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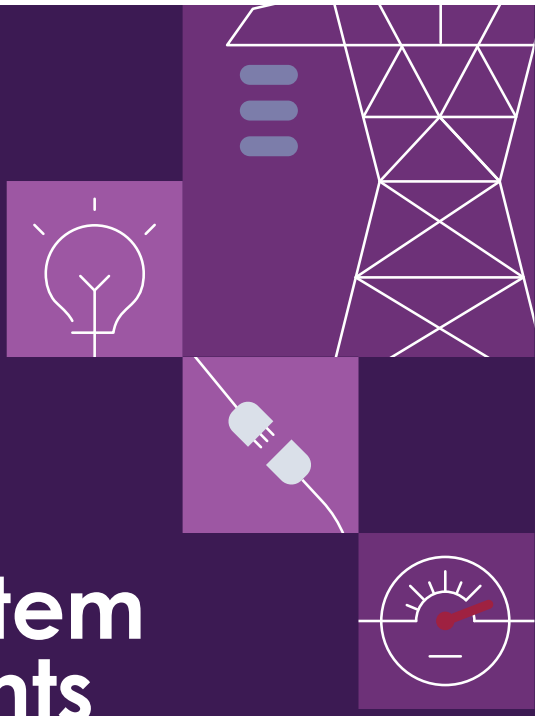

Amendments to System Strength Requirements Methodology and Power System Stability Guidelines

Draft Report and Determination – Implementation of Efficient Management of System Strength Rule

Published: July 2022

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Australian Energy Market Operator Ltd ABN 94 072 010 327

Notice of Second Stage Consultation – Amendments to System Strength Requirements Methodology and Power System Stability Guidelines

National Electricity Rules – Rule 8.9

Date of Notice: 29 July 2022

This notice informs all Registered Participants and interested parties (Consulted Persons) that AEMO is commencing the second stage of its consultation on the System Strength Requirements Methodology as well as consequential changes to the Power System Stability Guidelines. This consultation is being conducted under clauses 5.20.6 and 4.3.4 of the National Electricity Rules (NER), in accordance with the Rules consultation requirements detailed in rule 8.9 of the NER.

Invitation to make Submissions

AEMO invites written submissions on this Draft Report and Determination (Draft Report).

Please identify any parts of your submission that you wish to remain confidential, and explain why. AEMO may still publish that information if it does not consider it to be confidential, but will consult with you before doing so.

Consulted Persons should note that material identified as confidential may be given less weight in the decision-making process than material that is published.

Closing Date and Time

Submissions in response to this Notice of Second Stage of Rules Consultation should be sent by email to planning@aemo.com.au, to reach AEMO by 5.00pm (Melbourne time) on 19 August 2022.

All submissions must be forwarded in electronic format (both pdf and Word). Please send any queries about this consultation to the same email address.

Submissions received after the closing date and time will not be valid, and AEMO is not obliged to consider them. Any late submissions should explain the reason for lateness and the detriment to you if AEMO does not consider your submission.

Publication

All submissions will be published on AEMO's website, other than confidential content.

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Executive summary

In October 2021, the Australian Energy Market Commission (AEMC) released its final determination and rule on the efficient management of system strength on the power system. This introduced new requirements to be covered by the System Strength Requirements Methodology (SSRM) and System Strength Impact Assessment Guidelines (SSIAG).

The publication of this Draft Report and Determination (Draft Report) commences the second stage of consultation conducted by AEMO to amend the SSRM and to make minor updates to the Power System Stability Guidelines (PSSG) under the National Electricity Rules (NER).

AEMO thanks stakeholders for their participation in the first stage of consultation, which has informed this Draft Report.

This Draft Report marks the second stage of consultation on the SSRM and PSSG

AEMO commenced consultation on 26 April 2022, identifying the following broad categories of issues for the two primary system strength documents:

- For the SSRM - determining minimum fault level requirements, criteria for stable voltage waveforms ('efficient' level of system strength), forecasting inverter-based resource (IBR) connections and behaviour of synchronous machines, selection of system strength nodes, and planning for critical outages.
- For the SSIAG - the new system strength impact definition, proposed methodologies for preliminary and full assessments, a stability assessment methodology, calculation of system strength locational factors and available fault level, and demonstrating compliance with the new minimum access standards.

Due to the number and complexity of issues to be addressed, and following discussions with several participants and market bodies, AEMO extended the original consultation timeframe for these instruments. AEMO received 22 submissions in response to its issues paper, with a broad range of views on the necessary scope of amendments to the system strength instruments. AEMO thanks all stakeholders for their submissions, and appreciates the thoughtful contributions on these complex matters.

The *SSIAG* is now progressing under a separate consultation from the *SSRM* and *PSSG*. The issues relating to the *SSIAG* are not covered by this Draft Report other than to note any interdependencies.

AEMO's approach for the draft SSRM has evolved based on feedback

AEMO has issued a draft SSRM for further consultation. The draft SSRM reflects AEMO's draft determination of the following matters after considering all submissions, feedback from meetings with stakeholders, and contributions from the technical working group convened with network service providers.

- **AEMO will take a consultative approach to setting the system strength requirements.** AEMO intends to seek stakeholder feedback on key inputs where practical, including using one annual System Strength Report to consult on key factors for the following assessment. AEMO will also leverage the outcomes of existing regular consultation for the Integrated System Plan (ISP).
- **IBR forecasts for the efficient level of system strength will typically be consistent with the Integrated System Plan.** AEMO will provide forecasts for IBR connection and operation which will be consistent with the ISP wherever possible, but some changes to reflect the latest power system, market or policy outcomes may be required on a case by case basis.
- **Minimum fault level requirements must be set to ensure power system security, protection system operation and voltage control equipment performance.** AEMO will use the existing

minimum fault level requirements as a baseline. AEMO may re-assess the requirements to respond to material changes and updated limits advice.

- **The annual system strength report will identify critical planned outages that SSSPs must incorporate into their system strength planning**. This will ensure that sufficient system strength will be available to ensure power system security during critical network outages.
- **System strength nodes will be selected within SSSPs' networks.** AEMO has clarified that system strength nodes will need to be located within a System Strength Service Provider's transmission system. On a case-by-case basis, the SSSP may jointly plan with other Transmission Network Service Providers (TNSPs) and Distribution Network Service Providers (DNSPs) for the location of system strength services to meet the standard for each node, as well as assessing and consulting on non-network option.
- **Distributed energy resources.** AEMO does not intend to incorporate synchronisation of distributed energy resources in the calculation of minimum fault level requirements, as it is considered this will be addressed through other avenues in the NEM planning framework.
- **Different modelling techniques will be used for different time horizons.** Detailed electromagnetic transient (EMT) analysis will be prioritised for short-term power system stability studies where models are available (e.g. 1-2 years). However, for long-term time horizons, and when models are not available, alternative methods will be used.
- **A description of stable voltage waveforms is provided.** Although the NER already describe broad power system standards for voltage, the draft SSRM provides a system strength-specific description of stable voltage waveforms, against which System Strength Service Providers (SSSPs) will need to ensure that projected IBR connections and operation can be facilitated. This description is provided as a set of criteria.
- **Introduction of grid-forming inverters.** AEMO's NEM Engineering Framework includes a priority action to collaborate with industry on a voluntary specification for grid-forming inverters[1]. Such a document could assist with identifying a standardised way of determining system strength capability from grid-forming inverters.

Proposed minor updates to the PSSG are supported

AEMO has also published a marked-up draft of consequential amendments to the PSSG as a result of the efficient management of system strength rule change. The draft PSSG reflects AEMO's draft determination of the following matters after considering all submissions, feedback from meetings with stakeholders, and contributions from the technical working group convened with network service providers.

The amendments to the PSSG are to add a description of system strength to the appendix which defines and classifies different forms of power system stability, and to add a reference to the System Strength Report and the system strength standards to the appendix which lists the NER criteria around power system stability.

Stakeholders were broadly supportive of these consequential amendments.

Submissions are now invited

This Draft Report and the accompanying draft SSRM and PSSG have drawn on extensive stakeholder engagement through responses to the Issues Paper, meetings with stakeholders and a working group with Network Service Providers (NSPs).

[1] AEMO, *NEM Engineering Framework – priority actions*, June 2022, accessible via https://aemo.com.au/-/media/files/initiatives/engineering-framework/2022/nem-engineering-framework-priority-actions.pdf.

All stakeholders are invited to provide a written submission on any aspect of the draft SSRM or PSSG, and in particular the following questions:

- Does the draft SSRM support the proactive provision of system strength services in the NEM? If yes, why? If no, why not?
- Has AEMO appropriately incorporated feedback provided in submissions? If not, has AEMO adequately explained its reasoning for not incorporating feedback?
- Should one annual System Strength Report be used to consult on revisions to system strength nodes, assumptions, thresholds and planning margins to be used in the next assessment?
- Do stakeholders have specific views on appropriate values for assumptions, thresholds and margins which are referenced in the draft SSRM and which will be subject to annual feedback through the publication of the System Strength Report? These include:
    - prudent planning margins to be included in minimum fault level requirement assessments;
    - the time horizon for when detailed EMT analysis is appropriate, rather than high-level assessments, for assessment of both minimum fault level requirements and the efficient level of system strength;
    - a planning threshold for the voltage oscillations criterion of the description of stable voltage waveforms;
    - a value for the change in voltage phase angle for the change in voltage phase angle criterion of the description of stable voltage waveforms; and
    - market impact, or other metrics, for the criteria used to select critical planned outages.
- Do you have any further recommendations for enhancing the SSRM?

Submissions need not address every question posed and are not limited by those questions. AEMO welcomes feedback from stakeholders on the draft SSRM and PSSG by 19 August 2022.

1. Introduction

AEMO is consulting on amendments to the SSRM and minor updates to the PSSG. The publication of this Draft Report marks the commencement of the second stage of consultation on both documents.

1.1. Consultation timeline

The initial phase of this consultation also included amendments to the SSIAG, which is now progressing under a separate consultation. AEMO will release a separate consultation paper to obtain further feedback on detailed aspects of the SSIAG amendments before proceeding to a draft report and determination. Issues relating to the SSIAG are not covered by this Draft Report other than to note any interdependencies.

Due to the number and complexity of issues to be addressed and resolved, the publication date of this Draft Report was extended from AEMO's original consultation timeline. A revised indicative timeline for consultation on the SSRM and PSSG is outlined below. Future dates may be adjusted depending on the number and complexity of issues raised in submissions and any meetings with stakeholders.

Deliverable	Date
Notice of first stage consultation and Issues Paper published	Complete – 26 April 2022
First stage submissions closed	Complete – 1 June 2022
Draft Report, draft SSRM, draft PSSG and Notice of second stage consultation published	Complete – 29 July 2022
Submissions due on Draft Report	19 August 2022
Final Report, final SSRM and final PSSG published	29 September 2022

1.2. Previous engagement

Before publishing the Issues Paper, AEMO established a working group with TNSPs and DNSPs to provide technical input on the proposed amendments to the SSRM and SSIAG, and also met with peak bodies for other key stakeholder groups. The technical working group has continued to provide input to inform this Draft Report.

AEMO held a webinar on 17 May 2022 to provide information on the consultation. Approximately 50 stakeholders attended the webinar. Stakeholders included TNSPs, distribution network service providers, industry and consumer representatives and consultants. Discussion focused on location of system strength nodes, nature of system strength requirements for connecting parties under the new rules framework, and the forecasts against which the new system strength standards will be set.

AEMO received 22 written submissions on its Issues Paper, including a number of late submissions that AEMO has nevertheless considered in making its draft determination. One submission was confidential, but the stakeholder subsequently provided a public version. AEMO also met with some stakeholders to discuss their submissions.

Copies of all written submissions, the presentation from the forum, and brief meeting notes (all excluding any confidential information) have been published on AEMO's website[2].

1.3. Structure of this report

In this Draft Report:

[2] At https://aemo.com.au/consultations/current-and-closed-consultations/ssrmiag.

- Section 2 provides background on the system strength rule change.
- Section 3 provides a summary of material issues raised in the SSRM and PSSG.
- Section 4 provides a discussion on the material issues raised in the SSRM consultation and AEMO's responses.
- Section 5 provides a discussion on the material issues raised in the PSSG consultation and AEMO's response.
- Section 6 confirms AEMO's draft determination.

1.4. Submissions

AEMO invites feedback on the proposed approaches and other options or considerations, to help shape the final SSRM and PSSG, by 19 August 2022 in accordance with the details provided in the notice of second stage of consultation at the front of this report.

2. Background

2.1. Regulatory requirements

In October 2021, the AEMC released its final determination on the efficient management of system strength on the power system, and made National Electricity Amendment (Efficient management of system strength on the power system) Rule 2021 No. 11 (the Amending Rule).

The requires significant amendments and additions to the SSRM and SSIAG, and will also require some minor consequential changes to the PSSG. The NER requirements for the SSRM and PSSG are noted in this section, as the SSIAG consultation will proceed separately.

2.1.1. Changes to the SSRM

AEMO must update the existing SSRM[3] to reflect the Amending Rule by 1 December 2022, incorporating the information needed for the new standards for system strength (with both minimum and efficient levels of system strength).

