AEMO
AUSTRALIAN ENERGY MARKET OPERATOR
Victorian Planning

Victorian System Strength Requirement

July 2023

Regulatory Investment Test for Transmission

Project Specification Consultation Report

Important notice

Purpose

AEMO has prepared this Project Specification Consultation Report in accordance with clause 5.16 of the National Electricity Rules to, among other things, provide information about certain network limitations and potential options to address these limitations.

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Executive summary

The National Electricity Market (NEM) is changing rapidly. The integration of renewable generation continues to shift the geography and technical characteristics of supply, while an ageing fleet of coal-fired generators will progressively withdraw from the market over the coming decades. This has resulted in challenges managing system strength on the network.

In response to these challenges, the Australian Energy Market Commission (AEMC) in October 2021 made its final rule determination on Efficient Management of System Strength on the Power System[1]. This new system strength framework is intended to ensure power system security and enable a more rapid connection of inverter-based resources (IBR) such as solar and wind, with solutions that achieve economies of scale.

Under this framework, which comes into effect on 2 December 2022, AEMO Victorian Planning (AVP) is responsible for proactive provision of system strength services, as the System Strength Service Provider (SSSP) for Victoria, to ensure power system stability and to facilitate efficient generator and storage connections as set out in the 10-year forecast provided in the most recent System Strength Report[2]. AEMO (in its role as the national transmission planner) published the first System Strength Report in December 2022 under the evolved framework that defines the system strength requirements for Victoria over a 10-year outlook period.

Regulatory investment test for transmission (RIT-T)

The RIT-T is an economic cost-benefit test used to assess and rank different options that address an identified need. Its purpose is to identify the investment option that maximises the net economic benefit to all those who produce, consume and transport electricity in the market.

AVP is undertaking this RIT-T as a “reliability corrective action” as the considered options are to enable AVP to meet regulatory obligations and standards (National Electricity Rules (NER) S5.1.14). As such, the preferred option is permitted to have a negative net economic benefit.

This Project Specification Consultation Report (PSCR) is the first stage of the RIT-T process, and includes:

- A description of the identified need.
- A description of the credible options being considered to meet the identified need.
- The technical characteristics and performance requirements that a non-network option would need to deliver to meet the identified need.
- A discussion of specific categories of market benefit and their applicability to this RIT-T

Identified need for investment

The identified need is for sufficient system strength services to ensure the system strength standard as per NER S5.1.14 is met for both forecast minimum and efficient levels at each of the Victorian system strength nodes from 2 December 2025 onwards.

[1] AEMC, Efficient management of system strength on the power system, at https://www.aemc.gov.au/rule-changes/efficient-management-system-strength-power-system.

[2] AEMO, 2022 System Strength Report, at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/operability/2022/2022-system-strength-report.pdf?la=en.

AVP (subject to S5.1.14(b)(1) and (2)) is required to use reasonable endeavours to procure sufficient system strength services (network and/or non-network) to ensure minimum three phase fault level requirements are met in full at all times of the year. Additionally, system strength services are to be procured to ensure stable voltage waveform to allow for the connection and operation of forecast efficient level IBR.

Credible options

Through this RIT-T, AVP is considering various options to address the identified need. The recommended solution will be required to address the identified need and maximise net economic benefits (or minimise net economic cost to all those who produce, consume and transport electricity in the NEM.

Due to timing constraints[3], AVP does not consider network solutions alone to be a credible option to meet the system strength standard, at least by December 2025. As such, credible options for this RIT-T assessment are a portfolio of network and non-network options. It is expected that non-network system strength services will be procured to meet the system strength standard from December 2025. Subject to the submissions received under the Request for Information (RFI) process, it is expected both non-network and network options will be considered at the appropriate location and appropriate timing to meet the system strength standard in future.

AVP has identified that the equivalent network solution of synchronous condensers to meet the system strength standard is as shown in Table 1.

Table 1 Equivalent network solution to meet the system strength standard

System strength node	Equivalent network solution	Timing
Hazelwood	5 x 250 megavolt amperes reactive (MVAr) synchronous condensers	From December 2025 ongoing
Moorabool	1 x 250 MVAr synchronous condenser	From December 2025 ongoing
	2 x additional 250 MVAr synchronous condensers	From 2030 ongoing
Red Cliffs	1 x 125 MVAr synchronous condenser	From December 2025 to the commissioning of Project Energy Connect (PEC) Stage 2
	1 x 250 MVAr synchronous condenser	From 2032 ongoing

A. Timing is expected to align with Victoria – New South Wales Interconnector West (VNI West).

The size and location of the synchronous condensers are intended to be a guide for any equivalent non-network options.

As well as being critical in meeting the system strength standard in the short term (given the timing constraints for network solutions noted above), AVP expects non-network options to continue to be a major contributor in meeting the long-term system strength requirements beyond 2025.

Non-network options can be (but are not limited to):

- Synchronous machine – synchronous condensers and synchronous generators such as coal, gas and hydro that are capable of providing system strength services when dispatched in the energy market as quantified in the current Victorian system strength minimum generator combinations for a secure state[4].
- Modification to existing synchronous generators – synchronous generators may either be able to dynamically switch between operation as a synchronous condenser and operation as a generator, or to permanently

[3] NER 5.15.2(a)(3) requires a credible option to be implemented in sufficient time to meet the identified need.

[4] AEMO, April 2023 Transfer Limit Advice – System Strength in SA and Victoria https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/transfer-limit-advice-system-strength.pdf

convert from operation as a generator to operation as a synchronous condenser where hybrid operation is not feasible. The Australian Renewable Energy Agency (ARENA) has published a paper exploring the feasibility and technical challenges of converting synchronous generators into synchronous condensers. The paper was written in collaboration with AEMO, transmission network service providers (TNSPs), original equipment manufacturers (OEMs) and generators[5].

- Grid-forming batteries, generators, static VAR compensators (SVCs) and STATCOMs – grid-forming inverters, when appropriately tuned and configured, may be capable of providing system strength services to support IBR. AEMO as part of its Engineering Framework has published a voluntary standard for grid-forming inverters outlining the core technical capabilities which power electronic devices should have to be categorised as grid-forming inverters[6].

