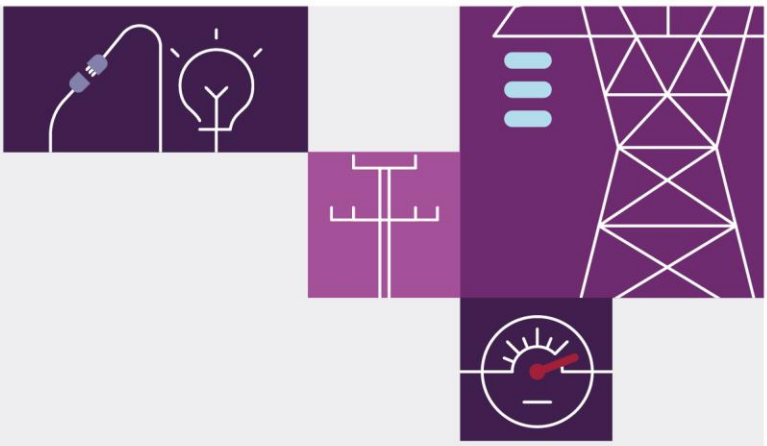
AEMO review of technical requirements for connection

October 2022

Approach Paper

Pursuant to clause 5.2.6A of the *National Electricity Rules*



Important notice

Purpose

AEMO is required to undertake a periodic review of technical requirements under clause 5.2.6A(a) of the National Electricity Rules, which commences with the publication of this Approach Paper.

This publication has been prepared by AEMO using information available as at 1 September 2022. Information made available after this date may have been included in this publication where practical.

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Version control

Version	Release date	Changes
1	12/10/2022	Initial version.

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Executive summary

Under clause 5.2.6A(a) of the National Electricity Rules (NER), AEMO must conduct a review of some or all of the technical requirements set out in Schedules 5.2, 5.3 and 5.3a of the NER at least once in every five-year period to assess whether those requirements should be amended. In this first review since the introduction of clause 5.2.6A[1], AEMO has focused on the technical requirements specified as access standards in each of the Schedules.

In conducting this review, AEMO is required to have regard to: (1) the national electricity objective (NEO); (2) the need to achieve and maintain power system security; (3) changes in power system conditions; and (4) changes in technology and capabilities of facilities and plant.

This Paper covers:

- The scope of the review, including the nature and extent of the issues to be reviewed;
- The technical requirements to be consulted on[2];
- The timing for the draft report; and
- Next steps involved in this AEMO review.

Following the finalisation of the review, AEMO may recommend NER amendments by way of a rule change request to the Australian Energy Market Commission (AEMC).

The Australian power system and the broader Australian economy are in a period of rapid transition, which has far-reaching impacts on operation of the power system. The changes encompass the composition of the power system's generation fleet, the nature of its loads, the technologies employed, and how the power system is operated.

AEMO's approach to this review aims to support the energy transition to a reliable power system based on renewable energy sources, while ensuring that the future power system can be operated securely and is sufficiently resilient to extreme conditions.

Key considerations

Key considerations concerning the review of NER Schedules 5.2, 5.3 and 5.3a include:

- Streamlining the technical standards for generating systems and integrated resource systems, to manage the high volume of connections required for the energy transition, without compromising power system security, by:
  - Aligning access standards with best technical performance of the power system;
  - Clarifying some clauses to promote certainty and reduce associated negotiation time;
  - Removing unnecessary technology-specific or ambiguous and out-dated wording; and
  - Considering whether some low value elements could be removed or refocused.

[1] AEMC. 2018. 'Generator Technical Performance Standards' Rule change (ref. ERC0222) 27 September 2018, at https://www.aemc.gov.au/rule-changes/generator-technical-performance-standards.

[2] Processes related to the Access Standards framework under the NER are not covered by this review that is specific to S5.2, S5.3 and S5.3a.

- Supporting the integration of grid-forming inverters in the technical standards by:
  - Removing any identified impediments to their connection;
  - Facilitating their potential contributions to improved technical outcomes for the power system; and
  - Considering what technical standards would be required from grid-forming inverters in a 100% renewable generation power system.
- Reviewing the connection standards for large loads, considering the anticipated growth of large converter-based loads (such as large hydrogen hubs) as part of the energy transition, and the trend towards customer provision of frequency control ancillary services (FCAS).
- Applying technical standards to plant type, rather than any registration category, in the context of this review by:
  - Reorienting NER Schedule 5.2 to consider generating systems, production units[3] and synchronous condensers; and
  - Reorienting Schedule 5.3a to direct current (DC) converters and DC links rather than the 'Market Network Service Providers' (MNSP) registration category.
- Refreshing the technical standards for DC interconnections and considering aligning them with bi-directional unit standards.

Supporting the energy transition through improved technical standards

The 2022 *Integrated System Plan* (ISP) anticipates an acceleration of generation connections to more than 4 gigawatts (GW) of new connections per year[4] between now and 2030, compared with 2.39 GW in 2020-21[5]. Considering that there are finite resources for connections, the efficiency of connecting new generation will be an important factor in meeting expectations for the energy transition.

Changes to technical standards can contribute to efficiency improvements, both in design and negotiation, and simultaneously improve outcomes for the power system where technical standards are oriented to achieving the optimal power system performance. This review will consider removing or qualifying requirements that may not add material value and ensuring that technical standards are commensurate with the impact of the plant on the power system. Removing unnecessary technology-specific language and concepts can also improve efficiency of the connection process by avoiding the need for complex, time-consuming negotiations when new technology challenges previous assumptions about plant behaviour.

Integrating grid-forming inverters in technical standards

Grid-forming inverter technology is likely to be critically important to the energy transition, but the technology is still rapidly developing and industry has limited experience in its application. AEMO proposes, for this review, to focus on changes to the technical standards that can be expected to facilitate the connection of grid-forming inverter technology and the beneficial capabilities they might provide.

