any possible investment.

The information in these documents reflect the forecasts, proposals and opinions adopted by Transgrid at the time of publication, other than where otherwise specifically stated. Those forecasts, proposals and opinions may change at any time without warning. Anyone considering information provided in these documents, at any date, should independently seek the latest forecasts, proposals and opinions.

These documents include information obtained from the Australian Energy Market Operator (AEMO) and other sources. That information has been adopted in good faith without further enquiry or verification. The information in these documents should be read in the context of the Electricity Statement of Opportunities, the Integrated System Plan published by AEMO and other relevant regulatory consultation documents. It does not purport to contain all of the information that AEMO, a prospective investor, Registered Participant or potential participant in the National Electricity Market (NEM), or any other person may require for making decisions. In preparing these documents it is not possible, nor is it intended, for Transgrid to have regard to the investment objectives, financial situation and particular needs of each person or organisation which reads or uses this document. In all cases, anyone proposing to rely on or use the information in this document should:

1. Independently verify and check the currency, accuracy, completeness, reliability and suitability of that information
2. Independently verify and check the currency, accuracy, completeness, reliability and suitability of reports relied on by Transgrid in preparing these documents
3. Obtain independent and specific advice from appropriate experts or other sources.

Accordingly, Transgrid makes no representations or warranty as to the currency, accuracy, reliability, completeness or suitability for particular purposes of the information in this suite of documents.

Persons reading or utilising this suite of RIT-T-related documents acknowledge and accept that Transgrid and/or its employees, agents and consultants have no liability for any direct, indirect, special, incidental or consequential damage (including liability to any person by reason of negligence or negligent misstatement) for any damage resulting from, arising out of or in connection with, reliance upon statements, opinions, information or matter (expressed or implied) arising out of, contained in or derived from, or for any omissions from the information in this document, except insofar as liability under any New South Wales and Commonwealth statute cannot be excluded.

Privacy notice

Transgrid is bound by the Privacy Act 1988 (Cth). In making submissions in response to this consultation process, Transgrid will collect and hold your personal information such as your name, email address, employer and phone number for the purpose of receiving and following up on your submissions.

Under the National Electricity Law, there are circumstances where Transgrid may be compelled to provide information to the Australian Energy Regulator (AER). Transgrid will advise you should this occur.

Transgrid's Privacy Policy sets out the approach to managing your personal information. In particular, it explains how you may seek to access or correct the personal information held about you, how to make a complaint about a breach of our obligations under the Privacy Act, and how Transgrid will deal with complaints. You can access the Privacy Policy here (https://www.transgrid.com.au/Pages/Privacy.aspx).

Executive summary

We are applying the Regulatory Investment Test for Transmission (RIT-T) to options that:

1. address a system strength Shortfall in the transmission network at Newcastle and Sydney West that is forecast to arise from 1 July 2025 and continue until 1 December 2025; and
2. deliver system strength services to the NSW power system to meet standards set by AEMO from 2 December 2025, including for the safe and secure operation of the power system (minimum level) and to facilitate the stable voltage waveform of new inverter-based renewable generators (efficient level).

Publication of this Project Specification Consultation Report (PSCR) is the first step in the RIT-T process. This PSCR is accompanied by an Expression of Interest (EOI), seeking non-network options from potential System Strength Contractors to address system strength requirements in NSW (i.e. third party businesses that provide system strength services to Transgrid under a network support contract).

This RIT-T examines network and non-network options to ensure compliance with system strength requirements of the NER and provide the greatest net economic benefit to the energy market.

Identified need: meeting system strength requirements in NSW

As the System Strength Service Provider for NSW we are required to make sufficient system strength available, as specified by AEMO, under NER:

- Clause 11.143.15 to address the system strength Shortfall declared by AEMO from 1 July 2025 to 1 December 2025 at Newcastle and Sydney West,[1] and
- Schedule 5.1.14 to provide the minimum and efficient levels of system strength forecast by AEMO at each of the NSW system strength nodes from 2 December 2025 into the future.[2]

We have therefore commenced this RIT-T to assess options to ensure the above NER requirements are met. We consider that this will enable us to identify the optimal solution to meet both the short-term and long-term needs.

System strength Shortfall (1 July 2025 – 1 December 2025)

Following the publication of AEMO's 2022 System Security Reports on 1 December 2022, AEMO gave notice to us under clause 11.143.14 of the National Electricity Rules (NER) that a system strength Shortfall is projected to occur at the Newcastle and Sydney West fault level nodes from 1 July 2025. A system strength Shortfall is an identified gap between the minimum fault levels that is projected to be available as a result of typical market dispatch (from existing synchronous generators), and minimum fault level requirements. A key cause of the projected system strength Shortfall is the planned early retirement of Eraring Power Station in August 2025. Under clause 11.143.15 of the NER, we must make system strength services available to address the expected system strength Shortfall identified by AEMO in its notice.

System Strength Rule Change (from 2 December 2025)

From 2 December 2025, a new system strength framework[3] ('System Strength Rule Change') will begin under the NER, requiring us to deliver system strength on a forward-looking basis to standards set by

[1] AEMO, December 2022, System security services – Revised notice and request under the National Electricity Rules (NER)
[2] AEMO, December 2022, 2022 System Security Report
[3] AEMC October 2021, *National Electricity Amendment Efficient Management of System Strength On The Power System) Rule 2021,* ERC0300: System strength final determination - 21 Oct 2021 (aemc.gov.au)

AEMO. Under this framework, system strength will be effectively 'unbundled' from the operation of the energy market, and we are required to establish a portfolio of solutions (network and/or non-network) to ensure minimum three-phase fault level requirements are met in full at all times of the year. This is a change from the system strength Shortfall methodology, where only the 'Shortfall' or gap in NSW's system strength has to be filled. In addition, we are required to deploy system strength solutions above the minimum levels to facilitate the stable connection and operation of the efficient level of renewable generators as they come online in NSW in the coming decade.

AEMO has indicated that where a Shortfall overlaps with the introduction of the new system strength framework, it expects System Strength Service Providers (Transgrid in NSW) to address Shortfalls as part of its overall delivery against the new system strength framework.

We consider this a 'reliability corrective action' as the considered options are for the purpose of meeting externally imposed regulatory obligations and service standards, i.e., Clause 11.143.15 and Schedule 5.1.14 of the NER.

Credible network options have been identified

We have identified credible network options that are likely to meet the identified need from a technical, commercial, and project delivery perspective.[4] We have determined that the installation of synchronous condensers is the most credible short- to medium-term network solution to contribute to meeting NSW's system strength needs, comprising:

- from 1 July 2025 to 1 December 2025, four synchronous condensers to address the system strength Shortfall declared by AEMO, and
- from 2 December 2025, approximately 20 synchronous condensers in total to meet the entire minimum and efficient levels of system strength required by AEMO's forecast, growing to 29 synchronous condensers in 2032-33 as more inverter-based renewables connect.

We note that supply chain constraints could impact on the feasibility of deploying synchronous condensers in the short term.

We expect that a combination of network and non-network options are likely to form a diverse portfolio of preferred solutions to meet system strength requirements from 2 December 2025 onwards, given the scale of the requirements and that existing solutions will continue to operate in the energy market for some period of time. The availability of cost-effective non-network solutions will commensurately reduce the number of synchronous condensers needed as a network solution.

System strength Shortfall (1 July 2025 – 1 December 2025)

In response to the declared Shortfall at Newcastle and Sydney West, we have identified a combination of network options to meet the Shortfall, as summarised in Table E-1. Synchronous condenser options that address the Shortfall would also contribute to meeting needs beyond 2 December 2025 under the System Strength Rule Change. As such, varying sizes and configurations of synchronous condensers and transformers were assessed.

We expect that non-network solutions may be able to meet all or part of the Shortfall, and if so, any network solution would be commensurately smaller.

[4] As per clause 5.15.2(a) of the NER.

Table E-1: Summary of capex for least-cost credible network options to meet the Shortfall

Option	Description	Least cost configurations[5]	Capex ($2021-22, ±25%)
Option 1	Meets the needs of the system strength Shortfall	Newcastle **or** Vales Point – 2 x 125MVA synchronous condensers **and** Kemps Creek **or** Sydney West – 2 x 125MVA synchronous condenser	$326-374M
Option 2	Meets the needs of the system strength Shortfall and provides a more scale efficient solution for future system strength needs	Newcastle **or** Vales Point – 2 x 200MVA synchronous condensers) **and** Kemps Creek – 2 x 200MVA synchronous condensers)	$349-351M
Option 3	Non-network options	The assessment of non-network options will depend on responses received to this PSCR and associated EOI	To be estimated based on responses to the EOI

System Strength Rule Change (from 2 December 2025)

We have estimated the network solutions which would be required to meet minimum and efficient levels of system strength under the System Strength Rule Change, based upon synchronous condensers being deployed to meet system strength requirements in full (without the support of non-network options). Approximately 20 synchronous condensers would be required from 2 December 2025 to meet NSW's system strength requirements, growing to 29 synchronous condensers in 2032-33 as more inverter-based renewables connect. [6]

This represents an 'upper limit' provided to indicate the scale of network solutions required. In practice, we expect that non-network solutions will play a significant role in providing these services, and that any network solution would be commensurately smaller. A portfolio of existing and emerging network and non-network solutions, including services from interstate, is likely to best meet the needs of the NSW power system and energy consumers throughout the energy transition.

Non-network solutions are likely to help address the identified need

Potential options to address the Shortfall and the System Strength Rule Change requirements may be an existing plant or new plant and can include but are not limited to:

- synchronous generators;
- synchronous hydro units operating in 'synchronous condenser' mode;
- conversion of existing synchronous generators to synchronous condensers;
- synchronous condensers (with or without fly wheels);
- grid forming battery energy storage systems;
- grid forming inverter-based renewable generators;

[5] This summary includes the lowest cost solution(s) from each Option to meet the need. Note that for all options, each synchronous condenser is coupled with a 275MVA transformer.

[6] Of the 27 synchronous condensers estimated for FY33, 24 are rated at 200MVA and 4 are rated at 125MVA.

- grid forming SVCs or STATCOMs; and
- other modifications to existing plant.

We have set out the characteristics (refer to Section 4) that non-network options would need to meet to be capable of contributing system strength services to meet the Shortfall and System Strength Rule Change requirements. The accompanying EOI provides greater detail and specifies the type and form of information we are seeking from proponents in order to have their solutions assessed in the PADR.

Submissions and next steps

The purpose of this PSCR is to set out the reasons we propose that action be taken, present the options that address the identified need, outline the technical characteristics that non-network options will need to provide, and allow interested parties to make submissions and provide input to the RIT-T assessment.

We welcome written submissions on materials contained in this PSCR. Submissions are due on 30 March 2023. Submissions should be emailed to our Regulation team via regulatory.consultation@transgrid.com.au.[7] In the subject field, please reference 'Meeting system strength requirements in NSW'.

At the conclusion of the consultation process, all submissions received will be published on our website. If you do not wish for your submission to be made public, please clearly specify this at the time of lodgement.

In addition, we are undertaking an EOI for non-network proponents to contribute to meeting system strength needs as set out in this PSCR. Proposals are due before 6pm, 30 March 2023. Submissions to the EOI will not be published on our website.

The next formal stage of this RIT-T is the publication of a PADR. The PADR will include the full quantitative analysis of all credible options and is expected to be published in mid-2023.

7 Transgrid is bound by the Privacy Act 1988 (Cth). In making submissions in response to this consultation process, Transgrid will collect and hold your personal information such as your name, email address, employer and phone number for the purpose of receiving and following up on your submissions. If you do not wish for your submission to be made public, please clearly specify this at the time of lodgement. See Privacy Notice within the Disclaimer for more details.

Contents

1. Introduction

We are applying the Regulatory Investment Test for Transmission (RIT-T) to options that:

1. address a system strength Shortfall in the transmission network declared by AEMO at Newcastle and Sydney West that is forecast to arise from 1 July 2025 and continue until 1 December 2025; and
2. deliver system strength services to the NSW power system to meet standards set by AEMO from 2 December 2025, including for the safe and secure operation of the power system (minimum level) and to facilitate the stable voltage waveform of new inverter-based renewable generators (efficient level).

We are required under the NER to provide these system strength services to maintain the safety, security and reliability of the power system.

On 15 December 2022, AEMO gave notice to Transgrid under clause 11.143.14 of the National Electricity Rules (NER) that a system strength Shortfall is projected to occur at the Newcastle (1,190 MVA) and Sydney West (1,026 MVA) fault level nodes from 1 July 2025. This reflects their latest analysis and expectations about project delivery timing and is an update to previously declared Shortfalls (including within the 2022 System Security Reports). Under clause 11.143.15 of the NER, Transgrid is responsible for making system strength services available to address the expected system strength Shortfall identified by AEMO in its notice.

