ELECTRICITY RULE CHANGE PROPOSAL

GENERATOR TECHNICAL REQUIREMENTS: SUBMISSION TO AUSTRALIAN ENERGY MARKET COMMISSION'S CONSULTATION PAPER

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AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

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1 INTRODUCTION

AEMO's Rule change proposal 'Generator Technical Requirements' seeks to reform the arrangements for connecting generators in the National Electricity Market (NEM). They are designed to support the development of a modern, advanced, and secure power system in an efficient manner.

The existing technical requirements for generators in the National Electricity Rules (NER) were written when the NEM's generation consisted predominantly of synchronous plant, with some amendments a decade ago to accommodate new technologies. The technical requirements have not been reviewed since that time, despite significant advances in the capability of asynchronous generation. Over this period there has also been significant changes in the volume and technical characteristics of connection proposals.

With a rapidly changing generation mix the future power system needs to be resilient and able to operate reliably and securely in an environment of:

- Lower system strength;
- Lower inertia;
- Higher use of remedial action schemes to manage system security for protected events; and
- Greater market engagement that sees rapid changes in power flows through highly responsive supply and demand systems.

These issues will continue to make the secure operation of the power system increasingly difficult. AEMO's Rule change proposal seeks to improve the generator technical standards in the NER to provide the capability within the NEM to support the ongoing secure operation of the power system. The proposed recommendations have been benchmarked against a range of international grid codes and regulatory frameworks, including:

- UK Grid Code – Connection conditions
- ENTSOE – European system operators – Network code – Requirements for generators
- Germany TenneT Transmission Grid code for high voltage and extra high voltage
- Denmark – Technical regulations for grid connection
- Ireland – Grid Code
- North American Reliability Corporation
- Electric Reliability Council of Texas
- Hydro Quebec – Generation connection requirements

The proposed generator technical standards are consistent with international practice, this is further detailed in Appendix A. In essence, benchmarking has indicated that the NEM is unusual in having a negotiated access framework with many international codes generally having a fixed minimum standard that is reasonably consistent with the automatic standard proposed by AEMO.

AEMO's Rule change proposal is based on current developments and understanding. As recommended by the Finkel Review, AEMO strongly supports the need for the technical standards to undergo regular

review to accommodate future needs, improvements in technology and to maintain alignment with international practice.

AEMO's Rule change proposal put forward a number of changes to the NER, including recommended wording for the revised Rule. Following the AEMC's publication of its Consultation Paper on AEMO's Rule change proposal, and subsequent stakeholder consultation activities, this submission builds on AEMO's original proposal in the following ways:

- Providing additional justification of the need for clarity in the intent of the negotiating framework for generator technical requirements;
- Providing additional support for the need to apply the new Rules as soon as possible; and
- Providing clarifications to specific technical recommendations of AEMO's Rule change proposal.

Rather than respond to each individual question in the AEMC's Consultation Paper, this submission instead focusses on the specific areas that AEMO has determined will benefit from further clarification beyond what was set out in AEMO's original Rule change proposal. This submission addresses:

- Question 4 - 'System strength access standard': covered in section 4.3
- Questions 11,12, and 13 – matters associated with the negotiating framework: covered in section 0
- Questions 14 & 15 – transitional arrangements: covered in section 0.

2 CLARITY IN THE NEGOTIATING FRAMEWORK

2.1 Statement of issue

In its Rule change proposal, AEMO made the following observations regarding the negotiating framework for new connections, and recommendations for the framework's improvement:

- AEMO considers that performance standards based on negotiated access standards are acceptable, provided that there is no adverse impact on either power system security or the quality of supply to other Network Users. Still, to maintain a robust power system, **AEMO expects any negotiated access standards should be as close as reasonably practicable to the automatic access standard**. In general terms, the closer a proposed negotiated access standard is to the applicable automatic access standard, the greater contribution to power system security and the less likely the need for operational constraints.
- The role of the minimum access standard should be to accommodate the connection of generating systems that are relatively insignificant and where the potential impact on the power system and other Network Users is likely to be minimal. AEMO, therefore, considers **that the automatic access standard, rather than the minimum access standard, should be considered the default starting point for negotiations** for connections and wishes to make this clearer in the NER.
- Predicting future power system security needs for the purposes of conducting negotiations today is a difficult task given the rapidly changing generation mix on the power system, asynchronous plant capabilities and the impacts of these changes on the power system. **The overarching principle should be to encourage the optimum performance of generation and strike an optimum balance between connection costs, network costs, and market costs** (e.g. lost opportunity costs due to security constraints).
- To deliver such an outcome, AEMO has proposed a clearer set of principles in clause 5.3.4A and, where appropriate, within each technical requirement. This is designed to **drive a top-down approach to this negotiation, particularly those requirements that impact power system security and are critical to the evolution of the power system**, while providing flexibility for negotiations where appropriate.
- A Connection Applicant would (a) **need to demonstrate that the prescribed capability cannot be provided** by the proposed technology and (b) to investigate whether or not it is required for the power system. Customers' need for access to a secure, reliable and efficient power system should be a Network Service Provider's (NSP) and AEMO's primary consideration.

The following sections build on AEMO's Rule change proposal and provide further clarity regarding the need for changes to the NER negotiating framework for generator technical requirements.

2.2 Objective of the performance standards negotiation framework

The National Electricity Objective (NEO) is to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers with respect to (amongst other things) price, reliability and security of electricity supply.

A clearer negotiating framework advances the NEO by:

- reducing the risk that generation plant is inadequately designed;
- better reflecting the changed context in which connections are now being negotiated;
- delivering greater consistency in the application of the NER across the regions that comprise the NEM, which decreases costs and facilitates investment;
- reducing the cost to participants, NSPs, and AEMO associated with the iterative nature of the current negotiating framework, a cost that is ultimately borne by consumers; and
- mitigating the need for separate jurisdictional technical standards. While there are sound reasons for applying separate jurisdictional arrangements in South Australia given the current NER technical standards, multiple overlapping frameworks are more complex than a single, flexible framework that is fit for purpose across the NEM.

