RULE CHANGE

Australian Energy Market Commission

DRAFT RULE DETERMINATION

National Electricity Amendment (Generator technical performance standards) Rule 2018

Rule Proponent

Australian Energy Market Operator

31 May 2018

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About the AEMC

The AEMC reports to the Council of Australian Governments (COAG) through the COAG Energy Council. We have two functions. We make and amend the national electricity, gas and energy retail rules and conduct independent reviews for the COAG Energy Council.

Summary

The Commission has made a draft rule changing the way that levels of performance are set for equipment connecting to the power system, particularly new generating systems. The changes enhance the rules to reflect the changing needs of the power system with the objective of maintaining power system security and quality of power supply at the lowest cost to consumers.

This draft rule is made in response to a rule change request submitted by the Australian Energy Market Operator (AEMO).

Context

The power system is experiencing a period of change as traditional forms of large-scale, synchronous, generation are retiring, and being replaced by intermittent, asynchronous, and increasingly distributed generation. This shift presents challenges for the secure operation of the power system. In particular, it is becoming more difficult to effectively control frequency and voltage, which could lead to significant power system disturbances and potentially blackouts.

As this shift occurs, some valuable attributes of synchronous generating systems are becoming available in reduced amounts.

The Commission's system security and reliability action plan (available on the AEMC's website) is addressing these changes to the power system in a coordinated manner. The Commission has already made a number of changes to the national electricity rules (NER) to address several of these matters, for example by requiring the procurement of inertia and system strength. This rule change is part of that action plan and will further enhance system security by implementing technical requirements that reflect the range of new generating technologies that are expected to connect to the system in the future and the implications of those technologies for system security and the quality of supply to other users.

The technical requirements currently set out in the generator access standards in the NER are no longer appropriate to address the needs of the power system as it transitions. In some cases, they are not sufficient to efficiently manage frequency and voltage within acceptable limits, or to limit the risk of major power system collapse when those acceptable limits are breached. In other cases they are not adequate to replace some of the valuable attributes being lost as synchronous generation retires, such as their inherent stabilising behaviour that assists the power system during certain disturbances.

The Commission's draft rule

Under the connections framework in the NER, connection applicants are able to negotiate with a network service provider (who is advised on some matters by AEMO) on the level of performance for the equipment they are seeking to connect to the power system. For each technical requirement, the negotiation occurs with a range provided by an automatic access standard (where a connection cannot be denied access on the

basis of that technical requirement) and a minimum access standard (below which a connection must be denied access) that are each set out in the NER.

The NER currently allows network service providers and AEMO, in respect of its advisory matters, to refuse to agree to a proposed negotiated access standard if, among other things, it would adversely affect system security or the quality of power supply to other network users. Other tools are also available to AEMO to manage power system security and to network service providers to manage their networks in accordance with their obligations under the NER. This includes through the design and augmentation of networks and use of network support services, the operation of the power system and the constraints applied, and the use of ancillary services.

In its rule change request, AEMO considered that the current process to negotiate access standards, and the access standards for generators, are no longer adequate to ensure the ongoing security of the evolving power system. AEMO therefore proposed changes to:

- the negotiating process used to set the levels of performance required of all equipment connecting to the power system, and
- a number of access standards for connecting generating systems, including those relating to active power capability and control, reactive power capability and control, reactive current response during disturbances, and the access standards related to the ability to maintain operation in the face of certain disturbances and low system strength conditions.

We agree with AEMO that a changing energy mix is creating new challenges for the efficient management of the power system in a secure state. In particular, the ability to effectively control frequency and voltage on the power system is diminishing as synchronous generating systems exit the market and new asynchronous generating systems and distributed energy sources replace them. The current negotiating process and generator access standards in the NER are no longer appropriate to address these challenges.

To address these issues, the draft rule improves and clarifies the negotiating process for connections so that negotiations can occur more efficiently and each connection has a level of performance that balances system security, quality of supply and cost. It also changes a number of the generator access standards, including:

- the requirements for generating systems to be able to control their active power output, to limit their contribution to frequency and voltage disturbances on the power system, and allow them to better respond to changes in frequency if they choose to do so
- the requirements for generating systems to be able to supply and absorb reactive power where these services are needed on the power system, to reduce the risks of voltage instability and collapse at an efficient cost for consumers
- the requirements for generating systems to be able to inject and absorb reactive current during disturbances, so that all units connecting can assist by supporting voltage levels in a predicable way when there are faults on the power system, and
- the requirements for generating systems to be able to maintain operation in the face of certain frequency and voltage disturbances (including faults and

contingency events) on the power system that are expected to become more severe over time, to better protect the power system from the risk of cascading failures that can lead to widespread blackouts.

A significant number of connection applications are currently before network service providers and AEMO. The draft rule would therefore introduce all of these requirements as soon as possible, balancing the risks of delay to the efficient operation of the power system in a secure state with the risks to investment certainty potentially created by a more rapid transition to the new rules.

Background to the connection process and technical requirements

This rule change relates to the levels of performance required of equipment connecting to the power system. Most of the changes relate specifically to the connection of generating systems, but the changes to the negotiating process will apply to the connection of all equipment.

The process to set those levels of performance occurs within the overall framework for connections to the power system. As part of that process a connection applicant submits an application to connect to the network service provider, which must include details of the levels of performance proposed for the connection.

For any given technical requirement, a connection applicant can propose to connect at the level set out in an automatic access standard, or propose a negotiated access standard that is at or above the minimum access standard. Where the automatic access standard is proposed by a connection applicant, the equipment will not be denied access because of that technical requirement. Equipment that does not meet the minimum access standard will be denied access.

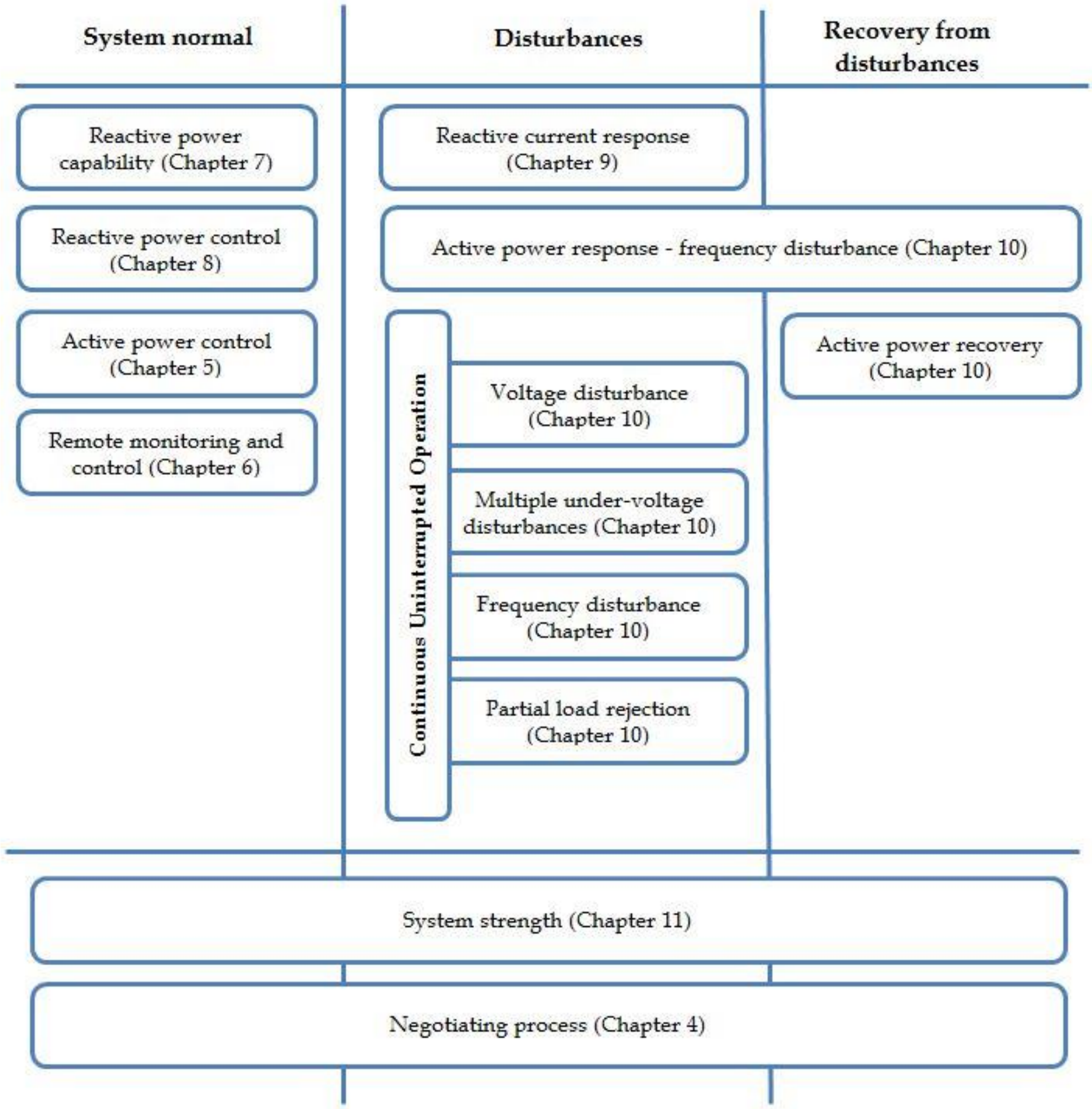
Where a negotiated access standard is proposed, the applicant and network service provider negotiate a level of performance for that technical requirement. AEMO advises the network service provider on the negotiation of some access standards, called AEMO advisory matters. The network service provider must reject a proposed negotiated access standard if, among other things, AEMO advises it would adversely affect power system security or if the network service provider considers it would adversely affect the quality of supply to other network users.

The levels of performance set through this process (the automatic access standard or other standard agreed by negotiation) become the performance standards applicable to the specific connected equipment. Those performance standards form part of the terms and conditions of the connection agreement between the connection applicant and the network service provider.

The access standards in the NER can therefore be viewed as the reference points used for negotiations between a connection applicant, the network service provider and, where relevant, AEMO, to set the specific levels of technical performance of equipment that connects to the power system.

The access standards for generators connecting to the power system relate to a wide range of technical requirements and are set out in Schedule 5.2 to the NER. They include technical requirements related to power system needs during normal operating conditions, during disturbances, and immediately following disturbances. Figure 1 below shows the range of technical requirements discussed in this draft determination that relate to these power system needs and the Chapter in this draft determination that discusses the technical requirement.

Figure 1 Technical requirements addressed in this rule change



Assessment of this rule change

In assessing this rule change request the Commission considered the issues raised by AEMO and the response that would best contribute to the achievement of the national electricity objective. In essence, the national electricity objective focusses on the long term interests of consumers.

The Commission considered how to best maintain power system security and the quality of supply at least cost to consumers. As part of this assessment, key principles the Commission applied were:

- access standards should not represent an inefficient barrier to entry for any technology type

- the arrangements should provide the right balance between investment certainty and having sufficient flexibility in regulatory arrangements, and
- costs and risks should be allocated to those parties that are best placed to bear and manage them.

The Commission has also sought to make sure that the access standards are technology neutral. In most cases this means expressing the access standards in the same way for all technology types. In some cases expressing access standards in the same way for all technologies would form a barrier to entry to a particular technology due to the inherent technical characteristics of the technology, without being necessary for the security of the power system. In these cases we have sought to minimise barriers to entry by expressing requirements differently for the different technologies, while requiring the same system security outcome from all technologies.

As part of its assessment, the Commission was informed by:

- submissions from generators and their consultants on the estimated cost impacts of the proposals
- advice from the Commission’s technical consultant DigSILENT Pacific, and
- a survey of equipment manufacturers conducted by the Commission's technical consultant to understand whether the technical requirements proposed in the rule change request could be met by current 'off-the-shelf' equipment at no extra cost or, if not, what additional costs would be likely to be incurred to meet the proposed requirements.

On 19 September 2017, the Commission published a consultation for the rule change request, and received 37 submissions. The Commission held a stakeholder workshop on 12 October 2017, and convened a technical working group of experts from industry to advise on technical matters, which met on 11 December 2017 and on 1 and 2 February 2018.

Throughout the process the Commission has appreciated the ongoing support and assistance from AEMO. The Commission and AEMO worked collaboratively, including on the technical working group, to carefully assess the issues raised and appropriate changes to the technical requirements. AEMO provided more formal updated views on its proposed changes several times during the rule change process, which are published on the AEMC website, as well as assisting the Commission by providing detailed further information and views in email correspondence and ongoing discussions. The Commission acknowledges that some parts of the draft rule differ from AEMO’s proposed positions. We will continue to work with AEMO and stakeholders to explore any remaining issues through our consultation on the draft rule and draft determination.

Negotiating process for connections

AEMO considered the current arrangements for the negotiation of access standards are not adequate to support the ongoing security and efficient operation of the power system. It considered connection applicants often submit levels of performance at the level of the minimum access standard, which is not appropriate in many cases. The

Commission considers there are areas that could be improved to clarify the negotiating process and better support the maintenance of power system security at least cost to consumers. There is no clear starting point in the current rules for negotiations to occur, which does not reflect the need to aim for levels of performance that are more likely to be appropriate for power system security. There is little guidance on the matters a connection applicant should consider when proposing a negotiated access standard, and what guidance there is does not appear to be used by applicants in practice. Further, when rejecting a proposed negotiated access standard, AEMO and network service providers can in some cases provide less information than is desirable for connection applicants to decide what to do next.

To address these issues, the draft rule includes:

- a requirement that when proposing a negotiated access standard a connection applicant must propose a level of performance that is as close as practicable to the automatic access standard, having regard to the need to protect plant from damage, power system conditions at the proposed location of the connection, and, the commercial and technical feasibility of complying with the automatic access standard, and
- where a negotiated access standard is proposed, a requirement for connection applicants to provide to the network service provider and AEMO reasons and evidence as to why the proposed negotiated access standard is appropriate.

The draft rule also includes a new obligation on AEMO and network service providers to provide to the connection applicant detailed reasons for either:

- rejecting a proposed negotiated access standard, based on certain criteria, including an adverse effect on power system security or the quality of supply to other network users, or
- requiring connection applicants to provide additional evidence to support proposed negotiated access standards.

These changes apply to all new major connections to the power system, including connecting generating systems, customers and market network service providers (in accordance with the transitional arrangements described later). The changes help negotiations to occur more efficiently and each connection to have a level of performance that balances system security, quality of supply and cost.

Active power capability

The ability of a generating system to control its active power output is relevant to the control of the frequency of the power system. An inability to control active power can also lead to changes in power flows, causing frequency instability, equipment loading limits, voltage instability and system security issues. Certain capabilities to control active power are needed to be able to offer frequency control ancillary services (FCAS), which are paid market services to assist with the control of frequency on the power system.

AEMO considered there is a risk that many new connecting generating systems would not enter the markets for provision of FCAS due to perceived barriers to entry related to the costs of retrofitting FCAS capabilities where this capability had not been agreed with the equipment manufacturer when the generating system was constructed. AEMO considered that this could result in future shortfalls in the provision of these services and risks to the security of the power system as existing generation retires. AEMO also considered there is the potential for many generating systems to connect that do not have adequate active power control capabilities, particularly ramp limit control, leading to significant swings in network power flows causing voltage instability and system security issues.

To address these issues AEMO proposed that the access standards in the NER require that:

- all generating systems have the capability to offer measurable amounts of at least one market ancillary service
- all scheduled and semi-scheduled generating systems have the capability to receive instructions via the automatic generation control system
- all semi-scheduled generating systems have active power control capability to meet a given ramp limit, and
- all non-scheduled generators have active power control capabilities.

The Commission's draft rule:

- requires all generating systems to have the capability to operate in frequency response mode. Requiring generators to record this capability in performance standards will allow generators to more quickly complete the process of becoming an FCAS provider, where they wish to do so in response to FCAS market prices. Mandating this capability will impose minimal costs on connections and is also unlikely to impact on the function of FCAS markets.

  The draft rule is different to AEMO's original proposal because we consider that it better meets the NEO. It will impose lower costs on generators, and ultimately consumers, than AEMO's proposed approach, while supporting power system security by enabling those generators who wish to offer FCAS to do so quickly, when this is most needed by the power system.
- requires all semi-scheduled generating systems to have the capability to control active power to a ramp limit, and requires all non-scheduled generating systems to have some form of active power control, to limit the contribution of these generating systems to frequency and voltage disturbances on the power system. This change is in line with the proposal made by AEMO.
- requires all scheduled and semi-scheduled generating systems to have automatic generation control capability to support the more efficient operation of the power system in a secure state. This change is in line with the proposal made by AEMO.

Remote monitoring and control

Remote monitoring capability refers to the real time provision of data to AEMO's control centre related to the status of the generating unit, supporting auxiliaries and other equipment such as reactive plant. Remote control capability refers to the ability for AEMO to remotely change certain settings in a generating system related to the control of active or reactive power.

AEMO considered that the increasing complexity of the power system and the necessity for faster operational actions has created a need for greater automation and coordination. This automation and coordination can be facilitated where generators have effective remote monitoring and control capabilities. AEMO therefore proposed introducing new remote control and monitoring requirements under both automatic and minimum access standards.

While AEMO's proposed changes to the automatic access standard would support efficient power system operation, the range of capabilities proposed are not required at all connection points and submissions from stakeholders noted that these requirements could impose unnecessary additional costs in certain circumstances. Accordingly, the draft rule includes most of AEMO's proposed changes in the automatic access standard, but also retains most of the existing minimum access standard, subject to some changes, to allow flexibility to negotiate to an appropriate outcome for each connecting generating system.

The draft rule:

- amends the existing automatic access standard, to allow AEMO to require a number of additional remote monitoring and control capabilities, and
- maintains the current level of the minimum access standard, subject to two changes that:
  - expand its coverage to include non-scheduled generating systems with nameplate capacity of less than 30 megawatts (MW), and
  - amend the requirements for data provision from semi-scheduled generating systems, to more closely align with modern operational practice for these generating systems.

Reactive power capability

Reactive power is necessary to support the voltage levels on the power system. Voltage reflects the dynamic balance between injection and absorption of reactive power in the local area of the power system. Shortfalls in reactive power capability can therefore lead to voltage instability or collapse. Responsibility for the provision of reactive power services has been traditionally shared between generators, network service providers, and loads. As the generation mix changes, some equipment that has traditionally provided reactive power capability, such as synchronous generating systems, is exiting the power system.

Current arrangements in the NER do not require a connecting generating system to provide a minimum level of capability for the supply or absorption of reactive power. AEMO considered these arrangements are not sufficient to maintain power system security in the context of a power system in transition.

The Commission considers the current arrangements, including a minimum access standard that does not require reactive power capability, provide the flexibility to set an appropriate level of performance for the needs of the power system at the lowest cost to consumers. In particular, there are likely to be some circumstances where a reactive power capability is not necessary to maintain the security of the power system or the quality of supply to other network users. Stakeholders held significant concerns that requiring reactive power capability where it is not needed could add significant additional costs for some connections.

However, as AEMO does not have an advisory function in the current arrangements for reactive power capability, there is a risk that in some cases insufficient capability may be required of a connecting generating system to maintain the security of the power system. To address this issue, the draft rule specifies the access standards for reactive power capability as an AEMO advisory matter and provides guidance that the level of reactive power capability must be sufficient to support the security of the power system.

Reactive power control

Where reactive power capability is needed to support the security of the power system and the quality of supply, it is also necessary to specify the characteristics of the reactive power response of the generating system. AEMO raised concerns that the current arrangements relating to voltage and reactive power control do not provide sufficient reactive power control capabilities for an evolving power system, requesting changes to requirements for:

- the mode of reactive power control a generating system must be capable of operating in
- voltage control mode capabilities, and
- the rise and settling times associated with the generating system's response to a step change in voltage.

The Commission agrees that the changing generation mix in the power system, including increasing penetration of distributed and asynchronous energy sources, presents increasing challenges for controlling voltage on the power system. In a range of respects the current arrangements are not adequate to address these challenges, and would also benefit from being simplified and made consistent with the way other access standards are specified.

To address these issues we have sought to achieve the outcomes requested by AEMO, but have implemented changes in a different manner in response to submissions from stakeholders, including network service providers, regarding the need for flexibility of approach in different parts of the network. The draft rule:

- changes the requirements for specifying the mode of reactive power control so that the automatic access standard is the capability to operate in all modes and switch between them (in accordance with a procedure agreed with AEMO and the network service provider), and the minimum access standard is the capability to either operate in voltage control mode, or otherwise in any other reactive power control mode with the agreement of AEMO and the network service provider
- provides that the mode of reactive power arrangements apply irrespective of the connection point voltage and the capacity of the generating system

- introduces a minimum access standard requirement for generating systems to have a voltage control system, where one is required, that:
  - regulates voltage at the connection point (or another agreed location on the power system or within the generating system) to within ±2% of the set-point, and
  - allows the voltage set-point to be controllable in the range of at least 98% to 102% of normal voltage at the connection point (or the agreed location)
- clarifies that voltage control can be implemented using a voltage-reactive power droop characteristic
- introduces new performance requirements for generating systems operating in reactive power or power factor control modes, and
- aligns the rise and settling time requirements for synchronous and asynchronous generating systems under the minimum access standard.

The draft rule also seeks to clarify the relationship between reactive power capability and reactive power control by specifying that the reactive power control characteristics are subject to the amount of reactive power capability determined to be needed for the connection.

Reactive current response during disturbances

During a fault on the power system, the main impact is a sudden drop in voltage that spreads out from the location of the fault. Synchronous generating systems that are exposed to those rapid changes in voltage will inherently respond, injecting or absorbing reactive current in a way that supports voltage on the power system. Other types of generating system do not inherently respond. The type of response they can provide to support voltage during voltage disturbances is affected by the overall architecture of the control of the system and has to be defined (or coded) into its control equipment.

Current arrangements for reactive current response during disturbances include a specified response for reactive current injection (and not absorption) under the automatic access standard, but no other specific response requirements are specified. AEMO considered these arrangements are not adequate to address the increasing difficulty of managing voltage levels across the power system caused by the changing generation mix.

The Commission considers that current arrangements are appropriate for connecting synchronous generating systems that provide a reactive current response during disturbances with characteristics that are inherent to the electro-mechanical nature of the machines. However, current arrangements are not appropriate for connecting asynchronous generating systems that do not provide an inherent response. Without clear guidance in the NER on how reactive current response is coded into the control equipment, there is a risk that asynchronous generating systems may not provide sufficient reactive current response during disturbances to support the security of the power system.

The draft rule therefore:

- retains current arrangements for synchronous generating systems as the current arrangements for those types of generating systems do not cause any system security concerns and they have limited flexibility to alter the reactive current response during disturbances without incurring significant additional cost, and
- introduces new arrangements for asynchronous generating systems that broadly reflect the arrangements proposed by AEMO, however providing more flexibility to account for different power system conditions and equipment limitations.

The draft rule also includes a new response limit proposed by AEMO to better align the existing automatic access standard with synchronous generating system capabilities and power system needs.

Continuous uninterrupted operation

It is important for the security of the power system that generating systems have the ability to keep operating when faced with disturbances caused by faults or generating systems and other equipment disconnecting. Such capabilities are important because a generating system that is unable to continue operating during and after a disturbance at its connection point will disconnect. This is referred to in the NER as a requirement to maintain 'continuous uninterrupted operation'. A generating system that cannot maintain continuous uninterrupted operation when faced with certain disturbances may increase the extent and severity of the disturbance experienced by other generating systems, potentially causing cascading failures and widespread blackouts.

As part of its rule change request, AEMO considered that asynchronous generating systems, which are increasingly connecting to the power system, may not have adequate capability to maintain operation in response to particular voltage and frequency disturbances in the power system. In addition, AEMO considered that changes in the generation mix may lead to more frequent and severe disturbances in the power system, such as frequency disturbances caused by reductions in system inertia, and voltage disturbances caused by reductions in system strength. AEMO considered that without clearly specified capabilities for generating systems to maintain operation in response to such disturbances the power system would need to be operated more conservatively, including by reducing interconnector flows and implementing constraints on generation.

To address these issues, AEMO proposed changes to the access standards related to requirements of generating systems to maintain continuous uninterrupted operation in response to particular disturbances. This includes access standards related to frequency disturbances, over-voltage and under-voltage disturbances, multiple voltage disturbances, active power recovery following a disturbance, as well as partial load rejection. In addition, AEMO proposed amendments to the definition of continuous uninterrupted operation in the NER.

The Commission's draft rule largely implements AEMO's proposed changes. This includes:

- amending the definition of continuous uninterrupted operation to provide greater clarity to network users

- strengthening existing requirements for generating systems to maintain continuous uninterrupted operation for particular disturbances
- introducing new requirements for generating systems to maintain continuous uninterrupted operation for certain multiple low voltage disturbances, and
- extending existing requirements to maintain continuous uninterrupted operation for particular partial load rejection events to asynchronous generating systems.