Potential benefits

To satisfy the RIT-T, the preferred option must maximise net market benefits (or minimise net cost) to all those who produce, consume and transport electricity in the market. AVP will consider the appropriateness of the following classes of market benefits for inclusion in the RIT-T:

- Changes in fuel consumption arising through different patterns of generation dispatch.
- Changes in voluntary load curtailment and involuntary load shedding.
- Changes in costs to other parties due to differences in the timing of new plant, differences in capital costs and differences in operational and maintenance costs.
- Differences in the timing of transmission investment.
- Changes in network losses.
- Option value benefit.

In addition, options may provide market benefits beyond the identified need, such as voltage support and inertia which may be considered in this RIT-T.

Next steps

The second stage of the RIT-T process is a full options analysis, followed by publication of a Project Assessment Draft Report (PADR) in accordance with clause 5.16.4 of the NER. The recommended preferred option may be a combination of network and non-network options. The third and final stage of the RIT-T process, the Project Assessment Conclusions Report (PACR), will make a conclusion on the preferred option.

AVP welcomes written submission on this PSCR. All feedback will be considered and will help refine the proposed preferred option to be published in the PADR.

Submissions are due on 6 October 2023 and should be emailed to SystemStrengthVIC@aemo.com.au.

[5] ARENA, Repurposing Existing Generators as Synchronous Condensers, at https://arena.gov.au/assets/2023/06/repurposing-existing-generators-as-synchronous-condensers-report.pdf.

[6] AEMO, May 2023, Voluntary Specification for Grid-forming Inverters, at https://aemo.com.au/-/media/files/initiatives/primary-frequency-response/2023/gfm-voluntary-spec.pdf?la=en&hash=F8D999025BBC565E86F3B0E19E40A08E#:~:text=This%20%E2%80%98voluntary%20specification%E2%80%99%20is%20a%20preliminary%20document%20to,in%20order%20to%20be%20categorised%20as%20grid-forming%20inverters.

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

AVP is also undertaking a RFI for non-network proponents to assist in meeting the system strength requirements as set out in this PSCR. The closing date for the RFI is 6 October 2023 and submissions to the RFI process will not be published on AEMO's website. However, certain pricing, size, technology and locational information submitted by respondents may need to be used by AVP in the PADR and PACR. As there are no credible network solutions available to meet the system strength standard as soon as December 2025, non-network options will be critical towards meeting the system strength standard. AVP strongly encourages all interested non-network proponents to make submissions to the RFI to ensure that a comprehensive suite of options are considered in the PADR to meet the system strength standard.

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1 Introduction

This Project Specification Consultation Report (PSCR) has been prepared in accordance with the requirements of clause 5.16 of the National Electricity Rules (NER), for a Regulatory Investment Test for Transmission (RIT-T).

In line with these requirements, this PSCR describes:

1. The identified need that AVP is seeking to address, and the assumptions used in identifying the need.
2. The technical characteristics that a non-network option would be required to deliver to meet the identified need.
3. All credible options that AVP is aware of that can meet the identified need.
4. The classes of market benefit that are likely not to be material.

The next stage of the RIT-T process is a full option analysis and publication of the Project Assessment Draft Report (PADR) for consultation, in accordance with the requirements of clause 5.16.4 of NER.

The PADR will include information on the proposed preferred option that maximises net market benefits, details on its technical characteristics, estimated implementation date, and analysis showing that the proposed preferred option satisfies the RIT-T.

The third and final stage of the RIT-T process, the Project Assessment Conclusions Report (PACR), will make a conclusion on the preferred option taking into consideration feedback received on the proposed preferred option presented in the PADR.

2 Identified need

2.1 Background

The power system is undergoing a transformational change, with an unprecedented increase in renewable generation, changes in consumption patterns, and the withdrawal of several existing conventional generation sources across the National Electricity Market (NEM). As the power system makes this transition, new sources of system strength will be required to maintain power system security. The provision of system strength services will also need to be diversified from the La Trobe Valley (where most system strength is provided today) to support the forecast distribution of large-scale wind, solar and battery storage connections across all of Victoria.

Power system security is the power system's capacity to continue operating within defined technical limits even if a major power system element, like a large generator or a major customer, disconnects from the system. To maintain power system security, a minimum level of system services like inertia, frequency control and system strength is required.

System strength is the ability of the power system to maintain a stable voltage waveform at any given location in the power system, both during steady state operation and following a disturbance. System strength has traditionally been provided by synchronous generation such as coal, gas-fired and hydro-electric power generation that is electromagnetically coupled to the power system. Inverter-based resources (IBR) – which include wind, large scale solar, and batteries – do not inherently provide system strength, and most existing IBR which use grid-following technology require adequate system strength for the inverters to work reliably.

