Amendments to AEMO instruments for Efficient Management of System Strength Rule

April 2022

Issues paper

National Electricity Market

System Strength Requirements Methodology

System Strength Impact Assessment Guidelines

Power System Stability Guidelines

Executive summary

Declining minimum operational demand, changing synchronous generator behaviour and rapid uptake of variable renewable energy (VRE) resources have combined to reduce the levels of system strength available in parts of the National Electricity Market (NEM), both to support stable operation of existing equipment and to host further inverter-based resources (IBR) as the Australian electricity sector transformation continues.

AEMO is initiating consultation on changes to its system strength instruments to implement a recent rule change by the Australian Energy Market Commission (AEMC), which enhances the regulatory framework to facilitate more efficient and timely provision of system strength for the NEM.

The system strength framework in the NEM has changed

The NEM is already at the international forefront of managing issues associated with low system strength, and recent years have seen significant innovation in the delivery of system strength services to meet minimum power system security needs. In October 2021, the AEMC made changes to the system strength framework in the National Electricity Rules (NER), to be progressively implemented from December 2022. The key elements of these changes are:

- From 1 December 2022, AEMO will provide an annual assessment of system strength requirements in the NEM for the coming decade, against a **new power system standard** comprising:
  - A **minimum fault level requirement** for power system security (expressed in MVA).
  - A requirement for stable voltage waveforms at connection points to host AEMO's forecast levels of new IBR resources (also known as the **efficient level of system strength**).
- Each NEM region's jurisdictional planning body for the transmission network, known as the System Strength Service Provider (SSSP), must plan to meet the standard, based on the requirements projected by AEMO, for each year from 2 December 2025.
- New **minimum access standards** for relevant generators, loads and market network service providers (MNSPs) will apply from 15 March 2023, requiring relevant plant to remain connected and operate stably at a short circuit ratio of 3.0. A minimum access standard for voltage phase angle shift limits has also been added for asynchronous generation.
- Revised system strength connection options with a new **system strength charging mechanism**. This allows proponents of new or modified connections of relevant plant (Applicants) to have the choice of paying a system strength charge to the region's SSSP or providing their own system strength ('remediating'). These arrangements will commence on 15 March 2023.

The forecast of the standard is expected to provide the certainty needed to plan and invest more efficiently for a secure power system. Planning approaches for the latter part of the 10-year forecasting horizon should be considered more flexibly, to incorporate new information and developments as the power system transformation continues.

AEMO is consulting on changes to its system strength instruments

AEMO is now initiating consultation on amendments to its System Strength Requirements Methodology (SSRM) and System Strength Impact Assessment Guidelines (SSIAG), as well as consequential changes to the Power System Stability Guidelines (PSSG).

Table 1 and Table 2 summarise the key issues canvassed in this Issues Paper, with further details and a full set of issues described in the body of the document.

AEMO welcomes stakeholder feedback in response to this Issues Paper by 1 June 2022. AEMO intends to release a Draft Report for further consultation in mid-2022.

Table 1 Summary of key issues for amending the SSRM

Amending Rule	Key issues for SSRM consultation
Minimum fault level requirements. For the first part of the new system strength standard, AEMO must set minimum three phase fault level requirements for each system strength node. SSSPs will need to plan their networks and deliver services to meet these requirements in full. AEMO will also need to meet its power system security responsibilities in operational timeframes based on these minimum requirements, depending on system conditions.	• Definition of 'stable power system operation' for the requirements to ensure, for each region in the NEM and over the coming decade. • Methods for ensuring requirements cover protection and voltage control system operation. • AEMO proposes to take the existing minimum fault level requirements as starting point to ensure a secure power system and allow continued operation of protection systems. • Application of the minimum fault level requirements in an operational context.
Criteria for a stable voltage waveform (efficient level). For the second part of the new system strength standard, AEMO must describe what is meant by stable voltage waveforms. SSSPs will assess how this can be achieved for the level and type of IBR projected by AEMO. This element of the new standard is also known as the 'efficient' level of system strength, and can be met by any means, not limited to fault level.	• Whether AEMO's suggested criteria appropriately define a stable voltage waveform. • Whether AEMO and industry can select an appropriate value for undamped voltage oscillations at a connection point. • Options for assessing stable voltage waveforms in the future, as the power system and technologies change.
Modelling future IBR and synchronous machine combinations. Both parts of the new system strength standard will be informed by assumptions AEMO will need to make about future behaviour and siting of generation, storage and loads in the NEM.	• Processes and information used by AEMO to project the quantity, type and location of new generation and generation retirements for the purpose of system strength assessments. AEMO's Integrated System Plan is likely to be primary source of information used for this work. • Assumptions about operational profile of generation, future network changes, and technical capability of future generation.
Locating system strength nodes. Selection of system strength nodes will be the first step in the preparation of the new system strength standard and will flow through to amendments in the SSIAG to introduce a locational system strength factor affecting newly-connecting generators.	• Criteria to be considered when selecting system strength nodes, for example locations where system strength is particularly important for power system stability or protection system operation. • Principles to guide system strength node selection, for example treatment of new node selection or minimum/maximum numbers of nodes per region.
Planning for critical outages. The Amending Rule provides for AEMO to incorporate critical outages on the power system when assessing the system strength requirements, in some cases.	• Under what conditions planned outages would be considered critical, and whether thresholds should be specified.

Table 2 Summary of key issues for amending the SSIAG

Amending Rule	Key issues for consultation
'General system strength impact'. New or altered plant connections will need to be assessed for a 'general system strength impact', comprising both adverse system strength impact and any additional reduction in the available fault level at the connection point.	• Seeking consideration of a materiality threshold for general system strength impact relevant for: – IBR and large IBR (LIBR) (size) – IBL (size, type of load, individual or cumulative)
Preliminary assessment of system strength impact 4.6.6.(b)(1A)	• Potential limitations of single machine infinite bus (SMIB) representations for use in determining system strength withstand quantity. • Whether appropriate engineering margins are to be applied for outcomes of SMIB assessments.
Methodology for full assessments of system strength impact	• Clarification of assessment timing and interdependencies. • Recommending change to full impact assessment requirement for completion prior to issue of 5.3.4A acceptance. • Consideration of changes to definition of 'committed' projects in the context of system strength assessments.
Methodology for stability assessment. If an Applicant elects to pay a system strength charge to access services from an SSSP, a stability assessment will be completed instead of a full assessment.	• Describing how a stability assessment differs from a full assessment. • Recommending sample scope for a stability assessment based on power system analysis taking into account steady state and post contingent voltage waveform stability. • Clarifying the consequences of an assessment of instability and recommending the resolution process pathway. • Recommending network service provider (NSP) consultation with AEMO on NSPs' results of stability assessment.
Calculation of system strength locational factors (SSLF). The SSLF is the ratio of the additional fault level required at the system strength node to restore the available fault level at the point of connection.	• Recommending input assumptions and treatment of inclusions for the target year. • Seeking considerations to determine when an SSLF cannot reasonably be determined or would be manifestly excessive.
Guidance on demonstrating compliance with minimum access standards. This relates to the new minimum access standard for operation at a short circuit ratio (SCR) down to 3.0.	• Recommending initiation of changes (such as generator performance standard (GPS) adjustment or setting changes) to reflect performance requirements under future conditions where the SCR approaches the level set in the standard and avoiding the additional burden for assessments where such may not be necessary.

Contents

Tables

Figures

1 Consultation process

As required by the National Electricity Rules (NER), AEMO is consulting on the System Strength Requirements Methodology (SSRM) and the System Strength Impact Assessment Guidelines (SSIAG) in accordance with clauses 5.20.6 and 4.6.6 and the 'Rules consultation procedures' in rule 8.9 of the NER. Consequential amendments to the Power System Stability Guidelines (PSSG) are also included in this consultation, in accordance with clause 4.3.4 of the NER and rule 8.9.

There is a glossary of terms used in this Issues Paper at Appendix A.

AEMO's indicative timeline for this consultation is outlined below. Dates may be adjusted depending on the number and complexity of issues raised in submissions and any meetings with stakeholders. Although AEMO currently intends to consult on amendments to all three documents through this consolidated process, the nature and extent of issues raised in submissions received may necessitate that consultation on one or more of the documents is completed through a separate timeline and process.

Deliverable	Indicative date
Issues Paper published	26 April 2022
Submissions due on Issues Paper	1 June 2022
Draft Report published, including a draft SSRM, SSIAG and PSSG	30 June 2022
Submissions due on Draft Report	21 July 2022
Final Report published, including the final SSRM, SSIAG and PSSG	1 September 2022

AEMO has established a working group with Transmission Network Service Providers (TNSPs) and Distribution Network Service Providers (DNSPs) to receive input on the amendments to the SSRM and SSIAG, including input relevant to the preparation of this Issues Paper. AEMO has also met with peak bodies for other key stakeholder groups to inform this Issues Paper.

In this Issues Paper:

- Section 2 provides background on the system strength rule change.
- Section 3 consults on the approaches being considered for the amended SSRM.
- Section 4 consults on the approaches being considered for the amended SSIAG.
- Section 5 proposes consequential changes to the PSSG, for any feedback.

AEMO invites feedback on the proposed approaches and other options or considerations, to help shape the draft and final SSRM, SSIAG and PSSG. Submissions in response to this Issues Paper should be sent by email to planning@aemo.com.au, to reach AEMO by 5.00 pm (AEST) on 1 June 2022. Further details are provided in the Notice of first stage of consultation accompanying this paper[1]. Prior to the submissions due date, stakeholders can request a meeting with AEMO to discuss the issues and proposed changes raised in this Issues Paper.

[1] AEMO, Notice of first stage of consultation, at https://aemo.com.au/consultations/current-and-closed-consultations/SSRMIAG.

2 Background

This section notes the context for this consultation, summarises the Australian Energy Market Commission's (AEMC's) rule determination driving the amendments to the SSRM and SSIAG, and lists the NER requirements for the SSRM and the SSIAG. It also notes the requirement for consequential amendments to the PSSG.

2.1 Context for this consultation

Action is needed to maintain power system security across the National Electricity Market (NEM) as the energy transformation continues at pace. In 2021 the NEM saw 239 days with more than 40% penetration of wind and solar generation. Minimum synchronous generation levels decreased from 13.75 gigawatts (GW) in 2018 to 9.9 GW in 2021.

The NEM was based on synchronous generation and high voltage alternating current (HVAC) systems. System strength is a fundamental physical (electromagnetic) requirement. In the NEM, this has traditionally been provided by the (at the time) prevalent large synchronous generation units. A minimum level of system strength is needed for a power system to remain stable under normal conditions and to return to a steady state condition following a system disturbance[2]. System strength can broadly be described as the ability of the power system to maintain and control the voltage waveform at any given location in the power system, both during steady state operation and following a disturbance. System strength can partly be represented by the amount of electrical current available when there is a disturbance on the system – fault current, measured in megavolt amperes (MVA) – but other electrical parameters are also important.

Declining minimum operational demand, changing patterns of synchronous generator operation, and rapid uptake of inverter-based resources (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. At the same time, these challenges present opportunities for innovative delivery of essential power system services, including system strength.

The NEM is already at the international forefront of managing issues associated with low system strength. In South Australia, ElectraNet has met system strength needs by installing four synchronous condensers. In Victoria, AEMO[3] has contracted system strength services from generator-owned synchronous condensers installed alongside solar farms. In Queensland, Powerlink worked with local solar and wind farms to re-tune their inverters and reduce the nearby system strength needs of the system. Across the NEM, generators have made unique agreements with NSPs to remediate their plant's impact on system strength; and across the industry, technology providers are considering how best to provide system strength in the future.

This Issues Paper begins AEMO's consultation on amending its system strength documentation, to implement the latest rule changes relating to system strength but also to further the NEM's transformation in system strength provision.

[2] For more information on system strength, see AEMO, *Power System Requirements*, July 2020, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power-system-requirements.pdf and AEMO, *System strength explained*, March 2020, at https://aemo.com.au/-/media/files/electricity/nem/system-strength-explained.pdf.

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

2.2 AEMC rule determination on efficient provision of system strength

The AEMC's October 2021 rule determination represents an evolution of the system strength framework which has been in place since 2017 and is intended to facilitate a proactive approach to providing the necessary system strength services at scale. The Amending Rule will be implemented in AEMO instruments including the System Strength Requirements Methodology (SSRM) and System Strength Impact Assessment Guidelines (SSIAG).

A system strength framework was introduced in the NEM in 2017

In 2017, the AEMC amended the NER to address the increasing need for system strength in the power system. Under that rule:

- AEMO set minimum three phase fault level requirements (MVA) at fault level nodes for each region of the NEM and assesses any shortfalls in fault level over the coming five years.
- TNSPs, as the designated system strength service providers (SSSP) for their respective NEM regions, were required to make system strength services available to address any declared shortfalls.
- Generation connection proponents and generators modifying their generating systems had to remediate any assessed adverse impact of their connection on system strength, based on a principle of 'do no harm'.

Under the existing framework, action has been taken in several transmission networks to maintain sufficient system strength. Some SSSPs have installed large synchronous condensers themselves or contracted spare capacity from proponent owned synchronous condensers, others have contracted system strength services from synchronous generators, and some have worked with proponents of IBR to 're-tune' their existing control systems to limit system strength issues from manifesting in the network. Many generators have also taken action under the "do no harm" principle of the 2017 framework, for example tuning their own control systems or procuring synchronous condensers for their connection.

Between April 2019 and October 2020, the AEMC conducted its 'Investigation into system strength frameworks in the NEM'[4], which found that the framework was not keeping pace with the power system transformation. In July 2020, the AEMC initiated consultation on a potential rule change for the system strength framework, following a proposal from Transgrid.

The 2021 rule represents a significant transformation of the system strength framework

In October 2021, the AEMC made its final determination and rule for the 'Efficient management of system strength on the power system'[5] in the NEM (Amending Rule).