From 2 December 2025 onwards, a new system strength framework will commence under the NER. Under the new framework, we will be required to act as a System Strength Service Provider (SSSP) that is responsible for planning and operating our network to ensure there is sufficient system strength available in the NSW power system to meet the standard required by AEMO. AEMO has indicated that where a Shortfall overlaps with the introduction of the new system strength framework i.e., a Shortfall occurs after 1 December 2025, SSSPs are expected to address Shortfalls as part of its overall delivery against the new system strength framework.

Publication of this Project Specification Consultation Report (PSCR) is the first step in the RIT-T process which will examine various network and non-network options to ensure compliance with the NER and provide the greatest net benefit to the market to address both the Shortfall and ongoing system strength requirements.

1.1. Purpose of this report

The purpose of this PSCR[8] is to:

- set out the reasons as to why we propose that action be taken (the ‘identified need’);
- present the options that we currently consider would address the identified need;
- outline the technical characteristics that non-network options would need to provide;
- summarise how we intend to assess the options for addressing the identified need in the Project Assessment Draft Report (PADR); and
- allow interested parties to make submissions and provide input to the RIT-T assessment.

Together with this document, we have also released an EOI to provide additional detail on the technical requirements for non-network options and to seek submissions from proponents of these options.

[8] See Appendix A for the National Electricity Rules requirements.

1.2. System strength is essential to maintaining a safe, secure and reliable power system

System strength is a fundamental service required for the power system to operate in a secure state. System strength can broadly be described as the ability of the power system to maintain and control the voltage waveform at any given location in the power system, both during steady state operation and following a disturbance[9]. It is one determinant of how well the power system can return to normal operation following a disturbance or fault[10].

To ensure that protection systems operate correctly and voltages stay within acceptable levels, a minimum amount of system strength is required. Three phase fault levels are used to define minimum system strength requirements, measured in MVA, which is proportional to the fault current (in Amps) and the voltage (in Volts). The fault current is the electrical current that flows during a fault (also known as the short circuit current)[11].

A power system with inadequate system strength raises the risk of system instability and supply interruptions to energy consumers. In a system with low system strength[12]:

- generators may be unable to remain connected during disturbances on the power system;
- control of the system voltage becomes more difficult; and/or
- protection systems that ensure safe operation of the network may not operate correctly.

1.3. The energy transition is changing how system strength is provided

System strength in Australia's electricity system has traditionally been provided by synchronous generators, as an intrinsic by-product of producing energy and reserves[13]. The NSW electricity system has historically relied on a minimum combination of thermal generation units being online at all times to keep the grid operating within its safe technical envelope.

As thermal generators retire or change their operating patterns, the power system will lose system strength (and inertia) and new sources will be required to replace those leaving the system to ensure the power system remains secure. AEMO has identified a system strength Shortfall from 1 July 2025 following the planned retirement of the Eraring Power Station. Gaps in system strength will grow as other coal generators retire, are mothballed, experience outages, or choose to 'economically-decommit' in response to changing energy market conditions.

Existing 'grid following' inverter-based renewables do not contribute positively to system strength. Additional system strength services will be required, over and above minimum levels, to facilitate the stable connection of approximately 15GW of new inverter-based renewables projected to be connected in NSW by 2029-30.

A range of new and existing technologies can be deployed to provide new sources of system strength – such as synchronous condensers, the conversion of existing thermal generators into synchronous

[9] AEMO, 2022, System Strength Requirements Methodology, https://aemo.com.au/consultations/current-and-closed-consultations/ssrmiag
[10] AEMO March 2022, System Strength - System strength in the NEM explained, System Strength Explained
[11] AEMO March 2022, System Strength - System strength in the NEM explained, System Strength Explained
[12] AEMO March 2022, System Strength - System strength in the NEM explained, System Strength Explained
[13] Australian Energy Regulatory, 2022, Compliance update – provision of essential system services

condensers, the operation of suitable hydro units in 'synchronous condenser' mode and grid forming batteries.

The operation of generation in the energy market can no longer be relied upon to provide system strength (and other system security services) as an unvalued externality. These services will need to be actively planned and managed throughout the energy transition, optimising contributions from existing, retiring and new sources.

1.4. Existing and emerging technologies will be pivotal to providing system strength into the future

We expect that a portfolio of existing and emerging network and non-network solutions will best meet the needs of the NSW power system and energy consumers throughout the energy transition. This may involve contracting with new and existing energy market participants and establishing new technologies and system strength services to ensure ongoing power system security. These could include:

- **Synchronous condensers** are a cost-effective, proven technology for proving system strength. Synchronous condensers have recently been deployed in South Australia to meet a system strength Shortfall.
- **Existing synchronous generators** dispatched in the energy market, such as coal, gas and hydro provide system strength as an intrinsic by-product of their operation. System strength services may be provided as part of typical dispatch in the energy market, or as additional generation services.
- **Re-purposing existing synchronous generators** as synchronous condensers or contracting with **existing synchronous hydro units** that may be able to operate in 'synchronous condenser' mode.
- **Emerging technologies** such as batteries or renewable generation with grid-forming inverters. If widely adopted and appropriately tuned, these technologies could contribute significantly to system strength.

1.5. System strength requirements are considered in AEMO's ISP and System Security Reports

Section 1.1 of AEMO's 2022 Integrated System Plan (ISP) identifies system strength as a fundamental power system requirement. In developing the ISP, AEMO considers the need for system strength/fault levels to be maintained above minimum requirements. AEMO details their system strength outlook in Appendix 7 of the 2022 ISP.

AEMO also publish detailed System Security Reports each year which forecast system strength. We have relied on AEMO's System Strength Reports and subsequent Shortfall notices in preparing this PSCR.

1.6. Submissions and next steps

The purpose of this PSCR is to set out the reasons we propose that action be taken, present the options that address the identified need, outline the technical characteristics that non-network options will need to provide, and allow interested parties to make submissions and provide input to the RIT-T assessment.

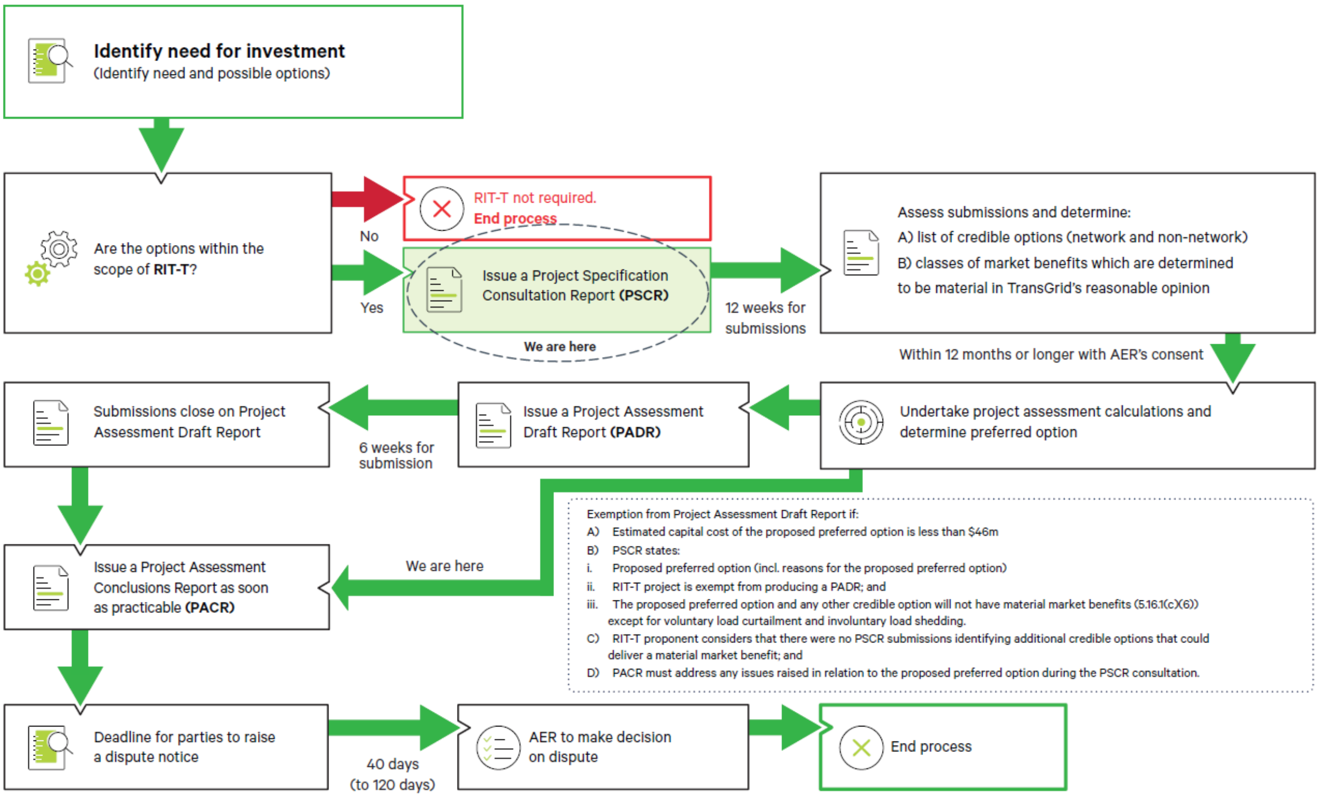
We welcome written submissions on materials contained in this PSCR. Submissions are due on 30 March 2023. Submissions should be emailed to our Regulation team via regulatory.consultation@transgrid.com.au.[14] In the subject field, please reference 'Meeting system strength requirements in NSW'.

At the conclusion of the consultation process, all submissions received will be published on our website. If you do not wish for your submission to be made public, please clearly specify this at the time of lodgement.

In addition, we are undertaking an EOI for non-network proponents to contribute to meeting system strength needs as set out in this PSCR. Proposals are due before 6pm, 30 March 2023. Submissions to the EOI will not be published on our website.

The next formal stage of this RIT-T is the publication of a PADR. The PADR will include the full quantitative analysis of all credible options and is expected to be published in mid-2023.

Figure 1-1: This PSCR is the first stage of the RIT-T process



[14] Transgrid is bound by the Privacy Act 1988 (Cth). In making submissions in response to this consultation process, Transgrid will collect and hold your personal information such as your name, email address, employer and phone number for the purpose of receiving and following up on your submissions. If you do not wish for your submission to be made public, please clearly specify this at the time of lodgement. See Privacy Notice within the Disclaimer for more details.

2. The identified need

2.1. Background to the identified need

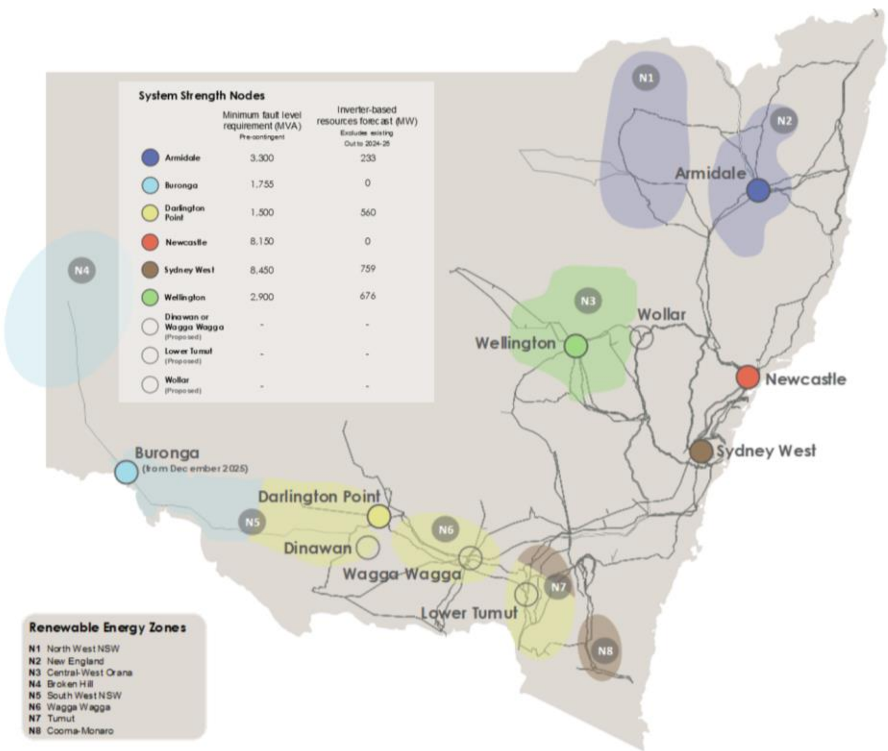
2.1.1. Our role in maintaining system strength

Under the NER, we are responsible for meeting specified levels of power system security services in NSW, including system strength, inertia and voltage control. As the System Strength Service Provider for NSW, we must ensure sufficient system strength services are available at all times to maintain the stability of the power system. AEMO forecasts the required levels of system strength that we are required to provide under two separate means:

1. until 1 December 2025, by specifying the minimum fault level requirements and declaring a fault level Shortfall when they forecast that these minimum requirements will not be met under the Fault Level Rule; or
2. from 2 December 2025, by specifying the minimum and efficient levels of system strength under the System Strength Rule Change.