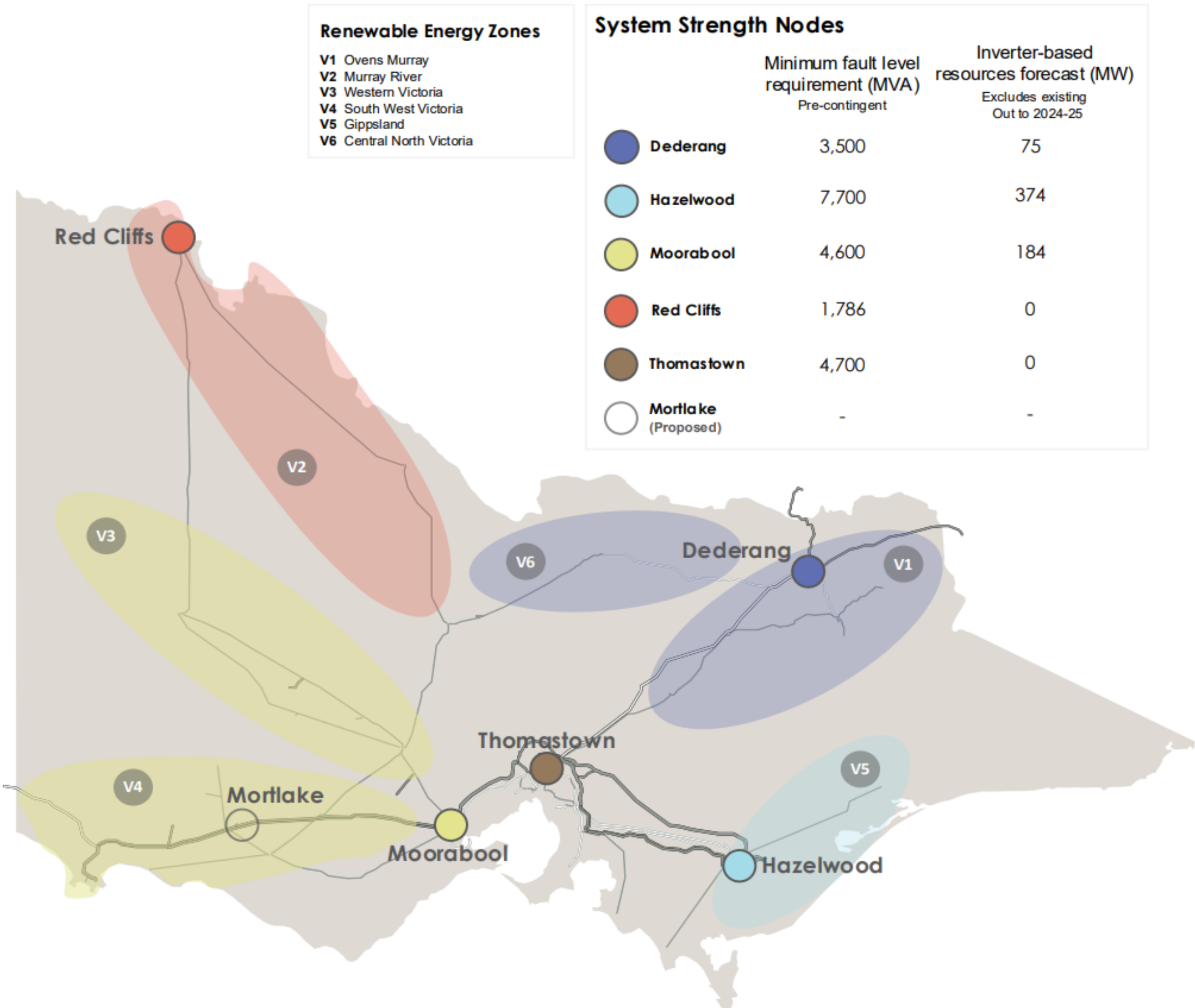
The transition from a power system with predominantly synchronous generation to a power system with high levels of IBR generation has introduced a need to replace the system strength provided by synchronous generators to ensure system security can be maintained, and allow IBR generation to work reliably.

In October 2021, the Australian Energy Market Commission (AEMC) made its final rule determination on Efficient Management of System Strength on the Power System. This new system strength framework consists of three components relating to the supply, demand and coordination of system strength, and introduces new obligations for System Strength Service Providers (SSSPs). AVP as the SSSP for Victoria is required to use reasonable endeavours to plan system strength services to meet the three-phase fault level requirement for a secure system under forecast future IBR connections for each system strength node. That is, AVP must plan to meet the current and future system strength need for Victoria.

The requirement will need to be met from 2 December 2025 as set out in the 10-year forecast provided in the most recent System Strength Report published in December 2022 by AEMO as the System Planner[7]. A total of five system strength nodes, as shown in Figure 1, have been declared in Victoria with a proposed system strength node at Mortlake being considered in future System Strength Reports.

[7] At https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/operability/2022/2022-system-strength-report.pdf?la=en.

Figure 1 System strength requirement outlook in 2025



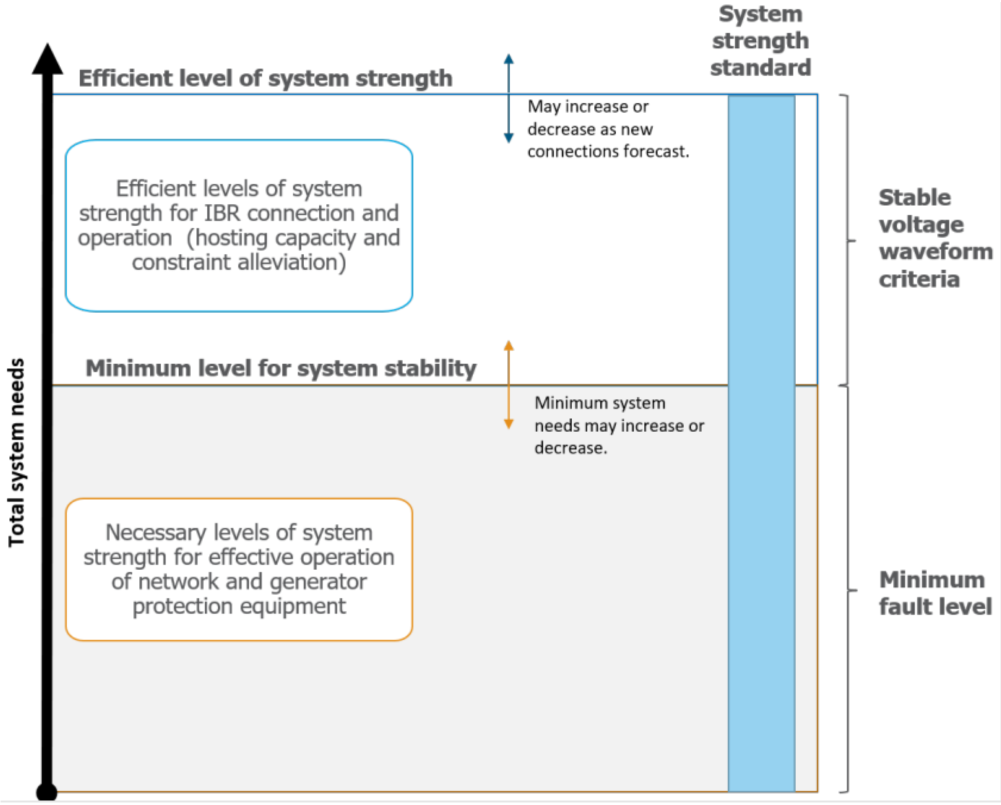
2.1.1 System strength standard

System strength can broadly be described as the ability of the power system to maintain a stable voltage waveform at any given location in the power system, both during steady state operation and following a disturbance.