> *The final rule is an important and enduring response to the significant transformation occurring in the power system with decarbonisation occurring at a rapid rate. This changing generation mix is increasing the demand for essential system services, such as system strength … This rule seeks to increase the supply of system strength, while minimising the demand that connecting parties have on system strength services. It also seeks to coordinating these through providing efficient locational and technological signals to connecting parties.*
>
> AEMC, Rule determination, Efficient management of system strength, 21 October 2021

[4] AEMC, 'Investigation into system strength frameworks in the NEM', at https://www.aemc.gov.au/market-reviews-advice/investigation-system-strength-frameworks-nem.

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

The Amending Rule has three key elements:

1. AEMO must specify revised system strength requirements for system strength nodes, forming the basis for a new **power system standard and corresponding transmission network performance requirements for system strength**. The standard comprises:

   – A **minimum fault level** requirement for power system security (expressed in MVA).

   – A requirement for a stable voltage waveform to host AEMO's forecast levels of new IBR resources (also referred to as the **efficient level of system strength**).

   Each SSSP must use reasonable endeavours to meet the new standard in its region. AEMO will start publishing the new system strength requirements on 1 December 2022. SSSPs – in conjunction with DNSPs where appropriate – must then plan to meet the standard by 2 December 2025, based on the projected system strength requirements published three years prior to the target year.

2. New **minimum access standards** for relevant generators, loads and market network service providers (MNSPs). These will apply from 15 March 2023, requiring relevant plant to remain connected and operate stably at a short circuit ratio (SCR) of 3.0. A minimum access standard for voltage phase angle shift limits has also been added to schedule 5.2 of the NER, applicable to asynchronous generation-.

3. Revised system strength connection options with a new **system strength charging mechanism**. This allows connecting parties to have the choice of paying a system strength charge or providing their own system strength ('remediating'). The charge varies by both location and the MVA the connecting plant will consume. It attempts to coordinate connections with the SSSPs' investments. These arrangements will commence on 15 March 2023, from which time a new connecting party may opt to pay the system strength charge rather than having to self-remediate.

The Amending Rule was intended to facilitate rapid connection of more generation and achieve economies of scale solutions

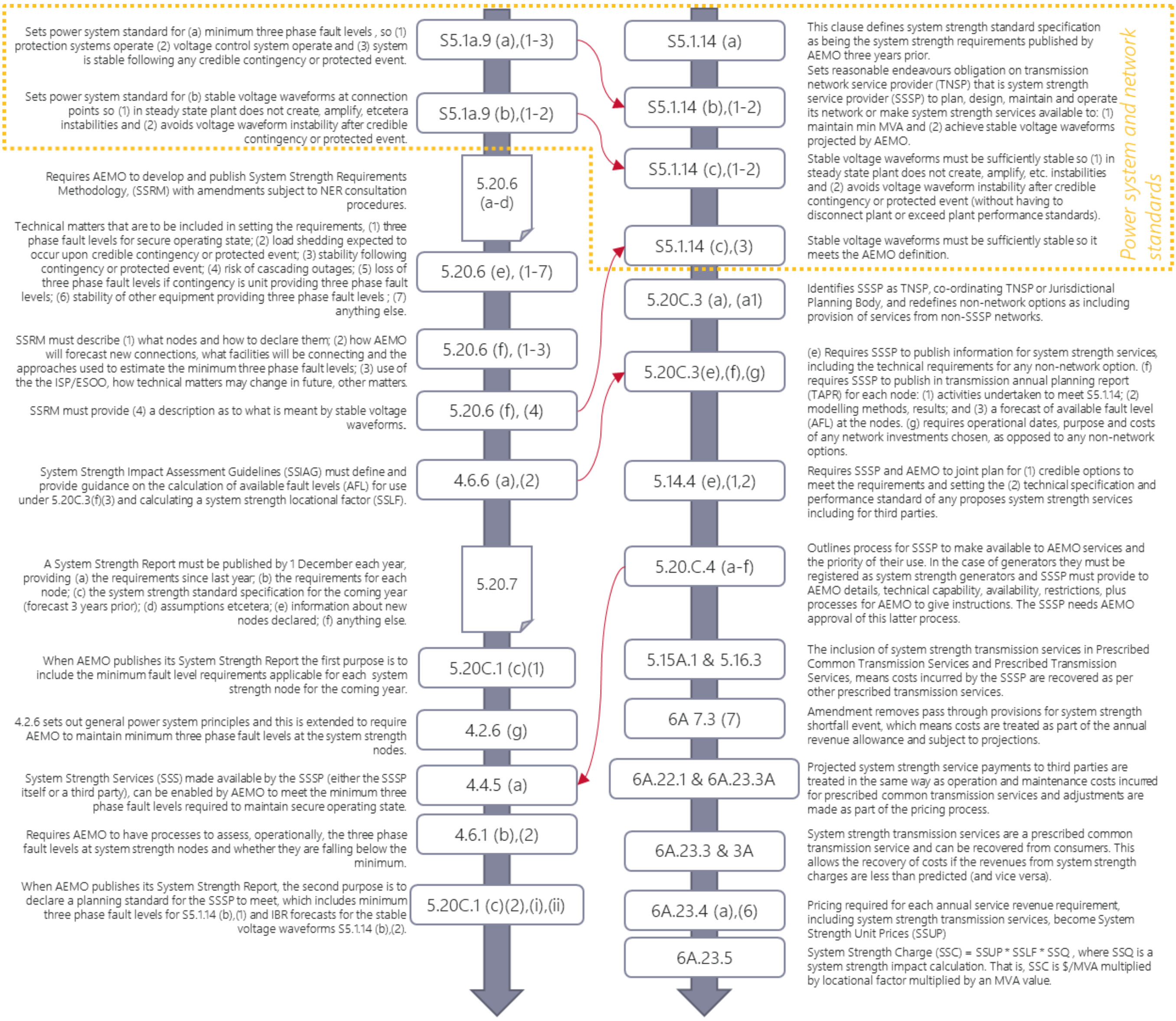
AEMO supported the direction and intent of this major rule change. AEMO understands that the intent of the Amending Rule was to enable a more rapid connection of large numbers of new inverter-based facilities with solutions that achieve economies of scale, informed by AEMO's forecasts aligned with its *Integrated System Plan* (ISP). Some of the key objectives of the Amending Rule were to:

- Provide a proactive framework so necessary services (to support efficient development of IBR) are available at scale, in a timely manner.
- Address coordination concerns about the existing 'do no harm' self-remediation framework for generator connections.
- Transfer responsibilities for provision of system strength services to TNSPs by making system strength a prescribed transmission service.
- Encourage generators to connect in locations where system strength is well supplied by the TNSP.

2.3 NER requirements

This Issues Paper consults on the amendments to be made to the SSRM and SSIAG as a result of the Amending Rule. Figure 1 maps the clauses in the Amending Rule which put obligations on either AEMO or the SSSP for a NEM region. The following sections then outline the new or amended requirements for the SSRM and SSIAG.

Figure 1 Amending Rule clauses which include obligations on AEMO and SSSPs*



* This figure is provided for background information purposes only. It may not be accurate, and is only intended to provide a summary view.

2.3.1 Changes to the System Strength Requirements Methodology

AEMO must update the SSRM[6] to reflect the amending rule, incorporating the information needed for the new standards for system strength (with both minimum and efficient levels of system strength).

Required content of the SSRM

New clause 5.20.6(f) of the NER requires that the SSRM must:

- Provide an overview of system strength nodes and the process to declare them.
- Describe how AEMO will:
  - Forecast new connections.
  - Determine the assumptions it will use about the facilities to be connected, and their contribution to matters taken into account in determining the system strength requirements.
  - Apply modelling and analysis to determine system strength nodes, and the minimum three phase fault levels at those nodes.
- Provide for AEMO to take the following into account when determining the system strength requirements:
  - The ISP.
  - The Electricity Statement of Opportunities (ESOO).
  - The matters from new clause 5.20.6(e) (listed below) relating to the power system conditions to be taken into account when preparing the requirements.
  - Any other matters AEMO considers appropriate.
- Provide a description of what is meant by stable voltage waveforms, including matters that may be taken into account by SSSPs to assess what may be required to achieve stable operation.

Mandatory considerations for system strength requirements

The SSRM must provide for AEMO to take the following matters into account in determining the system strength requirements for each region of the NEM (new clause 5.20.6(e) of the NER):

- The combination of three phase fault levels at each system strength node in the region that could reasonably be considered to be sufficient for the power system to be in a secure operating state.
- The maximum load shedding or generation shedding expected to occur on the occurrence of any credible contingency event or protected event affecting the region;
- The stability of the region following any credible contingency event or protected event.
- The risk of cascading outages as a result of any load shedding or generating system or market network service facility tripping as a result of a credible contingency event or protected event in the region.
- Additional contribution to the three phase fault level needed to account for the possibility of a reduction in the three phase fault level at a system strength node if the contingency event that occurs is the loss or

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

unavailability of a synchronous generating unit or any other facility or service that is material in determining the three phase fault level at the system strength node.

- The stability of any equipment that is materially contributing to the three phase fault level or inertia within the region.
- Any other matters AEMO considers appropriate.

Application in System Strength Report

AEMO will apply the amended SSRM to determine system strength nodes and the system strength requirements to be published in its annual System Strength Report under NER 5.20.7, starting from December 2022. Each System Strength Report must include, among other things:

- AEMO's forecasts, for each system strength node for the following decade, of:
  - The minimum three phase fault level.
  - The projected level and type of IBR and market network service facilities (used by SSSPs for the purpose of determining the efficient level of system strength).
- The system strength standard specification for each system strength node for the following year, being the forecast system strength requirements that were forecast for that node three years in advance.
- AEMO's assumptions used in determining the system strength requirements.
- Information about new system strength nodes declared since the last report, and possible future system strength nodes.

Section 3 provides information about the approaches AEMO is currently considering for the amended SSRM, and provides specific consultation questions for stakeholder feedback.

2.3.2 Changes to the System Strength Impact Assessment Guidelines

AEMO must also update the SSIAG[7] to reflect the amending rule.

Under the existing NER, prior to the Amending Rule, Network Service Providers (Connecting NSPs) must carry out a preliminary system strength impact assessment under NER 5.3.4B (Preliminary Assessment) at the connection enquiry stage for a proposed generation connection, or on receipt of a proposal to alter generating plant under NER 5.3.9(c1)[8]. If the Preliminary Assessment indicates that an Applicant's proposed plant or alteration will give rise to an adverse system strength impact, the Applicant must either submit a proposed system strength remediation scheme (SSRS) or fund the cost of system strength connection works (SSCW) conducted by the Connecting NSP. In assessing the subsequent application, the Connecting NSP carries out a full impact assessment under clause 5.3.4B (Full Assessment) and the parties would then negotiate the terms of the proposed system strength remediation required under an SSRS or SSCW.

[7] AEMO, System Strength Requirements Methodology, June 2018, at https://www.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.

[8] For the purposes of this Issues Paper, the proponents in both scenarios are referred to as "Applicants".

Required content of the SSIAG

Changes to the SSIAG are required to expand the types of proposed new connections or plant alterations that are subject to a system strength impact assessment (now also applicable to relevant load with large IBR), and incorporate the revised requirements in the Amending Rule. Under NER 4.6.6(a) and (b), the SSIAG must include:

- The methodology to be used by Connecting NSPs when assessing the general system strength impact of a proposed connection or alteration under clause 5.3.4B. The methodology must meet the requirements specified in NER 4.6.6(b) (see below), and must provide for two stages:
  - Preliminary Assessment, to be carried out using a simple isolated model such as a single machine infinite bus model, to screen for the need for a Full Assessment and determine the system strength locational factor (SSLF).
  - Full Assessment where required by NER 5.3.4B, to be carried out using an appropriate power system model specified by AEMO.
- The 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.
  - Provide guidance about the circumstances in which an SSLF is not reasonably able to be determined or would be manifestly excessive.
- Definition and guidance on the calculation of available fault levels at system strength nodes, to be used for the purposes of AEMO's system strength forecasts and for SSLF calculations.
- The methodology for assessing the short circuit ratio (SCR) for the purposes of the new access standards in NER S5.2.5.15(b), S5.3.11(b) and S5.3a.7(b).
- Guidance on the information required to demonstrate compliance with the minimum or negotiated access standards for SCR.
- Criteria for classification of a load as an inverter-based load.
- Criteria for classification of an IBR as a large IBR, taking into account plant type and size and other matters AEMO considers relevant to identifying IBR that may have a general system strength impact (above any materiality threshold specified in the SSIAG).
- A description of how AEMO assesses adverse system strength impacts.
- Guidance on the methodology to be used by Connecting NSPs when undertaking modelling to verify the stability of plant, where applicable.

Additional requirements for general system strength impact assessment methodology

New clause 4.6.6(b) includes additional requirements specific to the general system strength impact assessment methodology, which must:

- Exclude the impact on any protection system for a transmission network or distribution network.
- Provide guidance about the different network conditions and dispatch patterns and other relevant matters to be examined in a Full Assessment.

- Specify the nature of the impacts that AEMO considers to be general system strength impacts.
- Provide guidance about the matters that must be considered when determining whether a connection or alteration will result in a general system strength impact.
- Include if applicable any materiality thresholds below which an impact may be disregarded for the purposes of NER 5.3.4B(f)(3).
- Provide general guidance about options for system strength remediation schemes and system strength connection works.

Application by Connecting NSPs

Connecting NSPs will apply the revised SSIAG from March 2023 when conducting assessments for relevant connecting plant or plant alterations under amended NER 5.3.4B.

If a general system strength impact assessment is identified in the Preliminary Assessment, the SSLF calculated at that stage will determine the system strength charge that the Applicant can elect to pay when submitting its connection application. Where an election is made, a Full Assessment is not required and instead the plant must undergo modelling to verify its stability (Stability Assessment).