System strength

System strength is related to the sensitivity of voltages in the power system to faults, changes in generation and load, as well as network switching events. System strength can be described by reference to the amount of current that flows into a fault on the power system and measured using the metric of 'short circuit ratio' (where a high ratio represents a strong system and a low ratio represents a weaker system). System strength is typically greater in parts of the power system that are more interconnected and that have more synchronous generating systems (because they typically provide more current during faults compared to asynchronous generating systems).

System strength is deteriorating in some parts of the power system as the generation mix changes to include more asynchronous generating systems (which don't typically contribute as much fault current compared to synchronous generating systems). There is a risk to power system security if system strength reduces to levels at which some generating systems cannot operate stably.

In its rule change request, AEMO noted that the *Managing power system fault levels rule* recently made by the Commission requires network service providers to maintain the system strength at nominated points in the network above agreed minimum levels, and also requires new connecting generating systems to 'do no harm' to the minimum level of system strength being provided to any nearby generating system connection points. However, AEMO also considered that the *Managing power system fault levels rule* does not allow network service providers to require capability from a generating system to make efficient use of the available system strength, particularly in strong parts of the power system, and in doing so, potentially minimise costs for generating systems connecting in the future.

AEMO proposed addressing this issue by introducing a new minimum access standard (with no corresponding automatic access standard) that would require a generating system and each of its generating units to be capable of continuous uninterrupted operation for a short circuit ratio of 3.0 at the connection point, with the ability for AEMO and the NSP to negotiate a lower short circuit ratio where appropriate.

The Commission considers that the framework created by the *Managing power system fault levels rule* is likely to be sufficient to address the risks to power system security from reductions in system strength caused by a range of relatively severe events on the power system or longer term changes in the generation mix. In addition, the 'do no harm' requirement under the *Managing power system fault levels rule* will likely incentivise the installation of generating systems that are capable of continuous uninterrupted operation for the lowest expected three phase fault level at the connection point.

The Commission also considers that imposing costs or regulatory requirements on connecting generators in order to help facilitate future connections is contrary to the principles behind the transmission framework in operation in the NEM, as outlined by the Commission as part of the *Coordination of generation and transmission investment review*. Under the current transmission framework, generators are only required to bear the cost directly related to their connection at the time of their connection. This means that connecting generators do not bear a responsibility for future developments, assuming that a connecting generator does not create a system security issue for future connections. There is also insufficient certainty as to the magnitude of potential incremental costs on all connecting generators today as well as the magnitude of potential avoided costs for connecting generators and network service providers in future.

Matters relating to the coordination of generation and efficient use of and investment in network capacity are being considered as part of the AEMC's *Coordination of generation and transmission investment review*. This review will consider issues regarding the efficient connection of generation, and the regulatory changes that may be required to facilitate the connection of large amounts of new generation which may need to locate in areas that are at the edges of the existing network, in new renewable energy zones. The Commission welcomes stakeholder feedback on these issues as part of that review.

A system strength access standard could be reconsidered in future reviews of the generator technical performance standards once the *Managing power system fault levels rule* has been fully implemented and more information is available on the costs and benefits of a system security access standard.

The Commission has therefore made a draft rule that does not contain a new system strength access standard.

Consequential changes

The rule change request and stakeholder submissions raised a number of issues that relate to the implementation of the draft rule.

To address these issues the draft rule:

- introduces a framework for AEMO to review the access standards in the NER at least every 5 years, in accordance with a defined process and set of objectives
- introduces clear obligations for AEMO to provide the AER with an up-to-date copy of the register of generator performance standards (including the corresponding performance standards) annually and on request, or a copy of certain performance standards relevant to specified plant on request, and
- regarding the current arrangements for renegotiation certain of a generator's performance standards when equipment is altered:
  - clarifies the application of the arrangements
  - allows applicants to negotiate between the level of their existing agreed performance standard (instead of the specified minimum access standard) and the automatic access standard, and

— includes new references to specific access standards that are deemed to be affected (and therefore must be renegotiated) when altering certain listed equipment.

In addition, immediately following the making of any final rule, the Commission will request the Reliability Panel to review the template for generator compliance programs for consistency with the new access standards.

Transitional arrangements

In its rule change request, AEMO was concerned that if the final rule is not promptly implemented with effective transitional arrangements, a large number of generating systems (assets with a 20 year life) may be connected under current arrangements that AEMO considered to be outdated. AEMO therefore proposed transitional arrangements that would apply any amending rule to all connection applications not finalised by 11 August 2017 (the date they made the rule change request) and to create a mechanism to change certain performance standards agreed between 11 August 2017 and the date the rule is made.

The Commission agrees that if all of the generating systems with existing connection applications currently under consideration by AEMO and network service providers are able to proceed to connection under the current rules, a significant number of generating systems would be connected under arrangements we consider should be changed to better support the security of the power system. It is therefore appropriate to implement the new rule as quickly as is feasible, having regard to the prohibition on the AEMC making rules that have a retroactive effect.

The draft rule therefore includes transitional arrangements that:

- provide that the final rule would commence on the date that is 8 weeks after the date of the final determination, and
- for negotiations that on the date of commencement have a full set of access standards agreed for a proposed connection, allows for the access standards for the project to be based on the rules that were in force immediately prior to the commencement date.

Parties that have a full set of access standards agreed for the proposed connection prior to an offer to connect, have an offer to connect, or have entered into a connection agreement, are able to proceed to be commissioned in accordance with the rules in effect immediately before the commencement of the final rule. Where agreement on a full set of access standards in place on the commencement date was conditional, and a condition is not subsequently met, the new rules would then apply to the connection.

The draft rule also addresses matters for connections where a full set of access standards is not yet agreed as at the date the final rule commences. For these connection processes the network service provider is required to:

- notify the connection applicant that the new arrangements apply to their connection process, and
- to the extent necessary, provide the connection applicant with any further information relevant to the proposed plant (e.g. details of the relevant access

standards), and written notice of any further information to be provided by the connection applicant to the network service provider so that the connection applicant can prepare an application to connect, or so that the network service provider can prepare an offer to connect, under the new arrangements.

The draft rule does not allow the network service provider to charge an additional fee relating to a connection enquiry or application to connect, however the network service provider may still recover reasonable costs of work done relating to the connection and to facilitate the implementation of the new arrangements. The network service provider may also extend certain time periods to allow for additional time taken in excess of the period allowed in the preliminary program that is necessary to take account of the new arrangements.

Table 1 – Current arrangements, AEMO's proposed changes, and changes under the draft rule

Current arrangements	AEMO's proposed changes	Draft rule changes
Negotiating process for connections The negotiating process in clause 5.3.4A does not include clear guidance for connection applicants on the appropriate level of a negotiated access standard. Schedules to Chapter 5 note that negotiated access standards should be derived from the minimum access standard. Certain access standards in Schedule 5.2 note that for that particular technical requirement a negotiated access standard should be as close as practicable to the automatic access standard.	AEMO proposed requiring that: • a negotiated access standard be as close as practicable to the automatic access standard, and • a connection applicant submitting a negotiated access standard must provide evidence (to AEMO and the network service provider's satisfaction) that it is not practicable for the plant to achieve the automatic access standard	The draft rule requires that where a negotiated access standard is proposed: • it must be as close as practicable to the automatic access standard, having regard to the need to protect plant from damage, power system conditions at the proposed location of the connection, and, the commercial and technical feasibility of complying with the automatic access standard, and • the proposal must be supported with reasons and evidence as to why the proposed negotiated access standard is appropriate The draft rule also requires that AEMO and network service providers provide to the connection applicant detailed reasons for either: • rejecting a proposed negotiated access standard, based on certain criteria, including an adverse effect on system security or the quality of supply to other network users, or • requiring connection applicants to provide additional evidence to support proposed negotiated access standards.
Frequency response and active power control Current arrangements do not require all generators to have frequency control capability.	AEMO proposed requiring: • all generating systems to have the capability to offer one market ancillary service • all semi-scheduled generating systems to	The draft rule: • requires all generating systems to have the capability to operate in frequency response mode (subject to energy source availability)

The capability to control active power, including holding active power to a limit and controlling changes in active power to a ramp limit, only applies to semi-scheduled generation under the automatic access standard. Non-scheduled generating systems with nameplate capacity less than 30 MW are not required to have active power control capability. The NER state that automatic generation control (AGC) system is one of the preferred means to receive dispatch instructions, however there is no requirement for generators to have AGC capability under the NER.	have the capability to control active power output to a ramp limit • all non-scheduled generating systems, including generating systems with capability less than 30 MW, to have active power control capability, and • all scheduled and semi-scheduled generating systems to have the capability to receive and respond to AGC signals.	• amends the automatic access standard for frequency control, to state that generating systems must have the capability to offer all of the market ancillary services for provision of frequency control • introduces a definition of droop response and makes various clarifying amendments to the automatic access standard • requires all semi-scheduled generating systems to have the capability to control active power output to a ramp limit • requires all non-scheduled generating systems to have active power control capability, and • requires all scheduled and semi-scheduled generating systems to have the capability to receive and respond to AGC signals.
Remote monitoring and control The automatic access standard requires generating systems to have remote monitoring capability to provide specific information that AEMO requires to discharge its market and power system security functions. The minimum access standard requires generating systems to have remote monitoring capability for a subset of the remote monitoring capabilities established in the automatic access standard.	AEMO proposed changes that would: • amend the automatic and minimum access standard to increase the types of information that generating systems must provide through remote monitoring, and • introduce new remote control capabilities under both the automatic and the minimum access standards related to voltage set point and mode, AGC control and active power limits and ramp limits.	The draft rule amends: • the automatic access standard to increase the information that generating systems and units must provide • the automatic access standard to require generating systems to have remote control capability for voltage control, active power and AGC, and • the minimum access standard to expand its application to include all non-scheduled generating systems.
Reactive power capability	AEMO proposed an amended minimum access	The draft rule retains current arrangements,

The automatic access standard requires the capability to inject or absorb reactive power to a percentage of the rated active power of the generating system. The minimum access standard requires no capability to inject or absorb reactive power.	standard requiring sufficient reactive power capability to inject or absorb continuously an amount of reactive power of at least the amount required to enable the generating system to achieve the continuous controllable voltage set point range in S5.2.5.13. This would have the effect of mandating that all generators be capable of providing a reactive power response when required to do so by AEMO or the network service provider.	including a minimum access standard that does not require reactive power capability. The draft rule includes a provision specifying the access standard for reactive power capability as an AEMO advisory matter. The draft rule also provides guidance that the level of reactive power capability should be sufficient to support the security of the power system.
Reactive power control The existing automatic access standard requires the ability to operate in voltage control mode, and defines voltage control performance characteristics for a continuously controllable setpoint range to within a defined level of accuracy. The existing minimum access standard provides the ability for a generating system to operate in one of the reactive power modes other than voltage control (power factor or reactive control), depending on the size of the generating system and the connection point voltage. The existing automatic and minimum access standards define maximum acceptable settling times in response to a voltage step change of 5%. Existing arrangements under the minimum access standard provided for a longer allowable settling	AEMO proposed: • requiring all generators to be capable of operating in voltage control mode (irrespective of generating system capacity or connection point voltage), including a minimum continuously controllable voltage set point range • allowing embedded generators to operate in one of the reactive power modes other than voltage control (power factor or reactive control), but requiring them to be capable of switching to voltage control mode at any time with remote control capabilities, and • reducing the allowable settling times in response to a 5% step change in voltage for asynchronous generating systems under the minimum access standard.	The draft rule includes: • under the automatic access standard, the capability to operate in all modes and switch between them (in accordance with a procedure agreed with AEMO and the network service provider), and • under the minimum access standard, the capability to either operate in voltage control mode, or otherwise in any other reactive power control mode with the agreement of AEMO and the network service provider (regardless of the size of the generating system and the connection point voltage). The draft rule also: • includes new minimum performance requirements for voltage control mode that are largely in line with AEMO's proposed requirements, except they allow scope for tap-changing as a means of regulating voltages (and also explicitly allowing for

time for asynchronous generators than are allowed for synchronous generators.		voltage control using a voltage droop characteristic) • includes new performance requirements for generating systems operating in reactive power or power factor control modes • aligns the settling time requirements for synchronous and asynchronous generating systems under the minimum access standard.
Reactive current response during disturbances The existing automatic access standard includes a requirement for a certain magnitude of reactive current injection during faults. No explicit requirements are specified for reactive current absorption under the automatic access standard and no explicit requirements are specified for either reactive current injection or absorption under the minimum access standard.	AEMO proposed a prescriptive set of reactive current response requirements under both the automatic and minimum access standards applying to both synchronous and asynchronous generators. These requirements related to: • magnitude (slope) of reactive current injection and absorption • thresholds for triggering a reactive current response • duration of reactive current response • rise and settling times for reactive current response, and • ancillary requirements relating to flexibility in the point and method of measurement. AEMO also proposed a requirement for the maximum continuous current of the generating system to be available at all times.	The draft rule largely retains existing arrangements for synchronous generating systems, while clarifying the total required response capability for these generators. AEMO's proposed changes are largely adopted for asynchronous generating systems however with additional flexibility included in a range of response characteristics to account for equipment limits and power system conditions at the connection point.
Continuous uninterrupted operation Schedule 5.2 to the NER currently contains a range of access standards specifying requirements for generating systems and units to maintain	AEMO proposed updating several of the access standards that specify continuous uninterrupted operation requirements, to more appropriately reflect changing conditions in the power system as the generation mix changes.	The draft rule makes changes to the NER (that partly reflect AEMO's proposed changes) to better reflect changing power system conditions. This includes: • amending the definition of continuous

continuous uninterrupted operation for a range of disturbances, including voltage and frequency disturbances.		uninterrupted operation to provide greater clarity to network users • strengthening existing requirements for generating systems to maintain continuous uninterrupted operation for particular voltage and frequency disturbances • introducing new requirements for generating systems to maintain continuous uninterrupted operation for certain multiple low voltage disturbances, and • requiring asynchronous generating systems to meet existing requirements to maintain continuous uninterrupted operation for particular partial load rejection events.
System strength There is currently no explicit system strength access standard as part of the generator access standards in the NER. The Commission made the Managing power system fault levels rule on 19 September 2017 to address system security issues related to reductions in system strength in the power system. That rule commences in full on 1 July 2018.	AEMO proposed introducing a minimum access standard specifying that a generating system and each of its generating units must be capable of continuous uninterrupted operation for a short circuit ratio of 3.0 at the connection point. No automatic or negotiated access standards were proposed.	The draft rule does not contain a system strength access standard. The framework created by the *Managing power system fault levels rule* is likely to be sufficient to address risks to power system security from reductions in system strength. There is also insufficient certainty as to the magnitude of potential incremental costs on all connecting generators today as well as the magnitude of potential avoided costs for connecting generators and network service providers in future if a system strength access standard were implemented at this time. Issues related to the efficient connection of multiple generators are also being considered through other AEMC processes, including the *Coordination of generation and transmission investment* review.

Consequential changes N/A	N/A	The draft rule includes a number of additional changes that are consequential to making the rule, including: • introducing a framework for the regular review of access standards • introducing clear obligations for AEMO to provide the AER with information on generator performance standards, and • clarifying the operation of existing arrangements for renegotiation of performance standards when equipment is altered.
Transitional arrangements N/A	AEMO proposed applying any amending rule to all connection applications not finalised by 11 August 2017 (the date they made the rule change request) and to create a mechanism to change certain performance standards agreed between 11 August 2017 and the date the rule is made.	The draft rule would apply any final rule from the date that is 8 weeks from the date of the final determination. For negotiations that on the date of commencement have a full set of access standards agreed for a proposed connection, allows for the access standards for the project to be based on the rules that were in force immediately prior to the commencement date. The final rule would not affect existing connection agreements or offers to connect. Under the draft rule, where a connection applicant is required to comply with the new arrangements, the network service provider is required to: • notify the connection applicant that the new arrangements apply to their connection, and

		• provide the connection applicant with any further information relevant to the proposed plant (e.g. details of the relevant access standards), and written notice of any further information to be provided by the connection applicant to the network service provider so that the connection applicant can prepare an application to connect, or so that the network service provider can prepare an offer to connect, under the new arrangements.

Contents

1 AEMO's rule change request

1.1 The rule change request

On 11 August 2017, the Australian Energy Market Operator (AEMO) submitted a rule change request to the Australian Energy Market Commission (AEMC or Commission). The request sought changes to the access standards for generating systems in the national electricity rules (NER) and changes to the negotiating process in the NER that translates those access standards into the standard of performance required of the physical equipment that makes up and connects to the power system.

This draft determination sets out:

- a summary of, and a background to, the rule change request (Chapters 1 and 2)
- the approach to assessing the rule change request (Chapter 3)
- the Commission's assessment of and response to the issues raised by AEMO (Chapters 4 to 11), and
- the Commission's draft transitional arrangements and consequential changes (Chapters 12 and 13).

1.2 Current arrangements

This rule change relates to the levels of performance required of equipment connecting to the power system. These levels of performance are reached through the framework set out in Chapter 5 of the NER.[1] The levels of performance set under this framework become the performance standards applicable to the connected equipment. Those performance standards form part of the terms and conditions of the connection agreement between the registered participant and the network service provider.[2] Under this framework:

- access standards in the NER define the range of the technical requirements for the operation of equipment when negotiating the connection of generators, customers and market network service providers
- the access standards generally form a range for negotiation between the level of the minimum access standard and the automatic access standard
- for each technical requirement defined by the access standards a connection applicant must either:
  - meet the automatic access standard, in which case the equipment will not be denied access because of that technical requirement,[3] or

1 In particular, see clause 5.3.4A and Schedule 5.2.5 of the NER.

2 Clause 5.3.7(b) and (g) of the NER.

3 "Automatic access standard' is defined in Chapter 10 of the NER as "in relation to a technical requirement of access, a standard of performance, identified in a Schedule of Chapter 5 as an automatic access standard for that technical requirement, such that a plant that meets that standard would not be denied access because of that technical requirement"

- propose a negotiated access standard that is at or above the minimum access standard (also, by implication, below the automatic access standard)[4]

- after a negotiated access standard has been proposed, the applicant and network service provider negotiate a level of performance for that technical requirement, with the network service provider taking advice from AEMO for access standards that are specified as AEMO advisory matters.[5] The network service provider must reject a proposed negotiated access standard if they consider it would adversely affect power system security (where advised on this by AEMO) or the quality of supply to other network users, or otherwise fails to meet specific requirements applicable to a negotiated access standard identified in the relevant schedules of Chapter 5,[6] and
- equipment that does not at least meet the minimum access standard will be denied access because of that technical requirement.[7]

The access standards in the NER can therefore be viewed as the reference points used for negotiations between a connection applicant, the local network service provider and, where relevant, AEMO, to set the specific levels of technical performance of equipment that a connection applicant is seeking to connect to the power system.

The access standards for generators connecting to the power system relate to a wide range of technical requirements set out in Schedule 5.2 to the NER. They include technical requirements related to power system needs during normal operating conditions, during disturbances, and immediately following disturbances. Figure 1.1 below shows the range of technical requirements discussed in this draft determination that relate to these power system needs.

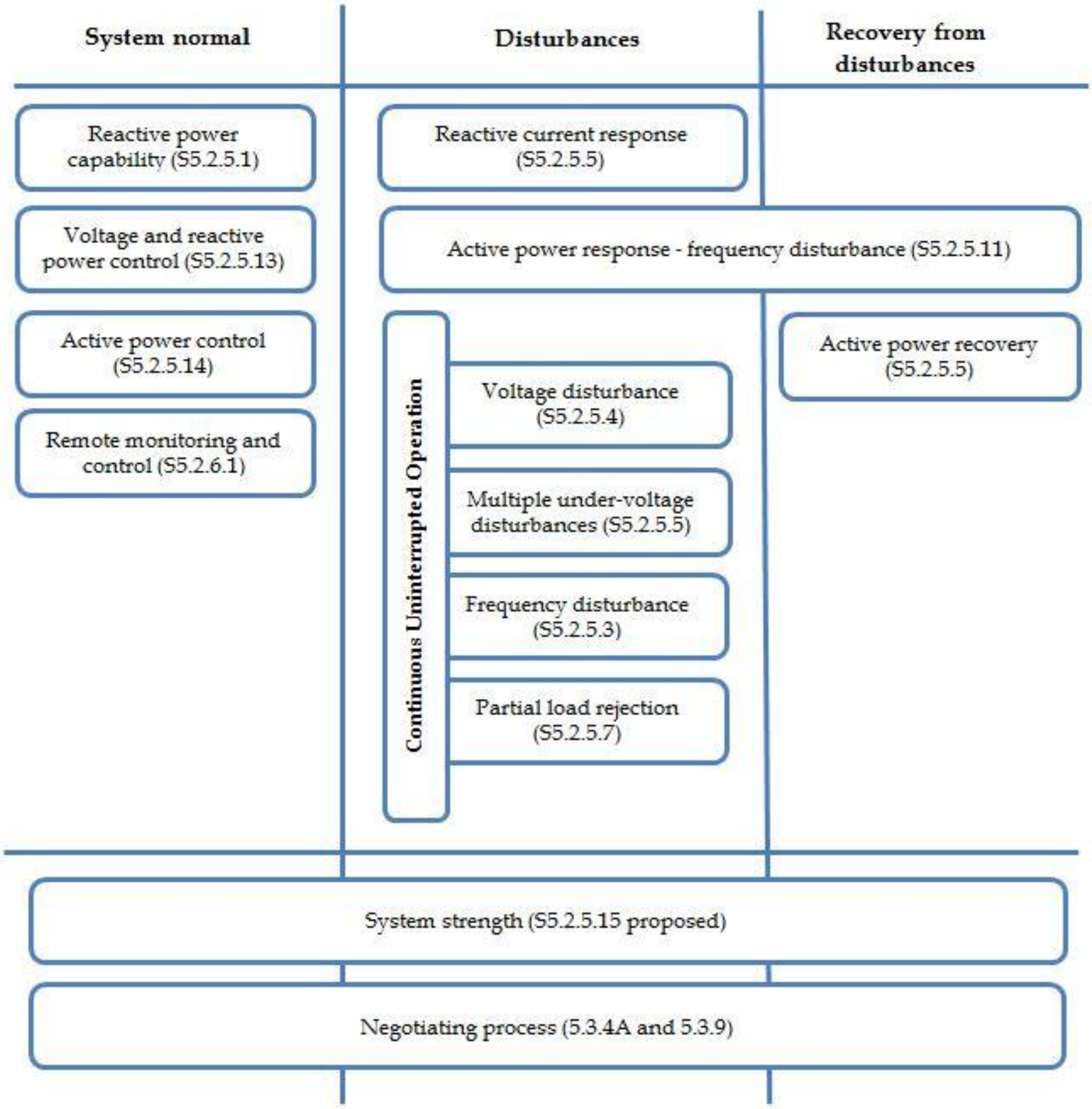
4 "Negotiated access standard" is defined in Chapter 10 of the NER as "in relation to a technical requirement of access for a particular plant, an agreed standard of performance determined in accordance with clause 5.3.4A and identified as a negotiated access standard for that technical requirement in a connection agreement."

5 Note some of the access standards in the NER specified as AEMO advisory matters. These matters generally relate to AEMO's system security functions under the National Electricity Law (NEL). A number of access standards are not AEMO advisory matters. AEMO is not required to provide advice to the network service provider for access standards that are not AEMO advisory matters.

6 See clause 5.3.4A(f) of the NER.

7 See clause 5.3.4A(f)(3) of the NER. "Minimum access standard' is defined in Chapter 10 of the NER as "in relation to a technical requirement of access, a standard of performance, identified in a Schedule of Chapter 5 as a minimum access standard for that technical requirement, such that a plant that does not meet that standard will be denied access because of that technical requirement."

Figure 1.1 Technical requirements addressed in this rule change



Some of the access standards require a generating system to change behaviour to actively support the power system, such as control active power or inject or absorb reactive power or current. Others require a generating system to be able to maintain operation while the power system changes, such as where a disturbance causes certain changes in voltage or frequency. Other access standards again play a supporting role, specifying the remote monitoring and control characteristics required of a generating system.

Details of the current arrangements in the NER relevant to each of the issues raised by AEMO in its rule change request are set out as those issues are discussed in Chapters 4 to 13.

1.3 Rationale for the rule change request

In its rule change request AEMO raised three principal concerns with the current arrangements:

- the current access standard settings for generating systems are not adequate to ensure the ongoing security of an evolving power system
- the negotiating process allows connection applicants to use the minimum access standard as a default setting when entering the negotiation of performance standards, which risks impacting the ongoing security of an evolving power system, and
- the ongoing security of the power system may be impacted if the large number of connection applications currently before network service providers and AEMO, as well as those applications expected to be made in the near future, are processed on the basis of the current access standards and negotiating process rather than the proposed new arrangements.