Under the new framework, the SSSP must meet the new power system standard for system strength as shown in Figure 2, comprising:

- A minimum three phase fault level requirement for power system security at each system strength node.
- A requirement for stable voltage waveforms at connection points to host levels of IBR forecast by AEMO (as the national transmission planner), also known as the efficient level of system strength, at each system strength node.

Figure 2 System strength standard



Source: AEMC National Electricity Amendment (Efficient Management Of System Strength On The Power System) Rule 2021 Final Determination.

NER S5.1a.9 outlines the standard, which sets a minimum three phase fault level requirement for power system security (expressed in megavolt amperes (MVA)), sufficient to enable:

- correct operation of protection systems of networks and Network Users (both transmission and distribution);
- stable voltage control systems; and
- the power system to remain stable following any credible contingency event or protected event.

Further to that, NER S5.1a.9 also outlines the requirement for stable voltage waveforms at connection points (also known as the efficient level of system strength) as part of the standard, such that:

- 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.

The System Strength Requirements Methodology provides further description of a stable voltage waveform based on four criteria. It should be noted that the description is not intended to characterise the behaviour of IBR during a fault. Rather, it attempts to describe criteria to achieve stable voltage waveform conditions under which IBR can operate without difficulty. In addition, this description is designed to facilitate a shift away from considering voltage waveform stability largely as an outcome of fault level contribution. The four criteria are:

- **Voltage magnitude** – the positive-sequence root mean square (RMS) voltage magnitude at a connection point does not violate the limits pertaining to voltage excursions, and the permissible voltage step change created by reactive power injection or absorption.

- **Change in voltage phase angle** – change in the steady-state RMS voltage phase angle at a connection point should not be excessive following injection or absorption of active power. A value between 30 and 60 electrical degrees could be used as a reasonable threshold to measure the steady-state change in voltage phase angle following active power injection or absorption at a connection point, noting this is not a hard limit.
- **Voltage waveform distortion** – the three-phase instantaneous voltage waveform distortion at a connection point should not exceed acceptable planning levels for pre-and post-contingent conditions. This can be assessed with reference to NER Schedule 5.1a, and acceptable voltage waveform distortion should be consistent with NER S5.1a.6.
- **Voltage oscillations** – any undamped steady-state RMS voltage oscillations anywhere in the power system should not exceed an acceptable planning threshold. A proposed planning threshold for acceptable oscillations of up to 0.5% peak-peak RMS voltage is being considered.

2.1.2 Operational Security Mechanism

AEMC is currently consulting on the Operational Security Mechanism (OSM) rule change[8]. The rule change is intended to address two issues:

- The regular use of interventions to ensure the system is secure as IBR connect and thermal generation exits the system. This regular use leads to inefficiencies and reduces the effectiveness of the interventions framework.
- A need to ensure the future requirements of the power system are met by providing incentives for new entrants and existing participants to make investment decisions that would see system security provided in the longer term.

The AEMC has changed approach from its draft determination, noting a simpler and more timely solution is required. The AEMC will release a directions paper in mid-2023[9] with a proposed solution addressing the issues raised above that involves building on existing tools to allow direct procurement of assets to provide system security quickly and easily.

At present, AVP does not expect this RIT-T will be impacted by OSM, but any contract procuring a system strength service will need to accommodate the introduction of such a mechanism.

2.2 Description of the identified need

The identified need considered by this RIT-T is the provision of minimum and efficient levels of system strength as forecast by AEMO (as the national transmission planner) at each of the Victorian system strength nodes from 2 December 2025 into the future, as per NER S5.1.14.

AVP as the Victorian SSSP is undertaking this RIT-T as a “reliability corrective action”[10] to assess options to ensure that NER requirements are met. A “reliability corrective action” allows for the identified credible option to minimise net economic cost while meeting the standard.

[8] AEMC, Operational Security Mechanism, at https://www.aemc.gov.au/rule-changes/operational-security-mechanism.

[9] AEMC, Forward Direction Note, at https://www.aemc.gov.au/sites/default/files/2023-05/Forward%20direction%20note.pdf.

[10] NER 5.10.2

System strength services considered in this RIT-T may also be capable of providing other services such as inertia and reactive support. Any additional needs which can be met by options considered in this RIT-T will be considered in the net benefits of each option.

2.3 Assumptions made in identifying the need

2.3.1 Minimum three phase fault level

The 2022 System Strength Report specifies the pre-contingent and post-contingent minimum three phase fault level at each system strength node as shown in Table 2 that has to be met at all times of the year starting 2 December 2025. These requirements are unchanged across the 10-year forecast.

Table 2 Victorian minimum three phase fault level requirement (MVA)

System strength node and voltage	Pre-contingency fault level requirement (MVA)	Post-contingency fault level requirement (MVA)
Dederang 220 kilovolts (kV)	3,500	3,300
Hazelwood 500 kV	7,700	7,150
Moorabool 220 kV	4,600	4,050
Red Cliffs 220 kV	1,786	1,036
Thomastown 220 kV	4,700	4,500

2.3.2 Efficient level

The 2022 System Strength Report specifies efficient levels of system strength to support forecast IBR generation. This forecast is subject to the assumed delivery and timing of transmission augmentations set out in Appendix A1.2 of the 2022 System Strength Report, including delivery of Victoria – New South Wales Interconnector West (VNI West) in 2032[11].

Table 3 summarises the modified forecast IBR generation at each system strength node with recent generation commitments subtracted from the relevant system strength node and technology type.