If the Applicant does not elect to pay the system strength charge, the Connecting NSP must proceed to a Full Assessment, which also considers the SSRS or SSCW necessary to remediate the plant's general system strength impact.

Section 4 provides information about the approaches AEMO is considering for new and amended aspects of the SSIAG, and provides specific consultation questions for stakeholders to consider.

2.3.3 Changes to the Power System Stability Guidelines

The Power System Stability Guidelines (PSSG) were originally consulted on in 2011-12 and published on 25 May 2012. The current PSSG pre-date any NER changes referencing system strength. AEMO must update the PSSG to define system strength in a similar manner to the other types of stability and ensure consistency with the new system strength framework.

Section 5 provides more detail on the changes to the PSSG.

2.4 Issues that are not part of this consultation

This consultation is limited to the matters that AEMO needs to consider in order to determine the necessary revisions to the SSRM, the SSIAG, and the PSSG.

In particular, this consultation will not examine transitional issues affecting:

- Existing connection enquiries.
- Applications to connect and connection agreements.
- Detailed NSP planning obligations.
- The continued assessment and remediation of fault level shortfalls arising between December 2022 and December 2025, which is provided for in new clause 11.143.14.

- The provision of system strength services.
- The calculation of system strength charges.

If stakeholders have questions about any of these (or other) transitional issues, they are welcome to contact AEMO via planning@aemo.com.au and best endeavours will be taken to provide an answer or to redirect the inquiry if need be.

Finally, for the sake of completeness, AEMO confirms that this consultation will not address any issues arising out of the application of Chapter 5A of the NER.

3 System Strength Requirements Methodology

AEMO must amend the SSRM to reflect the AEMC's 2021 Amending Rule, and at the same time will consider whether additional amendments, within the scope of the SSRM, are needed to address any residual practical implementation issues. In this section, AEMO provides information about the approaches under consideration for the amendments to the SSRM under five broad categories:

- **Minimum fault level requirements** (Section 3.1). For the first part of the new system strength standard, AEMO must set minimum three phase fault level requirements for each system strength node. SSSPs will need to plan their networks and deliver services to meet these requirements in full. AEMO will also need to meet its power system security responsibilities in operational timeframes based on these minimum requirements.
- **Criteria for a stable voltage waveform (efficient level)** (Section 3.2). For the second part of the new system strength standard, AEMO must describe what is meant by stable voltage waveforms, and the matters SSSPs may take into account in assessing how this can be achieved for the level and type of IBR projected by AEMO. This element of the new standard is also known as the 'efficient' level of system strength, and can be met by any means, not limited to fault level.
- **Modelling future IBR and synchronous machine connections and operation** (Section 3.3). Both parts of the new system strength standard will be informed by assumptions AEMO will need to make about future behaviour and siting of generation, storage and loads in the NEM.
- **Locating system strength nodes** (Section 3.4). Selection of system strength nodes will be the first step in the preparation of the new system strength standard and will flow through to amendments in the SSIAG to introduce a locational system strength factor affecting newly-connecting generators.
- **Planning for critical outages** (Section 3.5). The Amending Rule provides for AEMO to incorporate critical outages on the power system when assessing the system strength requirements, in some cases.

AEMO is seeking stakeholder feedback on the approaches under consideration for amending the SSRM, and has provided consultation questions in each section to guide feedback.

3.1 Minimum fault level requirements

3.1.1 Background and NER requirements

Minimum three phase fault levels are described in new clause S5.1a.9(a) as follows:

The power system should have minimum three phase fault levels sufficient to enable:

> *(1) the protection systems of transmission networks, distribution networks, Transmission Network Users and Distribution Network Users to operate correctly;*
>
> *(2) voltage control systems (such as reactive bank switching and dynamic voltage control) to be stable; and*
>
> *(3) the power system to remain stable following any credible contingency event or protected event.*

3.1.2 Key issues and proposed option(s)

Calculating minimum fault level requirements to enable protection system operation, voltage control system stability and power system to remain stable following a credible contingency or protected event requires consideration of a range of matters, including but not limited to:

- Overarching approach for determining minimum fault level requirements.
- Stable power system operation after a credible contingency event or protected event.
- Treatment of IBR when assessing minimum fault level requirements.
- Protection system operation.
- Voltage control system operation.
- Maintaining synchronism of distributed energy resources (DER).
- Application of minimum fault level requirements in an operational context.

Overarching approach for determining minimum fault level requirements

Determining and projected the minimum fault level requirement for the power system for the decade ahead is a complex exercise. Minimum fault level requirements are locationally specific and dependent on factors including generation type and availability, network topology, and protection scheme design.

AEMO intends to take the following approach to determining the minimum fault level requirements for the SSRM:

- Recognising that existing minimum fault level requirements across the NEM support power system stability and ensure security for 'system normal' for the current power system, AEMO will take the current minimum fault level requirements as a starting point for the minimum requirements under the new standard.
- It is assumed that the existing minimum fault level requirements provide for system strength for existing network equipment, generators, loads and market participants under 'system normal' for credible contingencies and protected events[9]. This does not include firm access, as this is not envisaged under the NER.
- AEMO will annually review the minimum fault level requirements with SSSPs. This will allow AEMO and SSSPs to assess the efficacy of future technological innovations and integrate them into future service provision as appropriate.
- The updated SSRM process for determining minimum fault level requirements will prioritise flexibility to allow appropriate responses to the NEM power system transformation.
- AEMO will incorporate prudent planning margins where appropriate to acknowledge technological and market uncertainty, and to ensure that the Amending Rule intent for proactive provision of services can be ensured.

Consultation questions

1. Do stakeholders have alternative suggestions for the approach to determining minimum fault level requirements?

[9] AEMO understands the Amending Rule was not intended to 'transfer' the provision of system strength for IBR that is currently accounted for in the minimum fault level requirements into the efficient level. Rather, newly-connecting (or modifying) IBR will be considered under the efficient requirement of the standard rather than the minimum requirement, subject to what is required to support IBR that helps to maintain power system stability and security.

Stable power system operation after a credible contingency event or protected event

Minimum fault levels must be sufficient for the power system to remain stable following any credible contingency or protected event. This must consider future network conditions[10] over the 10-year system strength reporting horizon (NER 5.20C.1 and S5.1a.9(a)(3)).

AEMO interprets the phrase 'power system to remain stable' in S5.1a.9(a)(3) to mean 'stable' as pertaining to a satisfactory operating state, consistent with clause 4.2.2(f). That is, AEMO will define stability for the purposes of minimum fault level requirements as stable operation of the system, both in a satisfactory operating state and following any credible contingency events or any protected event such that:

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 SSRM will specify the power system assumptions applied to study stability, to be consistent with the matters listed in new clause 5.20.6(e) of the NER and to consider what will be sufficient for the power system to remain stable following any credible contingency or protected event. For example, this is expected to include a provision that AEMO contingency studies will start from a system normal configuration with all transmission network elements in service[11]. Individual generating units may be out of service as per expected market behaviour.

From this starting point, AEMO expects to assess whether the system can be maintained in a secure operating state. On a case by case basis AEMO may assess if the system can be returned to a secure operating state as soon as practicable, and within at most 30 minutes following a credible contingency or protected event. AEMO notes that consideration may need to be made for any subsequent generation curtailment arising from any requirement to resecure the power system.

At present, the SSRM generally requires[12] that AEMO confirm power system stability for minimum fault level requirements using electromagnetic transient (EMT) analysis[13]. EMT analysis was chosen over other analysis methods[14] for its superior ability to model sub-synchronous control interactions between multiple IBR devices, as well as its superior ability to assess stability issues associated with fast control loops such as Phase-Locked-Loop (PLL).

However, EMT analysis is resource-intensive and to date has required the use of agreed generator models (accepted by the relevant Connecting NSP and AEMO) consistent with the final design parameters of a generating system. As the Amending Rule will require AEMO to forecast minimum fault level requirements for the coming decade, it will be necessary to consider power system stability using assumptions about what power system equipment may exist in the future, rather than modelling the known system and equipment. As such, an approach which does not rely on agreed and detailed plant parameters[15] will be needed, particularly beyond the initial years of the forecasting horizon.

[10] AEMO's proposed approach to consideration of 'future network conditions' is provided in Section 3.3.

[11] Excluding elements that are out of service as part of the system normal configuration, for example to maintain power system security.

[12] In some analysis, the use of steady state load flow analysis is permitted. For further details, refer to the July 2018 System Strength Requirements Methodology, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/System-Security-Market-Frameworks-Review/2018/System_Strength_Requirements_Methodology_PUBLISHED.pdf.

[13] AEMO uses PSCAD™ for electromagnetic transient analysis.

[14] AEMO uses PSS®E for root mean square steady-state load-flow analysis and fault calculations.

[15] These are only available for plant connecting in 1-2 years' time, not the entire 10-year horizon required.

AEMO is considering a flexible modelling approach in the amended SSRM, involving:

- For near-term projections, where it is feasible, use of detailed modelling and analysis to inform minimum fault level requirements. This is likely to be most feasible for the two- to three-year ahead timeframes only. This information then can be used by the SSSP to deliver system strength services. To a certain extent the near-term requirements can be applied in AEMO's operating standards.
- For longer-term projections, high-level methods that would help to quantify minimum fault level requirements would be applied, for example, high-level metrics could include Weighted Short Circuit Ratio (WSCR), Available Fault Level (AFL), or calculation the instantaneous change in network voltage magnitude and angle with reference to small perturbations in ΔP and ΔQ at a given node in the power system (for example use of the TYSL function in PSS®E). Another approach may be to approximate the required fault level for the switching of reactive plant.

Consultation questions

2. Do stakeholders have any alternative suggestions for the approach to assessment of projected minimum fault level requirements over the next decade? If so, please elaborate on techniques, requirements to implement, and potential benefits over simpler approaches.

Treatment of IBR when assessing minimum fault level requirements

To assess and apply the new system strength standard, it is necessary to decide whether and to what extent the operation of IBR (and different types of IBR) needs to be accounted for under the minimum three phase fault level and the efficient level respectively.

AEMO's understanding of the Amending Rule (particularly the new clause S5.1a.9(a)(3)) is that the efficient level is intended to accommodate connection and operation of new and modified IBR and generators, from a system strength perspective, while the minimum fault level requirement should allow stable operation of the power system accounting for existing IBR through historical system design and the 'do no harm' regime implemented in 2017.

AEMO does not consider that either the minimum or the efficient level will provide firm access to system strength, as this is not envisaged in the NER. In addition, it should be noted that assessment of both the minimum and the efficient levels will include impacts of IBR in some way, given their increasingly high penetration levels throughout the NEM and the interplay between IBR penetration and corresponding synchronous generator operation.

AEMO proposes that the minimum fault level requirements will continue to be set to incorporate IBR which was already accounted for in historical system design and under the 'do no harm' regime implemented in 2017, and that after the Amending Rule is in effect new and modified IBR will be accounted for under the efficient level. AEMO expects that SSSPs, TNSPs and DNSPs will continue to plan for system strength necessary to construct and operate any new regulated network assets which happen to be IBR, for example high voltage direct current (HVDC).

The existing NER access framework does not provide for firm rights of access to network capacity or market dispatch. AEMO will continue to employ constraints to individual plant to maintain overall system security, where required.

Consultation questions

3. In the context of clause S5.1a.9 of the Amending Rule, what are stakeholders' views on the inclusion or exclusion of existing and forecast IBR in the assumptions for determining minimum fault level requirements?

Protection system operation

Protection schemes generally need a minimum fault level amount to detect and discriminate faults, and therefore operate effectively to protect the power system as well as nearby people and assets. Protection schemes are highly complex and are designed relative to the primary system, the configuration of which changes significantly following contingency events. While protection system requirements have evolved over time, their application is sometimes constrained by existing primary system installations. Security and reliability of protection system operation continues to be an ongoing planning and operational consideration for NSPs, requiring regular reviews as the power system changes.

As synchronous generators retire and/or decommit, projected fault levels may change at a system strength node over time. For example, if a retirement or decommitment was expected in five years' time, the local SSSP would need to raise a potential protection scheme operation concern with AEMO well in advance. Through joint planning, AEMO and the SSSP would work together to either facilitate recalibration of the protection equipment or to raise the minimum fault level requirement to ensure that sufficient system strength services will be made available.

AEMO is proposing to continue to re-assess minimum fault level requirements in the NEM as the power system transforms. Robust joint planning will be required between AEMO and TNSPs, and between TNSPs and DNSPs, to ensure that protection scheme requirements are understood in advance of power system changes affecting fault level requirements. AEMO understands from NSPs that it is not practical to perform comprehensive decade-ahead studies about protection scheme requirements in time for the initial publication of the initial minimum fault level requirements prepared under the Amending Rule.

Consultation questions

4. What are stakeholders' views on how protection equipment requirements for minimum fault level can be assessed, both now and for the coming decade?
5. What are stakeholders' views on the future of protection scheme design and operation as the Australian power system transforms?
6. How could AEMO enhance the proposed approach to incorporating protection scheme operation into the minimum fault level requirements?

Voltage control system operation

In low fault level conditions, switching or operation of a range of network equipment may cause transient voltage fluctuations in the system, particularly switching of reactive devices such as capacitors or reactors. This can lead to equipment damage or cause inadvertent action of nearby plant, and must be minimised to ensure stable power system operation. Also, a certain amount of fault level is required for acceptable response from dynamic reactive power control devices such as static var compensators (SVCs).

AEMO is considering two methods to assess voltage fluctuations from switching of reactive plant at system strength nodes:

1. Using an Australian Standard (AS/NZ 61000.3.7) in cases where dynamic reactive plant has minimal impact on voltage fluctuations (NER S5.1a.5).
2. Performing detailed power system analysis where the effect of dynamic plant needs to be considered.