It is noteworthy that the NEM is unusual in having a negotiable access framework. Many of the international codes that AEMO has compared with, generally have a fixed minimum standard that is reasonably consistent with the automatic access standard proposed by AEMO. Therefore, not only do AEMO's proposals align with these international precedents, but the addition of a negotiation framework that allows applicants to negotiate lower access standards suggests that the proposed standards are less onerous than international standards.

2.3 New technology at unprecedented scale is transforming the power system, and functionality of the negotiating framework

The NEM is currently seeing an unprecedented number of new generator connection applications, almost all of which are asynchronous generators. The practical functionality of the negotiating framework is impacted by this transition across a number of key related areas (these are further expanded on below):

- Connection capacity & location;
- Rate of new connections;
- Technology type;
- Concurrent connections; and
- Uncertainty in modelling and forecasting.

2.3.1 Connection capacity, location and rate

Until recently, the negotiation framework only had to facilitate the negotiation and agreement of performance standards for a few new generating plants connecting every year. In the 2013 / 2014 financial year, about 10 connection applications for large scale generator connections were received across the whole NEM. In this context, the new generation capacity rarely had a material impact on power system security, particularly when each application was processed in isolation.

At present, there are approximately 100 active connection applications for new connections with a combined capacity of more approximately 15 gigawatts (GW). This is equivalent to about one third of the total 52.5 GW of electricity generating capacity in the NEM.[1] The *rate* at which new connection applications occur is also uncertain and changing. The overwhelming majority of the new connection applications relate to asynchronous plant that are focussed in particular regional areas with good wind and solar resources.

[1] As of October 2017

A step change in the NEM is occurring. The existing synchronous generating fleet is aging and being replaced overwhelmingly by non-synchronous generating plant. As the wind and solar energy resources are often located in more remote regions, new facilities are also seeking connection in weaker parts of the system, where higher plant standards are required. Further, more of the system is becoming weaker as synchronous generation retires.

Previously, synchronous generating systems contributed energy, inertia and short circuit current at varying levels. High levels of inertia made frequency stability easier to manage, and generally improved transient stability, while high fault currents were typically associated with improved voltage control, though with some plant risk associated with high fault levels. Risks to be managed related to the connection of plant with low inertia (stability risk) or high short circuit contribution (plant fault rating risk) and these required specific controls in the form of technical requirements.

Today, the predominance of asynchronous generating systems presents a different range of risks and opportunities. Asynchronous plant generally contributes no inertia, and as more of this type of plant connects, power system stability can become more restrictive and difficult to manage, impacting all participants. The same applies to low short circuit contribution, at low short circuit levels, plant is no longer at risk due to rating, but voltage stability can be more challenging to manage. As the transition from synchronous to asynchronous plant occurs at an increasing rate, the system security implications become more uncertain. AEMO's proposed clarification to the negotiating framework seeks to manage these issues by:

- Delivering higher technical capabilities to smooth and manage the transition;
- Establishing performance requirements consistent with international practices;
- Setting expectations to create a more efficient overall connection process; and
- Implementing a framework to update the technical requirements every 3 years, in accordance with Finkel Review recommendation 2.1[2].

2.3.2 Technology type

Australia is a relatively small market, so in order to be able to take advantage of the benefits of competition, our technical standards should be consistent with those that apply internationally.

AEMO has attempted to pitch the automatic access standard at a level that is consistent with the most progressive technical standards that are in use overseas. This approach allows the NEM to benefit from the latest technological developments without incurring excessive additional costs.

Given that modern plant is relatively modular and tailoring of performance is facilitated primarily through software control, the incremental costs of the additional capabilities in many cases should be modest, and so it is appropriate for the negotiating framework to be targeted towards achieving the automatic access standard. The alternative is that the NEM risks an influx of inferior plant in order to achieve modest short term cost savings, to the long term detriment of system security or overall higher cost market outcomes and increasing the requirements for future generators to connect.

New generating systems are long-life assets, and thus there is a need to ensure the capabilities they are built with today will continue to meet the needs of the power system of the future.

[2] Finkel review. *Independent Review into the Future Security of the National Electricity Market*, June 2017. Available at: http://www.environment.gov.au/system/files/resources/1d6b0464-6162-4223-ac08-3395a6b1c7fa/files/electricity-market-review-final-report.pdf

2.3.3 Concurrency of new connections

With a high number of new connection applications now being negotiated concurrently, AEMO considers that clarifying the negotiating framework to require a top-down approach to negotiating performance standards will promote:

- Equal treatment in the connection process where multiple generators are connecting in the same vicinity on similar timeframes. Each time a generator connects at a reduced negotiated access standard, it becomes less likely that the local network will have “headroom” available to securely integrate subsequent generators at the reduced negotiated access standard.
- A more efficient and clearer process for assessing connection applications by NSPs and AEMO – facilitating a faster connection process, enabling applicants to progress through to contractual, financing and construction stages more quickly.
- A more transparent process in that each applicant has a better understanding regarding the basis for competing projects. Where projects are competing on the basis of final cost of delivery of energy, it is preferable that savings represent innovations in technology and construction practices, not in reduced plant capability that represents a long term risk to the security of the power system.
- As noted by the Australian Competition & Consumer Commission (ACCC) when it established the existing framework, the framework should not provide existing participants with an advantage over those that seek to connect in the future, and vice versa[3].

2.3.4 Increasing uncertainty in modelling, forecasting and market scenarios

Under the existing negotiating framework, AEMO would advise an NSP to reject a proposed performance standard if it adversely affects power system security. Previously, power system security concerns were readily identifiable because the capability and performance of the power system, in particular synchronous generating systems, was predictable, especially when the number of new connections was low.

While AEMO can advise rejection of a proposed negotiated access standard on the basis of power system security concerns now and into the future, these future risks need to be demonstrated for AEMO to do so. Today, modelling and identifying impacts to power system security have become more difficult to forecast and model than in the past because of:

- Increasing volume of new concurrent connection applications.
- More complex generating system models.
- More complex operational scenarios.
- Difficulties in predicting the impacts of new technology and different markets (such as greater participation by utility scale storage, demand-side and ancillary service aggregators).