Table 3 AEMO System Strength Report 2022 – modified forecast IBR generation (MW)

System strength node	2025	2026	2027	2028	2029	2030	2031	2032	2033
Moorabool	0	0	92	92	92	153	944	1,456	1,556
Hazelwood	374	394	394	394	833	1,482	2,001	2,001	2,001
Dederang	0	0	0	0	0	0	0	264	264
Red Cliffs	0	0	0	0	0	0	0	354	1,437
Thomastown	0	0	0	0	0	0	0	0	0

A further breakdown by IBR type is shown in Table 4.

[11] It is expected that the timing of solar planting at Red Cliffs in the IBR forecast may change if VNI West is delivered prior to 2032. If an earlier VNI West timing, or any further changes, are adopted in future System Strength Reports, the impact on system strength requirements will be reflected in the RIT-T process.

Table 4 AEMO System Strength Report 2022 – forecast IBR generation by type (MW)

System strength node	Technology	Forecast IBR (MW)										
		Financial year ending										
		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Moorabool	Solar	0	0	0	0	0	0	0	0	0	0	0
	Wind	0	0	0	0	92	92	92	153	358	870	970
	Battery	0	0	0	0	0	0	0	0	586	586	586
	Total IBR	**0**	**0**	**0**	**0**	**92**	**92**	**92**	**153**	**944**	**1,456**	**1,556**
Hazelwood	Solar	0	0	0	0	0	0	0	0	0	0	0
	Wind	0	0	374	394	394	394	833	1482	2001	2001	2001
	Battery	0	0	0	0	0	0	0	0	0	0	0
	Total IBR	**0**	**0**	**374**	**394**	**394**	**394**	**833**	**1,482**	**2,001**	**2,001**	**2,001**
Dederang	Solar	0	0	0	0	0	0	0	0	0	0	0
	Wind	0	0	0	0	0	0	0	0	0	264	264
	Battery	0	0	0	0	0	0	0	0	0	0	0
	Total IBR	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**264**	**264**
Red Cliffs	Solar	0	0	0	0	0	0	0	0	0	354	1437
	Wind	0	0	0	0	0	0	0	0	0	0	0
	Battery	0	0	0	0	0	0	0	0	0	0	0
	Total IBR	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**354**	**1,437**
Thomastown	Solar	0	0	0	0	0	0	0	0	0	0	0
	Wind	0	0	0	0	0	0	0	0	0	0	0
	Battery	0	0	0	0	0	0	0	0	0	0	0
	Total IBR	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Forecast IBR generation in megawatts does not readily translate into a network metric to indicate possible system strength service requirement at the nodes. There are many factors which can impact the four criteria of stable voltage waveform. Stable voltage waveform can be enabled not only by well-known and understood solutions such as synchronous units but also by newer technologies like grid-forming inverters.

As an initial assessment for the PSCR, Available Fault Level (AFL) as outlined in the System Strength Impact Assessment Guideline[12] (SSIAG) has been used as a proxy metric in identifying the need for future system strength services to ensure stable voltage waveform with forecast IBR generation.

AVP has undertaken an AFL assessment with forecast IBR distributed within the renewable energy zones (REZs) to determine efficient and effective planting of system strength services for the associated system strength nodes and the wider system as a whole.

The values presented in Table 5 indicate the estimated additional fault level required to support the forecast IBR. The additional fault level requirement is provided as a guide highlighting emerging system strength risks rather than a firm requirement in ensuring stable voltage waveform for forecast new IBR. Therefore, system strength services may not need to provide substantial fault level, nor be located directly at the locations indicated. While

[12] AEMO System Strength Impact Assessment Guidelines V2, at https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/ssrmiag/final-report/system-strength-impact-assessment-guideline_v2.pdf.

Mortlake is not currently declared as a system strength node, AVP has identified the additional fault level required at Mortlake terminal station to support forecast IBR connection as part of the Moorabool system strength node.

Table 5 Estimated additional fault level required following a critical contingency to ensure stable voltage waveform for forecast new IBR connection (MVA)

System strength node	Location	2030	2031	2032	2033
Moorabool	Mortlake 500 kV Terminal Station	0	0	100	200
	Bulgana 500 kV Terminal Station	100	300	1,750	2,800
Hazelwood	Hazelwood 500 kV Terminal Station	300	1,300	1,350	1,500
Red Cliffs	New 220 kV terminal station near Kerang	0	0	0	1,900

A: The locations in Table 5 are indicative only.
B: New terminal station established as part of VNI West.

The Victorian Government has invested in two system strength projects (Koorangie Battery Energy Storage System (BESS) and Ararat Synchronous Condenser) as part of Stage 1 of the REZ Development Plan in the Murray River and Western Victoria REZs. These projects have been made available to meet Victoria's system strength requirement, which has reduced the need for additional system strength services in Victoria to support the forecast new IBR. The additional required fault level noted in Table 5 reflects the need for additional system strength services after considering both the contribution of these two system strength projects and contribution from units providing the minimum fault level requirements.

3 Potential credible options to address the need

AVP has identified that system strength services equivalent to six 250 MVA synchronous condensers are required in Victoria on an ongoing basis from December 2025 to meet the minimum fault level requirement. This ongoing requirement grows from six to nine 250 MVA synchronous condensers (or equivalent) to support forecast efficient IBR by 2033[13]. Additionally, a temporary system strength service is required at Red Cliffs from December 2025 until Project Energy Connect Stage 2 commissioning (currently anticipated in July 2026)[14].

AVP has determined that synchronous condensers are the only credible network option to meet the need for minimum and efficient system strength. Due to challenging supply conditions, AVP has estimated a three-year lead time for delivery of synchronous condensers, from an order being placed to completion of commissioning. Allowing time to complete this RIT-T before an order may be placed, it is estimated that network options can feasibly be implemented to meet the identified need from early 2028, noting this will be tested through any subsequent procurement process.

As such, AVP has identified that credible options will need to be a portfolio of both network and non-network options. It is expected that non-network system strength services will be procured to meet the system strength standard from December 2025. Subject to the submissions received under the RFI process, it is expected both network and non-network options will be considered at the appropriate location and appropriate timing to meet the system strength standard in the longer term.

3.1 Options to meet the minimum fault level

AVP has undertaken analysis which identifies that the following synchronous condensers, or equivalent services capable of providing three phase fault level, would be required to ensure minimum three phase fault level requirements are met. The analysis anticipates that neighbouring jurisdictions will meet their respective minimum fault level requirements.