The issues raised by AEMO in its rule change request are set out in more detail as those issues are discussed in Chapters 4 to 13.

1.4 Solution proposed in the rule change request

To address the issues raised in the rule change request, AEMO proposed:

- changing the levels of certain automatic and minimum access standards for generators, as well as introduce new access standards
- changing the process for negotiating performance standards, and
- implementing transitional arrangements applying the changes to all connection applications where the applicable performance standards had not been finalised before 11 August 2017.

The rule change request included a proposed rule. Copies of the rule change request and proposed rule are on the AEMC website, www.aemc.gov.au.

Details of the changes proposed by AEMO in its rule change request are set out as the issues raised by AEMO are discussed in Chapters 4 to 13.

1.5 The rule making process

On 19 September 2017, the Commission published a notice advising of its commencement of the rule making process and consultation in respect of the rule change request.[8] A consultation paper identifying specific issues for consultation was also published. To assist stakeholder engagement with the rule change, the Commission held a technical workshop for a wide range of stakeholders on 12 October 2017.

The Commission received 37 submissions as part of the first round of consultation. Just under half of the submissions were received late. The Commission considered all issues raised by stakeholders in submissions. Issues raised in submissions are discussed and

8 This notice was published under s. 95 of the NEL.

responded to throughout this draft rule determination. Issues that are not addressed in the body of this document are set out and addressed in **Appendix A**.

Throughout the process the Commission appreciated the ongoing support and assistance it received from AEMO. The Commission and AEMO worked collaboratively, including on the technical working group described below, to carefully assess the issues raised and appropriate changes to the technical requirements. AEMO provided formal updated positions on its proposed changes, responding to concerns raised by stakeholders and the Commission. These revised positions were provided as follows:

- on 24 October 2017 AEMO provided supplementary material on a range of matters raised by stakeholders in the workshop held on 12 October 2017, including in relation to reactive power capability, continuous uninterrupted operation requirements and active power capability
- on 9 November 2017 AEMO provided its submission to the consultation paper, which included revised positions on the proposed requirements for continuous uninterrupted operation during faults, system strength, key definitions and transitional arrangements
- on 16 March 2018 AEMO provided a report titled *Multiple low-voltage disturbance ride-through capability: justification of AEMO's proposal* including revised positions on the proposed requirements for continuous uninterrupted operation during multiple low voltage disturbances, and
- on 9 April 2018 AEMO provided a memorandum to the AEMC setting out a revised position on the injection of current during certain faults.

Each of these documents is published on the AEMC's website. AEMO also assisted the Commission by providing detailed further information and views in email correspondence and ongoing discussions.

On 28 November 2017 the Commission extended the period of time for making a draft determination. On 14 March 2018 the Commission further extended the period of time for making a draft determination until 5 June 2018, and extended the period of time for making a final determination until 2 October 2018. The timeframes were extended due to the complexity of the issues raised by the rule change and further issues raised by stakeholders during consultation. The Commission acknowledges that some parts of the draft rule differ from AEMO’s proposed positions. We will continue to work with AEMO and stakeholders to explore any remaining issues through our consultation on the draft rule and draft determination.

To assist with its consideration of the rule change request, the Commission convened a technical working group.[9] The technical working group met on 11 December 2017 and on 1 and 2 February 2018.

9 The technical working group was convened to assist the AEMC to consider the detailed technical issues raised by this rule change request. It is made up of representatives from the AEMC, AEMO, the Public Interest Advocacy Centre, Ergon Energy, TasNetworks, ElectraNet, Powerlink, RES Australia, Infigen Energy, Tilt Renewables, Origin Energy, Lloyds Register and WSP. Technical

1.6 Consultation on draft rule determination

The Commission invites submissions on this draft rule determination, including a draft rule, by 13 July 2018.

Any person or body may request that the Commission hold a hearing in relation to the draft rule determination. Any request for a hearing must be made in writing and must be received by the Commission no later than 7 June 2018.

Submissions and requests for a hearing should quote project number ERC0222 and may be lodged online at www.aemc.gov.au or by mail to:

Australian Energy Market Commission
PO Box A2449
SYDNEY SOUTH NSW 1235

consultants engaged by the AEMC to support the rule change process, DigSILENT Pacific, also attended relevant technical working group meetings.

2 Draft rule determination

2.1 The Commission's draft rule determination

The Commission's draft rule determination is to make a draft more preferable rule. The draft more preferable rule changes the process to negotiate access standards in the NER, as well as the levels of certain generator access standards in Schedule 5.2 to the NER.

The Commission's reasons for making this draft more preferable rule are set out in section 2.4.

This Chapter outlines:

- the rule making test for changes to the NER
- the more preferable rule test
- the assessment framework for considering the rule change request, and
- the Commission's consideration of the draft more preferable rule against the national electricity objective.

Further information on the legal requirements for making this draft rule determination is set out in **Appendix B**.

2.2 Rule making test

2.2.1 Achieving the national electricity objective

The Commission may only make a rule if it is satisfied that the rule will, or is likely to, contribute to the achievement of the national electricity objective (NEO).[10] This is the decision making framework that the Commission must apply.

The NEO is:[11]

> "to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to:
>
> (a) price, quality, safety, reliability and security of supply of electricity; and
>
> (b) the reliability, safety and security of the national electricity system."

2.2.2 Making a draft more preferable rule

The Commission may make a rule that is different (including materially different) to a proposed rule (a more preferable rule) if it is satisfied that, having regard to the issue or issues raised in the rule change request, the more preferable rule will or is likely to better contribute to the achievement of the NEO.[12]

10 Section 88 of the NEL.

11 Section 7 of the NEL.

12 See section 91A of the NEL.

The Commission has made a draft more preferable rule in this case because it considers the draft more preferable rule would be likely to better contribute to the NEO than the rule proposed by AEMO.

The Commission considers the draft more preferable rule better contributes to the NEO because:

- it addresses a range of identified risks to power system security and the quality of supply, as well as the efficient operation of the power system in a secure state, and
- it does so without imposing significant additional costs for consumers.

The draft more preferable rule strikes this balance by consistently applying the assessment framework to the issues raised under the rule change request. More detailed reasons for making this rule, including detailed analysis of the issues raised and appropriate response to them, are set out in sections 4.5, 5.3.5, 5.4.5, 5.5.5, 6.5, 7.6, 8.2.5, 8.3.4, 8.4.5, 9.5, 10.3.5, 10.4.6, 10.5.5, 10.6.4, 10.7.4, 10.8.4, 11.6, 12.2.2, 12.4.2, 12.5.2 and 13.5.

The draft more preferable rule is referred to throughout this draft determination as the "draft rule".

2.3 Assessment framework

In assessing the rule change request against the NEO the Commission has considered the following principles:

- maintaining power system security and the quality of supply at least cost to consumers
- allocating costs and risks to those parties that are best placed to bear and manage them
- providing the right balance between regulatory certainty and having sufficient flexibility in regulatory arrangements, and
- access standards should not represent an inefficient barrier to entry for any technology type.

The Commission's approach to the assessment of this rule change is discussed in detail in Chapter 3.

2.4 Summary of reasons

The draft rule is attached to and published with this draft rule determination. Its key features are set out below.

The Commission's draft rule changes the negotiating process so that negotiations can occur more efficiently and each connection has a level of performance that balances system security, quality of supply and cost. It also changes some of the generator access standards, including:

- the requirements for generating systems to be able to control their active power output, to limit their contribution to frequency and voltage disturbances on the power system, and allow them to better contribute to responding to changes in frequency

- the requirements for remote monitoring and control of generating system functions related to the control of the control of active and reactive power, to provide for appropriate real time power system management functions where they are needed
- the requirements for generating systems to be able to supply and absorb reactive power where these services are needed on the power system, to reduce the risks of voltage instability and collapse at an efficient cost for consumers
- the requirements for generating systems to be able to inject and absorb reactive current during disturbances, so that all units connecting can assist by supporting voltage levels in a predicable way when there are faults on the power system, and
- the requirements for generating systems to be able to maintain operation in the face of certain frequency and voltage disturbances (including faults and contingency events) on the power system that are expected to become more severe over time, to better protect the power system from the risk of cascading failures that can lead to widespread blackouts.

The draft rule also includes a number of changes that are necessary or consequential, or corresponding, to the making of the draft rule. This includes introducing a process for the regular review of access standards in the NER, introducing obligations for the provision of information on performance standards to the AER to support compliance activities, and clarifying the application and operation of arrangements for changing a generator's performance standards when equipment is altered.

The draft rule includes transitional arrangements that would introduce the new requirements as soon as possible, balancing the risks of delay to the efficient operation of the power system in a secure state with the risks to investment certainty potentially created by a more rapid transition to the new rules.

Detailed reasons supporting the Commission's draft rule are set out in Chapters 4 to 13.

3 Assessment framework

This Chapter discusses the assessment framework used in this rule change. The negotiation of access standards forms part of a broader negotiation process in which parties seek access to the power system. Any changes to the access standards therefore need to be considered in light of the philosophy underpinning this broader process. The roles of the automatic, negotiated and minimum access standards are also discussed.

3.1 Assessment framework

The Commission uses an assessment framework to evaluate whether a proposed rule, if made, is likely to promote the NEO. The assessment framework for this rule change includes the following factors.

3.1.1 Maintaining system security at the lowest costs to consumers

The objective of this rule change is to promote efficient investment in the power system, striking a reasonable balance between system security and the quality of power supply, and the price paid by consumers for that security and power quality.

Setting access standards that are too low may increase the risk that the system is not able to be maintained in a secure state, which may lead to load-shedding or blackouts, imposing costs on consumers. Standards that are too low may require AEMO and network service providers to operate the power system in an inefficient manner, such as through constraining the dispatch process, which can also impose material costs on consumers.

On the other hand, setting access standards that are too high would result in higher costs to consumers to maintain the power system at a higher standard than is needed to maintain the system in a secure state and not adversely affect quality of supply of other users. Another risk in setting the access standards too high is that it could affect the reliability of the system if it impacts the ability of generators to connect and deliver the level of supply required to meet consumer demand, leading to load shedding or blackouts. This also imposes significant costs on consumers.

Appropriate allocation of costs and risk

Regulation should seek to allocate costs and risks to the parties that are best placed to bear and manage them.

Generators are best placed to make investment decisions regarding the costs of meeting access standards and the potential revenues that are available from wholesale markets, and from providing services in ancillary service markets. AEMO is best placed to manage system security risks, and performance standards should reflect the current risks posed to system security. Transmission and distribution network businesses are also best placed to make investment and operational decisions to meet their obligations regarding the secure and reliable operation of their networks and quality of supply provided to network users.

Regulatory certainty and flexibility

Regulation should provide market participants with certainty regarding their respective roles and responsibilities. This certainty needs to be balanced with the need for flexibility to account for uncertain future outcomes.

Connection applicants seeking to connect to the power system should have a clear idea of what levels of performance they will be expected to meet. This will allow applicants to effectively factor in the cost of connection when making the decision to enter the market. AEMO and network service providers also need certainty that there will be sufficient capabilities from equipment connected to the power system to allow them to operate the power system in accordance with the system standards and the relevant power system and market operation obligations.

There is a trade-off between the certainty of imposing strict performance standards that must be met with the flexibility to negotiate standards on a case-by-case basis. The process to set performance standards should not pose an unnecessary inefficient barrier to entry, where a generating system that could connect to the network with no material system security implications is prevented from doing so because of a particular access standard that cannot be altered by negotiation.

Technology neutrality

The access standards for connecting generators should be, to the greatest extent possible, technology neutral. That is, they should not present an inefficient barrier to entry for any technology type.

As a general rule, the Commission considers that it is desirable for the access standards to be expressed in the same way for all technology types. However, the Commission recognises that there are some inherent physical differences between technologies, for example, between synchronous and asynchronous generating systems. Access standards that do not take inherent physical differences of different technology types into account may, as a side effect, prevent the connection of certain technology types that do note create material system security risks and should otherwise be able to connect. This would be an inefficient barrier to entry and would not be consistent with the NEO.

Therefore, technology neutrality does not imply treating all technology types the same but rather it means avoiding inefficient barriers based on technology. While in most cases this can be achieved by applying the same requirements regardless of technology type, it may be the case that, due to differences in inherent physical characteristics, it is necessary to express the access standards differently for different technology types. The objective of the principle of technology neutrality is to make sure that all technology types have an equal opportunity to connect to the power system in a way that does not impact system security and the quality of supply to other network users, subject to meeting all other requirements.

In short, the Commission is concerned with technology neutrality in terms of outcomes rather than wording for the purposes of the access standards.

Box 3.1 Method for applying the assessment framework

In assessing this rule change, the Commission has applied the assessment framework in the following way. For each issue in the rule change the Commission considered:

- what system security need each of the changes to the NER proposed by AEMO is designed to address
- the implications of each proposed change would have on the allocation of costs and the responsibility for maintaining system security and quality of supply to network users
- the potential costs and benefits of each proposed change
- whether the proposed change is appropriate to address any issues identified in relation to system security and quality of supply, relative to other tools available to AEMO and network service providers, and
- the relative benefits of flexibility and certainty.

In order to inform this analysis the Commission consulted widely and drew from the following sources of information:

- stakeholder submissions to the consultation paper
- technical advice from DigSILENT Pacific
- input from industry representatives that have participated in the Commission's technical working group[13]
- a survey of equipment manufacturers conducted on behalf of the Commission
- bilateral stakeholder meetings and discussions, and
- international evidence and examples.

3.2 Background

3.2.1 Rationale for specifying access standards

Equipment that connects to the power system needs to be able to perform in a manner that enables the power system to operate securely and reliably. For connecting generating systems, this means:

- having certain technical capabilities available while in normal operating conditions

13 The technical working group was convened with the assistance of Energy Networks Australia (ENA) and the Clean Energy Council (CEC) as a forum to provide detailed technical input into the rule change. The technical working group was made up of members from the AEMC, AEMO, DigSILENT Pacific (in their capacity as technical advisers to the AEMC), Electranet, Ergon Energy, Infigen Energy, Lloyds Register, Origin Energy, Powerlink, Public Interest Advocacy Centre, RES Australia, TasNetworks, Tilt Renewables and WSP.

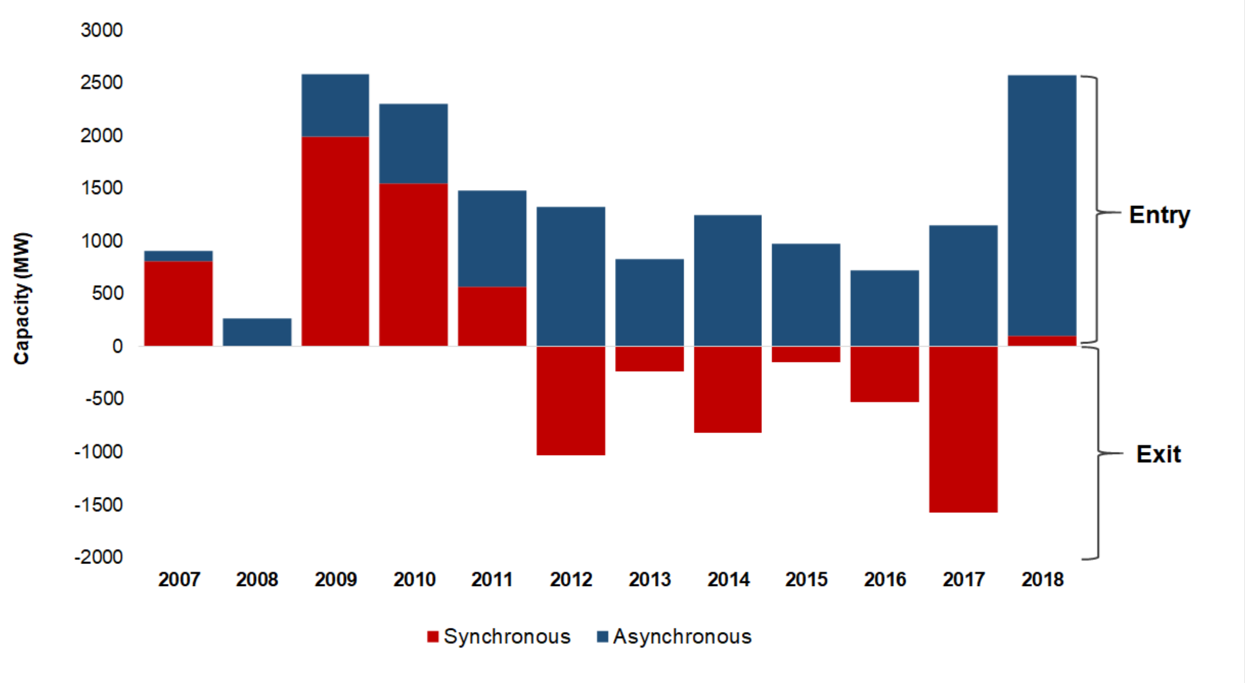
- the need to be able to withstand certain faults and provide support to the power system throughout the faults, and
- the ability to quickly recover after faults to help bring the power system back to normal operating conditions.

It is also important that AEMO and the network service provider being aware of the technical capabilities of generating systems, so they can operate the power system in a secure state.

Setting the technical requirements for specific equipment connecting into the power system is highly complex and involves consideration of a range of variables. Such variables include the local system conditions and the technical performance characteristics of the type of technology connecting, such as whether the generator is a synchronous or asynchronous generating system.

This rule change is being considered at a time where the power system is going through a number of significant changes. There are currently many connection applications and the technology type of the generating systems seeking to connect to the power system is changing. AEMO's rule change request is partly motivated by the fact that there are currently approximately 100 active connection applications for new connections.[14] Figure 3.1 shows the entry and exit of synchronous and asynchronous generating capacity in the NEM power system between 2007 and 2017, as well as the projected entry and exit of synchronous and asynchronous generating capacity in 2018.

Figure 3.1 Entry and exit of synchronous and asynchronous generation in the NEM power system



14 AEMO, submission to the consultation paper, p. 8.

3.2.2 The need for flexibility in setting the access standards

There is a range of options for setting the levels of performance for equipment that connects into a power system. Many international jurisdictions have grid codes that set out prescriptive, and often technology specific, requirements for the performance of equipment. However, many of these also retain some flexibility or option to set or tune particular technical performance parameters in a way that is appropriate for local power system conditions.

In Australia, the NER provide a process under which market participants can negotiate to set the levels of performance for equipment connecting to the power system.

AEMO's rule change request noted the rationale provided by the National Energy Code Administrator (NECA) in recommending the implementation of a negotiating framework in 2001. NECA's rationale focused on the need to make sure that technical standards drive the integrity of the power system while facilitating the objectives of the market, including a level playing field for all technologies.[15]

NECA considered that mandating a single set of standards would be inefficient as the cost of meeting mandated standards would vary dramatically for different types of plant.[16] Some types of plant could be designed and built to significantly overachieve a mandatory standard at low cost, while other plant may be unable to achieve that standard other than at a prohibitive cost.[17]

NECA ultimately recommended that flexibility was needed to minimise the cost of a fixed standard. It noted that "although standards are defined for the system as a whole, individual connection points may be able to accommodate greater flexibility in some aspects of the standards."[18] With some parameters, NECA considered the most important requirement for managing the system is to know how plant will react to system disturbances.[19] For other parameters, the technical requirements relate to the sum of connected parties rather than to an individual. In these cases NECA considered it is better to define the standard as a range and allow the relevant parties (connection applicants, network service providers and AEMO) to negotiate the appropriate level for a specific connection within that range.[20]

NECA therefore recommended an approach that allowed negotiation in order to achieve the flexibility considered desirable. The overall objective was to focus on "minimising barriers to entry consistent with achieving the system standards."[21] Put another way, the objective was to "ensure that capabilities and therefore costs are not higher than necessary to meet the defined system requirements."[22]

15 NECA, *Review of technical standards, final report, December 2001*, pp. 10-11.

16 Ibid, p. 101.

17 Ibid.

18 Ibid, p. 10

19 Ibid.

20 Ibid.

21 Ibid, p. 6.

22 Ibid, p. 6.

When negotiating access standards, different parties to the negotiation have different objectives. Network service providers and AEMO have regard only to the needs of the power system at that location, whereas generators have regard to the cost and speed of the connection process. The ability to negotiate allows for both of these competing incentives to be balanced in a way that maintains system security at least cost.

Connection applicants have the choice to meet the automatic standard in cases where their chosen equipment can meet this standard easily or at low cost. This increases the speed of the connection process and meets the system security needs of the power system. Applicants can also choose to propose a negotiated access standard, that is below the automatic standard, in cases where meeting the automatic standard would be difficult or costly to achieve. Given the incentives faced by applicants, they will only choose to enter into these negotiations when the costs (including the costs of delaying the connection process to complete the negotiation) are lower than the costs of meeting the automatic standard or if their chosen plant cannot meet the automatic access standard. In other words, this is a commercial decision for connection applicants.

AEMO and network service providers only have regard to the system security needs of the power system and the quality of supply for network users and can insist on a higher standard (up to the level of the automatic standard) if they consider that the proposed negotiated access standard is not sufficient to maintain system security and/or quality of supply because of power system conditions at that connection point.

3.3 Context

The framework for the setting and negotiation of performance standards is a part of the overall framework for connection to a transmission or distribution network and access to the power system. In assessing AEMO's proposed changes to the access standards the Commission considered how these changes impact and interact with the broader framework and the philosophy that underpins that framework.[23]

The National Electricity Market (NEM) is an open access regime in which transmission and distribution businesses have an obligation to deliver a reliable supply to their customers and to make offers to connect generators and loads that wish to connect to their networks.[24]

Connection applicants have the right to negotiate a connection to a network and pay a shallow connection charge relating to the immediate cost of their connection to the shared transmission network. But there is no 'firm access' to the market for connecting generating systems.[25] Generators have no guarantee that they can export all of their

23 For a comprehensive discussion of the current transmission framework in the National Electricity Market (NEM), see the stage 2 discussion paper of the *Coordination of generation and transmission investment review*, available at: https://www.aemc.gov.au/sites/default/files/2018-04/EPR0052%20-%20Discussion%20Paper%20for%20publication%20180413.pdf

24 See clause 5.1.3(a) of the NER.

25 Firm access rights refer to the right an individual generator has to access the transmission network that carries power from their facility to the market. Depending on the design of the market, access rights can be financial, physical or both. In the NEM a generator's right to use the transmission network, and therefore earn revenue, is based solely on whether or not it is dispatched by AEMO.

output to the market. Therefore, generators do not pay for the use of the transmission or distribution network.

There are two important implications of the philosophy underpinning the current connection and access framework for this rule change:

- connection applicants that are connecting generating systems to the power system should not bear the cost of future, uncertain network developments, including the risk of generator retirements or to facilitate the connection of subsequent generators, and
- the access standards should reflect the variety of conditions across the power system. This implies that the access standards should be sufficiently flexible to take local power system conditions into account regardless of the point of connection.

Each of these issues will be discussed, in turn, in this section.

First, the current open access framework means that connection applicants seeking to connect a generating system are only responsible for the costs of their own connection at the time that they connect to the power system. Applicants bear the immediate costs of connecting to the network through shallow connection charges and do not bear the responsibility for future developments, including the impact of the retirement of existing generation.

Generators have no control over future developments that may negatively impact on their ability to be dispatched and earn revenue. It is therefore inconsistent with the current framework for connecting generators to be asked to pay for the risk that other generators may enter or exit the market, through the costs of meeting higher performance standards. Such a requirement would impose costs on connecting generators to manage a risk that is beyond their control and is more appropriately allocated to other parties that have a responsibility to maintain system security, namely network service providers and AEMO.

The objective of AEMO's proposed changes to the access standards and process to negotiate access standards is to raise the capabilities of all new generating systems so that system security and quality of supply can be maintained. The motivation for these proposed changes is AEMO's view that managing power system security is becoming more difficult and is likely to become even more challenging in the future as technologies and locations change.