Where, as a result of these uncertainties, risks to power system security in the future cannot be accurately determined today, a responsible system operator must approach these issues with caution.

While AEMO sees merit in having a negotiating framework that allows lower performance levels to be accepted where there is a reasonable case to do to, AEMO believes that the practical application of such a framework should require applicants to justify why a standard lower than the automatic access standard

[3] Australian Competition and Consumer Commission, (2003). *Applications for Authorisation Amendments to the National Electricity Code Technical Standards,* page 6.

should be accepted, rather than AEMO having to prosecute a case for requiring a higher level of performance. AEMO recognises that participants may desire guidance on what might constitute reasonable evidence to support acceptance of a lower performance standard. AEMO considers this matter in section 2.6.

The transition from synchronous to asynchronous generating plant is a step change that should be reflected with an appropriate negotiating framework that will allow AEMO to better and more efficiently manage system security within this new paradigm. As noted in the Finkel Review, it is important that connection standards are "fit-for-purpose in a modern and rapidly transforming power system"[4].

2.3.5 What this means

Collectively, these factors have led to a fundamental shift in the connections landscape, necessitating a review of both the standards and the negotiation framework to ensure that both are fit for purpose today and for the foreseeable future (noting that the Finkel Review recommended generator technical requirements be reviewed periodically).

The high volume and complexity mean that future risks to power system security are subject to a broad range of uncertainty.

A responsible system operator must approach these uncertainties with caution.

AEMO has thus recommended that to support the ongoing development and secure and efficient operation of the power system, the connection and negotiation frameworks be made clear in its requirement for plant to aim for capability levels that are expected to remain suitable over the long term. This should be achieved by plant demonstrating capabilities nearer to the automatic access standards, not a system designed around the minimum access standards. As noted, the NEM is unusual in having a negotiable access framework. Many of the international codes that AEMO has compared with generally have a fixed minimum standard that is reasonably consistent with the automatic access standard proposed by AEMO[5].

AEMO sees merit in having a negotiating framework that allows lower performance levels to be accepted where there is a reasonable case to do to. However, these cases should be the exception rather than the rule. For instance, some plant may have desirable properties in terms of dispatchability and their ability to come online quickly, but their physical characteristics mean that they are unable to meet some of the automatic access standards. So long as the network conditions at the proposed connection point mean that the application of lower standards are unlikely to present a risk to system security, then it may be beneficial overall to relax the standards. If the plant is capable of meeting a higher standard, consistent with the long-term interests of consumers, at zero or modest additional cost, the negotiation framework should facilitate doing so.

2.4 Delivering flexibility

In its consultation paper, the AEMC has asked stakeholders what they see are the appropriate, respective roles of the automatic, minimum, and negotiated access standards. AEMO believes the roles of these standards are as follows:

[4] Finkel review. *Independent Review into the Future Security of the National Electricity Market*, June 2017, page 59. Available at: http://www.environment.gov.au/system/files/resources/1d6b0464-6162-4223-ac08-3395a6b1c7fa/files/electricity-market-review-final-report.pdf

[5] These are detailed in Appendix A.

- **Automatic access standard** – Sets the preferred performance level for all new connections where there is considered to be no adverse impact to power system security[6].
- **Negotiated access standard** - Allows for determining and agreeing generator performance standards that are set between automatic and minimum boundaries, where an NSP and AEMO are satisfied that there is a reasonable case for not meeting the automatic access standard and that accepting such a capability is unlikely to have a material impact to power system security.
- **Minimum access standard** – Sets the lower bound for any negotiated access standard. The role of the minimum access standard should be to accommodate the connection of generating systems that do not have a material impact on the system (e.g. due to their size and/or operating pattern) and where the potential impact on the power system and other Network Users is likely to be minimal.

In regards to these standards, Clause 5.1.3 of the NER states the following principles relating to *connection* to the *national grid:*

> (c) the technical terms and conditions of *connection agreements* regarding standards of performance must be established at levels at or above the *minimum access standards* set out in schedules 5.1, 5.2, 5.3 and 5.3a, with the objective of ensuring that the *power system* operates securely and reliably and in accordance with the *system standards* set out in schedule 5.1a;
>
> (d) a *Registered Participant* or person intending to become a *Registered Participant* may request *connection* of a *facility*, modification of a *connection*, or alteration of *connected plant* at a standard below an *automatic access standard* if the *connection,* modification to the *connection*, or alteration of *connected plan*t does not adversely affect:
>
> (1) *power system security*; and
>
> (2) the quality of *supply* to other *Network Users*;

AEMO believes the emphasis should be placed on the objective of ensuring the power system operates securely and reliability and that this is achieved by encouraging the optimum performance of generation at capabilities above, or at least close to, the automatic standard.

In an environment of rapid development, competing developments and numerous parties involved in the connection process across the NEM, there has been a trend towards participants proposing a default plant capability as the starting point for negotiations, with an expectation that NSPs and AEMO will prosecute the case for raising the standards. As the stakeholder with the most knowledge of their plant, AEMO believes it is reasonable to expect an applicant to consider how they might deliver an appropriate level of performance. If the applicant considers that the appropriate level should be set below the automatic standard, then they should make the case that their plant can operate stably under reasonably expected system conditions and that they've exhausted reasonable avenues to maximise the capability of their plant. Such an approach is good industry practice, which is also reflected in the NER's principles of connection to the power system, whereby the negotiating framework should result in the achievement of **long term** benefits in terms of cost and **reliability of the national grid**[7]**.**

AEMO acknowledges that clauses 5.3.4A(b)(1) and 5.1.3 (c) enable connection applicants to propose capabilities at the minimum access standard; which is part of the driver in proposing this clarity to the

[6] The automatic standard does not impose a limit on higher capabilities where these can be provided.
[7] NER Clause 5.1.3 (d) (e) (1)

negotiating framework. AEMO again notes such an interpretation was not the intention of the ACCC, which when authorising the current negotiated framework noted:

> *The Commission accepts, that given the current drafting of the proposed code changes, there may be the perception among intending applicants that all new connections could be made at the minimum access standard. Further, the Commission agrees that if this occurs, the performance of the power system would degrade over time[8].*
>
> ACCC, 2003

AEMO's proposed changes to clause 5.3.4A seek to clarify that any negotiated access standards should be as close as reasonably practicable to the automatic access standard, and coupled with recommendations to increase the performance requirements of the access standards, seek to ensure the performance of the power system does not degrade over time.