Required content of the SSRM

New clause 5.20.6(f) of the NER states:

(f) The *system strength requirements methodology* determined by *AEMO* must:

(1) provide an overview of *system strength nodes* and the process to declare them;

(2) describe:

(i) how *AEMO* forecasts new *connections* and the information it takes into account;

(ii) how *AEMO* will determine the assumptions it will use about the size, type and operational profile of *facilities* or classes of *facilities* to be *connected* and their contribution to the matters taken into account in determining the *system strength requirements*; and

(iii) the modelling and analysis methodologies *AEMO* will use to determine *system strength nodes* and minimum *three phase fault levels* at the *system strength nodes* and the matters it will take into account;

(3) provide for *AEMO* to take the following matters into account in determining the *system strength requirements*:

(i) the *Integrated System Plan* and the *Electricity Statement of Opportunities*;

(ii) the matters in paragraphs (e)(1) to (7) for each year of the forecast period; and

(iii) any other matters *AEMO* considers appropriate; and

(4) provide a description of what is meant by stable *voltage* waveforms for the purposes of clause S5.1.14(b)(2) (in addition to that provided in clause S5.1.14(c)) including the matters that may be taken into account by System *Strength Service Providers* to assess, for the level and type of *inverter based resources* projected by *AEMO* at *system strength nodes*, what may be required to achieve stable operation.

[3] AEMO, System Strength Requirements Methodology, July 2018, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/System-Security-Market-Frameworks-Review/2018/System_Strength_Requirements_Methodology_PUBLISHED.pdf.

Mandatory considerations for system strength requirements

- The SSRM must provide for AEMO to take the following matters into account in determining the system strength requirements for each region of the NEM (new clause 5.20.6(e) of the NER):
- (e) The *system strength requirements methodology* determined by *AEMO* must provide for *AEMO* to take the following matters into account in determining the *system strength requirements*:
- (1) the combination of *three phase fault levels* at each *system strength node* in the *region* that could reasonably be considered to be sufficient for the *power system* to be in a *secure operating state*;
- (2) the maximum *load shedding* or *generation shedding* expected to occur on the occurrence of any *credible contingency event* or *protected event* affecting the *region*;
- (3) the stability of the region following any credible contingency event or protected event;
- (4) the risk of cascading outages as a result of any load shedding or generating system or market network service facility tripping as a result of a credible contingency event or protected event in the region;
- (5) additional contribution to the *three phase fault level* needed to account for the possibility of a reduction in the *three phase fault level* at a *system strength node* if the *contingency event* that occurs is the loss or unavailability of a *synchronous generating unit* or any other *facility* or service that is material in determining the *three phase fault level* at the *system strength node*;
- (6) the stability of any equipment that is materially contributing to the *three phase fault level* or *inertia* within the *region*; and
- (7) any other matters AEMO considers appropriate.

Application in System Strength Report

AEMO will apply the amended SSRM to determine system strength nodes and the system strength requirements to be published in its annual System Strength Report under NER 5.20.7, starting from 1 December 2022. Clause 5.20.7 states:

> **5.20.7 Publication of System Strength Report**
>
> *AEMO* must publish annually by 1 December the *System Strength Report* on its website for the following year which must include:
>
> (a) a description of the *system strength requirements* determined by AEMO under rule 5.20C since the last *System Strength Report*;
>
> (b) the *system strength requirements* determined for each *system strength node*; and
>
> (c) the system strength standard specification (as defined in clause S5.1.14(a)) applicable at each *system strength node* during the 12 months following publication of the *System Strength Report*;
>
> (d) the assumptions used by *AEMO* to determine the *system strength requirements* including assumptions about the size, type and operational profile of *facilities* or classes of *facilities* to be *connected* and their contribution to the matters taken into account in determining the *system strength requirements*;
>
> (e) information about new *system strength nodes* declared since the last *System Strength Report* and an indication of possible future *system strength nodes* and when *AEMO* considers the nodes may be declared; and
>
> (f) information on any other matter that *AEMO* considers relevant.

2.1.2. Changes to the PSSG

The PSSG are made under NER clause 4.3.4(h), with the purpose of detailing the 'policies governing power system stability so as to facilitate the operation of the power system within stable limits' (clause 4.3.4(i)). The current PSSG were published on 25 May 2012 and pre-date any NER changes

referencing system strength. AEMO therefore needs to make consequential updates to the PSSG to define system strength in a similar manner to the other types of stability and ensure consistency with the new system strength framework.

2.2. Context for this consultation

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.

Traditionally, system strength services have been provided by large thermal and hydro synchronous generation units. However, with the rapid uptake of inverter-based resources, declining minimum operational demand and changing synchronous generation behaviour, action is now needed to ensure that system strength services are maintained into the future.

The NEM is already at the international forefront of managing issues associated with low system strength. In South Australia, ElectraNet has met system strength needs by installing four synchronous condensers. In Victoria, AEMO[4] has contracted system strength services from generator-owned synchronous condensers installed alongside solar farms. In Queensland, Powerlink worked with local solar and wind farms to re-tune their inverters and reduce the nearby system strength needs of the system.

Across the NEM, generators have made unique agreements with NSPs to remediate their plant's impact on system strength; and across the industry, technology providers are considering how best to provide system strength in the future.

Following the release of an Issues Paper in April 2022, this Draft Report is the next step in AEMO's consultation on amending its system strength documentation. These amendments are needed to implement the latest rule changes relating to system strength but also to further the NEM's transformation in system strength provision.

[4] In its capacity as the planner and shared TNSP for the declared shared transmission network in Victoria.

3. Summary of material issues

AEMO's summary of what it considers to be the key material issues arising from submissions to the Issues Paper, as they relate to the SSRM and the PSSG, are summarised in Table 1.

Table 1 Material issues relating to the proposed amendments to the SSRM and PSSG

No.	Issue	Instrument	Raised by
1	Overarching approach for determination of minimum fault level requirements, including starting point for minimum fault level requirements, definition of stable power system operation, and application of minimum fault level requirements in an operational context.	*SSRM*	Ausgrid, CEC, Citipower/Powercor, ElectraNet, Jacobs, MarinusLink, Powerlink, SA Power Networks, Shell Energy, Siemens Gemesa (SGRE), TasNetworks, TransGrid
2	How best to plan for sufficient fault current required for ongoing operation of protection schemes, for both the transmission and distribution networks.	*SSRM*	Akaysha Energy, Ausgrid, Citipower/Powercor, Clean Energy Council, Energy Queensland, Powerlink, SA Power Networks, SMA, TasNetworks
3	Criteria for stable voltage waveforms, particularly how specific AEMO's description of criteria should be, as well as consideration of appropriate analytical methods for assessing future compliance with the criteria.	*SSRM*	Citipower/Powercor, Energy Queensland, Fluence, Lakshan Bernard (Monash University), MarinusLink, Powerlink, Siemens Gemesa (SGRE), SMA, Tesla
4	Forecasting of inverter-based resources in the NEM, particularly how and when to deviate from Integrated System Plan projections, how precisely the network location of new generation can and should be modelled, and treatment of grid-forming inverters.	*SSRM*	Clean Energy Council, CitiPower/Powercor, Energy Queensland, Powerlink, SA Power Networks, Shell Energy, Siemens, TasNetworks, Tesla
5	How best to incorporate critical planned outages in the system strength standards.	*SSRM*	Ausgrid, AusNet, Powerlink, TasNetworks
6	Process for selection of system strength nodes, and associated system strength locational factor matters, including location of nodes and consultation on node selection.	*SSRM*	Ausgrid, AusNet, Clean Energy Council, CitiPower/Powercor, Energy Queensland, Jacobs, SA Power Networks, TasNetworks, Transgrid
7	Where responsibility lies for maintenance of synchronism of distributed energy resources, and status of technical understanding of this matter.	*SSRM*	Citipower/Powercor, Energy Queensland, Siemens Gemesa (SGRE), SMA, TasNetworks
8	Consequential amendments to the *PSSG* as a result of the efficient management of system strength rule change.	*PSSG*	Clean Energy Council, Energy Queensland, SMA, TasNetworks

Section 4 provides AEMO's assessment of each of the material issues for the SSRM. Section 5 provides AEMO's assessment of the material issues raised for the PSSG consultation. A detailed summary of issues raised in submissions and at meetings and forums, together with AEMO's responses, is contained in Appendix B.

4. Discussion of material issues for the SSRM

AEMO considers that seven material issues have been raised during the consultation on amendments to the SSRM, either by stakeholders or through AEMO's ongoing work to implement the amendments to the system strength framework.

The following sections provide a summary of each material issue, submissions received about the issue, and the considerations and analysis AEMO has applied in assessing the issue. A conclusion is then provided to state AEMO's position as reflected in the draft determination of the SSRM. The draft SSRM is published alongside this report for consultation.

4.1. Overarching approach for determining minimum fault level requirements

4.1.1. Issue summary and submissions

In the Issues Paper, AEMO proposed using the existing minimum fault level requirements across the NEM as starting point for new standard, given that the existing requirements currently support power system stability and ensure security for 'system normal' for the current power system. In addition, AEMO proposed that the updated SSRM process for determining the minima would prioritise flexibility to allow appropriate responses to the NEM power system transformation.

The Issues Paper also gave an indication of a proposed overarching approach to the assessment, defined 'stable power system operation' for the purposes of the assessment, and noted that the minimum fault level requirements would need to be adjusted to account for actual system conditions before they can be applied in real time operations.

Submissions were generally supportive of AEMO's proposed overarching approach on the assessment of minimum fault level requirements.

Extracts from submissions on this issue are below[5].

Ausgrid:

> Ausgrid broadly supports the proposed approach for determining minimum fault level requirements. However, we recommend that AEMO develop a consultation framework to drive consistency in how the methodologies and standards specified for minimum fault level calculation are developed and applied across AEMO and the TNSP's/DNSP's.

Clean Energy Council (CEC):

> We consider the general approach taken by AEMO in the Issues Paper [to system strength definition and node identification] to be sensible. While recognising that the paper sets out approaches at a high level, we encourage AEMO to provide additional detail as to how these processes will work in operation. Provision of this additional detail will enable the market to respond to identified needs for system strength, whether at the minimum or efficient level, by offering services to either AEMO and/or NSPs to help meet overall system strength requirements.
>
> For example, AEMO notes that when determining minimum fault level requirements, it will "incorporate prudent planning margins where appropriate to acknowledge technological and market uncertainty". We welcome further information from AEMO as to how and what volumes of system strength services will need to be procured in accordance with meeting this prudent planning margin. To

[5] Note that submissions quoted in this document are in **this font**.

be clear, we consider that including such a margin is a sensible approach; further detail as to its magnitude and qualities will enable participants to invest in assets that can help meet this prudent planning margin.

CitiPower/Powercor:

We do not believe that using the existing fault level is sufficient to determine the minimum fault level.

…

AEMO may wish to consider an alternative methodology. For example … Calculate the maximum (N-1) capacity of transmission lines (and/or transformers) that connect to a node … Use the maximum capacity to find the maximum fault level for this node to operate stably.

ElectraNet:

Minimum fault level requirements need to take into account:

a. Existing inverter-based resources (IBR) subject to any existing or forecasted operational constraints and limitations;
b. Forecast new IBR (noting that regional generation output is limited by operational demand and interconnector transfer capacity) and modifications to existing IBR (associated with asset replacement);
c. Protection system requirements to ensure secure operation of the power system;
d. Single power system prior outage conditions. There is an ongoing requirement for planned outages to support replacement, refurbishment and maintenance activities and the ability to secure these outages when needed is central to the provision of a safe, reliable and secure power system;
e. Historical required fault level to support the secure operation of power system for the already connected parties;
f. Local regional characteristics. For instance in South Australia, the minimum fault level cannot be any lower than the combined contributions from the ElectraNet transmission connected synchronous condensers and interconnectors.

Jacobs:

The commentary on reactive switching and Fault levels is reasonable. However, the impact of transformer energisation under low fault level conditions also needs to be considered (noting that Point on Wave switching won't be effective due to remanent flux issues).

Marinus Link:

Using the existing minimum levels defined at the current nodes is a prudent approach however it should be limited to nodes where the level was defined using a "Stage 2" approach in the existing guidelines. Those that are defined with the "Stage 1" approach risk setting the minimum levels too high and mean that the level will be required to be maintained by the SSSP.

We agree with the position AEMO has put forward in regards to the treatment of existing IBR being captured under the minimum levels and new and modified generators, MNSPs and large loads that are IBR will be captured under the efficient level of system strength. One clarification we feel is needed is whether new regulated assets which happen to be IBR will be accounted for under the minimum levels in the planning timeframe.

Powerlink:

Powerlink supports AEMO adopting the existing minimum fault level requirements and to only reassess if there is a major change in the power system that impacts the fault level required for secure operation.

…

Powerlink recommends that the minimum fault level should only be reassessed if there is a major change in the power system that has an impact on the fault level required to maintain secure operation and continued operation of protection systems. Examples include, but are not limited to:

- Technology advancements that are less reliant on fault level;
- Future uptake of Distributed Energy Resources (DER);
- Changes in the synchronous generation forecast; and
- A major change in network topology, including voltage level and/or technology (e.g. HVDC).

Any such changes to the minimum fault level must be done based on appropriate detailed EMT-type analysis. Therefore, such changes would only be made within the short to mid-term planning horizon when there is a clear line of sight of the emerging structural and/or technological changes to the power system. Otherwise the minimum fault levels should be maintained.

…

Minimum fault levels should be planned such that any constraints on Inverter Based Resources (IBR) plant due to system strength limitations do not pose a risk to the jurisdictional reliability obligations, when either:

- Returning the system to a new secure state following a credible contingency or protected event; or
- Operating the power system in a secure manner with a planned outage.

…

Powerlink agrees that the existing and committed IBR plant (prior to March 2023) should be included in the minimum fault level requirements and that the system strength required for all new IBR plant (post March 2023) should be accounted for under the 'efficient level' of system strength.