Some aspects of AEMO's rule change request could be considered as a potential expansion in the extent of ex-ante regulation of the power system, as AEMO appear to be seeking to expand the use of an existing tool (the process to set performance standards) to mitigate against a number of identified risks to system security in the

For further discussion of access arrangements in the NEM see AEMC, *Coordination of generation and transmission investment* Approach paper, pp. 24-27. Available at: http://www.aemc.gov.au/getattachment/2385256c-2e77-46ae-933d-0cbc68d3787c/Approach-paper.aspx future or that are expected to get worse over time.[26] There are a number of implications to this:

- the costs of increasing the access standards will be borne by connecting generators but the potential benefits in terms of system security are harder to define, particularly if the future turns out to be different from expectations, and
- changes to the access standards may change the balance of costs borne by different market participants to pay for the potential improvements to system security. Connecting generators may be incurring costs to maintain system security. In the absence of these stricter access standards and negotiating process for generators, costs to meet a similar level of system security could be incurred by AEMO or network service providers.[27]

Second, there is a risk that the overall costs of connections would increase if the access standards do not allow for differences in local power system conditions to be taken into account. Access standards that are not flexible and do not change despite different power system conditions at different connection points may increase total system costs through setting inappropriately high performance standards for all equipment connecting to the power system. This is because the costs of connection would always reflect the level of performance needed to maintain system security and quality of supply under the worst network conditions, which may not be applicable to all network connections.

There may be locations in the power system that do not require a new generating system to provide a particular technical capability or service to maintain the security of the power system or the quality of supply to other network users. In such cases it is not appropriate to mandate, through the access standards, that all connecting generators have this capability.

In other cases it may be necessary to set a clear minimum level of performance for all connections for a particular technical requirement through the access standards. This is appropriate for some technical capabilities that are required from all generating systems in order for the power system to remain in a secure state. Examples of such technical capabilities include the ability to maintain operation in the face of disturbances on the power system. If one generating system does not have such a capability there may be flow on effects for other network users and cascading failures. However, while some capability may be required from all generating systems, the exact level of capability required from each to maintain system security and quality of supply may vary, depending on local power system conditions, and this should be reflected in the levels of the access standards.

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26 The NER does not explicitly deal with the issue of how far into the future the access standards should look or on the issue of building "resilience" into the power system through the access standards. The characterisation of AEMO's proposal as an expansion of the role of the access standards may therefore be subject to some debate.

27 It may be appropriate for generators to be responsible for some elements of system security, for example active power support, as they are the only parties that can provide this capability to the system.

3.4 Roles of the minimum, negotiated and automatic access standards

This section explores the appropriate roles of the automatic, minimum and negotiated access standards, including AEMO and other stakeholder views as well as AEMC analysis.

3.4.1 Rule change request and AEMO submission

AEMO's rule change request suggested that the role of the automatic access standard is to be a "safe harbour" for connection applicants.[28] That is, if participants' equipment meets that standard they can be assured of connection without the need for further analysis by AEMO as to whether the plant will have an adverse impact on power system security.[29] AEMO's submission stated that the 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.[30]

The rule change request stated 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 small.[31] AEMO's submission added that the small impact on the power system and other network users may be due to the size or operating pattern of the proposed connection.[32]

AEMO's submission stated the role of the negotiated access standard is to allow for determining and agreeing generator performance standards that are set between automatic and minimum boundaries, where a network service provider 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.[33]

3.4.2 Stakeholder views

Few stakeholders offered their views on the conceptual or overarching roles of the different types of access standards.

Tilt Renewables considered that the role of the automatic access standard is to be the level of performance that a generator can meet, irrespective of location, and not cause the network service provider or AEMO to be unable to meet their obligations under the system standards, the quality of supply requirements, and the NER.[34] The submission further noted that the minimum access standard represents the level of performance that a generator can meet, assuming the most favourable location in the power system, and not cause the network service provider or AEMO to be unable to meet their

28 Rule change request, p. 19.

29 Ibid.

30 AEMO, submission to the consultation paper, p. 12.

31 Rule change request, p. 19.

32 AEMO, submission to the consultation paper, p. 12.

33 Ibid.

34 Tilt Renewables, submission to the consultation paper, p. 1.

obligations under the system standards, the quality of supply requirements, and the NER.[35] A negotiated access standard then represents the level of performance below the automatic access standard (and above the minimum) that a generator can offer in the circumstances of a particular connection, and that still allows the network service provider and AEMO to meet their obligations.[36]

TasNetworks considered the automatic access standard should be viewed as an integral part of the planning toolbox that will enable the power system to evolve in a manageable way, while continuing to provide mandated levels of supply security and reliability.[37] TasNetworks also noted that the newer concept of "resilience" should be considered.[38] The submission also considered the role of the minimum access standard should be to provide options to reduce levels of performance only where it is legitimately and demonstrably impractical or cost prohibitive to meet higher standards. It should not be the least cost pathway for any and all generators to use when connecting.

TasNetworks argued that when setting access standards, the AEMC should consider the incremental cost of the changes that may be necessary to a new generating system to meet the new standard, against the network or other costs that may be needed to provide the same services another way.[39] It noted that costs incurred by networks are directly passed on to consumers, whereas there is a less direct pathway for additional costs incurred by generators to be recovered from consumers.[40] A simple comparison of cost on different parties is therefore overly simplistic.[41]

Energy Networks Australia (ENA) considered that the role of the negotiated access standard is to maintain the highest level of system security.[42] It considered that economic considerations for individual proposals should not be valued above the overall security of the power system as this has a far wider impact on costs across the power system and to consumers.[43]

3.4.3 AEMC analysis

The objective of setting the levels of performance for equipment connecting to the power system is to meet the required levels of system security and quality of supply at the lowest long term cost to consumers. Meeting the objective is a product of both the negotiating range (set by the automatic and minimum access standards) and the process to negotiate to the appropriate levels within that range for any equipment that a participant is seeking to connect at a given connection point.

35 Ibid.

36 Ibid.

37 TasNetworks, submission to the consultation paper, p. 21.

38 Ibid.

39 TasNetworks submission to the consultation paper, p. 4.

40 Ibid, p. 5.

41 Ibid.

42 ENA, submission to the consultation paper, p. 11.

43 Ibid.

Achieving this goal requires a high degree of certainty and clarity underpinning the negotiating process to allow parties to efficiently negotiate to an appropriate position. This necessarily requires a clear understanding for all participants of the role of the high and low parameters for negotiation, as well as the role of the negotiating process to find the appropriate levels between those parameters. It also requires that all parties understand what the standard itself requires. If the requirements of an access standard are unclear, connecting parties may not be certain of what network service providers and AEMO expect of them in meeting the standard and also may frustrate the negotiation as the expectations of the parties are not aligned.

The Commission's views on the appropriate roles of the automatic, minimum and negotiated access standards are set out below.

The automatic access standard

The automatic access standard reflects the level of performance required of a connection such that it does not adversely affect power system security or the quality of supply to network users, regardless of the size, technology and location of the connection point.

This role of the automatic access standard reflects AEMO's view that it should be set at a level that is a 'safe harbour' for connection applicants, and more importantly, for the power system and other network users. The automatic access standard is the level of performance that would be appropriate in any location of the power system, for any connection.

In practice, this means considering, for each technical requirement, the level of performance that is needed so that any connection that meets this level of performance should not affect power system security or the quality of supply, under the poorest network conditions (relevant to that technical requirement) that are foreseeable across the power system.

Minimum access standard

The minimum access standard reflects the lowest level of performance required of a connection such that it does not adversely affect power system security or the quality of supply to network users, taking into consideration the size, technology and location of the connection.

In practice, this means considering the lowest level of performance that may be acceptable for a connection to do no harm in the best network conditions (relevant to that technical requirement) that are currently seen across the power system. This is the key distinguishing factor between the automatic and minimum access standards.

As discussed in section 3.3, the access standards should, to the greatest degree possible, reflect local power system conditions. This means that for some capabilities that are not required to be provided by all generating systems in all locations, it may be appropriate to set a minimum access standard at no capability. For those capabilities that are needed from all generators, the access standards should set the minimum level of performance that is acceptable when connecting to the power system.

Negotiated access standard

The negotiated access standard should reflect the objective of the negotiating framework itself, which is to provide the flexibility to agree on an appropriate level of performance for a generating system connecting to the power system at a given location at a given time. It is the tool used to achieve the appropriate levels of performance for equipment connecting to the power system, balancing system security and the quality of supply (which are the primary concerns of AEMO and network service providers respectively) and cost and speed of connection (which is the primary concern of connection applicants).

A negotiated access standard represents the point agreed by all parties to the negotiating process within the range provided by the automatic and the minimum access standard. It is the process that maintains system security and quality of supply at an efficient cost.

4 Negotiating process for connections

Box 4.1 Overview

AEMO considered the current arrangements, which allow the negotiation of access standards between the levels of the automatic and minimum access standard, are not adequate to support the ongoing security of the power system. It considered connection applicants often submit levels of performance at the level of the minimum access standard, which is not appropriate for the efficient operation of the power system.

The Commission considers there are no significant issues with the current process for the negotiation of access standards that would give rise to immediate system security concerns. The NER currently allows network service providers and AEMO, in respect of its advisory matters, to refuse to agree to a proposed negotiated access standard if it would adversely affect system security or the quality of power supply to other network users. Other tools are also available to AEMO to manage power system security and to network service providers to manage their networks in accordance with their obligations under the NER.

The Commission however identified two areas where the current process for negotiating access standards in the NER could be improved:

- the current guidance on negotiated access standards, together with evidence that some connection applicants do not take this guidance into account when proposing negotiated access standards (despite the availability of relevant data and information and the expertise to do so), may result in outcomes that are inconsistent with the maintenance of power system security at least cost to consumers, and
- when rejecting a proposed negotiated access standard, AEMO and network service providers can in some cases provide less information than connection applicants consider would be useful for them to appropriately address their concerns and propose a technical solution or provide further evidence to allay those concerns.

To address these issues, the Commission's draft rule includes:

- a requirement that when proposing a negotiated access standard a connection applicant must propose a level of performance that is as close as practicable to the automatic access standard, having regard to the need to protect plant from damage, power system conditions at the proposed location of the connection, and, the commercial and technical feasibility of complying with the automatic access standard, and
- where a negotiated access standard is proposed, a requirement for connection applicants to provide to the network service provider and AEMO reasons and evidence as to why the proposed negotiated access standard is appropriate.

The draft rule also includes a new obligation on AEMO and network service providers to provide to the connection applicant detailed reasons for either:

- rejecting a proposed negotiated access standard, based on certain criteria, including an adverse effect on power system security or the quality of supply to other network users, or
- requiring connection applicants to provide additional evidence to support proposed negotiated access standards.

The changes under the draft rule apply to all new connections under Chapter 5 of the NER, including connecting generating systems, customers and market network service providers (in accordance with the transitional arrangements described in Chapter 13).

4.1 Introduction

This Chapter sets out and considers:

- the current arrangements in the NER for the negotiation of access standards
- the issues raised by AEMO with the current arrangements and changes proposed to address those issues
- stakeholders' views, and
- analysis and conclusions.

The negotiating process provided for in the NER applies to the negotiation of access standards for all equipment connecting to the power system under Chapter 5 of the NER. The rule change request also proposes changes to the levels of particular access standards for generators connecting to the power system, discussed in subsequent Chapters.

The negotiating process provided for in the NER works together with the levels set for the access standards in the NER so that appropriate levels of performance for each technical requirement are set in performance standards for the connecting equipment. For this reason the draft decision setting the levels of generator access standards, discussed in subsequent Chapters, should be considered in light of the draft decision on the negotiating process set out in this Chapter.

4.2 Current and new arrangements

This section describes the current arrangements in the NER for the negotiation of access standards, as well as new arrangements in the connection process more broadly that will apply from 1 July 2018.

4.2.1 Current arrangements

All major equipment connecting to the power system does so under a framework for negotiating connection that is set out in Chapter 5 of the NER. The connection process involves the following steps:

- connection enquiry, where the applicant makes an enquiry to the local network service provider[44]
- response to the connection enquiry, where the network service provider informs the applicant of the information that it must provide to the network service provider to enable it to assess an application to connect, and provides the applicant with certain information, including written details of each of the technical requirements relevant to the proposed plant[45]
- application for connection, where the applicant makes an application to the network service provider to connect to the network and pays the application fee. For any technical requirement where the arrangement will not meet the automatic access standard, the applicant must submit a proposal for a negotiated access standard[46]
- preparation of the offer to connect, where the network service provider prepares the offer to connect and the connection applicant provides any further information reasonably required by the network service provider[47]
- offer to connect, where the network service provider makes the offer to the applicant, which includes the access standard for each technical requirement,[48] and
- finalisation of the connection agreements, where the applicant accepts the offer following negotiations and enters into a connection agreement with the network service provider.[49]

Through this process the levels of performance are set for each technical requirement. For a proposed connection, for any technical requirement where the applicant proposes levels of performance that do not meet the level of the automatic access standard, the applicant must include in the connection application a proposed negotiated access standard. This begins the negotiating process provided for in the NER, which is as follows:

- Following the receipt of a proposed negotiated access standard in an application for connection, a network service provider must consult with AEMO as soon as practicable in relation to AEMO advisory matters.[50]
- Within 20 business days following receipt of the proposed negotiated access standard and all information the connection applicant is required to provide in clause S5.2.4 (that is, certain detailed modelling information),[51] AEMO must

44 See clause 5.3.2 of the NER.

45 See clause 5.3.3 of the NER.

46 See clause 5.3.4 of the NER.

47 See clause 5.3.5 of the NER.

48 See clause 5.3.6 of the NER.

49 See clause 5.3.7 of the NER.

50 See clause 5.3.4(c) of the NER.

51 The specific requirement to provide information in clause S5.2.4 applies from 1 July 2018.

respond to the network service provider in respect of the AEMO advisory matters.[52]

- Within 30 business days following receipt of the proposed negotiated access standard and all information the connection applicant is required to provide in clause S5.2.4, the network service provider must respond to the connection applicant by rejecting or accepting the proposed negotiated access standard.[53]

If a proposed negotiated access standard is rejected, the connection applicant may submit a revised proposal, starting the negotiating process set out above over again. The network service provider must reject a proposed negotiated access standard if that connection would:[54]

- on AEMO's reasonable advice, adversely affect power system security
- in the network service provider's reasonable opinion, adversely affect quality of supply for other network users
- in the reasonable opinion of AEMO (in respect of an AEMO advisory matter) or the network service provider, be lower than the corresponding minimum access standard, or
- in AEMO's reasonable opinion, in respect of generating plant,[55] not satisfy the requirements applicable to a negotiated access standard in clauses S5.2.5, S5.2.6, S5.2.7 and S5.2.8 (that is all of the access standards and certain other requirements for connecting generators).

When rejecting a proposed negotiated access standard, the network service provider must advise the applicant of a negotiated access standard that the network service provider would accept.[56] However, the network service provider is not required to provide reasons for rejecting a proposed standard.

The agreed access standards form part of the terms and conditions of the connection agreement, and are taken to be the performance standards applicable to the connected plant for the relevant technical requirements.[57]

The process is relatively prescriptive, with defined timeframes for key steps the parties are required to take. However, the Commission understands that, in practice, it can be a more fluid iterative process as parties exchange relevant information to finalise negotiations.

The NER provide some guidance on how to approach negotiated access standards:

- Provisions in Chapter 5 on the mechanics of negotiations. These provisions specify that the limits of the negotiated access standard range are the automatic

52 See clause 5.3.4A(d) of the NER.

53 See clause 5.3.4A(e) of the NER.

54 See clause 5.3.4A(a) and (f) of the NER.

55 "Generating plant" is defined in Chapter 10 of the NER as "in relation to a connection point, includes all equipment involved in generating electrical energy".

56 See clause 5.3.4A(g) of the NER.

57 See clause 5.3.4A(i) of the NER.

and minimum access standards. They also set the process for a connection applicant to propose a negotiated access standard in a connection application and specify the powers of network service providers and AEMO in responding.

- Overarching guidance in the Schedules to Chapter 5. The Schedules to Chapter 5 contain the access standards themselves for different types of equipment. Each Schedule contains overarching and general guidance to assist the interpretation and use of the access standards within the Schedules. Schedule 5.2, which applies to generators, contains overarching guidance stating that negotiated access standards are derived from the minimum access standard.[58]
- Specific guidance in the access standards on requirements for a negotiated access standard. Most access standards provide specific guidance on the matters to be taken into account by the parties when proposing or reviewing a negotiated access standard for that particular technical requirement. Some access standards in Schedule 5.2 state that the negotiated access standard for that technical parameter is to be as close as practicable to the level of the automatic access standard, effectively reversing the overarching guidance.

The process to set performance standards for equipment connecting to the power system should also be considered in its broader context as one of a range of tools used by network businesses to meet the system standards and by AEMO to help maintain power system security, such as:

- the design and augmentation of the network and use of network support services
- the operation of the power system and the constraints applied, and
- the use of ancillary services.

4.2.2 New arrangements for connections from 1 July 2018

A final rule is due to be published on this rule change process by 2 October 2018. On 1 July 2018 a number of changes to the connection process in Chapter 5 of the NER are due to come into effect. Those changes were made pursuant to:

- the *Transmission connection and planning arrangements rule*
- the *Managing power system fault levels rule*
- the *Managing the rate of change of power system frequency rule*, and
- the *Generating system model guidelines rule*.

The issues discussed in this draft determination largely relate to the connection process as it exists today, however the changes due to come into effect on 1 July 2018 may also influence these issues. There are a number of new requirements flowing from the commencement of these rules that may impact the issues discussed in this draft determination. In particular network service providers will be required to provide more information to connection applicants following a connection enquiry. This includes a new requirement for network service providers to include a preliminary system

58 See clause S5.2.1(g) of the NER.

strength impact assessment in a response to a connection enquiry, following consultation with AEMO.[59]

There are also new requirements for connection applicants to provide more information to network service providers in a connection application. This includes:

- any proposal for a system strength remediation scheme,[60] and
- information for AEMO and the network service provider to perform power system simulation studies in accordance with the requirements specified in AEMO's power system model guidelines.[61]

The changes require network service providers to provide more information following a connection enquiry, particularly regarding the expected fault levels at the connection point. Connection applicants may also be required to provide more information accompanying a connection application. In particular more detailed modelling information may be required under the *Generating system model guidelines rule* (depending on how AEMO specifies information provision requirements in its guidelines), assisting network service providers and AEMO in performing power system models for, among other purposes, reviewing the connection application. This data can be requested from AEMO by a registered participant under the standing data provisions in clauses 3.13.3(k) and (l) of the NER.

4.3 Rule change request

This section describes the issues raised by AEMO in its rule change request and its proposed changes to address those issues.

4.3.1 Issues raised by AEMO

In its rule change request, AEMO considered that the current arrangements in the NER for the negotiation of access standards are not appropriate for the challenge of addressing the long term security needs of the power system.

AEMO stated that, in its experience, many connection applicants aim for the lowest level of performance allowed under the access standards (i.e. the minimum access standard) when entering negotiations, regardless of the needs of the power system.[62] Its submission to the consultation paper clarified this point, stating that "there has been a trend towards participants proposing a default plant capability as the starting point for negotiations, with an expectation that network service providers and AEMO will prosecute the case for raising the standards."[63]

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59 See clause 5.3.4B(a)(1) and (b) of the NER, in effect as at 1 July 2018. This arises out of the *Managing power system fault levels rule*.

60 See clause 5.3.4(g) of the NER, in effect as at 1 July 2018. This arises out of the *Managing power system fault levels rule*.

61 See clause 5.3.4(b)(3) and (4) and clause S5.2.4(b1) of the NER, in effect as at 1 July 2018. Changes in these clauses arise out of the *Generating system model guidelines rule*.

62 Rule change request, p. 19.

63 AEMO, submission to the consultation paper, p. 12.

AEMO argued that this behaviour risks negotiations taking place in a manner that is not consistent with system security and the long term interests of consumers.[64] It may lead to the connection of generating systems that cannot perform to the levels that are required to meet the future needs of the power system as it evolves.

In its rule change request, AEMO also stated that, over time, amendments to the specific guidance for the technical requirements for connecting generators have resulted in inconsistencies and have introduced ambiguity and uncertainty in the negotiation of access standards.[65] It considered that an approach that uses the minimum access standard as the starting point for negotiations is inconsistent with the requirement that a negotiated access standard must be set at a level that will not adversely affect power system security.[66]

AEMO's submission to the consultation paper stated that 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.[67] AEMO therefore considered the overarching principle should be to encourage the optimum performance of generation, striking the appropriate balance between connection costs, network costs, and market costs.[68]

AEMO also noted that 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.[69]

4.3.2 AEMO's proposed changes

Seeking to address these concerns, AEMO proposed changes to the negotiating process in the NER to:[70]

- remove the requirement specifying that a negotiated access standard must be no less onerous than the corresponding minimum access standard, and replace it with a requirement specifying that the negotiated access standard must "be as close as practicable to the automatic access standard and no less than the corresponding minimum access standard," and
- include a new requirement that a connection applicant submitting a proposal for a negotiated access standard must "provide with that proposal evidence (to AEMO and the network service provider's reasonable satisfaction) that it is not practicable for the applicable plant to achieve the relevant automatic access standard (including where there is a material risk that the applicable plant will be damaged if the level is set any higher than a specified level)."

64 Rule change request, p. 19.

65 Ibid.

66 Ibid.

67 AEMO, submission to the consultation paper, p. 7.

68 Ibid.

69 Ibid, p. 9.

70 Rule change request, p. 20.

AEMO's submission to the consultation paper notes that a connection applicant providing evidence that it is not practicable for the applicable plant to meet an automatic access standard, may include one or more of the following:[71]

- 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
- evidence that the deficiency in the plant cannot be reasonably addressed or compensated for, or managed in some other way, and
- evidence that the deficiency in the plant will not impact the network to which it is connected, either due to its location in the network or the installation of other equipment which will compensate for the deficiency.

4.4 Stakeholder views

This section outlines the views of stakeholders on the issues raised by AEMO and its proposed changes.

4.4.1 Generators, equipment manufacturers and consultants

Many generators (including applicants to build generating systems) stated that they generally aim for the levels of performance specified in the automatic access standards.[72] Some also noted they consider this to be the approach generally taken by connection applicants in the industry.[73] Consultants and some equipment manufacturers also held this view.[74]

Many stakeholders considered the reason to aim for the automatic access standard where possible is that the time and effort taken to negotiate access standards is often more costly than the capital expenditure reductions available, and thus a bias toward the automatic access standard as the starting point is commercially pragmatic.[75] For example, Advisian noted that none of their clients have aimed for minimum access standards due to the substantial costs involved in negotiations, studies and design of compliant plant, with the majority of costs associated with project delays.[76]

Some generators accepted AEMO's statement that connection applicants propose to connect at the levels of performance specified in minimum access standards regardless of the needs of the power system.[77] Most generators however considered that AEMO

71 AEMO, submission to the consultation paper, p. 14.

72 Submissions to the consultation paper: AGL, p. 9; Origin Energy, p. 4; PacificHydro, p. 13; RES Australia, p. 9; Edify Energy, p. 3; Stanwell, p. 4.

73 Submissions to the consultation paper: AGL, p. 9; Origin Energy, p. 4; PacificHydro, p. 13; RES Australia, p. 9; Edify Energy, p. 3.

74 Submissions to the consultation paper: Vestas, p. 5; Advisian, p. vi; WSP, p. 2.

75 Submissions to the consultation paper: Stanwell, p. 4; Origin Energy, p. 4; Pacific Hydro, p. vii; WSP, p. 2.

76 Advisian, submission to the consultation paper, p. vi.

77 Submissions to the consultation paper: Australian Sugar Milling Council (ASMC), p. 9; Tilt Renewables, p. 2; ESCO Pacific, p. 5.

and network service providers can already maintain power system security through the ability to reject a proposed negotiated access standard that they consider is too low.[78]

Some generators and consultants considered that AEMO and network service providers already have too much power in negotiations.[79] Advisian argued that AEMO and network service providers can frustrate and prevent projects from being registered, leading to 'gold plating' of generation assets for little or no discernible benefit to the network or other market participants.[80] ESCO Pacific considered that AEMO and network service providers use current arrangements increasingly to push for automatic access standards to be met, due to the administrative burden of processing large numbers of connections in a process designed for a small number of connections per year.[81] ESCO Pacific also notes that in some cases, a requirement to meet a standard is well known by AEMO and network service providers due to an incident elsewhere, but this is unable to be shared with connection applicants due to confidentiality obligations.[82] It notes it would be valuable to all participants if a process of information sharing could be established while also maintaining the required confidentiality.[83]

Some submissions raised issues with the role of AEMO and network service providers in the negotiating process. AGL noted that although it understands AEMO's role is to provide advice to network service providers on the impact of connections on the security of the power system, in practice, AEMO appears to hold greater authority to persuasively mandate technical requirements or delay execution of connection agreements.[84] A number of generators considered AEMO and network service providers have significantly greater negotiating power than connection applicants, due to the information they hold and their ability to reject proposed negotiated access standards under the NER.[85] The Clean Energy Council (CEC) considered that generators have no countervailing power in negotiations against AEMO's view of what is required for a secure power system.[86] RES Australia noted that although connection applicants in general aim to propose negotiated access standards at levels that do not affect power system security, they can disagree with AEMO on whether system security would be impacted, and further, AEMO and network service providers often also disagree with each other on these matters.[87]

Edify Energy however noted that the current connection framework provides a "good degree of information to set a realistic and demonstrable" level of performance for

78 Submissions to the consultation paper: ASMC, p. 9; CEC, p. 6; Meridian Energy, p. 6; Edify Energy, p. 5. Engie, p. 2; Snowy Hydro, p. 1-2; Terrain Solar, p. 3.