Further discussion regarding how AEMO expects the negotiation process to be interpreted is provided in section 2.6.

2.5 Delivering consistency

As noted in its Rule change proposal, AEMO believes that failure to ensure a consistent national approach to generator technical requirements risks the creation of insufficient, inefficient, and uncoordinated generation capabilities in the NEM.

AEMO believes that it is in part a lack of confidence in the NER's ability to ensure new generators have capabilities appropriate for the power system of the future that is leading some jurisdictions to consider technical standards outside the NER framework.

AEMO notes that in the Enquiry phase of the connections process, several NSP's seek to establish the principle and expectation that deviations from the Automatic Standards are minimised. AEMO considers that reflecting this in the Rules will improve consistency and clarify in the application of the NER across jurisdictions.

2.6 Expected interpretation of proposed framework

In its Rule change proposal, AEMO recommended that:

- The technical terms and conditions of connection agreements regarding standards of performance must, where possible, aim to meet or be as close as practicable to the automatic access standards.
- Where meeting the automatic access standard is not possible, or where it is not required for the secure operation of power system or adverse impact on other network users, the Connection Applicant must provide sufficient evidence to the NSP and AEMO as to why, and deliver the next best capability required for power system security as agreed with AEMO. The agreed performance standard must not fall below the minimum access standard, must not adversely impact other network users and should be as close as practicable to the automatic access standard.

[8] Australian Competition and Consumer Commission, (2003). *Applications for Authorisation Amendments to the National Electricity Code Technical Standards,* page 27.

The evidence required to reach an agreement for a specific negotiated access standard is likely to vary depending on the specific circumstances of the connection under consideration. Consistent with the type of information provided by some Proponents today, it is AEMO's expectation that evidence **may** include **one or more** of the following (as appropriate):

- Evidence that the plant physically cannot meet the automatic access standard and that other plant that could meet the standard is inappropriate for some reason. This could take the form of manufacturer data sheets, site or factory acceptance test results from other installations, or power system studies conducted by an appropriately qualified professional power system engineer. The information required could be agreed between the applicant, AEMO and the NSP.
- Evidence that the deficiency in the plant cannot be reasonably addressed or compensated for or managed in some other way (eg, by changing the plant specification or installation of other equipment). This could take the form of a report from an appropriately qualified professional engineer.
- Evidence that the deficiency in the plant will not impact the network to which it is connected, either due to is location in the network or the installation of other equipment which will compensate for the deficiency. This could be included in the connection studies report submitted to the NSP and AEMO at the time of the Connection Application.

As with negotiations under the current framework, the closer a proposed negotiated standard is to the automatic access standard, the less complex it will be for AEMO to assess and accept the proposal. This will reduce the time and cost of the application for AEMO, the applicant and NSP, resulting in lower cost pass through to consumers. Proposed negotiated performance standards that are closer to the lower end of the range require substantially more evidence from the connection applicant, and more effort is required from the NSP and AEMO in assessing the power system impact of the proposal.

AEMO expects that negotiations would continue to occur in good faith between the relevant parties as they do under the current Rules. Rather than a major change in the negotiating process, the proposed clarifications instead seek to shift the responsibility for justifying a departure from the automatic standards onto the applicant, as the party seeking the departure. Rather than establishing a reasonableness test that would be difficult to implement in practice, the intention of the clarifications is to incentivise applicants to seek out the best performance from their plant. As the party selecting the equipment, and deciding upon the settings of this equipment, AEMO believes this allocation of responsibility is appropriate.

3 TRANSITIONAL ARRANGEMENTS

3.1 The need for action

In its Rule change proposal, AEMO stated that:

- The existing generator technical requirements were designed for an era of generating systems with different technological characteristics and performance capabilities.
- The SA black system event in 2016 demonstrated weaknesses in the existing generator performance standards that adversely impacted on the security and reliability of the power system, in particular the ability of the generating fleet to withstand, ride through and support the power system during major contingency events. There is an expectation in the market and the wider community that the market institutions will move swiftly to address these weaknesses.
- The number of connection applications currently being processed by NSP's and AEMO is an order of magnitude greater than ever before. As generating systems are long-life assets, there is a need to ensure the capabilities they are built with today will continue to meet the needs of the power system into the future.

AEMO notes that in order to make its determination in regards to transitional arrangements, the AEMC considers that "developing an appropriate response to the issues raised by AEMO will require a more detailed understanding of the nature of the issues and potential impacts on system security that could arise from the connection of new equipment under existing arrangements[9]". AEMO encourages the AEMC to consider this issue in the context of overall market efficiency, and the need to avoid major supply disruptions in the future, rather than what specific security impacts might arise from any single project being connected under the old framework.

Weather is inherently uncertain. Given the rapid development and transformation of the energy market to one where we are becoming dependent on the weather for fuel, there is need for action as we are introducing increased uncertainty into the electricity system. This uncertainty and potential threat to security can realistically only be managed through appropriate technical standards that will allow secure management of the power system using the evolving generation fleet.

Consequently, AEMO continues to believe that it is critical that the proposed new technical requirements apply as soon as possible in order to support the transforming energy market.

In order to maintain power system security AEMO invokes constraint equations on the power system to ensure it remains within its technical envelope. If a power system security issue appears to affect a generator, group of generators, or a portion of the network, AEMO must operate the power system in order to manage it. The higher the performance standards of the generating fleet, the less likely it is that AEMO will need to constrain the operation of the power system in the future.