[3] Production unit is a term adopted in the Integrating Storage Systems into the NEM Rule. It refers to *plant* used in the production of electricity and all related equipment essential to its functioning as a single entity, and includes generating units and bi-directional units.

[4] Considering the ISP Step Change scenario which includes an additional 28 GW of grid-scale wind and solar and 4.6 GW of grid-scale storage. The ISP is available at https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp.

[5] As reported in the AEMC Reliability Panel's '2021 Annual Market Performance Report' (AMPR), based on AEMO generator survey data.

As flagged in its White Paper on 'Application of Advanced Grid-scale Inverters in the NEM'[6], AEMO is developing a voluntary technical specification for grid-forming inverters in parallel with this review. If work on the voluntary technical specification identifies critical additional technical standards, then those can be included in the current review. Otherwise, AEMO will work with stakeholders to identify appropriate standards.

Application of technical requirements to DC links and synchronous condensers

As presently worded, Schedule 5.3a applies to an MNSP rather than regulated DC converters or DC links more broadly, and potentially including back-to-back converters and DC link within a single region. Similarly, NER Schedule 5.2 applies to Generators (and, in future, Integrated Resource Providers[7]), but does not contemplate a synchronous condenser is connected to the NEM as a standalone device.

The impact of a DC link or synchronous condenser on the power system operation is a function of the plant design and operation, independent of the person connecting the plant. Consequently, AEMO will consider how the technical standards in NER Schedules 5.2 and 5.3a need to be amended or expanded to better incorporate the impact and capability of these types of plant, and how the application of those requirements can be decoupled from any particular registration category.

DC link technical standards

In the past 15 years since NER Schedule 5.3a was last reviewed, there have been significant developments in DC converter technology.

Modern DC converter technology typically has capabilities similar to inverters, and converters behave on the power system in a manner similar to bi-directional inverters, but the technical standards of Schedule 5.3a are generally lower and less detailed than Schedule 5.2. This review will consider the extent to which there is value in harmonising the requirements for DC converters under Schedule 5.3a with requirements for bi-directional units in Schedule 5.2.

Review of technical standards for loads

For loads, there is a trend, anticipated to continue, toward increased use of electronic and converter-front end loads. Some very large converter-based loads are already seeking to connect to the NEM, particularly large hydrogen production facilities. The energy transition is also likely to see large numbers of electric vehicle chargers connect to the NEM.

Load connections comprising large numbers of hydrogen electrolysers, for example, could have material impact on voltage and frequency stability, when tripped. Control systems of converter-based loads may interact with those of other connected plant in the network. This review will consider whether anticipated load developments warrant changes to technical standards for loads considering potential power system security impacts.

In addition, it is becoming more common for loads to participate in FCAS. The review will consider whether there is value in additional technical standards for loads that participate in FCAS.

[6] At https://aemo.com.au/newsroom/news-updates/application-of-advanced-inverters.

[7] Following implementation of the 'Integrating energy storage systems into the NEM' Rule change. At https://www.aemc.gov.au/rule-changes/integrating-energy-storage-systems-nem.

Timeline for the review

AEMO sees merit in targeting a fast-track rule change for this review. To enable this potential pathway, as set out in the National Electricity Law (NEL), AEMO would need to consult with industry on the draft rules that would be submitted to the AEMC. Considering the technical nature of the review, AEMO is considering an additional consultation stage. AEMO proposes to present the concepts and associated reasoning for changes in the draft report, and following consultation of the draft report, conduct a second consultation incorporating feedback and draft rules. This would enable stakeholders to provide feedback on the proposed rules drafting, which can then be incorporated into the final report. All material (including submissions) will be published on the AEMO website.

Key dates

- Publication of the draft report by 28 February 2023
- Consultation on the draft report closes on 16 April 2023
- Proposed consultation on rules drafting in Quarter 2 2023
- Consultation on rules drafting closes in Quarter 3 2023
- Final report in Quarter 4 2023.

Contents

1 Background

The National Electricity Rules (NER) detail the technical requirements that govern the connection of generating systems to the national grid and the capabilities they must deliver to support power system security. They also set out the process allowing National Electricity Market (NEM) participants to negotiate those standards.

In September 2017, AEMO submitted a rule change request to the Australian Energy Market Commission (AEMC) that, commencing from 5 October 2018[8], resulted in significant changes to the NEM technical performance standards for Generators and the negotiation process. Relevantly, this rule change also resulted in the obligation on AEMO to conduct a periodic review of those standards and recommend any changes that may result in a rule change proposal.

2 Scope of the review

2.1 Rule obligation

Clause 5.2.6A(a) of the NER stipulates that, at least once in every five-year period (commencing from October 2018), AEMO must conduct a review of some or all of the technical requirements set out in the following NER Schedules:

- 5.2 – Conditions for Connection of Generators;
- 5.3 – Conditions for Connection of Customers; and
- 5.3a – Conditions for connection of Market Network Services.

The purpose of such review is to assess whether these requirements should be amended, having regard to:

- The national electricity objective (NEO);
- The need to achieve and maintain power system security;
- Changes in power system conditions; and
- Changes in technology and capabilities of facilities and plant.

2.2 Issues for review include consideration of concurrent initiatives

To identify potential issues for this first review under clause 5.2.6A, AEMO conducted a scoping exercise that considered the relevant NER Schedules and criteria as well as relevant other matters including emerging issues and concurrent initiatives. Issues included in the review have been drawn from:

[8] AEMC. 2018. 'Generator Technical Performance Standards' Rule change (ref. ERC0222) 27 September 2018, at https://www.aemc.gov.au/rule-changes/generator-technical-performance-standards.