79 Submissions to the consultation paper: Advisian, p. vi; Pacific Hydro, p. 13.

80 Advisian, submission to the consultation paper, p. vi.

81 ESCO Pacific, submission to the consultation paper, p. 5.

82 Ibid.

83 Ibid; p. 7.

84 AGL, submission to the consultation paper, p. 8.

85 Submissions to the consultation paper: AGL, p. 8; CEC, p. 6; RES Australia, p. 9.

86 CEC, submission to the consultation paper, p. 6.

87 RES Australia, submission to the consultation paper, p. 9.

connecting equipment, while also noting that the current process can be long and expensive.[88]

Generators strongly opposed the changes proposed by AEMO. As noted above, most generators considered that AEMO and network service providers have sufficient existing powers to address the issues raised by AEMO, to the extent they are material. Generators also generally considered that the changes proposed by AEMO would result in a range of adverse impacts, including:

- the risk of 'gold plating' connecting generators, installing capabilities that are not required in many locations in the power system, representing inefficient costs that need not be borne by consumers[89]
- a reduction in the flexibility available to negotiate towards the appropriate levels of performance for local power system conditions,[90] and
- the introduction of a level of subjectivity and ambiguity in the negotiating process, leading to uncertainty in how the negotiating process may be interpreted and operate in practice.[91]

There was some support for, and less opposition to, AEMO's proposal to require connection applicants to aim for levels of performance that are as close as practicable to the automatic access standard as a starting point. For example, Origin Energy expressed support for this proposed change.[92]

Most of the opposition to the proposed changes focussed on the impact of introducing a new requirement that a connection applicant must provide evidence (to AEMO and the network service provider's reasonable satisfaction) that it is not practicable for the relevant plant to achieve the level of performance specified in the automatic access standard. It is this aspect of the proposed changes that was considered by some stakeholders to be likely to reduce flexibility and increase the costs of connecting generating systems. Advisian considered the proposed practicability test appears to insist on meeting the automatic access standard where it is physically possible to achieve it.[93] It considered this fails to take into account that it will always be physically possible to achieve the level of performance under the automatic access standard if enough resources are allocated to doing so. The result would therefore be higher than necessary costs, and a 'gold plating' of generation assets.[94]

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88 Edify Energy, submission to the consultation paper, p. 5.

89 Submissions to the consultation paper: Advisian, p. vii; Australian Sugar Milling Council, p. 11; Engie, p. 2; Meridian Energy, p. 7; Pacific Hydro, p. 15; Terrain Solar, p. 3; Tesla, p. 6; WSP, p. 2.

90 Submissions to the consultation paper: Advisian, p. vii; AGL, p. 7; CEC, p. 7; Engie, p. 2; GE Australia, p. 2; Meridian Energy, p. 7.

91 Submissions to the consultation paper: CEC, pp. 7-8; Edify Energy, p. 5; SMA, pp. 2-3; Terrain Solar, p. 3; Tilt Renewables, p. 2.

92 Origin Energy, submission to the consultation paper, p. 4.

93 Advisian, submission to the consultation paper, p. 5.

94 Ibid.

4.4.2 Network businesses

Few network businesses discussed in detail the materiality of the issues raised by AEMO. Most network submissions supported changing the negotiating process as proposed by AEMO to support the ongoing security of the power system as it evolves.[95]

Transgrid noted that in its experience, generators may currently aim for the minimum access standard, which may not be adequate into the future, given the rapidly changing power system.[96] Ergon and Energex noted that under the existing process, where a negotiated access standard is proposed, even though the NER allows AEMO and network service providers to protect system security, in practice the negotiations can "become controversial and commercial and/or political influences can be brought to bear, which can result in a less-than-optimal outcome."[97]

TasNetworks considered that there is a significant lack of clarity regarding the purpose of the access standards and the process to negotiate access standards, in particular, whether they are designed to manage the power system as it exists today, as it could be at some point in the future, or both.[98] TasNetworks considered generator performance standards are an important planning tool that places as much significance on potential future operating scenarios as on today's system needs.[99] They consider this sometimes leads to generators questioning the need for the levels of performance required, given the levels of performance are not needed today. TasNetworks noted it is addressing this issue by developing and publishing a document setting out its 'minimum negotiating position' on access standards.[100]

Energy Networks Australia (ENA) supported the proposed changes to the negotiating process. It considered that a general move toward the levels of performance specified in the automatic access standards would, all things being equal, be a net benefit to all stakeholders.[101] ENA considered the changes are likely to achieve the best overall performance capability, and ability to operate the power system, at the lowest cost.[102]

Some network businesses noted that a key positive aspect of the proposed changes is the proposal to shift the burden of proof onto connection applicants to demonstrate where they cannot meet the automatic access standards.[103] Ergon and Energex consider this shift in the burden of proof is consistent with the least-cost approach to maintaining security.[104] TasNetworks adds that it is reasonable to shift the burden onto

95 Submissions to the consultation paper: Ausgrid, p, 1; ENA, p. 11; Ergon and Energex, p. 12; TasNetworks, p. 21; Powerlink, p. 2; Transgrid, p. 3.

96 Transgrid, submission to the consultation paper, p. 3.

97 Ergon and Energex, submission to the consultation paper, p. 11.

98 TasNetworks, submission to the consultation paper, p. 20.

99 Ibid.

100 Ibid.

101 ENA, submission to the consultation paper, p. 11.

102 Ibid, p. 1.

103 Submissions to the consultation paper: Powerlink, p. 2; Ergon and Energex, p. 12; TasNetworks, p. 21.

104 Ergon and Energex, submission to the consultation paper, p. 12.

connection applicants due to the information they hold.[105] It is significantly more difficult for a network service provider to demonstrate that a generator 'can' offer something when the initial claim is that they cannot.[106]

Although there was widespread support from network businesses for the changes to the negotiating process proposed by AEMO, ENA recognised there were risks involved with the approach, noting that the reversal of the onus of proof potentially creates an adverse playing field for some generators.[107]

4.5 Analysis and conclusions

This section sets out:

- the Commission's analysis of the of the issues raised by AEMO, and
- the Commission's draft rule to address any material issues found.

4.5.1 Analysis of the issues

As discussed in greater detail in Chapter 3, the objective of the negotiating process is to maintain the power system in a secure state, and the quality of power supply within the levels specified in the system standards, at an efficient (least) cost to consumers. The current negotiating process broadly achieves this by clearly defining the roles and responsibilities of the parties to the negotiating process:

- connection applicants can propose lower levels of performance (down to the minimum access standard) for any reason they consider appropriate, subject to certain guidance described above
- AEMO can reject any proposed level of performance, for AEMO advisory matters, where it considers the connection would adversely affect power system security, and
- the network service provider can reject any proposed level of performance where it considers the connection would adversely affect the quality of supply to other network users.

The Commission considers these roles are appropriate, given the incentives and information each party holds. The outcome of this process, where connection applicants are driven by commercial imperatives and AEMO and network service providers safeguard the security of the power system and quality of supply, align with the objective of the negotiating process and the NEO. Accordingly, the process appears to be generally capable of providing for the needs of power system security and the quality of power supply at an efficient overall cost to consumers.

However, a range of material issues were identified by AEMO and other stakeholders. They relate to the clarity of the current process, the balance of negotiating power and the information available to parties to the negotiations.

105 TasNetworks, submission to the consultation paper, p. 21.

106 Ibid.

107 ENA, submission to the consultation paper, p. 11.

Clarity of the process and its objective

AEMO considered that amendments to the specific guidance on negotiated access standards for particular technical requirements have resulted in inconsistencies and have introduced ambiguity and uncertainty in the negotiation of performance standards. It also considers that the current rules allow a bias toward the minimum, which is not appropriate for maintaining power system security in a rapidly evolving power system.

As noted above, the overarching guidance in Schedule 5.2 to the NER identifies that negotiated access standards for generators are 'derived from the minimum access standards',[108] with guidance in some specific access standards departing from this overarching principle. However, few stakeholders appear to be aware of this, which was also confirmed in bilateral meetings and a technical working group convened for this rule change.[109] In the technical working group it was noted that some connection applicants appear to base their proposed negotiated access standards on the levels of performance agreed in their last connection, or the last connection negotiated by their consultants.

Further, as identified by TasNetworks, there is some ambiguity regarding the outcome that parties should seek to negotiate towards for any given technical requirement on a connection. For example, it is not clear whether the objective is to agree to levels of performance designed to manage the power system as it exists today, as it could be at some point in the future, or both.[110]

The Commission agrees that the current guidance on the appropriate levels of negotiated access standards is not clear and recognise evidence that many connection applicants do not take the existing guidance into account when proposing negotiated access standards. The Commission considers this may result in outcomes that are inconsistent with maintaining power system security at least cost to consumers because it can be difficult to arrive through negotiations at an efficient level of performance. Where a connection applicant proposes levels of performance that are lower than is appropriate for the power system conditions at the connection point, it can be difficult for AEMO and network service providers to negotiate to an appropriate level of performance for the connection. This can occur partly due to the information issues discussed below, and in spite of the existing ability for AEMO and network service providers to reject proposed levels of performance they consider are too low. This could impact the security of the power system the efficient operation of the power system in a secure state.

The Commission notes the comments from TasNetworks on the ambiguity regarding whether the objective of negotiations is to agree to levels of performance designed to

108 See clause S5.2.2 of the NER.

109 The technical working group was convened with the assistance of ENA and CEC as a forum to provide detailed technical input into the rule change. The technical working group was made up of members from the AEMC, AEMO, DigSILENT Pacific (in their capacity as technical advisers to the AEMC), Electranet, Ergon Energy, Infigen Energy, Lloyds Register, Origin Energy, Powerlink, Public Interest Advocacy Centre, RES Australia, TasNetworks, Tilt Renewables and WSP.

110 TasNetworks, submission to the consultation paper, p. 20.

manage the power system as it exists today, as it could be at some point in the future, or both.

The Commission considers that the existing negotiating frameworks should allow for known changes to the power system and account for those changes, such as planned entry and exit of other generating systems or equipment. It is not appropriate to impose the costs of accounting for uncertain future changes to the power system on generating systems connecting today. Consistent with the core principles underpinning the transmission connection framework, a connecting generating system (or other piece of equipment) should only be required to incur the shallow connection costs that relate to the impact of their connection at the time they connect, and should not be required to incur costs on connection to remediate the effects of uncertain events over the longer term, such as generator entry or exit.

Power imbalances and information asymmetries

There are inherent power imbalances between the parties negotiating the connection of equipment to the power system, as well as asymmetries in the information available to these parties. An imbalance in negotiating power inherently exists because a connection applicant will always have to negotiate with a monopoly provider (a network service provider) and a system operator (AEMO), who both hold information that is pertinent to the substance of the negotiation. Further, some of that information cannot be shared with the connection applicant due to its confidential nature. On the other hand, the connection applicant holds information on the performance and design of their proposed equipment, which is not readily available to the network service provider or AEMO.

Where a negotiating process is enforced by regulation, power imbalances and information asymmetries should be addressed to the extent they could lead to inefficient outcomes and are not limited by other factors, such as confidentiality obligations. Such imbalances are generally addressed by providing sufficient transparency of information so that the parties can efficiently reach agreement, without the costs of that transparency exceeding the benefits. Under the process to negotiate access standards, parties are required to share certain information to support the efficient negotiation of the appropriate levels of performance for a connection.

AEMO and stakeholders raised a number of issues relating to the imbalance of power between negotiating parties, and whether they are effectively addressed under the current arrangements for the provision of information supporting, and responding to, proposed negotiated access standards. More specifically, the issues raised relate to whether:

- there is enough information available to connection applicants early in the connection process to allow them to understand the levels of performance that are appropriate for the proposed connection, and effectively negotiate with network service providers and AEMO
- AEMO and network service providers have access to enough information held by the connection applicant to allow them to effectively assess the appropriate levels of performance for the proposed connection, and

- the negotiating power of AEMO and network service providers is appropriately balanced so they are constrained from being able to require levels of performance that are higher than necessary to maintain the security of the power system and the quality of supply to other network users at an efficient overall cost to consumers.

The following paragraphs address these questions.

AEMO argued that connection applicants can enter contractual obligations with technology providers for a connection before submitting negotiated access standards as part of a connection application, making it difficult to negotiate to levels of performance it considers appropriate for the connection. Stakeholder submissions and discussions at the technical working group meetings show that while some connection applicants carefully consider the likely levels of performance that AEMO and network service providers will consider necessary for the connection, others do not. Indeed, some stakeholders in the technical working group noted that they are aware of some connection applicants simply proposing performance standards with levels set on the basis of previous connections in other locations.

Stakeholders in the technical working group and in submissions considered there is generally sufficient data available to applicants early in the connection process to consider the level of performance that are likely to be appropriate for local power system conditions and accordingly to make appropriate technology decisions. This is still the case despite the fact that some network service providers tend to provide less information in response to a connection enquiry than was previously the case because the number of enquiries has significantly increased. As noted above, registered participants can request modelling information from AEMO under the standing data provisions in the NER, and the *Managing power system fault levels rule* also requires information on local power system fault levels to be provided to an applicant following a connection enquiry, which should provide further information on which to appropriately consider local power system conditions.

The data and information available to applicants can require complex analysis before being in a position to understand the levels of performance that AEMO and network service providers are likely to require and to confidently make decisions on the appropriate technology for the location. It is appropriate however to expect connection applicants to have access to a level of sophisticated technical analysis to anticipate the levels of performance that AEMO and network service providers are likely to consider appropriate for the location in the power system they are connecting to. Technical consultants are readily available where this expertise is not in house for a connection applicant, and in practice are widely used.

The Commission therefore does not consider that a lack of availability of data or information early in the connection process is causing the lack of consistency in the approach connection applicants take to considering the needs of the power system when proposing negotiated access standards. Rather, the Commission considers a number of other causes contribute to this, including the lack of clear guidance for negotiations identified above, and the lack of any specific requirements for connection applicants to support their proposed negotiated access standards with evidence as to why they are appropriate given system conditions at the connection point.

AEMO and network service providers however have an existing ability to address the issue that some connection applicants do not adequately consider the likely levels of performance that AEMO and network service providers will consider necessary for the connection. They can address this issue through their ability to reject proposed negotiated access standards. However, AEMO and network service providers consider it is difficult to use this ability where connection applicants have failed to adequately consider the needs of the power system before settling on a particular technology or design for their proposed connection.

In the Commission's view, connection applicants should attempt to anticipate the levels of performance AEMO and network service providers consider appropriate before making a connection application, and most do. However, they should consider this appropriately as part of their broader commercial and technical assessment of the project, taking into account the costs of the connection. Such an approach is likely to improve the overall efficiency of the negotiating process. The primary responsibility for considering the needs of the power system however should rest with the parties that have the incentive and information to do so; that is, AEMO and network service providers.

Indeed, many stakeholders considered that AEMO and network service providers have more negotiating power than is appropriate. They considered that network service providers and AEMO are able to frustrate the negotiation process by refusing to be forthcoming and transparent in negotiations. Examples noted by stakeholders included insisting on a particular level of performance, such as the automatic access standard, without providing reasons why that level of performance is needed.

If this behaviour is occurring, it may result in a situation where connection applicants are not provided with the information they need to respond to the rejection of a proposed negotiated access standard. Without such information it can be difficult for the connection applicant to develop a technical solution to the issue, develop further modelling or evidence to support its initial proposed level of performance, or pursue other investment opportunities. This issue could result in higher costs for connections than are needed for the management of power system security and the quality of supply for network users. The increased costs could occur due to both additional transaction costs incurred during negotiations or increased equipment costs where there are costs to meet a higher level of performance than is appropriate.

4.5.2 Conclusions

Based on the above analysis, the Commission considers the material issues raised by AEMO and stakeholders are:

- the current guidance on negotiated access standards, together with evidence that some connection applicants do not take this guidance into account when proposing negotiated access standards (despite the availability of relevant data and information and the expertise to do so), may result in outcomes that are inconsistent with the maintaining power system security at least cost to consumers, and
- when rejecting a proposed negotiated access standard, AEMO and network service providers can in some cases provide less information than connection

applicants consider would be useful for them to appropriately address their concerns and propose a technical solution or provide further evidence to allay those concerns.

The impact of any of these issues, individually or in aggregate, on power system security is expected to be relatively small. Existing provisions in the NER allow AEMO and network service providers to reject a proposed negotiated access standard if it will adversely affect power system security or the quality of power supply to other network users. Furthermore, the negotiating process to set performance standards for equipment connecting to the power system forms one part of a range of tools available to AEMO and network service providers to manage power system security and the quality of supply to network users.

However, these issues may influence the ability for parties to efficiently agree on negotiated access standards that are appropriate for local network conditions. This could potentially result in situations where connection applicants fail to anticipate the levels of performance network service providers and AEMO consider appropriate for the connection. Equally, these issues could result in AEMO and network service providers insisting on higher levels of performance than are necessary for local power system conditions.

The issues identified could therefore result in levels of performance that are not appropriate for the connection, and higher costs than are necessary to manage power system security and the quality of supply to network users. The higher costs could result from higher capital cost of generating systems connecting to the power system, or from a greater or lesser reliance on mechanisms such as network augmentation, the use of ancillary services or application of constraints, to maintain the security of the power system or the quality of supply than would otherwise be efficient.

4.5.3 Draft rule to address the issues

Box 4.2 Draft rule

To address the issues identified above, the Commission's draft rule includes the following changes in clause 5.3.4A of the NER:

- a requirement that when proposing a negotiated access standard a connection applicant must propose a level of performance that is as close as practicable to the automatic access standard, having regard to:[111]
  - the need to protect the plant from damage
  - power system conditions at the location of the proposed connection, and
  - the commercial and technical feasibility of complying with the automatic access standard, and
- a requirement for connection applicants to provide to the network service provider and AEMO reasons and evidence as to why the proposed

111 Clause 5.3.4A(b1) of the draft rule.

negotiated access standard is appropriate, taking into account the matters listed above and the requirements of clause 5.3.4A(b) (which includes, for example, matters of power system security and the quality of supply for other network users).[112]

The draft rule also includes in clause 5.3.4A of the NER a new obligation on AEMO and network service providers to provide detailed reasons for either:

- rejecting a proposed negotiated access standard, based on certain criteria, including an adverse effect on power system security or the quality of supply to other network users,[113] or
- requiring connection applicants to provide additional evidence to support proposed negotiated access standards to enable AEMO and the network service provider to continue assessing the proposed standard.[114]

The changes under the draft rule apply to all connections under Chapter 5 of the NER, including connecting generating systems, customers and market network service providers.

This section sets out the Commission's draft rule to address the issues identified above. The Commission has made a draft rule to introduce new obligations on connection applicants and new obligations on AEMO and network service providers.

New obligations for connection applicants

As noted above, the current guidance on negotiated access standards, together with evidence that some connection applicants do not take this guidance into account when proposing negotiated access standards (despite the availability of relevant data and information and expertise to do so), may result in outcomes that are inconsistent with the maintaining power system security at least cost to consumers.

This issue does not appear to be caused by a lack of information available to connection applicants that can be used to adequately anticipate the levels of performance that AEMO and network service providers consider appropriate for the connection. Furthermore, changes due to come into effect on 1 July 2018 should further improve the availability of useful information before a connection application is made. As a result, the Commission does not consider it appropriate to address this issue by requiring network service providers to provide more information to connection applicants in response to a connection enquiry.

The draft rule adopts elements of the changes proposed by AEMO. AEMO proposed introducing a principle that connection applicants should propose negotiated access standards that are as close as practicable to the automatic access standard, and to provide evidence to the satisfaction of AEMO and network service providers as to why it is not practicable for the applicable plant to meet the automatic access standard.

112 Clause 5.3.4A(b2) of the draft rule.

113 Clauses 5.3.4A(d1)(1)(ii) and 5.3.4A(g)(1)(ii) of the draft rule.

114 Clauses 5.3.4A(d1)(1)(i) and 5.3.4A(g)(1)(i) of the draft rule.

The Commission agrees with AEMO that an overarching objective for negotiations to aim for the automatic access standard is appropriate. Accordingly, the draft rule makes the automatic access standard is the starting point for negotiations and applies unless the applicant can justify a negotiated access standard. However, the Commission also agrees with stakeholder views that a requirement to provide evidence to the satisfaction of network service providers (and where relevant, AEMO) as to why it is not practicable to meet the level of the automatic access standard would be likely to result in the connection of equipment in some locations with levels of performance that are higher than what is necessary, potentially at significant extra cost. Indeed, given this proposed approach to negotiation would cover all connections and the negotiation of all access standards, the aggregate costs borne by consumers would likely be significantly higher than necessary to maintain power system security.

The change set out in the draft rule would set a clear expectation for connection applicants to aim for the automatic access standard, while also providing them with the ability to propose a lower level of performance if they consider it is appropriate for the circumstances of that connection (as supported by reasons and evidence). This would address the issue identified that the current arrangements do not clearly set a starting point for negotiations, and that most parties to negotiations are not aware of the limited guidance currently in the NER.

Under the draft rule, all parties to negotiations would operate on the common understanding that the starting point for negotiations is the level of the automatic access standard. The Commission notes that a number of existing access standards provide specific guidance that a negotiated access standard for that technical requirement should be as close as practicable to the level of the automatic access standard. No evidence has been provided suggesting that these current arrangements are not appropriate or are in practice unworkable. Rather, most evidence presented suggested that common industry practice is for connection applicants to aim for the level of the automatic access standard across all access standards.

The risk of generating systems connecting with levels of performance that are higher, and more costly, than necessary to manage power system security should be addressed by the new provision allowing the connection applicant to propose a negotiated access standard that is below the corresponding automatic access standard where, in its reasonable opinion, the negotiated access standard is appropriate having regard to the need to protect the plant from damage, power system conditions at the location of the proposed connection, and the commercial and technical feasibility of complying with the automatic access standard. This provides a clearer objective for connection applicants regarding the reasons they can take into account for proposing a lower level of performance than the level specified in the automatic access standard.

The Commission notes that this is consistent with the existing and clearly defined roles and responsibilities of different parties in the negotiating process. Under this process a connection applicant is able to propose a level of performance having regard to the commercial and technical feasibility of complying with the corresponding automatic access standard. Network service providers have the ability to reject a proposed negotiated access standard if on AEMO's reasonable advice the connection would adversely affect power system security, or in the network service provider's reasonable opinion the connection would adversely impact the quality of supply to other network users. In their assessment of these matters AEMO and network service providers do not consider the commercial and technical feasibility of the proposed levels of performance. If they consider the level of the automatic access standard is needed to maintain power system security or the quality of supply, that level of performance should be required regardless of the cost to the connection applicant. The result is a level of performance (and costs for consumers) that should be no higher than appropriate to maintain the security of the power system and the quality of supply.

The changes under this draft rule would set a clear onus on the connection applicant to prove why the proposed levels of performance in a negotiated access standard are appropriate for the connection. If there is some doubt regarding the appropriate level of performance, the outcome would be a level of performance that errs toward the automatic access standard (given the requirement that connection applicants must propose a level of performance that is as close as practicable to the corresponding automatic access standard). This could result in marginally higher standards of performance required of some connections (and therefore higher costs), however the Commission considers this is an appropriate outcome given the importance of maintaining power system security. In addition, AEMO and the network service provider will have the ability to require the connection application to provide additional evidence to enable it to continue assessing the proposed standard.

Some stakeholders questioned the need for any changes to the negotiating process on the basis that the ability for network service providers and AEMO to reject negotiated access standards is sufficient to address any issues. While the Commission disagrees that this ability of AEMO and network service providers alone is appropriate to address the issues identified, it should still play an important role. AEMO and network service providers could help discipline the behaviour of connection applicants through their existing ability under the NER to reject a proposed negotiated access standard, clearly setting expectations on the levels of performance they consider will not adversely impact power system security or the quality of supply to other network users. Faced with a clear and consistent approach taken by AEMO and network service providers, connection applicants would be in a better position to anticipate the levels of performance that are likely to be acceptable to AEMO and network service providers before submitting a connection application.

New obligations for AEMO and network service providers

The Commission notes the views of some stakeholders that when rejecting a proposed negotiated access standard, AEMO and network service providers may in some cases provide less information than connection applicants consider would be useful for them to appropriately address their concerns and propose a technical solution or provide further evidence to allay those concerns. The Commission considers the current negotiating process could be improved through more effective information provision requirements.