SA Power Networks:

Inclusion of existing and forecast IBR in the assumptions for determining minimum fault level requirements are advised. Although there should be a minimum synchronous fault level requirement which is independent on connection of different IBRs.

Shell Energy:

Shell Energy is comfortable with the proposed approach to determining minimum fault level requirements. However, we note that it will be crucial to provide transparency to all stakeholders regarding how the "prudent planning margins" are calculated. AEMO should clearly show the calculation methodology behind any proposed planning margin and the benefit it provides towards ensuring the intent of the Amending Rule is ensured for proactive provision of services.

We also note that there is little detail provided regarding what is meant by AEMO's stated intention to prioritise flexibility in the SSRM to allow appropriate response to NEM transformation. It is Shell Energy's view that the level of technical flexibility should be clearly defined for market participants with appropriate transparency around the process for determining the boundaries of this flexibility.

Shell Energy supports the approach outlined in the consultation paper [for assessment of projected minimum fault level requirements over the next decade] but notes that for effective feedback from stakeholders, AEMO must detail all modelling input assumptions as well as the reasoning or evidence behind the selection of the assumptions.

Siemens Gamesa (SGRE):

SGRE is supportive of the use of detailed PSCAD modelling in determining the fault level requirements for power system stability over short time horizons of 2-3 years. Over this short horizon the connecting plant and their expected capability is relatively well known and current PSCAD models can be substituted for connecting plant.

…

SGRE encourages AEMO to consider also using some detailed PSCAD modelling over the longer 10 year time horizon in addition to the other approaches suggested. However, considers that these long timeframe' planning assessments are less critical and their outcomes should be applied very cautiously to any network investment, due to the large uncertainty involved. SGRE suggests using one of the alternative assessment methods proposed by AEMO such as AFL as a first pass … Once a first pass is made, some locationally specific PSCAD modelling can be undertaken …

SGRE agrees with AEMOs assessment that historic plant and those connected under the 'do no harm' regime should be considered for the minimum fault level requirements in the current iteration. However, SGRE believes that in future the assessment of fault levels should consider the rise of new IBR technologies, specifically grid forming asynchronous plant, which provide a positive contribution to the system and thus may reduce the minimum fault level requirements.

TasNetworks:

Minimum fault level and stable voltage waveform assessments must be proportionate to the benefits derived from them. This will generally mean generic, simplified models are appropriate for longer time horizon modelling.

… annual reviews may not be warranted if there has been no significant changes on the network. An alternative approach may be a periodic engineering review where potential or actual changes to system security outcomes can be identified. This recognises that a detailed simulation based assessment may not always be the most appropriate approach for investigating all issues …

The proposed approach of taking the currently defined minimum fault levels as a starting point for the minimum requirements under the new standard is appropriate. TasNetworks agrees this is a pragmatic solution which addresses the system strength needs of the existing network and provides a workable base from which to project future requirements. This approach also avoids what could become a very significant undertaking to explicitly define minimum fault level requirements associated with transmission and distribution network protection systems. We do not contend that it is credible to undertake such an activity in the timeframes required to implement the efficient management of system strength rule change.

…

It is not practical to undertake detailed electromagnetic transient (EMT) simulations for future operating conditions extending much beyond the rolling three year time frame for which system strength must be proactively delivered … TasNetworks supports continued refinement of the available fault level (AFL) methodology, but also supports consideration of other high level methods.

For near-term projections, where EMT simulations become increasingly critical to demonstrate the efficacy of system strength solutions proposed to meet the standard, TasNetworks encourages AEMO to consider the development of a generic model library capable of representing the most common IBR plant.

TasNetworks agrees that the minimum fault level requirements should continue to incorporate IBR previously accounted for as part of historical system operating practices under the do no harm regime.

…

Transgrid:

> We support the approach AEMO has taken to meet its power system security responsibilities in operational timeframes based on the minimum three phase fault level requirements.

4.1.2. AEMO's assessment

General support for assessing minimum fault levels

AEMO welcomes the majority of submissions' support for its proposed approach to assessing minimum fault level requirements across the NEM. AEMO considers that the approach proposed in the Issues Paper strikes the right balance between proactive system strength provision to ensure power system stability for the present system, and flexibility to respond to the power system transformation which continues at pace.

A number of stakeholders supported the proposed treatment of existing inverter-based resources, as well as the proposal to use the existing requirements as a starting point while also leaving flexibility to amend and change those requirements where required.

Consultation processes

Several stakeholders requested transparency of and consultation on the inputs and assumptions to be applied in the preparation of the minimum fault level requirements, including the use of any planning margins. AEMO agrees that transparency and consultation is important. In this case, AEMO proposes:

- Consultation on inputs and assumptions will primarily rely on matters consulted on through existing processes such AEMO's *Inputs, Assumptions and Scenarios Report* (IASR) and the *Integrated System Plan*.
- AEMO will undertake joint planning with TNSPs to test modelling inputs and assumptions and local network understanding if the minimum fault level requirements are assessed.
- AEMO will publish the annual System Strength Report including description of inputs and assumptions applied in the assessment. AEMO will welcome feedback on the inputs, assumptions, thresholds, SSNs and margins proposed in the annual System Strength Report, and will seek to incorporate feedback in to the following year's assessment.
- One stakeholder recommended a dedicated consultation framework on the methodology applied for minimum fault level requirement assessment. AEMO considers that the current consultation on the SSRM is sufficient for this purpose, as it includes consideration of the methodology. There are also NER requirements for consultation should any future substantive amendments be made to the SSRM.

System strength nodes and assessments

- The Clean Energy Council has emphasised the importance of providing detail about how system strength standard assessment and system strength node creation will be done, in order to ensure that market participants can fully understand what system strength services are required and potentially offer to provide those services. On this matter, AEMO considers that SSSPs will undertake their own processes to seek and secure system strength services from a range of sources.
- AEMO elects to not incorporate the proposed fault level calculation methodology proposed by CitiPower/Powercor. AEMO considers that there are other important factors that must be modelled for incorporation in the minimum fault level requirements aside from transmission line capability, for example available synchronous generating machines, synchronous condensers, and other power system equipment and dynamics.

- AEMO notes the Jacobs comment about the need to consider the impact of transformer energisation under low fault level conditions, and will incorporate this consideration in to the assessment process noted in the draft SSRM. AEMO expects that this matter will need to be informed by local network understanding from TNSPs and DNSPs, but that it will be worthwhile to annotate it in the SSRM to make sure that it is incorporated where appropriate when setting the minimum fault level requirements.

EMT analysis

- Marinus Link has suggested that the existing minimum fault level requirements may be set 'too high' if defined by a 'Stage 1' versus a 'Stage 2' approach under the current SSRM. Under the current SSRM, Stage 1 assessments use RMS analysis whereas Stage 2 assessments use EMT analysis. As discussed in the Issues Paper, AEMO that wherever possible EMT analysis is a more precise method for assessing power system stability and the interactions between IBR. However, ability to use EMT analysis for setting minimum fault level requirements declines in cases where appropriate models are not available or for longer time horizons where there are significant power system uncertainties. This is due to both model unavailability and the resource-intensive nature of EMT analysis. AEMO considers that the proposed assessment approach strikes the right balance between different analytical methods based on the information and resourcing available at the time of the assessment.
- Regarding expanded use of EMT analysis where possible, AEMO agrees with TasNetworks that the creation of generic model libraries for EMT analysis could be beneficial. AEMO's NEM Engineering Framework may incorporates this alongside other priority actions[6].

Managing existing assets

- Regarding the treatment of regulated network assets which are IBR (including HVDC links), where their continued operation assists to maintain power system stability after a relevant contingency AEMO considers that this should be accounted for in the minimum fault level requirements. As a separate issue, AEMO notes that the system strength impact assessment provisions of the Amending Rule do not cover the impact of connecting new regulated network IBR, as opposed to *market* network service facilities. AEMO therefore expects that the inter-network connection negotiations involving (for example) an HVDC link, would need to address how to resolve any impact on the relevant SSSP's ability to meet both its minimum and efficient fault level standards under the NER.
- Although Powerlink has suggested that the minimum fault level requirements should be assessed such that they allow the power system to be operated in a secure manner when there is a planned outage, AEMO does not consider that this would be consistent with the efficiency objectives of the AEMC rule determination. AEMO considers that only critical planned outages which meet the thresholds discussed in section 4.5 should be incorporated into the assessment, in order to ensure prudent application of the planning and investment framework.
- AEMO confirms that the SSRM minimum fault level methodology is intended to ensure that the minimum requirements provide for sufficient system strength for power system stability and correct operation of protection and control systems, accounting for:
- Existing network equipment, generators, loads and market participants, noting that the existing 'do no harm' framework continues to require relevant generators to remediate any adverse system strength impact of their connection until March 2023.
- System normal and for when credible contingencies and protected events occur.

[6] AEMO, NEM Engineering Framework Priority Actions, June 2022, accessible via https://aemo.com.au/-/media/files/initiatives/engineering-framework/2022/nem-engineering-framework-priority-actions.pdf.

- In a narrow set of cases, AEMO may include critical planned outages in the assessment of the minimum fault level requirements, as discussed in section 4.5.

Expected level of access to system strength services

- The minimum fault levels are not intended to provide for 'firm' access, as this is not envisaged under the NER. Operation at minimum three phase fault levels – rather than the efficient levels required by the stable voltage waveform standard - may still require some plant to disconnect or vary its power transfer.

4.1.3. AEMO's conclusion

Following assessment of stakeholder feedback, AEMO concludes that the proposed treatment of minimum fault level requirements assessment in the Issues Paper is fit for purpose and aligned with the intent of the Amending Rule.

The draft SSRM published alongside this Draft Report implements the proposed approach from the Issues Paper, with some clarifications to reflect the assessment of stakeholder feedback provided above.

4.2. Ensuring protection scheme operation

4.2.1. Issue summary and submissions

The Amending Rule requires that the power system should have sufficient minimum three phase fault levels sufficient to enable correct operation of the protection systems of transmission and distribution networks.

In the Issues Paper, AEMO acknowledges the importance of fault level for protection system operation as well as the fact that these highly complex systems are designed relative to the primary network system. Although over time protection system design may become less reliant on fault levels from the power system, this evolution will sometimes be constrained by the design and configuration of existing primary system installations.

Extracts from submissions on this issue are below.

Akaysha Energy:

> Fault current should however be separated from the definition of system strength as although related, the two power system parameters are best separated due to the different technical requirements they fulfil.

Ausgrid:

> Ausgrid has several 132kV circuits which do not meet contemporary NER primary or backup clearing time requirements, where the existing protection schemes have been grandfathered since commencement of the NER …
>
> With the expected reduction of three phase fault levels, adequacy of these historic protection schemes to meet critical clearing times needs to be determined to understand whether this will pose an unacceptable power system security risk.
>
> Ausgrid may need to engage with AEMO/Transgrid to determine critical clearing time requirements on the 132kV system and resolve any change which may be necessary to the grandfathering arrangements.

CitiPower/Powercor:

> It is important to specifically require joint-planning between AEMO and DNSPs. This is because DNSPs rely on overcurrent and distance protection more often than TNSPs, as this equipment is far more

sensitive than TNSP equipment. We submit that AEMO/SSSP should work with DNSPs very closely to attempt to work through any protection equipment requirements.

Clean Energy Council:

We welcome further analysis from AEMO as to how to reduce systemic reliance on fault current for safe operation of protection equipment, such as by working with NSPs to install differential / distance type protection instead of overcurrent-based protection.

Energy Queensland:

We suggest Network Service Providers (NSPs) should determine the minimum fault level requirements of their protection systems so these can be considered in the determination of minimum fault level requirements.

Powerlink:

Powerlink does not support NSPs being asked to determine the minimum fault level below which protection systems will not function correctly. Rather, when a case for reducing minimum faults (based on the triggers described in question 2) is being assessed, then the scope of the investigation must consider the continued operation of protection systems. It does not naturally follow that protection problems uncovered, as part of this investigation, would drive higher minimum fault levels. The cost of modifying the impacted protection systems should be assessed such that the most efficient overall solution for customers is identified.

SA Power Networks:

…it should be noted that protection equipment needs to have appropriate measurement accuracy to be able to differentiate between normal load current and low fault level current, which could potentially differ by tens of Amps in certain low fault level areas.

SMA:

As a first step, it may well be efficient to mandate migration to current comparison protection for voltages above, for example, 66kV, and perhaps perform some analysis to confirm whether sub 66kV impedance protection can still be adequately graded under reduced fault level conditions.

TasNetworks:

TasNetworks contends that more focused efforts are required to properly understand the impact of IBR on network protection systems, both at transmission and distribution voltage levels. For this reason we believe the issue should be considered as part of the Engineering Framework being coordinated by AEMO.

There is little benefit in simply requesting protection settings from Network Service Provider (NSP). In TasNetworks view, this is not a technical challenge that can be addressed by attempting to build models and run simulations.

An interim approach could be to maintain the synchronous three phase fault level at all points in the network at or above historical minimums for intact network operation (either real time calculated or published values), on the reasonable assumption that this has been adequate to ensure correct protection operation at all voltage levels. A gradual reduction may be possible where a review of underlying design principles allow. Furthermore, in some areas of the network, the synchronous fault level requirement needed to support the operation of pre-existing IBR may inherently force operation to be at or above these levels, providing for a self-correcting outcome. This may be sufficient until system strength can be reliably sourced from grid-forming inverters, at which time, a more comprehensive solution will likely be needed.