- AEMO connections and operations teams;
- Network Service Providers;
- Issues raised in Connections Reform Initiative (CRI) discussions;
- Issues raised during the Central West Orana Renewable Energy Zone (CWO REZ) access standards consultation; and
- Issues raised by individual stakeholders to AEMO.

AEMO has also briefed the Clean Energy Council, Energy Users Association, Australian Energy Council, Energy Networks Association, and the Reliability Panel on the proposed scope, and invited feedback on the scope.

AEMO has identified the following concurrent initiatives relevant to this review:

- A rule change process on 'Efficient reactive current access standards for inverter-based resources'[9], which is currently underway, and may address some of the key issues from the context of the minimum access standards under NER clause S5.2.5.5.
- The CRI, which was established in early 2021 with the aim of addressing industry concerns about increasing complexities and delay in connecting inverter-based resources (IBR) to the NEM[10] or making changes to those connections. It is expected to result in future NER amendments. Reforms are being explored by the CRI Leadership Group in the areas of: network access, covering existing and emerging technologies; original equipment manufacturer data and modelling; streamlined connection process; investment certainty in R1[11]; introducing battery energy storage systems (BESS) behind existing generation; and a defined process to introduce changes to AEMO guidelines.
- The NEM 'Engineering Framework', which aims to define the range of operational, technical requirements to prepare the NEM for future operating conditions including for 100% instantaneous penetration of renewables. It has identified various gaps between current and future operating conditions that have implications for technical requirements or standards[12]. Relevant initiatives include a review of treatment of grid--forming inverters in the connection process under the current NER technical requirements, and an initiative to develop a voluntary specification.
- The fast-paced development of REZs, especially in New South Wales, Victoria and Queensland, which should itself see that the current connections framework is changed or enhanced as necessary, by solutions that, among other things, will mitigate the challenges of integrating a high penetration of variable renewable energy within the NEM. The New South Wales REZ connections process included the development of mandatory access standards, which are intended to allow well-designed generating systems and bi-directional systems to connect to the REZ without negotiation. The consultation feedback received by Energy Corporation of New South Wales (EnergyCo) from stakeholders has provided useful input into this review of technical standards.

[9] At https://www.aemc.gov.au/rule-changes/efficient-management-system-strength-power-system.

[10] Refer to the 'Connections Reforms Roadmap' December 2021 at https://aemo.com.au/consultations/industry-forums-and-working-groups/list-of-industry-forums-and-working-groups/connections-reform-initiative, which identifies more than 100 potential improvements to the NEM connection process and experience.

[11] In this context, R1 refers to the period between the execution of a connection agreement and the registration of the plant.

[12] AEMO. 2021. NEM Engineering Framework - Initial Roadmap, December 2021, at https://aemo.com.au/en/initiatives/major-programs/engineering-framework. https://aemo.com.au/-/media/files/initiatives/engineering-framework/2021/nem-engineering-framework-initial-roadmap.pdf.

- Significant changes to the system strength framework, following the 'Efficient management of system strength on the power system' rule change[13] (and associated changes to the 'System Strength Impact Assessment Guidelines'), which affect NER Schedule 5.2.
- The AEMC Reliability Panel Frequency Operating Standards Review 2022[14], which is considering, among other matters, the rate of change of frequency and frequency standards settings for contingency events, both of which may impact access standards requirements.
- Load and Grid Forming Working Groups to be established under the CRI Network Access Workstream, which will consider the technical requirements for large flexible load and grid forming connections.

The technical requirements that AEMO intends to review are set out in the next section of this Approach Paper and are focused on aspects of the access standards set out in the three specified NER Schedules. To the extent that AEMO, through its public consultation with stakeholders during the next phase of this review, identifies other relevant issues for review or important technical performance matters emerging in the NEM, these will also be considered and included as may be appropriate.

3 Technical requirements for review

3.1 Structural and general improvements

3.1.1 Balanced requirements to support the energy transition

The 2022 ISP anticipates an additional 28 GW of grid-scale wind and solar and 4.6 GW of grid-scale storage[15] capacity by 2030, compared with current levels. This is more than 4 GW of new connections per year, compared to an increase in grid-scale solar, wind and battery installation of 2.39 GW in 2020-21[16]. In addition, alterations to generation apply the same technical standards. Considering that there are finite resources for connections, the efficiency of connecting new generation will be an important factor in meeting expectations for the energy transition.

Changes to technical standards can contribute to efficiency improvements, both in design and negotiation, and simultaneously improve outcomes for the power system when access standards, especially automatic access standards and guidance clauses are oriented to achieving the optimal power system performance. This review will consider removing or qualifying requirements that may not add value while ensuring that technical standards requirements are commensurate with the impact of the plant on the power system.

There may be potential to reduce the technical standards for small generating systems or integrated resource systems, which in turn would reduce the time and resource requirements for connection and compliance assessments. However, this must be balanced against the aggregate impact of multiple small plant on the power system. In general, performance of the plant for system phenomena that are local in their impact may present

[13] At https://www.aemc.gov.au/rule-changes/efficient-management-system-strength-power-system.

[14] At https://www.aemc.gov.au/market-reviews-advice/review-frequency-operating-standard-2022.

[15] These ISP 'Step Change scenario' numbers include grid-scale battery and pumped storage. The scenario includes approximately 700 megawatts (MW) of additional hydro and gas-fired generation.

[16] As reported in the AEMC Reliability Panel's '2021 Annual Market Performance Report' (AMPR), based on AEMO generator survey data.

more potential for relaxation, whereas phenomena that affect a wide area are less amenable to technical standard relaxation.

Clarification of ambiguous requirements and materiality thresholds can also reduce the resources required for negotiation of access standards in some circumstances and promotes consistency across jurisdictions. Clarity of requirements must be balanced against retaining flexibility in the technical standards, because flexibility allows negotiation of appropriate standards in unusual circumstances, where engineering judgement is required.