In the absence of clear reasons for the rejection of a negotiated access standard, a connection applicant has limited information to decide what an appropriate response should be. If provided with clear reasons for the rejection of a negotiated access standard, a connection applicant could better decide whether to:

- accept the level of performance that the network service provider states would be accepted, and therefore any costs associated with meeting that level of performance
- negotiate to reduce the level of performance required, weighing the probability of reducing project costs with the transaction costs associated with negotiating, or
- abandon the proposed connection without incurring extra costs, and potentially decide to propose connecting in another location where the financial case for investment is more favourable.

The Commission has therefore made a draft rule to require AEMO and network service providers to provide detailed reasons for rejecting a proposed negotiated access standard, based on a failure to propose a negotiated access standard above the minimum access standard, an adverse effect on power system security, the quality of supply to other network users, a failure to meet specific requirements applicable for negotiated access standards for particular access standards or a failure of the connection applicant to provide sufficient evidence supporting the proposed negotiated access standard. This change would be likely to reduce the costs of negotiations, including delays to projects. It would also likely reduce the risk of equipment connecting with performance levels (and therefore costs) that are higher than necessary to maintain power system security and the quality of supply to other network users.

5 Active power capability

Box 5.1 Overview

In its rule change request, AEMO identified a number of issues related to active power control, including:

- a risk that semi-scheduled generators would not enter the markets for provision of frequency control ancillary services (FCAS) resulting in shortfalls in the provision of these services causing system security issues in future, and
- the potential for increased penetration of semi-scheduled and non-scheduled generation without active power control, leading to swings in network power flows causing system security issues.

To address these issues, AEMO proposed requiring:

- all generators to have the capability to offer measurable amounts of at least one market ancillary service
- all scheduled and semi-scheduled generators to have the capability to receive instructions via the automatic generation control system, and
- all semi-scheduled generators to have the active power control capability to meet a given ramp limit, and for all non-scheduled generators to have active power control capabilities.

The Commission has made a draft rule that includes the following:

- The Commission considers it would not be efficient to require all generating systems to have the capability to provide one of the market ancillary services. There is no apparent system security risk that would justify mandating this capability from all generators. Furthermore, mandating this capability would impose additional costs on generators but is unlikely to increase the supply of FCAS.

  However, the Commission considers that system security will be supported by requiring all generating systems to have the capability of operating in frequency response mode. This capability will allow generators to more quickly complete the process of becoming an FCAS provider, when they wish to do so in response to FCAS prices. Mandating this capability will impose minimal costs on connection applicants and should support system security.

  The draft rule therefore amends the minimum access standard to require all generating systems to have the capability to operate in frequency response mode.
- The Commission considers that power system security will be supported where all generating systems have some form of active power control, including the ability to control the rate at which active power output changes within the five minute dispatch period. This includes for both

semi-scheduled and non-scheduled generating systems.

The draft rule therefore requires all semi-scheduled generating systems to have the capability to not change active power output within five minutes by more than the rise and lower amounts specified in an instruction electronically issued by a control centre. It also requires all non-scheduled generating systems to have some form of active power control. Recognising cost impacts for non-scheduled generators, the draft rule allows for non-scheduled generators to negotiate to a lower level of active power control capability. This change is in line with AEMO's proposal.

- The Commission considers that power system security and more efficient operation of the power system will be supported where all semi-scheduled and scheduled generating systems have AGC capability. The draft rule therefore requires all scheduled and semi-scheduled generating systems to have AGC capability. This change is in line with AEMO's proposal.

The draft rule makes a number of further changes to improve clarity and better reflect what the Commission understands to be actual operational practice. These changes are discussed throughout this Chapter.

5.1 Introduction

This Chapter discusses AEMO's proposed changes to the access standards in the NER related to a generating system's ability to provide active power control. This includes AEMO's proposed changes relevant to:

- frequency response capabilities
- active power control, including ramping limit control capability, and
- automatic generation control capability.

For each of these topics this Chapter sets out:

- relevant technical background
- the current arrangements in the NER
- the issues raised by AEMO with the current arrangements and changes proposed to address those issues
- stakeholder views, and
- analysis and conclusions.

5.2 Background

Generators in the national electricity market are paid for the provision of active power. Active power refers to the portion of the output of a generating system that can be used to do physical work.[115] Active power is measured in watts, typically expressed as

115 Power in alternating current (AC) networks comes in two different types: active power and reactive power. Active power accomplishes useful work at the point of end use through the delivery of energy services (heat, lighting, motion). Reactive power, on the other hand, does not directly deliver

megawatts (MW). AEMO dispatches generators in order to match the supply of active power with demand. A generator's ability to participate in the dispatch process therefore requires it to have the ability to control its active power output.[116]

The ability of a generating system to control its active power output is critical to the management of frequency in the power system. Sudden events, such as the loss of a load or generating system, can create imbalances between active power output and load in the power system. This can result in a change in power system frequency.[117] Generating systems can increase or decrease their active power output to help address these frequency disturbances.[118]

Generating systems participating in the energy and ancillary services markets control their active power output to:

- meet dispatch targets, by changing and controlling active power output over a dispatch interval, and
- assist in the control of system frequency, by changing and controlling active power output in response to changes in power system frequency.

Synchronous generating systems use hardware and control software to control their active power output. This includes control hardware such as rate limiters as well as the control software of digital governors. It may also require installation of specific hardware in the generating system itself, such as hydraulic controls.

Asynchronous generating systems use control software and hardware to control their active power output. Some asynchronous generating systems, such as solar photovoltaic (PV) farms or battery storage facilities, control active power through their control software. Other types of asynchronous generating system, such as wind farms, may use specific hardware to provide this response, such as changing the pitch of turbine blades, as well as specific control software.

Additional equipment may need to be installed (for both synchronous and asynchronous machines) to support the provision of active power control. This may include:

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energy services to end users. Instead, reactive power is necessary to support the movement of active power through electricity networks and aid its conversion into a useful form.

116 This applies to semi-scheduled and scheduled generators, who are included in the central dispatch process. Non-scheduled generators are not required to participate in central dispatch, however may still be required to control their active power output under certain conditions.

117 A reduction in generation relative to load will result in a decrease in system frequency. A reduction of load relative to generation will result in an increase in system frequency.

118 These changes in active power output in response to changes in system frequency are provided by generators who are enabled to provide market ancillary services, known as frequency control ancillary services. There are currently eight market ancillary services designated under the NER: the raise and lower regulating services, which control frequency during normal system operation; and the fast, slow and delayed raise and lower services, which control more severe frequency deviations that can occur following a contingency event. Throughout this draft determination, the NER defined term *market ancillary services* is used interchangeably with the more commonly used frequency control ancillary services (FCAS). FCAS is not a NER defined term.

- equipment related to communications and supervisory control and data acquisition (SCADA) systems. This equipment may be used to support automatic generation control (AGC), mediated dispatch and/or regulating FCAS, and[119]
- monitoring and recording equipment, for measuring a response in FCAS markets, where a generator has been enabled and called on to provide a response.

5.3 Frequency control capability

This section discusses AEMO's proposed changes to the arrangements in clause S5.2.5.11 for setting the frequency control capability of a connecting generating system.

5.3.1 Technical background

Changes in the balance of generation and load can occur during normal operation of the power system, or following disturbances such as the unexpected disconnection of a generator or a large load. These changes will result in changes in the frequency of the power system; a loss of generation will result in a decrease in frequency, while a loss of load will result in an increase.

Generators can respond to these disturbances to assist in the management of the subsequent changes in power system frequency, by increasing or decreasing their active power output.

This capability to automatically adjust active power output in response to power system frequency is referred to as frequency response mode capability.[120]

The capability to operate in frequency response mode is an inherent characteristic of synchronous generation. It is provided through the action of governor controls, which sense localised changes in power system frequency and adjust the active power output of the generator accordingly.[121] Asynchronous generating systems can provide frequency response mode through the control software of inverters and power park controllers.

Frequency response can be provided in various ways. This may include generating systems that provide a "proportional" response, where the generator provides an active power response as a function of the change in power system frequency at the connection point. Alternatively, the response may be a "switched" response, where the generator provides a step change in active power output when the frequency moves past a particular threshold level.

Generating systems operating in frequency response mode providing a proportional response can change their active power output by reference to a number of settings:

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119 The AGC system allows AEMO to continually monitor system frequency and send control signals to ancillary service facilities providing regulation services so frequency is maintained within the normal operating frequency band of 49.85 Hz to 50.15 Hz. The AGC is also used for the purposes of directly controlling generator output through the process of central dispatch.

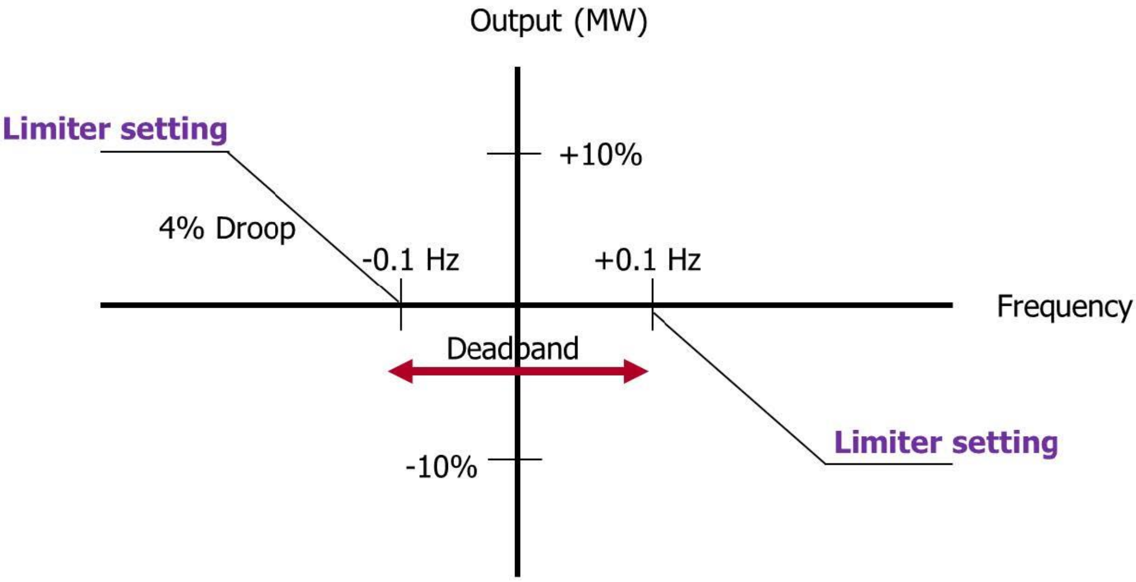
120 Frequency response mode is defined in Chapter 10 of the NER as: "The mode of operation of a *generating unit* which allows automatic changes to the generated *power* when the *frequency* of the *power system* changes."

121 Other types of control are used to provide active power responses to manage minor frequency deviations during normal operation of the power system.

- deadband: the deadband represents the range of power system frequency within which the generating system will not change its active power output
- droop: the droop describes how a generating system will change its active power output in proportion to a change in power system frequency, and
- limit: the limit describes the extent of the total increase or decrease in output of the generating system operating in frequency response mode.

A generalised description of a proportional frequency control response is described in Figure 5.1

Figure 5.1 Frequency response settings



In this diagram:

- the deadband is set to a value of +/- 0.1Hz, on either side of the nominal frequency. In the NEM, this nominal frequency is 50Hz/s, and is represented by the zero point at the intersection of the two axes. The deadband can be set at larger (broader) or smaller (narrower) values than this. This value dictates the extent of deviation of power system frequency from the nominal frequency that will occur before the generating system begins to respond by increasing or decreasing its active power output, and
- the droop setting is set to a value of 4%. This represents the rate at which the generator will change its active power output in response to a change in frequency. A 4% droop means that the output of the generator will change by ¼ (25%) for each 1% change in frequency.

In the NEM, generators operating in frequency response mode can provide their frequency response through the markets for FCAS. There are eight FCAS markets established in the NER, including the regulating raise and lower services,[122] and the

122 The regulating services are designed to correct the small imbalances between active power output and load that can occur during normal operation of the system.

fast, slow and delayed raise and lower services.[123] AEMO sets the specific requirements for these services, including when they are triggered and how long they must be provided, in AEMO's *Market ancillary service specification*.[124] FCAS are delivered on the basis that if the frequency falls, the generating system will increase active power output, and if the frequency rises, the generating system will decrease active power output, accordingly.

A generating system will operate in frequency response mode when it is enabled to provide contingency FCAS. Regulating services are facilitated through the action of the AGC, as discussed in section 5.5.

5.3.2 Current arrangements

Clause S5.2.5.11 of the NER sets out the capabilities for frequency control.

The automatic access standard requires that a generating system's active power transfer to the power system must not:[125]

- increase in response to a rise in system frequency, or
- decrease in response to a fall in system frequency.

Specifically, it is required under the automatic access standard to be capable of automatically increasing or decreasing its active power transfer to the power system by a defined amount, in response to changes in power system frequency.[126]

The generating system is then required to be able to provide this frequency response sufficiently rapidly, such that when the power system frequency moves outside specified frequency bands, the generating system is in a position to offer measurable amounts of lower and raise FCAS.[127]

The automatic access standard also establishes various parameters for this response, including by reference to the maximum operating level of the generator and the difference between the pre-disturbance level and the generator's minimum operating level. The automatic access standard also refers to the normal operating frequency band[128] as the trigger threshold for when the generator must begin to provide a active power response.

The minimum access standard requires that for a generating system under relatively stable input energy, active power transfer to the power system must not:

- increase in response to rise in system frequency, and

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123 These services, often described as "contingency" services, are used to correct major frequency deviations following events such as the loss of a generating system or major load.

124 AEMO, *Market ancillary service specification - version 5.0*, July 2017.

125 Clause S5.2.5.11(b)(1) of the NER.

126 Clause S5.2.5.11(b)(2) and (3) of the NER.

127 Clause S5.2.5.11(b)(2)(iii) and (3)(iii) of the NER.

128 Normal operating frequency band is defined in Chapter 10 of the NER as "in relation to the *frequency* of the *power system*, means the range 49.9 Hz to 50.1 Hz or such other range so specified in the *power system security standards*." Currently, this band is set at the range of 49.85 Hz to 50.15 Hz in the Reliability Panel's frequency operating standard.

- decrease more than 2% per Hz in response to a fall in system frequency.[129]

A key difference between the minimum and automatic access standards is that under the minimum access standard:

- there is no requirement to be capable of automatically increasing or decreasing active power transfer to the power system by a defined amount, in response to changes in power system frequency.
- a less onerous requirement is imposed in terms of the conditions under which the generator's active power output must not change, by referring to "relatively stable input energy"
- the generating system is allowed to decrease its active power output when system frequency falls, as long as this decrease is limited to no more than 2% per Hz, and
- there is no requirement for the generator to be in a position to offer any raise or lower services.

Clause S5.2.5.11 also sets out a number of other requirements in the negotiated access standard and general requirements, including specifying that any proposed increase and decrease in active power transfer to the power system are be as close as practicable to the automatic access standard for the plant. This access standard is also an AEMO advisory matter.[130]

The NER do not currently set out definitions for droop or deadband.

5.3.3 Rule change request

The key issue identified by AEMO was that the NER does not require all generators to have frequency response mode capability. Furthermore, AEMO considered that generators may not voluntarily enter the market for the provision of FCAS in future, to help manage the frequency stability of the power system.[131]

In particular, AEMO considered that the ongoing change in the generation mix may see an overall reduction in availability of FCAS. AEMO argued that this may occur as applicants connecting asynchronous generating systems may be unlikely to voluntarily invest in FCAS capability. AEMO stated that "despite increasing volatility in some of these [FCAS] markets, no asynchronous generator has yet been registered as a Market Participant in any of the FCAS markets."[132] AEMO considered that this trend was likely to continue, as "generation evolves and there are no direct incentives for Generators to install these capabilities within new generating systems to replace it."[133]

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129 Clause S5.2.5.11(c) of the NER.

130 Clause S5.2.5.11(d) to (h) of the NER.

131 AEMO, rule change request, pp. 42-43.

132 AEMO, rule change request, p. 41. AEMO noted in its rule change request that it was working with the Australian Renewable Energy Agency (ARENA) and the Hornsdale Stage 2 wind farm to demonstrate the capability of wind farms to provide all eight types of FCAS. The Hornsdale wind farm successfully trialed this capability in March 2018.

133 Ibid, p. 43.

AEMO argued that the lack of asynchronous generating systems participating in FCAS markets may be based on a number of perceived barriers to entry, including:[134]

- the cost to enable FCAS capabilities if they were not included in the original equipment specification, and
- commercial issues if financing and warranties did not consider the provision of FCAS.

AEMO stated that network service providers and connection applicants have found the existing specification of the required frequency response characteristics to be difficult to interpret and apply to the connection of new generating systems.[135]

Given these issues, AEMO therefore proposed a mandatory requirement for all generating systems to have frequency response mode capability, such that they would have the capability to provide at least one market ancillary service.[136] AEMO also identified that it would be preferable that a frequency control capability should be based on a droop type response, with this droop response to be adjustable and triggering response once power system frequency had moved outside a specific deadband limit.[137]

AEMO proposed achieving this by amending the minimum access standard to require all generating systems with a capacity of 30 MW or more to be able to participate in at least one of the markets for FCAS.

Specifically, AEMO proposed that the minimum access standard be amended to state that:

> "a *generating system* with a *nameplate rating* of 30 MW or more must be capable of automatically providing a proportional:
>
> (i) decrease in *power transfer* to the *power system* in response to a rise in *power system frequency* at the *connection point*; and
>
> (ii) subject to paragraph (c)(i)(ii), increase in *power transfer* to the *power system* in response to a fall in *power system frequency* at the *connection point*
>
> sufficiently rapidly and sustained for a sufficient period for the *Generator* to be in a potion [sic] to offer measurable amounts of *market ancillary services* to each of the *spot market* for at least one of the *market ancillary services*."

Importantly, AEMO's proposed change to the minimum access standard relates to the *capability* to provide a market ancillary service, rather than a requirement to actually provide the service itself. As such, AEMO did not intend for generators to be continuously active, or bid into existing FCAS markets. However, AEMO also stated that the capability "must be continuously available for service", and that the capability

134 Ibid.

135 Ibid.

136 The Commission notes that AEMO's proposed rule attached to the rule change request did not include a reference to frequency control mode, which is a NER defined term. See: AEMO, rule change request, proposed rule, clause S5.2.5.11.

137 Ibid.

might be voluntarily used by the generator, or when required to do so by AEMO or the network service provider.[138]

The Commission understands that AEMO's intention for the capability to be continuously available for service would mean that all necessary hardware and control software to provide an FCAS response, including supporting communications and SCADA equipment, would need to be installed and subject to all required compliance testing. However, it would not require the relevant generator to have registered the generating unit as an ancillary service generating unit, or to offer capacity into any of the spot markets for the various market ancillary services.

AEMO also proposed a number of changes to the form of the automatic access standard, to "clarify the frequency response expectations for plant" under the automatic access standard.[139]

AEMO proposed that the automatic access standard be amended to state that:

> "a *generating system* must be capable of automatically providing a proportional:
>
> (i) decrease in *power transfer* to the *power system* in response to a rise in *power system frequency* at the *connection point*, and
>
> (ii) increase in *power transfer* to the *power system* in response to a fall in *power system frequency* at the *connection point*
>
> sufficiently rapidly and sustained for a sufficient period for the *Generator* to be in a position to offer measurable amounts of *market ancillary services* to the *spot market* for each of the *market ancillary services*."

AEMO also proposed removing several clauses in the existing automatic access standard that describe the specific characteristics of the amount of active power provided in response to a frequency deviation. Specifically, AEMO proposed removing several clauses in S5.2.5.11(b)(2) to (3) that describe the frequency thresholds beyond which a generating system must provide an active power response, and the amount of response that should be provided. AEMO stated this is appropriate on the basis that the existing clauses are difficult to interpret and apply.[140]

AEMO also proposed that generator frequency response should be specified as a droop type response, once power system frequency moves outside a deadband.[141]

In the proposed rule drafting that accompanied the rule change request, AEMO set out several proposed changes to the definitions and general requirements of clause S5.2.5.11 of the NER. These included the following:

- deleting the in-clause definitions of maximum operating level, pre-disturbance level and system frequency

138 Ibid., p. 42.

139 Ibid., p. 43.

140 AEMO, rule change request, p. 43 and proposed rule, clause S5.2.5.11.

141 Ibid.

- introducing a new definition of maximum operating level in Chapter 10 of the NER, including changing references to "sent out generation" of semi-scheduled and scheduled generators to the "maximum *generation* to which it may be *dispatched* and as provided to AEMO in most recent *bid and offer validation data*"
- introducing a new in-clause definition for droop, being:

  > "droop means in relation to *frequency response mode*, the percentage change in *power system frequency* at the *connection point* required to produce a change in *power transfer* equal to the *maximum operating level* of the *generating system*"

- introducing several new requirements in the general requirements section of the clause including requirements for the generating system to:
  - provide a rapid active power response once frequency has moved outside of the deadband
  - set a deadband within a range of 0 to ±1.0 Hz
  - set a frequency droop within the range of 2% to 10%
  - not be required to operate outside minimum and maximum operating levels
- introducing new requirements for the performance standard to record: minimum and maximum operating levels; droop and deadband settings and agreed sustained response times
- deleting terms including system frequency and active power transfer and replacing those with more appropriate terms, and
- changing the negotiated access standard as follows:[142]

  > "A *Generator* proposing a *negotiated access standard* in respect of paragraph (c)(2)(1)(ii) must satisfy ~~demonstrate to~~ *AEMO* and the *Network Service Provider* that the proposed ~~increase and~~ decrease in *power transfer* ~~active power transfer~~ to the *power system* is ~~are~~ as close as practicable to the *automatic access standard* for that *plant*."

The rationale for some of these changes is to provide increased clarity and transparency for the operational characteristics of generators. For example, AEMO advised that this was the intent of requiring the specific levels of parameters such as deadband or droop to be defined within specific rules defined limits and then with actual settings recorded in performance standards.[143]

AEMO advised that the proposed clause S5.2.5.11(i)(1) above, which requires an active power response to occur "with no delay" once frequency has moved outside of a deadband, is intended to allow for the emergence of fast frequency response (FFR) type services in future. AEMO stated that as the format of these services are currently not

142 Note, underlined text is text that AEMO proposed be inserted, and struck through text is text that AEMO proposed be deleted.

143 This policy intent was not explicitly stated in the rule change request itself, but reflected in the proposed drafting accompanying the rule change request. See: AEMO, rule change request, proposed rule, clause S5.2.5.11.

defined, it was appropriate to specify relevant capabilities in this way, to allow for enablement of FFR from capable plant in future as these services are developed.[144]

In other cases, AEMO proposed amendment of some of the relevant definitions to improve clarity, or has proposed deletion as the definitions are no longer considered necessary. AEMO has advised that these changes are designed to bring the wording of the clause into line with the rest of the NER.

5.3.4 Stakeholder views

A number of stakeholders made submissions to the consultation paper regarding AEMO's proposed changes to the minimum access standard, with a focus on the proposed requirement for all generating systems to be capable of providing at least one market ancillary service.

Some stakeholders supported the proposed changes. Advisian considered that mandating active power control capabilities to respond to changes in system frequency and in some cases respond to signals from AEMO's automatic generation control system is necessary to ensure system security and reliability.[145] The Energy Networks Australia also supported AEMO's proposed approach, arguing that while mandating capability could create the risk of over-building, this would be compensated for by reductions in FCAS prices.[146]

The Australian Sugar Milling Council (ASMC) was also generally supportive, noting that most modern generating plant has the capability to control active power with little or no additional cost. However, the ASMC also noted that communications equipment associated with actually providing this capability may result in higher costs for remote generators.[147]

Several stakeholders argued that mandating the capability to participate in FCAS conflicted with fundamental market design principles. For example, AGL argued that mandating the capability to participate in FCAS markets would unnecessarily increase costs to create or widen a market, which directly conflicts with the principles and objectives of a deregulated energy market, while providing no additional assurance that a generating system will participate in FCAS markets.[148] The Clean Energy Council also argued that the proposed changes were unlikely to provide the benefits identified by AEMO, noting that mandating capability provided no guarantee of increased participation in the actual provision of FCAS. The CEC noted that:[149]

> "Generators have other commercial and technical drivers – such as contracting full energy volumes as part of their power purchase agreements or the availability of wind or solar resources – that would prevent them from actively participating in the ancillary services markets. …there would

144 AEMO, rule change request, p. 44.

145 Advisian, submission to the consultation paper, Appendix B, p. iii.

146 ENA, submission to the consultation paper, p. 7.

147 ASMC, submission to the consultation paper, p. 6.

148 AGL, submission to the consultation paper, p. 6.

149 CEC, submission to the consultation paper, p. 29.

> be little incentive to allow some 'headroom' for an uncertain revenue stream from an ancillary services opportunity. Obliging a new plant to have this ancillary services capability would do nothing, and appears to go against the AEMC's view that market- based solutions are consistent with the NEO."