4.2.2. AEMO's assessment

Assessing the fault level required for protection systems to operate

AEMO understands that when SSSPs have previously provided feedback on proposed minimum fault level requirements, they have assessed the requirements' impact on protection system operation. This has included considering whether the proposal reflected previous historical fault levels seen on the network, and then making a judgement about whether the levels would be sufficient for enabling future protection system operation. This may have required some case by case fault level studies for particular protection schemes.

AEMO understands from discussions with TNSPs that assessing the precise fault level requirements to enable correct operation of all protection systems in their networks will be a very resource-intensive exercise. Rough resource estimates provided by networks indicate that power system fault studies for a single busbar could take a week for one engineer to assess. There are of course thousands of busbars across the NEM.

While some stakeholders, including Powerlink and TasNetworks, do not consider a wholesale protection requirement assessment to be practical or recommended, others such as Energy Queensland, Powercor and Ausgrid recommend that these studies be undertaken.

On balance, AEMO is not proposing to include a wholesale request for protection scheme fault level requirements across the NEM as part of the regular assessment of minimum fault level requirements. Rather, AEMO proposes to reflect the assumption in the draft SSRM that the existing minimum requirements are sufficient to facilitate correct protection systems operation, and provide for minimum fault level requirements to be re-assessed when new or updated protection system information is provided to AEMO by an SSSP[7]. This provides for a pragmatic approach recognising that extensive in-depth studies across all networks are unlikely to be practical.

AEMO notes TNSP and DNSP submissions which recommend close joint planning on the matter of protection system operation and innovation, as well as the Clean Energy Council's call for further coordination and analysis of this important future power system challenge. AEMO will continue to undertake joint planning to understand emerging practices in protection scheme design and any opportunities for re-design to accommodate a lower fault level power system environment.

Distinguishing fault level requirements from voltage waveform stability

AEMO agrees with stakeholder views that it is important to separate the need for fault level in the power system, particularly for protection scheme operation, from the need for voltage waveform stability. The Amending Rule reflects this distinction in a dual system strength standard which includes a minimum fault level requirement and an efficient level, which is determined by the separate stable voltage waveform requirement.

4.2.3. AEMO's conclusion

AEMO does not propose to reassess fault level requirements for protection scheme operation as part of the annual system strength assessment. However, the draft SSRM allows for minimum fault level requirements to be updated when new information on the operation of protection systems is provided by SSSPs.

AEMO will continue to undertake joint planning with SSSPs to understand emerging practices in protection scheme design and any opportunities for re-design to accommodate a lower fault level power system environment.

[7] NSPs are expected to cooperate with and assist AEMO to discharge its power system security responsibilities (NER 4.3.4(a)), including by the provision of relevant information and operational limits.

4.3. Criteria for stable voltage waveform

4.3.1. Issue summary and submissions

In the Issues Paper, AEMO proposed a description for a stable voltage waveform for the purpose of enabling future IBR connection and operation, as well as three options for how SSSPs may assess the delivery of a stable voltage waveform. The proposed description for a stable voltage waveform is intended to identify the IBR-specific matters which must be considered. The three assessment methods proposed were:

- Option 1 – use of generic EMT models as a 'stand-in' for plant that has not been committed or connected
- Option 2 – available fault level calculation, and
- Option 3 – simplified switching studies to test voltage robustness.

Regarding the description of a stable voltage waveform, stakeholder submissions were divided. While some stakeholders consider that AEMO should not provide a description, and instead rely on existing NER clauses, others were supportive of the description, or were supportive subject to further clarifications or changes. Extracts from submissions on this issue are below.

Citipower/Powercor:

> We agree with the proposal.

Energy Queensland:

> We believe the description is sufficient for its purpose.

Fluence:

> Although welcome that clause S5.1a.9(b) defines stable voltage waveform, clearer info is needed on how the new description translate to how non-synchronous sources can best support this. We look to AEMO to provide further advice regarding the implications of using Available Fault Level (AFL) to assess the efficient level of system strength. Non-synchronous sources of system strength are rapidly emerging and undergoing demonstration on the broader power system. We hope that AEMO can mitigate the risk that NSPs may be restricted into only relying on synchronous sources.

Lakshan Bernard (Monash University):

> Since RMS voltage is a phasor quantity, it is important to consider the mapping between the actual voltage waveform and RMS phasor. An important consideration is how is the RMS value measured: is it with a True RMS meter or with a Phasor Measurement Unit or something else?
>
> …
>
> Clearly, there is not a one to one mapping between RMS voltage and voltage waveform. Hence, if using RMS voltage as a proxy for voltage waveform, if the RMS voltage shows instability, then further investigation is required to determine what is happening to the voltage waveform.
>
> The proposed requirement of 45° in 0.5 seconds, corresponds to a Rate of Change of Frequency (ROCOF) of 0.5 Hz/s. According to a 2017 report [reference], 0.5 Hz/s is a safe bound for the ROCOF.
>
> Monitoring the instantaneous voltage is very important to assess the stability of the voltage waveform. However, the sampling frequency should also be specified … Moreover, it is slightly vague how exactly the "closeness" to a pure 50 Hz sinusoid is evaluated … Thus, to avoid ambiguity, it would be helpful if AEMO clarified exactly what is meant by "closeness".

Powerlink:

Defining the stable voltage waveform separately could represent unnecessary duplication and may result into misinterpretations. We suggest that system standards defined in S5.1a of the NER are considered adequate to define a stable voltage waveform. If the system is meeting the system standards, then the voltage waveform should be considered as stable. As such, there is no need to define any additional metrics for a stable voltage waveform.

Shell Energy:

Shell Energy notes the consultation AEMO has undertaken with TNSPs and DNSPs on this issue and is generally supportive of the proposed description. However, we consider inverter designers and manufacturers to also be key stakeholders and encourage AEMO to engage with these parties to ensure their support for system requirements.

Siemens Gamesa (SGRE):

SGRE believes that an additional definition of "stable voltage waveform" by AEMO and many of the proposed concepts are already defined by various clauses of the NER. The term stable voltage waveform is wholly encapsulating and should not be used. SGRE encourages AEMO to consider separate names and definitions for the different power system phenomena that it is attempting to capture so that they may be used to accurately assess power system study outcomes … If these terms are defined separately, it would allow the industry to capture and address the actual issues occurring more accurately.

SMA:

The approach proposed appears pragmatic, and substantially more objective than measures associated with fault level, noting that the actual metrics should be given careful consideration in the implementation phase.

The terminology around pre-contingent and post-contingent conditions could be clarified to refer to voltage phase angle change on fault inception and fault clearance, presuming this is what is intended. A degree of detail as to how this voltage angle is calculated or measured would be necessary, given the mathematical challenges around determining the angle of a distorted wave form in time frames less than 2-3 cycles.

In addition to a maximum voltage angle shift, consideration should be given to metrics around sensitivity of voltage angle to injection of current in the d-axis, as a more representative representation of the vulnerability of the system to voltage angle instability from grid following inverters.

The question of wave form distortion in the cycles immediately following fault inception or clearance needs careful consideration, as non-fundamental components may indeed be helpful in restraining voltage angle, or indeed an un-avoidable artifact of optimised grid forming inverter design.

Tesla

Tesla recommends AEMO appropriately consider what provides the best balance between modelling complexity / resource requirements and sufficient accuracy at a first approximation for what impact IBR has on system strength provision going forward.

From the perspective of battery inverter models, Tesla views the first EMT option as the likely best outcome, acknowledging that it is time consuming. Option 2 is not considered appropriate for assessing inverter-based resources (IBR) and is not recommended (we note that available fault level is a proxy value – and does not provide any detailed insight into the actual network condition – e.g. there are connection points with 0 or negative AFL – which does not make sense in practice). Tesla is open to consider Option 3, but would require further detail to understand how it would apply in practice to battery systems (both grid-forming and grid-following).

Regarding analysis options for SSSPs to assess future delivery of a stable voltage waveform, stakeholder submissions were again divided. Extracts from submissions on this issue are below.

Citipower/Powercor:

> Option 1 is suitable for very short-term planning, for example now to one or two years into the future, where the models are better known, and the output is most accurate.
>
> Option 2 and 3 are suitable from a one or two year to 10 year planning horizons as they can be undertaken very quickly with low computational cost for each planning year. We further note that it (and all NEM NSPs) already maintain Available Fault Level (AFL) models of the current and future networks (due to existing SSIAG (5.3.4B) requirements) and therefore these can quite easily be expanded for future planning purposes (similar to what is done for DAPR/TAPR planning) without additional burden of creating models from scratch. Therefore this method is most appropriate for long term planning as long as AEMO/TNSPs/SSSPs consult with DNSPs for the creation of their AFL models. It is imperative that AEMO provide guidance on consistency between SSSPs, especially as system strength nodes can affect other regions (eg. Red Cliffs is a border node) as inconsistent approaches may lead to inconsistent investment in different NEM regions driving different connection conditions across NEM regions.

Energy Queensland:

> Ergon Energy and Energex believe the determination of the assessment process should largely be left to the SSSPs, as they are responsible for planning and delivering sufficient system strength to meet the stable voltage waveform criteria.
>
> Option 1. In our experience, EMT studies are the only way to sufficiently assess system strength. As such, this is our preferred approach.
>
> Option 2. Our experience with the Available Fault Level (AFL) methodology as part of the Preliminary Impact Assessment (PIA) process suggests this method is a poor indicator of system strength gaps. The PIA has often indicated a negative AFL but, once the projects have reached the Full Impact Assessment (FIA) stage with EMT assessment, there has been no evidence of system strength shortfalls.
>
> Option 3. While this option is very similar to Option 2, it is assessed in a different way, and it is not evident that it provides any advantage over Option 2.
>
> We suggest that SSRM should provide high level direction, for example, that EMT modelling should be used, but the specific details should be left to the SSSPs.

Marinus Link:

> Of the three options, Option 2, the calculation of Available Fault Level is the most appropriate for forecasting system strength. The use of generic EMT models will be highly sensitive to the parameters chosen and will not represent the actual instabilities that may be present in the future IBR, and instead may present as a different limitation that will not manifest when actual manufacturer models are tuned to the specific conditions. The third option, using the sensitivity coefficients would require an understanding of what values should be set as the threshold and it is not clear at present whether system strength issues will manifest anyway.
>
> It would be beneficial for the SSRM to indicate a preferred assessment process that the SSSPs should apply to prevent perverse outcomes at nearby nodes that are across regional boundaries.

Lakshan Bernard (Monash University):

> [Option 1] … it would be preferable to utilise a less resource intensive methodology to assess the bulk of the cases and reserve EMT assessment for cases that are marginal.

[Option 2] The main advantage of this option is that it is computationally easier to calculate fault levels than running EMT simulations. Furthermore, by considering fault levels, it gives some interpretability about the voltage stability after a disturbance. One of the difficulties of this option is determining the minimum Short Circuit Ratio (SCR) foreach IBR. Another limitation of this method it that it is not intuitive how AFL is related to the voltage stability when there is no disturbance in the network. Ultimately, this is a proxy method since the voltage waveform is not being directly assessed.

[Option 3] This option is also based on phasor model of the power system, hence it is computationally easier than running EMT simulations. Compared with AFL, it is more mathematically intuitive how the voltage phasor sensitivities to power flow contributes to instability in a weak grid … The main limitation of this option is that, since it considers the phasor voltage, it is not obvious what are the possible distortions to the actual voltage waveform. Thus, it is difficult for this option to assess instabilities caused by the PLL or the inner control loop.

In addition to the options proposed by AEMO (which are based on phasor and EMT modelling, it is also worthwhile considering the State Space Representation (SSR) of the power system …

…

Another option is state space representation (SSR). This has the advantage of being set in the time domain, thus considers the voltage waveform unlike phasor models. Compared with EMT simulations, SSR is suited to analyse small signal and oscillatory stability using eigenvalue analysis.

Powerlink:

Powerlink considers that option 1 (use of generic EMT models) is the only method suitable for assessing future voltage waveform stability (IBR stability). The other high-level metrics proposed in options 2 and 3 provide no insight into the system strength issues that need to be assessed and understood to determine the efficient level of system strength necessary to meet the forecast of IBR plant.

We believe that consistent methodology for system strength planning across NEM is important … We suggest the method of the assessments as per option 1 (use of generic models) and AEMO should provide some general guidance on the type of generic models that should be used by the SSSP. The SSRM should provide guidance and not be prescriptive. Assessment as per options 2 and 3 do not provide sufficient confidence in voltage waveform stability that is important of the stable operation of IBRs.

Shell Energy:

Shell Energy considers that, rather than AEMO specify processes to SSSPs, it may be better to require SSSPs to develop their own approach and to detail how this approach provides the optimum outcome. We note that it will be important that either an AEMO developed process or an SSSP developed process must allow SSSPs to set out the mechanisms by which system strength services may be self-supplied.

Siemens Gamesa (SGRE):

SGRE believes that a combination of the proposed methodologies should be used depending on the timeframe of the planning. SGRE also encourages AEMO not to overlook widespread use of PSSE dynamic modelling within its planning studies, as is used in other jurisdictions, notably the USA.

SSSPs are likely to be beholden to conflicting incentives and allowing them to follow the guidelines with no strict oversight by AEMO is likely to lead to greatly varying outcomes for different NEM regions and significant overinvestment in infrastructure.