AS/NZ 61000.3.7 method

This standard specifies allowable maximum voltage step change from the nominal voltage following reactive device switching[16]. To achieve this, a certain three phase fault level at a node with voltage control devices must be maintained, which can be calculated using the following equation:

$$Minimum\ Three\ Phase\ Fault\ Level\ (MVA) = Capacitor\ Bank\ Rating\ (MVAr) \div \Delta\ V(pu)$$

As an example, for a node with a 40 megavolt amperes reactive (MVAr) capacitor bank and the 3% voltage step change limit, the three phase fault level to be maintained is calculated to be 1333 MVA.

However, this requirement is based on steady state switching of the power system and does not consider the benefit of dynamic voltage control plant that may be present (and do not inject significant fault current). Thus, when considering system strength for voltage control requirements, AEMO could use the above approach for the assessment of minimum fault level requirements as a ‘baseline’ or ‘first pass’ assessment. This assessment is appropriate where there are no dynamic voltage control devices that may be able to suppress voltage fluctuations.

Power system analysis

If there are relevant dynamic voltage control devices nearby the reactive plant being switched, then AEMO would conduct further power system analysis to determine the appropriate fault level requirement to keep voltage step changes to allowable nominal voltages as per the requirement in the system standard. This power system analysis will depend on the specific dynamic plant involved.

In addition to standard dynamic voltage control devices, new technologies such as batteries with advanced inverter capability may increasingly be able to support reactive plant switching without the injection of significant fault current. AEMO proposes to include reactive control capability from new devices in the forecasts for the minimum fault level requirements where appropriate.

Consultation questions

7. Are there alternatives to the allowable voltage step change limit, according to the NER S5.1a.5, proposed by AEMO for testing that the minimum fault level requirements facilitate reactive control equipment operation?
8. Do stakeholders hold different views on how best to incorporate the impact of new technologies on reactive control equipment operation?

[16] AS/NZS 61000.3.7 Electromagnetic Compatibility standards (2007).

Maintaining synchronism of distributed energy resources (DER)

DER, including PV and battery storage systems (and potentially other distributed energy resources) are an increasingly important power system component which must be considered when assessing power system stability. There are two aspects that must be considered – the ability for distributed DER to stay synchronised with the system, and the need to plan for disconnection of distributed DER *en masse* as a credible contingency.

AEMO understands that distributed DER requires a minimum level of system strength to remain connected and synchronised to the network, and that lower system strength may be resulting in higher amounts of distributed DER disconnection after a disturbance. At present, it is not clear how best to calculate the amount of minimum fault level or system strength required for distributed DER to operate.

There are two options for incorporating synchronism of distributed DER into the new system strength standard – through the minimum fault level requirement for ensuring power system remains stable following a credible contingency, or through broader planning activities undertaken by NSPs, including but not limited to the stable voltage waveform element of the system strength standard. AEMO is seeking stakeholder and market institution feedback on where best to incorporate this need.

In order to plan for credible contingency events when and if distributed DER systems disconnect *en masse* from the power system, AEMO proposes to continue to assess the largest credible contingency size for distributed DER as part of testing appropriate credible contingencies and protected events when setting the minimum fault level requirements. Further details about how this value has been calculated in the past are available in the 2021 System Security Reports[17].

Consultation questions

9. Where should planning responsibility for synchronism of distributed DER lie – in the minimum fault level requirement of the system strength standard, the stable voltage waveform requirement of the system strength standard, or elsewhere in transmission and distribution network service providers' planning functions?
10. Do stakeholders have specific proposals for how to assess how distributed PV impact available fault levels considering their sparsity, uncertainty and visibility?

Application of minimum fault level requirement in an operational context

Under the Amending Rule, the minimum fault level requirements set by AEMO each year must be applied by AEMO in operating the power system for the following year (NER 5.20C.1(c)(1)). For these purposes, AEMO must ensure there are processes in place that allow AEMO to identify any system strength node where the three phase fault level is likely to fall below the minimum fault level (NER 4.6.1(b)(2)). These processes will also detail the operational actions that must be taken in the event that these operational limits are exceeded.

The minimum fault levels determined as part of the system strength requirements will need to be adjusted to account for actual system conditions before they can be applied in real time operations. This is because the minimum three phase fault level requirements are determined as part of a planning standard designed to facilitate efficient procurement of system strength services. In operational timeframes, the minimum fault levels needed at a

[17] AEMO, 2021 System Security Reports, December 2021, page 99. At https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/planning-for-operability.

node to maintain a secure operating state will vary depending on the actual operating conditions. For example, the operational minimum fault level requirement at night may be lower than that required during the day due to the lack of PV generation, or the operational minimum fault level requirements in Tasmania may be reduced during outages of Basslink. Accordingly, TNSPs will need to provide AEMO with relevant operational and limit advice that accounts for minimum fault levels in a range of operating conditions.

The minimum fault level requirements will be assessed for normal operating conditions allowing for a credible contingency or protected event. In practice, the operating instructions will also need to accommodate network outage conditions, and any additional actions needing to be taken to ensure the secure operating state of the power system is maintained.

Regarding the 4.6.1(b)(2) requirement for AEMO to have processes in place to identify any system strength node where the three phase fault level is likely to fall below the minimum level, AEMO is considering how best to implement this requirement.

Consultation questions

11. What other issues need to be taken in to account when considering the application of the minimum fault level requirements in an operational context?

3.2 Criteria for stable voltage waveform

3.2.1 Background and NER requirements

The stable voltage waveform criteria requirement, which supports the 'efficient level' of system strength for each node, is defined in new clause S5.1a.9(b) as follows.

There should be stable voltage waveforms at connection points in the power system such that:

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

(2) avoiding voltage waveform instability following any credible contingency event or protected event is not dependent on plant disconnecting from the power system or varying active power or reactive power transfer at connection points except in accordance with applicable performance standards.

This section considers how to describe what is meant by 'stable voltage waveforms', and the matters that SSSPs may take into account in assessing what is required to achieve stable operation of projected IBR. This description must be included in the SSRM under new clause 5.20.6(f)(4). The related topics of how AEMO projects IBR and selection of system strength nodes are considered separately in Sections 3.3 and 3.4 respectively. The question of demarcation between the minimum fault level requirement and the stable voltage waveform criteria is considered in Section 3.1.2.

3.2.2 Key issues and proposed option(s)

Two key issues have been identified regarding the assessment of stable voltage waveforms:

1. How to describe a stable voltage waveform for the purpose of enabling future IBR connection and operation.
2. How this may be assessed or analysed for the future given uncertainty about the future power system and technology capabilities.

In this section, AEMO proposes an approach for describing stable voltage waveforms, and then explores the issues associated with projecting how this may be modelled for the future power system.

Description of stable voltage waveforms

An initial proposal for the description of a stable voltage waveform is that the following items should be satisfied under post-fault or no-disturbance conditions. AEMO has proposed a post-fault and no-disturbance description, rather than a during-fault description, due to the potential impracticality of defining behaviour during fault conditions.

1. The positive-sequence RMS voltage does not violate the limits in the operational guides for respective transmission networks, for pre-contingent and post-contingent conditions.
2. Change in voltage phase angle at a transmission connection point should not exceed 45 electrical degrees pre- and post- a credible contingency event or protected event. While this is not a strict limit, it provides a reference, as this corresponds to a 0.25 hertz (Hz) change in frequency in the sinusoidal voltage waveform assuming a measurement window of 0.5 seconds. This is based on the standard equation of a sinusoidal, relating frequency and phase angle change, as below:

$$\Delta f = \frac{\Delta \delta}{360° x \Delta t}$$

3. The three phase instantaneous voltage waveform at connection points in the power system are as close to 50 Hz sinusoidal as possible, with voltage waveform distortion within acceptable levels, as determined by the respective TNSP or DNSP with reasonable allowance for any existing contracts, background harmonics, or power quality limitations.
4. Any undamped steady-state RMS voltage oscillations at a connection point or in the power system should not exceed an acceptable planning and connection threshold[18]. This value between 0.1% and 0.5% peak-peak RMS voltage, is under active discussion within the Power System Stability Working Group and Power System Modelling Reference Group convened by AEMO and including TNSP membership.

These items have been prepared following consultation with TNSPs and DNSPs.

In certain cases, it may be appropriate or necessary to conduct switching studies to consider any need to limit magnitude and/or propagation of faults, however this is not recommended in the majority of cases due to computational complexity.

Consultation questions

12. Do stakeholders consider the proposed description for stable voltage waveforms to be comprehensive? Are there any recommended additions or deletions? If so, why?

Assessment of stable voltage waveforms in the future

Determining the stability of existing and anticipated IBR often requires detailed electromagnetic transient (EMT) modelling. The accuracy of EMT studies is largely dependent on the accuracy of the plant models being tested.

[18] A voltage oscillation frequency of 7.5 Hz corresponds to 900 changes/minute assuming rectangular voltage characteristics and a 0.3% peak-peak RMS voltage fluctuation limit for a 230 V lamp application, per the Pst=1 curve in Annex A of IEC 61000-3-7.

Detailed EMT models do not exist for plant connecting in the future which have not yet been designed. Using EMT models to study network stability beyond ~2 to 3 years in the future can become increasingly imprecise.

Determining the level of system strength required to ensure stable voltage waveforms from plant that has not been committed and have no EMT models presents a challenge. A balance must be struck between modelling accuracy against the uncertainty of the system in the future. AEMO considers that there are three options available to assess stable voltage waveforms for the future system:

1. Apply generic EMT models as a 'stand-in' for plant that has not been committed or connected.
2. Available fault level calculation, using an RMS-based proxy study method.
3. Simplified switching studies to test voltage robustness.

Ensuring that voltage waveforms remain stable for future IBR connection and operation is the responsibility of the SSSP in each region. However, this assessment will be highly related to the assessment of the minimum fault level requirements (see Section 3.1.2). As such, AEMO is seeking to consult on the different assessment pathways that SSSPs may use for assessing whether future voltage waveforms remain stable, to seek some degree of alignment with processes to be applied for the minimum fault level requirements. The three options are explored further below.

Option 1 – Use of generic EMT models

Under this option, in the absence of accurate and actual plant model information for the future system, SSSPs would use generic models for both the assets providing system strength services as well as the future IBR to connect. However, AEMO notes that EMT studies have high modelling requirements and consequential resourcing impacts.

Option 2- Available fault level calculation

Available fault level (AFL) is a fault level-based estimation method for system strength. It estimates how much synchronous fault level may be required to allow stable operation of a given level of IBR in a certain area assuming a particular minimum short circuit ratio (SCR) that an IBR can stably sustain. This method provides a proxy for the underlying power system characteristics responsible for system strength.

Using this method, a negative AFL may suggest insufficient system strength at the point of the network under consideration, indicating possible instability of the voltage waveform. A positive AFL would suggest that there is likely to be adequate system strength to facilitate a stable voltage waveform output from the IBR plant, and possibly some additional hosting capacity.

By way of example, assuming a particular synchronous machine dispatch in Tasmania as well as a minimum SCR requirement of 2 at the connection point for the IBR (as per TasNetworks' target as detailed in the current SSRM), the following AFLs were calculated at two sample wind farm locations in Tasmania, in PSS®E.

Table 3 Available fault levels at sample Tasmanian wind farms

Wind farm	S_{SG}(MVA)	S_{TOTAL}(MVA)	Δ (S_{TOTAL}(MVA) - S_{SG}(MVA))	Available Fault Level (S_{SG}(MVA) - Δ)
WFA	260	492	232	+28
WFB	268	512	244	+24

where: S_{SG} = Synchronous fault level at the node

S_{total}	=	Indicative part of the AFL algorithm used to calculate Δ
Δ	=	Indicative fault level required to operate the IBR stably
AFL	=	Available fault level at the node.

These results show positive AFLs, indicating that both wind farms can maintain stable operation following credible contingency events, as the required minimum SCR has been met by the selected synchronous machine dispatch scenario.

Option 3 – Simplified switching studies to test voltage robustness

This option uses simplified switching studies to test voltage sensitivity through PSS®E, seeking to remove the use of proxy measures and instead broadly test underlying characteristics responsible for system strength.

The approach here frames 'system strength' as the robustness of the process by which alternating current (AC) voltages are established and maintained from the flow of energy (in the form of alternating current) in an electrical network. The method attempts to decouple system strength from synchronous fault level calculations which become less meaningful in an increasingly asynchronous network.

At any node in the power system, changes in power injection (or extraction) can affect the voltage waveform at the node. These changes can be observed in voltage magnitude and/or phase angle, and in active and/or reactive power components. The local voltage effect of the power injection (or extraction) can be represented as a function of the injected (or extracted) real and reactive power. Under this assessment option, it is assumed that the *sensitivity* of the local voltage waveform to that power injection (or extraction) can therefore be represented through the partial derivatives of that functional relationship. Four 'M' constants would be calculated from the partial derivatives to give an overview of local voltage waveform sensitivity.

$$M_P = \left.\frac{\partial |V|}{\partial P}\right|_{\substack{Q,\text{ sources}\\ \text{fixed}}} \qquad M_Q = \left.\frac{\partial |V|}{\partial Q}\right|_{\substack{P,\text{ sources}\\ \text{fixed}}} \qquad A_P = \left.\frac{\partial \delta}{\partial P}\right|_{\substack{Q,\text{ sources}\\ \text{fixed}}} \qquad A_Q = \left.\frac{\partial \delta}{\partial Q}\right|_{\substack{P,\text{ sources}\\ \text{fixed}}}.$$

This method would use the TYSL function in PSS®E to measure robustness of the voltage in a power flow. This is a useful first approximation to what happens in the wake of a disturbance within the network, before automatic controls have adjusted to restore appropriate steady state conditions (i.e. the timeframe where issues arise in high IBR networks).