AEMO provides system strength forecasts for each of the six 'system strength nodes' in NSW, as shown in Figure 2-1.

Figure 2-1: NSW system strength nodes and inverter-based renewables forecast[15]



A. Renewable energy zones are mapped to show where the majority of forecast IBR are expected, consistent with the ISP.
B. No offshore wind renewable energy zones have been shown in this figure as projected establishment of these renewable energy zones occurs outside the 10-year forecast in the ISP.

Source: AEMO, December 2022, 2022 System Security Reports

[15] AEMO, 1 December 2022, 2022 System Security Report, https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/system-security-planning, p. 20

2.1.2. Fault Level Rule – System Strength Shortfall (until 1 December 2025)

The Fault Level Rule introduced in 2017 put in place requirements for transmission network service providers (TNSPs) to meet specified minimum three-phase fault levels, and requires new connecting renewable generators to self-remediate any adverse system strength impacts resulting from their connection (the 'do no harm' provision).

Under the current NER:

1. AEMO determines the system strength requirements in each region at specified fault level nodes on the transmission network.
2. The system strength requirement is that the three-phase fault level at a fault level node must be maintained at or above the minimum three phase fault level determined by AEMO.
3. If AEMO assesses a likely fault level Shortfall at a fault level node, AEMO declares a system strength Shortfall.
4. the System Strength Service Provider must use reasonable endeavours to make a range and level of system strength services available to address the fault level Shortfall, taking into account planned outages, the risk of unplanned outages and the potential for the system strength services to impact typical patterns of dispatched generation in central dispatch (NER 11.143.15). The System Strength Service Provider must make available the least cost option or combination of options that will address the Shortfall.
5. The System Strength Service Provider must prepare and publish information to enable potential providers of system strength services to develop non-network options for consideration by the System Strength Service Provider. This RIT-T and the related EOI process for the Shortfall are intended to achieve this.

Following a Shortfall declaration, we must put in place network and/or non-network solutions to fill the gap between the minimum fault levels that is projected to be available from typical market dispatch and minimum fault level requirements. This rule is in effect until 1 December 2025, when a new rule for the efficient management of system strength comes into full effect.

2.1.3. Efficient management of System Strength Rule Change (from 2 December 2025)

Under the AEMC's 2021 final determination for the *Efficient management of system strength on the power system* (System Strength Rule Change), we are responsible for delivering system strength on a forward-looking basis to the standards determined by AEMO as set out in NER S5.1.14.

AEMO will forecast two system strength requirements:

1. Minimum fault level: for the safe and secure operation of the power system; and
2. Efficient level of system strength: to facilitate the stable voltage waveform of new inverter-based renewable generators surrounding specified system strength nodes.

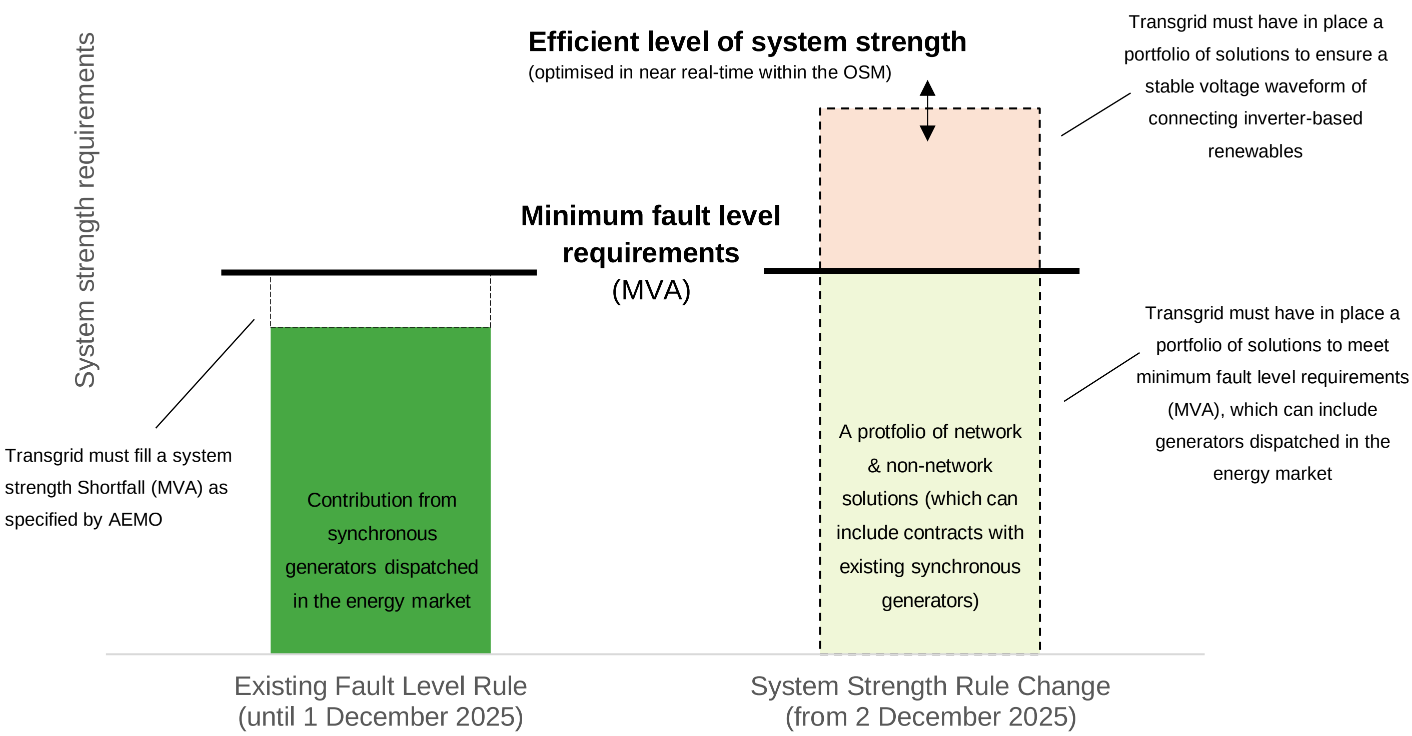
Under this framework, system strength will be effectively 'unbundled' from the operation of the energy market. We will be responsible for ensuring that the above requirements are met in full at all times of the year, rather than simply relying on the system strength contributions of synchronous generators as a by-product of their dispatch in the energy market and only filling a declared Shortfall.

Requirement 1: Minimum fault level requirements

AEMO sets the minimum three-phase fault level (MVA) required for a secure system at each node in the NEM. There are six nodes declared in NSW at: Darlington Point, Buronga (new node), Sydney West, Newcastle, Wellington and Armidale.

From 2 December 2025, we must have in place a portfolio of solutions (network and/or non-network) to meet the minimum three-phase fault level requirements at each system strength node, in full, at all times of the year. This is a change from the system strength Shortfall methodology, where only the 'Shortfall' or gap in NSW's system strength has to be filled, as described in Figure 2-2.

Figure 2-2: Transgrid responsibilities for meeting system strength requirements in NSW (conceptual)



Requirement 2: Efficient level of system strength

The System Strength Rule Change introduces a new obligation on us to provide additional amounts of system strength above the minimum level to support the connection of new inverter-based resources. New connecting generators will have the choice of either procuring system strength services from us (which in turn may be procured from non-network option proponents), or providing their own system strength.

AEMO has not specified 'fault level' as the metric to ensure a stable voltage waveform, and has instead defined four criteria that must be met, relating to voltage magnitude, change in voltage phase angle, voltage waveform distortion and voltage oscillations. This allows us to innovate in the way that system strength services are provided and provides greater flexibility to value system strength support. For example, studies published by Powerlink[16] indicate that grid forming batteries hold significant promise to contribute towards maintaining stable voltage waveforms and AEMO has contracted with a grid forming battery for system strength services[17].

[16] Powerlink, 2021, PSCAD assessment of the effectiveness of grid forming batteries, https://arena.gov.au/knowledge-bank/pscad-assessment-of-the-effectiveness-of-grid-forming-batteries/

[17] Edify, June 2022, Financial Close on the largest approved grid forming battery, https://edifyenergy.com/energy-storage-systems/financial-close-on-the-largest-approved-grid-forming-battery/

2.1.4. Contracts will operate in the new Operational Security Mechanism market

The Australian Energy Market Commission (AEMC) is currently consulting on the Operational Security Mechanism (OSM) rule change and has released a draft determination. The OSM will operationalise contracts that we enter into with System Strength Contractors, including services contracted under the Fault Level Rule and the System Strength Rule Change.

Based on the draft determination, the OSM is envisaged to be a near real-time market that will operate alongside the electricity spot market to ensure sufficient resources are available to maintain power system security. It is proposed to commence in October 2025. The OSM will dispatch services to ensure that sufficient system strength levels are always met and will co-optimise additional levels of system strength to enable the economically optimal level of renewable generation to operate stably. The efficient level of system strength will vary in near-real-time, based on factors such as the renewable generation availability, electricity spot prices and the cost of system strength services.

As the purpose of the OSM is to operationalise contracts, at this stage we do not envisage that it will impact this RIT-T.

2.2. Description of the identified need

As the System Strength Service Provider for NSW we are required to make sufficient system strength available, as specified by AEMO, under NER:

- Clause 11.143.15 to address the system strength Shortfall declared by AEMO from 1 July 2025 to 1 December 2025 at Newcastle and Sydney West,[18] and
- Schedule 5.1.14 to provide the minimum and efficient levels of system strength forecast by AEMO at each of the NSW system strength nodes from 2 December 2025 into the future.[19]

We have therefore commenced this RIT-T to assess options to ensure the above NER requirements are met. We consider that this will enable us to identify the optimal solution to meet both the short-term and long-term needs.

We consider this a 'reliability corrective action' under the RIT-T as the proposed investment is for the purpose of meeting externally-imposed regulatory obligations and service standards, i.e. NER Clause 11.143.15 and NER Schedule 5.1.14.

2.3. Assumptions underpinning the identified need

2.3.1. System strength Shortfall (1 July 2025 – 1 December 2025)

Following the publication of AEMO's 2022 System Security Reports, AEMO gave notice to us that a system strength Shortfall is projected to occur from 1 July 2025 at Newcastle 330kV and Sydney West 330kV nodes. This reflects their latest analysis and expectations about project delivery timing and is an update to previously declared Shortfalls (including within the 2022 System Security Reports).[20] On 15 December 2022, AEMO issued us with a notice to make system strength services available to address the Shortfalls

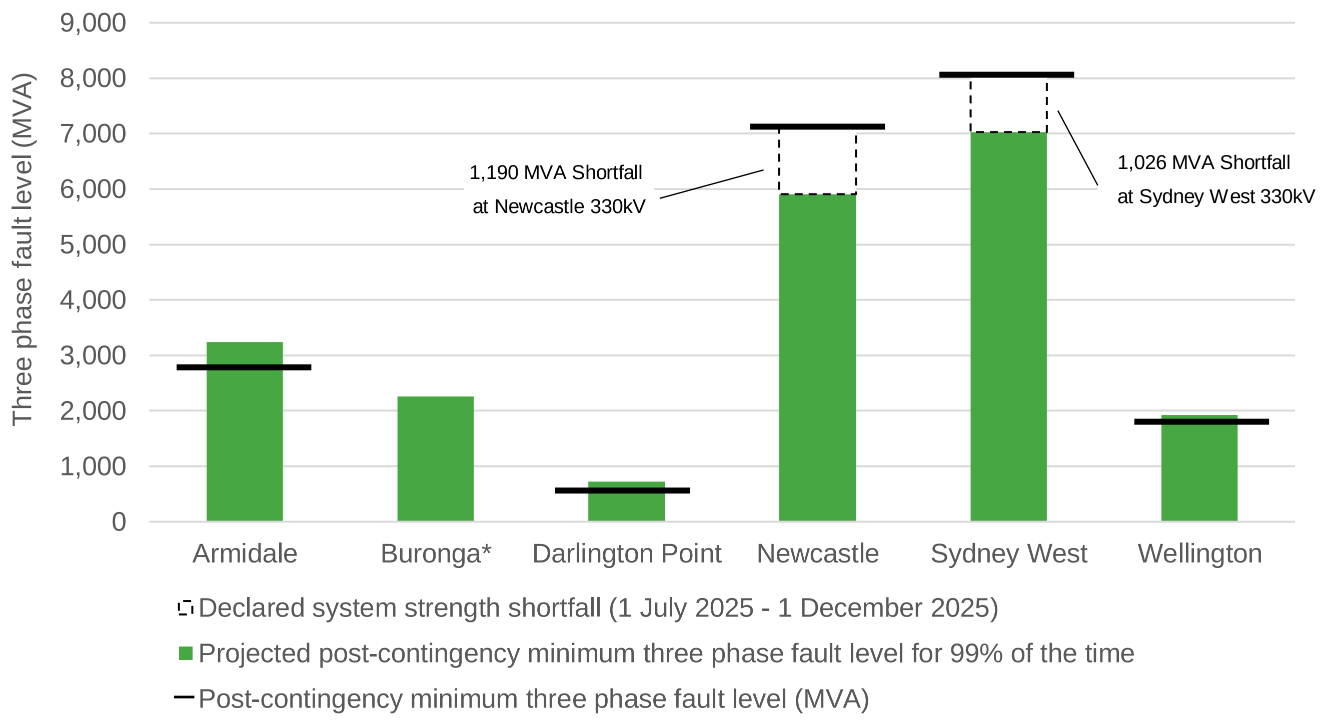
[18] AEMO, December 2022, System security services – Revised notice and request under the National Electricity Rules (NER)