Removing unnecessary technology-specific language and concepts can also improve efficiency of the connection process by avoiding the need for complex, time-consuming negotiations when new technology challenges previous assumptions about plant behaviour. However, this must also be balanced against technology-specific performance and limitations, where plant that would otherwise contribute positively to power system performance may be less capable in some specific aspects. In general, the preferred approach is for the technical standards to be outcome-focused, and technology-neutral, where possible.

3.1.2 Application of technical requirements for DC links and synchronous condensers

None of the schedules adequately captures the technical standards for DC links (including back-to-back converters and DC links within a single region) or synchronous condensers as plant types. Currently, the structure of the NER technical schedules limits the application of standards to facilities that are owned or operated by a participant in a particular registration category.

NER Schedule 5.3a was conceived for DC interconnectors, but is specifically linked to the MNSP registration category. In the NEM, a number of DC interconnections that were originally registered and operated to provide market network services have now converted to regulated networks, with only one registered MNSP now remaining. In the future other DC converters or DC links may be built which are also operated as regulated assets and may include back-to-back converters and DC links within a single region. The application of NER Schedule 5.1 (network performance requirements) is not a satisfactory alternative, as it does not capture the dynamic performance of DC converters.

Similarly, NER Schedule 5.2 applies to Generators (and, in future, Integrated Resource Providers[17]), but does not allow for the case where a synchronous condenser is connected to the NEM, as a standalone device, either by the NSP or another type of registered participant.

The impact of a DC link or synchronous condenser on the power system operation is a function of the plant design and operation irrespective of the person connecting the plant. Consequently, this review will consider how the technical standards in NER Schedules 5.2 and 5.3a need to be amended or expanded to better incorporate the impact and capability of these types of plant, and how the application of those requirements can be decoupled from any particular registration category.

3.2 Integrating grid-forming inverters

Grid-forming inverter technology is likely to be critically important to the energy transition, however the technology is still rapidly developing and industry has limited experience in its application. AEMO proposes, for this review, to focus on developing changes to facilitate connection of grid-forming inverters. This includes eliminating identified

[17] Following implementation of the 'Integrating storage systems into the NEM' rule. At https://www.aemc.gov.au/rule-changes/integrating-energy-storage-systems-nem.

impediments in the present technical standards to connection of grid-forming inverters, and ensuring that the standards facilitate (do not disincentivise) the potential contribution of grid-forming inverter capabilities to improved technical outcomes for the power system.

The rule change 'Efficient reactive current access standards for inverter-based resources'[18] may address some aspects of the NER S5.2.5.5 minimum access standards that add complexity to the connection of grid-forming inverters in the NEM. AEMO will continue to monitor and engage with the AEMC on this rule change. Changes to the associated automatic access standards will be considered in this review.

As flagged in its White Paper on 'Application of Advanced Grid-scale Inverters in the NEM'[19], AEMO is developing a voluntary technical specification for grid-forming inverters in parallel with this review. If work on the voluntary technical specification identifies critical additional technical standards, then those may be included in scope for the current review. Otherwise, AEMO will work with stakeholders to identify standards required to support the transition to a power system dominated by IBR.

3.3 Specific access standards

3.3.1 Schedule 5.2 – Conditions for connection of Generators

AEMO undertook a major review of NER Schedule 5.2 in 2018. Since 2018, the most significant new technical development has been the emergence of commercial options for grid-forming inverter technology. Review of Schedule 5.2 will consider changes to support the connection of grid-forming inverters as discussed in Section 3.2 and more general changes to improve the technical standards across all generating unit technologies:

- Refocusing standards, particularly automatic access standards, on the best outcomes for the power system;
- Correcting references to obsolete international standards or plant standards;
- Updating some oscillation detection and protection requirements; and
- Assisting with streamlining connections where this can be achieved through amendments to standards.

AEMO will also consider as part of this review any relevant matters emerging from concurrent reviews, including the AEMC review of the 'frequency operating standards'[20].

The issues that AEMO will review are set out in Appendix A1.1 to this Approach Paper.

3.3.2 Schedule 5.3 – Conditions for connection of Customers

For loads, there is a trend toward converter-front end loads. Some very large electronic and converter-based loads could soon connect to the NEM, particularly large hydrogen production facilities and data centres. Inverters utilised in hydrogen electrolysers may have similar technology and capabilities to grid-tied solar or BESS inverters.

Consideration needs to be given as to how these new IBR will impact the power system and whether any changes to customers' technical requirements or standards are required. Load connections comprising large numbers of hydrogen electrolysers could have material impact on voltage and frequency stability when tripped, and fast active

[18] At https://www.aemc.gov.au/rule-changes/efficient-reactive-current-access-standards-inverter-based-resources.

[19] At https://aemo.com.au/newsroom/news-updates/application-of-advanced-inverters.

[20] https://www.aemc.gov.au/markets-reviews-advice/review-of-the-frequency-operating-standardAt https://www.aemc.gov.au/market-reviews-advice/review-frequency-operating-standard-2022.

power ramping of large loads or ramping of large numbers of small loads in concert might adversely impact system frequency control. Conversely, controllable loads can also support frequency control through the provision of FCAS. Control systems of converter-based loads may interact with other IBR. This review will consider:

- Whether any changes need to be made for potential control interactions or operation under low system strength conditions;
- Reliability and stability impact of tripping very large loads;
- Frequency response and operation during a frequency disturbance, associated with provision of FCAS;
- Whether any changes should be made to the technical standards considering active power ramp rate of loads; and
- Correcting references to obsolete international standards.

The issues that AEMO will review are set out in Appendix A1.2 to this Approach Paper.