The network model would be prepared for a TYSL function and a TYSL would be applied to solve the network. After noting the voltage magnitudes and phase angles, the perturbation ΔP or ΔQ would be applied in the form of a bus shunt at the point of study, and a second use of TYSL would solve the perturbed network. The changes $\Delta|V|$ and $\Delta\delta$ at the point of study would then be read and used to compute estimates of the sensitivities M_P, M_Q, A_P and A_Q. This process would be repeated at each busbar to obtain sensitivity indices at each node of the system.

Results at each node would look like the following example table.

Table 4 Example sensitivity coefficients in Victoria region

FL Node	A_P	A_Q	M_P	M_Q
Node A **500 kilovolt (kV) bus**	0.004115105	0.000596046	4.77E-06	7.87E-05
Node B **220 kV bus**	0.009269714	0.000991821	3.70E-05	0.000175238
Node C **220 kV bus**	0.008616447	8.58E-05	5.25E-05	0.00017643
Larger values would represent higher sensitivity and therefore low system strength in the conventional sense.				

Consultation questions

13. To what degree should the SSRM indicate assessment processes that SSSPs may apply when assessing delivery of stable voltage waveforms for IBR connections and operation over the 10-year horizon?
14. What do stakeholders consider to be the pros and cons of the three proposed options for assessing future voltage waveform stability? Should any other options be considered? If so, what options?
15. Given the multitude of possible approaches, does AEMO have a role in providing guidance through the SSRM to encourage consistency between SSSPs where appropriate?

3.3 Modelling future IBR and synchronous machine connections and operation

In order to forecast system strength requirements over a 10-year horizon, a number of aspects of the power system need be forecast as inputs to assess the system strength requirements. Where possible, these will draw on the ISP and the ESOO. This section covers the specific aspects of what is forecast, and any additional assumptions needed to form the system strength requirements. These are:

- Quantity, type and location of new generation and generation retirement.
- IBR projections used to determine the system strength requirements.
- Technical capability of future plant.
- Future network development.

3.3.1 Background, and NER requirements

New clause 5.20.6(e), (f)(2) and (f)(3) set out matters to be included in the SSRM for the forecasting of connections and network augmentations for the purposes of system strength requirements, and are summarised in Section 2.3.1.

3.3.2 Key issues and proposed option(s)

The basis of the IBR forecast, and what matters and assumptions are used to determine the system strength requirements, will materially impact the system strength standard specification, and the scale of investment required to meet it.

The forecast of the standard is expected to provide the certainty needed to plan and invest more efficiently for a secure power system. Planning approaches for the latter part of the 10-year forecasting horizon should be considered more flexibly, to incorporate new information and developments as the power system transformation continues.

Quantity, type, and location of new generation and retirement

New connections include IBR and synchronous machines, for generation, storage and loads. AEMO proposes to use the most recent ISP as the starting point for the forecast type, quantity and location of new connections, and existing generation retirement. ISP information would be supplemented by any more recent updates available to AEMO at the time required for the system strength assessments, for example through ESOO and generation information page updates, or relevant government policies or market changes.

The ISP uses a scenario-based approach for future projections of IBR developments. AEMO proposes to select the most likely scenario as identified in the ISP as the basis of the forecasts used in the system strength requirements.

The physical location of new generation and storage will be based on ISP modelling. Two options for AEMO to provide new generation location forecasts are considered:

1. Projecting new generation and storage at an individual network bus.
2. Projecting new generation and storage at the renewable energy zone (REZ) level (noting that at some point, generation will need to be included in a network model).

AEMO makes informed allocations of new generation to existing and proposed network buses as part of the preparation of the ISP (but not published), however this may only be accurate in the near term, rather than across the full 10-year horizon. AEMO is seeking feedback on the pros and cons of each option.

NSPs may have additional information about the locations of connection interest, which can supplement the inputs to AEMO forecasting processes. This information can be, and is, shared through existing joint planning processes.

Since the ISP is published every two years, forecasts will be based on the most recent ISP, Draft ISP or ISP update. As noted above, ISP data may be adjusted for other relevant updates where available, such as the ESOO or REZ design reports. Consistent with the Amending Rule, AEMO would consult with SSSPs and other selected relevant stakeholders to discuss any changes to the projection where a deviation from the ISP results may be considered appropriate.

Unfortunately, the ISP does not forecast specific large loads connecting (such as data centres) or disconnecting (such as smelters) from the power system. It is unclear how these will be forecast beyond what is anticipated and committed, especially in terms of where they may connect. These large loads are expected to be impactful for system strength requirements, and AEMO proposes to work with SSSPs, TNSPs and DNSPs to understand anticipated load projects and include them in the system strength modelling where possible.

Consultation questions

16. Under what conditions, if any, do stakeholders consider that AEMO should deviate from the ISP's 'most likely scenario' for the purposes of the system strength requirements?
17. What locational detail should AEMO provide for new generation – a REZ level or a specific network bus?
18. What (if any) additional detail for new connections should be set out in the SSRM, in addition to the location and total megawatts (MW)?
19. Do stakeholders have specific suggestions for how potential new loads should be incorporated in the forecast?
20. Do stakeholders have specific suggestions for how DNSP-connected generation plant could be incorporated, given that the ISP predominantly considers transmission-connected plant?

IBR projections used to determine the system strength requirements

The level and type of IBR needs to be projected by AEMO for the next 10 years as part of the system strength requirements. This is used to inform the efficient level of system strength for the new standard, which should ultimately provide sufficient 'hosting capacity'[19] in the network for IBR connection and operation.

AEMO is proposing to forecast the level and type of IBR using an approach which approximates the key factors affecting the system strength requirement for stable operation of IBR using an equation, as well as reporting on the MW capacity of the projected IBR. This equation will include the significant contributing factors shown in Table 5.

Table 5 Factors for proposed IBR projection equation

Factor	Issues
MW capacity	This value will be available through the ISP forecasting process. AEMO proposes to use capacity outlook results rather than time sequential modelling, because the generation dispatch projection available from time sequential modelling does not give an understanding of the amount of inverters online. AEMO considers that inverters online is the key factor to be considered for system strength requirements.
The MVA rating of the IBR *MVA_factor*	The ISP only projects the MW installed capacity, and not the MVA rating of the plant.
The projected dispatch of the IBR *CoincidentFactor*	There are times where different IBR such as wind and solar, have a low coincident generation profile. This may reduce the need for system strength as IBR operates at different times. This coincident factor should be calculated in a way which does not introduce additional curtailment, and potentially ensures reactive support from IBR is available when needed.

To illustrate the form of this equation:

$$IBR\ to\ be\ hosted\ at\ a\ connection\ point = \left((Wind_{installedMW} + Solar_{installedMW}) * CoincidentFactor + Battery_{installedMW}\right) * MVA\_factor + MNSP_{MVA}$$

[19] See Figure C.3 at https://www.aemc.gov.au/sites/default/files/2021-10/ERC0300%20-%20Final%20determination_for%20publication.pdf.

AEMO is seeking stakeholder input on the proposed approach. This method has been proposed in order to target the factors most relevant for system strength requirements.

Consultation questions

21. Is this equation-based approach for projecting the level and type of IBR for setting the system strength requirements appropriate? If not, what alternatives should be considered, and why?

Technical capability of future plant

AEMO takes 'type' in new clauses 5.20.6(f)(2)(ii) and 5.20.6(f)(4) to refer to technical characteristics such as grid following or grid forming for IBR, or asynchronous versus synchronous connection for pumped hydro projects[20].

As the vast majority of new connections in the ISP are projections, and not specific anticipated or committed projects[21], some assumptions about the class of facilities need to be made. These assumptions will dramatically affect expected requirements for future system strength.

AEMO intends to undertake joint planning each year as it prepares its System Strength Report, including consulting with SSSPs about relevant technical capability of future plant. In general, AEMO considers it will be appropriate to make more conservative assumptions about technological innovation in the near term, and less so towards the latter part of the planning outlook, subject to evaluation of available evidence available about technical capabilities and market trends. AEMO does not propose to be prescriptive about assumptions in the SSRM itself, given the pace of technological innovation and changing market conditions.

In the near term, AEMO proposes conservative assumptions about the ability for new IBR plant to improve system strength. For example, in the near term it would be expected that new IBR connections would have grid following rather than grid forming inverters, but there may be cause to assume that in the latter part of the outlook period more grid forming inverters would be available.

Consultation questions

22. Do stakeholders have specific alternatives to suggest in response to AEMO's proposed approach to projecting technical capability of future plant? If so, what alternatives should be considered?

Future network development

Network augmentation can improve system strength and, consequently, support more renewable generation. Therefore, any network (or non-network) augmentation projects identified as committed or anticipated in the ISP and that are expected to be completed in the 10-year outlook period will be included. For example, Project Energy Connect (PEC) will improve the system strength at Red Cliffs after its expected commissioning date (currently July 2025).

[20] Snowy 2.0 has proposed three units to be synchronous pumps, and 3 units to be variable speed drives.

[21] Definitions of committed and anticipated generator projects are provided in the Generator Information updates available on the AEMO Generation Information Page, accessible via https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information.

However, the ISP does not necessarily identify all network projects that are committed or anticipated[22]. In this case, AEMO will draw on information in the NSPs' annual planning reports. Additionally, AEMO will draw on information from annual planning reports for any reconfiguration or retirement of network plant.

Consultation questions

23. Is including only committed and anticipated network augmentation projects suitable for forecasting system strength requirements?
24. Are there any other sources of information on network augmentations which need to be considered?

3.4 Locating system strength nodes

3.4.1 Background, and NER requirements

Under the Amending Rule AEMO must declare system strength nodes and their system strength specification over the coming decade. SSSPs are responsible for system strength services at each node.

Selection of system strength nodes will affect key values assessed in the SSIAG, particularly the system strength locational factor. This issue is considered in Section 4.6

3.4.2 Key issues

System strength nodes should be selected at points that are most suitable for maintaining minimum fault levels as well as the stability of the voltage waveform level of system strength required to host IBR connection and operation. As the power system transitions, more system strength may be required closer to the connecting IBR, and corresponding adjustments may be needed to the minimum fault level requirements. The Amending Rule continues to mandate that system strength nodes are located 'on a transmission network'.

AEMO proposes that the selection process will consider locations where all of the system strength specification factors considered in Section 3.1 and Section 3.2 are likely to be important for ensuring sufficient system strength is available for the future power system. Table 6 lists potential criteria important for the selection of system strength nodes, as well as a New South Wales-based example of a relevant node.

Table 6 System strength node criteria with New South Wales examples

Node criterion	Description	Example node in New South Wales
Power system to remain stable	Maintaining the amount of plant that is needed to not violate system stability constraints to meet demand	Either side of significant inter/intra-connectors which are supplying bulk load, for example, either side of the Queensland – New South Wales Interconnector (QNI)
Protection / plant settings	Sufficient fault level for protection / load requirement	Newcastle
Voltage control devices	Sufficient fault level to reduce voltage step transients for switching reactive plant device	Sydney West (NSW)
IBR resources	Ensure sufficient IBR to supply load without causing instability	Central-West Orana (CWO) REZ (NSW)

[22] For example, smaller projects which do not require a Regulatory Investment Test for Transmission (RIT-T) due to cost thresholds.

3.4.3 Proposed option(s)

AEMO is proposing to apply the criteria above to select system strength nodes through the application of the principles listed below.

Selecting the nodes for the minimum fault level requirement:

- There will not be any minimum or maximum number of nodes per region, but all efforts will be made to select them so as to ensure that monitoring and assessment remains practical, while also having sufficient nodes to allow appropriate locational factors to be calculated Creation of a new node will be considered if locational factors indicate that a new node is justified.
- New nodes may be established. New nodes will be established for network augmentation that AEMO considers anticipated or committed. In some cases, nodes could be removed if system strength requirements are better considered at other points on the network.
- Once nodes are selected, they will be treated the in the same way (maintaining the calculated minimum fault level of all the system strength factors) regardless of what criteria was used to establish the need for a node.
- If a region has an identified system strength issue, then a node will be placed at the location where it can be monitored and managed, regardless of whether a node identified using the same criterion has already been selected in that region.
- Any node may satisfy multiple criteria should it be necessary for system security. The largest fault level requirement would be selected for that node.
- The NER do not allow system strength nodes to be in distribution networks, although they may be located on transmission networks at or close to their interface with distribution networks.

Selecting nodes for the stability of the voltage waveform criteria:

- Where feasible, nodes for asynchronous resources will be selected at the bulk connection point(s) of REZs.
- If there is a region border in an area where there is a large amount of asynchronous connection, AEMO may place a node on either side of the region border.
  - For example, a node may be established at Red Cliffs (Victoria) and Buronga (New South Wales) even though they are electrically close.
- It is the aim for these nodes to broadly align with the projected ISP REZ developments, however, they will not necessarily be directly linked. Nodes will be placed where generation is planting.

Consultation questions

25. Do you consider that the proposed selection criteria will allow for an appropriate set of system strength nodes to be selected? If not, please provide specific alternatives or additions.
26. AEMO has not proposed to create a system strength node at every transmission busbar, to ensure practicality of assessment and monitoring of nodes. What do you think represents an appropriate balance between accuracy and practicality? If you do not agree with AEMO's proposal, please propose specific alternative assessment processes.

3.5 Planning for critical outages

3.5.1 Background, and NER requirements

The AEMC’s Final Determination confirms that the scope of the SSRM is broad enough for AEMO to take critical planned outages into account when setting the minimum fault levels[23].

Several NSPs have noted particular difficulties in maintaining system strength under network outage conditions given the present tight system conditions preventing the ability to take outages for major planned maintenance.

For planned outages, AEMO needs to be satisfied that power system conditions are likely to be sufficient to maintain power system security, including minimum system strength, voltage management, minimum demand or solar shake-off.