Table 6 Synchronous condensers or equivalent services to meet the minimum fault level

System strength node	Synchronous condensers or equivalent services	Timing
Hazelwood	5 x 250 megavolt amperes reactive (MVAr) synchronous condensers	From December 2025 ongoing
Moorabool	1 x 250 MVAr synchronous condenser	From December 2025 ongoing
Red Cliffs	1 x 125 MVAr synchronous condenser	From December 2025 to the commissioning of Project Energy Connect (PEC) Stage 2 in July 2026

[13] Six to nine synchronous condensers required not inclusive of the Victorian Government system strength projects.

[14] Consistent with the *Integrated System Plan* (ISP), this is when full capacity is expected to be available following commissioning and testing.

The need for system strength services outlined in Table 6 can be met by a combination of new synchronous condensers at the specified locations, and non-network options subject to submissions received under the RFI process.

Hazelwood

It is estimated that new synchronous condensers installed to meet the need at Hazelwood would need to be spread across both Hazelwood Terminal Station 500 kilovolts (kV) and Hazelwood Power Station 220 kV (or other nearby locations) due to space constraints at Hazelwood Terminal Station 500 kV. These space constraints may be further affected by future transmission and generator connections at Hazelwood, such as Marinus Link.

Moorabool

New synchronous condensers to meet the need at Moorabool are expected to be best placed on the 500 kV side of Moorabool Terminal Station to also better support future IBR at the Moorabool system strength node.

Red Cliffs

Prior to the commissioning of synchronous condensers as part of Project Energy Connect Stage 2, there is a temporary requirement for the equivalent of one 125 MVA synchronous condenser at the Red Cliffs system strength node. AVP does not expect that installation of new synchronous condensers will be an efficient option to meet the need at Red Cliffs, as this need is only temporary, nor would it be credible given current lead times for synchronous condensers. It is anticipated that non-network options will be the most efficient solution to meet this temporary need. As the Red Cliffs system strength node is in close proximity to the New South Wales system strength node at Buronga (which also comes into effect on 2 December 2025), it is anticipated that joint planning will be undertaken to address the temporary need for system strength services prior to Project Energy Connect Stage 2's completion.

The estimated capital cost of providing six synchronous condensers at Hazelwood and Moorabool is $823 million. Indicative class 5A (+- 30%) capital cost estimates for synchronous condensers have been developed with reference to the 2023 Transmission Cost Database[15], with more accurate figures expected based on information received in the RFI to be used for the cost-benefit analysis in the PADR. Operating and maintenance costs are estimated as 1% of the capital costs, but this will be reviewed as part of the PADR based on information received in the RFI.

3.2 Options to meet the efficient level

AVP has undertaken analysis that identifies that the following system strength services (or equivalent) would be required, in addition to the minimum fault level services outlined in Table 6, to ensure efficient system strength requirements are met. This analysis has assumed no additional system strength services from neighbouring jurisdictions[16].

[15] AEMO, 2023 Transmission Expansion Options Report Consultation, at https://aemo.com.au/consultations/current-and-closed-consultations/2023-transmission-expansion-options-report-consultation.

[16] Contributions from synchronous condensers installed in New South Wales at Buronga 330 kV and Dinawan 330 kV as part of Project Energy Connect have been included, because these services are located on the Victoria/New South Wales border where their contribution towards stable voltage waveform is significant.

Table 7 Efficient level synchronous condensers or equivalent

Location	System strength node	Proposed options	Timing
Moorabool Terminal Station 500 kV	Moorabool	1 x 250 MVAr synchronous condenser	From 2030
Bulgana Terminal Station 500 kV	Moorabool	1 x 250 MVAr synchronous condenser	From 2030
New proposed terminal station near Kerang 220 kV	Red Cliffs	1 x 250 MVAr synchronous condenser	From 2032[A]

A. Timing is expected to align with completion of VNI West.

The estimated capital cost of providing the three synchronous condensers in Table 7 is $406 million. Indicative class 5A (+- 30%) capital cost estimates for synchronous condensers have been provided, with more accurate figures expected to be used for the cost-benefit analysis in the PADR. Operating and maintenance costs are estimated as 1% of the capital costs.

Table 7 outlines potential locations for system strength services to support efficient forecast IBR, but the precise location, quantity and timing of future system strength services are all subject to uncertainty as the network changes, new technologies are explored, and generation connection location varies.

System strength services are expected to be deployed at locations that are found to be more effective in ensuring stable voltage waveform; that is, it may not be located at the system strength node but in close proximity to new generation. AVP anticipates the RIT-T will include appropriate triggers for system strength services required to facilitate efficient level of IBR beyond 2030, noting that the efficient level forecasts will continue to evolve during this RIT-T and beyond.

As the efficient level of IBR forecast is distributed in similar quantities across the various REZs in Victoria (V2 Murray River, V3 Western Victoria, V4 South-west Victoria and V5 Gippsland), the provision of system strength services will need to be diversified from the La Trobe Valley to support the forecast distribution of IBR connections across all of Victoria. Thus, AVP has identified the need for more system strength services for the Moorabool and Red Cliffs system strength node to support the generation in the west and north-west of Victoria, in addition to the concentration of system strength services at Hazelwood shown in Table 6 to address the minimum fault level requirement.

The synchronous condensers at the new terminal station near Kerang, proposed as part of VNI West, are required to support 1.4 gigawatts (GW) of the System Strength Report's forecast IBR at the Red Cliffs system strength node by 2033. This forecast IBR uses additional network capacity unlocked by VNI West. Therefore, AVP is actively investigating the possibility for the 400 megavolt amperes reactive (MVAr) dynamic reactive compensation at the proposed new 220 kV terminal station near Kerang identified in the VNI West RIT-T Project Assessment Conclusions Report[17] preferred option to be met with at least one synchronous condenser instead of other options like static VAR compensators (SVCs). This will align the deployment of the system strength service with the potential connection of new IBR unlocked by VNI West, minimising the risk of misalignment should VNI West be built earlier.