3.3.3 Schedule 5.3a – Conditions for connection of Market Network Services (DC interconnectors)

Modern DC converter technology typically has capabilities similar to inverters and converters behave on the power system in a manner similar to bi-directional inverters. NER Schedule 5.2 has more onerous requirements compared with Schedule 5.3 for MNSPs. This review will consider the extent to which there is value in harmonising the requirements for DC converters under Schedule 5.3a with requirements for bi-directional units in Schedule 5.2.

The review of Schedule 5.3a will consider the range of Schedule 5.2 technical standards, particularly focusing on:

- Reactive power capability and voltage control;
- Stability-related clauses;
- Alignment of protection requirements with generator requirements; and
- Correcting references to obsolete international standards.

This review will also consider the changes that will be implemented to NER Schedule 5.2 as part of the 'Efficient management of system strength on the power system' rule change[21].

The issues that AEMO will review are set out in Appendix A1.3 to this Approach Paper.

3.4 Matters outside this review

AEMO acknowledges that there are other aspects of the NEM connections and access framework that could benefit from review. Discussions have been taking place about issues including, but not limited to, connections processes, harmonics management and compliance processes, and processes related to provision of information and modelling.

At present, other initiatives operating in parallel with this review (such as the CRI and various rule changes), are examining improvements to the NEM connection process and applicable requirements.

[21] At https://www.aemc.gov.au/rule-changes/efficient-reactive-current-access-standards-inverter-based-resources.

The management of harmonics in the power system, and associated compliance requirements of generators and loads, were flagged by stakeholders as requiring review.

AEMO considers that broad changes to management of harmonics in the NEM would be beyond this review's scope. Nevertheless, AEMO would welcome stakeholder input on whether there is value in AEMO coordinating an industry review of harmonics management through a separate workstream with a view to revising the current framework in the rules, including associated access standards.

By and large, NER Schedules 5.2, 5.3 and 5.3a do not deal with broader procedural or administrative matters associated with NEM connection. Considering also that some process-related matters are being reviewed through the CRI, other than realignment of Schedules 5.2 and 5.3a to plant-type rather than registration category, process-related matters will not be considered or covered by this review.

Notwithstanding the stated scope and nature, AEMO will, where reasonable and appropriate:

- Highlight any other relevant and important technical requirements and other significant emerging issues relating to technical standards from concurrent reviews or initiatives; and
- Consider and consult further on any other relevant matter and broadly significant technical matters that may be identified through consultation on this review (including with the Reliability Panel).

4 Next steps

AEMO intends to publish a draft report into this review, on its website, by 28 February 2023. Pursuant to clause 5.2.6A(d) of the NER, the draft report will set out AEMO's recommendations (with reasons) for any amendments to the technical requirements under review and will invite stakeholders to make written submissions.

Pursuant to clause 5.2.6A(e) of the NER, within 12 months of the publication of this Approach Paper, AEMO will publish a final report that will set out AEMO's recommendations for any amendments to the technical requirements under review, having regard to any submissions and the following prescribed factors:

- The NEO;
- The need to achieve and maintain power system security;
- Changes in power system conditions; and
- Changes in technology and capabilities of facilities and plant.

As soon as practicable after the publication of its final report, AEMO will notify the AEMC as to whether AEMO will submit a rule change request resulting from this review.

In addition to formal submissions, AEMO proposes to use the Network Access Workstream of the CRI to engage with subject matter experts on changes to the technical standards.

AEMO's preference is for this review to be undertaken as a fast-track rule change process. To enable this potential pathway, AEMO is considering two stages of formal consultation into this review process:

- The draft report will present the concepts and reasoning for changes to the technical standards; and
- Following consultation on the draft report, and incorporation of feedback, a second consultation document incorporating draft rules could be prepared and consulted on.

Based on a publication date no later than 28 February 2023, submissions to the draft report will close on 16 April 2023. A decision on whether to proceed with the second consultation will be made following consideration of the initial feedback, in consultation with the AEMC.

AEMO anticipates the second consultation would be initiated in Quarter 2 2023 (ending in Quarter 3 2023) and, in any case, the publication of the final report will be in Quarter 4 2023.

The decision to proceed with a fast-track rule change process is at the AEMC's discretion and cannot be guaranteed.

All papers, reports, written submissions and other consultation material (other than information specifically identified as confidential) will be published on AEMO's website.

Any stakeholder wishing to discuss or obtain further information on this review may do so by emailing the AEMO Onboarding & Connections division (contact.connections@aemo.com.au) using the subject line "2022 AEMO review of technical requirements for connection".

A1. Issues for review

This appendix describes the issues identified for the technical standards Schedules 5.2, 5.3 and 5.3a. As flagged in the body of this report, there may be consequential issues that arise from concurrent reviews that will also form a part of this review's scope. The issues described in the following tables represent AEMO's preliminary view of the scope for this review and may be amended as further investigation and consultation are undertaken. Note that the issue descriptions reflect those gathered by AEMO in its initial scoping exercise – these require further exploration and validation before concluding that any change is warranted.