3.5.2 Key issues and option(s)

To assess whether to include a particular planned outage when setting the minimum fault levels, AEMO will need to decide which planned outages warrant coverage through the system strength standard. For these purposes AEMO proposes that the outage should be considered ‘critical’. AEMO proposes that a ‘critical’ planned outage from a system strength perspective would be one which would substantively prevent sufficient strength from being available to meet power system needs, at sufficient scale and/or duration to justify inclusion in the system strength standard.

AEMO is considering to what degree guidance on assessment of ‘critical’ planned outages should be set in the SSRM, versus being decided annually on a case-by-case basis ahead of the release of the System Strength Report. Were the thresholds for critical planned outage assessment to be set in the SSRM, potential thresholds could include:

- Outages of the elements (or feed-in components) of major interconnectors between NEM regions, or major intra-connectors within a region.
- Outages of network elements considered to be High Impact Outages.
- Outages of the elements connecting major generation centres or system strength source centres to the remainder of a region.
- Outages that remove key reactive plant from service.
- A threshold for which the duration of an outage is considered impactful.

Consultation questions

27. Are there specific changes that should be considered to the AEMO approach to what a ‘critical’ planned outage should be, and the potential thresholds for those outages? If so, please note alternatives.
28. Do you have a view on whether criteria for critical planned outages should be specified in the SSRM, versus a case-by-case assessment each year?

[23] AEMC, Efficient management of system strength on the power system, Rule determination, 21 October 2021, page 98.

4 System Strength Impact Assessment Guidelines

4.1 Updating the SSIAG

4.1.1 Background and NER requirements

NER clause 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 for new and modified connections will apply from 15 March 2023.

Table 7 describes the NER changes that AEMO needs to reflect in the amended SSIAG.

Table 7 Changes required by Amending Rule for the SSIAG

NER clause	Current requirement for SSIAG	Changes required by Amending Rule
4.6.6(a)	Set out the methodology to be used by Connecting NSPs when undertaking system strength impact assessments under clause 5.3.4B, in relation to a proposed new connection of a generating system or market network service facility, or an alteration to a generating system to which clause 5.3.9 applies.	• Methodology for system strength impact assessments also to apply to relevant loads with large IBR (LIBR) under expanded application of 5.3.4B. • Set out a methodology to be used by Connecting NSPs when calculating an SSLF. • Define and provide guidance on the calculation of, available fault levels (AFLs) at SSNs including for the purposes of forecasts under clause 5.20C.3(f)(3) and for the calculation of the SSLF for a connection point. • Prescribe, for clauses S5.2.5.15(b), S5.3.11(b) and S5.3a.7(b), the methodology for assessing the short circuit ratio (SCR). • Provide guidance on the information that must be provided to demonstrate compliance with the minimum access standard in clause S5.2.5.15(b), clause S5.3.11(b) or clause S5.3a.7(b) (as applicable), or if the procedures in clause 5.3.4A have been followed, the relevant negotiated access standard. • Prescribe the criteria for classification of a load as an inverter based load (IBL). • Prescribe the criteria for classification of an IBR as an LIBR, which must take into account plant type and size and other matters AEMO considers relevant to identifying IBRs that may have a general system strength impact above the threshold referred to in clause 4.6.6(b)(7). • Describe how AEMO assesses adverse system strength impacts. • Provide guidance on the methodology to be used by Connecting NSPs when undertaking modelling to verify the stability of plant in accordance with clause 5.3.4B(a2)(4).
4.6.6(b)(1)	The SSIAG must provide for a two-stage assessment process to be applied by Connecting NSPs comprising: • A Preliminary Assessment to screen for the need for a Full Assessment.	In addition to the original requirements, AEMO must include: • A requirement for Connecting NSPs to calculate the applicable SSLF as part of the Preliminary Assessment.
4.6.6(b)(1A)	N/A	The SSIAG must require the Preliminary Assessment to be carried out using a simple isolated model, such as a single machine infinite bus model.
4.6.6(b)(2)	The SSIAG must require the Full Assessment to be carried out using a power system model that is reasonably appropriate for conducting system strength impact assessments and applicable to the location on the	No change.

NER clause	Current requirement for SSIAG	Changes required by Amending Rule
	transmission network or distribution network at which the facility is or may be connected and specified by AEMO for this purpose.	
4.6.6(b)(3)	The SSIAG must exclude from the assessment of an adverse system strength impact the impact on any protection system for a transmission network or distribution network.	The reference to adverse system strength impact is replaced with general system strength impact.
4.6.6(b)(4)	The SSIAG must provide guidance about the different network conditions and dispatch patterns and other relevant matters that should be examined when undertaking a Full Assessment.	No change.
4.6.6(b)(5)	The SSIAG must specify the nature of the impacts that AEMO considers to be adverse system strength impacts and that must be avoided or overcome by undertaking SSCW or implementing an SSRS in accordance with clause 5.3.4B.	• The reference to adverse system strength impacts is replaced by general system strength impact. • There is no need to include reference to the adverse system strength impacts to be avoided or overcome by undertaking SSCW or implementing an SSRS.
4.6.6(b)(6)	The SSIAG must provide guidance about the matters that must be considered when determining whether a connection or alteration will result in an adverse system strength impact.	• The reference to adverse system strength impact is replaced with general system strength impact.
4.6.6(b)(7)	The SSIAG must include if applicable any thresholds below which an impact may be disregarded when determining the need for an SSRS or SSCW under clause 5.3.4B.	• The references to SSRS or SSCW are deleted.
4.6.6(b)(8)	The SSIAG must provide general guidance about options for SSRSs and SSCW.	No change.
4.6.6(b)(9)	N/A	AEMO must specify a methodology for calculation of the SSLF for an connection point, which must be representative of the impedance between the connection point and the applicable SSN and must use AFL as the basis for the methodology.
4.6.6(b)(10)	N/A	AEMO must provide guidance about the circumstances in which an SSLF is not reasonably able to be determined or would be manifestly excessive.

As noted by the AEMC in the Final Determination, there are several concepts and processes that are new.

The key function of the SSIAG under the NER is to prescribe how Connecting NSPs will assess the impact of certain connections to their networks on system strength. The Amending Rule expands the circumstances in which Connecting NSPs must assess this, as well as the scope of what they must assess. Table 8 highlights these changes.

Table 8 Changes to system strength impact assessments

	Requirement	Existing NER	Amending Rule
Affected Connections	**Situations requiring SSIA:**		
	• New connection of generating system[24].	✓	✓
	• New connection of market network service facility[25].	✓	✓
	• Alteration of generating system to which clause 5.3.9 applies.	✓	✓
	• New connection for a Network User to whom schedule 5.3 applies where the facility to be connected includes an IBR.	×	✓
	• Alteration to facility with IBR or market network service facility where clause 5.3.12 applies.	×	✓
Scope of Assessment	**Preliminary Assessment requirements:**		
	• Purpose is to screen for the need for a Full Assessment.	✓	✓
	• Calculate the applicable SSLF.	×	✓
	• Carry out assessment using a simple isolated model, such as a single machine infinite bus model.	×	✓
	• Assess general system strength impact.	×	✓
	• Exclude from the assessment the impact on any protection system for a network.	✓	✓
	Full Assessment requirements:		
	• Carry out assessment using a power system model that is reasonably appropriate and applicable to the location, as specified by AEMO.	✓	✓
	• Exclude from the assessment the impact on any protection system for a network.	✓	✓
	Stability assessment requirements:		
	• Where Applicant elects to pay a system strength charge, Connecting NSP completes a Stability Assessment in lieu of Full Assessment.	×	✓

The remainder of Section 4 discusses the key issues arising out of the required amendments to the SSIAG.

4.2 New system strength impact definition

4.2.1 Background, and NER requirements

The Amending Rule introduces the concept of 'general system strength impact', which requires assessment of both the adverse system strength impact of the proposed connection **and** any additional reduction in the AFL at the relevant connection point, as follows:

> 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*.

[24] Different words, but same meaning.

[25] Different words, but same meaning.

The Amending Rule did not change the substantive meaning of an 'adverse system strength impact', but extends its application to inverter based loads:

> An adverse impact, assessed in accordance with the *system strength impact assessment guidelines*, on the ability under different operating conditions of:
>
> (a) the *power system* to maintain system stability in accordance with clause S5.1a.3; or
>
> (b) a *generating system*, *market network service facility* or *inverter based load* forming part of the *power system* to maintain stable operation including following any *credible contingency event* or *protected event*,
>
> so as to maintain the power system in a *secure operating state*.

4.2.2 Key issues

Issue 1 Scope of assessment

The change from 'adverse' to 'general' system strength impact means that the SSIAG must be updated to include an assessment of the relevant plant's contribution to any reduction in the AFL.

Consultation questions

29. Should a material threshold be defined for the purpose of general system strength impact assessment? If so, what should those thresholds be and why (for IBL, load types, individual or cumulative, as well as generators including LIBR, connected into transmission and distribution networks)?
30. Are there any other issues relevant to the general system strength impact that AEMO ought to take into account?

4.3 Proposed methodology for Preliminary Assessments

4.3.1 Background, and NER requirements

Key changes to the SSIAG requirements relevant to Preliminary Assessments include:

- The Preliminary Assessment is intended to determine whether there is a general system strength impact.
- For the purposes of determining the basis of a system strength charge, the Preliminary Assessment must also deliver an estimate of the magnitude of the general system strength impact (or SSQ) and the SSLF calculation[26]. This issue and associated options are discussed in Section 4.6.
- The Preliminary Assessment methodology must use a simple isolated model[27].

[26] See New clause 4.6.6(b)(1)(i).

[27] See New clause 4.6.6(b)(1A).

4.3.2 Key issues

Issue 1 Preliminary Assessment based on SMIB EMT-type Models

New clause 4.6.6(b)(1A) requires the Preliminary Assessment to be carried out using a SMIB model (as an example of a simple isolated model).

The purpose of the SMIB PSCAD™/EMTDC™ studies during the Preliminary Assessment is intended to confirm:

- Stability at the proposed minimum SCR of the Applicant's plant.
- SCR withstand capability which is to be used in assessing the SSQ.
- The amount of charge for fee paying applicants.
- Whether investment may be required by the Applicant to meet the minimum SCR standard.

Key considerations for SCR capability assessments using SMIB models are:

- An EMT-type (PSCAD™/EMTDC™) SMIB model is required for this assessment.
- Plant SCR capability will be dependent on the inverter/control system settings, technology and its limitations.
- SMIB network representation and its limitations.
- Aggregation methodology of the reticulation system.

Consultation questions

31. Should there be an engineering safety margin applied to the SCR withstand capability calculation considering limitations associated with SMIB based evaluation?
32. Are there any other issues relevant to the Preliminary Assessment methodology that AEMO ought to take into account?

4.4 Proposed methodology for Full Assessments

4.4.1 Background, and NER requirements

The Full Assessment is carried out during the assessment of a connection application or plant alteration submission if the Preliminary Assessment indicated that the relevant connection or alteration would have an adverse system strength impact.

4.4.2 Key issues

Issue 1 Timing of Full Assessment

Where required, a Full Assessment is to be conducted after receiving a connection application, which must include a proposed SSRS unless the Applicant intends to fund SSCW or has elected to pay the system strength service charge. Section 3.3 of the current SSIAG includes guidance for Connecting NSPs on the timing for commencement of a Full Assessment, which AEMO intends to revisit. The Full Assessment may be an iterative or multi-part process, and there are interdependencies with the acceptance of suitable models and negotiated access standard proposals. AEMO therefore seeks feedback on whether the SSIAG should be amended to clearly outline the information and resources the Connecting NSP needs to both commence and complete the Full Assessment. For example, the adequacy of plant settings, fault ride through compliance assessment and its impact during unbalanced faults cannot be undertaken with RMS standalone models. To address this, EMTP/PSCAD modelling is presently being applied. These performance aspects must be captured before an adequate performance standard for NER S5.2.5.5 can be confirmed related to design, effectiveness and limitations of positive and negative sequence current components and resulting unbalanced voltage impact.

Issue 2 Definition of committed projects for Full Assessment

The current SSIAG specify when current generation and network service facility projects must be considered to be 'committed'. Only 'committed' projects are considered in the system strength impact assessment of a subject connection project.

Consistent with the Amending Rule, AEMO will expand this definition to cover relevant load projects. AEMO also seeks general feedback on the 'committed' criteria in the SSIAG. In particular, AEMO is seeking to better address 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.
- Already '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.

Issue 3 System strength remediation

Section 6 of the existing SSIAG provides guidance on potential options for SSCW and SSRS. This will require review to ensure the options are consistent with full remediation of the general system strength impact of a connection, assuming no contribution from any system strength services.

4.4.3 Proposed option(s)

Issue 1 Timing of Full Assessment

The NER envisage that a Full Assessment commences once a relevant application to connect, or a proposal to alter relevant plant, and SSRS (if one is being proposed), is submitted. However, the FIA and the access standards assessment have critical interdependencies. AEMO therefore proposes to revise the existing SSIAG section 3.3 to confirm that a Full Assessment should be completed prior to the demonstration and acceptance of negotiated access standards under NER 5.3.4A.

Issue 2 Definition of committed projects for Full Assessment

AEMO proposes that:

- Committed projects, to be taken into account in system strength impact assessments, should have reached the stage at which performance standards have been approved, with AEMO's advice having been issued to the Connecting NSPs (that is, removing the requirement for a connection offer to have been issued).
- Any notified proposal to change the project size, Original Equipment Manufacturer (OEM), or equipment design of a previously committed project, such that the model becomes unrepresentative, would revert the status of the project to uncommitted:

- As indicated earlier, material changes may include changes in project size or OEM.
- Non material changes may include:
  - Updated system planning and design data to account for finalisation of electrical balance of plant (for example, small change in transformer impedance, cable losses).
  - Changes in power plant controller (PPC) plant parameters used for regulation purposes.