[19] AEMO, December 2022, 2022 System Security Report

[20] Due to recent changes in assumptions regarding timing of future projects (following the publication of AEMO's 2022 System Security Reports), Transgrid and AEMO expect that the Shortfall sizes declared in the 2022 System Security Reports will now increase to be at the values set in the Update to the 2021 System Strength Report. Transgrid and AEMO will undertake joint planning to refine the shortfall size and appropriate solutions.

in accordance with NER clause 11.143.15. The 'Shortfall Period' under the existing Fault Level Rule will be 1 July 2025 to 1 December 2025 (with the new System Strength Rule Change commencing from 2 December 2025). The fault level requirements and Shortfall for the NSW system strength nodes are shown in Figure 2-3.

Figure 2-3: New South Wales fault level requirements, 2025-26 post contingency fault level projections[21] and Shortfalls



We are required to meet a 1,190 MVA fault level Shortfall at Newcastle 330kV and a 1,026 MVA shortfall at Sydney West 330kV, for the period 1 July 2025 to 1 December 2025, as set out in Table 2-1. Based on AEMO's assessment of the Shortfall, the system strength services are likely to be required for 10% of the time during this period.

Table 2-1: Summary of system strength shortfall requirements

Node	System strength need	Need date	Estimated need duration
Newcastle 330 kV	1,190 MVA of additional fault current	1 July 2025 to 1 December 2025	10% of the time
Sydney West 330 kV	1,026 MVA of additional fault current	1 July 2025 to 1 December 2025	10% of the time

Note that:

(a) The estimated need durations presented in Table 2-1 are based on the proportion of time that fault levels at each node are projected to fall below the minimum levels required. Depending on the constraints and capabilities of different technologies to start-up and respond instantaneously, non-

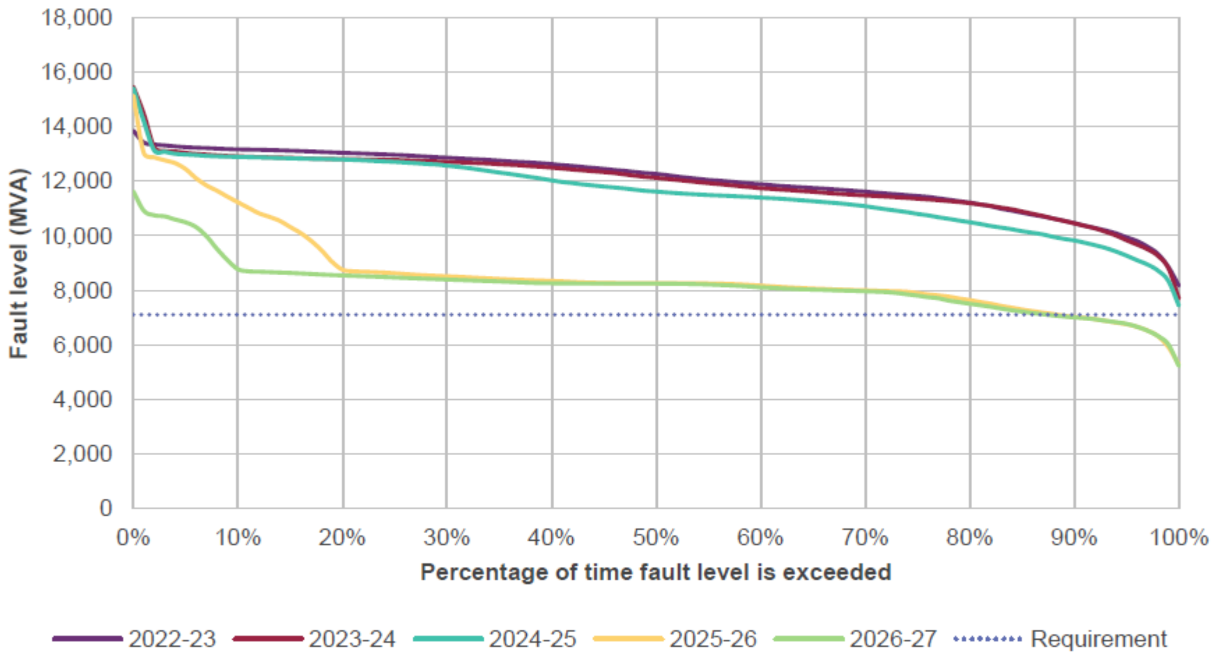
[21] Note that the Buronga node was recently added, and the minimum post-contingency value has not been determined. No Shortfall has been declared for Buronga.

network solutions providing system strength services may be required to operate for longer periods of time to meet these needs.

(b) Depending on the solutions proposed, we may determine that it is necessary to procure system strength services in larger volumes than implied by the levels of the declared Shortfalls. For example, if existing synchronous generators form part of the optimal solution, we would need sufficient confidence that the aggregate system strength services provided are additional to what would otherwise have been dispatched in the energy market.

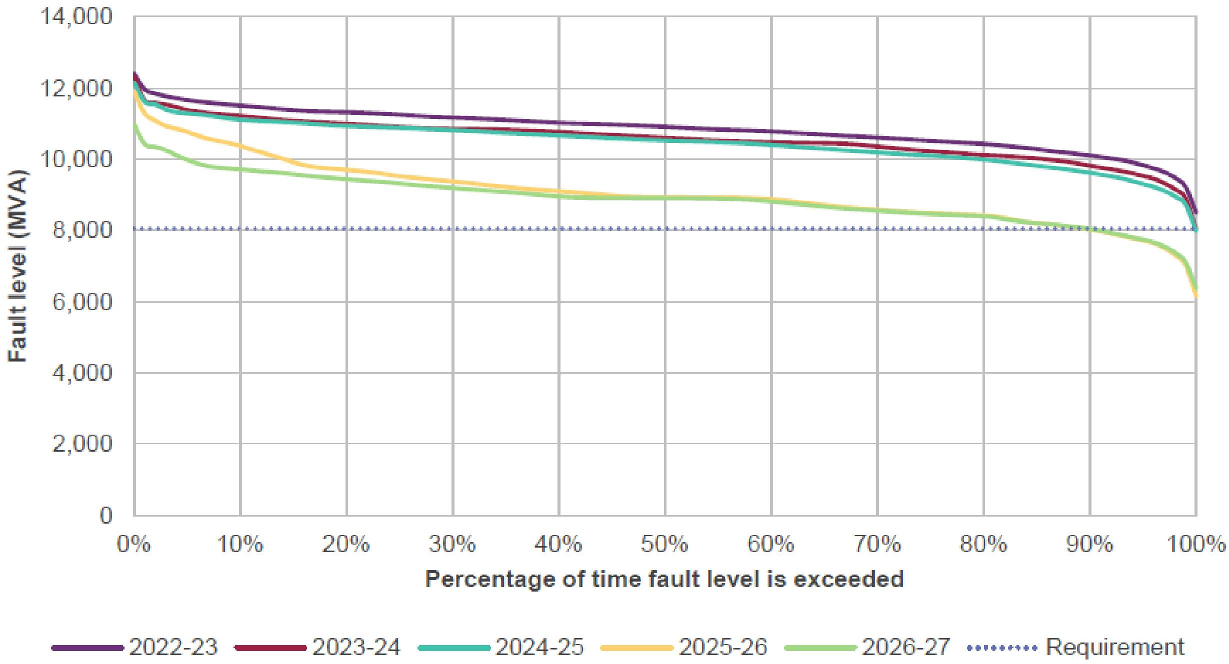
Figure 2-4 and Figure 2-5 present the projected fault level duration curves for Newcastle 330kV and Sydney West 330kV, respectively. AEMO's modelling suggests that the Shortfall is expected to materialise for approximately 10% of the year in 2025/26 at both locations.

Figure 2-4: Projected post-contingency fault level at Newcastle 330kV



Source: AEMO, May 2022, Update to 2021 System Security Reports

Figure 2-5: projected post-contingency fault level at Sydney West 330kV



Source: AEMO, May 2022, Update to 2021 System Security Reports

2.3.2. Minimum level of system strength (from 2 December 2025)

From the 2 December 2025 we are required as NSW's System Strength Service Provider to meet NSW's entire minimum fault level requirements (rather than just filling a declared Shortfall). AEMO has specified the pre- and post-contingency minimum requirements for the existing five NSW nodes, which remain unchanged from previous years, and has added one node at Buronga, as described above in Table 2-2.

The need is therefore to meet minimum fault level requirements in full at each node at all times of the year, from 2 December 2025 onwards. For example, at the Newcastle node, network and/or non-network solutions must be in place to meet a pre-contingency fault level of 8,150 MVA and a post-contingency fault level of 7,100 MVA fault level for all periods of the year. These solutions may be located within NSW, or interstate and may include existing synchronous generators dispatched in the energy market.

Table 2-2: New South Wales minimum fault level requirements

Node	System strength need (fault level, MVA)		Need date	Estimated need duration
	Pre-contingency	Post-contingency		
Armidale 330 kV	3,300	2,800	From 2 December 2025 onwards	100% of time
Buronga 220 kV	1,755	To be determined		
Darlington Point 330 kV	1,500	600		
Newcastle 330 kV	8,150	7,100		
Sydney West 330 kV	8,450	8,050		
Wellington 330 kV	2,900	1,800		

Source: AEMO, 1 December 2022, 2022 System Security Report

2.3.3. Efficient level of system strength (from 2 December 2025)

The System Strength Rule Change also requires us to provide sufficient system strength services to ensure the efficient amount of new inverter-based renewables will remain stable in steady state conditions and remain synchronised following credible contingency events[22].

AEMO provides a 10-year projection of the efficient level and type of inverter-based renewable capacity surrounding each node. Transgrid therefore has a need to enable the stable operation of some or all of the inverter-based renewables expected to connect in NSW over this period, including up to 5.8GW of additional renewables from 2 December 2025 (2025/26) and up to 15.4GW in 2029/30, as specified in Table 2-3.

Table 2-3: Summary of the efficient level of inverter-based renewables projected for NSW (GW generation capacity, cumulative)

System strength need date	From 2 December 2025 onwards						
Need duration	Variable. Co-optimised via the OSM to maintain system security and maximise the value of energy trade[23]						
Cumulative Inverter-based renewable capacity (GW) in NSW	**Darlington Point region**	**Wellington region**	**Sydney West region**	**Buronga region**	**Armidale region**	**Newcastle region**	**Total**
FY23	-	-	-	-	-	-	**-**
FY24	0.2	0.6	0.7	-	0.2	-	**1.8**
FY25	0.7	0.7	0.7	-	0.2	-	**2.3**
FY26	1.7	2.1	0.8	-	0.7	0.6	**5.8**
FY27	1.7	3.1	0.8	0.1	0.7	0.6	**6.9**
FY28	1.7	3.1	0.8	0.1	4.8	1.3	**11.8**
FY29	1.7	4.2	0.8	0.1	5.7	1.7	**14.2**
FY30	1.7	5.1	0.8	0.1	5.7	1.9	**15.4**
FY31	1.7	5.1	0.8	0.1	5.7	2.9	**16.4**
FY32	1.7	5.6	0.8	0.1	6.0	3.0	**17.3**
FY33	1.8	6.1	1.3	0.2	6.0	3.0	**18.4**

Source of inverter-based renewable capacity forecast: AEMO, 1 December 2022, 2022 System Security Report

AEMO has not specified 'fault level' as the metric for the efficient level of system strength, but rather several criteria that must be met to ensure a stable voltage waveform can be maintained. Voltage waveform stabilization can be supplied by both conventional system strength technologies that provide fault current (e.g. synchronous generators or synchronous condensers), as well as new innovative technologies including grid forming batteries and grid forming renewable generators. We consider that grid forming

[22] AEMC, 21 October 2021, Efficient management of system strength on the power system, rule determination, https://www.aemc.gov.au/rule-changes/efficient-management-system-strength-power-system

[23] Through the OSM, AEMO will assess in near real-time cost effectiveness of bringing on additional system security services to enable inverter-based renewables to operate stably. Where it is not economic to bring on additional system strength services to cover higher levels of renewable generation, renewables will be spilled.

batteries and grid forming renewable generation could play a significant role in meeting the efficient level of system strength.