A1.1 Schedule 5.2 Issues for review

Clause	Category	Description of issue
S5.2.1	Referencing Technical Standards to plant rather than registration category	Technical standard coverage based on plant type Currently Schedule 5.2 applies to the registration category of the connecting party rather than the plant to which the technical standards apply. This means that its applicability depends on who is connecting the plant rather than the nature of the plant itself. This means that Schedule 5.2 cannot be applied to synchronous condensers, unless connected by a Generator or Integrated Resource Provider. The impact of the plant on the power system does not depend on who is connecting, but rather on what is connected.
S5.2.5.1	Streamlining connections Re-orienting to best power system performance	Voltage range for reactive power Requiring full reactive power injection capability for high voltages up to 110% of normal voltage and full reactive power absorption capability for voltages down to 90% of normal voltage might not be consistent with the operation of the power system and could put unnecessary stresses on generating systems.
S5.2.5.2, S5.2.5.6, S5.2.5.10	Updating standards references	Correct references to superseded standards There are cross references to outdated standards related to harmonics and voltage fluctuations. Additionally, there are obsolete or incorrect references for plant standards in S5.2.5.2, S5.2.5.6 and S5.2.5.10.
S5.2.5.4	Streamlining connections	Point of application for over-voltages (medium voltage connections) The introduction of "Connection to dedicated connection assets Rule" (ERC0294) makes it more likely that large connections will have medium voltage (MV) connection points. The current automatic access standard (AAS) of clause S5.2.5.4 was amended in 2018 in consideration of potential high voltage (HV) system disturbances under abnormal power system conditions. The application of the AAS is more onerous when applied to MV connections. Consideration will be given to defining a point of application for MV connections, considering the work undertaken to define the NSW REZ Access Standard for this clause.
S5.2.5.4	Streamlining connections	Over-voltages above 130% The current Rule requires the generating system to remain in continuous uninterrupted operation for 0.02 seconds for voltages greater than 130% of normal voltage, without an upper limit. Equipment generally needs to be protected from damage that can arise from overvoltage.
S5.2.5.5	Re-orienting to best power system performance	Clarify intent on reactive current injection settings In the 2018 technical standards changes, the AEMC sought to document an intent that the reactive current injection settings for faults and over-voltage contingency events should be set at values that optimise power system performance. However, the drafting is not clear and has resulted in multiple interpretations.

Clause	Category	Description of issue
S5.2.5.5	Grid-forming inverters Streamlining connections	Reactive current injection – rise time /settling time alternative The reactive current injection rise time and settling time requirements introduced in 2018 have raised some issues regarding the practical range of fault voltage profiles (i.e. not necessarily step-like) and the nature of generating unit response (not stationary, after the initial fast response). The minimum access standard is the subject of the current AEMC Rule change 'Efficient reactive current access standards for inverter-based resources'[22]. AEMO is considering what changes should be made to the automatic access standard with a view to integrating grid-forming inverters in the generator technical standards, and, more generally, streamlining the connections process.
S5.2.5.5	Grid-forming inverters Re-orienting to best power system performance	Commencement of reactive current response The current drafting, introduced in 2018, implies that reactive current response to faults or overvoltages should not commence in the range 90% to 110% of connection point normal voltage. This is technology-specific wording that is inconsistent with the way grid-forming inverters respond to voltage disturbances and, as a result, may disincentivise capability that may contribute to better power system outcomes.
S5.2.5.5	Re-orienting to best power system performance	Overvoltage management during and after faults The way that an asynchronous unit manages its reactive current injection for unbalanced faults affects the phase voltage during and immediately after a fault. The amount of reactive current injection also affects overvoltages immediately after fault clearance for both unbalanced and balanced faults. The Rules do not specify what acceptable performance is in regard to over-voltages on un-faulted phases during a fault, or over-voltages after a fault. Although the requirement to remain in continuous uninterrupted operation for S5.2.5.5 means that any overvoltage a plant causes during or immediately after a fault should not cause it to disconnect from the power system, and requires that any overvoltage caused by it should not exacerbate the fault for any other connected plant. In practice it is very difficult to eliminate an overvoltage at the time of fault clearance, where the generating system is injecting reactive current immediately prior to a fault, as there is a finite time after the clearance of the fault to detect the change in voltage. Overvoltage issues on fault recovery are likely to become worse as the system fault level reduces with retirement of synchronous generating systems. The need to avoid over-voltages on the system should be a consideration in deciding the amount of reactive current injection that is appropriate for the power system. Other strategies that reduce reactive current injection over time or coordinate with the anticipated protection clearance time might also be worth considering.
S5.2.5.5	Streamlining connections	Active power recovery The CRI, in their review of minimum access standard for S5.2.5.5, suggested that the active power recovery requirement post-fault should be subject to the voltage recovering above 90% of connection point normal voltage. This review will consider adopting this proposal for both the minimum and automatic access standards.
S5.2.5.5	Grid-forming inverters	Rapid active power injection Currently the Rules do not require any overload capability from IBR. Recent research suggests that capacity for additional rapid active power injection may be an important characteristic for grid-forming inverters. This might be provided as overload capability or alternatively by headroom on capacity. The requirements around rapid active power injection are likely to be considered in conjunction with the voluntary grid-forming inverter specification identified as a priority action under the Engineering Frameworks review. AEMO will consider the work toward, and outcomes of, this initiative in framing any changes to the technical standards.

[22] At https://www.aemc.gov.au/rule-changes/efficient-reactive-current-access-standards-inverter-based-resources.

