Amendments to the System Strength Impact Assessment Guidelines

Draft Report and Determination

Published: January 2023

Notice of Second Stage Consultation – Amendments to the System Strength Impact Assessment Guidelines

National Electricity Rules – Rule 8.9

Date of Notice: 12 January 2023

This notice informs all Registered Participants and interested parties (Consulted Persons) that AEMO is commencing the second stage of its consultation on amendments to the System Strength Impact Assessment Guidelines (SSIAG).

This consultation is being conducted under NER 4.6.6, in accordance with the Rules consultation requirements detailed in rule 8.9 of version 184[1] 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 ssiag@aemo.com.au, to reach AEMO by 5.00 pm (Melbourne time) on 10 February 2023.

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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[1] This consultation commenced before the effective date of the National Electricity Amendment (Improving consultation procedures in the rules) Rule 2022 No.6 and will continue under the previous version of rule 8.9.

Contents

Executive summary

The publication of this Draft Report and Determination (Draft Report) commences the second stage of the Rules consultation process conducted by AEMO to amend the System Strength Impact Assessment Guidelines (SSIAG) under the National Electricity Rules (NER).

AEMO commenced this consultation with the publication of an Issues Paper on 26 April 2022 as a result of the publication of the National Electricity Amendment (Efficient management of system strength on the power system) Rule 2021 No.11 (Amending Rule). The Issues Paper addressed proposed changes to the System Strength Requirements Methodology (SSRM), Power System Stability Guidelines (PSSG) and SSIAG.

Due to the number and complexity of issues, AEMO is now progressing consultation on the SSIAG amendments separately from the SSRM and PSSG.

At a high level, the Amending Rule requires the SSIAG to address the following:

- A methodology for undertaking system strength impact assessments.
- A methodology for undertaking the calculation of a system strength locational factor (SSLF), including guidance on the circumstances in which it might not be reasonably able to be determined or be manifestly excessive.
- A threshold below which a system strength impact may be disregarded for the purposes of NER 5.3.4B(f)(3) (Materiality Threshold).
- A definition and guidance on the calculation of available fault levels (AFLs) for the purposes of calculating the reduction in AFL at a connection point and for the purposes of forecasting AFLs at system strength nodes (SSNs).
- A methodology for assessing the short circuit ratio (SCR) for the purposes of new SCR access standards.
- Guidance on information to demonstrate compliance with the new SCR performance standards.
- The criteria for classification of a load as an inverter-based load (IBL).
- The criteria for classification of an inverter-based resource (IBR) as a large inverter-based resource (LIBR).
- How AEMO assesses adverse system strength impacts.
- Guidance on the methodology to be used when undertaking modelling to verify the stability of plant.

AEMO's approach to the SSIAG issues has evolved as a result of the submissions and further discussions with Consulted Persons, the Australian Energy Market Commission (AEMC) and the Australian Energy Regulator (AER).

This consultation is focused on the processes to be undertaken by Network Service Providers assessing proposed new or altered connections of certain types of plant to their networks (Connecting NSPs). These are referred to in the current SSIAG as a 4.6.6 Connection.

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The key issues this consultation needs to address for AEMO to compile a draft SSIAG, and AEMO's draft proposals on each of them, are detailed in the table below.

Issue	Submissions and AEMO's draft proposal
General system strength impact	While the Amending Rule introduces the concept of 'general system strength impact' and requires an assessment of both the adverse system strength impact of a 4.6.6 Connection and any additional reduction in the available fault level (AFL) at the 4.6.6 Connection Point, submissions proposed that only one or the other be considered when assessing whether there is a general system strength impact. The Amending Rule clearly provides a definition of what a general system strength impact is and AEMO is unable to ignore one aspect or the other.
Materiality Threshold	This concept appears in several contexts in the Amending Rule. Essentially, it refers to a threshold whereby plant can be considered to have no, or negligible, impact on the system strength of a network. AEMO received considerable diversity of opinion, not only as to a suitable metric, but as to whether a threshold should even be specified. There were numerous suggestions of measures from Consulted Persons, however, AEMO was unable to determine a Materiality Threshold based on either the adverse system strength impact or reduction in AFL component of the definition of general system strength impact.
no Materiality Threshold is specified below which a general system strength impact may be disregarded.	The key issue with Preliminary Assessments is the Amending Rule requirement that they be carried out using a single machine infinite bus (SMIB) model. Many submissions noted that this is unlikely to be workable as suitable models are rarely available at this stage of the connections/alterations process. AEMO agrees with this and proposes two methodologies for the Preliminary Assessment: one where suitable models are available, and one where they are not.
Full Assessment	The key issue with Full Assessments relates to the criteria by which proposals to connect plant other than the 4.6.6 Connection can be considered to be "Committed" and included in Full Assessment studies. AEMO considered all suggestions and has concluded that there should be no alteration to the Commitment criteria. Some submissions also conflated the Commitment criteria with considerations of proposed network facilities or proposed retirements of network facilities, which are separately addressed in the SSIAG. AEMO's approach to including these in the Full Assessment studies has been clarified.
Stability Assessment	As the Stability Assessment is a new step in the system strength impact assessment process, the draft SSIAG contains a new section describing the process in detail. Consulted Persons raised concerns about the similarity of Stability Assessments with Final Assessments. AEMO confirms that the two are very similar in that both require detailed power system analysis. The scope is proposed in detail in the draft SSIAG and, while there is some doubt as to whether the Connecting NSP must undertake the Stability Assessments, AEMO considers it appropriate that they do so.
System strength locational factor (SSLF)	AEMO recognises that the requirement in the Amending Rule for the SSLF to be representative of the impedance between the 4.6.6 Connection Point and the applicable system strength node (SSN) could result in SSLFs that would make sub-transmission, especially distribution, connected projects financially unviable. To address this, AEMO has determined that it could exercise some discretion over whether to adopt the formula included in AEMC Final Determination but not in the Amending Rule. AEMO considers that its formulation of the SSLF calculation in the draft SSIAG provides a pragmatic application of the Amending Rule.
Available Fault Level (AFL)	The Amending Rule prescribes the use of AFL as a metric in the assessment of the impact of a 4.6.6 Connection on system strength and, while submissions were made as to its appropriateness as such a metric, AEMO is unable to ignore it. AEMO has amended the formula posited in the Issues Paper to specify how the AFL reduction at a 4.6.6 Connection Point should be calculated, as well as a methodology for determining the AFL at SSNs for the purposes of forecasts.
System strength remediation (SSR)	There are two types of SSR: system strength remediation schemes (SSRSs) and system strength connection works (SSCW). AEMO proposed to delete some items from the list of acceptable SSRSs in the SSIAG but there were only two submissions on the issue. Based on a re-evaluation of what should delineate an SSRS from an SSCW, AEMO will only include SSR undertaken behind a 4.6.6 Connection Point as an acceptable SSRS, while all other types of SSR will be classified as SSCW. Corresponding changes are proposed to both lists.
Short Circuit Ratio (SCR)	The key issue relating to the use of SCRs arises in the context of assessing a 4.6.6 Connection's ability to meet the new access standards proposed by the Amending Rule and demonstrate ongoing compliance. After considering the submissions on these matters and following discussions with various Consulted Persons[2], industry bodies and the AEMC, AEMO considers that the SCR defined by the Amending Rule is not the appropriate metric by which to assess plant capability for the purposes of the access standards. The draft SSIAG proposes that the

[2] See the list in the table in Section 1.

Issue	Submissions and AEMO's draft proposal
	appropriate metric is the "Withstand SCR" capability and provides a methodology for assessing compliance with the relevant access standards, as well as a methodology for assessing the SCR.
Criteria for classification of load as IBL and IBR as LIBR	As this is intended to be a criterion by which a 4.6.6 Connection is to be assessed as having an impact on the system strength of a network, AEMO proposes to adopt a conservative threshold of 5 MW or 5 MVA, as appropriate. Subject to further consultation submissions on this matter, AEMO does not propose different criteria.

AEMO recognises that there are several matters prescribed by the Amending Rule that, on closer review and analysis in the course of this consultation, are likely to prove impracticable or deliver outcomes that were not envisaged by the AEMC when it made the Amending Rule. In particular, the following issues might require revision and, if appropriate, submission of further rule change proposals, following operational experience or subject to further consultation feedback:

- Mandatory use of a simple isolated model such as a SMIB model to undertake Preliminary Assessments.
- Appropriateness, and assessment, of the reduction of AFL at the connection point of a 4.6.6 Connection (4.6.6 Connection Point) as a measure of general system strength impact.
- Calculation of system strength quantity (SSQ) and its relationship with the AFL at a 4.6.6 Connection Point.
- Calculation of the SSLF as being representative of impedance between a 4.6.6 Connection Point and the relevant SSN.
- Technology-appropriate access standards, especially for grid-forming technology.
- Distinguishing between SCR and Withstand SCR and the circumstances in which each is applicable.

After considering the submissions received and following discussions with Consulted Persons, industry bodies and the AEMC[3], AEMO's draft determination is to amend the System Strength Impact Assessment Guidelines in the form published with this Draft Report.

Submissions are invited in accordance with the Notice of Second Stage of Consultation from Consulted Persons on the draft SSIAG and the issues and questions discussed in this Draft Report.

[3] See the list in the table in Section 1.

1. Stakeholder consultation process

As required by NER 4.6.6, AEMO is consulting on amendments to the System Strength Impact Assessment Guidelines (SSIAG) in accordance with the Rules consultation procedures in rule 8.9 (as set out in version 184 of the NER)[4].

The first stage of this consultation covered amendments to the SSIAG, the System Strength Requirements Methodology and the Power System Stability Guidelines required by the Amending Rule. The latter two documents are now the subject of a separate consultation[5].

Due to the number and complexity of issues to be addressed and resolved, the publication date of this Draft Report was extended. A revised indicative timeline for consultation on the SSIAG amendments is outlined below. Future dates may be adjusted depending on the number and complexity of issues raised in submissions.

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 and Notice of Second Stage Consultation published along with draft SSIAG	12 January 2023
Submissions due on Draft Report	10 February 2023
Final Report published along with final SSIAG published	15 March 2023

AEMO issued a Notice of First Stage Consultation on 26 April 2022 along with an Issues Paper describing the changes required by the Amending Rule[6].

AEMO received 20 written submissions in the first stage of consultation that addressed the SSIAG.

AEMO presented the Issues Paper at a webinar it hosted on 17 May 2022 and held several meetings with industry representatives as detailed in the table below.

Participant	Date of meeting
NSP Working Group	07 April 2022, 19 May 2022, 21 June 2022, 15 July 2022
ElectraNet, TasNetworks, AEMO (Victoria Connections), Powerlink Queensland, AusNet	24 May 2022, 26 May 2022, 30 May 2022, 13 June 2022
AEMC	02 June 2022, 03 June 2022, 08 June 2022, 16 June 2022
Powerlink Queensland	17 June 2022, 14 Oct 2022
AEMO Victorian Connections	12 Oct 2022
TransGrid	14 Oct 2022
TasNetworks	21 Oct 2022
Clean Energy Corporation (CEC)	22 June 2022
Australian Energy Regulator	22 June 2022

[4] This consultation commenced before the effective date of the National Electricity Amendment (Improving consultation procedures in the rules) Rule 2022 No.6 and will continue under the previous version of rule 8.9.

[5] See https://aemo.com.au/consultations/current-and-closed-consultations/ssrmiag.

[6] See https://aemo.com.au/consultations/current-and-closed-consultations/ssrmiag.

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Participant	Date of meeting
Tesla	23 June 2022
Windlab	12 July 2022
ElectraNet	19 July 2022, 24 Oct 2022
SA Power Networks	20 July 2022
Essential Energy	20 July 2022
AusNet Services	20 July 2022
Edify Energy	27 July 2022, 18 Oct 2022
Total Eren	19 Oct 2022
Iberdrola	20 Oct 2022
Siemens Gamesa Renewable Energy (SGRE)	27 July 2022
Neoen	29 July 2022, 18 Oct 2022
Citipower & Powercor	02 August 2022

Copies of all written submissions (excluding any confidential information) have been published on AEMO's website at: https://aemo.com.au/consultations/current-and-closed-consultations/ssrmiag.

The publication of this Draft Report marks the commencement of the second stage of the consultation on the amendments to the SSIAG.

Note that there is a glossary of terms used in this Draft Report at Appendix A.

2. Background

2.1. NER requirements

AEMO is required to make and publish the System Strength Impact Assessment Guidelines (SSIAG) under NER 4.6.6. The key function of the SSIAG under the NER is to prescribe how specified Network Service Providers (Connecting NSPs) in receipt of the types of connection enquiries and applications for connection or submissions for alterations to plant referred to in NER 5.4.3B(a) (4.6.6 Connections) will assess the impact of the relevant connections to their networks on system strength.

2.2. Context for this consultation

On 21 October 2021, the AEMC published the National Electricity Amendment (Efficient management of system strength on the power system) Rule 2021 No.11 (Amending Rule), by which it amended the system strength framework in the NER.

The main impacts of the Amending Rule are to expand the circumstances in which Connecting NSPs must assess the impact of certain connections on system strength and the scope of what they must assess.

At a high level, the Amending Rule requires the SSIAG to address the following:

- A methodology for undertaking system strength impact assessments.
- A methodology for undertaking the calculation of a system strength locational factor (SSLF), including guidance on the circumstances in which it might not be reasonably able to be determined or be manifestly excessive.
- A threshold below which a system strength impact may be disregarded for the purposes of NER 5.3.4B(f)(3) (Materiality Threshold).
- A definition and guidance on the calculation of available fault levels (AFLs) for the purposes of calculating the reduction in AFL at a connection point and for the purposes of forecasting AFLs at system strength nodes (SSNs).
- A methodology for assessing the short circuit ratio (SCR) for the purposes of new SCR access standards.
- Guidance on information to demonstrate compliance with the new SCR performance standards.
- The criteria for classification of a load as an inverter-based load (IBL).
- The criteria for classification of an inverter-based resource (IBR) as a large inverter-based resource (LIBR).
- How AEMO assesses adverse system strength impacts.
- Guidance on the methodology to be used when undertaking modelling to verify the stability of plant.

NER 11.143.2(c) requires AEMO to amend and publish the SSIAG by 1 December 2022 to take into account the Amending Rule. The amended assessment requirements will apply to 4.6.6 Connections from 15 March 2023.

3. Summary of material issues

The key material issues arising from the proposal and raised by Consulted Persons are summarised in the following table.

No.	Issue	Raised by
1	General system strength impact	APD Engineering, AusNet, SA Power Networks, SGRE, Shell Energy, Tesla
2	Materiality Threshold	APD Engineering, Citipower & Powercor, Ergon Energy & Energex, Powerlink Queensland, TasNetworks
3	no Materiality Threshold is specified below which a general system strength impact may be disregarded.	Akaysha Energy, Ausgrid, APD Engineering, CEC, Citipower & Powercor, ElectraNet, Ergon Energy & Energex, Powerlink Queensland, SGRE, Shell Energy, Tesla, TasNetworks, Transgrid
4	Full Assessment	APD Engineering, Citipower & Powercor, ElectraNet, Ergon Energy & Energex, ESCO Pacific, Powerlink Queensland, SGRE, TasNetworks
5	Stability Assessment	APD Engineering, Ausgrid, AusNet, Bo Yin, Citipower & Powercor, ElectraNet, Ergon Energy & Energex, Powerlink Queensland, SGRE
6	System strength locational factor	APD Engineering, AusNet, CEC, Citipower & Powercor, ElectraNet, Ergon Energy & Energex, SGRE, TasNetworks, Tesla, Transgrid
7	Available Fault Level	APD Engineering, CEC, Citipower & Powercor, Ergon Energy & Energex, Marinus Link, SGRE, TasNetworks
8	System strength remediation	APD Engineering, Tesla
9	Short Circuit Ratio	APD Engineering, CEC, Citipower & Powercor, Ergon Energy & Energex, Keith Frearson, Powerlink Queensland, SGRE, TasNetworks
10	Criteria for classification of load as IBL and IBR as LIBR	SGRE

Section 4 discusses these material issues and presents AEMO's consideration of submissions and draft proposals on each of them. A detailed summary of issues raised by Consulted Persons in submissions, together with AEMO's responses, is contained in Appendix B.

4. Discussion of material issues

4.1. General system strength impact

4.1.1. Issue summary and submissions

While the current SSIAG require consideration of the adverse system strength impact of a 4.6.6 Connection, the Amending Rule introduces the concept of 'general system strength impact', which requires assessment of both the adverse system strength impact of a 4.6.6 Connection and any additional reduction in the available fault level (AFL) at the 4.6.6 Connection Point.

AEMO did not propose how it would assess this and invited submissions on this issue. Several submissions were received[7].

Provision of examples to illustrate how AEMO defines adverse system strength impact

APD Engineering

> General system strength impact is now defined by the reduction in AFL and any adverse system strength impact. APD recommends that AEMO consider providing practical examples in the SSIAG to demonstrate the intended meaning of adverse system strength impact. APD believe there would be significant benefit to the industry as a whole for further tangible examples, case studies, and measures published in the SSIAG to help the industry understand AEMO's position on what constitutes adverse system strength impacts.

Tesla

> Worked examples of a battery system with grid-forming inverter capabilities would be beneficial to help demonstrate and clarify our current understanding that these types of assets should have zero system strength charges applied (as a connecting generator / integrated resource provider), whilst also being viewed to positively contribute to system strength remediation (SSR).

General system strength impact at connection point only

AusNet

> **AusNet encourages AEMO to clarify the implications for Applicants whose connection would cause an adverse system strength impact at their connection point but not the relevant SSN.**
>
> The Issues Paper references the Amending Rule which states the system strength impact assessment should assess a 4.6.6 Connection Point's adverse system strength impact and reduction in AFL at its connection point.
>
> …
>
> AusNet seeks clarification about the treatment of 4.6.6 Connections that would cause a general system strength impact by reduction in AFL at their connection point but limited to no impact or impact within a defined material threshold at the relevant SSN. In our view, it would be unreasonable for an Applicant to pay SSC in this scenario.

Collective impact of distribution-connected generation on SSNs

SA Power Networks

> Have AEMO considered a collective impact from distribution-connected generating systems on the TNSP defined SSNs?

[7] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms and terms that are defined in the Glossary.

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Absolute fault levels vs AFLs when assessing general system strength impact

SGRE

> SGRE encourages AEMO to consider actual transmission capacity when assessing general system strength impact. Due to transmission capacity constraints, restoring AFL back to its prefault level may provide limited benefit to the system while imposing a significant cost burden on Applicants.
>
> The proposed methodology can give way to ever increasing installation of synchronous condensers and an unnecessary increase in fault level, while other aspects of system operation including transmission capacity and inertia are limiting factors. Using absolute fault level values instead of AFL could provide a more robust criteria for assessment.

Consideration of connections that improve system strength

Shell Energy

> Shell Energy considers it important that as well as any reduction in system strength capability, the assessment of system strength impact should consider connections that improve system strength capability. This would provide a more balanced view of system strength changes and potentially help avoid unnecessary costs in system strength provision.

4.1.2. AEMO's assessment

Each submission on the application of the concept of a general system strength impact deals with a different issue, and all are addressed below.

Provision of examples to illustrate how AEMO defines adverse system strength impact

AEMO agrees with APD Engineering that Connecting NSPs and Applicants would benefit from the inclusion of examples of how to apply the calculations of AFLs. Examples of how an adverse system strength impact should be assessed are not included as this requires simulation using PSCAD™/EMTDC™ models of plant.

General system strength impact at connection point only

The assessment of whether there is a general system strength impact requires consideration of whether there is an adverse system strength impact and a reduction in AFL. The definition of adverse system strength impact refers to the impact of a 4.6.6 Connection on power system stability. Power system stability is assessed by reference to NER S5.1a.3 and is not exclusive to the 4.6.6 Connection Point.

On the other hand, the definition of general system strength impact clearly states that any reduction in AFL is only considered at the 4.6.6 Connection Point:

> In relation to a new *connection* or an alteration to a *generating system* or other *connected plant*, the amount equal to its *adverse system strength impact* as well as any additional amount by which it reduces the *available fault level* at the *connection point* for the new *connection* or *connected plant*, assessed in accordance with the *system strength impact assessment guidelines*.

It follows that the Connecting NSP must also determine the general system strength impact by reference to the reduction in AFL at the 4.6.6 Connection Point. While, as AusNet suggested, it might be unreasonable for an Applicant to pay the SSC where the 4.6.6 Connection has limited or no impact on the AFL at the nearest SSN, the Amending Rule is clear. If practical experience shows this to produce unreasonable outcomes, this could form the basis for a request for a rule change.

Collective impact of distribution-connected generation on SSNs

AEMO agrees that there is a benefit in considering the collective impact of both transmission and distribution projects but, in the first instance, these should be addressed during joint planning between NSPs.

Batching of projects to allow for collective assessment of more than one 4.6.6 Connection is permitted in the current SSIAG and remains permissible in the draft SSIAG.

Absolute fault levels vs AFL when assessing general system strength impact

AEMO sought clarification from SGRE on its suggestion regarding the use of "absolute fault levels" instead of AFL, who confirmed that this is intended to refer to synchronous fault levels only.

The use of AFL is discussed in section 4.7.2.

Consideration of connections that improve system strength

There are two elements to assessing whether there is a general system strength impact:

- Whether an adverse system strength impact exists.
- Whether there is an additional reduction in AFL at the 4.6.6 Connection Point.

AEMO has redrafted the matters for a Connecting NSP's consideration when assessing whether there is a general system strength impact, by including various plant and contingency events for consideration. These matters do not distinguish between plant that has a positive or negative impact on system strength. If they meet the criteria stated in the draft SSIAG, they must be included in the relevant assessment.

4.1.3. AEMO's conclusion

The draft SSIAG includes the following:

- A description of how AEMO would assess whether there is an adverse system strength impact and how stability should be assessed.
- Examples of the calculation of the reduction in AFL at a 4.6.6 Connection Point.

4.2. Materiality Threshold

4.2.1. Issue summary and submissions

AEMO did not express a view in the Issues Paper on whether there should be a Materiality Threshold in the SSIAG for the purpose of system strength impact assessments and sought submissions on the issue.

Several submissions were made on whether AEMO should specify a Materiality Threshold[8].

[8] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms and terms that are defined in the Glossary.

APD Engineering

A material threshold should be defined to minimise project impacts to developments that pose a negligible impact on system strength. Consideration should be given to define the AFL threshold as either a portion of the total synchronous generation fault level at the connection point, or an absolute reduction in AFL. This should be applicable to both IBR and LIBR. This should apply to a single IBL, Large IBR (LIBL) or an accumulated IBL within a localised area, such as a distribution zone. The purpose of such a threshold would be to ensure a well-tuned plant of commercially small size (<5MW) can connect to the network and not be required to acquire SSR for a negligible reduction in AFL.

Citipower & Powercor

A material threshold [should] be defined. This can be applied in percentage as per:

AFL change (in MVA)/ (MW at connection point x MCSR of Plant).

However, we would like to express our concern if a 4.6.6 Connection is required to not only remediate its adverse system strength impact but also the reduction in AFL at the connection point. The latter will mean any new connection who opts not to pay the SSC will need to install "a form of fault level compensation devices" if they have a min SCR for stable operation higher than zero. For example, a 100 MW new connection with a MSCR of 2 will need to compensate for a 200MVA reduction in AFL at the connection point. And the solution is very limited, i.e., synchronous condensers. This may not be really neccessary, resulting in over-investment and can also lead to other consequences (e.g., increasing fault level design requirement, increasing complexity of system operation, etc.). Again we would like to note recommend that the AFL concept needs to be reviewed.

Ergon Energy & Energex

We do not consider that a materiality threshold is required as we understand that the proposal is that Applicants will remediate as required according to any adverse system strength impacts identified in the Full Assessment.

Powerlink Queensland

To avoid the unintended consequences of this new framework, the Materiality Threshold for ‘adverse system strength impact’ should be maintained as it is currently defined in the existing SSIAG. A Reduction in AFL due to a 4.6.6 Connection should only be calculated if a 4.6.6 Connection is shown to have an adverse system strength impact as per the criteria in the existing SSIAG. In the absence of the Materiality Threshold that is based on adverse system strength impact, all small IBR plants connecting remote from the SSN will be forced to connect small synchronous condensers or grid forming batteries irrespective of the technical need. This additional cost (irrespective of the need) will impose significant impediments to small IBR plants connecting to the distribution network.

…

General system strength impact has two parts;

1. adverse system strength impact and

2. reduction in AFL.

The materiality threshold for adverse system strength impacts should remain the same as it is currently defined in SSIAG. However, the threshold for a reduction in AFL should be carefully considered. Even remote IBR plants can have an impact on the AFL at the connection point of another IBR plant. Therefore, a reduction in AFL should only be considered as general system strength impact if a 4.6.6 Connection is causing an adverse system strength impact.