Issue 3 System strength remediation

AEMO proposes to review section 6 of the SSIAG to clarify that:

- The mitigation measures – whether SSCW or SSRS – should fully remediate the assessed general system strength impact.
- Inter-trip schemes and dispatch constraints cannot be applied to address a reduction in AFL.

Consultation questions

33. What criteria should be applied to determine whether a project is classified as a committed project for Full Assessment purposes? Why?
34. How and when is it appropriate to include future network augmentations (new transmission upgrades, configuration changes, considered projects, system strength remediation upgrades etc.) into the Full Assessment? Why?
35. Are there any other issues relevant to the Full Assessment methodology that AEMO ought to take into account?

4.5 Proposed methodology for Stability Assessment

4.5.1 Background, and NER requirements

Under the Amending Rule, for Applicants who elect to pay the system strength charge, the Connecting NSP will need to carry out a Stability Assessment using a methodology to be set out in the SSIAG[28].

The Stability Assessment methodology is a new requirement for the SSIAG[29].

4.5.2 Key issues

Issue 1 Scope of Stability Assessment

The purpose of the Stability Assessment as set out in new clause 5.3.4B(a2)(4) is to verify the stability of the Applicant's plant. The Final Determination confirms[30] that the Stability Assessment requires wide-area EMT modelling to map power electronic converter interactions with the power system.

[28] New clause 5.3.4B(a2)(4) of the NER.

[29] Under new clause 4.6.6(a)(8).

[30] AEMC, Efficient management of system strength on the power system, Rule determination, 21 October 2021, pages 26, 170, 172.

Issue 2 Timing for Stability Assessment

The timing of commencement and completion of the Stability Assessment (after an Applicant elects to pay the system strength charge) is an important consideration, particularly in relation to the assessment of relevant access standards proposed under NER 5.3.4A. Under the Amending Rule, the Connecting NSP and AEMO must take into account the performance required to be provided by the SSSP at the relevant SSN for the Applicant to meet the proposed standards. On that basis, the Stability Assessment would need to be finalised (with the connection demonstrating stable operation) before the Connecting NSP and AEMO could accept any negotiated access standards that are potentially affected by the level of system strength.

Issue 3 Consultation with AEMO

While the Amending Rule does not require consultation with AEMO on the Stability Assessment results, AEMO considers that it would be appropriate for AEMO to review those results to minimise the risk of issues being identified at a later stage.

Issue 4 Consequences of Plant Instability

It is also necessary to consider what happens if the Connecting NSP is unable to verify plant stability at the conclusion of the Stability Assessment.

4.5.3 Proposed option(s)

Issue 1 Scope of Stability Assessment

A potential Stability Assessment scope is provided below for consultation. AEMO is seeking detailed input to define the Stability Assessment, including the range of analysis and outcomes.

Potential Stability Assessment Scope (example only)

The Stability Assessment is a subset of power system analysis focused on the efficacy of system strength services in ensuring stable voltage waveform for the operation of power systems with power electronic interfaced plants (generators, loads and/or transmission/distribution devices). 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), whereby detailed assessment of the compliance of the plant is reserved for proposed performance standard due diligence assessments. 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.

A Stability Assessment does not consider detailed compliance assessment for plant performance during a fault, which relates to compliance and design aspects (subject to detailed assessment) for the plant itself, which may require their own solutions. Examples of potential solutions include the installation of dynamic reactive plant, synchronous condensers and capacitor banks; control coordination and so on. These internal plant design matters are not expected to be remediated by the SSSP.

Figure 2 shows an example of a fictitious network whereby system strength services are utilised to support operation and voltage waveform stability of many dependent grid following IBRs (loads and generation) subject to power system contingencies.

Figures 3 and 4 are presented for indicative purposes to illustrate the proposed methodology for the Stability Assessment concerned with voltage waveform stability. They show an example of the NEM power system response to a contingency event and the impact of implementing a system strength solution. These figures are particularly focused on the technical time domains that differentiate the detailed assessment (during the fault) of relevant access standards from a Stability Assessment (after the fault). The period of interest for the Stability Assessment commences immediately following the contingency event. Issues with plant performance during the event will need to be addressed by the Applicant during the connections process. Steady state performance is assessed in the period prior to a contingency.

Figure 2 High-level illustration of system strength services, and provision of system strength to various IBR subject to system contingencies

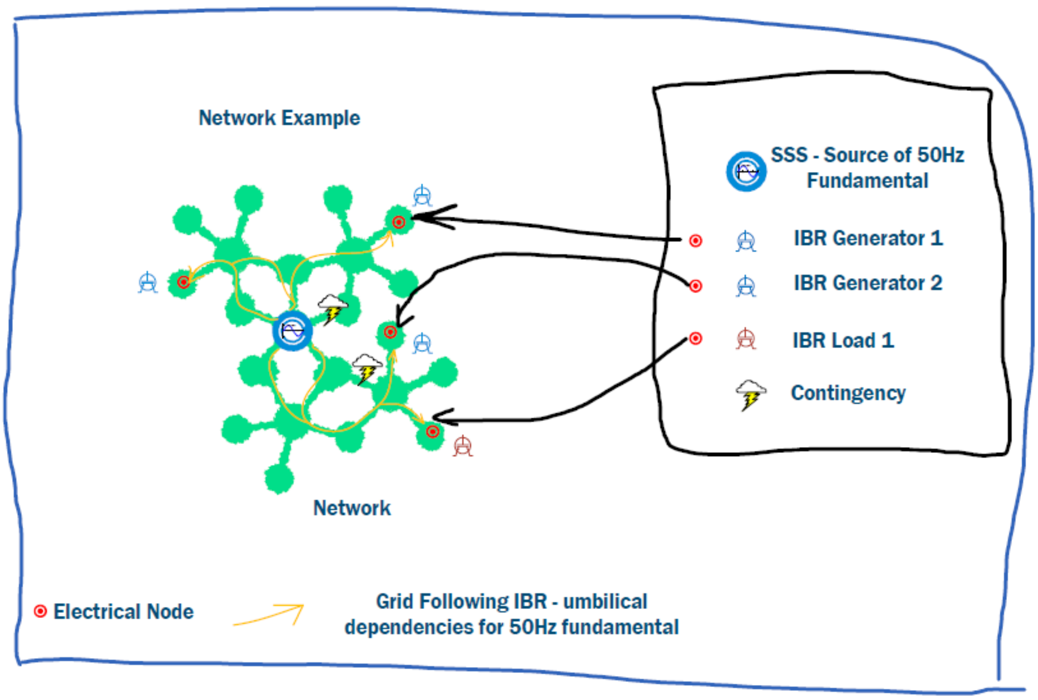


Figure 3 Example of unstable voltage waveform following contingency event

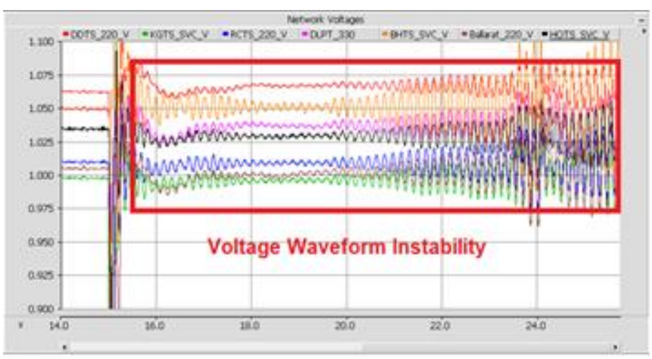


Figure 4 Example of system strength services (effectiveness) – voltage waveform stability evaluation in the post contingent period

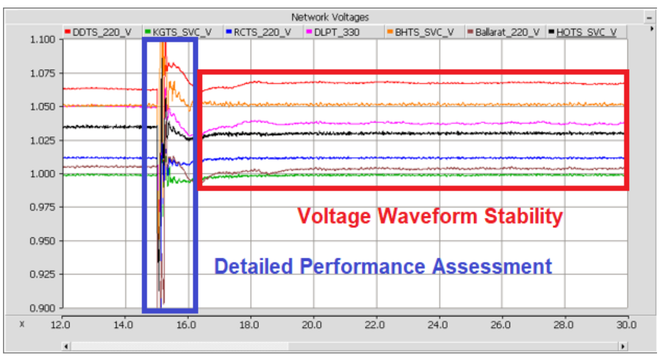
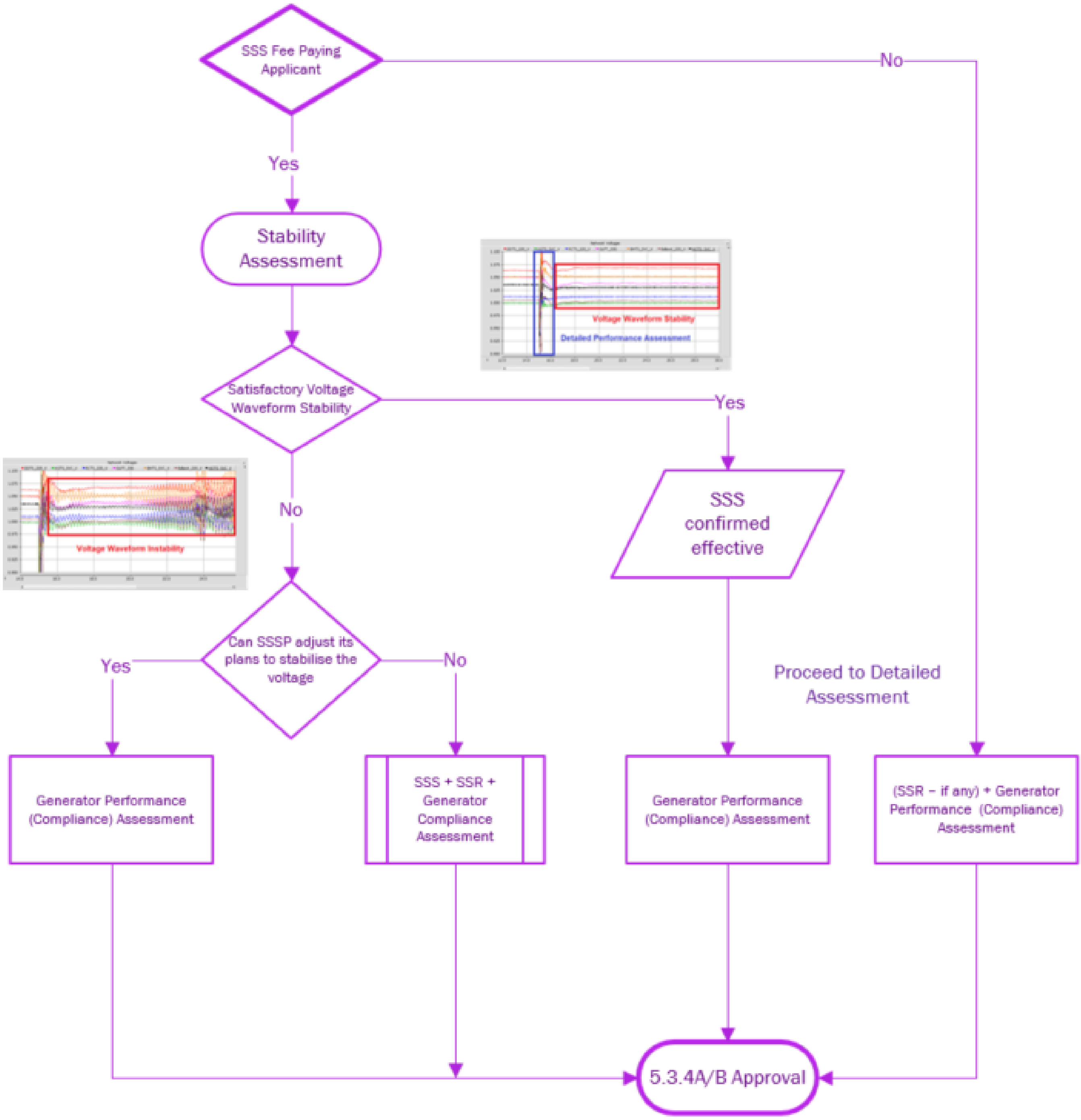


Figure 5 provides an example flowchart of the Stability Assessment process.

Figure 5 System stability process flowchart



Issue 2 Timing of Stability Assessment

AEMO proposes to specify in the SSIAG the interdependencies that could affect the commencement and completion of a Stability Assessment. This includes any assumptions, technical inputs and relevant negotiated access standards that will need to be considered as part of the Stability Assessment.

Issue 3 Consultation with AEMO

AEMO proposes (consistent with NER clause 5.14.4) that Connecting NSPs consult with AEMO on the results of a Stability Assessment, providing sufficient information for AEMO to verify the results.

Issue 4 Consequences of plant instability

If a Connecting NSP cannot verify plant stability following the completion of a Stability Assessment, the resulting actions will depend on the reasons for the instability. As the Final Determination points out[31], instability issues created by insufficient system strength would be for the SSSP to use reasonable endeavours to resolve, if the deficiency results from not meeting the standard for AEMO's forecast level of IBR connections. In any event, plant stability needs to be demonstrated in conjunction with the proposed access standards. Any 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 system strength services are available.

Consultation questions

36. Is the proposed scope of a Stability Assessment appropriate?
37. Are there any studies, contingencies, and evaluations that should, or should not, be part of a Stability Assessment? Why?
38. What study assumptions could be recommended to ensure there is no "free rider" situation for (system strength services) non-paying Applicants?
39. Are there any other issues relevant to the Stability Assessment methodology that AEMO ought to take into account?

4.6 Guidance on the calculation of SSLF

4.6.1 Background, and NER requirements

The Amending Rule requires the SSIAG to include the methodology to be used by Connecting NSPs when calculating an SSLF, which must be representative of the impedance between the connection point and the applicable SSN and must use AFL as the basis for the methodology. 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[32].