3.3 Non-network options

Non-network options must be capable of addressing, in part or full, the minimum fault level requirements and/or supporting stable voltage waveform for forecast IBR at the various system strength nodes. The size and location

[17] At https://aemo.com.au/initiatives/major-programs/vni-west/reports-and-project-updates.

of the synchronous condensers outlined in Table 6 and Table 7 are intended to be a guide for equivalent non-network options.

Examples of non-network options are:

- Synchronous machines – synchronous condensers and synchronous generators such as coal, gas and hydro are capable of providing system strength services when dispatched, as quantified in the current Victorian system strength minimum generator combinations for a secure state[18].
- Modification to existing synchronous generators – synchronous generators may either be able to dynamically switch between operation as a synchronous condenser and operation as a generator, or to permanently convert from operation as a generator to operation as a synchronous condenser where hybrid operation is not feasible. The Australian Renewable Energy Agency (ARENA) has published a paper exploring the feasibility and technical challenges of converting synchronous generators into synchronous condensers. The paper was written in collaboration with AEMO, transmission network service providers (TNSPs), original equipment manufacturers (OEMs) and generators[19].
- Grid-forming batteries, generators, SVCs and STATCOMs – grid-forming inverters, when appropriately tuned and configured, may be capable of providing system strength services. AEMO as part of its Engineering framework has published a voluntary standard for grid-forming inverters outlining the core technical capabilities which power electronic devices should have to be categorised as grid-forming inverters[20].

3.3.1 Information to be provided by proponents of a non-network option

The above is not an exhaustive list of potential non-network services. AVP welcomes all non-network service providers to make submissions via the RFI process on potential non-network options they believe can help address the identified need outlined in this PSCR.

3.3.2 Availability

Non-network options are expected to be an integral part of the portfolio of system strength services to meet the system strength standard. The standard must be met at each system strength node at all times of the year, from 2 December 2025 onwards. AVP will be seeking individual system strength services with high availability (> 95%) to form the bulk of the portfolio of system strength services. AVP also greatly values the service's flexibility to co-ordinate planned outages. The individual services procured must have sufficient availability and flexibility to co-ordinate planned outages to allow the portfolio of system strength services to meet system strength standard at all times.

3.3.3 Technical requirement

The non-network options must:

- be capable of operating continuously during contracted periods at the contracted capability;

[18] AEMO, April 2023 Transfer Limit Advice – System Strength in SA and Victoria, at https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/transfer-limit-advice-system-strength.pdf.

[19] ARENA, Repurposing Existing Generators as Synchronous Condensers, at https://arena.gov.au/assets/2023/06/repurposing-existing-generators-as-synchronous-condensers-report.pdf.

[20] AEMO, May 2023, Voluntary Specification for Grid-forming Inverters, at https://aemo.com.au/-/media/files/initiatives/primary-frequency-response/2023/gfm-voluntary-spec.pdf?la=en&hash=F8D999025BBC565E86F3B0E19E40A08E#:~:text=This%20%E2%80% 98voluntary%20specification%E2%80%99%20is%20a%20preliminary%20document%20to,in%20order%20to%20be%20categorised%20as%20grid-forming%20inverters.

- be capable of operating continuously during and after a credible contingency;
- incorporate the capability to transmit 4-second SCADA signals to AEMO;
- provide a material positive system strength contribution, for example from solutions with a rated capacity greater than 50 MVA;
- comply with any relevant performance standards specified in the applicable connection agreement (whether or not registered with AEMO); and
- comply with any applicable requirements of the NER.

Further technical requirements are outlined in the RFI document.

3.3.4 Location

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

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 system strength need will provide a greater system strength contribution. Solutions may also contribute to meeting system strength requirements at more than one system strength node.

AVP is required to ensure that the system strength standard is met for both system normal and following a credible contingency or protected event. Therefore, AVP will consider the system strength service capability post network credible contingency in meeting both the minimum and efficient level of system strength for a system strength node and REZ.

3.3.5 Dispatch through the Operational Security Mechanism (OSM)

The AEMC is currently consulting on its OSM rule change. The OSM aims to provide a framework for scheduling of system strength services procured through this RIT-T. A forward directions note[21] was released in May 2023 indicating that the close-to-real-time market approach proposed in the draft determination would be costly and complex to implement, prompting a need for a more simple and timely solution.

The method of dispatching system strength services and the division of responsibility between AEMO and SSSPs is still subject to the final determination of the OSM rule change. AVP does not anticipate that the outcome of the OSM will materially impact the decision making of this RIT-T, however any system strength service will need to accommodate the introduction of such a mechanism.

A directions paper is expected to be released for the OSM rule change in mid-2023 with a final determination expected by the end of 2023. AVP will include provisions relevant to OSM and OSM-like mechanisms in any eventual procurement contract.

[21] AEMC, Update on the direction for the Operational Security Mechanism rule change, at https://www.aemc.gov.au/sites/default/files/2023-05/Forward%20direction%20note.pdf.

3.4 Material inter-network impact

AVP anticipates that the possible credible options may have a material inter-network impact. The NER glossary defines *material inter-network impact* 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."

AVP will undertake a screening test[22] to indicate that a transmission augmentation has no material inter-network impact. To be classified as no material inter-network impact, the augmentation will need to satisfy the following:

- a decrease in power transfer capability between transmission networks or in another TNSP's network of no more than the minimum of 3% of the maximum transfer capability and 50 megawatts (MW);
- an increase in power transfer capability between transmission networks or in another TNSP's network of no more than the minimum of 3% of the maximum transfer capability and 50 MW,
- an increase in fault level of no more 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

AVP expects the credible options identified will result in an increase in fault level by more than 10 MVA at any substation in another TNSP's network. The size of increase in fault level will depend on the submissions received, noting the number, size, technology type and location of the credible options (network and non-network). AVP will request an augmentation technical report from AEMO if necessary to assess the impact of the options and potential remediation required.