TasNetworks

TasNetworks considers the materiality threshold for adverse system strength impact and additional reduction in AFL as separate issues.

The materiality threshold for adverse system strength impact should remain unchanged at effectively zero. Any negative impact on power system security as identified through consideration of the NER technical schedules (under Chapter 5) should be analysed in detail by AEMO and the Connecting NSP and SSSP, with subsequent management strategies developed.

In respect to incremental changes in AFL due to a 4.6.6 Connection, a materiality threshold is complex due to the unintended consequences of the proposed methodology for calculating SSLF.

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> Defining the materiality threshold in terms of acceptable dynamic performance outcomes when system strength levels are at a minimum may help address these unintended consequences. For example, if a 4.6.6 Connection can operate without causing adverse system impacts when the system is operating at minimum fault levels, then this could be defined as having no general system strength impact. This removes the need to calculate SSLF and SSC, and remove the need to self-remediate. The potential implications of this approach will require further detailed consideration, especially for transmission connections which may exhibit similar issues depending on their electrical distance from the SSN.

4.2.2. AEMO's assessment

Submissions indicate there is some confusion as to how the Materiality Threshold applies and its implications.

NER 5.4.3.B(a2) requires Connecting NSPs to undertake a Full Assessment following the Preliminary Assessment, unless:

- the Preliminary Assessment indicates there will be no general system strength impact or the impact is below any threshold specified in the SSIAG for the purposes of NER 5.3.4B(f)(3); or
- the Applicant has elected to pay the SSC.

NER 5.3.4B(e) requires a Connecting NSP to undertake system strength connection works (SSCW) at the Applicant's cost if a Full Assessment indicates that a 4.6.6 Connection will have a general system strength impact, unless one of the circumstances listed in NER 5.3.4B(f) occurs. One of those is, to the extent that the impact is below any threshold specified in the SSIAG[9].

The threshold applied for the purposes of NER 5.3.4B(a2) and (e) is the Materiality Threshold that AEMO is required to specify in the SSIAG under NER 4.6.6(b)(7).

AEMO has considered the issues raised in the submissions under two headings:

- Application of Materiality Threshold.
- Value of Materiality Threshold.

Application of Materiality Threshold

As explained above, the Materiality Threshold is relevant to the assessment of general system strength impact.

It is instructive to review the definition of general system strength impact, which is:

> In relation to a new *connection* or an alteration to a *generating system* or other *connected plant*, the amount equal to its *adverse system strength impact* as well as any additional amount by which it reduces the *available fault level* at the *connection point* for the new *connection* or *connected plant*, assessed in accordance with the *system strength impact assessment guidelines*.

So, both the Preliminary Assessment and Full Assessment are required to assess the general system strength impact of a 4.6.6 Connection. Its components are, as observed correctly by Powerlink Queensland:

- Adverse system strength impact.
- Reduction in AFL at the 4.6.6 Connection Point.

[9] See NER 5.3.4B(f)(3).

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APD suggested that the Materiality Threshold should apply to the AFL only, whereas Citipower & Powercor and TasNetworks submitted that it should apply to the assessment of an adverse system strength impact only.

Powerlink Queensland submitted that the AFL should not be considered at all unless the Connecting NSP found there was an adverse system strength impact. Similarly, as noted in section 4.1, AusNet considered it would be unreasonable for an Applicant to pay the SSC where a general system strength impact was assessed by reason of a reduction in the AFL at the 4.6.6 Connection Point but with no impact, or impact below the threshold specified by AEMO, at the relevant SSN.

TasNetworks suggested that assessments should be based on minimum fault levels and a focus on adverse system strength impacts, thus removing the need to calculate SSLF, SSC and the need for SSR if the 4.6.6 Connection can operate without causing an adverse system strength impact. TasNetworks also noted the need for further detailed consideration of the potential implications of this approach.

AEMO considers that the Amending Rule is clear; the Materiality Threshold should apply to both elements of the general system strength impact. The requirement to assess (and, if necessary, remediate) both elements is confirmed in the AEMC Final Determination[10]:

> … the draft rule proposed that the [Connecting] NSP's assessment of the [Applicant's] impact on the local system strength will not be done in reference to the adverse system strength impact, but rather to the concept of 'general system strength impact'.
>
> This is the amount equal to [4.6.6 Connection]'s adverse system strength impact as well as the amount of available fault current it reduces at its [4.6.6 Connection Point] as a result of its connection. The latter would be equivalent to the SSQ, which would be determined from the SCR performance standard and the rating of the IBR plant. However, the [4.6.6 Connection] must be able to operate stably in the network it is connecting to, which is why it must also make sure it remediates its adverse system strength impact.

This reinforces AEMO's conclusion that there should be only one Materiality Threshold, and not directed at one, or other, of the elements of a general system strength impact even though it is possible that the Materiality Threshold could have two parts addressing each aspect of the definition of a general system strength impact.

Value of Materiality Threshold

As noted earlier, the purpose of the Materiality Threshold is to determine whether a general system strength impact is so immaterial that there is no need for remediation. APD's observation to this effect is correct.

The difficulty, however, arises with the identification of a suitable metric.

Submissions on this issue are summarised in the table below:

Consulted Person	Proposed Materiality Threshold
APD Engineering	Define the AFL threshold as either a portion of the total synchronous generation fault level at the connection point, or an absolute reduction in AFL.
Citipower & Powercor	AFL change (in MVA)/(MW at 4.6.6 Connection Point x MSCR[11] of 4.6.6 Connection).

[10] See page 167.

[11] Minimum short circuit ratio.

Consulted Person	Proposed Materiality Threshold
Ergon Energy & Energex	None required.
Powerlink Queensland	There should be no Materiality Threshold for 'adverse system strength impact'. A reduction in AFL should only be calculated if a 4.6.6 Connection is shown to have an adverse system strength impact.
TasNetworks	There should be no Materiality Threshold for 'adverse system strength impact'. A Materiality Threshold to cover the reduction in AFL should be assessed by reference to acceptable dynamic performance outcomes when system strength levels are at a minimum.

As can be seen, there is considerable diversity of opinion, not only as to a suitable metric, but as to whether a threshold should even be specified.

AEMO recognises that a type of materiality threshold already exists for plant with a capacity of <5 MW/MVA. Owners or plant below that capacity are not generally required to be registered under the NER so, APD's concern that Applicants with 4.6.6 Connections of that size, or smaller, not be subject to a requirement to remediate system strength is addressed.

Any threshold above 5 MW/MVA would be arbitrary because system strength is a localised phenomenon; plant of a similar size can have an adverse impact in some locations, but not others.

AEMO also considered whether it could formulate a metric based on either the adverse system strength impact, or AFL component, of the definition of general system strength impact but was unable to because:

- Whether plant will have an adverse system strength impact is, essentially, a binary issue. It cannot be quantified.
- Not all plant intended to be covered by the Amending Rule would reduce the AFL at the 4.6.6 Connection Point.

AEMO considers it preferable to undertake further consultation before making a determination on this issue.

4.2.3. AEMO's conclusion

Subject to further submissions on this matter, no Materiality Threshold is specified below which a general system strength impact may be disregarded.

4.3. Preliminary Assessment

4.3.1. Issue summary and submissions

The Amending Rule will require changes to the Preliminary Assessment methodology. In the Issues Paper, AEMO considered that the purpose of the single machine infinite bus (SMIB) PSCAD™/EMTDC™ studies required to undertake the Preliminary Assessment is to confirm:

- Stability at the proposed minimum SCR of an Applicant's plant.

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- The short circuit ratio (SCR) withstand capability (Withstand SCR)[12].
- The indicative SSC to enable an Applicant to determine whether to pay that charge or fund the remediation of the estimated general system strength impact of the 4.6.6 Connection.
- What the Applicant will need to do to meet the minimum access standard for SCR[13].

Moreover, there are several key considerations when assessing Withstand SCR using SMIB models:

- An EMT-type (PSCAD™/EMTDC™) SMIB model is required.
- SCR withstand capability is dependent on the 4.6.6 Connection's inverter/control system settings, technology and its limitations.
- SMIB network representation and its limitations.
- Aggregation methodology of the reticulation system.

The Issues Paper also considered whether AEMO should apply an engineering safety margin to address the SMIB model limitations.

Several submissions were received[14]. For convenience of discussion, they have been grouped by issue.

SSQ

Akaysha Energy

> … quantification of system strength by the traditional short circuit MVA metric is an outdated methodology of diminishing relevance as the modern power system transitions toward domination by inverter-based generation. The more forward looking and pragmatic system strength assessment methodology would be to use agreed maximum allowable levels of voltage waveform amplitude and phase disturbance. The measurement methodology could be adopted by a number of potential methods, including simulation of applied faults over a range of impedances for specific durations to a standardised set of network locations to quantify the disturbance resilience in each location.
>
> This measurement methodology allows for a more technology agnostic approach and is not biased toward the physical advantages synchronous machines possess over inverter-based technologies when assessed against the current short circuit MVA basis. A technology agnostic measurement approach is critical in ensuring the lowest cost solution for energy stakeholders, particularly noting recent power system studies validating the advantages of grid forming inverters over synchronous condensers for supporting the grid.

SGRE

> SGRE believes that there is little merit in running a Preliminary Assessment as described as:
>
> - There is always going to be a general system strength impact for grid-following IBR in this framework,
> - SSLF, being a deciding and important factor, cannot be correctly calculated using AFL and in a SMIB environment,
> - The SSQ calculation cannot be completed at the Preliminary Assessment stage as the tuning of the plant to meet its expected performance has not been carried out and negotiated.

---

12 Which is used in calculating SSQ: see New clause 6A.23.5(j).

13 See New clause S5.2.5.15, New clause S5.3.11 and New clause S5.3a.7.

14 Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms and terms that are defined in the Glossary.

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SGRE believes that AEMO must publish a full methodology of the SMIB studies required for SSQ and SSLF calculations directed to Applicants for indicative assessment to enable them to run the studies themselves when comparing OEMs or deciding on the pay or remediate.

Modelling

Akaysha Energy

Connection Enquiries / Applications:

Akaysha also raise concerns around the implications of the SSIAG and subsequent information provided by Connecting NSPs to Applicants during the Connection Application process. Akaysha's position is that elements of the Preliminary Assessment are now for much of the NEM redundant as even in traditionally strong network locations, NSPs have been declaring AFLs inconclusive, reflective of the complexity of the present power system and the challenges with their ability to specify clear system strength levels. Additionally, the specification of singular short circuit and X/R ratios[15] to be used in power system studies is inappropriate considering the fundamental variability of the actual values seen in the real power system. Akaysha supports changes to the SSIAG that provide more useful information on system strength risks to Applicants, and suggests SCR and X/R values provided to Applicants instead being generalised with appropriate sensitivities also tested.

Ausgrid

As it stands the Preliminary Assessment is carried out as under S5.4A, in response to a Preliminary Enquiry from an Applicant. Noting that DNSP's are not able to charge for a preliminary response under the existing NER, any further assessment carried out by the DNSP's during these early stages, such as the requirements for model assessments for a Preliminary Assessment, will have implications upon response timeframes on an already constrained resource and additional costs to be born by the DNSP.

At the early stages of these projects Applicants have very limited information on their development, with most only able to provide the bare minimum required under S5.4A. The requirement to provide a PSCAD model at these early stages to form part of the Preliminary Assessment will add little value given the limited information available at the preliminary enquiry stage and only serve to add to the ever-increasing costs for generator assessments.

The timing for the additional information to be provided by the DNSP as a part of the new requirements of the Preliminary Assessment (i.e. PSCAD model) may be better during the detailed assessment phase of the project, as opposed to upfront as a part to the proponents PE submission. Under the current Chapter 5.3.4 process Ausgrid would capture any SSR requirements if a 4.6.6 Connection pose an impact upon system strength to the network.

CEC

We are broadly supportive of the approach taken to the SSIAG, however further work is required to ensure that modelling obligations placed on Applicants through this process are proportionate and in accordance with the underlying policy intent of the framework – namely to reduce complexity and speed up the connection process.

…

The CEC recognises the importance of the modelling process at connection for the generator's performance and system impacts. However, this Preliminary Assessment is a source of material cost and time spent in the connection process. AEMO must ensure that changes to this process align with the principles and objectives of the Amending Rule and hasten this process.

The proposed Preliminary Assessment modelling requirements may require additional resourcing by Applicants given the use of PSCAD modelling rather than PSSE. Given the more onerous process, the CEC encourages AEMO to consider its use through the entire connection study and modelling process where appropriate. That is, as the Preliminary Assessment will be more comprehensive, we expect it should be adequate to provide a basis for later Full Assessment and connection study modelling in order to minimise re-work at these later stages; this process should encourage streamlining across the broader connection studies and modelling process.

Following the Preliminary Assessment which should indicate the system strength impact, it is likely this will decrease through the connection process as an Applicant finalises design and tuning. We consider this is an efficient solution and is an ideal outcome for system strength.

[15] Ratio of reactance to resistance.

Citipower & Powercor

A standardised Preliminary Assessment model (or at least low fault level models) could be provided by AEMO as part of OPDMS.

X/R ratios can have a material impact on the plant stability assessment so it should be considered in the SMIB Preliminary Assessment.

ElectraNet

ElectraNet request consideration is given to the following:

…

3. Fit-for-purpose modelling of DER in relation to planning of fault level obligations for SSS;
4. Modelling of IBR for PSS/E fault level assessments must utilise models or fault calculation methodologies which are supported by OEM advice and field verification where possible;
5. The proposed methodology for Preliminary Assessments relies on the use of a SMIB PSCAD model to assess the minimum SCR withstand capability of a proposed facility. This minimum SCR capability is then used to determine the general SSQ that forms part of the calculation of SSC.

   ElectraNet notes that this process brings forward the requirement for PSCAD models to be available at the time of Connection Enquiry rather than at the time of Connection Application as was the case prior to the Amending Rule. The existing experience that Applicants have typically not yet selected an OEM at the time of Connection Enquiry and the extensive efforts required by the Applicant, Connecting NSP and AEMO to test and accept PSCAD models is important to recognise here. It is understood that one objective of the Amending Rule was to reduce the reliance on detailed assessments and thereby reduce the duration of the connection process. It is not clear that the requirement for PSCAD models at the enquiry stage will assist in this objective.

   …

   Additionally, and as noted in the Issues Paper, the plant SCR capability determined at this stage will be dependent on inverter/control system settings. It is important to recognise that the SCR withstand capability of a plant and other key performance criteria to be determined during Generator Performance Standard (GPS) negotiation are often inversely related (i.e. low SCR withstand capability is generally difficult to achieve in combination with high speed control system and inverter response). Since this SCR capability will subsequently be used to assess the SSQ and therefore impacts on the SSC, ElectraNet notes that this is likely to encourage detuning of controls and subsequently reduced GPS performance levels.

Ergon Energy & Energex

It is not clear how the SMIB assessment can practically be done at the Preliminary Assessment stage.

In our experience, key project decisions such as selecting the OEM have not been made nor has any level of generating system design been done. This makes it unlikely for there to be a model available for the SMIB assessment and therefore generic models are most likely to be used at this stage. This was raised in our submission to ERC0300.[16]

Accordingly, the assessment will need to be repeated at Application stage to confirm the Preliminary Assessment, and this will need to be allowed for in the process.

TasNetworks

The process of undertaking Preliminary Assessments may need to be re-evaluated depending on how materiality thresholds are defined. It may be that a simplified model becomes a small section of network that emanates outward away from an SSN toward proposed IBR connections (with the remainder of the network represented as an appropriate equivalent impedance). While it may prove possible to simplify this assessment to something equivalent to the example provided above[17], the parameters should be carefully determined from the full system model, especially for calculation of SSLFs.

[16] https://www.aemc.gov.au/sites/default/files/documents/ergon-energex.pdf.

[17] See section 4.6.

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, and views the first EMT option as the likely best outcome, acknowledging that it is time consuming.

Engineering Safety Margin

APD Engineering

As per New clause 4.6.6(b)(1A), the SSIAG must require a 'Preliminary Assessment' to be carried out using a simple isolated model, such as a SMIB model, in PSCAD. The purpose of this Preliminary Assessment is to determine whether there is a general system strength impact. This is specifically intended to confirm the following:

- Stability of the plant at the proposed minimum SCR
- The plant SCR withstand capability for use in calculating the general system strength impact (or SSQ) and the SSLF.

The above analysis will be used to determine the amount of SSC, or whether an Applicant requires remediation equipment to meet the minimum SCR standard.

In APD's experience, there are a few factors that could affect the outcome of the abovedescribed analysis. It is understood that the plant SCR withstand capability largely depends on each 'generating unit' (e.g. inverter) minimum SCR withstand capability as well as all the impedances between the 'generating units' and the connection point of the generating system.

It has become standard practice in the industry that at the early design stages, many assumptions are made in determining the cable lengths, cable impedances, the transformer impedances, etc. Moreover, soil resistivity and the actual site conditions which could affect the impedances are usually ignored throughout the connection studies. Hence it is fair to assume that no tolerances are considered in the early design stages and in the creation of the SMIB model of the generating system.

It is noteworthy that for each electrical equipment, the OEM can design and build the equipment within a certain tolerance (e.g. ±10% for transformer impedances as per the IEC standard). These tolerances can be adjusted depending on the commercial procurement contracts; however, they cannot be eliminated. Hence, for instance, in a transformer, a difference in impedances is expected between the final product and the specifications used in the early design stages/studies.

As already mentioned, the plant SCR withstand capability is largely dependant on the reticulation system impedance and the minimum SCR withstand capability of each individual inverter. As an example, if the inverter minimum SCR withstand capability is 3, depending on the reticulation system/electrical Balance of Plant, this could result in a plant withstand capability of 4. Hence, a tolerance on all electrical equipment that connect the individual generating units to the connection point should be considered to account for the worst-case scenario. For instance, if a park transformer with a 12% impedance is assumed in the connection studies, an impedance of 12% + 1.2% = 13.2% should be used for the purpose of the Preliminary Assessment. The same goes for all other electrical equipment between the inverter and the connection point.

In addition to the tolerance in impedances, the method of aggregating the plant for creating the SMIB model could also affect the outcome of the Preliminary Assessment. This is especially more profound in generating systems with large reticulation systems such as wind farms. In these plants, aggregating the plant into a SMIB, or a simple representation with a few aggregated generators would not be able to account for the minimum SCR an inverter would see at the end of the longest feeder in the plant. Hence, The plant minimum SCR withstand capability should be determined by accounting for the weakest System Strength point in the reticulation system. Hence, an appropriate methodology/tolerance should be employed in making the simple isolated model of the plant for the purposes of the Preliminary Assessment.

ElectraNet

The limitations of SMIB type analysis are also important to note, since interactions between nearby plant are not captured by this approach and so the outcomes cannot capture all aspects of plant stability or system strength impact. Since the Amending Rule requires that a simplified isolated model be used, consideration of engineering safety margins in assessing SCR withstand capability would appear sensible.

Ergon Energy & Energex

… it would be prudent to include a safety margin to the SCR withstand capability.

Powerlink Queensland

The purpose of the Preliminary Assessment is to assist with advising Applicants their likely SSC and therefore there is no need to include any safety margin.

SGRE

SGRE would encourage AEMO not to apply engineering safety margins to the SCR withstand capability of 4.6.6 Connections. It is recognized that the original intent of the AFL calculation in the current Preliminary Assessment is as a screening method for connections, thus a conservative approach was taken. However, in this case, any additional safety margin applied by AEMO would have an additional cost burden on the Applicants. It is likely that the AFL calculation is already conservative.

In addition, it should be recognized that in general it is not possible for devices to operate at full output at very low SCR, regardless of technology type.

Shell Energy

When modelling is undertaken using SMIB-type models a safety margin should only be applied when justification can be supplied. Understanding when an OEM has already applied a safety margin to its technical specifications will be a key determinant as to whether or not to apply a safety margin when modelling the equipment. Doubling the safety margin in a model will lead to unnecessary costs over time.

TasNetworks

TasNetworks does not consider an engineering safety margin to the SCR is necessary during the Preliminary Assessment. The Applicant has an obligation under the NER to provide technical data as part of the application process. A nominal safety margin does not adequately address any underlying issue with the use of a simple isolated model required to be used at the Preliminary Assessment stage.

Availability of load models

Transgrid

We understand that the methodology for system strength impact assessments will include loads that have large IBR under NER 5.3.4B. As such, appropriate Electromagnetic transient (EMT) modelling will also need to be incorporated into the framework. Transgrid has witnessed rapid load growth in Sydney West fault level node driven by large data centre connections. Given there is limited EMT models for large data centres, assessing the impact of these types of IBL for system strength requirements will be difficult. EMT modelling requirements of different type of IBLs (mine loads, data centres and other large industrial facilities) including key control system models and model aggregation techniques must be clearly identified to avoid any ambiguity.

Other Issues

Tesla

- There would be significant benefit if Advanced Inverters had a clear pathway to connect with access standards appropriate for allowing the full benefits of virtual synchronous machines to be realised (for example a pathway similar to that for synchronous generation or a hybrid of the asynchronous and synchronous generation pathways).

4.3.2. AEMO's assessment

The issues raised in the submissions will be addressed in turn.

SSQ

SSQ is defined in NER 6A.25.3(j) as:

> (j) Subject to paragraph (k)[18], the *system strength quantity* for a *system strength connection point* is the product of:
>
> (1) the *short circuit ratio*; and
>
> (2) the *rated active power*, rated *power transfer capability* or *maximum demand* for the *system strength connection point*,
>
> each as agreed in accordance with NER S5.2.5.15, S5.3.11 or S5.3a.7 (as applicable) and recorded in the relevant *performance standards* for the *plant connected* at the *system strength connection point*.

While the short circuit ratio, or SCR, is defined as:

> For a *connection point* for *plant*, the synchronous *three phase fault level* (expressed in MVA) at the *connection point* for the *plant* divided by:
>
> (a) in the case of a *generating system*, its *rated active power* (expressed in MW);
>
> (b) in the case of a *market network service facility*, its rated *power transfer capability* (expressed in MW); and
>
> (c) in the case of an *inverter based load*, its *maximum demand* at the *connection point* (expressed in MW),
>
> to avoid doubt, in each case excluding any *fault current contribution* from the *plant* side of the *connection point* when calculating the *three phase fault level*.

For completeness, the definition of three phase fault level is:

> Measured in MVA at a location on a *transmission network* or a *distribution network*, the product of the pre-fault *nominal voltage* (measured in kV between a pair of phases), the fault current in each phase for a three phase fault at the location (measured in kA), and the square root of 3.

The key input in both the calculations of SSQ and SCR for a 4.6.6 Connection is its rated active power, power transfer capability or maximum demand. While the performance standards of plant will not be known at the Preliminary Assessment stage, Applicants are capable of specifying the proposed maximum capacity of the 4.6.6 Connection for the purposes of calculating an estimate of the SSQ.

Akaysha Energy suggested a preferable methodology for assessing SSQ, but in light of the definition of SSQ in the Amending Rule, there are no other options for its assessment. AEMO's proposal is closer to the NER definition, but it also allows for consideration of the inherent strength of the connecting network[19].

SGRE suggested that the SSQ calculation cannot be completed at the Preliminary Assessment stage in a SMIB environment, however, NER 5.3.3(b5)(3) and NER Schedule 5.4B both refer to the indicative SSQ as one of the results to be provided to an Applicant. AEMO considers that this requirement can be met by using the formula in NER 6A.25.3(j).

[18] Not relevant to this discussion.

[19] See the discussion of AEMO's rationale for applying an adjustment to the SSQ formulation for the purposes of the SSIAG in Appendix C.

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AEMO has sought to implement the Amending Rule with respect to the indicative SSQ calculation at the Preliminary Assessment stage. While not part of the System Strength Impact Assessment Guidelines, calculation of the SSQ is an important part of the overall implementation of the new system strength framework. AEMO has therefore prepared some example calculations of the SSQ quantity which are documented in Appendix C. The SSQ in combination with the locational factor and unit rate for centrally provided system strength will determine the payment for connecting parties choosing to use the centrally provided service, hence it is important to consider how this is calculated.

AEMO has some concerns regarding the calculation of SSQ and is seeking feedback on the calculation methodology outlined in Appendix C or other options which would provide the appropriate information to connecting parties. AEMO is also seeking feedback on whether a change to the Amending Rule would be appropriate and, if so, whether that should align with the approach in Appendix C, noting that a rule change can be submitted by anyone.

Several submissions referred to the impracticality of SMIB modelling to conduct a Preliminary Assessment as it is unlikely that suitable models will be available at the connection enquiry stage and, even if they were, this will not reduce complexity or speed up the connection process.