4.3.2. AEMO's assessment

Describing a stable voltage waveform

AEMO agrees with submissions that noted that stable voltage waveform requirements are broadly covered in the system standards fixed in the NER. However, the Amending Rule clearly requires that AEMO describe stable voltage waveforms. AEMO understands that the AEMC intent is for the description to provide clarity for SSSPs and generator proponents about the implementation of the new system strength standard, and to support the decoupling of fault level and voltage waveform stability in the ongoing delivery of power system stability through the transition to high penetration of inverter-based resources.

AEMO notes that many stakeholders consider the proposed definition to be sufficient, and that several have provided specific feedback. AEMO's assessment of the specific feedback received is as follows.

- Several submissions (Fluence and Siemens Gamesa) have asked for clearer information on how the description can be interpreted by potential providers of non-synchronous sources of system strength, so that SSSPs will be able to seek system strength services from both synchronous and non-synchronous sources when seeking to meet the system strength standard at each node. AEMO agrees that this is a good aim and will endeavour to provide additional information. For financial year 2022-23, AEMO has committed to collaborate with industry on a voluntary specification for grid-forming inverters. Such a document could assist with identifying a standardised way of determining system strength capability from grid-forming inverters, which in turn could inform future process development under the SSRM.
- Regarding the Siemens Gamesa suggestion to consider separate names for the power system phenomena that the description is attempting to capture, AEMO doesn't consider that such terms exist at present but welcomes specific suggestions on this matter from stakeholders.
- Regarding the proposed criterion regarding positive-sequence RMS voltage adherence with operational guides, AEMO agrees with stakeholders' feedback that further clarity is needed. Monash University has emphasised the importance of understanding how the RMS value will be measured/calculated. However, AEMO considers that the average responding RMS meter calculations used in field measurements is still a reasonable representation of system voltage waveform stability and easy to measure, such as in real-time operations or using RMS type positive-sequence simulation programs (like PSS®E). If the stakeholders deem it necessary, a true RMS calculation can always be incorporated as part of EMT simulations or field measurements.
- AEMO agrees with feedback stating that it will be important to understand how the 'closeness' to a pure 50 Hz sinusoid will be evaluated. AEMO considers that the existing NER clauses such as S5.1a.6 on voltage waveform distortion could be used to satisfy this criterion and no additional specifications are provided as part of the definition to avoid further duplication of specifications.
- SMA suggested that consideration be given to metrics for sensitivity of voltage angle to injection of current in the d-axis. AEMO is concerned that this would be difficult to measure in real-time operations or field measurements, given existing difficulties in measuring this value even in modelling environments at this stage. AEMO considers that for pre- and post-disturbance conditions, the sensitivity of voltage angle changes to active power injection is a sufficiently good representation of the stability of the d-axis current component and that therefore measuring phase angle changes pre- and post-contingency is sufficient.
- SMA has asked whether references to pre- and post-contingent conditions refer to voltage phase angle change on fault inception and fault clearance. AEMO confirms that this is the intention of the wording, and that AEMO is proposing to exclude the fault period itself from the description. However, at this stage, AEMO does not have a specific timeframe or number of cycles under which compliance should be assessed. Should this become clearer over time as SSSPs seek to implement the new system strength standard, this could be updated in the SSRM.

- Shell Energy has requested that AEMO engage with inverter designers and manufacturers as well as TNSPs and DNSPs on the preparation of the description of stable voltage waveforms. AEMO confirms that several inverter designers and manufacturers contributed submissions to the Issues Paper consultation, and that their feedback has been duly considered and incorporated. AEMO is also conducting ongoing one on one stakeholder meetings where considered necessary.

Assessing the connection and operation of IBR while maintaining a stable voltage waveform

- Stakeholder submissions were divided on the three options proposed for SSSPs to assess connection and operation of IBR while maintaining a stable voltage waveform. This diversity of feedback reflects the complexity of this issue and the fact that it is an area of ongoing innovation in the power system.
- On the one hand, EMT analysis is the most precise way to assess power system stability for the purposes of system strength. On the other, EMT analysis is very resource intensive and arguably not possible for modelling beyond the coming one or two years without the creation of a generic library of IBR models. Even then, the use of a generic model library may diverge too far from physical reality to be useful without requiring re-modelling once the actual equipment design is known.
- AEMO acknowledges the limitations with the available fault level and voltage phasor metric options (based on PSS®E type switching studies) proposed as an alternative to EMT analysis. Stakeholders rightly point out that these methods may give a broad understanding of stability, largely assuming that fault level and phasor voltage can give sufficient sense of stability of the system, but that the drawbacks could be missing the IBR interaction issues (such as sub synchronous control interactions) as well as inappropriately assuming that fault level is required to address stability issues relating to IBR integration in the power system.
- Ultimately this issue will need to be considered as an ongoing area of power system analysis innovation. AEMO's understanding is that practical difficulties impede the ability to provide a perfect analytical option in the near term.
- AEMO thanks stakeholders for providing responses regarding whether AEMO should present analytical options, a preferred method, or defer entirely to SSSPs to derive their own options. Given the complexity in identifying a preferred or ideal option, as evidenced in the diversity of stakeholder submissions as well as AEMO's on assessment, AEMO considers that a coordinating role from AEMO on this matter would be most appropriate at present.

4.3.3. AEMO's conclusion

Based on stakeholder feedback, AEMO concludes that changes are needed to the proposed description of stable voltage waveforms in order to provide clarity about the proposed criteria. In the draft SSRM provided with this Draft Report, AEMO has made changes to attempt to make the description clearer. AEMO welcomes any further feedback or questions.

Regarding the proposed options for SSSPs to assess stable voltage waveforms over the planning horizon, AEMO is of the view that the SSRM should still include the three proposed options as well as noting that alternatives may emerge over time. AEMO acknowledges that at present none of the options is perfect for application over the entire ten-year planning horizon, and that SSSPs will need to select appropriate options for the various parts of the planning horizon. AEMO would seek to update the SSRM over time as analysis methods become clearer, if a preferred option were to emerge over time, or if new methods are uncovered.

AEMO's NEM Engineering Framework may incorporate action to engage with stakeholders regarding the value of a generic EMT models library.

4.4. Forecasting inverter-based resources (IBR) in the NEM

4.4.1. Issue summary and submissions

In the Issues Paper, AEMO proposed forecasting IBR in the NEM for the purposes of setting system strength standards by using the ISP as a starting point and deviating where justified by a significant power system or market change.

Most of the submissions supported the ISP being used as a starting point for analysis, with the CEC encouraging "AEMO to develop formal processes to take advantage of bottom-up investment market information and feed it into its planning processes." Citipower/Powercor agreed that "a 'most likely scenario' approach with sensitivity studies applied to the input is the most appropriate forecasting approach". Powerlink suggested including inputs such as jurisdictional government policy, jurisdictional REZ development, timing, location and size of new large block loads – noting this is difficult and that AEMO be able to update IBR forecast outside of the annual cycle to minimise uncertainties in the supply and demand sides. TasNetworks suggested consulting with SSSP's and having the ability to "modify ISP outcomes within the three year planning timeframe to align with the most current information".

AEMO also proposed:

- An equation based approach for projecting the level and type of IBR.
- An approach for projecting the technical capability of future plant.
- Inclusion of only committed and anticipated network augmentation projects for forecasting system strength requirements and other sources of information.

The main submissions on the issues are extracted below:

Accounting for future generation and load

Clean Energy Council (CEC):

> The CEC notes AEMO's discussion regarding how to account for future location of generation and load. This is an unarguably complex assessment. In a general sense, we encourage AEMO to acknowledge the asymmetry of risks associated with this uncertainty – that is, the costs of underestimating likely future IBR volumes at a given location will far outweigh the costs of overestimating these volumes. In the latter case, assets may be underutilised for a short time before generation connects; in the former, the already significant delays in connecting new generation will be further exacerbated, driving up investment and operational costs.

Locational detail for new generation

Citipower/Powercor:

> New generation should be modelled down to a specific bus. Also, whilst it is easier to estimate generation as direct connected to a specific node, it is highly likely the generation will connect downstream of that node (for example in the distribution system) and therefore be subject to a material amount of impedance between the 'system strength node' and the generating system.

Energy Queensland:

> Ergon Energy and Energex suggest as much locational detail as possible should be provided.

Powerlink:

> Powerlink recommends that AEMO only forecast IBR at the REZ and/or zonal level. This can include forecasts for wind, solar, BESS and IBR loads. The local TNSP/SSSP will model the location of plant within a REZ or zone taking account of relevant local knowledge such as connection enquiries and

connection applications, their own connection market intelligence, joint planning with DNSPs, and any jurisdictional access reforms that may apply.

Shell Energy:

Shell Energy prefers the use of a zonal approach, though not necessarily aligned to REZ topography alone. This approach would define a zone using a grouping of select buses within a close geographical region similar to the approach taken by Powerlink in defining its grid regions in its Annual Planning Report.

Siemens Gamesa (SGRE):

SGRE prefers connection projections to be provided for specific network buses. The outcome would be increased transparency to connecting parties, allowing participants to understand exactly where generation was considered in defining fault level requirements and to better locate their projects in areas that are likely to provide a faster connections process.

AEMO should focus on REZ level predictions of wind, solar, energy storage and other generation types. Projecting new generation at an individual network bus will be difficult, particularly if significant new network is required to support a new stream of development.

TasNetworks:

TasNetworks is currently dealing with an unprecedented level of interest in new customer connections varying significantly in size. TasNetworks supports the current Joint Planning approach where NSPs provide AEMO with regular updates of connection activity that can be used as inputs to refine processes like the annual System Strength Report. At this stage, it is difficult to see how loads can be incorporated into the forecast except in the case where government policy has explicitly set out to encourage the development of particular sectors.

Additional details for new connections

CitiPower/Powercor:

AEMO should include forecasts for each generation technology separately (e.g., wind vs PV vs BESS vs hydrogen, etc)

Energy Queensland:

We suggest the technology types should also be provided. For example, synchronous, grid following, grid forming.

Powerlink:

Powerlink recommends the following specification:

- Plant type (e.g. Large Scale solar farm, wind farm);
- Timing;
- REZ allocation (more specific only if agreed under joint planning); and
- MW/MVA size.

Siemens Gamesa (SGRE):

SGRE would prefer information on average, minimum, and maximum project sizes considered and the specific technology type to be included. For wind projects in particular, large project sizes can indicate significantly different performance requirements and balance of plant design compared with smaller projects.

Accounting for future generation and load in the forecast

Energy Queensland:

> As TNSPs have well established processes for forecasting demand, we suggest these be incorporated. Ergon Energy and Energex suggest DNSPs could provide information regarding projects which are currently active for the earlier years of the forecast.

Powerlink:

> Joint planning between NSPs and AEMO is required as part of the load forecast process. NSPs manage the connections of new and existing loads. Through these relationships, NSPs are at the forefront of understanding plans for expansion and/or electrification of existing energy usage. NSPs are also responding to a large number of new large load enquiries and may for their own internal planning processes be engaging consultants to inform macroeconomic projections. Whilst still preserving required confidentiality requirements, AEMO should have visibility of this additional information so that these views can be reconciled against any top down forecast that AEMO (and/or their Consultants) develop.

Incorporating DNSP-connected generation plant in the forecast

Citipower/Powercor:

> Further to our approach suggested in Question 1 [Citipower/Powercor suggested the use of thermal capacity based approach rather than using the existing fault level to determine minimum fault level], the available capacity (and therefore required system strength) of the distribution network can easily be forecast using the suggested method and can be provided up to the "system strength node". Further given that DER are by definition distribution-connected, it is essential that DNSPs provide specific input into the ISP for planning of DER and this can be by providing the system strength requirements of the DNSP's network to the SSSP.

Powerlink:

> AEMO's ISP forecast of IBR plant is aligned with Renewable Energy and decarbonisation targets and also takes into account the decommitment of synchronous generators. As recommended in question 17, AEMO should forecast at the REZ or zone level only. The allocation of IBR generation between the TNSP and DNSP networks should be informed by Joint Planning between the respective NSPs. Powerlink understands that it is not the intent of the Amending Rule to guarantee system strength for all IBR plant located anywhere within a DNSP network.

SA Power Networks:

> Could consider DNSPs being able to create their own System strength nodes based on minimum fault level requirements at TNSP-defined SSNs. Also, DNSPs should be able to charge embedded generators a flat fee as a system strength charge which can be passed on to TNSP for system strength remediation schemes.

Siemens Gamesa (SGRE):

> SGRE believes that AEMO should perform an assessment and release a public report of the impact of DNSP-connected plant on system strength and use this assessment for the basis of any decision to include or exclude DNSP connected plant from planning studies.

Equation based approach for projecting IBR

Energy Queensland:

> We note the equation does not include a term for the forecast Inverter Based Loads and suggest this be considered.

Powerlink:

> AEMO should only forecast the capacity of wind, solar, battery and IBR load connecting into REZs and/or within zones. The SSSP should determine the efficient level of system strength based on 100% availability of inverters and wind turbines. The SSSP can determine how to appropriately take account of the expected diversity in MW output between IBR plants within and between adjacent REZs when determining the efficient level of system strength. This may also consider the impact of REZ transmission limitations and/or upstream transmission limitations. The relevant local knowledge such as connection enquiries and connection applications, their connection market intelligence, joint planning with DNSPs should be considered by the SSSP while planning for the efficient level of the system strength. The SSRM should not be prescribing how the SSSP determines the efficient level.

Shell Energy:

> Shell Energy believes that the most important question related to IBR is the proportion of these installations that will self-supply system strength resources through grid-forming inverters. The levels of penetration of these inverter systems will be crucial to determining the requirements for system strength services. Clear details about how AEMO and SSSP's will determine the assumptions around and requirements for grid-forming inverters should be set out in the SSRM.