Alinta queried the costs associated with meeting AEMO's proposed change, stating that some of the proposed new requirements would be technically unworkable, and if at all feasible would in any event be highly expensive.[150]

A number of stakeholders argued that if AEMO's rule change was mandating actual FCAS response from plant, this could have significant impacts for the connection of asynchronous generating systems. For example, the CEC argued that as most renewable (asynchronous) generating systems are always supplying the most power possible, AEMO's proposed change would effectively require constant derating of the plant or the installation of battery storage.[151]

Stakeholders also commented on AEMO's other proposed changes to the frequency response capabilities. GE Australia commented on AEMO's proposal to require the access standards to include a specific deadband, stating any relevant deadband for provision of frequency control services should be included in the frequency operating standards.[152] Origin Energy stated that consideration of droop control should not occur as part of this rule change, but as part of the frequency control frameworks review. Origin Energy also argued that:[153]

> "Should mandatory droop control be required by new generators, Origin would prefer that units are only required to have the capability to provide droop control, not mandatory participation. Generators should be free to determine the percentage of droop control they provide to the market."

RES Australia expressed concerns with AEMO's proposed automatic access standard, stating that the:[154]

> "proposed automatic access standard of … "offering market ancillary services to the spot market for each of the market ancillary services" do not recognise the variable nature of renewable resources and cannot be achieved without additional equipment, such as energy storage. This is not a technology neutral approach and will require a negotiation. In other words, present a barrier to entry."

Advisian noted that while the proposed automatic access standard referenced all of the market ancillary services, different generation types may not be capable of offering into all of these markets.[155]

150 Alinta, submission to the consultation paper, p. 5.

151 CEC, submission to the consultation paper, p. 29.

152 GE Australia, submission to the consultation paper, p. 17.

153 Origin Energy, submission to the consultation paper, p. 2.

154 RES Australia, submission to the consultation paper, p. 8.

155 Advisian, submission to the consultation paper, p. 34.

Hydro Tasmania noted that other forms of frequency response existed in the NEM, including switched response type FCAS and that these other types of frequency response appeared not to be covered by AEMO's proposal.[156]

5.3.5 Analysis and conclusions

This section sets out:

- the Commission's analysis of the of the issues raised by AEMO, and
- the Commission's draft rule to address any material issues found.

Box 5.2 Draft rule

The draft rule makes a number of changes to clause S5.2.5.11 of the NER related to frequency control. These include:

- amending the minimum access standard to require all generating systems to be capable of operating in frequency response mode (subject to energy source availability), so that they can provide an automatic active power response to a change in frequency of the power system (where the change in active power may be proportional or otherwise as agreed with AEMO and the network service provider)[157]
- amending the requirements of the automatic access standard, to specify that to meet the automatic access standard, a generator must be capable of offering measurable amounts of all of the market ancillary services for provision of frequency control[158]
- introducing a requirement in the general requirements to record in the performance standards the market ancillary services the generating system is capable of offering, including the performance parameters and requirements that apply to each market ancillary service[159]
- removing the existing specification of generator response included in the current automatic access standard, including references to the maximum operating level of the generator and the difference between the pre-disturbance level and the generator's minimum operating level. This is intended to improve clarity for network service providers, AEMO and generators when negotiating access standards[160]
- introducing new general requirements for those generating systems that provide a frequency control response under the automatic access standard,

156 Hydro Tasmania, submission to the consultation paper, p. 13.

157 Clause S5.2.5.11(c)(2) of the draft rule.

158 Clause S5.2.5.11(b)(2) of the draft rule.

159 Clause S5.2.5.11(i)(5)(ii) of the draft rule.

160 Clause S5.2.5.11(b)(2)(i) and (ii) and clause S5.2.5.11(b)(3)(i) and (ii) of the NER.

or through a negotiated access standard, to:

  - have the capability to set a deadband within the range of 0 to ± 1 Hz around the nominal frequency of 50Hz[161]
  - have the capability to set a droop response within the range of 2% to 10%[162]
  - be able to provide a change in power transfer to the power system with no delay once the frequency of the power system leaves a deadband around 50Hz[163]
  - clarify that a generating system is not required to operate outside minimum or maximum operating levels in response to changes in power system frequency,[164] and
  - clarify that a generating system is only required to operate in frequency response mode when enabled for the provision of a relevant market ancillary service[165]

- introducing a definition of droop[166]
- removing the negotiated access standard requirements that provide for clause S5.2.5.11 to be an AEMO advisory matter and for the negotiated access standards to be as close as practicable to the automatic access standard, on the basis that both of these are now captured by proposed amendments to the negotiation framework at clause 5.3.4A, discussed in Chapter 4[167]
- moving the requirement for the levels of the maximum and minimum operating levels to be recorded in the performance standards to the general requirements,[168] and
- amending and deleting a number of terms in the clause to better reflect operational practice including the definitions of maximum operating level, pre disturbance level and system frequency, and use of the term active power transfer.[169]

Changes to the minimum access standard

The Commission considers that generators should make the decision whether to incur the costs associated with entering FCAS markets. AEMO's proposed change to the

161 Clause S5.2.5.11(i)(2)(i) of the draft rule.

162 Clause S5.2.5.11(i)(2)(ii) of the draft rule.

163 Clause S5.2.5.11(i)(1) of the draft rule.

164 Clause S5.2.5.11(i)(3) of the draft rule.

165 Clause S5.2.5.11(i)(4) of the draft rule.

166 Clause S5.2.5.11(a) of the draft rule.

167 Clauses S5.2.5.11(d) and (f) of the NER.

168 Clause S5.2.5.11(i)(5)(i) of the draft rule.

169 Clause S5.2.5.11(a) of the draft rule.

minimum access standard would impose a regulatory obligation to incur these costs, which the Commission considers is contrary to the market based provision of FCAS. The Commission considers AEMO's proposed changes would not increase the supply of FCAS and would not therefore provide system security benefits, while imposing significant costs on generators and ultimately consumers.

However, the Commission considers there may be benefits in requiring generating systems to have frequency response mode capability and for this to be recorded in a performance standard. A number of stakeholders considered this general capability could be provided by all generating systems.[170] The Commission understands that frequency response mode is an inherent capability of most generating systems and can be included in new generating systems at effectively zero cost.

The Commission considers that requiring this capability will support system security, by supporting generators who wish to enter the markets for the provision of FCAS to do so as quickly as possible, in response to high FCAS prices. This will support system security by allowing for the rapid supply of FCAS where an urgent system need for FCAS has been signalled through high FCAS prices.

Importantly, requiring this capability stops well short of requiring any generator to have the capability to offer a market ancillary service, as originally proposed by AEMO. It does not require generators to undertake any of the additional investments or incur any additional costs associated with testing and registering to participate in FCAS markets. The Commission considers that these decisions must be made voluntarily by the generator, in response to market price signals. Mandating that generators record a basic level of frequency response mode capability in the performance standards is not intended to replace or interfere with a generator's decision to respond to price signals and enter FCAS markets.

This section sets out the Commission's assessment of AEMO's proposed changes to the minimum access standard, including:

- assessment of the materiality of system security issues, and
- potential impacts on FCAS markets from AEMO's proposed minimum access standard.

It then describes the requirement introduced in the draft rule for all generating systems to have frequency response mode capability

Assessment of materiality: system security issues

AEMO considered a key reason for mandating all generating systems have the capability to provide at least one of the market ancillary services was to address the risk of future FCAS shortfalls. A lack of future FCAS could have negative impacts on system security, such as difficulty in keeping system frequency stable during normal operation and recovering from major frequency disturbances following contingency events.

AEMO stated this potential FCAS shortfall may occur as semi-scheduled generating systems are unlikely to have the capability to provide FCAS. AEMO noted that to date,

170 Submissions to the consultation paper: Advisian, p.iii; ENA, p. 7; Australian Sugar Milling Council, p. 6.

there had been no voluntary, market based entry of asynchronous, semi-scheduled generation into the markets for FCAS.[171] When combined with the possibility of the exit of existing FCAS providers, or that these providers may operate less frequently, this could cause a decrease in available FCAS.

AEMO noted that this risk may be particularly present in some parts of the power system where there are relatively fewer generating systems registered as FCAS providers. AEMO considered that if these units unexpectedly exit, operate less frequently, or decide to deregister as FCAS providers,[172] this could significantly and rapidly reduce the amount of FCAS available in those regions.

Frequency is a fundamental parameter that must be managed to maintain stability in an AC power system. In the NEM, frequency is controlled by generating systems that are registered to provide FCAS. It is therefore critical that there are enough of these generating systems registered and actively providing FCAS, to maintain the frequency stability of the power system.

However, the Commission does not consider there is any evidence of a shortfall in the supply of FCAS in the power system in the medium to longer term. As such, there appears to be no reason to mandate that all generating systems are required to invest in the capability such that they can participate in FCAS markets.

In the medium term, volumes of capacity registered to provide FCAS suggests there is sufficient capability to meet system needs. Even in those parts of the NEM where local requirements for FCAS may be imposed, there appears to be adequate volumes of capacity available to meet system needs.[173] For example, in South Australia, where the local requirement for regulating raise FCAS is around 30 MW, the registered regulation raise capacity is around 500 MW.[174]

More generally, the Commission considers that mandating the capability to provide at least one market ancillary service is in excess of system needs. The volume of FCAS typically procured by AEMO is intended to cover the largest credible contingency in the

171 As noted above, AEMO acknowledged the AEMO joint trial project with ARENA at the Hornsdale wind farm. The Hornsdale Power Reserve battery has also entered the market for the provision of FCAS, with funding support originally provided by the South Australian government.

172 Generators may elect to deregister older thermal units as market ancillary services generating units, as operating in frequency response mode can impose additional operational burdens on older plant. Generators may therefore elect to withdraw from FCAS markets if this will help to reduce the risk of failure and maintenance costs for older thermal units.

173 FCAS can be sourced on a local or system wide basis. When the mainland power system is operating in a fully synchronous mode with all AC interconnectors in full operation, system frequency can be controlled through FCAS located anywhere in the power system and FCAS can be procured on a system wide basis. For example, a decrease in frequency caused by the loss of a generator in South Australia can be addressed by increasing the energy output of a generator in Queensland. However, in some instances, FCAS may need to be sourced on a local basis, such as where there is a credible loss of interconnection with the rest of the power system. South Australia is subjected to this requirement from time to time, when loss of the Heywood interconnector is reclassified as a credible contingency event.

174 Taken from the AEMO Registration and Exemption list, viewed 26 April 2018.

system.[175] It follows that if all new generating systems were required to be "continuously available for service" to provide a FCAS response (as would be required under AEMO's proposed minimum access standard), the amount of FCAS available to respond would, over time, be well in excess of likely FCAS requirements.

AEMO stated that in the longer term, FCAS shortfalls may exist as historically no semi-scheduled generating system has voluntarily registered to provide FCAS. While the Commission acknowledges that to date, there has not been any market driven entry into FCAS markets by semi-scheduled generating system it does not automatically follow that semi-scheduled generating systems will not register to provide FCAS in future.[176]

The Commission acknowledges the risk identified by AEMO that sudden exit or deregistration of existing FCAS providers could cause FCAS shortfalls. However, as FCAS is a globally sourced service, the exit of a single FCAS provider (even a very large one) will not automatically result in a shortfall that may contribute to a system security risk. This risk may be more pertinent in regions where FCAS is provided by a relatively small number of providers, and where islanding, or the risk of islanding of the region can result in local FCAS requirements. However, this risk does not warrant the imposition of a requirement to mandate capabilities from all connecting generating systems to be capable of offering one or more market ancillary services.

FCAS as a market service

Generators currently decide whether to incur the costs associated with providing a particular market ancillary service, on the basis of expected revenue they would earn through the provision of that particular service.[177] Generators are therefore the sole party who bears the risk of these costs.

Mandating the capability to participate in ancillary services markets from all generating systems represents a significant departure from this market based approach. It is also likely to significantly increase costs for generators and ultimately consumers. These costs would be incurred regardless of whether the generator actually registered to participate in FCAS markets.

The Commission understands that AEMO's intention in proposing the minimum access standard was that generating systems would have the capability to provide an active power frequency response, for at least one market ancillary service, as soon as this response was required for frequency control. The implication of this is that the generating system would need to have all supporting equipment installed and ready to provide the market ancillary service. This could impose additional hardware costs for

175 Other processes and metrics are used by AEMO to determine the volume of regulating FCAS required at any given point in time.

176 The Commission acknowledges that there may be some barriers to participation in existing markets for FCAS, including the current definitions of contingency services and the extent to which FCAS market prices can support long term investment. The Commission is considering these issues through its broader examination of the markets for FCAS, in its Frequency control frameworks review. See: www.aemc.gov.au

177 Generators may face other incentives, such as hedging their exposure to the cost of contingency raise services, which are recovered from generators.

generating systems. For example, for the delivery of a contingency FCAS, the generator would need to install and test high speed monitoring and recording equipment.

Further costs would be incurred through commissioning and ongoing compliance testing obligations. Stakeholders advised the costs of this ongoing compliance process are in the range of $100,000 – $150,000, for the provision of a specific market ancillary service. This cost would be incurred both at the time of commissioning and on an ongoing basis every few years as the generating system's performance is tested. This ongoing compliance testing may also extend the amount of time that generating units are offline, increasing operational costs which are ultimately borne by consumers. These costs would be incurred regardless of whether the generating system was actually registered to provide FCAS. When multiplied across all new generating systems in the fleet, these costs would likely be significant.

The Commission also notes that the actual provision of FCAS is voluntary and accepts stakeholder views that the proposed minimum access standard would not necessarily result in an increase in generating capacity registered to provide FCAS.[178] A generator has to register a generating unit as a market ancillary service generating unit and then make an offer into the relevant ancillary services market, before it actually provides FCAS. Mandating that generating systems have FCAS capability would not require registration to provide a market ancillary service, and would therefore not provide any certainty that the generator in question would actually provide the service. Some stakeholders also suggested that the incentives faced by the operators of some asynchronous generating systems are to maximise active power output, meaning that they would be unlikely to voluntarily hold back output to provide the "headroom" needed to bid into some FCAS markets, even if they had the capability to do so.[179]

Given these factors, the Commission considers that AEMO's proposed minimum access standard would impose significant costs on consumers, and would be unlikely to increase the actual availability FCAS capability.

Alternative minimum access standard: mandating frequency response mode capability

The Commission does not consider it would be efficient to require generating systems to have the capability to offer one market ancillary service, for the reasons set out above

However, the Commission considers that requiring generating systems to have frequency response mode capability is likely to support improved system security outcomes.

As discussed in section 5.3.1, frequency response mode capability is different to the capability to offer one of the market ancillary services. The Commission understands that the former is effectively an inherent characteristic of most modern generating systems and should impose very low to zero costs, whereas the latter requires additional investment, registration and compliance testing, resulting in additional costs.

178 AGL, Consultation paper submission, p. 6; GE Australia, p. 17.

179 CEC, Consultation paper submission, p. 29.

The Commission considers that requiring generating systems to have frequency response mode capability as part of the minimum access standard is likely to support improved system security outcomes. It will do so by enabling generators and AEMO to respond as rapidly as possible to system needs for frequency control, by minimising the amount of time to register new sources of FCAS.

The Commission acknowledges AEMO's concern that the unexpected exit, or deregistration, of large thermal units could cause rapid decreases in the availability of FCAS. This could occur in regions where there is a relatively small number of remaining generating systems. Although the Commission does not consider that the risk of this scenario occurring warrants mandating all generating systems having the capability to offer a market ancillary service, it could still result in an increased system security risk if the available supply of FCAS were to become particularly tight in the region.

The Commission considers that, under this scenario, system security would be supported if generating systems in the region able to promptly respond to FCAS market prices, by quickly completing the process necessary to be able to register as FCAS providers. Supporting generators in promptly completing this process will help to quickly deliver the volumes of FCAS needed to reduce the risk of frequency instability.

The Commission understands that there are a number of steps that a generating system must complete before it can be registered as an FCAS provider. This includes the installation of any necessary additional equipment to deliver FCAS (such as high speed monitoring and recording devices), as well as the physical compliance testing of the capability to provide the specific service that the generator has elected to provide.

However, before this can occur, it is necessary for AEMO and the generator to understand the fundamental capability of the generating system to actually operate in frequency response mode. If this capability is not documented in the original performance standards of the generating system, it may take some time to undertake the necessary testing to determine these underpinning plant characteristics, to support the subsequent processes of equipment installation and registration.

The Commission notes comments from stakeholders that in some instances, these frequency response characteristics are known to the operator of the generating system, resulting in no material delay to the overall process of becoming an FCAS provider. However, the Commission has been advised that in other circumstances, the frequency response mode characteristics may not have been explicitly recorded at the time of commissioning, and may be unknown to the owner of the generating system. This may occur where a generating system has been on sold between parties. It may be exacerbated where the owner of the generating system no longer has a contractual relationship with the original equipment manufacturer, potentially resulting in material costs if the manufacturer is required to provide an update or otherwise alter control software.

Under this scenario, additional testing and modelling may need to occur before the subsequent steps in the process of becoming an FCAS provider can be completed. the Commission has been advised by AEMO that this can materially delay the FCAS registration process.

The Commission considers that requiring frequency response mode capability from all generating systems will help to address the risk of this scenario occurring in future. Furthermore, the Commission understands that this capability can be included in new generating systems at close to zero cost.

The Commission understands that frequency response mode capability is inherent in most modern synchronous and asynchronous units. Advice from DigSILENT Pacific is that most modern synchronous units will include a configurable primary frequency controller as part of the digital governor. These digital governors can be programmed to provide whatever frequency response is desired, as limited by the physical capability of the generating system itself.[180] Importantly, if specified as a capability at the outset for new synchronous units, the Commission understands that the cost of providing frequency response mode capability is nominal or very close to zero.

For asynchronous units, frequency response mode capability is dictated by the controls programmed into the control software. The Commission understands that as this capability can be enabled through changes to control parameters, it is effectively costless for asynchronous generating systems.[181]

Furthermore, the Commission understands that commissioning and compliance testing obligations for this capability are significantly less than for the capability to provide one market ancillary service. AEMO have advised that field testing is not obligatory, and that there are a range of options available for testing, including simulation studies or monitoring of in-service performance. Compliance costs should therefore be very low, or effectively zero for this capability, significantly reducing cost implications for consumers.

The Commission also notes that mandating frequency response mode capability is consistent with, or may in fact be less onerous than approaches taken in a number of international jurisdictions. For example, the US Federal Energy Regulatory Commission recently mandated frequency response mode capability as part of a more onerous obligation to provide mandatory primary frequency response capability.[182] The Commission understands that a number of other jurisdictions set similar requirements

180 For example, hydro units can operate in frequency response mode, but the speed of this response is dictated by the physical inertia of the water in the penstock. Other types of generation may be constrained by internal stability limits, such as maintenance of boiler pressure.

181 The Commission acknowledges comments from some stakeholders that semi-scheduled generating systems may be built on the basis of maximising active power production for the purposes of meeting power purchase agreements or maximising renewable energy certificate production. As such, provision of FCAS may not have been considered in the business case for the generating system. However, given that frequency response mode capability comes at very low cost, its inclusion in performance standards should not materially impact on the business case for the generating system. Furthermore, the Commission notes that frequency response mode capability is not a requirement to have the capability to participate in FCAS markets, nor is it a requirement to register as an FCAS provider or to offer FCAS. As such, it does not requirement semi-scheduled generating systems to be operated in manner other than what its operators choose. Again, this should not have a material impact on the business case for new semi-scheduled generating systems.

182 Federal Energy Regulatory Commission, *Essential Reliability Services and the Evolving Bulk-Power System – Primary Frequency Response*, 17 November 2016. See: https://www.ferc.gov/whats-new/comm-meet/2016/111716/E-3.pdf

for the provision of frequency response capability, including Alberta,[183] British Columbia,[184] and Ireland.[185]

Given these considerations, the draft rule includes a new minimum access standard in clause S5.2.5.11 of the NER for all generating systems to be capable of operating in frequency response mode.[186]

As discussed above, requiring frequency response capability is not equivalent to requiring a generator to have the capability to offer a market ancillary service, as originally proposed by AEMO. Mandating that generators record a basic level of frequency response mode capability in the performance standards is not intended to replace or interfere with a generator's decision to respond to price signals and enter FCAS markets. In order to make this clear, the draft rule explicitly states in the general requirements that a generating system is required to operate in frequency response mode only when it is enabled for the provision of a relevant market ancillary service.[187]

The Commission has also accounted for a number of other issues in making the draft rule. These include:

- As mentioned above, frequency response mode capability can include both proportional and switched type responses. The Commission notes comments from stakeholders that switched responses may be appropriate from some generating systems in some conditions.[188] The draft rule accounts for this by allowing for the frequency response mode capability to be a proportional response type, or otherwise as agreed with AEMO and the relevant network service provider.[189]
- Semi-scheduled generating systems may be constrained in their ability to change their active power in response to frequency, on the basis that the underlying energy source may be unavailable. The draft rule accounts for this by clarifying that the frequency response is subject to energy source availability.[190] As with the Commission's assessment of active power control capabilities, the Commission considers that semi-scheduled generating systems with active power output dependent on energy source availability would not be required to install any form of energy storage to meet this capability requirement
- Some generating systems may only be able to provide a frequency response as an increase or a decrease in active power output. For these reasons, the draft rule

183 AESO, *ISO rules*, 30 April 2018

184 BC Hydro, *60 kV to 500 kV Technical Interconnection Requirements For Power Generators,* 2 June 2014, p. 26.

185 EirGrid, *EirGrid Grid Code*, June 2015.

186 Clause S5.2.5.11(c)(2) of the draft rule.

187 Clause S5.2.5.11(i)(4) of the draft rule.

188 HydroTasmania, submission to the consultation paper, p. 11.

189 Clause S5.2.5.11(c)(2) of the draft rule.

190 Ibid.

allows for either an increase or a decrease in active power in response to a change in power system frequency.[191]

Changes to the automatic access standard

The Commission considers that AEMO's proposed changes to the automatic access standard are broadly appropriate. These changes should provide sufficient flexibility for connection applicants, AEMO and network service providers to agree efficient generator performance standards.

The draft rule includes a number of changes that reflect AEMO's proposed changes, with some amendments to further clarify the context of the automatic access standard.

The draft rule changes the automatic access standard to require the generator to have the capability to be in a position to offer measurable amounts of all market ancillary services for the provision of frequency control.[192] The Commission notes concerns from stakeholders that some generation technologies are unable to offer all of the market ancillary services; for example, some larger thermal units may be physically unable to offer fast FCAS services.[193] Similar physical limitations may apply to hydro generation, or to energy constrained batteries.

The Commission notes these issues raised by stakeholders, but considers that negotiation of access standards will lead to outcomes that reflect the capabilities and limitations of generating plant. The negotiating process will allow for an appropriate level of capability to be agreed on a case by case basis, taking into account both system needs and the physical capability of particular plant.

More generally, the Commission considers that the automatic access standard set out in the draft rule is appropriate, given that there are technologies that are capable of providing all of the existing market ancillary services. Large scale battery storage, for example, is able to offer regulating services, as well as fast, slow and delayed raise and lower contingency services, provided the battery has sufficient capacity. Solar PV generating systems may also be able to offer the full range of market ancillary services, subject to energy source availability.

There may also be parts of the power system where there is need for generating systems to be able to offer all of the market ancillary services. As noted above, there are parts of the power system where the supply of FCAS may tighten in future. If there is a real and imminent system need for new generating systems to have the full suite of FCAS capabilities, or to have a specific set of FCAS capabilities, AEMO and the network service provider may require this level of performance from the connecting generator through the process of negotiating performance standards.

Given the existence of these technologies capable of providing all of the market ancillary services, and that there may be parts of the power system where there is a system need for a generating system to offer all of the market ancillary services, the

191 Ibid.

192 Clause S5.2.5.11(b)(2) of the draft rule.

193 Advisian, Consultation paper submission, p. 34.

Commission considers it appropriate that the draft rule includes the capability to offer each of the market ancillary services in the automatic access standard.

The Commission also notes comments from stakeholders regarding whether reference to the existing market ancillary services in the automatic access standard could create complexities, if the NER definitions of those services were to change in future. Specifically, concerns were raised that there may be uncertainty in terms of how a generator can prove that it continues to be compliant with the automatic access standard over time, if the range of market ancillary services standards referred to in the automatic access standard were to change. This is because the automatic access standard simply refers to the capability to offer "all market ancillary services for the provision of frequency control". These market ancillary services may change, either in terms of what services are defined in the NER, and how their specific characteristics are defined in the market ancillary services specification (MASS).