The AEMC Final Determination states:

> The burden on [Applicants] to model their system strength impact, and various remediation options, will also be reduced because [an Applicant] can choose to pay the charge early in the connection process. This is done at the preliminary impact assessment stage in response to a connection enquiry and will be carried out using simple, isolated modelling — being a [SMIB] model. Should [an Applicant] elect to remediate its impact (perhaps because the charge is very high because the [4.6.6 Connection's] location is electrically remote from a [SSN]), then the more complex and lengthy full impact assessment process — as per the current arrangements— is required to determine the remediation requirement. In this case, the [Applicant] has selected this route in full knowledge that it has these necessary, lengthy processes. In turn, these effects **should speed up the connection process and reduce the administrative burden and uncertainty associated with the costs and risks of connection to the power system for [Applicants]**.[20]

Further…

> The evolution of 'do no harm' into the SSR includes the option for new connections to pay a charge to avoid having to undergo a full impact assessment and the associated remediation obligations. This is a new and different avenue to obtaining compliance with NER 5.3.4B. This allows them to better account for their impact on system strength and the associated costs. This in turn **creates a simpler, faster and more predictable renewables and battery connection process** and promotes investor confidence.[21]

AEMO considers that the desired outcome expressed by the AEMC is not consistent with a mandate for SMIB modelling for a Preliminary Assessment, as it is unlikely to create a "simpler, faster and more predictable renewables and battery connections process".

AEMO agrees that there is, generally, a lack of suitable models at the connection enquiry stage, because Applicants have not made key decisions around plant procurement or even the location of the 4.6.6 Connection Point.

To address the Amending Rule, AEMO proposes to apply the modelling requirement where suitable models and other key information are available (including treatment of X/R ratios and other key variables) and will also provide an alternative path where they are not.

[20] Emphasis added. See page 51 of the AEMC's Final Determination.

[21] Emphasis added. See page 52 of the AEMC's Final Determination.

AEMO recognises that providing an alternative to assessment by way of SMIB modelling does not adhere to the Amending Rule because the Amending Rule mandates the use of SMIB modelling. Subject to submissions received in response to this Draft Report, AEMO will explore the feasibility of proposing an amendment to the Amending Rule that is more consistent with the information likely to be available at the connection enquiry stage.

Engineering Safety Margin

Five submissions addressed this issue and three of those suggested that an engineering safety margin should not be determined. Only APD considered that a 10% engineering safety margin could be applied, while Shell Energy noted that one should be specified only if OEMs had not specified a tolerance and it was otherwise justified.

AEMO acknowledges that there are tolerances that could affect the evaluation of a plant's Withstand SCR capability, including shortcomings in network representation when using a simplified SMIB. While submissions are focused on the primary balance of plant items and uncertainties associated with cable impedances etc, other important factors must be taken into account, as well. Model validity, modelling artefacts and suitability of models and the simplification in the SMIB can lead to fictitious assessments and phenomena that are not regularly experienced or tested as part of the technical due diligence carried out during the connection/alteration assessment processes. This equally applies to inverter control systems, settings, plant level controllers and so on.

AEMO does not propose to specify an engineering safety margin in the SSIAG. Nevertheless, AEMO expects Connecting NSPs to apply good engineering practice, which could include the application of a safety margin having regard to the quality and extent of information received from an Applicant, the validity of that information and understanding of the aggregation method applied for the 4.6.6 Connection when evaluating a 4.6.6 Connection's low Withstand SCR capabilities.

Availability of load models

Transgrid suggested that AEMO should specify the modelling requirements of different types of IBLs (mine loads, data centres and other large industrial facilities) including key control system models and model aggregation techniques to avoid any ambiguity.

AEMO shares Transgrid's concerns for the types of IBLs for which there is not much information available on which technical due diligence can be carried out to a reasonable degree of confidence. In the absence of further information, AEMO recommends that these types of 4.6.6 Connections be evaluated on a case-by-case basis, in accordance with the Power System Model Guidelines. Consulted Persons are welcome to provide further feedback on this matter through consultations on (update of) Power System Model Guideline, connection reform initiatives and access standards review.

Other Issues

Tesla's submission suggests there are benefits in providing a clearer pathway to connect advanced inverters/virtual synchronous machines with appropriate access standards. AEMO considers that the type of plant Tesla is referring to might best be considered in a comprehensive review of the access standards, followed by a rule change proposal if any gaps or barriers to participation are identified. Consulted Persons are welcome to provide further feedback on this matter through consultations on (update of) Power System Model Guideline, connection reform initiatives and access standards review.

4.3.3. AEMO's conclusion

AEMO has redrafted the sections dealing with Preliminary Assessments in the draft SSIAG to address the issues discussed in section 4.3.2, namely:

- The indicative SSQ is capable of calculation at the Preliminary Assessment stage.
- AEMO provides two methods for undertaking a Preliminary Assessment; one where suitable models are available, and one where they are not.
- AEMO does not propose an engineering safety margin.

4.4. Full Assessment

4.4.1. Issue summary and submissions

AEMO considered how the Amending Rule will affect the Full Assessment methodology and posed several issues for consideration in the Issues Paper, which are considered separately.

Relationship between the Full Assessment and access standard assessments

AEMO was concerned whether the timing for the commencement of a Full Assessment requires revision and whether the SSIAG should detail the information and resources a Connecting NSP needs to commence and complete a Full Assessment.

Key concerns for AEMO are:

- The interdependencies between the Full Assessment and due diligence carried out by AEMO and Connecting NSPs to assess the suitability of proposed negotiated access standards and the availability of suitable models.
- The importance of capturing 4.6.6 Connection performance prior to commencing the due diligence carried out by AEMO and Connecting NSPs to assess the suitability of proposed negotiated access standards.

Submissions were received on this issue[22].

APD Engineering

> AEMO has proposed to require a Full Assessment to be conducted prior to the demonstration and acceptance of proposed GPS under NER 5.3.4A. In doing so, AEMO are removing the requirement for a Full Assessment to commence only after AEMO issue a letter of satisfaction with the GPS under NER 5.3.4A. This will also make 5.3.4A dependant on conclusion of a Full Assessment and any SSR requirements of 5.3.4B.

[22] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms and terms that are defined in the Glossary.

> APD concur with AEMO that, in some circumstance, a Full Assessment may be required to demonstrate compliance with proposed GPS or to provide evidence of required amendments to a proposed GPS. …
>
> APD consider it important to clearly define the exact milestones in the connection application process that would allow a 4.6.6 Connection to commence a Full Assessment. With AEMO's proposed changes, APD consider the timing and pre-requisites for commencement of a Full Assessment become relatively undefined if the milestone of achieving a NER 5.3.4A letter is removed. In the Issues Paper, AEMO have proposed this change without defining a new clear milestone, which poses increases risk to project timeframes. Furthermore, this may introduce financial implications if contractual obligations are dependent on achieving the 5.3.4A milestone only.
>
> It is expected that all existing requirements leading up to a Full Assessment should be met prior to a Full Assessment commencing. That is, under the proposed change AEMO would need to decide the Applicant has used all available information to them in development of the GPS. AEMO would be agreeing the proposed GPS would be acceptable should they pass a Full Assessment. The Full Assessment would then be the last step in confirming these. A new public set of formal acceptance criteria should be made available to Applicants to formalise a new milestone in the connection application process for Full Assessment commencement. This is then considered the same as the exiting process being undertaken for Full Assessments but with an additional milestone to avoid iterations of 5.3.4A letters. It is currently unclear if there would be any benefit from the proposed re-definition of the SSIAG Section 3.3 (a).
>
> In order to gain efficiencies from the proposed change the formal acceptance criteria for Full Assessment commencement may include due diligence completion of all NER clauses except for schedule S5.2.5.5. This would allow Full Assessment works to commence earlier than currently possible and in parallel with completion of the current due diligence processes.

Powerlink Queensland

> Due to the critical interdependencies between the GPS and Full Assessment, Powerlink agrees with AEMO that a Full Assessment should be carried out prior to finalising the GPS.

Commitment criteria for other plant connected to a network

The SSIAG currently uses the term "Committed" to identify other connection projects that should be included in the power system studies carried out during a Preliminary Assessment and Final Assessment.

The SSIAG currently define Committed as follows:

> In respect of a proposed *connection* other than the 4.6.6 Connection:
>
> (a) AEMO has issued a letter to the Connecting NSP under NER 5.3.4A indicating that AEMO is satisfied that each specified proposed *access standard* meets the requirements applicable to the relevant *negotiated access standard* under the NER;
>
> (b) AEMO and the Connecting NSP for that proposed *connection* have accepted a detailed PSCAD™/EMTDC™ model of that proposed *connection* provided by or on behalf of the *Connection Applicant* meets the requirements of the *Power System Model Guidelines*;
>
> (c) any proposed *system strength remediation schemes* or *system strength connection works* in respect of that other proposed *connection* have been agreed between the relevant parties, or determined by a *dispute resolution panel*;
>
> (d) an *offer to connect* has been issued by the Connecting NSP in accordance with NER 5.3.6; and
>
> (e) there is no reasonable basis to conclude that the model previously provided is materially inaccurate, including following commissioning of the *connection*.

In the Issues Paper, AEMO proposed to expand this definition to cover relevant load projects but also sought feedback on the 'committed' criteria, in particular, issues arising from:

- Multiple concurrent connection applications in proximate locations progressing at different rates at different times, and additional projects becoming Committed while a Full Assessment is in progress.

- Committed projects changing in scope, design, or intended commissioning date during the course of a Full Assessment, making it difficult or impossible to incorporate a representative model of those projects for assessment purposes.

Submissions were received on this issue[23].

APD Engineering

APD also agree with the approach to guarantee a stable baseline of the network model (however, a stable baseline should also be clearly defined) for a 4.6.6 Connection by only including committed projects. It is currently considered that committed projects would be defined as those that have offers to connect issued (5.3.4A and 5.3.4B accepted). This is deemed a necessary approach as it is required to not put undue financial risk onto an Applicant due to potential issues of any other connection applicant's plant.

…

The revised definition of a committed project states that any equipment design of a previously committed project, such that the model becomes unrepresentative, would revert the status of the project to be uncommitted. This would lead to significant financial consequences for Applicants, for example:

- At the R1 submission stage if there is a change in reactive power contribution from the harmonic filter, the project would become uncommitted.
- A reduction to the maximum MVA for a generating system would also lead to the project becoming uncommitted

This may lead to a financial disincentive for projects to make changes to a generating system that benefit the connecting network. It would also significantly increase the risk of developing a new project.

Given the significant financial risks, the technical trade-off for uncommitting a project should be appropriately justifiable. The criteria for uncommitting a project could be refined to more clearly understood material changes such as:

- A fundamental change in generating technology
- Increase in active power export capacity in MW
- Increase to the proposed minimum SCR

In terms of a Full Assessment, should projects other than the 4.6.6 Connection become uncommitted a consistent approach for management of this eventuality must be defined. It must be considered if a project has been included in a Full Assessment that later becomes uncommitted, do the results of the Full Assessment remain an accurate representation of the network performance such that they are still granted weight and merit. AEMO would need to determine a set of technical criteria to determine all Full Assessment studies run with the now uncommitted generating system in service be required to be repeated without it.

Citipower & Powercor

We consider that it may be punitive that for any change in project size or OEM to cause a project to be considered uncommitted. There are events outside of the control of an Applicant that may require them to change size or OEM for example the bankruptcy of a supplier.

We further submit that it will be more fair to apply a time limit for which a 5.3.9 package to be accepted by AEMO and the Connecting NSP.

Further it is considered that if an Applicant is still able to meet or exceed its existing GPS with a different OEM then it would appear punitive to de-commit such a project.

If a project receives and executes a connection offer after a 5.3.4A/B is issued by AEMO, a 5.3.7g notice is provided to and acknowledged by AEMO, it is considered a committed project. Is AEMO now proposing to have another definition of "committed" status for Full Assessment purposes? How are these two "committed" statuses linked to each other? It would be very confusing if a project has different "committed" statuses if they only make a change in size (size

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reduction) or inverters/turbines (when an OEM discontinue one product range and offer a newer one which is slightly different).

In addition, the Connecting NSP would only issue an offer to connect to a project once AEMO issues 5.3.4A/B approval. If the project is later changed from "committed" to "uncommitted" status, based on this proposal, then what would be the impact to the executed connection offer/contract?

ElectraNet

ElectraNet request consideration is given to the following:

…

6. When undertaking Full Assessments, ElectraNet considers that the criteria applied to determine whether a project is classified as a committed project should be the formal acceptance of a project's GPS, and successful completion of the project's Full Assessment or Stability Assessment as applicable. At this stage, the models and performance obligations of a particular project are assessed, documented and accepted, and the project is at a sufficiently advanced stage to support inclusion in studies assessing other proposals.

Ergon Energy & Energex

We believe the current definition of committed project should be maintained. For example, 5.3.4a achieved with an agreed PSCAD model and Connection Agreement has been executed.

It is not clear why AEMO is proposing to remove the requirement of the Connection Offer being accepted. If the intention is to allow 'batching' of similarly progressed projects, it is considered there is already the allowance for this with 5.4.5 of the existing SSIAG.

ESCO Pacific

ESCO Pacific broadly support AEMO's initiative to review the criteria for determining committed projects for Full Assessment purposes, noting the inefficiencies and inconsistencies in the criteria NSPs currently use to determine projects that should be included, resulting in unnecessary costs, iterations and delays.

As such, ESCO Pacific proposes that projects in the final stages of access standards acceptance should be considered committed for system strength impact assessment purposes. These are projects of which GPS have been materially agreed but without an issued connection offer. The classification of such projects as committed for system strength impact assessment purposes should be limited to a defined time window, for example, within 6 weeks such that if a connection offer is not issued within the specified period, the project would revert to an uncommitted status.

Furthermore, where a committed project makes material changes to its GPS and undergoes a 5.3.9 process such that the model becomes materially inconsistent with them, the status of the project would be reverted to uncommitted if the project is unable to complete the 5.3.9 process within a defined period for example within 12 weeks.

Powerlink Queensland

To avoid the possibility of banking system strength capacity, an appropriate threshold criteria should be applied prior to considering a project as 'committed' for the Full Assessment purposes. Powerlink has experienced projects that achieve GPS (5.3.4A/B) acceptance, but yet do not proceed to connect. Powerlink recommends that a pre-requisite for a project receiving 'committed status', from a system strength perspective, should include a formal acceptance of the connection offer and a 5.3.7(g) response to AEMO from the Connecting NSP.

…

Once the GPS has been agreed and the Applicant has accepted a connection offer, a project should be considered committed.

We do not agree that a material change in the proposed generator should revert the committed status to uncommitted. Instead, a project should follow the 5.3.9 process and reassess the general system strength impact.

SGRE

Projects can be considered committed for Full Assessment purposes once their proposed performance standard has been approved.

TasNetworks

TasNetworks supports consistency in the definition of a committed project. Our current understanding is that a committed generation project is one that has accepted an Offer to Connect having proceeded through the processes of NER Chapter 5. A committed project will therefore have an agreed GPS. For load connections, TasNetworks has defined its requirements to achieve committed status in its Guide to Transmission Connections.

TasNetworks is cautious about allowing a committed project to be downgraded where material changes to the design are subsequently proposed. While many of the studies undertaken to reach the offer to connect stage will need to be repeated, a project considerably advanced through the process should continue to be assumed as proceeding. Any subsequent changes to plant performance would need to be negotiated with the NSP via the relevant provision of the NER. The intent should be to try and avoid multiple study iterations and focus rather on engineering robust solutions which are tolerant to a range of different input assumptions.

Network augmentations and retirements

While the Issues Paper considered the application of Commitment criteria in the context of Full Assessments, these only refer to projects other than network augmentations and retirements[24].

Submissions were received[25] on the treatment of proposed network augmentations or retirements of network facilities.

APD Engineering

APD believe the main consideration should be the time at which Applicants will be fully operational. It may not be practical for a project to complete Full Assessment with future network augmentations significant timeframes in advance given the likelihood of other significant changes to the network that may occur in the interim which may impact the outcomes. It is considered the Applicant must be informed prior to augmentations if there is risk they may not be allowed to operate should the plant not meet performance standards after the augmentations.

The Applicant should be made aware of these future network augmentations and associated risks, and a risks-based approach be considered. Should it be considered feasible, an Applicant may be able to complete online commissioning and post-commissioning activities prior to the future network augmentations, there should be no barrier to the plant connecting and commencing commercial operation.

It is understood that the Connecting NSP would be required to conduct a Full Assessment inclusive of the future network augmentations and the Applicant's plant, and if issues are identified the Applicant's plant would not be able to operate until these are resolved.

This approach would allow online commissioning and post-commissioning activities to proceed in parallel with any required settings or design modifications to be implemented for operation after the network augmentations are completed.

Citipower & Powercor

We do not consider it appropriate to include future network augmentations as the network should be assessed under worst case conditions.

If future network augmentations are not included this ensures that generating plant are capable of operating under worst case conditions.

The only condition that future network augmentations should be considered is if the 4.6.6 Connection intends to be constrained until network upgrade is fully commissioned.

[24] Proposed network augmentations and retirements were considered in the context of the SSLF calculation. See section 4.6.

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ElectraNet

ElectraNet request consideration is given to the following:

…

6. … Future network augmentations should be included once they achieve sufficient funding certainty from NSPs (e.g. completed a RIT-T or, for smaller projects, are endorsed by the respective NSP). Emphasis should be placed on the relative timing of network augmentations and the likely date of connection for customer connection projects when considering the inclusion of future network augmentations.

Ergon Energy & Energex

We suggest future augmentations be included once they have achieved financial approval (committed).

Through Joint Planning the TNSP/DNSP can decide how to treat projects which have not yet reached the committed stage.

ESCO Pacific

Future network augmentations as identified in sources such as jurisdictional REZ planning frameworks, the Integrated System Plan (ISP), Electricity Statement of Opportunities (ESOO) and NSPs Annual Planning Reports should be included in the Full Assessment. The inclusions of such future network augmentations adopt a realistic, transparent and forward-looking approach to the modelling of the future network. It avoids high investment and operational costs to Applicants and prevents underestimation of likely future network augmentations.

SGRE

Network augmentations must be included as soon as accurate models are available and there is confidence with their commissioning relevant timeframes for commissioning of the project under study. If it is the case that a network augmentation, which is uncertain, could significantly impact the outcome of the Full Assessment then it must be assessed on a case by case basis.

TasNetworks

Future network augmentations should be included to the extent that they are necessary to support the 4.6.6 Connection. It is essential that network modelling includes the new generator or load physically connected to the network, including any system strength solutions required. TasNetworks recommends that the status of network related augmentations be communicated by NSPs through Joint Planning activities undertaken in conjunction with AEMO.

Multiple concurrent applications in proximate locations

The Issues Paper did not consider the treatment of concurrent applications in proximate locations. Nevertheless, APD Engineering addressed the issue in its submission[26].

APD Engineering

AEMO raises concerns in Section 4.4.2 Issue 2 dot point 1 in relation to address issues arising from multiple concurrent connection applications in proximate locations. In Section 4.4.3 Issue 2 AEMO identify committed projects included in a Full Assessment should have reached the stage at which performance standards have been approved. However, in Issue 1, it is indicated that these projects themselves must have passed a Full Assessment themselves prior to acceptance of their GPS under NER 5.3.4A. This is not considered to address AEMO's concern, on the contrary it is considered to likely further exacerbate the issue by resulting in the requirement to potentially conduct more Full Assessments if exact criteria for Full Assessment commencement are not adequality defined.

In the interests of efficiency and alleviating the burden increases in Full Assessments would produce on industry, it may be considered that all plants that have reached an 'Full Assessment ready' stage but not currently completed a Full Assessment, be concurrently integrated into a single model for a Stability Assessment. Unlike the proposed Stability Assessment in the Issues Paper, all new plants connection point quantities should be recorded not only specific network node voltages, but the data would not be assessed unless the Stability Assessment acceptance criteria was not met. This

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> would allow early determination of specific plant that may breach Stability Assessment and Full Assessment acceptance criteria, as if an issue was identified it may be determined which plant/s are responsible. This could occur at set intervals throughout a year if there are multiple concurrent connection applications in proximate locations (proximate locations should be explicitly defined). This approach could only be considered should the network have sufficient hosting capacity to facilitate connection of all nearby plants and Applicants agree to this approach.
>
> If issues are identified with a currently non-committed but 'Full Assessment ready' plant (reactive power in phase with voltage oscillation, etc) the plant deemed to cause the issue would be removed from service and Full Assessment can continue on all other 'Full Assessment ready' plant. If no issues are observed, the existing data collected can be used for more detailed analysis and Full Assessment on all applicable plant without the need to re-produce simulation results.

Specification of Performance Standard Interdependencies

While AEMO did not consider the interdependencies between Full Assessments and access standard assessments in detail in the Issues Paper, APD Engineering made a submission on the issue[27].

APD Engineering

> AEMO has proposed NER 5.3.4A cannot be finalised until completion of a Full Assessment where applicable. APD consider the applicable GPS schedules and clauses that the Full Assessment outcomes will have bearing over should be explicitly defined. APD consider that the full scope of the Full Assessment remains undefined in this regard in the Issues Paper.

Transparency

While AEMO did not consider transparency in the Issues Paper, Citipower & Powercor made a submission on the issue[28].

Citipower & Powercor

> Greater transparency between AEMO and NSPs, and between NSPs, should be required as part of the Full Assessment Methodology. Better transparency of adjacent projects reduces the need for rework for projects, reducing connection costs. This transparency should also include system strength solution(s) that the SSSP is planning to implement, otherwise over-investment may occur as nearby NSPs will be unaware of these solutions.

4.4.2. AEMO's assessment

Some submissions indicate a potential misunderstanding around the NER requirements for the commencement of a Full Assessment for a 4.6.6 Connection and the application of the criteria by which other plant (including network augmentations) should be included in the power system studies to be carried out as part of the Full Assessment.

The issues raised in the submissions will be discussed under their separate headings.

Relationship between the Full Assessment and access standard assessments

There were two submissions on timing. One supports AEMO's proposal to require a Full Assessment to be carried out prior to finalising the access standards, whereas the other is opposed to it.

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Powerlink Queensland correctly points out that there are interdependencies between a Full Assessment and the due diligence carried out for the purposes of assessing the acceptability of proposed access standards. While Powerlink is not specific, AEMO notes that the 4.6.6 Connection's access standards can only be approved following the completion of Full Assessment, and approval of any SSR.

APD suggests that the removal of a NER 5.3.4A letter as a milestone will result in uncertainty as to when a Full Assessment should commence but proposes a replacement criterion of due diligence completion of all proposed access standards except for those under NER S5.2.5.5 to allow a Full Assessment to commence in parallel with completion of the due diligence.

AEMO considers that the Connecting NSP must complete the Full Assessment prior to completing the due diligence of an Applicant's proposed negotiated access standards, consistent with existing connection processes. Consulted Persons are reminded that SCR access standards will need to be proposed, which are an integral part of the matters that a Connecting NSP must consider when conducting a Full Assessment.

To further aid Applicants in understanding key milestones, the SSIAG will include flowcharts of the system strength assessment process within the connection and alteration processes, to illustrate how the two interact, which indicate that the Full Assessment will be undertaken prior to finalising proposed access standards.

Commitment criteria for other plant connected to a network

The commitment of other plant proposed to be connected to a network is important because this will determine whether they are to be included in the power system studies to be carried out as part of the Full Assessment.

There are two issues here:

- When to include plant other than the 4.6.6 Connection under consideration.
- When Committed plant should no longer be considered to be Committed.

Each will be addressed in turn.

When Plant should be considered Committed

There is no all-purpose, universally applicable definition of 'committed' in the NEM. AEMO understands that each NSP has a different approach to determining what is 'committed' for different purposes, for example, planning vs connections, and AEMO considers it important to apply one set of criteria for the purposes of the SSIAG. This disparity of views is reinforced by the submissions, and it is apparent that different NSPs even had a different interpretation of the current SSIAG definition of Committed.

Submissions on this issue are summarised in the table below.

Consulted Person	Determinative action to consider project Committed
APD Engineering	Offer to connect issued
Citipower & Powercor	No comment
ElectraNet	Formal acceptance of performance standard and successful completion of Full Assessment or Stability Assessment, as applicable

Consulted Person	Determinative action to consider project Committed
Ergon Energy & Energex	Formal acceptance of performance standards and execution of connection agreement
ESCO Pacific	Performance standards materially agreed and offer to connect issued within 6 weeks
Powerlink Queensland	Formal acceptance of offer to connect and NER 5.3.7(g) notice to AEMO
SGRE	Formal Acceptance of performance standards
TasNetworks	Formal acceptance of performance standards and offer to connect

There are currently four criteria that need to be met for a project to be considered Committed[29], but submissions focused on the first and fourth criteria.

(a) Acceptance of negotiated access standards.