Siemens Gamesa (SGRE):

> SGRE believes that if a co-incidence factor is applied by AEMO then it is likely that there would be some operating scenarios that result in curtailment of generating plant. Thus, this co-incidence factor should be applied sparsely and with great care.

TasNetworks:

> TasNetworks does not support the proposed use of a coincident factor to refine the need for system strength. This approach assumes that system strength is a function of MW output which is not always the case. We understand that examples already exist in the NEM where it has been shown that the number of inverters online is the key variable, not the MW output. TasNetworks also considers that using a coincident factor introduces a level of complexity that is not justified due to the number of variables and inherent uncertainties already being managed. Under the efficient management of system strength rule change, AEMO provides a forecast of IBR connections and SSSPs define how system strength is subsequently provided to maintain a secure operating state. As a result, the SSRM should not be prescriptive in this regard.

Projecting technical capability of plant

Energy Queensland:

> While more sophisticated technology may be utilised in the future, it is our experience that proponents will generally choose the least costly technology. Therefore, advancements which are not mandatory should not be relied upon in determining requirements.

Powerlink:

> Powerlink recommends that the technical capabilities of future plants should be defined by the SSSP based on their market intelligence, customer engagement and commercial negotiations.

Shell Energy:

> Shell Energy disagrees with the proposed default conservative approach to projecting technical capability of future plant. Our view is that connection inquiries should nominate the type of inverter to be used (grid-forming vs non-grid forming) and that this should be factored into system strength requirement calculations. This information would then feed into projections of future trends which would inform longer term requirements.

Siemens Gamesa (SGRE):

> SGRE encourages AEMO to consider uptake of the system strength service charge. It is highly likely that with the current rules many connecting plant would opt to self-remediate their general system strength impact. If this is the case and is not considered in AEMOs planning studies then it would likely result in an essentially double up of system strength services imposing extremely significant cost burdens.
>
> [SGRE noted model selection is important for PSCAD studies and for those of more than a couple of years, AEMO should consult with equipment manufacturers (OEMs) through individual engagement processes on detailed PSCAD models and support for model tuning of representative future plant.]

TasNetworks:

> TasNetworks agrees with the proposed approach to projecting the technical capability of future plant. While grid-forming controls are rapidly evolving for use in battery energy storage systems (BESS) and to a lesser extent large scale solar, we agree that this type of solution is likely some way off for other types of IBR. A decision on whether BESS is or isn't grid-forming can be made on a regional basis, with the general expectation that any BESS located in Tasmania would be grid-forming by default given the specific characteristics of our network. Consultation with the SSSP is the recommended strategy going forward to address this issue.
>
> In regards to future network developments, ignoring or underestimating network augmentations required to connect new generation sources and/or load may lead to inaccurate predictions of system strength requirements. TasNetworks supports:
>
> - the use of Joint Planning activities to communicate what is required to support various levels of REZ development; and
> - including in the system strength analysis any REZ network development that is identified by the Jurisdictional Planner as necessary, including REZ development that does not meet the definition of a committed project

Sources of information on network augmentations projects used for forecasting system strength requirements

Clean Energy Council:

> The proposed arrangements must be compatible with jurisdictional schemes such as the New South Wales REZ scheme and associated approach to system strength. It is important for this framework to have transparent responsibilities for the jurisdictional planners / network operators across jurisdictional and REZ boundaries, through joint planning processes. This will also ensure consistency in definition and measurement of system strength shortfalls across regions. The CEC supports the flexibility around this outlined in the Issues Paper as well as the flexibility of the jurisdictional planner / network operator as System Strength Service Provider (SSSP) to address system strength needs.

Citipower/Powercor:

> Similar to the Annual Planning Reports (DAPR and TAPR), the ISP should consider all forecasts without augmentation, and then provide any "committed and anticipated network augmentation projects" as part of proposed solutions with the appropriate information (as per NER 5.12.2(C)(5)).

Energy Queensland:

> We believe that significant distribution projects could be shared via joint planning if pertinent to system strength… Ergon Energy and Energex suggest DNSPs could provide information regarding projects which are currently active for the earlier years of the forecast.

Marinus Link:

Given the impact that network augmentations can have on the system strength requirements and the far reaching 10-year timeframe of the forecast, we feel that actionable network augmentations should also be considered in the outlook.

Powerlink:

Powerlink considers network augmentations that are consistent with the assumptions of where new IBR plant are located and required for efficient market outcomes should be included. These augmentations may be informed by the ISP or other market analysis performed by the jurisdictional planner and should be included when assessing the required level of system strength. Ignoring this may lead to over investment in system strength. These decisions sit with the SSSP when designing the efficient level of system strength to host the forecast levels of IBR. The SSSP in consultation with TNSP (through joint planning where TNSP is not the SSSP) should also consider likely reinvestments in the network (as per their respective TAPRs) as assets reach end of technical life. The SSSP will need to balance this likely reinvestment in network (that may increase fault levels) against the possibility that non-network solutions may (in full or in-part) be the preferred solution. These decisions rest with the SSSP.

AEMO should not specify the technology type of the IBR (i.e., grid forming versus grid following) as part of their forecast. The allocation between technology types should be based on discussions between the SSSP and prospective BESS proponents with consideration given to potential system strength and/or inertia services that may incentivise grid forming technology.

4.4.2. AEMO's assessment

AEMO received mixed feedback regarding forecasting IBR in the NEM, most notably the location of IBR, the future network augmentations included in system strength assessments and the technical capability of plant. AEMO recognises the intention of the Amending Rule is to be procuring system strength services ahead of time, rather than after the plant is connected. The forecast of IBR is central to achieving this.

AEMO's assessment of the specific feedback received is as follows:

- When forecasting the quantity and location of new IBR, AEMO will ensure suitable joint planning activities are undertaken. AEMO agrees that joint planning with the NSPs is critical to ensure satisfactory outcomes which reflect the latest available information.
- Most stakeholders had the view that AEMO should be forecasting the location of new IBR at a REZ level (or ISP sub region), allowing the NSPs to refine this with further information and local knowledge to specific buses where required. It is important to note that while AEMO's forecasts may be at a REZ level, this will be refined through joint planning to be as accurate as possible. AEMO agrees that the ISP REZs serve as a suitable overarching forecast, with joint planning and specific information from the NSPs the most appropriate way to allocate IBR to more specific network locations. This includes considering what is connected to a DNSP's network.
- Regarding the type of IBR forecast and additional details for new connections, most stakeholders proposed high level plant parameters such as type (e.g., Wind, PV, BESS), timing, location, and size (MW/MVA) is appropriate. Regarding specific technical capability, stakeholders generally agreed with the proposed approach that uses market trends to inform the capability of plant. Shell disagreed with the concept of using a conservative approach and proposed that connection enquiries should nominate the type of inverter to be used. AEMO understands that typically the connection inquiry stage is not certain enough to be used given the level of change seen from connection enquiry stage to commissioning. A conservative approach (informed by market trends)

seems prudent given the intention of the Amending Rule.[8] The CEC also noted the asymmetric risk associated with uncertainty of insufficient system strength.

- Both EQL and Powerlink highlighted the role of joint planning in forecasting of new IBR loads. AEMO agrees that the joint planning process will help inform the preparation of forecasts for IBR loads.
- AEMO's NEM Engineering Framework highlights the importance of defining the necessary capabilities for grid-forming inverters to help guide OEMs and developers toward designs that support power system security. For financial year 2022-23, AEMO's NEM Engineering Framework includes a priority action to collaborate with industry on a voluntary specification for grid-forming inverters.

4.4.3. AEMO's conclusion

AEMO has updated its approach for forecast IBR for the draft SSRM to note that suitable joint planning activities will be undertaken when preparing the forecast. AEMO will provide forecasts of IBR at a REZ level and undertake joint planning with NSPs to refine this to specific locations where possible and prudent. Likewise, joint planning will serve to inform the forecast size, and quantity of new IBR loads, in addition to AEMO's ongoing information-gathering exercises for forecasting purposes.

The network augmentations included when performing assessments of system strength will include committed and anticipated projects. In addition to what was proposed in the Issues Paper, network augmentations that are not committed or anticipated, but would be required to feasibly connect the forecast amount of IBR, will be included when AEMO is conducting system strength standard assessments.

AEMO has decided to not use the equation proposed in the Issues Paper to represent the IBR hosted at the connection point. Instead AEMO will simply project the MW capacity (including loads where possible) expected to be connected, and note the type of plant. AEMO has concluded that the proposed coincident factor does not provide meaningful benefit given the key factor is number of inverters online, which is not always represented by co-incident factor. Likewise, the MVA factor is better captured in technical capabilities of the plant, which can be refined through joint planning and market trends as needed.

4.5. Including critical planned outages

4.5.1. Issue summary and submissions

In the Issues Paper, AEMO proposed that a 'critical' outage from a system strength perspective is one that substantively prevents sufficient strength from being available to meet power system needs. AEMO also sought feedback on potential thresholds and whether these should be specified in the SSRM or on an annual case-by-case assessment.

Extracts from submissions on this issue are below.

Ausgrid:

> Critical outages which may affect power system operation due to decreasing three phase fault levels are a key parameter in determining minimum three phase fault level requirements. Flexible power system operation is needed for maintenance and augmentation of the network and it may be constrained by minimum fault levels as critical outages may prevent network access when needed.

[8] See ERC0300: System strength final determination, paragraph 30, AEMC. https://www.aemc.gov.au/sites/default/files/2021-10/ERC0300%20-%20Final%20determination_for%20publication.pdf

> Ausgrid and other DNSPs need to be actively involved in the review of system strength to minimise the risk of system strength changes unduly limiting DNSP switching flexibility–avoiding to security and reliability risks to customer.

AusNet:

> Strongly supports the AEMO's decision to take critical planned outages into account when setting the minimum fault levels through its proposed definition. Inclusion of case studies or scenarios would aid clarity how that definition will be applied.
>
> [Regarding the AEMO's definition of critical planned outages and threshold criteria]… If applied appropriately, we consider the AEMO's approach provides appropriate coverage of known planned outage scenarios that are the highest priority to undertake from a network reliability and security perspective.
>
> [AusNet also suggests that] AEMO develop a series of scenarios or case studies in its SSRM to provide further guidance to System Strength Service Providers (SSS Providers) around what constitutes a critical planned outage… [and] Recommends the AEMO includes an addition clause in its threshold criteria that enables it to consider other circumstances not captured by its existing criteria that may be deemed a critical planned outage.

Powerlink:

> Powerlink agrees that critical outages include those network elements that have the greatest impact on system strength and the hosting capacity of IBR plant. This can include outages on interconnectors and on major intra-regional grid sections. In all cases though the outage has the effect of decoupling source of system strength from the impacted IBR plant. An outage should also be considered as 'critical' if constraints on IBR output due to this outage pose a risk to reliability of supply, or the fault levels under the outage are not remain adequate for continued operation of protection systems.

TasNetworks:

> Customer impacts and outcomes should be a key criteria when defining critical outages, including customer cost impacts of allowing unconstrained Inverter Based Resources (IBR) during some planned outages.

4.5.2. AEMO's assessment

There was general agreement on the Issues Paper proposal to incorporate critical planned outages, with stakeholders providing further detail and recommendations. In considering these issues, AEMO has also had regard to the AEMC's final determination on the Amending Rule, which indicates that SSSPs should consider options to address critical planned outages on a case-by-case basis, rather than AEMO including the critical planned outages in the "baseline network standard"[9].

AusNet suggested that examples of critical outages be included in the SSRM, and provided their own example. AEMO prefers to avoid specific examples in the SSRM itself, given the significant potential for circumstances to change over time. AEMO has instead provided in the draft SSRM for AEMO to prepare a list of critical planned outages using specified criteria, in consultation with SSSPs, as part of the annual determination of system strength requirements. SSSPs This list would be provided to SSSPs for incorporation into their annual planning for system strength, which is expected to result in efficient solutions to allow those outages to proceed while maintaining power system security. This may be

[9] Page, 98, AEMC, *Rule determination National Electricity Amendment (Efficient management of system strength on the power system) Rule 2021*, October 2021, accessible via https://www.aemc.gov.au/sites/default/files/2021-10/ERC0300%20-%20Final%20determination_for%20publication.pdf.

achieved by the provision of system strength services, operational limits or contingency plans advised to AEMO, or a combination of measures. .

AusNet also suggested AEMO include a clause which allows some flexibility for critical outages which do not fall under the other criteria. AEMO has added an additional criterion to provide this flexibility, allowing for management of any unforeseen issues.

Powerlink and TasNetworks suggested linking critical outage criteria to supply risk and protection operation, and TasNetworks noted the NEM does not provide generators firm access to the power system. AEMO agrees that linking the criteria to security risk and market efficiency is appropriate.

AEMO agrees with Powerlink's suggestion that in some cases critical planned outages may include those where IBR is required to stay online for power system security purposes. In those specific instances, AEMO may include a critical planned outage in the minimum fault level requirements, subject to a sufficiently high threshold being met for amount of IBR needing to be kept online.

TasNetworks suggested that adverse market outcomes could be a threshold for a critical outage. AEMO agrees with this suggestion, and will in some cases incorporate critical planned outages in the minimum fault level requirements where their adverse market outcomes can be considered to be sufficiently impactful.