Another reason to avoid delays in bringing the new technical requirements into effect, by 'grandfathering' a large number of current connection applicants, is that this may trigger further State-based technical standards to deal with these projects in the interim. Such an outcome runs contrary to the objective that a single national connection framework is likely to deliver the most efficient outcome for consumers.

[9] AEMC, (2017). *National Electricity Amendment (Generator Technical Performance Standards) Rule 2017.* Consultation Paper, page 45

Accordingly, AEMO considers that the long term interests of consumers will be best served if 'grandfathering' of existing connection applications under the existing Rules framework is kept to the lowest number of generating systems possible. This will be even more important the longer the Rule change is under consideration.

3.2 Appropriate point in the connection process to apply the new Rules

The typical stages of establishing or modifying an existing connection, including alterations to connected generating plant, include:

- Pre-feasibility
- Connection Enquiry
- Connection Application
- Offer to Connect
- Contracts (Connection Agreement)
- Construction
- Completion.

Further details can be found on AEMO's website.[10]

AEMO recommends that the transitional arrangements for the proposed Rule be applied from **the date of the Final Determination**, with the new technical requirements to apply to all negotiations of performance standards under clause 5.3.4A from this date.

While the Rules contemplate that performance standards will be dealt with before an offer to connect is issued, AEMO is aware of some inconsistencies in application of the existing process.

In AEMO's view, the transitional arrangements for the new Rule should reflect the following:

- For any project where AEMO has advised (as required by the NER) the connecting NSP on the appropriateness of a proposed negotiated access standard, and a negotiated access standard that is acceptable to AEMO and the NSP has been provided to a Connection Applicant as part of an offer to connect, the new Rule would not apply.
- For any project where a negotiated access standard has not been accepted by AEMO and the NSP, the new Rule shall apply.

Given the large number of projects at various stages of the connection process, a transitional arrangement for any new technical requirements must strike a reasonable balance between maximising the capability of the generation fleet and recognising that projects currently in the late stages of the connection process may be materially affected if their generating systems do not easily meet the new requirements. AEMO recognises this need, and noted in its Rule change proposal that the transitional arrangements should make allowances for late stage projects where there are extenuating circumstances in AEMO's reasonable opinion.

In combination, the transitional arrangements should strike a sufficient balance by delivering the long term needs of the power system, while recognising the practical challenges of moving to new technical

[10] Transmission and distribution connections in the NEM - process overview: https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Network-connections/Transmission-and-distribution-in-the-NEM--process-overview

requirements for applications that are well advanced, and ensuring reasonable consideration is given to projects where appropriate.

AEMO notes that the last time there was a significant change to the generator performance standards was over a decade ago, in early 2007, in the National Electricity Amendment (Technical Standards for Wind and other Generator Connections Rules) 2007. The transitional provisions that applied in respect of that set of amendments provided that:

> "Unless a Generator and a Network Service Provider otherwise agree, a negotiated access standard that is the subject of a negotiating process as at the [date on which the amending Rule commenced operation], is to be negotiated in accordance with the old Chapter 5 as if the Amending Rule had not been made"[11]

While this may have been appropriate in 2007, AEMO is of the view that generous grandfathering arrangements along these lines are not sustainable as the NEM's transition from synchronous to asynchronous fleet progresses, particularly given the present scale and speed of this transition.

Of the current active connection proposals, around 2 GW[12] of projects currently have agreed generator performance standards in place, meaning a significant amount of new capacity will connect to the power system under the existing rules. AEMO estimates that approximately 4 GW[13] in capacity will be approaching the stage in the process at which generator performance standards will be finalised in the next six months.

While the NSPs and Connection Applicants currently negotiating connection agreements may not know the exact final detail of the changes, AEMO believes that by the time the new Rule takes effect, they will have had reasonable opportunity to develop an understanding of the new requirements, and in most cases, could reasonably be expected to at least have plant that can meet, or exceed, the new *minimum access standards*. The new technical requirements have been the subject of considerable discussion with industry, not only in the context of this Rule change proposal, but also through the recent Essential Services Commission (ESCOSA) of South Australia's Inquiry into the licensing arrangements for generators in South Australia. AEMO's published advice to ESCOSA stated that AEMO intended to submit a Rule change to implement the proposed changes across the NEM[14].

Furthermore, AEMO notes that the ESCOSA requirements (which broadly reflect the automatic access standard) came into effect without a transition period. Project proponents that were seeking generation licences assessed themselves against the new criteria and advised ESCOSA whether they could meet the proposed requirements, and if not, what capability they could provide. Where their capability was below the required levels, AEMO advised ESCOSA on what a suitable performance level would be given the specifics of the project and how far the project had progressed through development.

[12] Excluding South Australian projects as these are covered by the ESCOSA technical requirements.
[13] Ibid.
[14] AEMO, (2017). Recommended Technical Standards for Generator Licence Conditions in South Australia, page 2. Available at: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Reports/2017-ESCOSA-Review--Final-Report.pdf

4 TECHNICAL RECOMMENDATIONS

4.1 Supplementary advice

AEMO has considered the preliminary feedback received from stakeholders. Feedback has been given directly and via the industry workshop conducted by the AEMC on 12 October 2017. As a consequence, AEMO developed and provided a Supplementary Material document to the AEMC, and the AEMC have published that document[15].