All seven NSPs who made submissions on this issue agree that acceptance of access standards[30] should be a criterion.

AEMO does not consider ESCO Pacific's proposal that projects should be considered Committed if the access standards have been materially agreed is workable, as it would give rise to argument over the meaning of 'material' and the timing of when the criterion is met, diverting resources away from completing technical due diligence studies. It is more likely to give rise to the sort of arbitrariness ESCO Pacific is concerned about in its submission.

AEMO considers that acceptance of access standards by both AEMO and the Connecting NSP should remain a criterion.

(b) Connecting NSP and AEMO acceptance of a detailed PSCAD™/EMTDC™ model.

No submissions were made on this criterion.

Noting that the provision of suitable models is a pre-requisite to the commencement of technical due diligence studies for the purpose of assessing the proposed access standards, AEMO proposes to retain this criterion.

(c) SSR is agreed or determined by Dispute Resolution Panel.

There were no submissions on this criterion.

AEMO considers that this should be retained as a criterion.

(d) Offer to connect issued by Connecting NSP.

Ergon Energy & Energex and TasNetworks submitted that the current definition of Committed requires acceptance of an offer to connect. Paragraph (d) of the definition

[29] The fifth criterion (material inaccuracy of model) is used to determine whether a previously Committed project should no longer be considered to be Committed and is discussed in the next sub-section.

[30] While most submissions refer to 'GPS' as a shorthand, the Amending Rule incorporates market network service facilities and loads, as well. AEMO has used the generic term 'access standards' to be consistent with NER 5.3.4A and NER schedules 5.2, 5.3 and 5.3a.

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states that the offer to connect has been **issued**. The question of acceptance was considered in AEMO's final report on the 2018 SSIAG, and deliberately not included[31].

AEMO considers that Powerlink Queensland's submission that the NER 5.3.7(g) notice be a criterion is impractical as the finalisation of a connection agreement can be held up by any number of matters unrelated to system strength or performance.

AEMO considers the NER 5.3.7(g) notice is too late in the process for plant to be considered Committed for the purposes of assessing system strength and is not convinced that it should delete this criterion from the definition. It is likely that adoption of this criterion would result in more re-assessments.

All bar one submission was focussed on generation connections. Only TasNetworks commented on load connections, noting that it has defined its requirements to achieve committed status in its Guide to Transmission Connections. AEMO considers that TasNetworks should be applying the SSIAG definition for the purposes of undertaking a Full Assessment.

Committed plant ceasing to be Committed

Full Assessments must be carried out using the most up-to-date information about other projects.

Several submissions commented on the impact of changing the status of other projects on the Applicant, which could result in expense and delay through no fault of the Applicant. AEMO agrees that the risks Applicants are exposed to when seeking connection to the power system should not be understated and acknowledges that the relative rate of progression of electrically close projects causes uncertainty with system strength impact assessments. Nevertheless, it must not be forgotten that the risks to power system security are a primary consideration, affecting everyone connected to the power system.

Moreover, it is expected that the efficient system strength framework introduced by the Amending Rule could reduce this uncertainty risk for Applicants.

Submissions on this issue are summarised in the table below.

Consulted Person	Criteria that warrant considering a project to cease being Committed
APD Engineering	• A fundamental change in generating technology • Increase in active power export capacity in MW • Increase to the proposed minimum SCR
Citipower & Powercor	If the Connection Applicant could not complete NER 5.3.9 process within 12 weeks
ESCO Pacific	If the Connection Applicant could not complete NER 5.3.9 process within 12 weeks
Powerlink Queensland	Nothing warrants change to Committed status
TasNetworks	Nothing warrants change to Committed status

[31] System Strength Impact Assessment Guidelines, Final Report and Determination, June 2018, section 4.1.2. Available at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-security-market-frameworks-review/2018/final_determination_ssiag_published.pdf?la=en&hash=55F14CFB90AABAEC308B1B25E8AEC1E4.

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Paragraph (e) of the definition of Committed requires a reasonable basis for concluding that a model previously provided is materially inaccurate. For AEMO, the ability to assess the impact of a 4.6.6 Connection using the most up-to-date information about other plant proposed to be connected is a critical element when undertaking a Full Assessment. For Applicants impacted by the application of paragraph (e), the results of their Full Assessment would need to be verified with updated models and data. Any conclusions reached by AEMO and the Connecting NSP would be invalidated otherwise, and AEMO will need to be satisfied that the altered landscape does not give rise to an adverse impact on power system security.

Each of the three grounds suggested by APD Engineering as being appropriate for ceasing to consider a project as Committed could be a reason why a previously supplied model might be materially inaccurate, however, to restate paragraph (e) in the precise terms suggested could preclude other causes where a model might be materially inaccurate.

Citipower & Powercor considered it punitive for projects to be considered not Committed if, amongst other things, they could still meet or exceed their performance standards with a different OEM. In AEMO's experience, Applicants who change OEMs in the course of a connection application or proposed alteration may require additional time (to re-develop their project and associated models) to meet model acceptance tests or previously agreed access standards, resulting in significant delays, effort and cost on everyone involved.

The further suggestion from Citipower & Powercor, supported by ESCO Pacific, that it would be more appropriate for AEMO to provide a timeframe for a Committed project owner to complete the NER 5.3.9 process within 12 weeks is also impractical given the many variables at play. Consequently, a 12-week time limit would be no less punitive than the current criterion.

AEMO agrees with TasNetworks that Connecting NSPs should try to avoid multiple study iterations and focus on engineering robust solutions that address a range of different input assumptions.

Citipower & Powercor's question about the impact on a connection agreement if a project's circumstances changed following execution, is not within the scope of the SSIAG. It would be appropriate for these consequences to be addressed by the agreement, having regard to the potential impact on the Connecting NSP for its system strength assessments and other obligations.

Network augmentations and retirements

Section 5.2 of the current SSIAG requires consideration of all existing networks and any proposed network augmentations or retirements of network facilities if the consultation period of the project assessment conclusion report during a RIT-T has concluded.

The rationale for including network augmentations and retirements in the power system studies carried out during a Full Assessment is no different to including 4.6.6 Connection projects. There is always a lead time before any 4.6.6 Connection is likely to be operational and changes to the network need to be taken into account as well as changes to other existing plant and Committed 4.6.6 Connection projects.

The current SSIAG does not include reference to network augmentations and retirements in the definition of Committed because that is a term used to identify other proposed connections being assessed at around the same time as a 4.6.6 Connection. Future network developments are addressed in section 5.2 of the current SSIAG.

There are two key considerations:

1. Whether the Full Assessment should be undertaken in consideration of system normal conditions and other conditions prescribed in the SSIAG, but not worst-case.
2. Whether the network should be represented as it exists at the time of the assessment, or at some future date and, if so, the date at which it should be considered.

As a general proposition, AEMO considers that the assessment should be carried out assuming system normal conditions and to this extent, disagrees with Citipower & Powercor. Moreover, their suggestion that the only condition on which future network augmentations should be considered is if the 4.6.6 Connection intends to be constrained until the network upgrade is fully commissioned seems unnecessarily impractical.

The second, namely, when to include a proposed network augmentation or retirement in the assessment, is what section 5.2 of the current SSIAG is attempting to address.

Future network augmentations are usually publicly announced. As ESCO Pacific points out, they are usually identified in publications such as jurisdictional REZ planning documents, AEMO's Integrated System Plan and Electricity Statement of Opportunities and NSPs' Annual Planning Reports.

TasNetworks recommends that the status of network augmentations should be communicated by NSPs through their joint planning activities with AEMO. Ergon Energy & Energex also consider that network augmentation projects that are not yet committed should be reviewed on a case-by-case basis through joint planning between the NSPs and AEMO.

The current SSIAG, however, requires all proposed network facilities or proposed retirements of network facilities to be included in a Full Assessment only if the consultation period for the project assessment conclusion report has concluded, meaning that the NSP must have largely completed an economic regulatory assessment of the project by way of a public consultation.

Ergon Energy & Energex submit that future network augmentations should be included only if they have achieved financial approval. Unless these types of decisions are publicly announced at all times, AEMO does not consider this to be an appropriate criterion.

SGRE submits that network augmentations should be included once accurate models are available and there is confidence they will meet their timeframes for commissioning of the 4.6.6 Connection, otherwise, if a network augmentation could significantly impact a Full Assessment outcome, it must be assessed on a case by case basis. AEMO notes that this would provide no objectively transparent criteria and could result in inconsistent application, as interpretations will vary significantly on the sufficiency of model accuracy or confidence levels for completion dates.

TasNetworks considers that future network augmentations should be included to the extent that they are necessary to support the 4.6.6 Connection. It is essential that network modelling includes the augmented network, 4.6.6 Connection and any SSR.

Submissions were also concerned with scenarios that place a 4.6.6 Connection at risk of not being able to operate if a given network augmentation does not proceed. APD proposes that Applicants be allowed to carry out online commissioning and post-commissioning activities in parallel with any required settings or design modifications to ensure operation of the 4.6.6 Connection after completion of the network augmentation.

AEMO considers that the most equitable outcome is to include future network augmentations and retirements from the approximate date that a 4.6.6 Connection is likely to be operational to ensure that it reflects the actual network at that time. AEMO considers that referring to "considered projects" meets this outcome.

Multiple concurrent connection applications in proximate locations

Section 5.4.5 of the current SSIAG permits the concurrent assessment of 4.6.6 Connections, and AEMO agrees that APD Engineering's proposed approach would be efficient in relevant situations. AEMO cannot, however, legislate the terms under which concurrent assessments could occur. These will be for the Connecting NSP to resolve with Applicants directly.

AEMO proposes to retain batching as an option for Connecting NSPs in the draft SSIAG.

Specification of Performance Standard Interdependencies

AEMO does not consider it feasible to implement APD's submission that the interdependencies between specific access standards and a Full Assessment be detailed in the SSIAG because they are not clear-cut or uniform across all possible connection/alteration scenarios.

Transparency

Citipower & Powercor raised the issue of transparency of the Full Assessment methodology:

- Between AEMO and NSPs.
- Between NSPs, with respect to adjacent projects, including SSR, to reduce the need for re-work, reducing connection costs.
- In the context of system strength solutions an SSSP is planning to implement.

Insofar as the Full Assessment methodology is concerned, AEMO has proposed amendments to be clearer and more specific in the draft SSIAG.

In relation to projects in adjacent networks, AEMO sought to address this by the provision of a secure database and requirements in section 4.3 of the current SSIAG, for NSPs to update Committed project information on that database promptly. NSPs may also consider arrangements they can put in place themselves under NER 5.3.8(c) to exchange information about projects under assessment in adjacent network areas. AEMO welcomes any advice on how it can facilitate increased transparency and collaboration across NSPs when assessing potential interactions between projects in adjacent networks.

AEMO assumes that system strength solutions an SSSP is planning to implement would generally be subject to a regulatory investment test, with sufficient transparency around that process.

4.4.3. AEMO's conclusion

The draft SSIAG includes flowcharts of the system strength assessment process within the connection and alteration processes, to illustrate how the two interact, and confirming that the Full Assessment will be undertaken prior to finalising proposed access standards.

Section 3.3(a) of the current SSIAG will be deleted from the draft SSIAG, which, instead, specifies the information requirements to be met by Applicants whose 4.6.6 Connections are subject to a Full Assessment. The draft SSIAG cross-refers to the Generator Connection Application Checklist[32], which AEMO intends to update to apply to relevant loads and market network service facilities.

The provisions governing whether network augmentations or retirements should be included in the studies will be expanded to include distribution network augmentations and retirements. Moreover, Connecting NSPs will be required to conduct the assessment under system normal conditions and all other conditions required by the SSIAG.

4.5. Stability Assessment

4.5.1. Issue summary and submissions

A Stability Assessment must be carried out by the Connecting NSP instead of a Full Assessment where an Applicant elects to pay the SSC when it submits an application to connect or a submission to alter connected plant[33].

The purpose of a Stability Assessment is to verify the stability of the 4.6.6 Connection[34] and the Amending Rule requires AEMO to prescribe in the SSIAG the methodology for carrying out a Stability Assessment[35].

The AEMC Final Determination confirms[36] that the Stability Assessment requires wide-area EMT modelling to map power electronic converter interactions with the power system.

Issues that AEMO proposed to address in the SSIAG are:

- Scope of the Stability Assessment
- Timing of the Stability Assessment
- Consultation with AEMO

[32] See https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/participate-in-the-market/network-connections/transmission-and-distribution-in-the-nem/stage-3-application.

[33] See New clause 5.3.4B(a2)(4).

[34] See New clause 5.3.4B(a2)(4).

[35] See New clause 4.6.6(a)(8).

[36] See pages 26, 170 and 172.

- Consequences of Instability

Submissions were received on some of these matters[37].

Scope of Stability Assessment

The Stability Assessment is a subset of power system analysis focused on the efficacy of system strength services (SSS) in ensuring a stable voltage waveform for the operation of power systems with power electronic interfaced plant (generators, loads, transmission/distribution devices). As such, AEMO expects it to be performed using EMT modelling for a range of disturbances. The scope, however, will be restricted to the observation of power system voltages at key system nodes while the detailed assessment of a 4.6.6 Connection's compliance with its proposed performance standards will be carried out during relevant due diligence assessments. AEMO also proposes to include in the SSIAG a process flowchart in the form of Figure 5 in the Issues Paper.

Several submissions were received on these matters[38].

APD Engineering

> While APD consider the proposed scope of a Stability Assessment is appropriate in a general sense as described in Section 4.5.3 of the Issue Paper …, there is still room for additional details to remove any ambiguities on the extent of the scope. It is stated that a Stability Assessment is a subset of power system analysis focused on the efficacy of SSS in ensuring stable voltage waveform. The subsequent discussion in the section implies that this subset will be limited to studying the power system response for a range of disturbances including credible contingencies and protected events using an EMT model of the grid. APD consider that it is important to provide explicit details in SSIAG on the acceptance criteria of a Stability Assessment as the Figures 3 and 4 indicate that the focus is only limited to post-disturbance root mean square (RMS) voltage magnitude at key system nodes. However, Section 3.2.2 … indicates that definition of stable voltage waveform has other elements than the RMS voltage magnitude. Therefore, it is suggested that AEMO further clarify the assessment criteria (in other words, what does AEMO mean by satisfactory voltage waveform stability) of a Stability Assessment.
>
> There is also ambiguity around the starting point of a Stability Assessment. The general indication throughout the Issues Paper is that SSSP should provide adequate SSS in order to maintain the minimum levels of system strength for the stable operation of the power system with the existing plant at the time of assessment. As such, a Stability Assessment at first should ensure that the existing power system meets all the criteria for stable voltage waveform. This should equally apply to any committed plants considered for a Stability Assessment for a newly connecting plant, i.e. the power system with all the committed plants prior to the 4.6.6 Connection should meet all the criteria for a stable voltage waveform. …

Ausgrid

> It is not clear what the differences are between the Full Assessment and the Stability Assessment.

AusNet

> **AusNet recommends the SSIAG provide greater flexibility for Connecting NSPs to account for the individual nuances within each .. Stability Assessment rather than attempt to form a generic scope of studies.**
>
> …

[37] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms and terms that are defined in the Glossary.

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In general, AusNet supports the proposed scope of a Stability Assessment that ensure stable voltage waveform at key SSNs both in a satisfactory operating state and following any credible contingency events or any protected event described in NER S5.1.2.1. This is consistent with the definition of stability stated in NER S5.1.8 ensuring:

(a) the power system will remain in synchronism.

(b) damping of power system oscillations will be adequate; and

(c) voltage stability criteria will be satisfied.

The focus on the detailed compliance assessment for plant performance should be addressed in the Full Assessment.

AusNet notes that there is a need for some flexibility of scope to ensure the practicality of each assessment. ...

…

The issue of what should or should not be considered as part of a Stability Assessment is nuanced. There are many customised aspects for each connection that need to be considered and attempting to form a generic scope of studies … may not be practical or efficient.

AusNet recommends that providing flexibility in the SSIAG to alter the scope of studies contingencies and evaluations in agreeance between the Connecting NSP and AEMO will maintain a level of necessary practicality.

To demonstrate this point, AusNet examples are provided in the Appendix.

Appendix on Stability Assessment

Base case selection

The base case selection should be tied to how the system is intended to operate, since it has significant impact on how the connection dynamically interacts with its surrounding network. Key factors influencing the Stability Assessment results includes, but are not limited to:

- Synchronous unit scarcity
- Network sparsity
- Nearby IBR density
- Active and passive reactive power compensation devices.
- Operational limits

Such attributes of the base case must be considered and agreed between the Connecting NSP and AEMO before proceeding with each … Stability Assessment.

Range of interaction selection & network reduction

It must be clear what type of interactions are of interest for the Stability Assessment and what are the potential participating elements. The stability types to be studied will also directly impact the type of network reduction that is required. For example, depending on the connection location, the following aspects may need to be considered:

- SSO – Sub synchronous Oscillation problems
- SSR – Sub synchronous Resonance: passive elements (e.g., series compensated lines)
- SSTI – Sub synchronous Torsional Interaction: active elements (e.g., power system controls, HVDC, static var compensator (SVC), static synchronous compensator (STATCOM), high-speed governor, Power System Stabiliser)
- SSCI – Sub synchronous Control Interaction: interaction between power electronic control systems, e.g., of HVDC or Doubly-Fed Induction Generator Wind Turbine Generator, and series compensated lines. Purely electrical phenomenon (not related to mechanical shaft system)

Any network reduction (physical, topological, or modal) must be appropriate for the study type and capture elements most likely to participate in the stability interaction.

Legacy plant modelling

Depending on the connection and the information available, each Stability Assessment needs to consider the most appropriate way to treat legacy plant models, depending on the potential for affecting the 4.6.6 Connection. For example:

- Should generic models be used? How credible would the results be? How would they be tuned?
- Could an alternative approach be considered, such as increasing the source impedance of the equivalent NEM model? By how much? What X/R ratio?
- Should any legacy plant with limited information simply be ignored?

Impact of generator dispatch on sub-transmission or lower

For transmission connections, the use of existing generator dispatch patterns and transfer limit advice is appropriate when selecting a base case operational envelope. However, for sub-transmission and distribution connections, it may be impractical or financially unviable to consider a range of dispatch patterns of transmission-connected generation when performing a Stability Assessment, as this may necessitate the assessment to be performed in a NEM-wide EMT model.

Often, sub-transmission modelling starts from a controlled voltage source behind a source impedance without any dynamic models associated with it. Inertia and frequency aspects of the upstream system therefore will not be captured, and studies typically focus on local control interactions and impacts to the nearest SSN.

In the new paradigm the Amending Rule has created, it may be simplest that the source impedance of the reduced network should be mutually agreed with the SSSP, but in any case, this approach would need to be evaluated on a case-by-case basis and agreed between the Connecting NSP, the SSSP, and AEMO.

Concurrent applications

Due to the nature of the connection process, not all the active generation projects may be considered simultaneously. There may be a need to consider a Stability Assessment for the 4.6.6 Connection on its own, and then rerun the assessment with all the potential generators wanting to connect. Whatever the approach may be, it must be agreed upon between parties and be practical for the specific conditions affecting the connection.

Contingency consideration

In some areas of the network, some contingencies are more likely to occur than others, with protection clearance times and auto-reclose times varying considerably. When performing a Stability Assessment, it is important to use contingencies that are practical for the location in the network, not simply chosen from a pre-defined list. Local network planners should be consulted when considering these contingencies.

…

AusNet offers the following items for consideration from both a transmission and distribution perspective.

- Should N-1 for the system strength devices be considered?
- Should the generators be tuned for the current minimum SCR at the connection point without considering the SSS device? Or should generators be tuned to achieve best satisfactory voltage waveform considering the proposed SSNs?
- What if there are multiple SSNs in one case? How can one define the tuning objective?

Bo Yin

Like the Full Assessment, a Stability Assessment would be performed via EMT modelling for a range of disturbances, however, it is reduced in the observability of variables (observation of system voltages at key system nodes). This approach is considered to be aligned with the requirement to ensure stable voltage waveform in a steady state as well as following the contingency, but not during the event.

Citipower & Powercor

The proposed scope appears appropriate.

ElectraNet

ElectraNet request consideration is given to the following:

…

7. … ElectraNet notes that careful consideration is important in defining the key system nodes at which system voltages are monitored for the assessment. As a minimum, it is considered that the following locations should be included for the monitoring of voltage performance: the 4.6.6 connection point, all regional SSNs, locations of key system dynamic reactive support devices, interconnector nodes and nodes at which significant IBR connections are located. Additionally, ElectraNet considers that the real and reactive power flow on major intraregional and inter-regional transfer paths should be examined, and the aggregated regional IBR real power response should be monitored in order to detect plant disconnection and low voltage ride-through retriggering type issues in the wider system.

   Disturbances should include key contingency events (credible as well as those specified in existing customer GPS and those in the proposed GPS for the 4.6.6 Connection) and switching of key network elements (reactive plant, lines, transformers) to examine stability for smaller disturbances.

   The dispatch of other IBR in the studies needs to be carefully considered to ensure that the assessment covers sufficiently broad system operating scenarios (noting that the dispatch of IBR will vary with time of day and season).

   In situations where the Connecting NSP is not the SSSP (e.g. a DNSP connection), it is suggested that the SSSP also be consulted on the results of the stability assessment. The SSSP is clearly required to be involved due to the need to assess whether the SSS plans can be adjusted to mitigate issues or if the Applicant is required to bring other remediation. This is implied as necessary by the AEMO flow chart but not clearly discussed in the current AEMO proposed approach.

Ergon Energy & Energex

> In practice the Stability Assessment and Compliance Assessment will use the same set of study results. Furthermore, post fault instability can be a result of the 4.6.6 Connection not meeting its GPS, so this should not automatically be attributed to insufficient system strength. As such, it is unclear from a technical perspective why AEMO proposes to separate Compliance Assessment from the Stability Assessment.
>
> …
>
> … recommend including high-level guidelines regarding the minimum scope of network which should be modelled in the study. For example, full NEM, the region in question or a sub region.

SGRE

> … the proposed scope of the Stability Assessment is not appropriate. For the Stability Assessment it is critical that all information is confirmed not assumed before the study is carried out. The performance of a 4.6.6 Connection after the fault is impacted by the performance during the fault so neglecting any changes in this will lead to inaccurate outcomes.

NSP undertaking Stability Assessment

Although not raised by AEMO in the Issues Paper, a submission was received on this[39].

Citipower & Powercor

> We would like the SSIAG to address which party should perform the Stability Assessment. As per AEMO flow chart shown in Figure 5, it is the Connecting NSP who is also the SSSP (so that it can adjust its plants to stabilise the voltage waveform). However, if the Connecting NSP is an DNSP, the DNSP cannot tune the SSSP plants.

Timing

AEMO proposes that a Stability Assessment be finalised before any negotiated access standards that are AEMO advisory matters are approved by AEMO. AEMO proposes to specify any assumptions, technical inputs and relevant negotiated access standards that will need to be considered. This is consistent with currently applied method for the purpose of finalising Full Assessments and acceptance of negotiated access standards.

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Several submissions were received on these matters[40].

SGRE

> If the Stability Assessment happens before GPS negotiation, then what happens if/when control or plant changes are necessitated by the negotiation.

Committed

This issue was raised by AEMO in the Issues Paper, but in another context. APD Engineering submitted on the issue in this context, as well[41].

APD Engineering

> It is generally assumed that all committed plants considered, should have undergone a Full Assessment or a Stability Assessment prior to them being considered for a Stability Assessment of another plant.
>
> …
>
> It is also suggested to include a section providing the 'Definition of committed projects for Stability Assessment' similar to 'Definition of committed projects for Full Assessment' in Section 4.4.2 of the Issue Paper.

Further Studies

Although not raised by AEMO in the Issues Paper, submissions were received on whether further studies should be carried out[42].

APD Engineering

> AEMO's expressed intention of the Stability Assessment is to identify steady state voltage stability using wide-area EMT studies. APD suggests that these studies should be undertaken at a variety of network voltage conditions. Minor changes (<3%) in voltage of nearby network buses can reveal control system interactions that are not observed during operation at the given condition. Changes to voltage occur in the network during normal operation due to loading, transformer tapping and reactor shunts. This is why it is important to conduct the Stability Assessment at a defined variety of network voltages. The number of these voltage conditions to be assess should be determined by AEMO following consideration of the effort intended for the Stability Assessment, noting that currently, the Stability Assessment has the potential to be only marginally less effort than a Full Assessment.
>
> …
>
> APD believe that AEMO is required to specify the approach that they are planning to use to determine the cause of a voltage waveform instability: i.e. whether it is caused by the insufficient provision of SSS by SSSP or by the plant itself. Figure 5 of the issue paper indicates, when the criteria for satisfactory voltage waveform stability is not met by a plant, the SSSP adjusts its plans to stabilize the voltage in the first instance. However, it is not entirely clear how to establish whether an SSSP has done what is required to remedy the issue in case the issue remained following the adjustments by SSSP. For instance, a similar size plant with the same Balance of Plant with another OEM may be able to meet the stable voltage waveform criteria following the SSSP adjustments while the plant under study may still fail the criteria. Thus, a collaborative approach is required between the SSSP and the Applicant to work out the SSS adjustments and SSRS to meet the stable voltage waveform criteria in such circumstances. It would help Applicants who have paid an SSC if AEMO is able to specify the level of expectation on SSRS as a result of a Stability Assessment, in order to make Applicants aware the level of further work required in such circumstances.