4.5.3. AEMO's conclusion

AEMO has updated the criteria for critical planned outages proposed in the Issues Paper to incorporate feedback on specific matters proposed by Powerlink, TasNetworks and AusNet. Planned outages will be incorporated into system strength planning subject to sufficiently high criticality thresholds being met. AEMO has updated the critical planned outage criteria in the draft SSRM.

A list of critical planned outages, selected after SSSP consultation, will be published as part of the annual System Strength Report. SSSPs are expected to incorporate the impact of these critical planned outages into their planning, and provide services or other mechanisms to ensure the minimum three phase fault level can be maintained accordance with power system security requirements at each impacted SSN for the duration of each relevant outage.

4.6. Selecting system strength nodes

4.6.1. Issue summary and submissions

AEMO has proposed selection criteria that will be used to select a set of system strength nodes. The issues paper also noted that AEMO has not proposed to create a system strength node at every transmission busbar.

The main submissions on these issue are extracted below:

System strength nodes selection criteria

Ausgrid:

> We support the establishment of system strength nodes but believe that the approach must further consider suitable locations within DNSP networks, in addition to the number and choice of locations on TNSP networks.
>
> System strength has strongly locational characteristics…While there will clearly be investments in the transmission network, in some cases system strength remediation may be most effectively and efficiently delivered from within a DNSP's network…There is a strong risk that more electrically remote nodes on the transmission network will send incorrect signals to distribution connected generators and/or DNSPs with an increased risk of inappropriately rendering system strength investments non-viable.

AusNet:

> AusNet suggests a minimum of seven system strength nodes are required in Victoria…This includes the five existing fault level nodes plus one additional node in Bulgana and another in Heywood.

Clean Energy Council:

> In terms of the location of nodes, AEMO's approach appears to be sensible. However, there remains a degree of further detail needed in terms of how node identification will be aligned with state based REZ declaration. We are confident that AEMO will take a pragmatic approach to node identification and align this with the development of REZs under the various state-based schemes, wherever this is possible. Such a proactive application of the national frameworks will reduce the extent of jurisdictional duplication necessary in REZ buildout.
>
> The CEC supports the use of existing forecasts (including the ISP and ESOO) to inform forecasts of system strength demand and node location… We also encourage AEMO (working with SSSPs through joint planning) to carefully consider how node identification and the provision of system strength can be coordinated with other system requirements… We also encourage AEMO to consider other system needs, such as system restart and restoration, when planning for the location of system strength nodes. Carefully located system strength nodes with rightsized assets to meet system strength needs at those nodes, can likely provide a material 4 additional benefit in the event of a major supply disruption or black system event, primarily as system restoration support services. Again, we consider that storage assets or synchronous condensers located for system strength provision can also provide these services.

Citipower/Powercor:

> We consider that every transmission node should have system strength requirement. Our experience is the AFL for every node on the transmission network can be calculated as quickly as just a select few with a PSS/E model. We have scripts to run AFL on every distribution node (down to the MV bus) in our network (which are far more nodes that the transmission network), and therefore it should be relatively straightforward for this to be undertaken at the transmission level.
>
> It is also noted that MLFs are calculated for every transmission network node and therefore the SSLF (and therefore System Strength Nodes) can and should be treated the same to ensure economic investment into all parts of the NEM.
>
> Further, selecting only specific some nodes in the transmission network will most likely create uneconomic investment into that node. An example here being that system strength investment into the Red Cliffs node will not improve system strength at Kerang for loss of the Red Cliffs to Kerang line, and therefore Kerang (and others) not having system strength requirements will result in Kerang never experiencing system strength investment to allow for this credible contingency event. Finally, due to the non-linear characteristic of fault level and impedance, a limited set of system strength nodes in the network will result in a non-linear/reasonable system strength investment

Energy Queensland:

> As system strength nodes cannot be located in distribution networks, we suggest it may be more appropriate to locate a system strength node at or near all TNSP/DNSP connection points in order to facilitate efficient connection of generation into the distribution network. This is particularly applicable to the Queensland network, which has extensive sub-transmission networks remote from the transmission network and numerous registered inverter-based generators currently connected with more proponents anticipated to apply for connection.

Jacobs:

Use of only a few system strength nodes not particularly useful as Renewable Generation is being added across the ENTIRE network. AEMO should provide minimum fault level load flow case to allow generators to assess requirements at nodes other than Minimum SS nodes.

SA Power Networks:

…There also should be a set of system strength nodes in the distribution network. If AEMO is not going to formally define these nodes then DNSPs should be given authority to define and manage their own minimum system strength levels on the distribution network.

TasNetworks:

TasNetworks supports the proposed selection criteria, but seeks an opportunity to review how the selection process would work in the Tasmanian region. [As well as the four existing fault level nodes] …We anticipate that additional nodes will be necessary to help manage new REZ areas [in Tasmania] as they are developed.

Transgrid:

Transgrid broadly supports the system strength node selection process outlined [in the Issues Paper] …However, SSNs should:

- Be well defined
- Be carefully located and identified
- Have appropriately defined Electrical distance. The electrical distance threshold between SSNs needs to take into consideration the topology of the network and the locations of the available renewable generation resources in the region
- Align with renewable zones developed under state-based schemes.

Well-defined SSNs will avoid excessive system strength remediation charges and prevent small to medium sized renewable generators connecting to DNSP networks to be unfairly disadvantages. New SSNs and new system strength remediation locations will also need to be carefully selected and identified to avoid excessive system strength charges being required for multiple IBRs in the network.

4.6.2. AEMO's assessment

A number of stakeholders raised concerns and issues around node selection, and how DNSP connected generation or remote generators is covered by this framework given the non-linear characteristics of network impedance. AEMO agrees this is a complex issue and careful consideration how distribution and remote generation is covered by this system strength framework, how nodes can be selected to reflect the system strength requirements of distribution connected generation and what investment signals are given.

AEMO considers that the underlying objective of the Amending Rule is to facilitate proactive, bulk provision of system strength services, given the fast increasing penetration of utility-scale IBR and the pace of the electricity transformation underway. AEMO has proposed a system strength node selection process which it considers to be consistent with this objective, recognising both the limitations and the allowances in the Amending Rule with regard to distribution networks, in that:

- System strength nodes can only be located on transmission networks, noting that where appropriate they may be located close to distribution network interfaces.
- Minimum fault levels should be set to achieve stable protection system, voltage control system and power system operation at transmission and distribution levels, requiring robust and effective joint planning between SSSPs and DNSPs.

- Solutions for the provision of system strength services should be appropriately located to achieve the standard at each node, including in distribution systems where that is most efficient.
- Treatment of individual generation connections at various points in the distribution networks will be covered in the amendments to the SSIAG, which is subject to a separate consultation process.

AEMO acknowledges that over time it may become clear that further focus on distribution networks will be required.

Additionally CitiPower/Powercor suggested that every node on the transmission system should be a system strength node and AFL can be easily calculated for each node. AEMO agrees that AFL is a straightforward calculation, but accurately defining what the actual system strength requirement is (which requires EMT modelling), is considerably more complicated compared to performing fault calculations. As such AEMO does not consider it appropriate to select many system strength nodes, or to propose that each transmission node should be a system strength node.

AEMO notes AusNet's submission suggesting new system strength nodes in the Victoria region, and will continue to consider node selection through the joint planning process.

4.6.3. AEMO's conclusion

Consistent with the assessment above, AEMO has not made major changes to the system strength node selection approach proposed in the Issues Paper, and has reflected the original position in the draft SSRM.

AEMO notes that under the present framework, system strength nodes can only be declared in a SSSPs network[10]. However, the assessment of stable voltage waveform is not solely undertaken at system strength nodes.

Regarding stakeholder concerns about inclusion of distribution-connected generation in the system strength services provided by SSSPs, AEMO considers individual DNSPs may joint plan with their local SSSP for instances where there is sufficient distribution-connected generation expected to justify consideration of system strength services be required for the local system strength node.

4.7. Maintaining synchronism of distributed energy resources

4.7.1. Issue summary and submissions

In the Issues Paper, AEMO noted that there are two options for incorporating synchronism of distributed DER into the new system standard - through the minimum fault level requirement for ensuring power system remains stable following a credible contingency, or through broader planning activities undertaken by NSPs, including but not limited to the stable voltage waveform element of the system strength standard.

It was also noted that in order to plan for credible contingency events when and if distributed DER systems disconnect en masse from the power system, AEMO proposed to continue to assess the largest credible contingency size for distributed DER as part of testing appropriate credible contingencies and protected events when setting the minimum fault level requirements.

The main submissions on these issue are extracted below:

Planning responsibility for synchronism of distributed DER

Citipower/Powercor:

[10] Clause 5.20.C1 of the NER,

We agree with the proposal for AEMO to continue to assess the largest credible contingency size for distributed DER as part of testing appropriate credible contingencies and protected events when setting the minimum fault level requirements. Further, a system strength node in the transmission network may have a very small bearing on the fault level seen at the 240/415V level, and even the 22kV feeder level, which can be far more dependent on the impedance of the applicable transformer than the network impedance. Therefore, it is important that enough system strength nodes are chosen so that minimum fault level for all DER are adequately considered. Further investigation is required to understand the impact of DER on system strength as well as the minimum fault level/system strength required for DER to remain synchronised to the network and operate stably

Energy Queensland:

It is our view that this responsibility should lie within the distribution network service provider's (DNSP's) planning functions. DNSPs are already engaging with significant technologies, volumes and magnitudes of DER within the context of the network for which the DNSP is responsible. Each DNSP has some similarities, but there is also some uniqueness for which the DNSP is best placed to be accountable and responsible.

Powerlink:

Powerlink recommends that the fault level requirements for DER synchronism is best captured in 'minimum fault level' requirements. As DER investment, such as rooftop PV, electric vehicles and household batteries is driven by electricity customer preferences it is appropriate that the power system fault level needed to support this DER is included in the minimum fault level requirement. The cost of meeting this minimum fault level is then recovered from electricity consumers.

Siemens Gamesa (SGRE):

SGRE is of the belief that DER should not be included in the minimum fault level requirement of the system strength standard. With current transmission system modelling tools used by AEMO the level of detail required to assess any impact of transmission system strength on DER operation at the LV level is not available. Any attempt to use current modelling tools and practices to assess this is highly likely to be highly inadequate and result in false system strength requirements.

SGRE would support any rule changes proposed by AEMO to shift obligation on planning, management, and performance of DER generating systems to DNSPs, who are best placed to manage them and their connection requirements. Or any changes AEMO proposes to further improve DER technical standards, such as AS 4777.

SMA:

Transition of the NEM to host high levels of IBR could conceivably widen the range of conditions experienced by embedded generation, and indeed inverter connected load. Experience with current following IBR is that the key survivability / stability conditions relate to the ability of current source inverters to push or pull the voltage angle as they try to follow the external grid angle. This suggests metrics around sensitivity of in fault voltage angle at key busses to angle of current injection from surrounding busses could be effective in determining the potential for fast voltage angle instability. As Distribution Network Service Providers (DNSPs) have best visibility of embedded generation, it would appear pragmatic for responsibility for assessing and managing these issues should also lie with the DNSPs.

TasNetworks:

….in TasNetworks' view, the fundamental risk to be managed during low system strength operating conditions is the wider propagation of low voltage disturbances and the ability to recover voltage

quickly upon fault clearance. The system security consideration is the increasing number of photovoltaic (PV) systems exposed to voltage conditions that may result in their generation being interrupted for a sufficiently long time as to negatively affect network frequency (and the recovery of network voltages as a feedback effect). Further investigation is required to understand:

- what metrics should be applied and what limits are appropriate to those metrics;
- what technological solutions exist as an alternative to simply increasing minimum fault levels, noting that this basically equates to an increased number of online voltage sources capable of counteracting the effects of fault events; and
- the maximum allowable contingency size and how this translates to network voltage control requirements, i.e. at what point is there a problem that requires proactive management.

TasNetworks requests that this issue is more thoroughly described and understood before a course of action is committed to. There may be opportunities to address this issue as part of NSP planning functions. Solutions could include:

- density limits on PV;
- increased scrutiny of PV performance characteristics; and/or
- increased real time visibility of distribution networks.

Proposals for how to assess distributed PV impact available fault levels

Citipower/Powercor:

Type testing in lab environment or test bench to assess the limit and/or sensitivity of different DER inverters should be undertaken. Subsequently, an analytical approach can be developed to assess the aggregated impact of DER.

Energy Queensland:

Ergon Energy and Energex are not aware of any extensive research or detailed investigation into the system strength requirements of small-scale inverter-based renewable generation (where small-scale in this context is less than 5MW). For this reason, we do not have a suggestion for an assessment methodology and identify this as an area for future research.

SA Power Networks:

It should be noted that DNSP connected distributed PV or BESS generating systems can have an impact on the Transmission defined system strength nodes if considered as one lumped generating system. Should DNSP connected unregistered generating system be subjected to system strength charges to address this? If so there should be something in the updated guidelines about how and who will be responsible to enforce this.

Siemens Gamesa (SGRE):

Available fault level is already an imprecise calculation. SGRE does not believe adding further uncertainty in available fault level calculations by considering DER (while the actual impact of DER is in no way well understood) will provide any way expedite the connection of new IBR plant, which is the intent of the ERC0300 rule change.

SMA:

[When assessing distributed PV available fault levels]…a wide range of embedded connected generation, and indeed large inverter-controlled load is likely to be relevant to these considerations.