AEMO's supplementary material document provided clarification in response to a number of questions raised by the AEMC and proposed revised drafting for a number of the proposed rule amendments. The clauses that have been redrafted or further amended are summarised below:

- **S5.2.5.1 Reactive power capability** – clarification included in the clause to note that the upper boundary for the minimum access standard is the automatic access standard. A further amendment was made to correct a drafting error made in the original proposal.
- **S5.2.5.4 and S5.2.5.5** – included an additional phrase to provide a greater degree of flexibility in establish a negotiated access standard, relating to the maximum allowable amount of reduction in generation. Compared with the existing provisions, the redrafting restores the flexibility allowance to S5.2.5.4 and extends the same flexibility to S5.2.5.5.
- **S5.2.5.5** – AEMO proposed adding paragraphs to the general requirements such that acceptable levels of reactive current injection and active power recovery time can be agreed with the NSP to suit the local network characteristics and the agreed amounts recorded in the performance standards.
- **S5.2.5.11** – included an additional phrase to ensure that the agreed droop settings for frequency response are recorded in the performance standards.
- **Continuous uninterrupted operation** – redrafted definition to clarify that the required performance during a disturbance only applies to reactive power requirements, specifically the requirements under clause S5.2.5.5

In addition to the supplementary material, AEMO proposes further revisions to the proposed technical standards as detailed below.

4.2 Disturbance ride through: high voltage disturbance ride through

In its Rule change proposal, AEMO made a number of recommendations in relation to high voltage disturbance withstand capability. In summary these were such that:

- The system standard for high voltage be increased to better reflect the over voltage risk imposed by broader adoption of special protection schemes that utilise high speed load shedding to mitigate the impact of *protected events.*

[15] AEMO supplementary advice - http://www.aemc.gov.au/getattachment/2bbe030c-cf1d-4c73-9ff0-73e5bb7f91c1/AEMO-GTR-RCP-Supplementary-Material.aspx

- The minimum access standard for S5.2.5.4 (generating system performance for voltage disturbances) include an over voltage withstand requirement identical to the automatic access standard.

In light of feedback from industry regarding potential cost impacts, AEMO considers that the proposal should be adjusted to better reflect operational practice and plant capability. AEMO therefore proposes the following in respect of high voltage withstand and ride-through capability.

- The system standard for high voltage be retained according to the existing S5.1a.4. This ensures that already connected plant is not exposed to a higher requirement than currently exists. AEMO notes that primary plant operated by NSPs will generally have sufficient over voltage withstand capability as per existing Australian Standard specifications to meet the revised standard, but the cost imposed to other connected participants is likely to be significant.
- The proposed automatic access standard for high voltage withstand for generating systems be retained to reflect the over voltage risk imposed by broader adoption of special protection schemes that utilise high speed load shedding. AEMO considers that ensuring generation facilities remain in continuous uninterrupted operation as a consequence of operation of special protection schemes implemented to manage *protected events* will support the recovery of the power system and limit the impact of such events.

  A higher capability will deliver benefits to ensure that the system is resilient to severe and rare events and will also be beneficial during black start operations. AEMO considers that where high voltage withstand capability can be reasonably delivered it will offer benefits to the ongoing operation of the power system in the future.
- To accommodate flexibility and recognise the limited capability of some plant, AEMO proposes that the minimum access standard defined in S5.2.5.4 be adjusted to require a lower level of over voltage withstand, both in terms of the extent of over voltage and withstand duration.

The amended proposed clauses are as follows:

S5.1a.4 Power frequency voltage

No change to existing clause.

S5.2.5.4 Generating system response to voltage disturbances

Automatic access standard

(a) The *automatic access standard* is a *generating system* and each of its *generating units* must be capable of *continuous uninterrupted operation* where a *power system* disturbance causes the *voltage* at the *connection point* to vary within the following ranges:

(1) ~~*voltages* over 110%~~ 130% of *normal voltage* for a period of at least 0.02 seconds ~~the durations permitted under clause S5.1a.4~~;

(2) 125% to 130% of *normal voltage* for a period of at least 0.2 seconds;

(3) 120% to 125% of *normal voltage* for a period of at least 2.0 seconds;

(4) 115% to 120% of *normal voltage* for a period of at least 20.0 seconds;

(5) 110% to 115% of *normal voltage* for a period of at least 20 minutes;

(6) 90% to 110% of *normal voltage* continuously;

(7) 80% to 90% of *normal voltage* for a period of at least 10 seconds; and

(8) 70% to 80% of *normal voltage* for a period of at least 2 seconds.

Minimum access standard

(b) The *minimum access standard* is a *generating system* including all operating *generating units* must be capable of *continuous uninterrupted operation* where a *power system* disturbance causes the *voltage* at the *connection point* to vary within the following ranges:

(1) ~~*voltages* over~~ 115% to 120% of *normal voltage* for a period of at least 0.1 seconds ~~the durations permitted under clause S5.1a.4~~; ~~and~~

(2) 110% to 115% of *normal voltage* for a period of at least 0.9 seconds;

(3) ~~in the range of:~~

~~(i)~~ 90% to 110% of *normal voltage* continuously, provided that the ratio of *voltage* to *frequency* (as measured at the *connection point* and expressed as percentage of *normal voltage* and a percentage of 50 Hz) does not exceed:

(A~~1~~) a value of 1.15 for more than two minutes; or

(B~~2~~) a value of 1.10 for more than 10 minutes.;

(4) 80% to 90% of *normal voltage* for a period of at least 5 seconds; and

(5) 70% to 80% of *normal voltage* for a period of at least 2 seconds.

4.3 System strength

AEMO's generator technical standards Rule change proposal included a proposed generator access standard relating to plant capability to maintain continuous uninterrupted operation at a particular level of system strength. The drafting of the proposed new access standard was based on concepts that were dealt with in another ongoing rule change – Managing power system fault levels which was a draft determination stage at the time. Subsequent to AEMO's generator technical standards rule change being submitted, the Managing system fault levels rule change was finalised, the final determination was substantially different from the draft and no longer used the term short circuit ratio. As such, it is necessary that the proposed generator access standard for system strength be reviewed.

AEMO considers that the use of short circuit ratio is an appropriate tool to use in determining pant capability. We now include an X/R (reactance to resistance) ratio to provide greater clarity regarding the capability requirement. As noted in AEMO's Supplementary Material document, the short circuit ratio and X/R apply at the connection point to ensure that the generating units, auxiliary support plant and reticulation systems are designed appropriately to meet the system requirements.