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Citipower & Powercor

> The number of transmission lines that connect to a node should be considered. For example, in comparing Kerang to Shepparton:
>
> - Kerang has two lines connected, disconnection for maintenance of either line will result in almost halving of the system strength and therefore both lines should be considered critical
> - Shepparton has 4 lines connected, disconnection for maintenance of one line may result in a negligible change in system strength and therefore that line should be considered non-critical.
>
> Therefore, a % change threshold after contingency should be considered to determine whether a contingency is critical. That is, if loss of the KGTS-BETS line causes the fault level at Kerang to drop by a material percentage it should be considered critical. For SHTS if a threshold of 20% is selected, then 3 out of the 4 lines connected to SHTS can be considered critical. If 30% or something higher is chosen, then none will be considered critical.

Ergon Energy & Energex

> … a comprehensive set of S5.2.5.5 studies and some key S5.2.5.13 studies should be included. These are required for Compliance Assessment, confirming there are no adverse control interactions and assessment of sufficient system strength.

Powerlink Queensland

> We recommend that Stability Assessment should include both fault ride through and steady state response.
>
> …
>
> Performance during a fault is very much dependent on system strength and on the plant design (e.g. not enough voltage support at fault recovery, slow active power recovery time etc.) System strength cannot be separated from the fault ride through response and only considered for post fault control interactions.
>
> If a 4.6.6 Connection is showing acceptable performance in the RMS domain and through SMIB at the defined SCR, it should be considered that plant stability issues are due to the lack of system strength. If the SSSP considers that by some control tuning, stability can be maintained, Applicants should be coordinating this with the SSSP.

Free-Rider Problem

Although not raised by AEMO in the Issues Paper, submissions were received on this[43].

APD Engineering

> To ensure that there are no circumstances that may allow “free rider” Applicants with respect to SSS, additional EMT studies can be completed with any nearby remediation measures out-of-service. By doing so, this would ensure that the Applicant is not reliant on the system strength contributions from any other Connection Applicant or SSRS. If the Applicant can demonstrate a positive outcome for Stability Assessment in these scenarios, then it can be determined that they are not receiving a “free ride”.

AusNet

> [Ensuring there is no “free rider” situation for SSS non-paying Applicants] could be managed through defining the base case with the SSS-providing devices switched out, or reserving certain system strength in defining the Full Assessment base case for those that opt to be non-paying Applicants.

Citipower & Powercor

> The SSS required to meet the minimum system strength level considering all committed projects should be included. Any other additional SSS above meeting the minimum should be excluded to ensure there is no "free rider"

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If we need to assess multiple projects at the same time (like the WMZ integration or the proposed batching process), then we may need to assess both non-paying and paying projects together and hence need to work out a solution to ensure there is no "free rider".

Ergon Energy & Energex

We suggest the study should be run starting with the minimum fault level case, i.e., exclude forecast SSS.

Powerlink Queensland

Projects that require additional system strength support (in additional to minimum fault level) and their respective system strength support should be excluded from the assessment.

SGRE

SGRE believes that the current scope is unlikely to result in any "free rider" situation.

Consequences following failure of Stability Assessment

The Amending Rule does not address the consequences of a Connecting NSP's finding that the 4.6.6 Connection is not stable. AEMO proposes to address this in the SSIAG. Any identified issues will need to be addressed either by the Applicant (where associated with its own plant configuration), or by operational arrangements that will apply until sufficient SSS are available.

Submissions were received on this matter[44].

AusNet

Remediation options

Although there may be no ambiguity if a Stability Assessment has passed, it is less clear if the Stability Assessment fails. In particular, how to attribute the cause, given that the performance of plant may be highly operating-point dependent.

If a stability issue has been found at the Stability Assessment stage:

- What are the remediation tuning objectives? Should the control system be tuned to achieve satisfactory voltage waveform at key SSNs by sacrificing the performance of the participated generators? Or should the control system be tuned for the best performance at their own connection point considering the projected minimum SCRs? Should the control system be tuned for available or proposed SSS?
- Consider a connection in the sub-transmission or distribution system. If the SSRS is to add or alter reactive compensation devices or synchronous condensers, should the stability analysis always be done by the TNSP/SSSP rather than the DNSP to achieve the most economical results? (Noting that this may disincentivise generator connections in sub-transmission or distribution systems due to the extra interface layer, which takes more time, effort, and cost).

Bo Yin

I have below suggestion on the Stability Assessment process[45] as follows:

✓ Full Assessment should be performed if the SSSP fails to achieve satisfactory voltage waveform stability upon completion of Stability Assessment especially at the initial stage of evolving do no harm obligation to the system strength framework.

✓ Full Assessment should be performed

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[45] Amendments to AEMO instruments for Efficient management of system strength rule pg44

a. To identify IBRs with less SCR withstand capability and perform control improvement or retuning to reduce its needed system strength level for stable operation. If improvement or retuning is not possible, active power curtailment could be imposed to reduce its need for higher the efficient level of system strength for stable operation.

b. To identify instability due to large amount reactive current injection and fast active power recovery following contingency

c. To achieve better system level coordination of voltage & reactive power control strategy / proper tuning of SVCs for instability mitigation.

The aim is to reduce the need for efficient level of system strength for IBRs, especially grid following type based IBRs, connection and operation, and to achieve more effective use of SSS and share the associated costs more efficiently between consumers and connecting parties at the end.

…

SGRE

SGRE believes that if an Applicant elects to pay the SSC, then the obligation should be on the Connecting NSP to ensure that the system is stable. Thus, if the outcome of the Stability Assessment is that the system is not stable then the obligation should be on the Connecting NSP to ensure that the system is modified to accommodate the 4.6.6 Connection.

SGRE believes it will be an extremely difficult to define whether issues are in the scope of the Connecting NSP or Applicant to resolve with the current proposed methodology. The proposed Stability Assessment methodology creates a conflict of interest for the Connecting NSP, who will be required to both determine the outcome of the assessment and the scope of work required by themselves.

Determining cause of voltage waveform instability

Although not raised by AEMO in the Issues Paper, submissions were received on this[46].

APD Engineering

AEMO is required to specify the approach that they are planning to use to determine the cause of a voltage waveform instability: i.e. whether it is caused by the insufficient provision of SSS or by the 4.6.6 Connection itself. Figure 5 of the Issues Paper indicates, when the criteria for satisfactory voltage waveform stability is not met, the SSSP adjusts its plans to stabilize the voltage in the first instance. However, it is not entirely clear how to establish whether an SSSP has done what is required to remedy the issue in case the issue remained following the adjustments by SSSP. For instance, a similar size plant with the same Balance of Plant with another OEM may be able to meet the stable voltage waveform criteria following the SSSP adjustments while the 4.6.6 Connection may still fail the criteria. Thus, a collaborative approach is required between the SSSP and the Applicant to work out the SSS adjustments and SSRS to meet the stable voltage waveform criteria in such circumstances. It would help Applicants who have paid an SSC if AEMO is able to specify the level of expectation on SSRS as a result of a Stability Assessment, in order to make them aware the level of further work required in such circumstances.

Bo Yin

If the voltage waveform stability is not satisfactory and SSSP fails to adjust its plans to stabilise the voltage, the identified issues will therefore need to be addressed either by the Applicant (where associated with its own plant configuration), or by operational arrangements that will apply unless (and until) sufficient SSS are available.

In my opinion, there might be worth to perform Full Assessment for further investigation if the SSSP fails to achieve satisfactory voltage waveform stability upon completion of Stability Assessment. The reasons are listed as below:

Firstly, the Applicant has obligation to fulfil amending rule S5.2.5.15 and S5.2.5.16 with which it can remain connected and operate stably at an SCR of 3.0 for voltage phase angle shift limits less than 20 degrees at the 4.6.6 Connection Point. It is expected that 4.6.6 Connection has superior SCR/phase shift withstand capability compared to some of or most of the existing generators. Therefore, it has less tendency to initiate unstable control interaction (inverter instability)

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or cause oscillatory voltage following the contingency. As a result, the instability cannot be easily addressed by tuning of the 4.6.6 Connection or its re-configuration.

Secondly, integrating 4.6.6 Connection (let limiting the discussion with grid following type based IBRs) in general reduces the SCR (by any SCR definition) seen from the committed generators under the same SSN. If one or some of the existing generators could not withstand reduced SCR, it might exhibit oscillatory behaviour in the SSN as shown in Figure.3[47]. The above-mentioned existing generator(s) are the root cause of the instability.

Measures could be taken to identify these generators having less low SCR withstand capability and control improvement and control parameters re-tuning can be carried out to reduce the demanded system strength level for maintaining the voltage waveform stability for the area. This will be beneficial for the future Applicants in the area as well.

Thirdly, the NER S5.2.5.5 has very demanding requirement for reactive current injection during fault and active power recovering post fault in the AAS. The high reactive current injection has the potential to cause instability due to hunting or retriggering of the LVRT control logic especially during shallow fault and furthermore could cause issues with the generating unit's ability to detect fault clearance locally by sensing the restoration of voltages.[48]

Further, projects which have fulfilled AAS with grid following type IBRs has difficult in operating stably under reduced or low SCR conditions. This is because when voltage has been cleared by protection e.g., removing one of faulted transmission line, the active power increases rapidly and flow on larger impedance of the circuit which will drive voltage down again and cause a further voltage dip. The large amount of reactive current injection will drive IBRs voltage high and thus out of fault again. The retriggering FRT has the potential to cause instability as well.

The exiting generators fulfilling S5.2.5.5 have potential to cause instability following contingency. Therefore, it is good to investigate the voltage waveforms for these generators to determine whether they are the troublemakers.

Fourthly, based on previously experience with Full Assessments, there were many occasions that the tunings have been required for SVCs or system level coordination of voltage and reactive power control in a large area.

It is recommended that the above-mentioned three possible instability contributors (or more) should be considered with Full Assessments to determine root cause of voltage waveform stability and reduce the demanded system strength level for the given SSN. I understand tremendously endeavour is needed to remove these bottlenecks of voltage waveform instability. However, if it is not being addressed carefully at the initial stage of evolving do no harm obligation to system strength framework, they could always be root cause of voltage waveform instability in many Stability Assessments. The resulting voltage waveform instability cannot be remediated by Applicant self-tuning. As a result, there is tendency that the Applicant will need to pay SSR in addition to SSS.

This is contradicted with the aims of evolving do no harm obligation to system strength framework which is aimed for more effective use of SSS and sharing the associated costs more efficiently between consumers and connecting parties

On the other hand, if Full Assessment has been performed where Stability Assessment fails, it has potential to reduce the need of **the efficient level of system strength** for the future connecting IBRs stable operation by improving the existing generators withstand capability of low SCR grid and better system level coordination of voltage & reactive power control strategy / proper tuning of SVCs etc. Together with the enforcement of new **minimum access standards**, less voltage waveform stability is expected to see in the future and less efficient level of system strength is expected to be needed for stably operating of IBRs during steady state and following contingency.

4.5.2. AEMO's assessment

Scope of Stability Assessment

AEMO is required by the Amending Rule to outline the methodology to be used by Connecting NSPs when undertaking Stability Assessments. In the Amending Rule, the Stability Assessment appears to have a different purpose to the Full Assessment, however, to reach the conclusion that a 4.6.6 Connection can operate stably requires, effectively, the same analysis required to undertake a Full Assessment.

[47] Amendments to AEMO instruments for Efficient management of system strength rule pg43.

[48] NATIONAL ELECTRICITY RULE CHANGE PROPOSAL, Reactive current response to disturbances (clause S5.2.5.5), GE International Inc, Gold wind Australia, Siemens Gamesa Renewable Energy and Vestas Australia.

For this reason, the methodology will be similar to that for Full Assessments, however, as this is a new requirement, there will be a need for the methodology to be used in practice before it can be fine-tuned. AEMO proposes to outline the methodologies for each type of assessment separately. Regardless of the type of assessment, it is fundamental power system analysis.

Both Ausgrid and Ergon Energy & Energex question the difference between the Full Assessment and the Stability Assessment. AEMO agrees with Ergon Energy & Energex that the same power system analysis is required for both. This is also implicit in the AEMC Final Determination[49].

AEMO considers that a simple way of differentiating between the Stability Assessment and a Full Assessment is this: a Stability Assessment requires a Connecting NSP to validate a 4.6.6 Connection's stability, whereas a Full Assessment requires not just validation of the stability of a 4.6.6 Connection, but also an assessment of the reduction in AFL at the 4.6.6 Connection Point and whether the proposed SSRS/SSCW can remediate it.

To verify the stability of the 4.6.6 Connection, Connecting NSPs are expected to evaluate not only the performance of the 4.6.6 Connection but also plant representing the SSS for which the Applicant will be paying, to ensure that it addresses the general system strength impact of the 4.6.6 Connection, as well as undertake power system analysis across their network.

AEMO agrees with AusNet's observations in the "Appendix on the Stability Assessment" part of its submission concerning the practicalities and matters to be considered when determining the extent of the network to be analysed during PSCAD™/EMTDC™ modelling.

AEMO agrees with APD and ElectraNet's suggestion to include switching events and different operating conditions in the studies.

AEMO agrees with SGRE's submission that stability is impacted by the performance and characteristics that could occur during a disturbance as well as post-contingent periods.

NSP undertaking Stability Assessment

AEMO considers that the Amending Rule requires the Connecting NSP to undertake Stability Assessments of all 4.6.6 Connections proposed to be connected to its network.

There is much discussion in the AEMC Final Determination about the need for SSSPs to undertake "wide-area EMT modelling" to verify the stability of 4.6.6 Connections, however, both NER 4.6.6(a)(8) and 5.3.4B(a2)(4) allocate this responsibility to the NSP which, in context, refers to the Connecting NSP. If the AEMC had intended for this obligation to be imposed on an SSSP, those provisions would have been directed to the SSSP as many others in the Amending Rule are.

AEMO also notes that TNSPs advised the AEMC during Amending Rule consultation that they would undertake wide-area EMT modelling to verify the stability of connecting plant during the connection process in any event[50].

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[49] See the discussion on voltage waveform stability on page 172.

[50] See page 171 of the AEMC Final Determination.

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Nevertheless, issues associated with plant providing SSS needs to be resolved with the relevant SSSP as part of their joint planning activities with the Connecting NSP.

Timing

The only submission on timing was from SGRE, who asked: If the Stability Assessment happens before performance standard negotiation, what happens if/when control or plant changes are necessitated by the negotiation?

AEMO's response is that the Stability Assessment will need to be rerun where the changes are considered sufficiently material.

Committed

The term 'Committed' will apply to both Full Assessments and Stability Assessments, which will mean that other plant considered must have undergone their own assessments to be considered to be Committed and included in a Stability Assessment. This does not preclude a Connecting NSP from assessing two or more 4.6.6 Connections in a batch.

Prior to batching, the Connecting NSP should perform a conventional stability and constraint assessment, utilising PSS®E RMS software to ensure that appropriate modelling (operating point) conditions are set prior to undertaking the Stability Assessment studies in PSCAD™/EMTDC™.

Further Studies

Submissions raise questions and highlight some misunderstandings about the requirements Connecting NSPs must meet when evaluating a 4.6.6 Connection. Some also made recommendations about what should be within the scope of a Stability Assessment.

AEMO's responses to specific issues raised in submissions are as follows:

- APD suggests the use and application of minor voltage changes to reveal control system interactions. AEMO proposes detailed requirements when undertaking a Stability Assessment, including the base level of matters that Connecting NSPs should consider. Listed among these are different operating conditions and switching studies.
- CitiPower & Powercor and Ergon Energy & Energex raise valid points. The definition of general system strength impact is clear and precise as to the events a Connecting NSP should be evaluating. The SSIAG does not provide a methodology for assessing proposed access standards, other than for the SCR access standard (NER S5.2.5.15) as required by the Amending Rule. All other relevant studies will still be detailed in the Access Standard Assessment Guide[51]. AEMO encourages those who have suggestions regarding the assessment of access standards to contribute these in AEMO's consultation of access standards review.
- AEMO agrees with Powerlink Queensland that "system strength cannot be separated from the fault ride through response and only considered for post fault control interactions."

[51] See https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/participate-in-the-market/network-connections/transmission-and-distribution-in-the-nem/stage-3-application.

AEMO, however, cannot ignore the Amending Rule, which explicitly splits system strength into fault current characteristics required for protection purposes versus those required for stable voltage waveform.

Free-Rider Problem

AEMO does not consider it appropriate for either the stability or full assessments to take abstract evaluations into the NEM-wide power system where system strength schemes (and those dependant on it) are removed fictitiously for the purpose of evaluating self-remediating Applications. This raises the following concerns:

- Creating of unrealistic technical environment, including evaluation of all proposed access standards, which are assessed in the abstract, namely in the absence of actual power system conditions
- Time, cost and effort required to undertake these abstract assessments for which performance in the actual network is proposed.
- The meaningful outcome of assessments and extrapolation to performance during actual power system conditions.

More broadly, the Amending Rule is expected to address the free-rider issue because every Applicant whose 4.6.6 Connection gives rise to a general system strength impact (comprising both adverse system strength impact and reduction in AFL at the connection point) must either:

1. Remediate the general system strength impact by proposing an SSRS.
2. Pay the SSC which, ultimately, funds the SSS that an SSSP will provide to address the general system strength impact.

Consequences following failure of Stability Assessment

AEMO considers that the Applicant should have options if a 4.6.6 Connection fails to operate stably. Applicants can seek to address the instability by making control system or other changes to the 4.6.6 Connection and, if all else fails, they could suggest an SSRS or request the Connecting NSP to provide SSCW to address the instability.

AusNet posed a series of questions about remediation tuning. AEMO considers that any remediation should be designed to suit the network characteristics, type of plant involved and the magnitude of the problem. Tuning a 4.6.6 Connection's control systems or installing additional equipment within the 4.6.6 Connection are options. If control system tuning is the preferred option, it should be carried out under actual power system conditions, not fictitious SCR levels. Where available, and subject to co-ordination between DNSPs and TNSPs as part of their joint planning, tuning or optimisation of SSS might also be an option. AEMO notes, however, that it could have broader consequences for all parties involved where:

- New plant installed to provide SSS has completed its commissioning.
- Changes might be required to the SSS being provided by existing plant (for example legacy synchronous machine).

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AusNet also asked about 4.6.6 Connections to a sub-transmission or distribution system. AEMO considers that, as SSRS refers to remediation behind the 4.6.6 Connection Point, there needs to be a degree of joint planning and co-ordination between all parties involved if there is also a need for SSCW.

A matter that AEMO has not addressed is the consequences of a 4.6.6 Connection not operating stably due to issues within the Connecting NSP's network and invites submissions on how that might be addressed.

Determining cause of voltage waveform instability

The Connecting NSPs will need to identify the root cause of any voltage waveform instability.

AEMO agrees with comments that:

- The Connecting NSP and the Applicant should collaborate when trying to resolve instability of the 4.6.6 Connection.
- There could be various causes of 4.6.6 Connection instability.

Due to the complex nature of the power system, many components, operating conditions, interactions and instabilities could occur. AEMO is unable to prescribe an exact method for use by Connecting NSPs to assist with their root-cause evaluation. Each situation needs to be evaluated on a case-by-case basis for an appreciation of the problem before the feasibility of solutions can be considered.

A point of clarification

In its submission, APD Engineering refers to the need for an SSRS as part of a Stability Assessment. An Applicant whose 4.6.6 Connection is subject to a Stability Assessment is not required to submit an SSRS, nor is the need for an SSRS within the scope of a Stability Assessment.

An SSRS might be required, however, if at the conclusion of the Stability Assessment, the Connecting NSP concludes that a 4.6.6 Connection cannot operate stably, as discussed above.

4.5.3. AEMO's conclusion

As the Stability Assessment is a new step in the system strength impact assessment process, the draft SSIAG contains a new section describing the process in detail as well as addressing the issues discussed in section 4.5.2.

In section 8.10 of the SSIAG proposes that the Connecting NSP be responsible for addressing any identified instability and AEMO seeks comments from Consulted Persons on this.

4.6. System strength locational factor

4.6.1. Issue summary and submissions

The Amending Rule requires the SSIAG to include the methodology to be used by Connecting NSPs to calculate a system strength locational factor (SSLF), which must be representative of

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the impedance (electrical distance) between the 4.6.6 Connection Point and the applicable SSN and must use AFL as its basis[52].

The SSIAG must also provide guidance about the circumstances in which an SSLF is not reasonably able to be determined or would be manifestly excessive[53].

Elements of SSLF calculation

In the Issues Paper, AEMO proposed to address:

- Network modelling assumptions – The treatment of committed, anticipated and proposed network augmentation projects, as they could affect AFL calculations and, hence, SSLF calculations. AEMO proposed that:
  - Committed or anticipated network augmentations be modelled in their target year.
  - Existing SSS should be modelled in-service. All other services to be modelled out of service.
  - Any proposed SSS should be modelled in the target year.
- Calculation methodology – AEMO proposed that the SSLF should be calculated using the difference between the AFL at the 4.6.6 Connection Point and the SSN, taking into account impedance between the two locations as follows:
  - The SSLF will be the ratio of the additional fault level at the SSN required to restore the AFL at the 4.6.6 Connection Point.
  - Where a 4.6.6 Connection Point is co-located with the SSN, the ratio will be unity.

Several submissions were received on this issue[54].

APD Engineering

> In the Issue Paper, the SSLF is defined as the ratio of the additional fault level at SSN required to restore the AFL level at the 4.6.6 Connection Point. A ratio is between two quantities and one quantity is 'the additional fault level at SSN required to restore the AFL at the 4.6.6 Connection Point'. For clarity, it is proposed that AEMO provide this ratio as an equation clearly identifying the two quantities. Based on our understanding we presume SSLF is defined by the following equation.
>
> $$SSLF = \frac{\text{The additional fault level at SSN required to restore the AFL at the Applicant's connection point}}{\text{The difference between pre and post connection AFL at the Applicant's connection point}}$$
>
> It is also not clear what AEMO mean by 'to restore the AFL'. Does it mean to achieve the same AFL at the connection point pre and post connection of 4.6.6 Connection? For example, if the AFL at a certain connection point pre connection is 100MVA, is the same level expected post connection? Is it fair to assume that the AFL at any 4.6.6 Connection Point prior to its connection will be positive if the minimum fault level requirement at SSNs is met by the SSSP given AEMO only consider the existing IBR for the evaluation of the minimum fault level requirement (page 20 of Issue Paper)? An AFL at a given connection point (prior to the connection of the 4.6.6 Connection) may already be negative if all the nearby committed IBR plants are also considered. Therefore, AEMO is required to specify how the committed IBR plants should be treated in SSLF calculation methodology similar to specifying the inclusion of committed or anticipated network augmentations in the model.

[52] See New clause 4.6.6(a)(1).

[53] See New clause 4.6.6(b)(9) & (10).

[54] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms and terms that are defined in the Glossary.

AusNet

AusNet shares concerns expressed in AEMO's working group that the methodology for determining the SSLF included in the AEMC's final determination is flawed and requires fundamental changes. If left unresolved, purchasing centralised system strength at the closest SSN will nearly always be financially unviable.

…

The AEMC's Efficient management of system strength on the power system final determination included a methodology for determining the SSLF.[55]

The AEMO System Strength Working Group recently discussed a concern that this methodology for determining the SSLF does not appropriately consider the non-linearities of the physical network and the net result is that the SSLF often results in a 'manifestly excessive' value even for connections close to a SSN.

AusNet has considered this issue further and shares this concern. Without fundamental changes to how the SSLF is calculated, purchasing a centralised SSS provided at the closest SSN will nearly always be financially unviable. AusNet notes that this issue is exacerbated in the sub-transmission and distribution system which generally has a much higher impedance than the transmission network.

AusNet is concerned that the methodology for determining the SSLF will disincentivise new connections within the subtransmission and distribution networks. These connections are typically smaller in size to that of transmission connections and may become unviable if forced to consider expensive individual SSRSs. Pushing these connections towards individual SSRSs may also introduce coordination and inter-plant stability challenges. These technical risks were a key issue the Amending Rule was aiming to rectify.