Clause	Category	Description of issue
S5.2.5.5	Streamlining connections	Volume and measurement location of reactive current injection[23] The current Rule requires for the automatic access standard a maximum reactive current injection of 4% of maximum continuous current /% of voltage, and 6%/% for current absorption. The measurement location by default is at the connection point, but alternative locations can be proposed, such as the unit terminals. Both the %/% and the measurement location impact the design of the generating system, and the effect is greater for some technologies (such as wind farms) than others. This review will consider whether the current requirements of the automatic access standard are appropriate, and whether the drafting could be improved for clarity.
S5.2.5.5	Streamlining connections	Multiple fault ride through The multiple fault ride through (MFRT) provisions of S5.2.5.5 were introduced in 2018. AEMO's review will consider if any changes or clarifications are needed to this clause to assist in streamlining the connection process.
S5.2.5.8	Re-orienting to best power system performance	Rapid proportional over-frequency response Clause S5.2.5.8 includes a requirement for emergency over-frequency active power reduction. The clause allows several mechanisms, including one which relies on reduction in active power proportional to frequency above a certain threshold. The current rule wording requires the plant to have reduced its output by half within 3 seconds of the frequency reaching 52 Hz. This formulation is problematic in practice because generating units are only required to remain in continuous uninterrupted operation up to 52 Hz, and therefore may trip as soon as the frequency exceeds this level.
S5.2.5.8	Re-orienting to best power system performance	Behaviour of hydro generating systems during over-frequency events – emergency over-frequency response In hydro-generating systems there may be physical limitations due to the design of the hydraulic systems that prevent some plant from meeting the emergency over-frequency response requirements, except by tripping the plant. In a future power system with low inertia, it would be detrimental to the power system operation to trip hydro units for over-frequency events, as this would exacerbate the rate of change of frequency. The review will consider whether there is a more appropriate way of specifying emergency over-frequency response for plant with physical limitations on active power ramp rate.
S5.2.5.10	Oscillation monitoring and protection	Update detection and response requirements for oscillations on asynchronous generating systems The automatic access standard of clause S5.2.5.10 requires an asynchronous generating system to have capability to disconnect promptly in response to an instability in active power, reactive power or voltage at its connection point. It is undesirable to trip generation that is responding to an oscillation to damp it, or if the generation is not responding to the oscillation. A more nuanced approach is desirable, which considers the materiality of the oscillation, and the extent to which the generating system is contributing to it[24].
S5.2.5.13	Re-orienting to best power system performance Grid-forming inverters	Clarify the criteria for establishing rise time and settling time Currently in S5.2.5.13, the automatic and minimum access standards together give a range of requirements for rise time and settling time of voltage active power and reactive power in response to voltage/reactive power and power factor steps. The assumption arising from the Chapter 5 connection negotiation framework is that shorter rise times and settling times lead to better power system outcomes. However, this is not always correct when considering a range of short circuit levels on the power system. The review will consider what should be done to re-orient this clause towards providing the best outcomes for the power system for the expected range of conditions. In addition, the clause as it currently stands requires settling times for voltage for reactive power control and power factor control. These control modes do not control voltage, so the settling time of voltage is not relevant. These issues impact grid-forming inverters and other technologies.

[23] The corresponding minimum access standard is the subject of current Rule change 'Efficient reactive current access standards for inverter-based resources' at https://www.aemc.gov.au/rule-changes/efficient-reactive-current-access-standards-inverter-based-resources.

[24] AEMO is currently consulting on this matter. See 'NER S5.2.5.10 Guideline Consultation', at https://aemo.com.au/en/consultations/current-and-closed-consultations#e=10.

Clause	Category	Description of issue
S5.2.5.13	Re-orienting to best power system performance Grid-forming inverters	Voltage control at generating unit level and slow voltage setpoint change A related issue is that the current Rule drafting implies control at the generating system level and impedes the provision of voltage control at the unit level. Provision of voltage control at the unit level and slower plant level control could be beneficial to stability for a distributed generating system that has communications delays between a plant controller and the units. It could also make the system more robust in the event of communications faults. This review will consider what might be done to provide more flexibility around the configuration of generating system controls, where this can be demonstrated to provide improved power system performance.
S5.2.5.13	Streamlining connections	Clarify when multiple modes of operation are required In the 2018 technical standards a requirement was introduced in the AAS for generating systems to be able to operate in voltage control, power factor and reactive power control, and to be capable of switching between them. This requirement can lead to a large cost for assessment, testing and on-going compliance, and may not add value in all cases. The review will consider how this clause might be clarified to assist in streamlining the connection process.
S5.2.5.13	Streamlining connections	Materiality thresholds on settling time Materiality thresholds can be useful to eliminate unnecessary assessments and negotiations.
S5.2.5.13	Streamlining connections	Voltage settling time requirement in reactive power mode At present S5.2.5.13 requires a settling time calculation for reactive power control steps. However, the voltage is not controlled, and is a by-product of the background voltage and the reactive power change.
S5.2.5.13	Re-orienting to best power system performance	Impact of a generating system on power system oscillatory stability S5.2.5.13 currently includes requirements around the impact of the generating system on oscillation frequencies of the power system. The review will examine whether those requirements are clear and adequate considering the increasing proportion of IBR on the power system.
Continuous uninterrupted operation	Grid-forming inverters Streamlining connections	Review of continuous uninterrupted operation definition and usage Grid-forming inverters respond to power system disturbances in ways more akin to synchronous machines than grid following inverters. They typically respond nearly instantaneously to voltage angle jumps and voltage magnitude changes, and respond to rate of change of frequency with synthesised inertial response. Unlike synchronous machines these characteristics are affected by programmable settings, rather than physical design of the plant. These characteristics are often beneficial to the power system, but under some conditions may provide less-desirable outcomes. The complex contingency event responses that can occur could be interpreted as conflicting with the present definition of continuous uninterrupted operation. The review will consider changes to the definition of continuous uninterrupted operation and the clauses in which this definition is used, to identify where the current technical standards might represent impediments to connection of grid-forming inverters and provision of performance characteristics that benefit the power system. The review will also look at how the current definition works for the various clauses in which it is used, more generally for all technologies.
General	Streamlining connections	Consider reduced requirements for small connections At present there are few technical standards that consider reduced requirements for small connections or distribution connections that are made under S5.2. The negotiation framework requires all generators to target automatic access standards unless the connection applicant negotiates for a lower standard. The cost and time associated with doing so, or alternatively, demonstrating compliance at automatic access standard level may not be warranted for small generating systems, and the benefit of automatic access standard level performance from small generators may be low. However, reductions in standards must also be balanced against the possible impact of multiple small generating systems responding in concert. The review will consider for what clauses and conditions simplification of access standards for small plant might be beneficial.