[22] Criteria for Assessing Material Inter-Network Impact of Transmission Augmentation https://aemo.com.au/-/media/files/electricity/nem/network_connections/transmission-and-distribution/170-0035-pdf.pdf

4 Materiality of market benefits

4.1 Classes of market benefit expected to be material to the RIT-T

The NER require that all classes of market benefits be considered as material in a RIT-T assessment unless the RIT-T proponent can demonstrate that:

- A specific class (or classes) of market benefit is unlikely to materially affect the outcome of the assessment of the credible options under the RIT-T.
- The cost of undertaking the analysis to quantify that benefit would likely be disproportionate to the "*scale, size and potential benefits of each credible option being considered in the report*".

AVP will consider the appropriateness of the classes of market benefits outlined below for inclusion in this RIT-T:

- Changes in fuel consumption arising through different patterns of generation dispatch.
  - Procurement of system strength services will result in changes to minimum generation combinations which may allow for better utilisation of lower-cost fuel sources.
- Changes in voluntary load curtailment and involuntary load shedding.
  - Procurement of system strength services will ensure sufficient system strength for efficient IBR to operate, which improves availability of supply at times of high demand and therefore helps meet reliability requirements. This is expected to reduce voluntary load curtailment and involuntary load shedding.
- Changes in costs to other parties due to differences in the timing of new plant, differences in capital costs and differences in operational and maintenance costs.
  - Procurement of system strength services unlocks IBR access to the NEM. This may avoid (or defer) the need for new investment to maintain the same level of reliability and dispatchable supply.
- Differences in the timing of transmission investment.
  - System strength services may provide inertia and voltage control which reduce the need for other investments.
  - System strength services may alleviate certain network limitations and may defer the need for transmission investment.
- Changes in network losses.
  - System strength services may increase network losses depending on its operational requirement, while new unlocked IBR will impact network losses as the flows from generation to load centre will change.
- Option value benefit.
  - Uncertainties in generation expansion and transmission development in other regions mean there is value in retaining flexibility to respond to new information as or when it emerges. The ability to roll out network and non-network solutions incrementally may provide option value benefits and would allow better management of uncertainty in generation and transmission development projections. The ability to design network solutions with optionality for scale-efficient expansion in future may also provide benefits.

Legislation is being drafted to introduce an emission reduction objective into the national energy objective[23]. AVP will continue to monitor the progress and potential impact the change will have on this RIT-T.

4.2 Classes of market benefit not expected to be material to the RIT-T

The following classes of market benefits are not likely to be material to this RIT-T assessment:

- Changes in ancillary services costs.
  - There is no expected material change to the costs of frequency control ancillary services (FCAS), and no expected change to network support and control ancillary services (NSCAS), and system restart ancillary services (SRAS) as a result of the augmentation options being considered. These costs are therefore not expected to be material to the outcome of the RIT-T assessment.
- Competition benefits.
  - This class of benefit is not expected to impact the ranking of options in this RIT-T and the cost of undertaking the analysis is considered disproportionate to any benefit.

[23] https://www.energy.gov.au/sites/default/files/2023-06/Incorporating%20an%20emissions%20reduction%20objective%20into%20the%20national%20energy%20objectives%20-%20Information%20Paper.pdf

5 Assessment approach

5.1 Base case

In the PADR, AVP will undertake assessment with a 'do nothing' base case consistent with the RIT-T Application Guidelines by comparing the base case against the costs and benefits of credible options to address the identified need. The base case will be consistent with the latest *Inputs, Assumptions and Scenarios Report* (IASR) and will consider actionable *Integrated System Plan* (ISP) projects.

AVP would not meet the system strength requirement under the base case. The base case reflects a state of the world in which AVP does not take any action to address the identified need, thus directions are issued to existing synchronous units to operate where possible to maintain system security. In the event of a lack of system strength due to insufficient availability to be directed of synchronous units or other system strength services, the network may become unstable, and experience reduced effectiveness of protection systems and generators not being able to remain connected, which would lead to major supply interruption[24].

The base case will act as a benchmark and provide a common reference point in the cost-benefit analysis when assessing the various credible options. It should be noted that some of the base case consequences described above may not be able to be captured within the market modelling, making the total costs of the base case look more favourable than in reality. However, for the purposes of comparing, contrasting and ranking credible options, this should not be an impediment as the RIT-T is being undertaken as a "reliability corrective action" and therefore the preferred option may have a negative net economic benefit (that is, a net economic cost), as long as the option maximises the net economic benefit while meeting the standard.

5.2 Analysis period

The RIT-T analysis will be undertaken from 2025-26, to the earlier of 2049-50 or the end of the asset life. This period was selected to allow consideration across the planning horizon of the asset life, complexity and size of the various potential system strength services.

The period takes into account the size and complexity of the system strength services that will be required in Victoria over the planning horizon. 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.

[24] In reality, the procurement of services under this RIT-T will ensure these base case consequences are avoided.

5.3 Scenario

For modelling this RIT-T, AVP will adopt the inputs, assumptions and scenarios in the 2023 IASR[25], due to be published by the end of July 2023. Variations, omissions or additions of the scenarios in the IASR will be considered if necessary to meet the requirements of reasonable scenarios set in the RIT-T instrument.

[25] See https://aemo.com.au/consultations/current-and-closed-consultations/2023-inputs-assumptions-and-scenarios-consultation.

6 Next steps

AVP welcomes written submission on this PSCR, particularly in relation to non-network options and assessment approach. All feedback will be considered and will help refine the proposed preferred option to be published in the PADR. At the conclusion of the consultation process, all submissions received will be published on AEMO's website. If you do not wish for your submission to be made public, please clearly stipulate this at the time of lodgement.

AVP is also undertaking a Request for Information (RFI) for non-network proponents to assist in meeting the system strength requirements as set out in this PSCR. The closing date for the RFI is 6 October 2023 and submissions to the RFI process will not be published on AEMO's website. However, certain pricing, size, technology and locational information submitted by respondents may need to be used by AVP in the PADR and PACR. As there are no feasible network solutions available to meet the system strength standard in the short term from December 2025, non-network options will be critical towards meeting the system strength standard. AVP strongly encourages all interested non-network proponents to make submissions to the RFI to ensure that a comprehensive suite of options are considered in the PADR to meet the system strength standard.