We must provide sufficient system strength services to ensure that the efficient level of new connecting inverter-based renewable generators have stable voltage waveforms. The requirement for stable voltage waveforms is such that:[24]

- in steady state conditions, *plant* does not create, amplify, or reflect instabilities; and
- 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*.

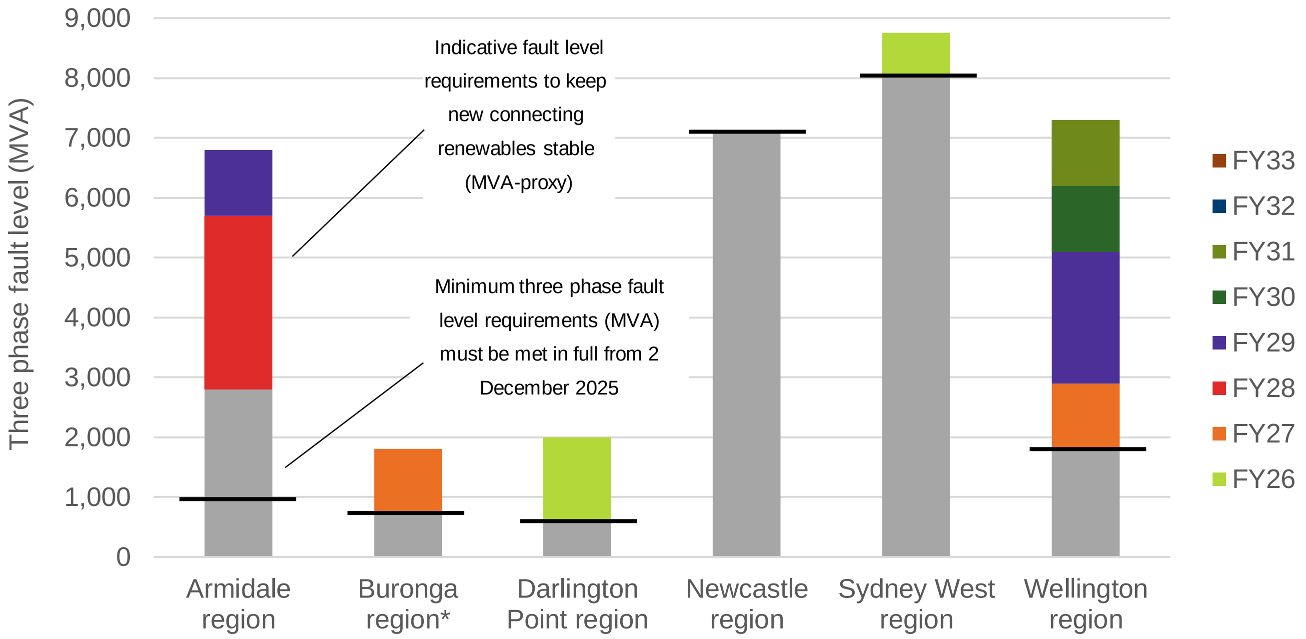
A stable voltage waveform is defined by four criteria:[25]

1. **Voltage magnitude:** the positive-sequence RMS voltage magnitude at a connection point does not violate the limits in the operational guides for the relevant network.
2. **Change in voltage phase angle:** changes 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.

We have estimated the approximate fault level that would be required to ensure a stable voltage waveform for new connecting renewables, as an indicative proxy for the quantum of system strength services required to meet the efficient level, above and beyond the minimum fault level requirements shown in Figure 2-6. Fault levels required for the efficient level represents an upper limit, as our analysis assumes the coincident operation of all wind and solar generators. Due to the variable nature of renewable generation, some quantum of these system strength services may be required most of the time, and others less frequently, as determined through the OSM.

[24] AEMO, 2022, System Strength Requirements Methodology
[25] AEMO, 1 December 2022, 2022 System Security Report

Figure 2-6: NSW's combined minimum post-contingency fault level requirements from 2 December 2025 and efficient fault level projections to FY33, as a proxy for stable voltage waveform



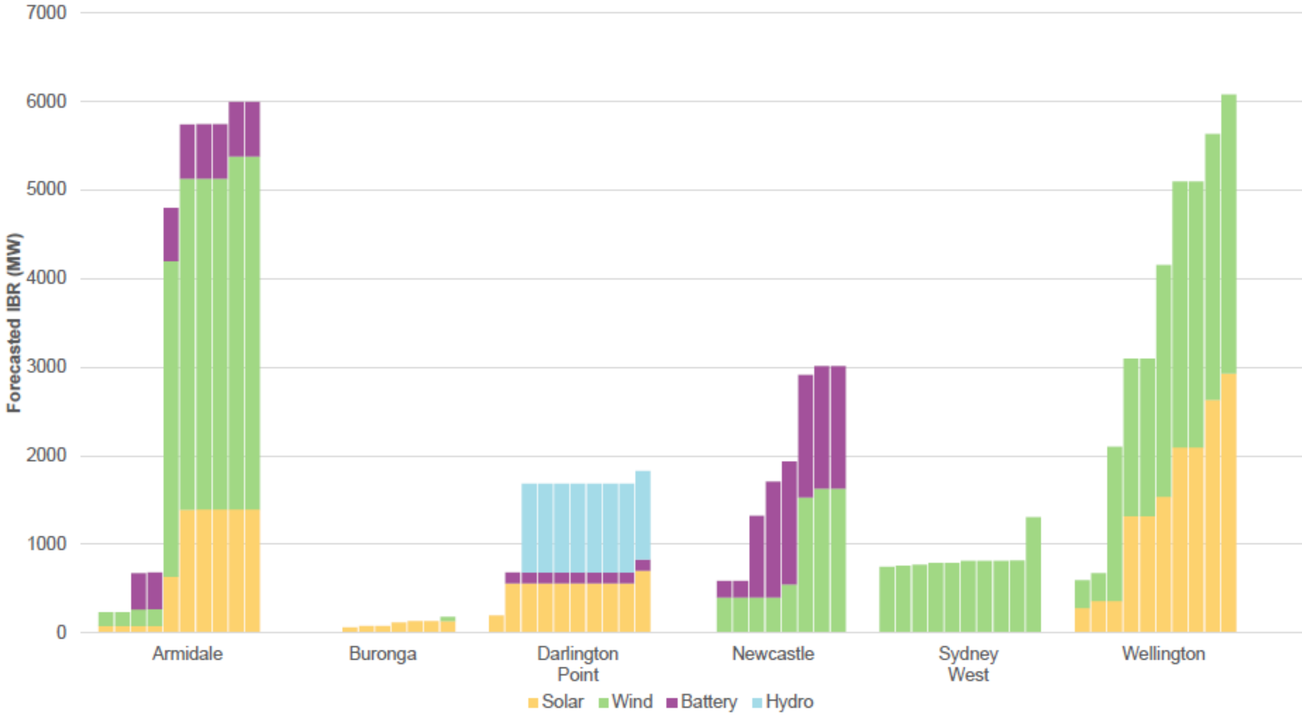
Note: 1) Analysis is on a post-contingency basis, using the Available Fault Level methodology, assuming Short Circuit Ratio (SCR) requirements of 3 for renewables prior to renewable energy zones (REZs) being developed (minimum access standard under the System Strength Rule Change) and 2.2 for renewables within REZs (minimum access standards within NSW Government REZs). Note that ensuring that minimum fault levels are achieved in NSW also provides system strength services to stabilise new connecting renewables. 2) Buronga's minimum post-contingency fault level requirements have not been established – for this chart an estimate has been used.

Figure 2-6 suggests that from 2 December 2025 (2025/26), up to 2,100 MVA of fault current provision may be needed at various locations in NSW to ensure the stable operation of new renewable generation, and up to 11,500 MVA of fault current by 2029-30. Eventually, system strength services to support the stable voltage waveform of new renewables may be of a similar magnitude to the minimum fault level requirements at some nodes.

Underpinning AEMO's assessment of the need is the 10-year forecast of the efficient level and type of inverter-based renewables and market network service facilities required in NSW under the Step Change Scenario[26] shown in Figure 2-7. AEMO has noted that the near-term years of the forecast may require adjustment by the System Strength Service Provider when preparing system strength services, as more information becomes available about newly committed inverter-based renewables and market network service facilities.[27]

[26] A table of forecasted level and type of inverter-based renewables and market network service facilities can be found on page 28 of AEMO's 2022 System Security Reports.
[27] AEMO, 1 December 2022, 2022 System Security Reports

Figure 2-7: AEMO's forecasted level and type of inverter-based renewables and market network service facilities for the next 10 years



Source: AEMO, 1 December 2022, 2022 System Security Reports

3. Options that meet the identified need

We consider credible options in this RIT-T assessment as those that would meet the identified need from a technical, commercial, and project delivery perspective[28] This includes any credible options that are put forward by proponents in response to this PSCR and associated EOI.

This RIT-T assesses options to address both the AEMO declared system strength Shortfall from 1 July 2025 to 1 December 2025 as well as meet the new minimum and efficient level of system strength requirements (as a result of the System Strength Rule Change) from 2 December 2025 onwards. We consider that this will enable us to identify the optimal solution to meet both the short-term and long-term needs.

We have outlined credible network options in this PSCR which involve the installation of synchronous condensers to contribute to meeting NSW's system strength requirements.

We consider that non-network solutions may be able to form credible options for this RIT-T, either as standalone options or in combination with network options (or components of these options). Section 4 and the accompanying EOI provide details on the technical information that proponents of non-network options need to provide in order to enable their option to be considered in this RIT-T. We are seeking to identify potential solutions which can contribute to providing system strength:

- for the Shortfall period from 1 July 2025 to 1 December 2025,
- to meet the minimum and/or efficient level of system strength from 2 December 2025, or
- over both periods.

Through this RIT-T we will assess the timing and requirements for the optimal mix of option(s) that will address the identified need. Due to the scale of the system strength need from 2 December 2025 onwards, we expect that a combination of network and non-network options will form part of the long-term solution.

3.1. Base case

Consistent with the RIT-T requirements, the assessment undertaken in the PADR will compare the costs and benefits of each credible option to a 'do nothing' base case. The base case is the (hypothetical) projected case if no action is taken, i.e.,:[29]

> *"The base case is where the RIT-T proponent does not implement a credible option to meet the identified need, but rather continues its 'BAU activities'. 'BAU activities' are ongoing, economically prudent activities that occur in absence of a credible Option being implemented"*

Under the base case, we would not meet the Shortfall or the new requirements to provide a minimum and efficient level of system strength into the future. Under these conditions, it is expected that AEMO would direct existing synchronous generators to operate, where possible, to maintain system security. In the event that insufficient system strength is available as thermal generators retire or are unavailable, there is expected to be significant interruption of supply to loads in NSW under normal and contingency conditions.

Insufficient system strength in certain areas of the network could lead to generators being unable to meet their technical performance standards as well as being unable to remain connected to the system at times.

[28] As per clause 5.15.2(a) of the NER.
[29] AER, August 2020, Regulatory Investment Test for Transmission Application Guidelines, p. 21.

This could also lead to voltage instability and a decrease in the effectiveness of the protection systems used by network businesses, generators and large customers. If not addressed, these effects could in turn lead to system instability and major supply interruptions.

While this is not a situation we plan to encounter, and this RIT-T has been initiated specifically to avoid it, the assessment is required under the RIT-T to use this base case as a common point of reference when estimating the net benefits of each credible option.

At this stage, we are not intending to quantify the full extent of the expected involuntary load shedding under the base case as part of the PADR analysis, as each option will address the system strength requirements and avoid largely the same amount of unserved energy, i.e., quantifying the full extent of avoided involuntary load shedding under each option will not assist in identifying the preferred option under the RIT-T.