Tesla:

> In general, we note that active DER offers much greater value than passive DER and should be incentivised to help contribute to system stability and reliability outcomes.
>
> A key feature and underlying principle of all reform should therefore be that orchestrated, controllable, 'active' DER is better for the electricity network than passive DER. Orchestrated DER can be used to provide valuable market and network services (e.g. frequency control ancillary services, fast frequency response, inertia, voltage support, peak demand reduction and a variety of other new and emerging services). Orchestrated DER can also be optimised to respond dynamically to network and market signals to ensure that AEMO's system operations are supported across both distribution and transmission layers.
>
> However, the ability for the industry to make the shift from passive to active DER is dependent on customers being incentivised to hand over control of 'their' DER; and on operators, aggregators, and service providers investing in the engineering development for products, platforms and optimisation software, as well as understanding the associated regulatory and legal compliance burden from providing these services. If this upfront cost and burden outweighs the incentives, and the customer has a choice in passive DER as an alternative, then the DER industry will likely self-select a focus on passive DER, which would be a suboptimal long-term outcome and likely result in unnecessarily heavy handed 'blunt' mitigations such as mandatory remote disconnection that has been recently considered.

4.7.2. AEMO's assessment

AEMO considers that power system services (potentially including system strength) required to ensure synchronism of DER currently fall under the planning responsibility of DNSPs and should not be explicitly considered in the preparation of system strength standards for system strength nodes in SSSPs' networks. AEMO considers this position to be consistent with the AEMC final rule determination which was focused on system strength provision for utility-scale IBR.

Separately, AEMO will continue to apply its existing approach where DER disconnection is included in the largest credible contingency studied, where relevant and consistent with the latest understanding of DER behaviour.

4.7.3. AEMO's conclusion

AEMO has not included a requirement to consider synchronism of DER in the system strength standard assessment processes outlined in the draft SSRM.

5. Discussion of material issues for the PSSG

Of the 22 submissions AEMO received in response to the Issues Paper, four provided feedback on the PSSG. The issues raised, and AEMO's responses, are provided in this section. The draft PSSG, incorporating AEMO's proposed amendments, is published alongside this report for consultation.

5.1. Need to update the PSSG

5.1.1. Issue summary and submissions

In the Issues Paper, AEMO identified that the PSSG, have not previously been updated to recognise the NER system strength framework, and that it would be appropriate to do so in conjunction with the implementation of the Amending Rule.

Submissions from the Clean Energy Council and TasNetworks agreed with this need and supported a limited update of the PSSG.

5.1.2. AEMO's assessment and conclusion

AEMO confirms that the PSSG amendments will be limited, specifically to define strength in a similar manner to other types of stability and to ensure consistency with the new system strength framework.

5.2. Scope of PSSG amendments

5.2.1. Issue summary and submissions

The Clean Energy Council noted that any broader questions of system stability and how it is managed should be subject to an appropriately scoped review of the PSSG, separately to this consultation process.

Energy Queensland suggested that compliance with NER S5.2.5.10 (Protection to trip plant for unstable operation) requires further clarity, particularly for asynchronous generators. Energy Queensland understood AEMO has already commenced work on producing a guideline to this effect and suggested efficiency could be gained by combining this with the PSSG.

SMA considered that the PSSG should more precisely define and include aspects of system performance that are currently referred to broadly as system strength. This includes "voltage angle jump on fault inception and clearance, in fault voltage angle rate of change, sensitivity of voltage angle to incremental Id injection, including in faults.

5.2.2. AEMO's assessment and conclusion

AEMO agrees with the Clean Energy Council's view that, in respect of the PSSG, this consultation should be limited to the minor updates necessary to reflect the NER system strength framework as implemented by the Amending Rule, rather than any broader review of the PSSG. AEMO proposes as far as practical to reference relevant system strength requirements from other published instruments, rather than repeating them in the PSSG.

AEMO appreciates the different issues raised by Energy Queensland and SMA, however, at this time does not propose a wholesale review of the PSSG to address those matters. Specifically:

- AEMO will continue to address any regulatory issues relating to generator connections, in consultation with industry stakeholders and the AEMC. The potential issues noted by Energy Queensland are out of scope of this update of the PSSG.

- The PSSG does not specify measures of stability in precise detail for any of the stability types. Many of the specified measures are either in the NER or other consulted documents and these are referenced in the PSSG.

6. Draft determination

Having considered the matters raised in submissions and at meetings/forums, AEMO's draft determination is to:

- Replace the existing System Strength Requirements Methodology with the draft SSRM published with this Draft Report.
- Amend the Power System Stability Guidelines in the form of the marked-up draft PSSG published with this Draft Report.

The amended SSRM and PSSG will take effect by 1 December 2022 and the amended SSRM will be used for the purposes of the System Strength Report to be published by AEMO on that date.

Appendix A. Glossary

Term or acronym	Meaning
AEMC	Australian Energy Market Commission
AFL	*available fault level*
Amending Rule	National Electricity Amendment (Efficient Management of System Strength on the Power System) Rule 2021
CIGRE TB 671	CIGRE Technical Brochure TB 671 entitled “Connection of Wind Farms to Weak AC Networks”
DNSP	*Distribution Network Service Provider*
EMT	Electromagnetic transient.
Final Determination	AEMC, Efficient management of system strength on the power system, Rule determination, 21 October 2021, at https://www.aemc.gov.au/sites/default/files/2021-10/ERC0300%20-%20Final%20determination_for%20publication.pdf
Full Assessment	The assessment referred to in new clause 4.6.6(b)(1)(ii)
IBR	*inverter based resource*
MNSP	*Market Network Service Provider*
NEM	*National Electricity Market*
NER	National Electricity Rules
NSP	*Network Service Provider*
OEM	Original equipment manufacturer
PLL	Phase-Locked-Loop
PSCAD™/EMTDC™	Power Systems Computer Aided Design / Electromagnetic Transient with Direct Current
PSS®E	Power System Simulator for Engineering
PSSG	Power System Stability Guidelines
PV	Photovoltaics
REZ	Renewable energy zone
SCR	*short circuit ratio*
SSIAG	System Strength Impact Assessment Guidelines
SSLF	*system strength locational factor*
SSN	*system strength node*
SSRM	System Strength Requirements Methodology
SSSP	*System Strength Service Provider*
Stability Assessment	The assessment referred to in new clause 4.6.6(a)(8)
TNSP	*Transmission Network Service Provider*

Appendix B.Summary of submissions and AEMO responses

Table 2 below lists the substantiative issues raised in consultation and AEMO's response.

Table 2 Summary of submissions and AEMO responses

No.	Consulted person	Issue	Instrument	AEMO response
1	Various	Determining minimum fault level requirements	SSRM	See section 4.1
2	Various	Ensuring protection scheme operation	SSRM	See section 4.2
3	Various	Criteria for stable voltage waveforms	SSRM	See section 4.3
4	Various	Forecasting inverter-based resources in the NEM	SSRM	See section 4.4
5	Various	Planning for critical outages	SSRM	See section 4.5
6	Various	Selection of system strength nodes	SSRM	See sections 4.6
7	Various	Maintaining synchronism of distributed energy resources	SSRM	See section 4.7
8	Citipower/Powercor Powerlink, SGRE	How to assess voltage control system operation needs for the purpose of setting the minimum three phase fault level requirements, including alternatives to the allowable voltage step change limit, and how best to incorporate the impact of new technologies on reactive control equipment operation. Citipower/Powercor "We agree with the proposal and support the use of AS61000.3.7:2001." Powerlink "Allowable voltage step change limit is managed by NSPs to meet the system standards. AEMO should be guided by NSPs if there is any additional fault level requirements for NSPs to maintain the system standards … Powerlink agrees with the assessment methodologies proposed by AEMO. To incorporate the impact of new technologies it is likely that dynamic power system analysis will be required to assess compliance against the system standards." SGRE "SGRE encourages AEMO to frequently reassess any minimum fault level limits based on the switching of reactive plant through detailed power system analysis. It is expected that as generation with high dynamic reactive capability becomes distributed throughout the NEM, the requirement for large network reactive plant may be reduced due to very high levels of dynamic reactive support … The proposed method from AS/NZ 61000.3.7 is not forward looking and does not consider the evolution of the power system to incorporate a large amount of IBR which provides dynamic reactive power support."	SSRM	In the Issues Paper, AEMO proposed two methods for consideration for assessing voltage fluctuations from switching of reactive plant at SSNs: assessing steady state switching of the power system against allowable maximum voltage step change from the nominal voltage for the plant, using thresholds from AS/NZ 61000.3.7, and performing detailed power system analysis where the effect of dynamic plant needs to be considered. AEMO agrees with Powerlink and SGRE that incorporation of new technologies is likely to require detailed power system analysis. However, at present AEMO does not see evidence that new technologies are providing the necessary fault current injection to address transient voltage fluctuations in the system. AEMO has included a position in the draft SSRM which indicates that assessment against AS/NSZ 61000.3.7 will be the primary assessment method for ensuring that the minimum fault level requirements enable voltage control system operation. A note is added to state that in future detailed power system studies may be justified on a case by case basis.
9	Jacobs	"5. AEMO has conflicting roles:	SSRM	AEMO is a not-for-profit, independent entity with no commercial or business interest

No.	Consulted person	Issue	Instrument	AEMO response
		a. System Strength Service Provider (SSSP) in Victoria b. Provide System Strength Report which determines SS levels and advises on potential shortcomings to be remedied by SSSP."		in system strength outcomes. AEMO's functions – both for its Victorian planning and system operator roles – are conferred by law and undertaken as statutory obligations. As the Victorian SSSP, AEMO cannot benefit from system strength determinations – it does not own, operate or derive income from regulated assets, other than as required to recover its costs including payments to declared transmission system operators.
10	Jacobs	"The System Strength requirements seem to apply only to Customers, Generators and Merchant Network Service Providers – NOT Transmission Network Service Providers."	SSRM	The system strength standard is to be met by TNSPs who are designated as the jurisdictional planning bodies. In terms of the application of the amended system strength impact assessment and remediation requirements for new connections, only generators, large IBR customers and **market** NSP connections are covered by that part of the framework.
11	Jacobs	"The commentary on reactive switching and Fault levels is reasonable. However, the impact of transformer energisation under low fault level conditions also needs to be considered (noting that Point on Wave switching won't be effective due to remanent flux issues)."	SSRM	AEMO considers that although low system strength may exacerbate inrush current issues, it is not the sole or primary driver and should be addressed through separate operational and design processes rather than the system strength framework.
12	SGRE	"Siemens Gamesa understands the intent of ERC0300 is to enable the efficient connection of the significant number of projects through centralized system strength planning. However, the proposed frameworks and methodology do not appear to support this objective and will result in proponents choosing to self-remediate rather than paying the charges for a more centralized approach. The proposed planning methodology is believed to lead to overinvestment and ultimately increase the cost burden on energy consumers. In addition to different technology types considered in planning studies [for projecting technical capability of future plant], SGRE encourages AEMO to consider uptake of the system strength service charge. It is highly likely that with the current rules many connecting plant would opt to self-remediate their general system strength impact. If this is the case and is not considered in AEMOs planning studies then it would likely result in an essentially double up of system strength services imposing extremely significant cost burdens."	SSRM	AEMO has endeavoured to prepare the draft SSRM to be consistent with the AEMC intent for the rule change. AEMO does not consider that assumptions about uptake of the system strength charge would fit within the intent for the IBR forecasting role required under the Amending Rule. A number of the SGRE issues were related to the SSIAG and AEMO will consider these through SSIAG consultation
13	Various	AEMO has proposed two methods for assessing voltage fluctuations, one using the Australian Standard (AS/NZ 61000.3.7) and the other, performing detailed power system analysis where effect of dynamic plant needs to be considered. AEMO sought feedback on	SSRM	AEMO notes this feedback and will ensure that the approach taken is sufficiently flexible to incorporate local networks' requirements, where these are already agreed between AEMO

No.	Consulted person	Issue	Instrument	AEMO response
		alternatives to the allowable voltage step change limit and also how to incorporated new technologies on reactive control equipment operation. Extracts from submissions on this issue are below. Citipower/Powercor: We further note that voltage step change of capacitor/reactor sizing is normally limited to the step size of the OLTC of the nearby transformer(s). That is, if the step size of the OLTC is 1.5%, then the capacitor/reactor step size is normally sized so that it equals 1.5%. EQL: Ergon Energy and Energex currently use 5% as the voltage step change limit and this is assessed after any dynamic voltage control equipment has responded.		and the network as part of power system operational protocols.
14	Clean Energy Council; TasNetworks	Recognised need for update and supportive of a limited update of the Guidelines to address the issues raised by the Efficient Management of System Strength Rule change.	PSSG	See Section 5
15	Clean Energy Council	"Broader questions of system stability and how this managed should be subject to an appropriately scoped review of the *PSSG* and should be addressed separately to this process."	PSSG	See Section 5
16	Energy Queensland	"Compliance with S5.2.5.10 requires further clarity, particularly for asynchronous generators. It is understood AEMO has already commenced work on producing a guideline to this effect and suggest efficiency could be gained by combining the two documents."	PSSG	See Section 5
17	SMA	*PSSG* should "more precisely define and include aspects of system performance that are currently referred to broadly as system strength." This includes "voltage angle jump on fault inception and clearance, in fault voltage angle rate of change, sensitivity of voltage angle to incremental Id injection, including in faults."	PSSG	See Section 5

Appendix C. Draft System Strength Requirements Methodology

The Draft System Strength Requirements Methodology is published as a separate document on AEMO's website with this Draft Report.

Appendix D. Draft Power System Stability Guidelines

The Draft Power System Stability Guidelines are published as a separate document on AEMO's website with this Draft Report.