CEC

We also believe it is critical for further work to be undertaken by AEMO before the methodology for setting SSLFs. This methodology must ensure it encourages system strength procurement at an acceptable cost and avoid situations where connection location away from the SSN results in excessive cost. This could result in Applicants electing to self-remediate and therefore reduce the scale and scope efficiencies associated with the system strength frameworks.

We understand this issue has been discussed in AEMO's System Strength Working Group and request further engagement before the proposed amendments to the instruments are finalised. A workshop with relevant stakeholders, including CEC representatives, NSPs and generation / storage developers will assist in the resolution of any issues arising with the development of the SSLF.

Citipower & Powercor

We consider the proposed methodology will result in manifestly excessive SSLF for almost all distribution-connected generators.

For the purposes of providing an example, we have considered a currently connected 19.8 MW generator in our network:

- A 1000 MVA fault level source at the Dederang 220 kV bus will cause a 0.05 MVA fault level increase at that generator connection point
- A 1000 MVA fault level source at the Red Cliffs 220 kV bus will cause a 0.21 MVA fault level increase at that generator connection point
- To increase by 1 MVA at the connection point this will be approximately a 4762 MVA fault level source at Red Cliffs, which is 5 times larger than the minimum fault level requirement at Red Cliffs.

This example links to Q25[56], where it is very important that every node in the transmission network is chosen as a SSN to assist to mitigate this issue.

We consider the SSLF should be calculated on a per generator connection point basis, on the amount at which they cause their AFL to fall below zero.

[55] The SSLF changes the magnitude of the SSC that a connection would face depending on its electrical distance (impedance) from the closest SSN. Page 160 of the AEMC's final determination notes the SSLF would be calculated as the ratio of additional fault level that would need to be added at the nearest SSN to restore the AFL at the connection point to the pre-connection level, and the system strength quality requirement of the connecting party plant.

[56] Response to question about criteria for selection of SSNs in the System Strength Requirements Methodology.

It is not clear whether the SSLF will take into account contingencies, as previously stated a generator connected to Kerang will have much smaller SSLF without contingencies than it would with contingencies.

It is also important to note that even with all transmission nodes defined as SSNs, there is a major flaw in the proposed approach. The transmission network is an interconnected system where most nodes will have fault currents flowing from different lines/directions. If a new 4.6.6 Connection Point is in between two SSNs A and B, it will get fault currents through both nodes A and B. Hence if we only use one of nodes A and B in the calculation of the AFL restoration, it will not accurately reflect the real system.

ElectraNet

ElectraNet request consideration is given to the following:

…

8. The proposed calculation approach for SSLF uses the additional fault level required at the SSN to restore AFL at the 4.6.6 Connection Point as the basis for establishing the locational cost of providing SSS. ElectraNet notes that this approach results in SSLFs that increase rapidly and to unreasonable levels for locations only two to three busses away from the SSN. This is because of the non-linear nature of fault currents in the network. The following table provides SSLFs calculated using the proposed approach for the SA system at Davenport 275 kV and for locations up to four buses away. ElectraNet considers that SSLFs of this size are unreasonable. It is suggested that an alternative approach (for example, assessing network impedance relative to the SSN) to utilising fault current is considered as the basis for SSLF calculations.

Location	SSLF (Applying proposed fault level based approach)
Davenport 275kV (SSN)	1.00
Cultana 275kV (one bus away)	2.65
Cultana 132kV (two busses away)	9.13
Yadnarie 132kV (four busses away)	317

SGRE

SGRE believes that the calculation of SSLF must be revised from that proposed in the Issues Paper. The basis of AFL for calculation of the SSLF is not suitable, simply using synchronous fault level would be much more suitable. AFL is not accurate enough to tie to SSC that impose a significant financial burden on Applicants.

It is also important to note that AEMO has already excluded several grid-following IBR plant from it's System Strength Limits[57] calculation indicating that they have no contribution (either positive or negative) on the system strength outcome for South Australia. This indicates that AEMO is aware that some grid-following plant will not adversely impact system strength, and it would be manifestly unjust to charge all plants.

TasNetworks

Based on the proposed methodology, the SSLF will vary depending on what is assumed as the base fault level at a given connection point. The more fault current that is required to be transferred across the network impedance (between the SSN and 4.6.6 Connection Point), the higher the SSLF will become. This is demonstrated by the example in Figure 1. The issue being highlighted is that SSLF will not be a constant value if fault level requirements increase at a particular connection point over time, for example, if more than one IBR connects at the same location.

This example shows how the SSLF will vary depending on the assumed base level of system strength from which the incremental requirement is being assessed. There are also likely to be complications for the calculation of SSLF if a SSN and 4.6.6 Connection Point are located within a meshed network which allows fault current to be delivered from multiple

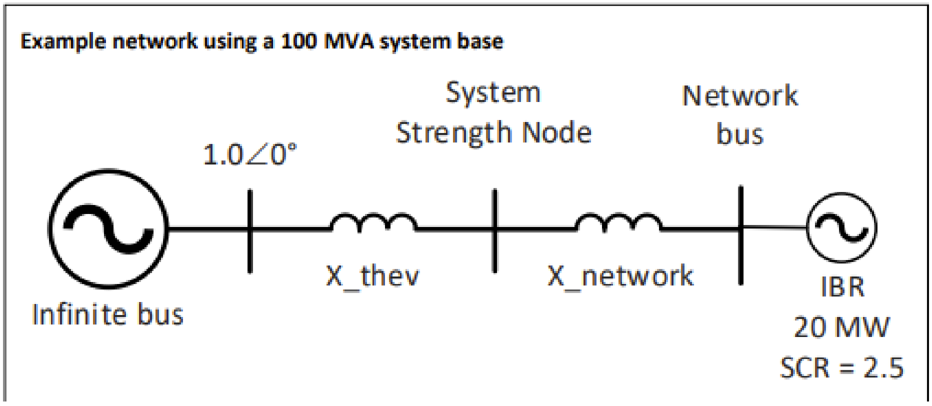
[57] AEMO Transfer Limit Advice – System Strength in SA and Victoria, https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/transfer-limit-advice-system-strength.pdf.

locations (and directions). … the SSLF calculation methodology might be acceptable for a basic REZ design based on a hub and spoke concept where simple radial connections emanate from some central point, however the calculation becomes more complicated if the IBR is located within part of the meshed network. TasNetworks recommends AEMO provide further guidance on what system conditions SSSPs should assume when calculating SSLFs.

Because SSNs must be located on the transmission network, it is likely that most distribution network connections will have high SSLFs due to the impedance of upstream assets. This will encourage Applicants to self-mitigate even if this is not the most efficient option and potentially dilutes the benefits intended by the Amending Rule. For example, it could result in multiple small synchronous condensers being installed throughout distribution networks which is not only inefficient, but could also lead to high fault level issues.

TasNetworks is concerned that there are unintended consequences for future developments in some parts of the network – particularly distribution networks, if there is relatively high impedance between the proposed connection points and the transmission network SSNs. Where possible, the SSIAG must address this unintended consequence of the calculation methodology. A suggestion on how the materiality threshold could help solve this issue is provided in the next section.

Figure 1: Calculating System Strength Locational Factor



Notes:

- X_thev = 0.1 p.u.
- Fault Level at the SSN = 1000 MVA (10 p.u) before new IBR connects to the network.
- X_network = 0.1 p.u. This could represent the impedance of a step down transformer supplying a lower voltage distribution network bus, or a transmission line to a remote point in the network.
- Fault level at the Network bus = 500 MVA (5.0 p.u).
- New 20 MW IBR wanting to connect to the network will have an assessed SSQ of 50 MVA (20 MW x SCR requirement of 2.5).

The proposed methodology for calculating the SSLF is to determine the ratio of additional fault level at the SSN to restore the AFL at the 4.6.6 Connection Point. TasNetworks understand this equates to providing an additional 50 MVA of fault level at the network bus.

To achieve this, the source impedance 'X_thev' (being the effective impedance looking back into the rest of the network) needs to change to increase the SSN fault level to be a calculated value of 12.2 p.u (1222 MVA). This delivers a fault level of 550 MVA at the network bus, thus satisfying the NER criteria.

Using the proposed methodology, the SSLF in this scenario is

(1222 – 1000) MVA / 50 MVA ≈ 4.4.

This results in the SSSP charging the Applicants for providing 222 MVA of fault level at the SSN (if the Applicant didn't choose to self-mitigate).

If a further 50 MVA of fault level was subsequently required at the 4.6.6 Connection Point, the following needs to occur:

- the source impedance needs to reduce to 'X_thev' = 0.0666 p.u.
- fault level at the SSN increases to 1500 MVA.

- fault level at the network bus now equals 600 MVA.

Using the proposed methodology, the SSLF in this second scenario is

(1500 – 1222) MVA / 50 MVA ≈ 5.6.

Tesla

Tesla seeks greater clarity on how AEMO will implement the updated methodology to be used in calculating SSLFs, "which must be representative of the impedance between the connection point and the applicable system strength node, and use available fault level as the basis for the methodology", and how this is intended to align with the criteria for a stable voltage waveform in practice. In other words, more detail on how the new standard also known as the 'efficient' level of system strength will be applied to grid-forming inverters, noting it "can be met by any means, not limited to fault level".

Ideally, AEMO can propose a methodology which also accounts for actual grid impedance and essentially differentiates between "low impedance & low short circuit systems" vs "high impedance & low short circuit systems". In general, Tesla believes the proposed voltage and angle sensitivity indices would be a better indicator compared to SCR.

In addition, AEMO should also establish a protection only minimum short circuit-level guidance so that "controls" (ie Grid forming inverters) and protection short circuit MVA can be segregated. Protection remains an independent issue and industry would benefit from having AEMO treat it separately.

For all of the above reasons, worked examples of a battery system with grid-forming inverter capabilities would be beneficial to help demonstrate and clarify our current understanding that these types of assets should have zero system strength charges applied (as a connecting generator / integrated resource provider), whilst also being viewed to positively contribute to SSR (as a potential supply side asset to support system strength contributions for individual plant and/or SSSPs). We note this is shown in equation form on page 47 of the Issues Paper…:

…

It would benefit industry if AEMO could clearly confirm the above interpretation for battery systems with grid-forming inverters through the next phase of the consultation and/or via any supplementary guidance notes that can be developed to inform project proponents.

Transgrid

We understand that AEMO has proposed an SSLF in section 4.6 [of the Issues Paper] that will be used to determine the SSC. In our view, the calculation may result in skewed outcomes due to the non-linearities of the physical network and therefore lead to inflated charges.

Transgrid has undertaken analysis on the Darlington Point 330 kV SSN based on the proposed SSLF calculation methodology which AEMO has outlined in section 4.6, the results of which are represented in Table 1.1. The analysis concludes that the SSC for connections that are not directly located at a defined SSN will be excessive. The results show greater implications for [distribution] connected generators. This is due to the long electrical distance to a defined SSN. As SSNs can only be defined in the transmission network, most of the IBR connections on the DNSP network will have excessive SSC that will drive those Applicants to remediate their system strength impact locally, which may be financially unviable for some small generators.

Table 1.1

	SSLF	Distance from Darlington Point SSN
Darlington Point 132 kV	2	N/A
Coleambally 132 kV	3	13.3 km
Deniliquin 132 kV	28	166 km
DNSP Gen 1 132 kV	33	116 km
DNSP Gen 2 132 kV	59	163 km

The least cost centralized SSR may have network augmentations at one or multiple locations that differ from the SSNs. Therefore, we suggest that the SSC should reflect the impact based on the electrical distance to the actual remediation locations, not just the SSNs. Furthermore, the remediation work to increase system strength at one SSN may have an impact to other SSNs located in close proximity. This particular factor would need to be considered in the SSLF methodology.

Given the above, we recommend AEMO to undertake further analysis and refine the SSLF methodology in order for it to be workable and fair.

Transgrid broadly supports the SSN selection process outlined in section 3.4. 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 SSC and prevent small to medium sized renewable generators connecting to DNSP networks to be unfairly disadvantages. New SSNs and new SSR locations will also need to be carefully selected and identified to avoid excessive SSC being required for multiple IBRs in the network.

Guidance on when SSLF not required to be calculated

In the Issues Paper, AEMO proposed to provide guidance where SSLF cannot be calculated – AEMO had not identified in the Issues Paper any further examples where the SSLF is not reasonably able to be determined or would be manifestly excessive.

Only one submission was received on this issue[58].

Ergon Energy & Energex

We consider the Applicant to be best placed to determine whether the SSLF is excessive. For example, they can complete the cost-benefit assessment of paying the charge versus bringing their own SSR or improving plant fault level requirements.

4.6.2. AEMO's assessment

The SSLF is a variable used in the calculation of the SSC, but it is defined in the Amending Rule by reference to certain technical variables.

Various issues were raised in submissions, which AEMO will address individually.

Elements of SSLF calculation

NER 4.6.6(b)(9) of the Amending Rule requires AEMO to:

(9) specify a methodology for calculation of the *system strength locational factor* for a *connection point*, which must be representative of the impedance between the *connection point* and the *applicable system strength node* and must use *available fault level* as the basis for the methodology; and

There are three elements used in the methodology that are **mandatory**: impedance, the applicable SSN and the AFL.

For the purposes of the SSLF calculation, synchronous fault levels at the SSN are assumed as the AFL to represent the minimum required fault level that the relevant SSSP must maintain consistent with the system strength requirements.

[58] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms and terms that are defined in the Glossary.

The proposed methodology for the calculation of SSLF in the draft SSIAG considers both synchronous and asynchronous contributions. AEMO is unable to adopt SGRE's suggestion to consider actual transmission capacity when assessing general system strength impact or inertia, because a representation of the power system is based on the inclusion of synchronous and asynchronous fault current sources, and impedance, and does not take into account transmission congestion or inertia.

AEMO recognises that the requirement for the SSLF to be representative of the impedance between the 4.6.6 Connection Point and the applicable SSN can result in SSLFs that make sub-transmission, especially distribution, connected projects financially unviable, but that is what the Amending Rule clearly requires.

Working Group discussions yielded a suggestion that, perhaps, a matrix approach in lieu of using SSNs might be more appropriate, however, AEMO considers this would be in breach of the mandatory requirements for the methodology.

AEMO shares the concerns raised on the restatement of the SSLF calculation in the AEMC Final Determination as[59]:

> The relative electrical distance from the closest system strength node for a newly connecting generator or load. This would be calculated as the ratio of the:
>
> - additional fault level that would need to be added at the nearest system strength node to restore the available fault level (AFL) at the connection point to the pre-connection level, and
> - system strength quantity requirement of the connecting party plant.

Submissions included examples confirming the impractical implementation of the SSLF using this formulation due to the high degree of power system nonlinearities. As a result, AEMO cannot adopt the AEMC's proposed formulation from the AEMC Final Determination. AEMO considered that it must develop an SSIAG methodology that attempts to circumvent the power system's nonlinearities, while being representative of the impedance between the 4.6.6 Connection Point and the applicable SSN and use AFL as the basis for it.

AEMO considers that the identification of the 'applicable SSN' for the purposes of the methodology leaves some room for discretion. To require this to be the nearest SSN without consideration of whether it is within the same network to which an Applicant seeks connection would unduly complicate the connection negotiations. Where a 4.6.6 Connection is to a transmission network, the 'applicable SSN' should be within the same network; where it is to a distribution network, AEMO considers that the 'applicable SSN' should be located within the same region to which the Applicant seeks connection.

The final issue is the use of AFL in the calculation. Submissions were made as to whether it was an appropriate element in the calculation of the SSLF, however, the Amending Rule is clear that the AFL must be used as 'the basis for the methodology'.

APD Engineering questions how committed IBRs should be treated and if it is fair to assume that the AFL at any connection point will be positive if the minimum fault level requirements at the SSN are met. AEMO stresses that the SSLF calculation is for a standalone 4.6.6 Connection where the calculation is impedance-based in isolation of other projects and with

[59] See page 161 of the AEMC Final Determination.

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respect to a single SSN. It is necessary to calculate the SSLF for a standalone 4.6.6 Connection and avoid multiple current source injections, which would render the SSLF to be unreasonably sensitive to generation dispatch scenarios. Nevertheless, if a change in network impedance (for example, a new transmission line) is likely to be available within an appropriate timeframe, the SSLF calculation would reflect the change in circumstances.

Decimal places

The Working Group sought clarification on how many decimal places should the calculation be limited to and AEMO considers that a minimum of three and a maximum of four is adequate.

Guidance on when SSLF not required to be calculated

There was a suggestion that it be left to the Applicants to determine if an SSLF was excessive.

NER 4.6.6(b)(10) of the Amending Rule requires AEMO to:

> (10) provide guidance about the circumstances in which a *system strength locational factor* is not reasonably able to be determined or would be manifestly excessive.
>
> Example
>
> Where the *system strength locational factor* tends to infinity, or where it would result in a *system strength charge* that could not reasonably be expected to be paid in preference to *system strength connection works* or a *system strength remediation scheme*.

Transgrid suggests that well-defined SSNs will avoid an excessive system strength charge (SSC) and prevent Applicants seeking connection to distribution networks from being unfairly disadvantaged. AEMO infers from this that more SSNs would need to be declared, however, AEMO considers that fewer SSNs would be more practical and align better with the Amending Rule. In any event, the modelling and analysis methodologies AEMO will use to determine SSNs to comply with the Amending Rule is being addressed separately through the consultation on the amendments to the System Strength Requirements Methodology[60].

For the purposes of this consultation, the Amending Rule only requires AEMO to provide 'guidance' on the circumstances in which an SSLF is not reasonably able to be determined or would be manifestly excessive.

After exploring the issue further, AEMO cannot identify any further suggestions other than what is already in the example expressed in the Amending Rule.

Point of Clarification – SSLF not relevant to location of SSR

AEMO wishes to emphasise that the SSLF is a factor used in the calculation of the SSC an Applicant would have to pay if the Applicant did not provide its own SSR; it does not restrict the location of any proposed SSR.

Equally, the SSLF calculation is not a limitation on the location or size of plant that will ultimately provide SSS.

[60] See https://aemo.com.au/consultations/current-and-closed-consultations/ssrmiag.

4.6.3. AEMO's conclusion

AEMO has proposed a methodology that it considers meets the Amending Rule for calculating the SSLF in a new section of the draft SSIAG.

4.7. Available Fault Level

4.7.1. Issue summary and submissions

The Amending Rule requires the SSIAG to include a definition of AFL, including for the purposes of forecasting AFLs at SSNs under NER 5.20C.3(f)(3) and for the calculation of the SSLF for a 4.6.6 Connection Point[61].

Appropriateness of AFL as a measure of system strength

Although not raised by AEMO in the Issues Paper, several submissions were received on this issue[62].

CEC

> Further work should be undertaken to assess the implications of using AFL as a metric for assessing the efficient level of system strength. While we appreciate this is a relatively well understood metric, there is a risk that it is overly focussed on the capabilities and characteristics of synchronous machines. The CEC appreciates that the framework acts as a guideline to how AEMO will undertake its analysis. However, care must be taken to ensure that any use of AFL in AEMO's minimum fault level planning processes does not translate into restrictions on how NSPs model and then deliver on their requirements as SSSPs for the efficient level. Our concern is that a reliance on AFL metrics in this case could reduce the use of non-synchronous sources of system strength, given it is (historically, at least) been a metric based around the provision of synchronous fault current. We welcome further advice from AEMO as to how this outcome could be avoided.

Citipower & Powercor

> Using AFL to calculate SSLF is a flaw approach due to the non-linear characteristic of fault level and impedance. For two projects connecting to the same node, if their sizes are different, they may have different SSLF. For example, one is 100 MW and the other one is 200 MW, both with a MSCR of 3, it means one project needs 300 MVA AFL and the other needs 600 MVA AFL at the connection point. However, the additional fault levels required at the nearest SSN are not proportional, which means different SSLFs.

SGRE

> … AFL is always an indicative number and should never be used to calculate critical criteria with significant financial impacts like the SSLF. The industry is at a stage where a separation between network strength and synchronous fault level is required due to advancing technology, and although SGRE commends AEMO for attempting to address this it is clear they have been hamstrung by the required use of the AFL in the Amending Rule.

TasNetworks

> AFL is of limited value unless all IBR connected to the network is assessed in parallel, taking into account the network impedances between them. The method described in the Issues Paper appears to only consider the SCR requirements of plant at the one particular bus being studied.
>
> As part of preparations to implement the efficient management of system strength rule change with TasNetworks, we have already defined our own methodology for calculating AFL based on previous work published by the Council on

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61 See New clause 4.6.6(a)(2).

62 Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms and terms that are defined in the Glossary.

Large Electric Systems (CIGRE). TasNetworks looks forward to sharing our work with AEMO and other members of the System Strength Working Group and looks forward to discussing how our approach can inform the SSIAG.

The following submissions responding to AEMO's proposed changes to the System Strength Requirements Methodology are relevant to this issue[63]:

Energy Queensland

…Our experience with the AFL methodology as part of the Preliminary Assessment process suggests this method is a poor indicator of system strength gaps. The Preliminary Assessment has often indicated a negative AFL but, once the projects have reached the Full Assessment stage with EMT assessment, there has been no evidence of system strength shortfalls.

SGRE

AFL 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 Amending Rule.

AFL reduction formula for 4.6.6 Connections

In the Issues Paper, AEMO proposed to amend the definition of AFL in the SSIAG by using a formula, which incorporates grid-forming and grid-following generating units and relevant loads.

Several submissions were received on this issue[64].

APD Engineering

For the AFL equation in Section 4.7.3, APD believe that it is reasonable to assign k = 0 for grid forming IBR when not used for SSS given that it does not require a certain synchronous fault level to operate stably. However, assigning k = -1 when grid forming IBR are used for SSS is not entirely accurate in APD's opinion due to the fact that grid forming inverters may not necessarily be required to specify a 'SCR_withstand', as they do not require a withstanding synchronous fault level to operate stably. Therefore, grid forming IBR when used for SSS should be considered under SSG and should be excluded from the RHS of the equation. AEMO has also introduced a scaling factor 'alpha'. There are no details on the rationale for this scaling factor or how it will be determined. AEMO is required to include further details in SSIAG on how this factor is determined.

In the current SSIAG, Section A.2.2 provides details of how an AFL calculation is practically performed using standard fault level calculations in PSS®E. It is not clear from the Issue Paper whether AEMO is planning to retain the same approach for AFL calculation in the new SSIAG. It is suggested that AEMO provide details of practical implementation of the AFL equation in PSS®E using a wide area network similar to the current SSIAG.

As highlighted in our response to Question (40)[65], it is ambiguous how AEMO is planning to treat the committed IBR plants in the AFL calculations. APD are of the view that committed IBR plants should be considered in AFL calculations together with the SSS adjustments by SSSP to accommodate them. Therefore, AEMO is required to specify how the committed IBR plants should be treated in AFL calculation methodology.

Ergon Energy & Energex

We suggest the methodology should look at the worst case post contingency network configuration when determining the AFL.

Marinus Link

[63] Available at https://aemo.com.au/consultations/current-and-closed-consultations/ssrmiag.

[64] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms and terms that are defined in the Glossary.

[65] The question is about other issues to be taken into account in the calculation of SSLF that AEMO ought to take into account.

> The AFL definition proposed in the [Issues] Paper only takes into account the impact of a single IBR when in fact it should be the sum of the impacts of all nearby IBR subtracted from the SSG. Further definition of the scaling or reduction coefficient α is needed to understand the intent of such a factor. The proposed methodology reduces the impact of all IBR to a single bus which is appropriate for the purpose of demonstrating the concept of AFL however for it to be used in the wider network, the methodology in the current SSIAG and in section 3.3.2 of this consultation with minor adjustments to take grid forming converters into account would be more appropriate.

SGRE

> Both system normal and N-1 pre-fault conditions should be considered.
>
> …
>
> The Issues Paper presents little insight into the co-efficient α in the proposed AFL calculation. However, this co-efficient can have a significant impact on the AFL outcome, without a rigorous description SGRE cannot fully infer the method being proposed by AEMO.
>
> The AFL calculation also appears to consider that a grid forming IBR used for SSS increases system strength in direct proportion to its minimum SCR withstand capability. This leads to a perverse outcome. SGRE would encourage AEMO to consider how grid-forming IBR providing SSS are considered in the AFL calculation.
>
> … the technology co-efficient in the AFL calculation is too simplistic and restrictive. It is not reasonable to expect zero impact (zero coefficient) on AFL with grid forming plant. As these plants are developed further it is likely that there will be significant differences in performance and capability between implementations and these must be considered.