Transgrid notes that the avoided lost load will be the same under all options and will therefore not affect the RIT-T outcome.[30] [31]

3.2. Options to address the declared system strength Shortfall (1 July 2025 to 1 December 2025)

AEMO has advised us that a system strength Shortfall is projected to occur from 1 July 2025 at the Newcastle 330kV node (1,190 MVA) and at the Sydney West 330kV (1,026 MVA) node. We have identified two potentially credible combinations of network options to meet the declared system strength Shortfall, based on combinations of synchronous condenser sizes installed at different sites on our network. We note that supply chain constraints could impact on the feasibility of deploying synchronous condensers in the short term; this will be assessed further during the PADR stage.

As there is a relatively large electrical distance between the Newcastle and Sydney West nodes, installing synchronous condensers at a single substation is not considered optimal. As such, a range of combinations of existing substation sites for synchronous condensers installations were assessed as follows:

- Kemps Creek and Vales Point
- Kemps Creek and Newcastle
- Sydney West and Newcastle
- Sydney West and Vales Point
- Vineyard and Vales Point
- Vineyard and Newcastle

We are required to meet fault level requirements in both steady state conditions as well as during contingencies. As such, the number of feeders at each site and the rating of synchronous condensers are important considerations in determining the credible network options.

---

30 Biggar, D., May 2017 An Assessment of the Modelling Conducted by Transgrid and Ausgrid for the 'Powering Sydney's Future' Program, pp. 12-16.

31 Transgrid considers this approach is consistent with the view of Dr. Biggar, Special Economic Adviser to the AER, in his 2017 review of the Powering Sydney's Future RIT-T, where it was noted that the unserved energy under the base case is essentially irrelevant and, in that case, as is the case for this RIT-T, the unserved energy reaches astronomically high levels under the base case. Dr. Biggar suggested it is not correct to allow these costs to increase to arbitrarily high levels and that they should be capped, which allows a more meaningful comparison between options.

Table 3-1 summarises each of the credible options we currently consider can meet the identified need to address the Shortfall.

These options are able to address the 1 July 2025 Shortfall, and will contribute to meeting system strength needs beyond 2 December 2025 under the System Strength Rule Change. Option 2 presents a more cost-effective solution if additional synchronous condensers are required to meet needs beyond 2 December 2025. As noted above, we consider that non-network solutions may be able to form credible options for this RIT-T, either as standalone options or in combination with network options (or components of these options). The requirement for a scalable network solution is therefore dependent on the non-network solutions proposed in response to this PSCR and accompanying EOI.

Table 3-1: Summary of capex for least-cost credible network options to meet the system strength Shortfalls

Option	Description	Least cost configurations[32]	Capex ($2021-22, ±25%)
Option 1	Meets the needs of the system strength Shortfall	Newcastle **or** Vales Point – 2 x 125MVA synchronous condensers **and** Kemps Creek **or** Sydney West – 2 x 125MVA synchronous condenser	$326-374M
Option 2	Meets the needs of the system strength Shortfall and provides a more scale efficient solution for future system strength needs	Newcastle **or** Vales Point – 2 x 200MVA synchronous condensers) **and** Kemps Creek – 2 x 200MVA synchronous condensers)	$349-351M
Option 3	Non-network options	The assessment of non-network options will depend on responses received to this PSCR and associated EOI. Section 4 and the accompanying EOI provide details on the technical information that proponents of non-network options need to provide in order to enable their option to be considered in this RIT-T	To be estimated based on responses to the EOI

Indicative cost estimates for the credible options have been provided with more accurate figures expected to be used for the cost-benefit analysis in the PADR. In addition, while we currently expect that annual operating costs can be proxied as one per cent of the total capex, this will be reviewed as part of the PADR and more specific estimates may be developed.

3.2.1. Option 1 – 125 MVA synchronous condensers

Option 1 involves constructing synchronous condensers at Newcastle or Vales Point and Kemps Creek substations as the likely optimal locations to address the Shortfall. Table 3-2 provides details on the

[32] This summary includes only the lowest cost solutions from each Option to meet the need. Note that for all options, each synchronous condenser is coupled with a 275MVA transformer.

proposed investment, estimated capex and fault level contributions for each location. It is expected that this option would be commissioned in 2025/26 to address the Shortfall.

Table 3-2: Option 1 – Details on proposed investment, capex and fault level contributions

Existing Substation Site	Expected capital expenditure ($2021-22, ±25%)	Proposed investment	Fault level contribution at 330kV busbar
Sydney West	$196M	2 x 125 MVA synchronous condenser installation at Sydney West 330 kV Substation each with Transformer 275 MVA	1874 MVA
Newcastle	$170M	2 x 125 MVA synchronous condenser installation at Newcastle 330 kV Substation each with a 275 MVA transformer	1874 MVA
Vales Point	$178M	2 x 125 MVA synchronous condenser installation at Vales Point 330 kV Substation each with a 275 MVA transformer	1874 MVA
Kemps Creek	$156M	2 x 125 MVA synchronous condenser installation at Kemps Creek 330 kV Substation each with a 275 MVA transformer	1874 MVA

3.2.2. Option 2 – 200 MVA synchronous condensers

Option 2 involves constructing synchronous condensers at Newcastle or Vales Point and Kemps Creek substations as the likely optimal locations to address the Shortfall and to provide a scale efficient solution to install additional synchronous condensers to meet future system strength needs (if required).Table 3-3 provides details on the proposed investment, estimated capex and fault level contributions for each location. It is expected that this option would be commissioned in 2025/26 to address the Shortfall.

Table 3-3: Option 2 – Details on proposed investment, capex and fault level contributions

Site	Expected capital expenditure ($2021-22, ±25%)	Proposed investment	Fault level contribution at 330kV busbar
Newcastle	$182M	2 x 200 MVA synchronous condenser installation at Newcastle 330 kV Substation each with Transformer 275 MVA.	2222 MVA
Vales Point	$180M	2 x 200 MVA synchronous condenser installation at Vales Point 330 kV Substation each with Transformer 275 MVA.	2222 MVA
Kemps Creek	$169M	2 x 200 MVA synchronous condenser installation at Kemps Creek 330 kV Substation each with Transformer 275 MVA.	2222 MVA

3.2.3. Option 3 – Non-network solution

We consider that non-network solutions may be able to form credible options for this RIT-T, either as standalone options or in combination with network options (or components of these options).

While the ultimate assessment of non-network options will depend on responses received to this PSCR, at this stage, we consider these technologies may include, but are not limited to, the following:

- synchronous generators;
- synchronous hydro units operating in 'synchronous condenser' mode;
- conversion of existing synchronous generators to synchronous condensers;
- synchronous condensers (with or without fly wheels);
- grid forming battery energy storage systems;
- grid forming inverter-based renewable generators;
- grid forming SVCs or STATCOMs; and
- other modifications to existing plant.

Section 4 and the accompanying EOI provide details on the technical information that proponents of non-network options need to provide in order to enable their option to be considered in this RIT-T.

3.3. Options to address requirements from System Strength Rule Change (from 2 December 2025)

We have estimated that an entirely network-based solution required to the meet the minimum and efficient levels of system strength under the System Strength Rule Change (using synchronous condensers) would require approximately 20 synchronous condensers from 2 December 2025, growing to 29 synchronous condensers in 2032-33 as more inverter-based renewables connect. This is presented in Figure 3-1.

This represents an 'upper limit' provided to indicate the scale of solutions required. We expect that non-network solutions will play a significant role in providing system strength, and that any network solution would be commensurately smaller as a result. Non-network options may also be required to meet system strength needs in the short-term until network options can be constructed and commissioned (where they are assessed to form part of the preferred options). A portfolio of existing and new network and non-network solutions, including services from interstate, is likely to best meet the needs of the NSW power system and energy consumers throughout the energy transition.

Figure 3-1: Estimated number of synchronous condensers needed to meet NSW's system strength requirements in full (without the support of non-network options). Of the 29 synchronous condensers estimated for FY33, 25 are rated at 200MVA and 4 are rated at 125MVA.

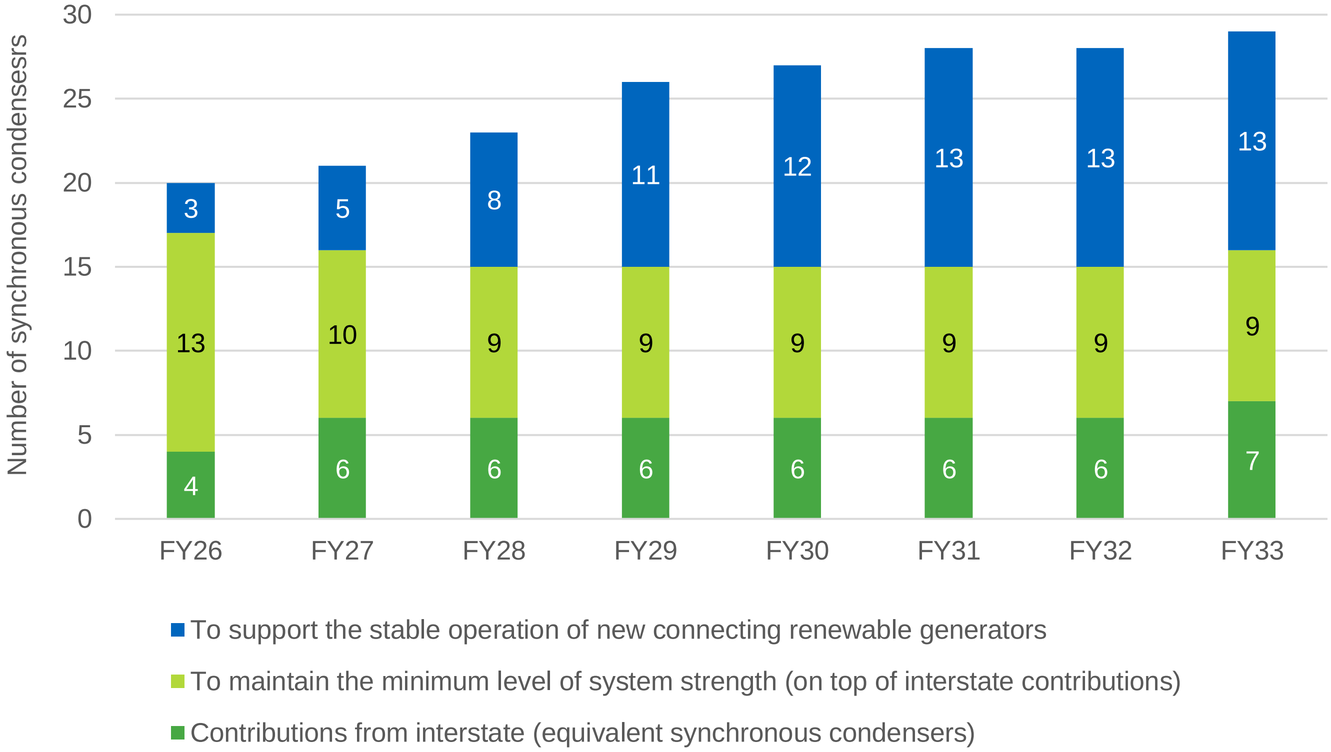


Figure 3-1 shows that:

- If the System Strength Service Providers in other jurisdictions provide the minimum level of system strength as required under the System Strength Rule Change, this will also provide a contribution to meeting the minimum system strength levels in NSW.
  While we do not currently have contracts in place for the provision of these services, we do not expect to duplicate them in NSW. If a network support agreement cannot be reached, additional services within NSW would be required, equivalent to approximately 4 synchronous condensers located in NSW in 2025-26, growing to approximately 7 synchronous condensers in 2032-33. The growth in interstate system strength contributions can be attributed purely to the connection of major transmission projects,[33] which reduce network impedance and facilitates the flow of system strength within NSW and between states.
- In addition to interstate system strength contributions, the estimated number of 200MVA synchronous condensers required to meet minimum levels of system strength in NSW falls from 13 on 2 December 2025 (2025/26) to 9 in 2027/28, due to major transmission projects facilitating the flow of system strength.
- The need for system strength services to support the stable voltage waveform of new connecting renewable generators grows over time, as more inverter-based renewable generators connect to the network in NSW.