4.6.2 Key issues

Issue 1 Network model assumptions

The treatment of committed, anticipated and proposed projects relating to network augmentations (e.g. transmission upgrades and SSS) could affect fault level calculations and hence impact SSLF calculations.

[31] On page 26.

[32] See new clauses 4.6.6(a)(1) and 4.6.6(b)(9) & (10).

Issue 2 SSLF calculation methodology

There may be circumstances where an SSLF is not reasonably able to be determined or would be manifestly excessive, although joint planning should minimise this possibility. The examples provided at the end of new clause 4.6.6(b)(10) are:

- Where the SSLF tends to infinity (and therefore is not reasonably able to be determined).
- Where the SSLF would result in a charge that could not reasonably be expected to be paid in preference to a SSRS or SSCW (and therefore could be said to be manifestly excessive).

4.6.3 Proposed options

Issue 1 Network model assumptions

AEMO suggests the Connecting NSP's calculation should be based on the following assumptions:

- Committed or anticipated network augmentations to be modelled in target year.
- Existing SSS to be modelled in-service. All other services to be modelled out of service.
- Any considered project proposed as an SSS, built for the purpose of providing a SSS, to be modelled in the target year.

Issue 2 SSLF Calculation Methodology

The SSLF will be calculated using the difference between the AFL at the connection point and the SSN, taking into account impedance (i.e. electrical distance) between the two locations as follows:

- SSLF is the ratio of the additional fault level at SSN required to restore the available fault level at the Applicant's point of connection.
- For connections sharing the same point as the SSN, the ratio will be unity.

AEMO has not, at this stage, identified any additional circumstances for the application of clause 4.6.6(b)(10) (when no SSLF should be calculated) other than the examples given in that clause. However, there could be challenges associated with other system driven limitations, such as earth fault limitations, or large IBR plant, where scales of system strength solutions are more optimal locally rather than via SSN.

A determination that an SSLF would result in a 'manifestly excessive' system strength charge compared with the expected cost of self-remediation via SSCW or a SSRS cannot be marginal. It must be evident that no reasonable Applicant would opt to pay the system strength charge in any circumstances, such that it is not worth doing the detailed SSFL calculation. AEMO seeks feedback on the considerations Applicants would take into account in making this decision, as well as the factors that are likely to result in a very onerous SSLF.

Consultation questions

40. Are there any other issues relevant to the calculation of SSLF that AEMO ought to take into account?

4.7 Guidance on the calculation of AFL

4.7.1 Background, and NER requirements

The SSIAG must include a definition of AFLs at SSNs, including for the purposes of forecasts under clause 5.20C.3(f)(3) and for the calculation of the SSLF for a connection point[33].

AEMO has defined the AFL in the current SSIAG as:

> *The actual Synchronous Three Phase Fault Level minus the required Synchronous Three Phase Fault Level specified by an Asynchronous Generator.*

The SSIAG further defines Synchronous Three Phase Fault Level as:

> *The three phase fault level comprising synchronous machines only, in MVA.*

4.7.2 Key issues

AFL provides a proxy for the system strength at a connection point. It represents the impact that an IBR connection imposes on the three phase fault level at its connection point. It is dependent on the plant characteristics and modelled network configuration. To get an accurate representation of AFL, these inputs need to be well defined.

The definition of AFL in the SSIAG must be amended to incorporate grid forming and grid following generators, as well as relevant loads. Similarly, the definition of Synchronous Three Phase Fault Level must be updated to include any contribution from plants providing SSS, including synchronous condensers.

4.7.3 Proposed option(s)

AEMO proposes the following methodology to redefine AFL:

$$\mathrm{AFL(MVA)} = \mathrm{S_{SG}} - \mathrm{k} * \alpha * \mathrm{ES_{rated}} * \mathrm{SCR_{\_withstand}}$$

k: Technology coefficient, where:

k = 0 when grid forming IBR (not used for SSS)

k = -1 when grid forming IBR is used for SSS

k = 1 for grid following IBR and HVDC links (for grid forming HVDC, the k factor shall be decided on a case-by-case basis in consultations with OEM and AEMO).

α: Scaling or a reduction coefficient

S_{SG}: The fault level calculated with only Synchronous Generators (SG) connected to the network, including any SSS provided by SSSPs. Guideline will specify methodology for calculation of short circuit current including assumptions for prefault conditions, e.g. IEC60909, IEEE/ANSI/ASCC.

$SCR_{\_withstand}$: Declared withstanding SCR at the PoC for which the plant can stably operate.

ES_{rated}: Effective rated MVA for the plant being evaluated (or as otherwise agreed by AEMO, NSP and the Applicant considering specific circumstances), where:

[33] See New clause 4.6.6(a)(2).

For active power generating system, $ES_{rated} = P_{rated}(MW)$;

For IBR active power load, $ES_{rated} = P_{rated}(MW)$;

For IBR reactive power load, $ES_{rated} = Q_{rated}(MVar)$;

For transmission connected dynamic reactive plant, $ES_{rated} = Q_{rated}(MVAr)$;

For HVDC systems, $ES_{rated} = P_{rated}(MW)$

For a generating system composed of active power component and dynamic reactive power component, $ES_{rated} = P_{rated}(MW)$)

P_{rated}: For active power generating system, $P_{rated}(MW) = MVA$.

Consultation questions

41. What is the preferred methodology and pre-fault condition assumption for calculation of short circuit currents? Why?
42. Are there any other issues relevant to the calculation of AFL that AEMO ought to take into account?

4.8 Guidance on demonstrating compliance with new minimum access standards

4.8.1 Background, and NER requirements

The Amending Rule introduces SCR minimum access standards for IBR, including asynchronous generating units[34], inverter based loads[35], and market network service facilities[36].

- For high SCR connections (e.g. 6 and higher) it is plausible that the SCR may change over time as system conditions change. The Amending Rule requires connecting plants to meet the minimum access standard SCR of 3.0. At this stage, AEMO is not proposing that NSPs undertake unnecessary assessments at SCR of 3 for the original connection when this is not applicable. If the need arises to demonstrate compliance at SCR of 3 at a later point in time, this can be dealt with via change processes already established in the NER.
- For low SCR connections, Applicants must meet SCR of 3.0 as per the Amending Rule.

The minimum access standards themselves are expressed in substantially the same terms for all relevant types of IBR, but there are specific provisions for asynchronous generating units that permit additional ways of achieving compliance. The new minimum access standards for asynchronous generation, IBL and market network service facilities are set out in turn below.

[34] See New clause S5.2.5.15.

[35] See New clause S5.3.11.

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

Asynchronous generating units

New clause S5.2.5.15(b) to (f):

(b) The *minimum access standard* is a *generating system* comprised of *asynchronous generating units* must have *plant* capability sufficient to operate stably and remain *connected* at a *short circuit ratio* of 3.0, assessed in accordance with the methodology prescribed in the *system strength impact assessment guidelines*.

(c) The *performance standards* in the *connection agreement* must record:

(1) the agreed value of the *short circuit ratio* which must be the minimum of 3.0 and the value at which the *generating system* has *plant* capability sufficient to operate stably and remain *connected*;

(2) the *rated active power* used to calculate the value of the *short circuit ratio*; and

(3) any arrangements agreed under paragraph (e),

(d) The *plant* capability [recorded in the performance standards] may be demonstrated with any appropriate *control system* and/or *protection system* settings. The settings used may be different to the setting required for compliance with other *performance standards* established under this clause S5.2.5.

(e) If the *generating system* is not capable of meeting the *minimum access standard*, the *Generator* may, if agreed by *AEMO*, the *Network Service Provider* and the *System Strength Service Provider*, achieve compliance by demonstrating it has:

(1) in accordance with paragraph (f), legally binding commitments to make additional investment in its *plant* or for the supply to it of services to remedy, at its cost, the shortfall in capability, either on *connection* or in agreed circumstances (such as the occurrence of an event that results in a change to the *three phase fault level* at the *connection point*); together with

(2) operational arrangements agreed with the *Network Service Provider* that apply when the investment or services referred to in subparagraph (1) have not yet been made or are not available.

(f) For paragraph (e)(1) the *Generator* may:

(1) reach agreement with the *Network Service Provider* for the *Generator* to undertake investment in its *plant* to achieve *plant* capability sufficient to operate stably and remain *connected* at a *short circuit ratio* of 3.0; or

(2) procure from the *Network Service Provider*, the *System Strength Service Provider* or another *Registered Participant*, services to enable the *generating system* to operate stably and remain *connected* at a *short circuit ratio* of 3.0 but calculated using a *three phase fault level* at the *connection point* that excludes any contribution from the facilities providing the service.

Inverter-based loads

New clause S5.3.11(b) to (d):

(b) The *minimum access standard* is electrical *plant* must have *plant* capability sufficient to operate stably and remain *connected* at a *short circuit ratio* of 3.0, assessed in accordance with the methodology prescribed in the *system strength impact assessment guidelines*.

(c) The *performance standards* in the *connection agreement* must record:

(1) the agreed value of the *short circuit ratio* which must be the minimum of 3.0 and the value at which the *plant* has *plant* capability sufficient to operate stably and remain *connected*;

(2) the *maximum demand* used to calculate the agreed value.

(d) For paragraphs (b) and (c), the *plant* capability may be demonstrated with any appropriate *control system* and/or *protection system* settings. The settings used may be different to the setting required for compliance with other *performance standards* established under this schedule.

Market Network Service Facilities

New clause S5.3a.7(b) to (d):

(b) The *minimum access standard* is an installation comprised of electrical *plant* must have *plant* capability sufficient to operate stably and remain *connected* at a *short circuit ratio* of 3.0, assessed in accordance with the methodology prescribed in the *system strength impact assessment guidelines*.

(c) The *performance standards* in the *connection agreement* must record:

(1) the agreed value of the *short circuit ratio* which must be the minimum of 3.0 and the value at which the *plant* has *plant* capability sufficient to operate stably and remain *connected*;

(2) the *maximum demand* used to calculate the agreed value.

(d) For paragraphs (b) and (c), the *plant* capability may be demonstrated with any appropriate *control system* and/or *protection system* settings. The settings used may be different to the setting required for compliance with other *performance standards* established under this schedule.

Consultation questions

43. For (high SCR) connections where SCR may change over time, what would be a sensible process to trigger the need for GPS assessment or confirmation of compliance at SCR of 3.0?
44. Are there any other issues AEMO should take into account when considering compliance of affected plant?

5 Power System Stability Guidelines

5.1 Background and NER requirements

Under NER clause 4.3.4(h) and (i), AEMO is required to develop and publish guidelines for power system stability, to include the policies governing power system stability so as to facilitate the operation of the power system within stable limits. The current version of the PSSG was published in 2012.

5.2 Key issue

The PSSG do not explicitly cover system strength and how it relates to power system stability (and by extension security). The PSSG should be consistent with the new system strength framework.

5.3 Proposed option

AEMO proposes to update the PSSG in the following respects:

- To include a definition of system strength in line with the NER and this consultation, specifically in Appendix 1.
- To ensure the application of the PSSG extends to MNSPs and registered customers in respect of IBR to which the new system strength framework applies.

Consultation questions

45. Is it necessary to include the definition of system strength in the PSSG?
46. Are there any other areas in the PSSG that need to be updated for system strength?
47. Is there any other section of the PSSG that needs to be updated or reviewed?

Glossary

Terms defined in the NER have the same meanings in this Issues Paper. 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 Issues Paper are defined in this table.

Term or acronym	Meaning
AEMC	Australian Energy Market Commission
AFL	*available fault level*
Amending Rule	National Electricity Amendment (Efficient Management of System Strength on the Power System) Rule 2021
Applicant	Any of the following: • *Connection Applicant* under new rule 5.3 of the NER. • *Generator* proposing to alter *generating plant* to which clause 5.3.9 applies. • *Network User* or MNSP proposing to alter *connected plant* that includes LIBR, where new clause 5.3.12 applies.
CIGRE TB 671	CIGRE Technical Brochure TB 671 entitled “Connection of Wind Farms to Weak AC Networks”
Committed	As defined in the current SSIAG
Connecting NSP	The *Network Service Provider* responsible for responding under NER Chapter 5 to an enquiry or *application to connect*, or a proposal to alter a *generating system*.
CWO	Central-West Orana (New South Wales)
DNSP	*Distribution Network Service Provider*
DPV	Distributed photovoltaics
EMT	Electromagnetic transient.
Existing clause [number]	A clause from the NER prior to its amendment by the Amending Rule.
FAT	Factory acceptance test.
Final Determination	AEMC, Efficient management of system strength on the power system, Rule determination, 21 October 2021, at https://www.aemc.gov.au/sites/default/files/2021-10/ERC0300%20-%20Final%20determination_for%20publication.pdf
Full Assessment	The assessment referred to in new clause 4.6.6(b)(1)(ii)
HIL	Hardware-in-the-loop
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 clause 5.3.4B(f)(3)
SCR method	Minimum SCR method: A screening method based on ‘available fault level’ method described in Appendix A of the SSIAG and consistent with that documented in CIGRE TB 671.
MNSP	*Market Network Service Provider*
NEM	*National Electricity Market*
NER	National Electricity Rules
New clause/rule [number]	A clause or rule from the NER as amended by the Amending Rule
NSP	*Network Service Provider*
OEM	Original equipment manufacturer
PHIL	Power hardware-in-the-loop
PLL	Phase-Locked-Loop

Term or acronym	Meaning
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
REZ	Renewable energy zone
RL	Resistive and Inductive
SCR	*short circuit ratio*
SMIB	Single machine infinite bus
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)
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)
System Strength Standard Specification	The system strength standard specification referred to in new clause S5.1.14(a)
TNSP	*Transmission Network Service Provider*