4.7.2. AEMO's assessment

The term "available fault level" is new to the NER. It is defined as having the meaning given to it by AEMO in the SSIAG and is used four times in the Amending Rule:

- In NER 4.6.6(a)(2), when describing the contents of the SSIAG, which include a definition and guidance on the calculation of AFLs at SSNs for the purpose of forecasts under NER 5.20C.3(f)(3) and for the calculation of the SSLF for a 4.6.6 Connection.
- In NER 4.6.6(b)(9), when requiring AEMO to specify a methodology for the calculation of the SSLF for a 4.6.6 Connection, which must be representative of the impedance between the 4.6.6 Connection Point and the applicable SSN and must use the AFL as the basis for the methodology.
- In NER 5.20C.3(f)(3), when describing the contents of a Transmission Annual Planning Report, which include an SSSP's forecast of the AFL for each SSN over the period for which AEMO has determined system strength requirements, where applicable determined in a manner consistent with the methodology in SSIAG.
- In the definition of general system strength impact, where the reduction in AFL at a 4.6.6 Connection Point is specified as one of its components.

The AEMC Final Determination does not provide further detail on the use of the AFL, other than to confirm that it is one of two measures by which one can determine whether there is a need for SSR as a result of a 4.6.6 Connection and that both the adverse system strength impact and reduction in AFL need to be addressed by any SSR[66]:

> Under the draft rule the [Applicant] choosing to remediate would need to implement a [SSRS] or fund the [Connecting] NSP to undertake [SSCW] to address the general system strength impact. That is, the [Applicant] would need to restore the [AFL] at the [4.6.6 Connection Point] and address any residual adverse system strength impact. The Commission considered that in practice, it is likely that a [SSRS] or [SSCW] that are sufficient to restore the [AFL] would also

[66] See pages 168-169.

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> provide sufficient system strength to maintain power system security, but a system strength impact assessment would be required to confirm this.
>
> Requiring the IBR plant to address the general system strength impact, by restoring the [AFL] at the [4.6.6 Connection Point] to the pre-connection level and addressing its adverse system strength impact, means that its connection would not bring forward costs of meeting system strength needs for the [Connecting] NSP or future connecting IBR plant. That is, all connecting IBR plant would be required to address its full impact on system strength, which avoids some [Applicants] free-riding on existing system strength in the network.

Appropriateness of AFL as a measure of system strength

AEMO considers that submissions on the appropriateness or implications of the use of AFL as a measure of system strength raise an issue that AEMO cannot address as it has been clearly prescribed in the Amending Rule as a component of various elements used to quantity system strength.

Its appropriateness as a measure is something that practical experience will illuminate and could, subject to further submissions, be included in a future rule change proposal.

In the draft SSIAG, AFL has different applications and assumptions:

- For the calculation of SSLF, it is based on the equivalent source representation of the SSN and avoids the highly nonlinear nature of the power system that would otherwise distort its calculation.
- For the projection of AFLs at SSNs for planning purposes, the methodology takes into account both the synchronous fault levels and asynchronous fault level “consumption” required by IBR and the resulting quantity is the difference between synchronous fault levels and cumulative levels (synchronous plus asynchronous fault level reduction). The forecast AFLs at SSNs is only used as a proxy and can be negative in some parts of the NEM.

For the purposes of assessing whether a 4.6.6 Connection will give rise to a general system strength impact, a reduction in AFL is determined at the 4.6.6 Connection Point, not at some other, remote point in the power system.

AFL reduction formula for 4.6.6 Connections

The AFL will be used only as a proxy to assess the impact of 4.6.6 Connections that are comprised of IBR. Importantly, it does not indicate the actual fault current of the IBR.

The AEMC Final Determination states that the reduction in AFL is “equivalent” to the SSQ, which would be determined from the SCR performance standard and the rating of the IBR plant[67]. The SSQ for a 4.6.6 Connection Point is defined in the Amending Rule as the product of:

(1) the SCR; and

(2) the rated active power, rated power transfer capability or maximum demand of the 4.6.6 Connection,

[67] See page 167.

each as agreed and recorded in the relevant performance standards for the 4.6.6 Connection[68].

The SCR is defined in the Amending Rule by reference to the Synchronous Three Phase Fault Level at the 4.6.6 Connection Point.

In light of the issues raised in the submissions AEMO proposes to equate the definition of SSQ with the reduction in AFL at the 4.6.6 Connection Point, which is consistent with the AEMC Final Determination and CIGRE Technical Brochure TB 671 entitled “Connection of Wind Farms to Weak AC Networks”.

This approach will result in very high AFL reduction quantities that could be very difficult, or impractical, for an Applicant to remediate. This will affect all asynchronous plant, including grid-forming technology. Therefore, AEMO proposes that the calculation takes into account minimum factors, such as power transfer and voltage stability limitations, equipment ratings on the Connecting NSP’s network, and load and generation diversity when proposing the adequacy of the proposed SSRS in addressing the reduction in AFL element of the definition of general system strength impact.

Calculation of AFL for forecasting

There were no submissions on this issue.

AEMO has proposed a methodology for the calculation of AFLs at SSNs for the purpose of forecasts under NER 5.20C.3(f)(3).

4.7.3. AEMO’s conclusion

The draft SSIAG will:

- Define AFL as a proxy measurement for the reduction in AFL.
- Specify a formula to calculate the reduction in AFL at a 4.6.6 Connection Point based on CIGRE Technical Brochure TB 671.
- Specify a methodology for calculating AFLs at SSNs for the purpose of forecasts under NER 5.20C.3(f)(3).
- Provide examples of how to calculate the reduction in AFL at a 4.6.6 Connection Point and at SSNs for the purpose of AFL forecasts.

4.8. System strength remediation

4.8.1. Issue summary and submissions

The current SSIAG includes guidance on options for system strength connection works (SSCW) and system strength remediation schemes (SSRS), which Connecting NSPs must consider as part of the Full Assessment[69].

[68] See New clause 6A.23.5(j).

[69] See NER 4.6.6(b)(8).

AEMO proposes to update the options to ensure that they are consistent with the Amending Rule. In the Issues Paper, AEMO proposed two significant changes:

- Removal of any doubt that SSCW and SSRS should fully remediate the general system strength impact found at the conclusion of the Full Assessment on the assumption that there are no SSS available to address that impact.
- Removal of inter-trip schemes and dispatch constraint equations.

There were two submissions on SSR[70].

APD Engineering

> 2. Inter-trip schemes and dispatch constraints cannot be applied to address a reduction in AFL.
>
> APD consider use of these schemes should be assessed on merit, cost and risk basis. An intertrip may be acceptable for some projects where an alternate may not be feasible due to technical or financial constraints. A rule against these options may not benefit the overall power system or its customers, as it may result in the network receiving less benefits from smaller generating systems that may not be viable if other options are required.

Tesla

> **Maintaining synchronism of distributed energy resources (DER)**
>
> Tesla is keen to understand AEMO's thinking on this issue and would welcome a follow up workshop to discuss. 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.
>
> **Related barriers in the Rules**
>
> Beyond the specific system strength instruments, Tesla observes that an unintended consequence of the NER (notably the access standards in Schedule 5.2 for asynchronous generation) is that a project with grid-forming inverter technology is assessed against access standards that appear more suited to asynchronous generating systems that are of a grid-following nature, which can trade-off some of the benefits offered by advanced inverters. Ideally the NER would promote these grid-forming technologies and encourage targeted system strength capabilities that actively support grid stability with high levels of IBR, delivering more beneficial outcomes for the power system overall. **There would be significant benefit if Advanced Inverters had a clear pathway to connect with access standards appropriate for allowing the full benefits of virtual synchronous machines to be realised (for example a pathway similar to that for synchronous generation or a hybrid of the asynchronous and synchronous generation pathways). Tesla would welcome a technical workshop on the subject to further unpack these issues and associated trade-offs**.
>
> …
>
> **Overview of barriers to Grid-forming Inverters**

[70] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms and terms that are defined in the Glossary.

> Updating and developing fit for purpose instruments to enable system strength provision will be critical to accelerate demonstration of advanced inverter capabilities, overcome existing barriers, and improve industry understanding to accelerate deployments. Currently, both project developers and SSSPs are hesitant to explore grid-forming inverters as a potential remediation solution and supplier of system strength, given the additional complexity to connect (i.e. higher costs, longer time) and uncertain treatment under the system strength framework (both existing and proposed).
>
> In particular, if connecting in a 'weak' part of the grid, projects are likely to consider traditional synchronous solutions over grid-forming inverters (despite commercial benefits of battery systems) purely to mitigate the additional uncertainty of connection risks or assessment processes.
>
> **Storage proponents need more confidence in a streamlined connection process for advanced inverter capabilities** (given the connection process is already the key bottleneck for projects), **and industry (including SSSPs) need greater upfront clarity on how the new system strength assessment framework will apply** (i.e. projects cannot face additional delays and/or costs). We believe AEMO is well placed to work with industry to achieve these objectives.

4.8.2. AEMO's assessment

The definitions of both SSRW and SSCW in the Amending Rule refer to the need to "remedy or avoid a general system strength impact" arising from a 4.6.6 Connection. Hence, for them to be acceptable in the first instance, they must be capable of addressing both elements of a general system strength impact, namely, the adverse system strength impact and reduction in AFL at the 4.6.6 Connection Point.

SSRS

The need to delete post-contingency control schemes and dispatch constraint equations was referred to in the Issues Paper; AEMO considers this to be appropriate as they do not address the reduction in AFL at a 4.6.6 Connection Point. This does not preclude their use where they are agreed in the performance standards, or for operational reasons to manage network constraints.

The current SSIAG does not make clear that SSRS should be situated behind the 4.6.6 Connection Point. Section 6.2(c) does not meet this requirement and should be deleted.

AEMO also considers section 6.2(b) of the current SSIAG should be deleted because it has proven ineffective, generally resulting in a cycle of proposals and counter-proposals as Applicants try to ascertain appropriate control system settings by trial and error. This adds time and cost to the connection process without a corresponding benefit.

On the other hand, AEMO considers that section 6.1(h) of the current SSIAG should be included as a type of SSRS only and accepts Tesla's submission that there are currently barriers to the inclusion of grid-forming unless the relevant plant's Withstand SCR capability is acceptable.

As part of this consultation, AEMO has considered the impact of grid-forming technologies and, more specifically, has tested different grid-forming BESS. AEMO's limited work (in co-operation with different OEMs) evaluating the ability of utility scale grid-forming BESS to assist system strength, in particular, voltage waveform stability, is promising[71], however, other impacts identified in AEMO's other works include:

[71] P.F. Mayer. M.Gordon. WC Huang, C.Hardt, "Improving grid strength in a wide-area transmission system with grid forming inverters", IET Generation, Transmission & Distribution, 3 May 2022 (https://doi.org/10.1049/gtd2.12498)

- Not all technologies show consistent benefits to system strength.
- The scope and functional composition of grid-forming capabilities are different between OEMs and the underlying converter technologies.
- Some technologies have been found to:
  - Exhibit oscillatory instabilities, which can be remedied through tuning.
  - Deploy grid-following or switching between grid-forming and grid-following during, and following, contingencies.
  - Can lose control on application of critical contingencies driven by application of PLL or grid following control topologies (could be an OEM-specific feature).
  - Have different degree of voltage stabilisation capabilities in different operating modes. It is currently unknown the extent of operation flexibility can the grid forming devices be deployed to address system strength issues.

Hence, AEMO needs time to consider the use and application of grid-forming devices, including their control systems for SSR purposes, and operation while in full charging and discharging mode. The use and application of grid-forming wind or solar plant to support system strength (as a form of SSRS), or voltage waveform stability, is unknown due to a lack of information and will have to be demonstrated throughout the connection process. Consulted Persons are welcome to provide further feedback on this matter through consultations on (update of) Power System Model Guideline, connection reform initiatives and access standards review.

It is possible that grid-forming BESS might only exhibit an adverse system strength impact and will have to meet the SCR minimum access standard, as they are considered to be “asynchronous generating units”.

SSCW

The corollary to SSRS is SSCW, which must be situated within a network.

This necessitates an amendment to section 6.1(c) and removal of section 6.1(h) of the current SSIAG.

4.8.3. AEMO’s conclusion

SSRS

AEMO proposes to amend the existing list of potentially acceptable SSRSs by deleting the following:

- Contracting with Generators with synchronous generating systems for the provision of SSS.
- Post-contingency control schemes.
- Dispatch constraint equations.

AEMO will add the use of grid-forming technology as possible SSRS by moving it from the existing list of acceptable SSCW.

The new list can be found in section 5.1.2 of the draft SSIAG.

SSCW

AEMO proposes to amend the existing list of potentially acceptable SSCW by deleting the use of grid-forming technology and amending the use of lower impedance transformers so that they must be situated within a network.

The new list can be found in section 5.2.2 of the draft SSIAG.

4.9. Short Circuit Ratio

4.9.1. Issue summary and submissions

The Amending Rule introduces SCR minimum access standards for 4.6.6 Connections covering asynchronous generating units[72], inverter-based loads[73], and market network service facilities[74], although there is provision for negotiated access standards, as well.

Effectively, all 4.6.6 Connections that are subject to the new SCR access standard need to demonstrate that their plant has capability that is sufficient to operate stably and remain connected at an SCR of 3.0, assessed in accordance with methodology prescribed in the SSIAG.

SCR vs Withstand SCR

Although not raised as an issue in the Issues Paper, there were several submissions on this issue[75].

CEC

> We also note and appreciate AEMO's pragmatic approach in terms of demonstrating compliance with the new system strength access standard, reflecting actual SCR at the 4.6.6 Connection Point. It would be preferable to codify this kind of assessment, so that all AEMO connection engineers can make these assessments with equal confidence.

Citipower & Powercor

> Our preferred methodology is that of A.2.2 of the existing SSIAG and 6.6.2 of TB 671. This methodology uses classical fault assumptions (voltage = 1.0 pu) using the Automatic Sequence Fault Calculation (ASCC) method and all previous Preliminary Assessments by NSPs should have been performed following these existing guidelines.
>
> AS 3851 which is commonly used over IEC60909, or the usage of IEC60909 (c=0.9) or other methods are not as reproducible over different model snapshots.

Keith Frearson

[72] See New clause S5.2.5.15.

[73] See New clause S5.3.11.

[74] See New clause S5.3a.7.

[75] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms and terms that are defined in the Glossary.

> The Issues Paper seems to be considering SCR as a criterion. However, SCR assessment needs to consider "nearby" IBR to be consistent with CIGRE TB 671. The only problem with this, as a concept, is that the definition of "nearby" is not available.

TasNetworks

> It is reasonable to have the Applicant demonstrate (through simulation) that the plant controls are capable of being configured to operate at an SCR of three. TasNetworks has requested similar demonstrations of capability for an SCR of two using simplified network representations and our intended negotiated access standard for the Tasmanian region going forward will continue to be two. Inevitably there are performance trade-offs at lower system strength operating conditions, so some pragmatism is ultimately required when comparing performance.

Reassessment of performance standards

In the Issues Paper, AEMO raised the ability of 4.6.6 Connections to continue to meet this standard in the face of rapidly changing network conditions.

Only a few submissions were received on this issue[76].

APD Engineering

> It is importance to always maintain an acceptable level of system strength at different nodes of the grid such that the network is always operating securely and reliably. When a plant is proposed to connect to a node of the network, it is tuned to comply with the NER requirements assuming the minimum SCR at the 4.6.6 Connection Point at that point of time. A GPS is then proposed and after going through a rigorous process is accepted by the NSP/AEMO and becomes the GPS of the generator.
>
> Tuning of the plant is usually a time-consuming and effort-intensive task. Once a GPS is approved and a generating system is constructed, any process which would invalidate the existing GPS, or would trigger the need for another GPS assessment, should not result in ceasing of the plant generation or any loss of revenue. Accordingly, a sensible process for GPS assessment would provide the generator with a gap period in which it would have the opportunity to re-assess its GPS and potentially re-adjust its parameters such that it can comply with the NER under the minimum SCR of 3.0. In order to provide the generator with such gap period, proper planning practices should be adopted to predict the system strength level ahead of it actually reaching critical levels. Under such scenario It would make sense to trigger the change process once the SCR at a certain point reaches levels or is predicted to reach levels below 6.
>
> …
>
> A change in the system strength over time is inevitable at different network nodes. At the early stages of the connection application, a generating system is being tuned to meet a certain access standard at the connection point and this is reflected in the GPS. Usually, it is much easier to achieve a higher access standard when the generator is connecting to a node with a high SCR. This GPS usually becomes the baseline for any changes that might occur in the plant parameters/electrical Balance of Plant and any access standard which demonstrate a lower performance would not be accepted by AEMO/NSP. An example of this is the 5.3.9 process, where the existing GPS is usually taken as the baseline and an access standard lower than the existing GPS usually won't be acceptable.
>
> If a change process is to trigger and the generating system is to be re-tuned/re-adjusted to comply with the NER under new SCR conditions, it would be fair to provide the Generator with the opportunity to go below the levels that are already proposed in their existing GPS. This is because some certain high-performance standards that can be achieved in high SCR conditions might not be achievable or could result in poor performance of the plant/grid under low SCR conditions. An example for this is the Iq injection requirement where a k-factor of 4 could result in an acceptable performance under high SCR conditions, however, the same k-factor could result in oscillations, retriggering of the inverters and potentially voltage overloads under a low SCR condition.
>
> Another aspect which seems important is to make sure that a gap period is provided to the affected Generators, as going through the change process could be time-consuming and effort-intensive.

Citipower & Powercor

[76] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms and terms that are defined in the Glossary.

[Releasable User Guide] and [generating system data sheets] should state an approximate SCR for which current settings are appropriate to meet performance (below which settings changes may be necessary).

When the SSSP/AEMO are assessing the minimum fault level requirements each year, the SCR for each generator can be checked to see whether it has fallen below this threshold (at which point a S5.2.2 or 5.3.9 should be initiated by the generator).

…

Generating Systems should be required as part of their on-going compliance to submit to Connecting NSP/AEMO if there are any probable "system strength" issues (after contingencies) found that could require a settings change under S5.2.5.15.

Further Generating Systems should be required to regularly estimate the system strength (using a Q vs V relationship) and if this changes significantly it should be reported to Connecting NSP/AEMO for them to assess and ensure compliance. This could be in the form of a FRT performance report that is provided to the Connecting NSP/AEMO on a regular basis as an annual report (or every 3 years).

Ergon Energy & Energex

… a GPS reassessment should occur whenever the fault level drops below the level at which the plant was designed and tuned to operate. This should also be triggered if a Full Assessment or Stability Assessment identifies an issue with plant tuning.

Powerlink Queensland

While planning for the efficient system strength, if the SSSP believes that a plant that was originally tuned for higher SCR could be retuned at a lower SCR and that would minimise the amount of system strength needed for the future IBR plants, the SSSP should be able to require the plant to change its settings under S5.2.2.

SGRE

While in general SGRE agrees with AEMOs proposed approach, it is unclear how general system strength impacts will be calculated and what charges/self remediation will be required if this standard is not assessed during connection.

TasNetworks

TasNetworks' approach has been to require plant to operate against the lowest practical fault level to which it could be exposed and still be expected to operate satisfactorily. This can result in a connection point SCR of greater than three. It would be our intent to include appropriate wording within future performance standards that allows for future alteration of plant controls to enable operation at lower levels of system strength if required in the future. This would be managed under the existing provisions of Schedule 5.2.2 (Generators), Schedule 5.3.4 (Customers), and Schedule 5.3a.2 (Market Network Service Providers).

A potential trigger for such changes could be where an SSSP determines that a change in plant control settings is the preferred credible option as part of undertaking Regulatory Investment Test for Transmission (RIT-T) studies. Existing RIT-T principles must be followed when investigating future options to meet the System Strength Standard set by AEMO. Having a formal mechanism (via the NER and performance standards) to legitimately request changes to existing plant should make such processes somewhat easier. TasNetworks proposes that as part of any such request, a GPS reassessment be undertaken to understand the detailed implications of making changes to the plant controls.

Other Issues

SGRE

SGRE noted that AEMO has modified the wording of S 5.2.5.15 (d) in a way that the performance of the plant is assessed and negotiated at its lowest claimed SCR capability. This will result in many parallel studies and tuning for different SCR levels (Min and operational) during the connection stage.

AEMO and Connecting NSPs should provide some dispensation to Applicants who elect to pay the SSC on certain performance clauses, in particular NER S5.2.5.1 and S5.2.5.5. It is expected that if the SSSP provides system strength using a SynCon then the device installed by the SSSP will provide significant reactive power capability and Iq injection, reducing the performance required by nearby plant to support the network. This will also incentivize Applicants to pay the SSC rather than self remediating.

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4.9.2. AEMO's assessment

SCR vs Withstand SCR

When AEMO commenced its review of submissions, it became clear that it would be necessary to distinguish between SCR as defined in the Amending Rule and "Withstand SCR"[77]. While both are measured at a 4.6.6 Connection Point, they mean different things:

- The SCR refers to the Synchronous Three Phase Fault Level provided by the Connecting NSP at the 4.6.6 Connection Point.
- "Withstand SCR" refers to the lowest Synchronous Three Phase Fault Level at the 4.6.6 Connection Point required for the 4.6.6 Connection to operate stably.

Considered in the context of the proposed access standards, it is the Withstand SCR capability that must be exhibited by plant connecting to a network, not what the Connecting NSP can provide. AEMO recognises that using the term "Withstand SCR" to describe the relevant access standards does not adhere to the Amending Rule and, subject to submissions received in response to this Draft Report, will explore the feasibility of proposing an amendment to the Amending Rule that reflects reality more closely.

Reassessment of performance standards

NER 4.15(a) requires Registered Participants to meet or exceed their performance standards at all times. The obligations in that provision are quite extensive and warrant reproduction:

> (a) A *Registered Participant* must:
>
> (1) ensure that its *plant* meets or exceeds the *performance standard* applicable to its *plant*; and
>
> (2) ensure that its *plant* is not likely to cause a material adverse effect on *power system security* through its failure to comply with a *performance standard*; and
>
> (3) immediately ensure that its *plant* ceases to be likely to cause a material adverse effect on *power system security* through its failure to comply with a *performance standard*, if:
>
> (i) the *Registered Participant* reasonably believes that by failing to comply with a *performance standard*, its *plant* is likely to cause a material adverse effect on *power system security*; or
>
> (ii) *AEMO* advises the *Registered Participant* that by failing to comply with a *performance standard*, the *Registered Participant's plant* is likely to cause a material adverse effect on *power system security*.

APD's submission that, once a performance standard is approved and a generating system is constructed, any process that would invalidate it, or trigger the need for a performance standard reassessment, should not result in ceasing of generation or loss of revenue, is not consistent with NER 4.15(a).

NER 4.15 also requires Registered Participants to develop and implement compliance programs under which they must monitor compliance with all performance standards applicable to their plant and notify AEMO if they become aware that their plant is breaching, or is likely to breach, a performance standard. This notification then requires AEMO to give the

[77] See also the discussion and AEMO's rationale for applying an adjustment to the use of Withstand SCR for the purposes of the SSIAG in Appendix C.

Registered Participant time to rectify the breach (or anticipated breach) and the Registered Participant is then required to rectify the breach.

The fact that a change in the system strength over time is inevitable does not affect these obligations. System strength changes might no longer be adverse for Applicants following implementation of the Amending Rule.

AEMO considers that a variation of the suggestion from Citipower & Powercor and Powerlink Queensland might work as a mitigation against this risk, namely, plant performance can be reviewed annually following publication of the system strength requirements to check whether it is at risk of breaching the performance standards. If it is, the Registered Participant could seek to retune its plant or initiate an alteration to the plant to address the issue.

4.9.3. AEMO's conclusion

The draft SSIAG includes the following:

- The methodology for SCR assessments.
- The Withstand SCR assessment, including the methodology for demonstrating a Withstand SCR of 3.0, the matters to be considered by the Connecting NSP, the tests to be carried out and the acceptance criteria.
- Guidance on the information that must be provided to demonstrate compliance with the performance standards relating to SCR.

4.10. Criteria for classification of load as IBL and IBR as LIBR

4.10.1. Issue summary and submissions

The Amending Rule requires AEMO to prescribe the criteria for classification of:

- a load as an inverter based load (IBL)[78]; and
- an inverter based resource (IBR) as a large inverter based resource (LIBR) that must take into account plant type and size and other matters AEMO considers relevant to identifying IBR that could have a general system strength impact[79].

While the Amending Rule does not provide any further guidance on these requirements, the AEMC Final Determination provides a rationale, by stating that the issue turns on whether Applicants need to remediate the general system strength impact of their 4.6.6 Connections. The AEMC states[80]:

> The requirement would apply to any party that consumes SSS as a consequence of that connection — this will be set out in AEMO's SSIAG.
>
> This generally means those liable under the SSR will be:
>
> - generating systems 5MW or greater connecting to either the transmission or distribution networks

[78] See New clause 4.6.6(a)(5).

[79] See New clause 4.6.6(a)(6).