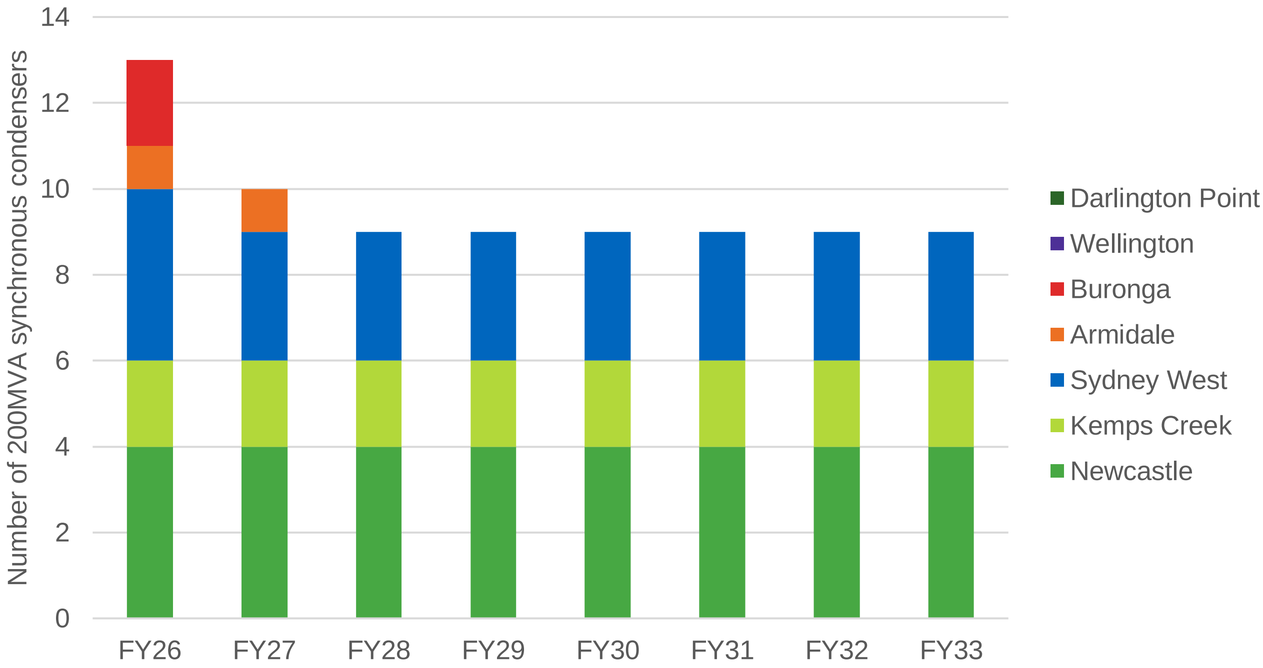
Further breakdowns of the requirements to meet the minimum and efficient levels of system strength are provided in the following sections.

[33] Major transmission projects are modelled to commence service in line with Actionable dates set out in the 2022 Integrated System Plan.

3.3.1. Options to meet the minimum level of system strength

We estimate that 13 synchronous condensers (200 MVA[34]) would be required to meet the minimum levels of system strength specified by AEMO in 2025/26, above and beyond interstate contributions. As shown in Figure 3-2, this falls to 9 in 2027/28 following the commissioning of major transmission projects identified in AEMO's ISP. The short-term deployment of non-network solutions may prove to be an economically viable alternative to network solutions that are not required on an ongoing basis.

Figure 3-2: Estimated number and location of synchronous condensers to meet NSW's minimum fault level requirements, beyond interstate contributions



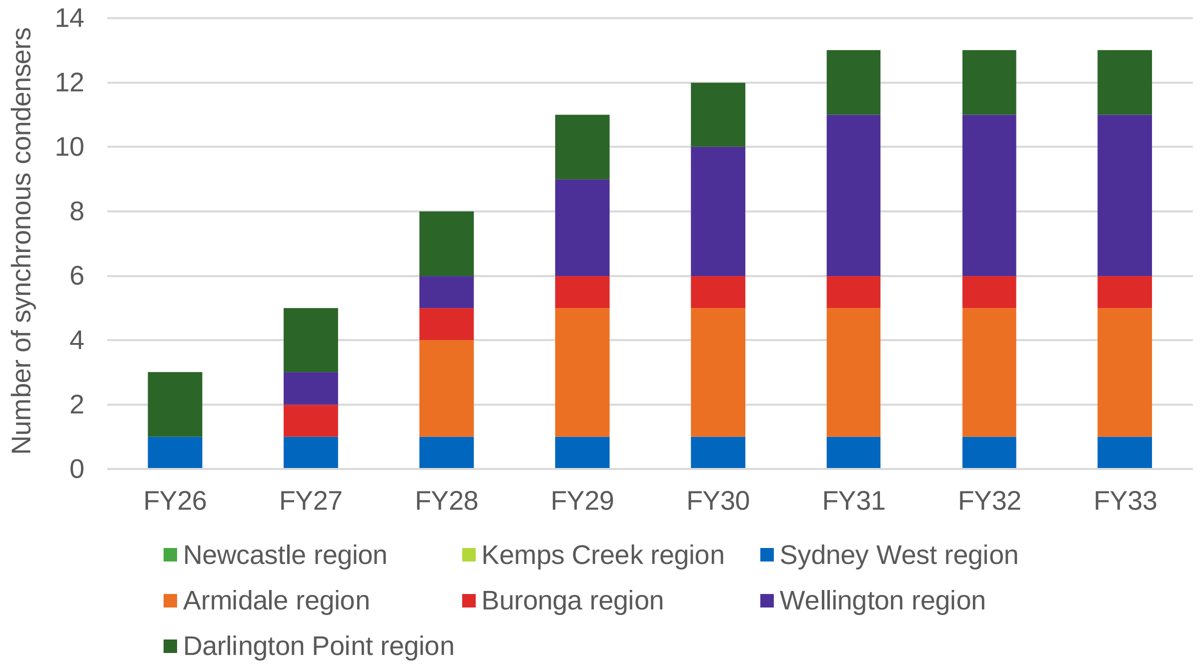
3.3.2. Options to meet the efficient level of system strength

We estimate that an additional 3 synchronous condensers would be required to meet the efficient levels of system strength specified by AEMO in 2025/26, above and beyond interstate contributions and minimum system strength requirements. As shown in Figure 3-3, this is expected to increase to 13 in 2029-30 as more inverter-based renewables connect to the NSW power system.

With the exception of 3 x 125MVA Synchronous condensers in 2025-26 and an additional 1 x 125MVA unit in 2027-28,[35] all other units are sized at 200MVA.[36] It is envisaged that these synchronous condensers would be located in the vicinity of new connecting renewable generators, rather than at the system strength node itself.

[34] Each with a 275MVA transformer.
[35] Each with a 170MVA transformer.
[36] Each with a 275MVA transformer.

Figure 3-3: Additional number of synchronous condensers needed to meet NSW's efficient level of system strength across different regions (cumulative), beyond interstate contributions and beyond requirements to meet minimum levels of system strength



3.4. Options considered but not progressed

We have also considered whether other options could meet the identified need. Reasons these options were not progressed are summarised in Table 3-4.

Table 3-4: Options considered but not progressed

Option	Reason(s) network options were not progressed
Grid forming SVCs	Grid forming SVC's have not currently been proven at scale for providing fault current and have a high cost and low overload capability compared to the credible options presented, hence this option is considered not commercially feasible.
> 200 MVA Synchronous condensers	The installation of very large, 250 MVA synchronous condensers was assessed, but considered not feasible due to maximum weight limits for road transport in NSW. While this option is technically feasible if some NSW roads and bridges were upgraded, due to likely costs, this option is considered not commercially feasible.
Synchronous condensers at Vineyard or Sydney West (200MVA units) substations	Physical constraints at these substations means that locating synchronous condensers at these substations is either not technically feasible or requires extensive modifications at the sites, increasing the costs to locate synchronous condensers at these sites with no additional benefits relative to the other sites assessed. Therefore these options are considered not commercially feasible.

3.5. Material inter-network impact is expected

Transgrid has considered whether the credible options listed above is expected to have material inter-regional impact[37]. A 'material inter-network impact' is defined in the NER as:

> "*A material impact on another Transmission Network Service Provider's network, which impact may include (without limitation): (a) the imposition of power transfer constraints within another Transmission Network Service Provider's network; or (b) an adverse impact on the quality of supply in another Transmission Network Service Provider's network."*

AEMO's suggested screening test to indicate that a transmission augmentation has no material inter-network impact is that it satisfies the following[38]:

- a decrease in power transfer capability between transmission networks or in another TNSP's network of no more than the minimum of 3 per cent of the maximum transfer capability and 50 MW
- an increase in power transfer capability between transmission networks or in another TNSP's network of no more than the minimum of 3 per cent of the maximum transfer capability and 50 MW
- an increase in fault level by less than 10 MVA at any substation in another TNSP's network; and
- the investment does not involve either a series capacitor or modification in the vicinity of an existing series capacitor.

We consider that the credible options considered may increase the fault level in another TNSP's network by at least 10 MVA. We intend to request an augmentation technical report from AEMO in relation to the options being considered in this RIT-T.[39]

[37] As per clause 5.16.4(b)(6)(ii) of the NER.

[38] Inter-Regional Planning Committee. "*Final Determination: Criteria for Assessing Material Inter-Network Impact of Transmission Augmentations*." Melbourne: Australian Energy Market Operator, 2004. Appendix 2 and 3. Accessed 23 June 2021. https://aemo.com.au/-/media/files/electricity/nem/network_connections/transmission-and-distribution/170-0035-pdf.pdf

[39] NER clause 5.21(d)(1)-(3).

4. Characteristics for non-network options

This section describes the technical characteristics and requirements that a non-network option would need to deliver to address the identified need.

While this section summarises these expected requirements, the accompanying EOI provides further detail regarding the types of information we require from proponents in order to have their solutions assessed at the PADR stage. We encourage interested parties to submit through the EOI their existing or potential non-network solution to support in addressing the identified need.

4.1. Eligible non-network option

At a minimum, potential non-network options submitted through this PSCR and associated EOI must:

- if submitted to **address the Shortfall** (between 1 July 2025 and 1 December 2025):
  - address the Shortfall, in part or full, at the Newcastle 300kV and/or Sydney West 330kV fault level nodes;
  - be available on or after 1 July 2025. New projects must provide evidence that services will be available on or soon after 1 July 2025;
  - be available until at least 1 December 2025 and may be submitted for a longer period of service to address the System Strength Rule Change requirements (e.g. up to 30 years);
- if submitted to **address the System Strength Rule Change** (from 2 December 2025 onwards):
  - in part or full, address minimum fault level requirements and/or support a stable voltage waveform for new connecting inverter-based renewables surrounding NSW fault level nodes (efficient level);
  - be available on or after 2 December 2025 for a defined period of service (e.g. up to 30 years);
- meet the requirements set out in section 4.4 (as applicable);
- be commercially and technically feasible;
- provide a material quantity of system strength services, for example from solutions with a rated capacity greater than 50MVA; and
- be in the name of one contracting party.

4.2. Potential non-network options

Non-network solutions are required to contribute in part or in full to the:

- Shortfall requirements set out in Table 2-1, and/or
- Minimal fault level requirements set out in Table 2-2, and/or
- Efficient level of system strength requirements set out in Table 2-3.

Potential non-network solutions may be existing plant or new plant and can include but are not limited to:

- synchronous generators;
- synchronous hydro units operating in 'synchronous condenser' mode;
- conversion of existing synchronous generators to synchronous condensers;
- synchronous condensers (with or without fly wheels);
- grid forming battery energy storage systems;
- grid forming inverter-based renewable generators;
- grid forming SVCs or STATCOMs; and

- other modifications to existing plant.