Clause	Category	Description of issue
Possible new standard	Grid-forming inverters	Consider possible new requirements At present there is no requirement for black-start, islanded operation or inertial response mentioned in the technical standards. Functionality for black-start services and islanded operation are normally dealt with by other means, for example through service mechanisms. In the case of islanded operation, S5.2.5.8 allows for disconnection of generating systems under islanded conditions where this is necessary. AEMO will consider whether there is any need to codify these requirements in the technical standards, or whether these capabilities or services are better procured/obtained by other means. AEMO will also consider any technical requirements that might arise from discussions with stakeholders around the development of a voluntary specification for grid-forming inverters, and through the Network Access workstream of the Connections Reform Initiative.
Possible new standard or new part of S5.2.5.8	Re-orienting to best power system performance	Response on failure of communications or other systems At present AEMO has a guideline on the expected requirements for response to communications failure, but this is not a rules requirement. The review will consider whether there is value in codifying in a Schedule 5.2 requirement that following failure of communications systems or control systems, a generating system or integrated resource system should respond in a manner that is safe and does not materially reduce power system security or quality of supply, or whether this is adequately covered elsewhere in the rules.

A1.2 Schedule 5.3 Issues for review

Clause	Category	Description of issue
S5.3.7, S5.3.8, S5.3.9	Updating standards references	Correct references to superseded standards There are cross references to outdated standards related to harmonics and voltage fluctuations.
S5.3.9	Stability impact of design and technology	Contingency size and technology impact on stability The next 10 years could see some very large loads connect to the NEM, for example, associated with production of green hydrogen. Many of these new loads have converter front-ends. It is unclear whether there is potential for control interaction between converter-based loads and other IBR. This review will consider the potential impacts of these plant on the stability of the power system, and whether there is a need for standards modification. This might include consideration of the maximum size of a contingency, and the stability impact of loss of that load.
S5.3.9, S5.3.10	Operation during frequency disturbances and FCAS	Operation of large loads during frequency disturbances Currently S5.3.9 requires a substation to have continuous uninterrupted operation with the levels of voltage, harmonics, unbalance and voltage fluctuation specified in the system standards as modified in accordance with the relevant provisions of Schedule 5.1. However, it does not appear to extend to the load connected to the substation. If large loads trip during over-frequency events or high rate of change of frequency, in conjunction with an over-frequency, they could materially exacerbate a frequency disturbance. Further, if loads are participating in FCAS service provision for over-frequency events, they will need to remain in service to fulfil these obligations. This review will consider whether there is a need to amend this standard to require additional performance of loads for over-frequency conditions. For under-frequency events the current requirement in S5.3.10 is for under-frequency load shedding facilities for loads greater than 10 MW. Consideration could be given to whether, for large inverter-based loads, provision of fast run-back capability might be an alternative to load shedding.

Clause	Category	Description of issue
Possible new clause	Active power ramp rate	Limiting active power ramp rate Currently non-scheduled loads, like non-scheduled generators, do not have limitations on the rate of change of active power. Unlike generators there are no limitations to the size of non-scheduled loads that connect to the power system. If a load is large relative to the demand of the region, or if there are multiple loads, which in aggregate are large and which may operate without diversity, then rapid active power ramping may impact frequency control on the power system. Variations in plant active power are managed through dispatch to the extent they are forecast, FCAS and primary frequency response. The extent to which such variations in active power would affect the cost of operation of the power system might depend on the relative size of other variations in supply or demand. It must also be considered that not all loads can be readily controlled to limit the rate of change of active power.

A1.3 Schedule 5.3a Issues for review

Clause	Category	Description of issue
S5.3a.1a and subsequent clauses[25]	Application to DC interconnections	Application of the technical standards to plant type At present Schedule 5.3A applies only to MNSPs. That registration category is not often used in the NEM. If the proponent does not intend to register as a MNSP, it is unclear what technical standards would apply for a new or changed DC link. The review will consider whether it is appropriate to extend the application of the Schedule to DC links and DC back-to-back interconnections more generally.
S5.3a.4 S5.3a.5 S5.3a.6 S5.3a.8 S5.3a.13 S5.3a.14	Power system performance	Alignment with bi-directional plant standards In a power system, a DC interconnector acts either as a sink or source of power on the power system. The impact on the power system is then very much like a bi-directional unit, and there may be merit in applying similar technical standards to those required by bi-directional units which are managed under Schedule 5.2. Voltage source converter technology, in particular, has voltage control-characteristics and reactive power capability very similar to IBR generation. The review will examine the extent to which the technical standards for bi-directional units should be applied to DC link and DC back-to-back converters to provide a similar level of power system security.
S5.3a.10 **S5.3a.11 S5.3a.13**	Updating standards references	Correct references to superseded standards There are cross references to outdated standards related to harmonics and voltage fluctuations and operation in the presence of voltage fluctuations and harmonics.
Possible new standard	Islanding and black-start	Islanding and black-start performance Some interconnector technologies can support the power system by providing grid--forming capabilities and black-start capability like grid-forming inverters. As the level of synchronous generation in the NEM declines with retirement of thermal generation, the provision of these capabilities will have increasing value in the NEM. The review will consider whether provision of such capabilities should form a part of the technical standards.

[25] Including S5.3a.7 under 'Efficient management of System Strength in the Power System Rule', at https://www.aemc.gov.au/rule-changes/efficient-management-system-strength-power-system.

Glossary

This document uses many terms that have meanings defined in the National Electricity Rules (NER). The NER meanings are adopted unless otherwise specified.

Term	Definition
AAS	automatic access standard
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
CRI	Connections Reform Initiative
FCAS	frequency control ancillary services
IBR	inverter-based resources
MFRT	multiple fault ride through
MAS	minimum access standard
NSP	Market Network Service Provider
NEM	National Electricity Market
NEO	national electricity objective
NER	National Electricity Rules
NSP	Network Service Provider
REZ	renewable energy zone