The proposed access standard includes only a minimum access requirement. No automatic access standard has been specified, recognising that there may be some applications relating to connection points that are very weak and appropriate performance standards will need to be negotiated between the connection applicant and their Network Service Provider. The nature of such connection points will require specialised and detailed negotiation, assessment and design to establish acceptable

performance standards and ensure that suitable equipment with appropriate control system settings is connected.

AEMO notes that the understanding of system strength limitations and control measures is a developing field internationally. Short circuit ratio as a measure of a generating system's stability limitations is presently the most widely used and understood methodology. As experience and knowledge in this area develops, there may be other alternatives that emerge. AEMO recommends that the generator technical standards include a system strength requirement based on short circuit ratio. Given the rapidly changing nature of technology, international standards and the power system, as with all the technical requirements this may be revised in future reviews of the standards.

The amended proposed access standard and associated definition/s are given below.

S5.2.5.15 System Strength

Minimum access standard

(a) The *minimum access standard* is a *generating system* and each of its *generating units* must be capable of *continuous uninterrupted operation* for a *short circuit ratio* of 3.0 and a reactance to resistance (X/R) ratio of 3.0 at the *connection point*.

Negotiated access standard

(b) *AEMO* must advise on matters relating to *negotiated access standards* under this clause S5.2.5.15.

GLOSSARY

New Definition

short circuit ratio

In relation to:

(a) a *generating system*, the ratio of the *three phase fault level* (in MVA) at the *connection points* for the *generating system* to the *maximum operating level* of the *generating system* (in MW).

This access standard has been proposed to ensure that plant that is designed to operate with a minimum system strength capability, to mitigate against future decreases in short-circuit ratio. Without such a standard, there is a risk that lower capability plant could be installed which could as a consequence restrict access to the NEM by other applications.

The standard will in effect operate as a plant standard, ensuring that all plant within a generating system is capable of being operated to a base minimum short circuit ratio. While AEMO requires that an applicant be able to demonstrate the plant capability at low SCR, the design and tuning of plant and control systems will need to be specific to each connection point – such that the plant operates stably and in accordance with its agreed performance standards based on the characteristics of the connection point.

In terms of assessing compliance specific to this performance standard, AEMO would therefore expect to be making an assessment based on plant data sheets or manufacturers' statement of capability combined with an engineering assessment considering the impact of the generating system's internal reticulation network.

For clarity, AEMO notes that the recommended system strength capability is focussed on the generating system in isolation, looking inside the generating system rather than the external network. The objective is to establish a baseline of capability as far as equipment design practices are concerned. Calculation methods such as composite short ratio or weighted short circuit ratio are not applicable in this context.

These calculation methods for the aggregation of multiple, electrically close asynchronous generating systems and formation of a large virtual plant will be dealt with in the interim system strength impact assessment guidelines that AEMO is developing under the new Rule made as part of the Managing power system fault levels Rule change[16].

[16] AEMC. *Managing power system fault levels*. Available at: http://www.aemc.gov.au/Rule-Changes/Managing-power-system-fault-levels

5 EXPECTED BENEFITS AND COSTS OF THE PROPOSED RULE

In assessing AEMO's Rule change proposal, AEMO understands that the AEMC is seeking to ensure a balance between the security benefits that the new standards will bring against the marginal cost of meeting these standards.

AEMO believes the majority of the recommended automatic access standards can be met by the majority of asynchronous generating systems at little or no marginal cost increase.

AEMO has developed its recommendations to take advantage of global technological developments while minimising potential costs, by amending the technical standards to reflect the capabilities of modern technology. In developing its proposals for revised generator technical standards, AEMO reviewed the standards applying internationally[17]. The intention was to minimise any cost impact, recognising that the Australian market is small and it is unrealistic to expect that new plant designs can be driven by NER technical requirements.

Table 1 in Appendix A summarises the expected cost impact associated with each of the proposed amendments to generator technical standards.

In the majority of cases, the standards AEMO has proposed are consistent with international grid codes[18], noting a degree of variation relating to local requirements and regulatory conditions. AEMO adopted this approach to ensure that suitably designed and operated plant will be available to connect within the NEM at marginal (if any) increased cost. AEMO acknowledges that such plant could only be deployed with proper adjustment and tuning of control and protection parameters to suit local conditions, and that plant that is not designed to meet major international grid codes is unlikely to be able to meet the proposed standards. AEMO considers plant that is incapable of meeting the standards should not be widely used, and that alternative suppliers offering suitably designed plant exist across the international market.

For a small number of the amended technical standards, there is limited precedence in international codes. These emerging areas relate to multiple disturbance ride-through requirements, high voltage disturbance withstand capability and specifications regarding system strength. Each of these issues are material in the context of the NEM, representing scenarios that have been experienced and are expected to be exacerbated by the development of the NEM as a system with high levels of connected asynchronous generating systems. Further discussion is provided in **Table 1**.

AEMO acknowledges that some of the proposed technical requirements have the potential to impose costly physical constraints on some synchronous generating units. In these cases, the proposed framework provides flexibility to accommodate negotiated access standards where power system security can still be assured. AEMO also notes that some additional flexibility has been proposed for high voltage disturbance withstand capability, as discussed in section 4.2.

In summary, AEMO is of the view that the proposed amended technical requirements are sufficiently consistent with international practice and flexible in their application to ensure that developers have the opportunity to procure plant that includes the required capability and to be deliverable at marginal increased cost.

[17] Refer Table 2 for list of international grid codes AEMO benchmarked our Rule change against
[18] Ibid

APPENDIX A. COST IMPACT OF AMENDED ACCESS STANDARDS

Table 1 outlines how the proposed standards compare to international practice, which determines the likely cost impact of adopting the change. Table 2 lists the grid codes included in AEMO's review.