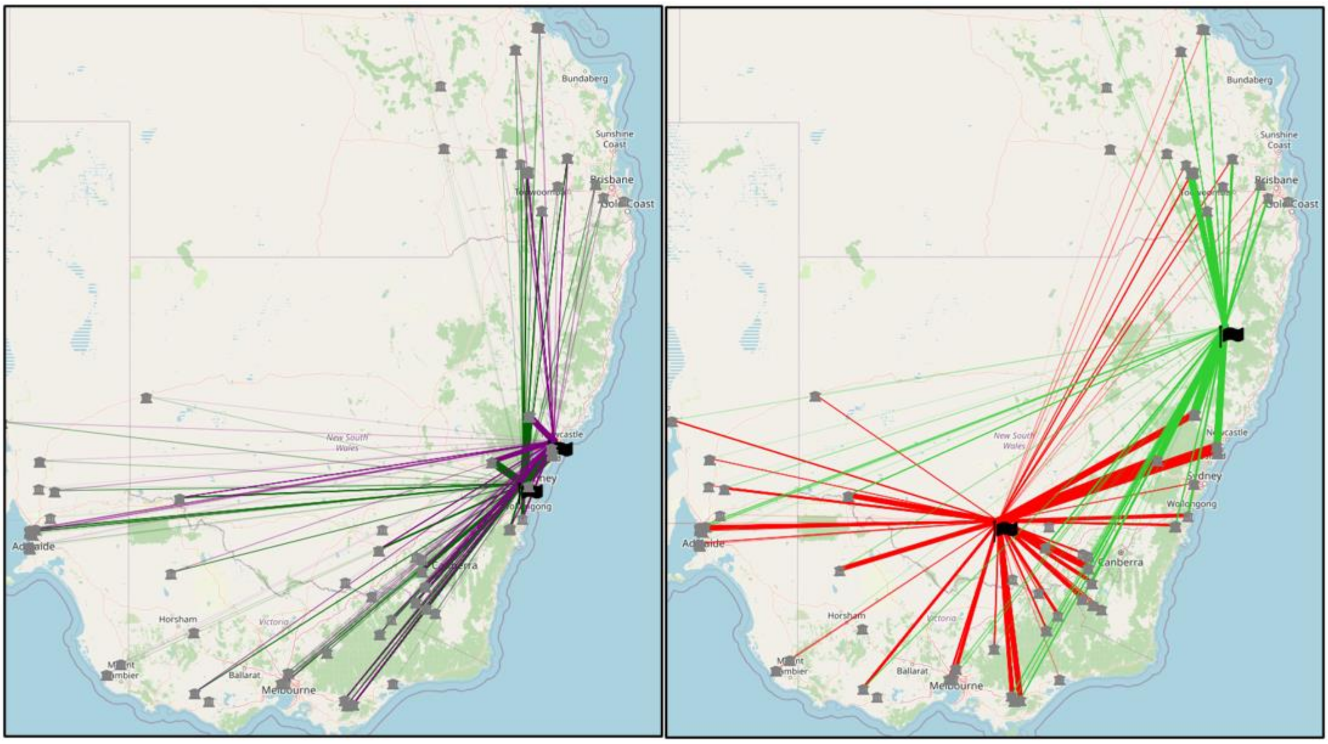
These solutions will be assessed in the RIT-T economic evaluation on a total cost basis, consistent with the RIT-T Application Guidelines published by the AER.

4.3. Location of non-network options

Non-network options that provide system strength services are not restricted by state boundaries. Solutions which contribute to meeting NSW's needs can be located outside of NSW.

System strength naturally diminishes with electrical distance as a result of the network's impedance, which is a function of physical distance and the capacity of the network. As such, non-network options that are located closer (electrically) to the respective system strength node will provide a greater system strength contribution to that node. Solutions may also contribute to meeting system strength requirements at more than one system strength node. Figure 4-1 presents a visualisation of indicative fault level contributions that existing synchronous generators in the NEM make to four NSW fault level nodes.

Figure 4-1: Visualisation of indicative fault current contributions of each synchronous generator in the NEM to NSW's Newcastle (purple lines) and Sydney West (dark green lines) fault level nodes in the left map and Darlington Point (red lines) and Armidale (light green lines) fault level nodes in the right map. Thicker lines indicate a greater system strength contribution.



4.4. Characteristics of non-network options

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

- 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 notification from AEMO or Transgrid to enable the services, proposed services must commit and continuously maintain the service as soon as possible from the time of the enablement request;

- once the system strength response is enabled, the service shall remain activated until a signal 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 services;
- 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, including Battery Energy Storage Systems; and
- if a generation service is proposed (either standalone or in conjunction with other services), the system security service will be required to operate "on demand" at certain times to satisfy Transgrid's power system security requirements. Such operation will be required regardless of the pool price at the time.[40]

[40] During the Shortfall period (1 July 2025 to 1 December 2025) generators providing system strength services cannot set the electricity pool price. Following the introduction of the OSM, the AEMC envisages that the pool price would be considered in calculating payments to OSM participants.

5. Materiality of market benefits

The NER requires that all categories of market benefit identified in relation to the RIT-T are included in the RIT-T assessment, unless the TNSP can demonstrate that a specific category (or categories) is unlikely to be material in relation to the RIT-T assessment for a specific option.[41]

The PSCR is required to set out the classes of market benefit that the TNSP considers are not likely to be material for a particular RIT-T assessment.[42]

At this stage, we consider that all categories of market benefit identified in the RIT-T have the potential to be material with the exception of competition benefits and changes in ancillary services costs.

5.1. Wholesale market modelling will be adopted for the PADR analysis

The options considered in this PSCR are expected to affect outcomes in the wholesale market, relative to the base case, particularly for potential non-network solutions.

We expect the following categories of market benefit to be estimated using wholesale market modelling as part of the PADR:

(a) changes in fuel consumption arising through different patterns of generation dispatch;

(b) changes in price-responsive voluntary load curtailment;

(c) changes in involuntary load shedding;

(d) avoided/deferred capital and operating expenditure associated with new generation/storage in the NEM;[43]

(e) differences in the timing of unrelated transmission expenditure (e.g., intra-regional transmission investment associated with the development of REZs); and

(f) changes in network losses.

We will take into account option value as part of the PADR for any options that exhibit the requisite flexibility for option value to exist, e.g. Option 2 to install larger synchronous condensers to allow for future expansion.

As the credible options considered in this PSCR do not address network constraints between competing generators, and all credible options are expected to meet the system strength requirements, competition benefits are not expected to be material for this RIT-T assessment.

A discussion of why we consider changes in ancillary service costs are not expected to be material for this RIT-T assessment is provided in the section below.

---

41 NER clause 5.16.1(c)(6).

42 NER clause 5.16.4(b)(6)(iii).

43 Referred to as ‘changes in costs for parties, other than for Transgrid, due to differences in the timing of new plant, capital costs and operating and maintenance costs’ under the RIT-T.

5.2. Changes in ancillary service costs are not expected to be material

While the cost of Frequency Control Ancillary Services (FCAS) may change as a result of changed generation dispatch patterns and changed generation development following any increase to transfer capacity from the options, we consider that changes in FCAS costs are not likely to be materially different between options and are not expected to be material in the selection of the preferred option. FCAS costs are relatively small compared to total market costs.

There is unlikely to be material changes to the costs of Network Control Ancillary Services (NCAS), or System Restart Ancillary Services (SRAS) as a result of the options being considered.

Depending on the responses received to this PSCR and the associated EOI, we will consider whether these ancillary service costs are material as part of the PADR.

6. Overview of the assessment approach

This section outlines the approach that we intend to apply for the PADR when assessing the net benefits associated with each of the credible options against the base case.

6.1. Assessment against the base case

As outlined in Section 3.1, all costs and benefits will be measured against a base case where the Shortfall or the new requirements to provide a minimum and efficient level of system strength into the future are not provided. Under the base case scenario, NSW will experience system strength Shortfalls from July 2025, and the magnitude of this Shortfall will increase over the next decade.

Under these conditions, it is expected that AEMO would direct existing synchronous generators to operate, where possible, to maintain system security. In the event that insufficient system strength is available as thermal generators retire or are unexpectedly unavailable, there is expected to be significant interruption of supply to loads in NSW under normal and contingency conditions.

6.2. Assessment period and discount rate

The RIT-T analysis will consider a 20-year assessment period from 2022-23 to 2041-42. This period was selected considering the period for which forecasts are available and the size, complexity and expected asset lives of the options and provides a reasonable indication of the costs and benefits over a long outlook period.

Where the capital components of the credible options have asset lives extending beyond the end of the assessment period, the NPV modelling includes a terminal value to capture the remaining asset life. This ensures that the capital cost of long-lived options over the assessment period is appropriately captured, and that all options have their costs and benefits assessed over a consistent period, irrespective of option type, technology or asset life. The terminal values will be calculated based on the undepreciated value of capital costs at the end of the analysis period and expected operating and maintenance cost for the remaining asset life.

At the time of producing the PADR, we would adopt the central scenario discount rate in AEMO's latest Input Assumptions and Scenarios Report (IASR) (currently 5.5 per cent per the latest 2021 IASR). We will also undertake a sensitivity analysis on the discount rates using a lower bound that reflects the pre-tax real WACC in the AER's latest final decision for a transmission business in the NEM (currently 2.3 per cent),[44] and an upper bound that reflects the upper bound scenario discount rate in AEMO's latest IASR (currently 7.5 per cent per the latest 2021 IASR). The discount rates presented here will be updated to reflect any more recent IASR and AER determination that is published prior to the PADR.

6.3. Approach to estimating option costs

The initial cost estimates presented in this PSCR are subjected to change following further analysis. It is intended that cost estimates will be further refined at the PADR stage, and this process may be informed by submissions received from this PSCR. We estimate our cost estimates to be within +/- 25 per cent of the

[44] The lower bound discount rate is based on the WACC (pre-tax, real) in the most recent final decision for a TNSP revenue determination which was Powerlink in April 2022. *AER Powerlink Transmission Determination 2022-27 PTRM*

actual cost at the PADR stage. We will undertake sensitivity analysis on this range of capital costs in the PADR.

Initial routine operating and maintenance cost estimates have been estimated at one per cent of the capital expenditure. These costs will also be refined during the PADR stage to reflect what would be incurred under each option.

6.4. Wholesale market modelling will be based on the latest AEMO IASR assumptions

We note the importance of ensuring that the outcome of this RIT-T assessment is robust to different assumptions about how the energy sector may develop in the future. Network investments are long-lived assets, and it is important that the market benefits associated with these investments do not depend on a narrow view of potential future outcomes, given that the future is uncertain.

We are intending to model the market benefits of the credible options across different scenarios using wholesale market modelling. These scenarios will be based on those consulted on and summarised in the 2021 IASR released by AEMO in July 2021 (and used in the 2022 ISP) and will reflect a sufficiently broad range of potential outcomes across the key uncertainties that are expected to affect the future market benefits of the investment options being considered.

We acknowledge that AEMO's 2023 IASR may be released while this RIT-T is undertaken and we intend to base the RIT-T market modelling against the latest assumptions.

6.5. We will also conduct sensitivity analyses

In addition to the scenario analysis, we will also carry out sensitivity analyses on the results of the most likely scenario to determine whether or not the outcome of the RIT-T will change, and if so, the extent of this change. This involves carrying out a threshold analysis for network capex and discount rate sensitivities to identify the extent to which the level of network capex and discount rate estimates need to change, to be able to affect the RIT-T outcome.

Given the recent commitment by State Energy Ministers to include an emissions objective in the National Electricity Objective, we also propose to consider the sensitivity of the results if the greenhouse gas emissions implications of each option are taken into account. The inclusion of an emissions objective will naturally involve trade-offs, requiring a weighing up of the emissions objective along with price, reliability, safety and security. It is unclear at this stage how the emissions objective will be implemented, and therefore how the trade-offs will be weighed up. In light of this, we are currently examining how we might estimate and value the costs of greenhouse gas emissions associated with each option as well as how we would account for this in the RIT-T.

6.6. We will provide transparency on the drivers for the timing of the proposed investments

We will outline the factors driving the timing of investments for each of our options in our RIT-T. For example, the timing of the proposed investments could also relate to the inflexible timings inherent to the end-to-end process of designing, manufacturing, and constructing the network solution i.e., synchronous condensers.

We will investigate how the timing of the proposed investments for each option would be impacted by changes in the parameters for each scenario e.g., differences in capex spend.

Appendix A Compliance checklist

This appendix sets out a checklist which demonstrates the compliance of this PSCR with the requirements of the National Electricity Rules version 192.

Rules clause	Summary of requirements	Relevant section
5.16.4 (b)	A RIT-T proponent must prepare a report (the project specification consultation report), which must include:	–
	(1) a description of the identified need;	2
	(2) the assumptions used in identifying the identified need (including, in the case of proposed reliability corrective action, why the RIT-T proponent considers reliability corrective action is necessary);	2
	(3) the technical characteristics of the identified need that a non-network option would be required to deliver, such as: (i) the size of load reduction or additional supply; (ii) location; and (iii) operating profile;	4
	(4) if applicable, reference to any discussion on the description of the identified need or the credible options in respect of that identified need in the most recent Integrated System Plan;	1
	(5) a description of all credible options of which the RIT-T proponent is aware that address the identified need, which may include, without limitation, alternative transmission options, interconnectors, generation, system strength services, demand side management, market network services or other network options;	3
	(6) for each credible option identified in accordance with subparagraph (5), information about: (i) the technical characteristics of the credible option; (ii) whether the credible option is reasonably likely to have a material inter-network impact; (iii) the classes of market benefits that the RIT-T proponent considers are likely not to be material in accordance with clause 5.15A.2(b)(6), together with reasons of why the RIT-T proponent considers that these classes of market benefits are not likely to be material; (iv) the estimated construction timetable and commissioning date; and (v) to the extent practicable, the total indicative capital and operating and maintenance costs.	3 & 5