[80] See page 23 and pages 153-154 of the AEMC Final Determination.

- loads that contain a LIBR (as defined by AEMO in its SSIAG) for whom Schedule 5.3 of the NER applies
- MNSPs.

In essence, the criteria AEMO is required to determine are the size and other parameters of a load or IBR above which they are to be treated as a 4.6.6 Connection because the size of their system strength impact is likely to require remediation[81].

There was only one submission on this issue[82].

SGRE

> … an appropriate threshold for IBL that does not inhibit the development of future medium scale load pilot projects should be defined by AEMO. Currently, the low installed base of large IBL means their impact on system strength and power system operation is not well established. Simultaneously, some future electrified load industries, such as electrolysis-based hydrogen production, are in their infancy. Adding an additional cost burden in these industries may stifle development of these technologies within Australia.

4.10.2. AEMO's assessment

In light of the uncertainty as to the materiality of their impact, AEMO proposes that the criteria for classification of a load as an IBL and an IBR as an LIBR be consistent and should be as low as is feasible.

4.10.3. AEMO's conclusion

AEMO proposes a threshold capacity of 5 MW or 5 MVA (as appropriate) in determining whether a load is an IBL and an IBR should be an LIBR. Subject to further consultation submissions on this matter, AEMO does not propose different criteria.

[81] See also footnote 265 on page 154 of the AEMC Final Determination.

[82] Note that submissions quoted in this document are in this font; a footnote in this font indicates that the footnote is copied from the submission. In the interests of saving space, AEMO has replaced descriptions in the submissions with acronyms and terms that are defined in the Glossary.

5. Other matters

5.1. No markup

AEMO has taken the opportunity to amend the current SSIAG by deleting much of the explanatory information that was included in that version, as it was not considered to be necessary anymore.

Moreover, since the changes made to the SSIAG are extensive, no marked up version will be released.

5.2. Restructure

AEMO has restructured the SSIAG and included additional explanatory information to make the respective requirements clearer to Connecting NSPs and Applicants and, where appropriate, cross-referenced the requirements to existing requirements applicable to connection applications and the like.

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6. Draft determination

Having considered the matters raised in submissions and at meetings/forums, AEMO's draft determination is to amend the System Strength Impact Assessment Guidelines in the form of Attachment 1, in accordance with NER 4.6.6.

Appendix A. Glossary

Terms defined in the NER have the same meanings in this Draft Report. For ease of reading, they have not been italicised except in direct extracts or where used for definitional purposes in the table below. Other special terms and acronyms used in this Draft Report are defined in this table.

Term or acronym	Meaning
4.6.6 Connection	As defined in the SSIAG.
4.6.6 Connection Point	As defined in the SSIAG.
AEMC	Australian Energy Market Commission.
AEMC Final Determination	Rule Determination - National Electricity Amendment (Efficient management of system strength on the power system) Rule 2021. Available at https://www.aemc.gov.au/rule-changes/efficient-management-system-strength-power-system.
AFL	*available fault level*. As defined in the SSIAG.
Amending Rule	National Electricity Amendment (Efficient Management of System Strength on the Power System) Rule 2021 No.11.
Applicant	As defined in the SSIAG.
Committed	As defined in the SSIAG.
Connecting NSP	As defined in the SSIAG.
DNSP	*Distribution Network Service Provider*.
DPV	Distributed photovoltaics.
EMT	Electromagnetic transient.
Existing clause/rule [number]	A clause/rule from the NER prior to its amendment by the Amending Rule.
FAT	Factory acceptance test.
GPS	Generator *performance standard*.
IBL	*inverter based load*.
IBR	*inverter based resource*.
LIBR	large inverter-based resource.
Materiality Threshold	A reduction in AFL below which an impact may be disregarded for the purposes of NER 5.3.4B(f)(3).
MNSP	*Market Network Service Provider.*
NEM	National Electricity Market.
NER	National Electricity Rules. NER followed by a number indicates the corresponding rule or clause of the NER.
New clause/rule [number]	A clause/rule from the NER as amended by the Amending Rule.
NSP	*Network Service Provider*.
OEM	Original equipment manufacturer.
Preliminary Assessment	The assessment referred to in New clause 4.6.6(b)(1)(i).
PSCAD™/EMTDC™	Power Systems Computer Aided Design / Electromagnetic Transient with Direct Current.
PSS®E	Power System Simulator for Engineering PV Photovoltaics.
RIT-T	Regulatory Investment Test for Transmission.
RMS	Root mean square.
SCR	*short circuit ratio.*
SMIB	Single machine infinite bus.

Term or acronym	Meaning
SSC	*System strength charge*.
SSCW	*system strength connection works*.
SSIAG	System Strength Impact Assessment Guidelines.
SSLF	*system strength locational factor*.
SSN	*system strength node*.
SSQ	As defined in New clause 6A.23.5(e).
SSR	System strength remediation.
SSRS	*system strength remediation scheme*.
SSS	*system strength service.*
SSSP	*System Strength Service Provider.*
Stability Assessment	The assessment referred to in New clause 4.6.6(a)(8).
STATCOM	Static synchronous compensator.
SVC	Static var compensator.
Synchronous Three Phase Fault Level	As defined in the SSIAG.
TNSP	*Transmission Network Service Provider*.
VMM	Virtual Machine Mode.
Withstand SCR	See section 4.9.2.
X/R ratio	Ratio of reactance to resistance.

Appendix B. Summary of submissions and AEMO responses

No.	Consulted person	Issue	AEMO response
1	APD Engineering, AusNet, SA Power Networks, SGRE, Shell Energy	General System Strength Impact See section 4.1.1.	See sections 4.1.2 & 4.1.3.
2	APD Engineering, AusNet, Citipower & Powercor, Ergon Energy & Energex, Powerlink Queensland, TasNetworks	Materiality Threshold See section 4.2.1.	See sections 4.2.2 & 4.2.3.
3	Akaysha Energy, APD Engineering, CEC, Citipower & Powercor, ElectraNet, Ergon Energy & Energex, Powerlink Queensland, SGRE, Shell Energy, TasNetworks, Transgrid	Preliminary Assessment See section 4.3.	See sections 4.3.2 & 4.3.3.
4	APD Engineering, Citipower & Powercor, ElectraNet, Ergon Energy & Energex, ESCO Pacific, Powerlink Queensland, SGRE, TasNetworks	Full Assessment See section 4.4.1.	See sections 4.4.2 & 4.4.3.
5	APD Engineering, Ausgrid, AusNet, Bo Yin, Citipower & Powercor, ElectraNet, Ergon Energy & Energex, Powerlink Queensland, SGRE	Stability Assessment See section 4.5.1.	See sections 4.5.2 & 4.5.3.
6	APD Engineering, AusNet, CEC, Citipower & Powercor, ElectraNet, Ergon Energy & Energex, SGRE, TasNetworks, Tesla, Transgrid	System Strength Locational Factor See section 4.6.1.	See sections 4.6.2 & 4.6.3.
7	APD Engineering, CEC, Citipower & Powercor, Ergon Energy & Energex, Marinus Link, SGRE, TasNetworks	Available Fault Level See section 4.7.1.	See sections 4.7.2 & 4.7.3.
8	APD Engineering, Tesla	System Strength Remediation See section 4.8.1.	See sections 4.8.2 & 4.8.3.
9	APD Engineering, CEC, Citipower & Powercor, Ergon Energy & Energex,	Short Circuit Ratio See section 4.9.1.	See sections 4.9.2 & 4.9.3.

No.	Consulted person	Issue	AEMO response
	Keith Frearson, Powerlink Queensland, SGRE, TasNetworks		
10	SGRE	Criteria for classification of load as IBL and IBR as LIBR See section 4.10.1.	See sections 4.10.2 & 4.10.3.
11	APD Engineering	A minor omission is also observed in Figure 5 that it is not stated that a Full Assessment is undertaken for non SSC-paying Applicants. This needs to be corrected to accommodate a Full Assessment prior to the proposed SSR and GPS. It is also observed that the acronym 'SSR' in Figure 5 is not listed under the Glossary of the Issue Paper. APD presume that 'SSR' is System Strength Remediation and therefore propose AEMO to correct the acronym to 'SSRS' to align with the Glossary.	Noted.
12	Akaysha Energy	Akaysha are in principle supportive of urgent changes to the methods used for system strength assessment and planning in the NEM. Generally, Akaysha advocates strongly for the utilisation of methods that facilitate a technology agnostic approach to system strength management in the NEM, enabling the lowest cost solutions to be implemented.	Noted.
13	Akaysha Energy	Oscillatory Stability Management of power system oscillations and small signal stability additionally needs modernisation with the weakening power system. Akaysha do not propose any specific strategies for future management of oscillatory stability, however we note that new high-inertia synchronous condensers with no active power control can introduce further detrimental risks to power system stability. Continued use of short circuit MVA based quantification of system strength will encourage further deployment of synchronous condensers to new VRE generators for the sole purpose of creating short circuit MVA, subsequently introducing further power system risks. Hence, Akaysha recommends a new system strength quantification method enabling potential new multi-capability technologies with active power control such as grid-forming BESS to avoid the introduction of further oscillatory risks.	AEMO shares the concern expressed. See also the discussion in section 4.7.2.
14	Ausgrid	There appear to be multiple pathways available to Applicants: 1) pay the SSC and avoid the Full Assessment and complete only the Stability Assessment; 2) complete the Full Assessment and provide their SSRS; 3) complete the determined SSCW when required. Clarification is sought to map out the pathway the Applicant will be required to follow.	AEMO agrees that these are **options** for Applicants (in fact, the third is for the Connecting NSP to complete at the Applicant's expense). These options are given in the Amending Rule. It would not be appropriate for AEMO to specify anything Applicants might be required to follow.
15	CEC	**Implications for system and connections now and in the future** It is important for AEMO to consider the implications of the amendments on connections now and in the future. It is important to ensure longevity of the proposed amendments and provide investment certainty to the market. Appropriate grandfathering arrangements should be in place to minimise the extent existing connections must reconsider GPS through the 5.3.9 provisions. The CEC acknowledges AEMO's consideration of how technology capability will improve in the future. It is important to consider to implications to IBR which are increasingly using grid-forming inverters and any impacts on existing contracts for these Applicants. We note the importance of separate work conducted by AEMO through the grid-forming inverter white paper and Engineering Framework. Given grid-forming	Noted. There is an opportunity to address these sorts of changes in the next consultation on the SSIAG.

No.	Consulted person	Issue	AEMO response
		technology is an emerging consideration within regulatory frameworks, it is important for a definition to be clearly identified to provide certainty to OEMs and Applicants. We support AEMO progressing work in this area through the Engineering Framework and encourage this work to be expedited, as this will lead to more efficient solutions to be reached sooner. Finally, the proposed arrangements must consider the changing regulatory environment of the NEM and the current processes, namely the access reform work being undertaken by the Energy Security Board. Given several different locational frameworks exist, it is important to provide clarity and alignment where needed to ensure investment certainty.	
16	Citipower & Powercor	Co-ordination between AEMO and Connecting NSPs could be improved.	Agreed, but this is not a matter for the SSIAG.
17	Keith Frearson	AEMO has conflicting roles: a. SSSP in Victoria b. Provide System Strength Report which determines SS levels and advises on potential shortcomings to be remedied by SSSP.	Noted, however, the SSIAG apply across the NEM and there are no requirements applicable in Victoria that would not apply elsewhere.
18	SMA	P. 8 Paragraph 4: "*Declining minimum operational demand, changing patterns of synchronous generator operation, and rapid uptake of IBR have combined to reduce the levels of system strength required to support stable operation of existing equipment and to host further IBR as the transition to net zero policy objectives continues*" It is the uptake of IBR that utilises grid following, or immature grid forming control algorithms that can cause adverse impacts, not the fundamental characteristics of IBR technology itself. In theory it is mathematically possible to identically replicate the response of a synchronous machine using advanced IBR technology. However, in practice a more efficient solution is likely to differ somewhat from one to one representation, in order to minimise the cost of short term current capability and provide improved transient stability relative to equivalent synchronous machines. Nonetheless, it is important to note that the reliance on external system strength sources is not a fundamental requirement of IBR per-se, rather it is a consequence of using control algorithms other than mature "grid forming" algorithms.	Noted.
19	SMA	This section can be summarised as creating enhanced power system standards aimed at increasing system strength, a minimum access standard for operability of generation of SCR 3.0 and mechanism for centralised planning and charging for "system strength". It is suggested that the following aspects require careful consideration to ensure that this framework delivers efficient outcomes to the market: 1. The operability of generation of SCR 3.0 is a lax standard and much higher than the capability of mainstream grid following IBR currently under serial deployment in the NEM. This creates a risk of low grade technology being able to connect inefficiently consuming available system strength and so reducing the overall hosting capability of the transmission network. This increases cost for subsequent connection of grid following IBR and hence the NEM as a whole. In the absence of suitable mechanisms to tighten this standard, this risk can be partially mitigated through careful application of the guideline to ensure the cost of connecting equipment with high system strength consumption is efficiently allocated to the relevant generator.	Noted, however, these are issues that should be directed to the AEMC, in the context of any rule change proposal.

No.	Consulted person	Issue	AEMO response
		2. The opportunity for monopoly NSPs to market SSS to connecting parties potentially creates a perverse incentive against working constructively with connecting parties to arrive at efficient, low cost solutions. Likewise, it would appear that NSPs are indeed incentivised to progress inefficient central solutions in order to maximise revenue, rather than being motivated to enthusiastically work with connecting parties to find efficient solutions, either self-remediation or avoiding the need for remediation entirely. In order to mitigate this risk somewhat, it is suggested that the guideline should create a reverse onus of proof on the monopoly NSP to demonstrate the detailed technical requirement for any "remediation" they identify. Use of coarse approximations such as three phase fault level and AFL methodologies should be explicitly prohibited. The guideline should also ensure that the monopoly NSPs are required to work in good faith, providing a high level of transparency and timely support in progressing and optimising proposals for "self-remediation" or removing the need for remediation entirely. 3. With the emergence of large scale inverter connected storage, the potential for the transmission network to host inverter based technology could increase by multiples of 2-3, as it allows additional renewable energy generators to be matched with IBR storage of a similar capacity. This increase could be much greater if new energy intensive load such as hydrogen production or other industry types locate in the same resource rich areas. If grid following IBR fault level is compensated for with synchronous plant, the fault level is further increased by the contribution of the synchronous plant. It is therefore easy to envisage that parts of the transmission network which are currently considered "saturated" from a thermal rating perspective could experience fault levels of over 300% of current levels as capacity opens up by storage installations and load. This creates the risk that generation hosting capability of the network could actually be constrained by fault level rating of equipment. As such, close scrutiny would need to be applied to centralised or "self-remediation" proposals involving auxiliary plant, synchronous or otherwise, to ensure that it does not degrade ultimate hosting capacity of the existing transmission network by un-necessarily or inefficiently consuming fault level headroom, or indeed degrading as transient stability modes, as observed already in some areas of the NEM. **Conclusion** SMA proposes the use of advanced IBR technology and well developed and robust grid forming control algorithms as a more efficient alternative to increase and guarantee system stability as more IBR are connected to the NEM. The current maturity level of technology and the ongoing developments that will be ready in the next year, allow for the use of IBR in improving system stability through the provision of system strength to the required levels according to the characteristics of the point of interconnection.	
20	Transgrid	**IBL definition** In order to assess the impact of large IBR loads, the term 'inverter based loads' contained in the SSRM must be clearly defined to include the type and size of the load. This will allow for clear interpretation and application of the new performance standard that will eliminate ambiguity. This would also include the definition contained in the system strength impact assessment requirements for IBL. We suggest clearly outlining the requirements for a Preliminary Assessment and a Full	See sections 4.8.2 and 4.8.3.

No.	Consulted person	Issue	AEMO response
		Assessment and clear guidance on the requirements to provide SCR withstand capability of IBLs from OEMs.	

Appendix C. Discussion of SSQ & SCR and rationale for changes to NER formula

C.1 Definition of SCR and SSQ according to NER

NER 6A.23.5(j) defines the *system strength quantity* for the *system strength connection point* as the product of:

(1) the *short circuit ratio*; and

(2) the *rated active power*, rated *power transfer capability* or *maximum demand* for the *system strength connection point*.

With the *short circuit ratio* defined in Chapter 10 as:

For a *connection point* for *plant*, the synchronous *three phase fault level* (expressed in MVA) at the *connection point* for the plant **divided** by:

(a) in the case of a *generating system*, its *rated active power* (expressed in MW);

(b) in the case of a *market network service facility*, its rated *power transfer capability* (expressed in MW); and

(c) in the case of an *inverter based load*, its *maximum demand* at the *connection point* (expressed in MW)

in each case, excluding any fault current contribution from the plant side of the connection point when calculating the three phase fault level.

For example, a 100 MW wind farm connected to a network with a Synchronous Three Phase Fault Level of 500 MVA at the wind farm's connection point will have an SCR of 500/100 = 5.

C.1.1 Mathematical Description

Rewriting this definition using mathematical terms, for a generating system, this yields:

$$SSQ = \mathrm{SCR} \times \mathrm{P_{rated}} \quad \text{eq.(1)}$$

SCR can be written as:

$$SCR = \frac{\mathrm{S_{3\varphi}}}{\mathrm{P_{rated}}} \quad \text{eq. (2)}$$

Substituting eq. (2) into eq. (1) results in SSQ providing a circular reference to the Synchronous Three Phase Fault Level:

$$SSQ = \mathrm{S_{3\varphi}} \quad \text{eq. (3)}$$

Where

SSQ: system strength quantity

SCR: short circuit ratio

$\mathrm{P_{rated}}$: rated active power

$\mathrm{S_{3\varphi}}$: Synchronous Three Phase Fault Level

After considering the submissions on these matters during the consultation on the amendments to the SSIAG, and following discussions with various Consulted Persons, industry bodies and the AEMC, AEMO considers that the SCR, as defined by the Amending Rule, is not the appropriate metric by which to assess plant capability for the purposes of the access standards. The draft SSIAG proposes that the appropriate metric is the "Withstand SCR" capability and provides a methodology for assessing compliance with the relevant access standards, as well as a methodology for assessing the SCR. Therefore, the actual intended SSQ expression is assumed to be:

$$SSQ = \mathrm{SCR}_{\mathrm{withstand}} \times \mathrm{P}_{\mathrm{rated}} \quad \text{eq. (4)}$$

C.2 Proposed change in SSQ calculation

When applying SCR as a metric to quantify either SSQ or the quantity of system strength that must be remediated, the following must be considered as a minimum:

- Appropriate representation of the power system.
- System limitations beyond the control of the 4.6.6 Connection.

The term 'system strength' is determined by its impedance, controllability, short circuit fault levels, sensitivity to voltage changes, mechanical inertia, and there could be other quantifiers and inputs to represent characteristics of the grid with low SCR, and their classification into weak or strong grids. Alternative representations, typically used in a SMIB environment to create system equivalents, is nothing more than a relationship of the power system short circuit current and DC power injection at a specific bus. SCR is not an indicator of the strength of an entire power system, but only a proxy measure at a single point within the power system.

While the use and application of a SMIB could be adopted as an indicative measure for evaluating the Withstand SCR of plant, it does not explicitly consider complete nonlinear behaviours, including, without limitation:

- size of the power system
- impact of network capacitance and resonance points
- nonlinearity in the components and control elements in the power system
- dynamical interactions within the power system
- uncertainty in load behaviour
- different time scales of equipment responses in the power system
- change in network configuration

Furthermore, the evaluation of Withstand SCR (for example, based on the withstand stress test increases in Thevenin equivalent impedance) would result in failures of the generation undergoing evaluation (regardless of whether it is synchronous or asynchronous, and includes grid-forming technology). Equally, the approach would result in very high SSQs that could be impractical and unnecessary for an Applicant to address by either paying the SSSP to remediate or remediate by submitting an SSRS or paying the Connecting NSP to remediate by completing SSCW.

- The failures demonstrated in a SMIB environment are not necessarily a correct representation of the actual plant capability and, in a very basic form, must account for the fundamental stability limits governing the maximum power transfer and voltage stability between two transfer buses, which are the responsibility of the Connecting NSP and is not within the design responsibility of the Applicant seeking connection.
- The SSQ, along with the SSLF and system strength unit price, make up the formula used to determine the SSC, which is required to be provided to the Applicant by the SSSP as part of the response to a connection enquiry. All three elements are important for Applicants to make a decision regarding use of the SSS provided by the relevant SSSP. While it is not envisaged that a high degree of precision is required in the calculation of the SSQ at the connection enquiry stage, (it could be rounded to the nearest 5 or 10) it should be reasonably reflective of the required quantity of system strength to support the 4.6.6 Connection. Hence, it should take into account the characteristics of the location of the power system where the 4.6.6 Connection will be connecting, so as to encourage connections at strong parts of the power system through a lower requirement and should also take into account the technical characteristics of the 4.6.6 Connection, so as to encourage connection with technical characteristics that require less system strength to operate.
- Therefore, AEMO proposes that the calculation of SSQ could be reduced through an approximation, which takes into account minimum factors, such as power transfer and voltage stability limitations, but not resulting in values lower than 1.2 (i.e. equivalent Withstand SCR of 1.2)

$$SSQ = (\mathrm{SCR_{withstand}} - 1.2) \times \mathrm{P_{rated}}$$

and for Applicants who opt to submit an SSRS, further consideration could be given to equipment ratings on the Connecting NSP's network, load and generation diversity in addressing the required reduction in AFL.

Therefore, the proposed approach will lead to following outcomes:

For an Applicant opting to pay the SSC, the calculation of SSQ will be a fixed quantity approximated by:

$$SSQ = (\mathrm{SCR_{withstand}} - 1.2) \times \mathrm{P_{rated}}$$

And for an Applicant opting to submit an SSRS, the required reduction in AFL is to be established by:

$$\Delta\mathrm{AFL}(MVA) = (-\mathrm{SCR_{withstand}} + \alpha) \times \mathrm{P_{rated}}$$

Where

α = Stability coefficient[83] relating power system limitations beyond the 4.6.6. Connection for which the lowest value must not be less than 1.2.

In this instance, the value of α is to be established on a case-by-case basis by the Applicant. It will be the Applicant's responsibility to specify the residual risk, limitations and stability margins of the connecting network. This could result in a prolonged engineering exercise but could also result in more opportunistic treatment of risks and opportunities.

C.3 Hypothetical examples

C.3.1 Low SCR connection

100MW Wind Farm connecting into a power system with the following characteristics:

$S_{3\varphi}$	300MVA
$SCR_{withstand}$	1.7

This results in the following quantities:

- SCR at the connection point is 3.
- SSQ using the proposed method will be 50MVA (SSQ using mathematical representation from C.1.1 would otherwise be 170 MVA).

Prior to submitting the Connection Application, the Applicant must make a decision whether to pay the SSC or self-remediate.

- Option 1: If the Applicant has opted to self-remediate, the Applicant must submit an SSRS, which demonstrates remediation up to and not lower than the stability coefficient. An example of a hypothetical remediation could be sufficient equipment to allow operation at a low(er) SCR, including, without limitation: 15 MVA synchronous condenser, 25 MVA grid-forming BESS, 40 MVAR STATCOM or tuned control systems of a wind farm etc.
- Option 2: Applicant decides to pay the SSC and pay the equivalent 50MVA projection at the relevant SSN (i.e. SSLF * SSQ) to impose the general system strength impact obligations to the Connecting NSP/SSSP.

C.3.2 High SCR connection

100MW Wind Farm with the following characteristics connecting into a power system:

$S_{3\varphi}$	2000MVA
$SCR_{withstand}$	1.7

This results in the following quantities:

[83] The need for stability coefficient: since SSQ equates to a multiplier between the Withstand SCR and the rated power of a 4.6.6 Connection, its remediation can never have the outcome of bringing the SSQ to zero because neither the Withstand SCR, nor rated power, can be zero. Therefore, the calculation of AFL must account for the difference between the Withstand SCR and the limitations of the power system at the 4.6.6 Connection Point (see Section 5.1.2 of SSIAG) where the limitation is expressed as an approximate stability coefficient.

- SCR at the connection point is 20.
- SSQ using the proposed method will be 50MVA (SSQ mathematical representation from C.1.1 would otherwise result in 170 MVA).

Prior to submitting the Connection Application, the Applicant must make a decision whether to pay the SSC or self-remediate.

- Option1: Applicant has demonstrated that provision of Withstand SCR below its stated value of 1.7 is unlikely to occur, i.e. the existing system strength (including forecast of AFL, done in co-ordination with the NSP) of 20 is unlikely to fall to extremely low values below 10 and yet alone below 2, before other system issues eventuate. Therefore, no remediation is required, and system stability coefficient has been found to be much higher than the Withstand SCR.
- Option 2: Applicant decides to subscribe to SSC regardless.