Table 1: Cost impact of amended access standards

Clause	Summary of amendment	International practice	Cost impact
S5.2.5.1	Minimum access standard increased from no reactive power capability to a capability range derived from the applicable S5.2.5.13 voltage control range. The required capability is to be limited by automatic access range of ±0.395 of rated active power (i.e. 0.93 power factor).	It is typical to require a power factor range similar to the NER automatic standard. There is generally some allowance given to reduce requirements at voltage extremities (e.g. capacitive capability is not required for high voltage levels etc.).	As the automatic access standard is consistent with international practice, AEMO does not consider that amending the minimum access standard should represent a material cost impact or represent a barrier to entry.
S5.2.5.13	All facilities to have voltage control capability, with an allowance for embedded generation to also have power factor or reactive control modes, and that generating systems rated < 30 MW may have limited performance requirements for the voltage control.	Voltage control is required for transmission and higher capacity connections. Other forms of control (power factor and reactive power) are often applied to medium voltage connections (e.g. 33 kV or less). Usually all control capabilities are contained within the overall control systems, with one form selected as the operational mode.	As the international practice typically requires a range of capability within control systems, AEMO does not consider that the proposed amendments should represent a material cost impact or represent a barrier to entry.

Clause	Summary of amendment	International practice	Cost impact
S5.2.5.5 Disturbance ride through	Reactive current injection is required during low voltage and high voltage disturbances.	The reactive injection is consistent with German and Danish codes. Differences exist in how the current injection is calculated, variable 'k' factor, requirements specific to positive and negative sequence contributions, tolerance levels for injection and specific recommendation to prioritise Q over P during a dip. There are some restrictions on reactive current injection in distribution networks with high fault levels.	Given the general functionality is required elsewhere, AEMO considers any cost impact will be related to tuning to meet local conditions. The cost impact is likely to be minimal.
	Active power recovery following a disturbance must be specified. Active power must recover to 95% of pre-disturbance levels (subject to changed energy source conditions) within a range of 100 ms to 1 second.	Specifying active power recovery is consistent with international practice. British and Irish codes have similar recovery times (1 second), German and Danish codes allow slower recovery time (5 seconds).	AEMO notes that it may be challenging for some older technologies to meet faster recovery times, particularly for weak connection points, but the control functionality exists and additional cost impact should be confined to control system tuning.
	Multiple fault ride-through withstand capability. The proposed requirement is that a generating system must withstand 15 disturbance events within a 5 minute period, the total cumulative duration of time that voltage may be less than 90% of normal voltage is 1,800 ms for the automatic access	Multiple fault ride through is rarely addressed internationally. The Danish grid code has the most specific requirements at present, these do have some variation for different technologies. The Danish equivalent requires a lesser number of events (up to 12 unsymmetrical faults), but similar time	AEMO notes that there may be some challenge to meet greater number of events, but the time exposure (which is the limiting factor for some technologies) is less than international requirement, and functionality exists. AEMO further notes the consequence of multiple generating systems disconnecting due to

Clause	Summary of amendment	International practice	Cost impact
	standard and 1,000 ms for the minimum access standard.	duration. Internationally such capability is under review, driven by the SA black system event in 2016. The need for definition of requirements for repeated disturbances has been acknowledged in a special report by the United States national reliability body, the North American Electric Reliability Corporation (NERC).	multiple events represents a significant cost to the consumers.
S5.1a.4 S5.2.5.4	High voltage ride through – AEMO proposed to increase the over voltage withstand capability requirements.	Data indicates that the proposal is more challenging than European standards at the upper voltage levels, but is broadly consistent with Hydro Quebec for these.	AEMO notes that there may be costs associated with meeting the originally proposed requirements. To mitigate this risk, we have amended our proposal and now recommend retaining S5.1a.4 in its current form. A modified proposal has been made in relation to S5.2.5.4, allowing for flexibility by providing lower capability requirements as the minimum access standard. Please refer to section 4.2 for further discussion.
S5.2.5.11	Frequency response – generating systems should have the capability to operate in frequency response mode.	International practice is consistent with the proposal.	Given the general functionality is required elsewhere, AEMO considers any cost impact is likely to be minimal.
S5.2.5.14	Active power control including ramp limit.	International practice is consistent with proposal.	Given the general functionality is required elsewhere, AEMO

Clause	Summary of amendment	International practice	Cost impact
			considers any cost impact is likely to be minimal.
S5.2.5.15	System strength – plant capability to operate stably in low system strength conditions	This matter is not addressed in international standards. The issue is an emerging one, and one where Australia is highly exposed due to the topology of the NEM.	AEMO notes that this standard does not have an international equivalent but considers that the requirement is well within the capability of modern plant. The purpose of including this standard is to ensure that a minimum level capability is established within connected plant, to manage evolution of the system and expected erosion in system strength
S5.2.6.1	Provide real-time information about their active power control systems to AEMO	These recommendations are consistent with Electric Reliability Council of Texas (ERCOT), which oblige all generators to notify the system operator about changes to active power control settings. Online monitoring and control are widely used throughout the world.	Given such functionality is widely used AEMO expects minimal additional cost, this will primarily be in the form of additional signalling bandwidth.

Table 2: Referenced Grid Codes

Europe Transmission Network System Operators (ENTSOE)	Network Code - Requirement for Generators
Denmark Energinet.dk	Regulations for Grid Connection
	Technical regulations for PV plants > 11 kW
	Technical regulations for thermal plants > 11 kW
	Technical regulations for wind power plants > 11 kW
	Technical regulations for battery plants > 11 kW
Canada Hydro Quebec	Medium voltage generation connection requirements (in French)
	Transmission network generation connection requirements
Germany Tennet	
	Tennet Grid Code – High voltage and extra high voltage
VDE	VDE-AR-N 4120 (no link)
Great Britain National Grid	National Grid Full Grid Code
	National Grid Connection Conditions
Ireland and Northern Ireland Eirgrid	Eirgrid (Ireland and Northern Ireland) Grid Code
US North American Electric Reliability Corporation (NERC)	Special Assessment: Interconnection Requirements for Variable Generation (2012) Integration of Variable Generation Technology Task Force reference papers
Electric Reliability Council of Texas (ERCOT)	Requirements set out in *BAL-001 TRE -1*