The Commission considers that generators, network service providers and AEMO will negotiate performance standards on the basis of the version of the NER and the MASS that is current at the time. Therefore, a generating system would meet the automatic access standard if it was capable of providing the full range of market ancillary services as contemplated by the NER, and reflected in the MASS, at that time. Once the performance standards are agreed, any subsequent changes to the NER, or MASS, do not have any impact on those agreed performance standards.

In order to clarify this, the draft rule includes a general requirement that the performance standards should record the specific market ancillary services that have been agreed between the generator and AEMO.[194] The generator will therefore have met the automatic access standard, and will be held to continue to meet the automatic access standard, where the performance standards have recorded the capability to provide a set of market ancillary services that correspond to the definition of those services in the NER and MASS at that point in time.

The Commission acknowledges the potential emergence of new frequency control market ancillary services, such as the fast frequency response services as contemplated by AEMO in the rule change request.[195] The Commission considers that linking the generator's performance standards to a version of the NER and MASS will not prevent a generator from registering to provide differently specified services in future, if the parameters of those services exceed the range of services recorded in the generator's performance standards.

The draft rule also takes into account the future development of other market ancillary services, unrelated to frequency control.[196] While not currently the case in the NEM, other jurisdictions do have market ancillary services that relate to non-frequency control needs of the system, such as fast active power recovery following a disturbance and the provision of voltage control.[197] Accordingly, the draft rule specifies that the

194 Clause S5.2.5.11(i)(5)(ii) of the draft rule.

195 AEMO, rule change request, p. 43.

196 Currently, the only market ancillary services defined in the NER relate to frequency control.

197 For example, in Ireland, Eirgrid procure a fast post fault active power recovery service on a market basis.

capabilities described in the automatic access standard are related to the market ancillary services for the provision of power system frequency control only.

AEMO's rule change request also proposed the deletion of several clauses in the existing automatic access standard. These clauses specified the frequency bands that serve as the trigger for generating systems to provide a frequency response, as well as defining the amount of active power to be delivered by reference to the generating system's minimum and maximum operating levels.[198] AEMO stated that these clauses were difficult to interpret and apply by generators, network service providers and AEMO in the negotiation of generator performance standards.

The Commission notes AEMO's comments and agrees that these clauses could impede the efficient negotiation of generator performance standards to the extent that they do not provide effective guidance to network service providers and generators negotiating performance standards. They have been removed from the draft rule.

AEMO's other proposed changes to clause S5.2.5.11

AEMO proposed a number of other changes to clause S5.2.5.11 of the NER, including changes to the general requirements as well as several changes intended to improve the clarity of the access standard.

Changes to the general requirements

AEMO proposed several new clauses to define the capability for a generating system to:[199]

- respond as rapidly as possible once frequency had moved outside a deadband
- the deadband to be set within the range of 0 to +/- 1 Hz, and
- a frequency droop to be set within the range 2% to 10%.

AEMO also proposed a clause to clarify that a generating system would not be required to operate outside its minimum and maximum operating levels. AEMO also proposed that the GPS should specify the deadband and droop settings applied, as well as the agreed time for sustained response in power transfer to a rise or fall in power system frequency at the connection point. Finally, AEMO also proposed that a generator providing an active power response should do so as rapidly as possible once the power system frequency has left the deadband around 50 Hz.

As discussed above, the draft rule requires the performance standards to record the market ancillary services that the generating system is capable of offering, including the performance parameters and requirements that apply to each such market ancillary service.[200] The Commission considers that this requirement is sufficient to provide clarity on the actual parameters of the service or services that the generator has agreed to provide.

198 Clause S5.2.5.11(b)(2) and (3) of the NER.

199 AEMO, rule change request, proposed rule, clause S5.2.5.11.

200 Clause S5.2.5.11(i)(5)(2) of the draft rule.

The draft rule requires generators to be capable of setting deadband and droop responses within the ranges proposed by AEMO.[201] The Commission considers that will provide clarity as to the capabilities that a generating system must have in order to be able to set deadbands and droop responses that lie within these ranges. Where relevant, AEMO, the generator and the relevant network service provider may then determine what the specific values for deadband and droop should be, on the basis of any specific market ancillary service that the generator has agreed to provide.

AEMO also proposed that the NER should include a new definition of droop. The Commission agrees that inclusion of a droop definition will improve clarity for participants. However, following consultation with stakeholders, DigSILENT Pacific and AEMO, the draft rule sets out an amended definition of droop:

> "droop means in relation to *frequency response mode*, the percentage change in *power system frequency* as measured at the *connection point*, divided by the percentage change in *power transfer* of the *generating system* expressed as a percentage of the maximum operating level of the *generating system*. Droop must be measured at frequencies that are outside the deadband and within the limits of *power transfer*."[202]

The draft rule introduces several new clauses in the general requirements that are intended to clarify what a generating system must do when providing a market ancillary service for the provision of frequency control. These clauses are intended to clarify that a generating system:

- is not required to operate outside of its maximum or minimum operating levels when providing a frequency control response. This is intended to reflect the fact that a generating system can only provide a frequency control response when it has sufficient active power capacity to do so,[203]
- is only required to operate in frequency response mode when enabled for the provision of a relevant market ancillary service. This is intended to reflect the fact that the minimum access standard is not intended to require a generating system to provide a frequency control response, unless the generator has agreed to do so through the standard arrangements for the provision of a frequency control market ancillary service,[204] and
- should provide an active power response with no delay beyond that required for stable operation, or inherent in the plant controls, once the frequency of the power system as measured at the connection point leaves a deadband around 50 Hz.[205] This is intended to clarify that an active power response should be provided as rapidly as possible within physical limits, as long as this response meets the agreed bounds of the specific market ancillary service being provided.

201 Clause S5.2.5.11(i)(2) of the draft rule.

202 Clause S5.2.5.11(a) of the draft rule.

203 Clause S5.2.5.11(i)(3) of the draft rule.

204 Clause S5.2.5.11(i)(4) of the draft rule.

205 Clause S5.2.5.11(i)(1) of the draft rule.

General changes to improve clarity and reflect operational practice

The draft rule has deleted a number of clauses from S5.2.5.11 as they have been moved to other parts of the NER. Clauses S5.2.5.11(d) and (f) have been deleted as they have now been superseded by the proposed negotiation framework in clause in 5.3.4A and associated definitions in Chapter 10 of the NER. Clause S5.2.5.11(e) has been moved from the negotiated access standard to the general requirements.[206]

The draft rule also makes a number of changes to the wording and structure of clause S5.2.5.11 for the reasons set out below, including:

- Deletion of the in-clause defined term **pre-disturbance level**: As discussed above, several parts of clauses S5.2.5.11(b)(2) and (3) of the NER have been deleted from the draft rule. As the term pre-disturbance level was used only in these clauses, it has been deleted from the draft rule.
- Replacement of the in-clause defined term **system frequency** with *frequency* of the *power system* as measured at the *connection point*: This replaces an in-clause term with several terms defined in Chapter 10 of the NER, and ties the frequency measurement to the connection point. The Commission understands that this more accurately reflects actual operational practice.
- Amendment of the in-clause defined term **maximum operating level**: This term has be amended to replace references to sent out generation to instead refer to information provided in bid and offer validation data, for scheduled and semi-scheduled generating systems and units. The information provided in bid and offer validation data is updated more frequently and provides a more accurate reflection of actual operational capacity of these units and systems.
- Replacement of *active power* transfer with *power transfer*: Use of the Chapter 10 defined term *power transfer* more accurately reflects operational practice.
- Amendment of clause S5.2.5.11(b)(2)(iii) to insert the words "and sustained for a sufficient period". This reflects operational practice of the delivery of FCAS, which is delivered on the basis of how rapidly it is delivered, and how long it is sustained.

5.4 Active power control and ramp rate

5.4.1 Technical background

Active power control refers to the ability of a generating system to increase, decrease and maintain its active power output at a given level for a defined amount of time.

Within this overall definition, ramp limit capability refers to the speed at which a generating system can change its active power output, over a given time frame.

The ability of generating units to control changes in their active power output relates to the controllability of the underlying energy resource.

Generating systems with controllable energy sources (including synchronous units such as hydro or thermal) can directly control active power output. These generating systems

206 Clause S5.2.5.11(i)(5)(i) of the draft rule.

can typically increase, decrease and hold steady their output within defined limits.[207] These generating systems can control their active power output in various ways. For larger generating systems, this may involve equipment such as rate limiters, or operating the generating system in different modes. Smaller generating systems may face greater challenges in controlling their active power output, particularly in meeting particular ramp limits, if their control equipment is less sophisticated.

For generating systems with variable energy sources (including asynchronous wind or solar PV generating systems), the ability of a generating system to control its active power may be affected by changes in energy source availability. In particular, these generating systems may not be able to control a decrease in active power output, where this decrease is the result of a reduction in the availability of the relevant energy source, such as a reduction in available sunlight as a cloud passes over a solar PV farm. However, these generating systems can control their upward ramp rates, where the underlying energy source becomes available again. For example, control software for solar PV generating systems can operate the unit in a way that increases active power output gradually as the cloud passes and irradiation returns.

Generators may also need to install communications and monitoring capability to support their active power control capability, if the relevant control limits are applied through electronic instructions from the AEMO control centre.

5.4.2 Current arrangements

Generators are subject to various requirements in clause S5.2.5.14 related to how they control their active power output during a dispatch interval. These include the following key requirements:

- Scheduled and semi-scheduled generating systems are required to control their active power so that they meet the dispatch targets that they receive as part of their dispatch instructions from AEMO.[208]
- AEMO may include a ramp rate in its dispatch instruction for specific generating systems, which specifies the rate at which the generating system may change its active power output through the dispatch interval.[209]
- AEMO also state that generating units will generally be expected to ramp linearly from their initial energy output or consumption to their dispatch target.[210]
- The NER also impose FCAS cost liabilities on generators, unless the generator "achieves its dispatch target at a uniform rate".[211]

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207 Noting that the abilities of some thermal units to do this may be limited in some very specific cases, such as small thermal units that depend on the variability of supply of methane sourced from landfill.

208 Noting this is a requirement for scheduled generators under the automatic access standard in clause S5.2.5.14(a)(1) and a requirement for semi-scheduled generators under the minimum access standard in clause S5.2.5.14(b)(1).

209 Clause 4.9.5(a)(3) of the NER.

210 AEMO *System Operating Procedure 3705 - Dispatch*, 14 August 2017, p. 10. AEMO advise that this expectation applies to both scheduled generating units and scheduled load, even if those units or loads are not on the AGC.

The capabilities set out in the access standards for active power control reflect these general requirements on generators to control their active power.

These capabilities are set out in clause S5.2.5.14 of the NER, on the basis of the scheduling classification of a generating system. These capabilities also differ between the minimum and automatic access standards. Importantly, clause S5.2.5.14 of the NER currently does ***not***apply to generating systems with a combined nameplate rating of less than 30 MW.

The active power control capabilities set out in clause S5.2.5.14 of the NER are as follows:

- Scheduled generators:
  - Automatic access standard: the generating system must be able to maintain and change active power output in accordance with dispatch instructions. Ramping from one dispatch interval to the next must be done linearly
  - Minimum access standard: equivalent to the automatic access standard but with no requirement for linear ramp capability
- Semi-scheduled generators:
  - Automatic access standard: subject to energy source availability,[212] the generating system must be able to automatically increase or decrease its active power output within 5 minutes at a constant rate, to or below a level specified in an electronic instruction from a control centre. The generating system must also be able to automatically limit its active power output to this given level.

    The automatic access standard also requires that the generating system must be capable of not changing its active power output within 5 minutes by more than specific raise and lower amounts issued electronically from a control centre. Finally, as with scheduled generating systems, the semi-scheduled generating system must be capable of ramping its active power output linearly from one level of dispatch to another.
  - Minimum access standard: the generating system must be able to maintain and change its active power output in accordance with its dispatch instructions.
- Non-scheduled generators:
  - Automatic access standard: the automatic access standard for non-scheduled generation is the same as the automatic access standard for semi-scheduled generating systems, ***except*** that it does not include the

211 Clause 3.15.6A(k)(5) of the NER.

212 The term "energy source availability" is not defined further in the NER. The Commission understands it to refer to the availability of underlying intermittent fuel resources needed to support relevant intermittent generation types. For wind generating systems, this would include wind at a speed sufficient to support the operation of turbines to produce power output. For solar PV generation, this would include sufficient solar irradiation such that solar PV panels can produce power output.

requirement for the generating system to ramp its output linearly from one dispatch interval to the next.

— Minimum access standard: the generating system must be capable of reducing its active power output within 5 minutes to or below a level necessary to manage network flows as specified in a verbal instruction from a control centre. The generating system must also be able to automatically limit its active power output to this given level.

  Subject to energy source availability, the generating system must also be capable of not changing its output by more than a value specified in a verbal instruction. Finally, the generating system must have the capability to be upgraded to receive electronic instructions from the control centre and implement them in 5 minutes.

A key issue to be noted here is that although the NER require generating systems to have some capability to control active power, the extent of these obligations may differ markedly between different types of generating systems. Firstly, while clause S5.2.5.14 sets out active power control obligations for non-scheduled generators, it excludes those non-scheduled generators with a nameplate capacity of less than 30 MW.[213] Secondly, while the automatic access standard sets out requirements for semi-scheduled generating systems to be capable of controlling the level and rate of change of their active power output, the only requirement under the minimum access standard is to change active power output in accordance with dispatch instructions.

5.4.3 Rule change request

AEMO stated that there is a strong potential for an increasing number of smaller, co-located generating systems in the NEM that may display coordinated, rapid and uncontrolled changes in active power output. These may include:

- market, non-scheduled generating systems or storage systems[214] that are responsive to the wholesale market spot price. These generating systems may rapidly increase output in response to a spike in the wholesale spot price, or may decrease output in response to a decrease in spot price.
- co-located semi-scheduled or non-scheduled generating systems that are dependent on the same energy resource. AEMO highlight the case of separate but closely located solar PV generating systems that demonstrate coordinated ramping behaviours at sunrise and sunset or in response to the same change in weather conditions.

AEMO considered that these units may be subject to sudden increases and decreases in their active power output. These sudden changes may in turn impact on local network

213 Typically, any generating system with a nameplate capacity less than 30 MW will be classified as non-scheduled. However, AEMO has discretion to classify larger units as non-scheduled, in specific circumstances. The Commission understands that in practice, these larger non-scheduled generating systems are those with limited, or seasonally varying, output. For example, some co-generating units that utilise sugar cane waste may be larger than 30 MW but are classified as non-scheduled.

214 Market, non-scheduled generating systems do not participate in central dispatch, but receive the spot price for their output.

quality of supply and voltage stability. If large enough in terms of total MW output, they may also impact on the generation and load balance and hence the frequency of the power system.[215]

AEMO stated that its concern was that the NER:

- currently allow the connection of small generating systems whose active power output cannot be directly controlled over short timeframes
- do not currently set minimum standards to ensure active power limits can be set, or to ensure that limits to rate of change of active power can be set.

AEMO stated that its ability to dispatch generating systems with appropriate ramp rates will become a critical factor in managing the supply and demand balance of the NEM in the future.[216]

Given these issues, AEMO have proposed the following changes to clause S5.2.5.14 to:[217]

- require semi-scheduled generating systems and units to have ramp rate limit capability under the minimum access standard. Currently this capability is only required under the automatic access standard for semi-scheduled generating systems units.

  This would have the effect of making ramp limit capability mandatory for all semi-scheduled generating systems and units.
- remove the limitation of the application of NER clause S5.2.5.14 to generating systems comprised of generating units with a combined nameplate rating of 30 MW or more.

  This would have the effect of expanding the existing automatic and minimum access standards for non-scheduled generating systems to cover generating systems with capacity of less than 30 MW.

AEMO noted that this aspect of its rule change request relates solely to the capability to control active power, not how this capability may be used in an operational sense. AEMO acknowledge that any changes to operational processes would require changes to Chapters 3 and 4 of the NER.

5.4.4 Stakeholder views

Origin Energy, Tilt Renewables, TransGrid and TasNetworks were generally supportive of the concept of requiring some ramp limit capability from all generating systems.[218] TransGrid stated that:

> "A controlled rate of change of active power will be important with very high levels of renewable penetration in certain parts of NEM (e.g. South

215 Rule change request, p. 47.

216 Ibid., p. 48.

217 Rule change request, p. 46.

218 Submissions to the consultation paper: Origin Energy, p. 9; TransGrid, p. 2; Tilt Renewables, p. 6; TasNetworks, p. 11.

> Australia, south-west New South Wales and western Victoria). There could be significant frequency and voltage control issues due to high rate of change of active power if appropriate measures are not incorporated.”

However, Alinta considered that the extension of requirements for active power control capability to generating systems of capacity less than 30 MW would “add non-trivial costs in establishing a new connection and is highly likely to be financially unviable for small generating systems to implement in practise."[219]

This concern regarding cost implications for small generating systems was also raised by Pacific Hydro, Advisian, the Australian Sugar Milling Company (ASMC) and Terrain solar.[220] ASMC stated that these capabilities should be considered in the context of the costs they would impose on smaller generators, with discretion to be exercised by AEMO and network service providers. Pacific Hydro argued that this would act as a barrier to small generation investment.

Energy Australia stated that AEMO's proposed rule was unclear as to whether this would require all sized generating systems to have facilities to provide active power control, including whether the standard would extend to a domestic customer installing solar PV generating systems. Energy Australia questioned whether the costs of this would align with any system benefits.[221]

Stakeholders also discussed use of the term "subject to the energy source availability", as proposed by AEMO in its proposed changes to S5.2.5.14(b)(3). GE Australia commented that its understanding of the proposed drafting was that the ramping limit capability was subject to energy source availability and was therefore not a requirement for installation of battery storage.[222] However, Terrain Solar considered that it was unclear as to whether the proposed drafting was effectively a requirement to install battery storage.[223]

5.4.5 Analysis and conclusions

Box 5.3 Draft rule

The draft rule makes a number of changes to clause S5.2.5.14 of the NER related to active power control. These include:

- removing the current restriction of application of active power control capability, under both the minimum and automatic access standard, to generators with a nameplate capacity of less than 30 MW[224]
- amending the requirements under the minimum access standard for

219 Alinta, submission to the consultation paper, p. 5.

220 Submissions to the consultation paper: Pacific Hydro, p. xxvi; Advisian, p. 14; Terrain Solar, p. 6; ASMC, p. 5.

221 EnergyAustralia, submission to the consultation paper, p. 2.

222 GE Australia, submission to the consultation paper, p. 18.

223 Terrain Solar, submission to the consultation paper, p. 6.

224 Clause S5.2.5.14(a) and (b) of the draft rule.

non-scheduled generation to:[225]

- specify that a ramp rate can be set as a predetermined value as negotiated between AEMO, the network service provider and the generator
- delete the requirement that a non-scheduled generator has the capability to be upgraded to receive electronic instructions

- amending the minimum access standard to require semi-scheduled generating systems, subject to energy source availability, to not change active power output within five minutes by more than the raise and lower amounts specified in an instruction electronically issued by a control centre.[226]

This section sets out:

- the Commission's analysis of the of the issues raised by AEMO, and
- the Commission's draft rule to address any material issues found.

In assessing the proposed changes, the Commission considered:

- the system security implications of rapid changes in active power output from co-located generation
- the rationale for and implications of setting these requirements as a minimum access standard, and
- the costs associated with mandating this capability from all generating systems.

Assessment of materiality: system security issues

Increased penetration of dispersed, variable, and price responsive generation has the potential to drive material swings in active power output on the power system. If these swings are uncontrolled, they can have implications for the management of localised voltage stability.

The Commission therefore considers that the NER should be amended so that all semi-scheduled and non-scheduled generating systems and units have some capability to control their active power output, including the capability to limit the rate at which active power changes within a dispatch interval.[227]

Since 2007, around 7.5 gigawatts of asynchronous generation has connected to the NEM. Around half of this capacity has consisted of semi-scheduled wind farms, with utility scale solar PV generating systems becoming increasingly prevalent.[228] The output of active power produced by these semi-scheduled generating systems is based

225 Clause S5.2.5.14(b)(2) of the draft rule.

226 Clause S5.2.5.14(b)(3)(ii) of the draft rule.

227 Clause S5.2.5.14 of the NER refers to semi-scheduled generating systems and units. For brevity, in this section reference is made to only to generating systems but this can be read to include generating units, as per the wording of the clause.

228 AEMC Reliability Panel, *2017 Annual Market Performance Review*, 20 March 2018, p. 26. The remaining asynchronous connections since 2007 have consisted of small scale PV generating systems.

on the availability of the underlying energy source. In the absence of some form of energy storage, changes in the energy source availability result in changes in the active power output.

Rapid changes in the availability of the energy source can therefore result in rapid changes in active power output. For example, a cloud passing over a solar PV generating system may see a rapid reduction in active power. Similar reductions may occur for wind farms following a significant decrease in wind speed. Once the underlying energy source is available again, the generating systems may rapidly increase their active power output.

For semi-scheduled units, the key system security benefit of active power control relates to control over the speed at which active power output is returned to former levels, following an interruption to energy source availability. While rapid decreases in active power following a reduction in energy source availability can affect system stability, it is not possible for semi-scheduled units to control this decrease as it is due to events outside the generating system's control (a loss of energy source availability). However, the rate and which active power is returned to former levels can be controlled. The main benefit of active power control capability is therefore to control the sudden upswings in active power when the energy source returns.

Semi-scheduled generating systems will tend to locate where energy sources are optimal, such as areas with high annual levels of sunshine, or high average wind speeds.[229] This can result in clustering, or co-location of these energy source dependent variable generating systems. This clustering may exacerbate the extent of active power swings, if many generating systems are subject to the same variations in underlying energy source availability.

Small, dispersed, non-scheduled generating systems and units may also exhibit similar swings in active power output, where they receive revenue from the wholesale spot market. Non-scheduled generating systems are typically smaller units and do not participate in central dispatch.[230] However, as these generating systems receive revenue from the wholesale spot market , changes in the spot price may result in rapid increases in active power output to maximise revenue. These generating systems may then rapidly decrease their active power output if spot market prices decrease rapidly.

This potential for rapid, uncontrolled swings in active power output can affect system security.

Voltage stability is vulnerable to rapid and uncontrolled swings in active power, particularly in parts of the power system that operate at lower voltage or have low levels of system strength.[231] If voltage instability cannot be controlled properly, it can

229 The Commission notes that other factors, such as network availability, will also bear on the locational decisions of these units.

230 The NER define non-scheduled generating systems as those with nameplate capacity less than 30 MW. However, in some instances, AEMO is able to classify generating systems with nameplate capacities larger than 30 MW as non-scheduled, where certain conditions are met.

231 Distribution network service providers have advised that lower voltage parts of their power system demonstrate high levels of impedance, meaning that rapid changes in active power flow through the network can have material impacts on system voltage.

propagate across the system and lead to voltage collapse, causing other generators to disconnect and interrupting supply to consumers.

AEMO advised that rapid, uncontrolled swings in active power may also affect power system frequency. This may require AEMO to procure additional regulating FCAS. More generally, it may lead to challenges in maintaining the security of the system and reducing the ability of the power system to manage the impacts of contingency event disturbances.

The Commission acknowledges the possibility of these frequency stability impacts. However, the Commission considers that the probability of these impacts occurring is potentially lower than for voltage instability, on the basis that the total active power swing would need to be large to impact on frequency stability across the interconnected power system. Furthermore, the impacts of these swings may be at least partly addressed through changes in forecasting capabilities and the dispatch of other sources of generation.

The Commission therefore considers that system security will be improved if all connecting semi-scheduled and non-scheduled generating systems are required to have a minimum level of active power control capability, including ramp limit capability. On this basis, the draft rule extends the coverage of the minimum and automatic access standards to all generating systems (including non-scheduled generating systems) including those with a nameplate capacity less than 30 MW.[232] The draft rule also increases the obligations on semi-scheduled generating systems under the minimum access standard, to require these generating units to have ramp limit capability.[233]

Mandating active power control capability through the minimum access standard

The Commission's approach to the role of the minimum access standard is that it represents the lowest level of performance required of a connection such that it does no harm to the power system generally, or to any other user specifically. Generally the Commission considers a minimum access standard mandating a particular capability is necessary where all generating systems need to have the capability to maintain the security of the power system.

The capability to control active power meets this general approach to the setting of a minimum access standard. As discussed above, uncontrolled changes in active power output, particularly from clusters of generating systems, poses a risk to system security primarily through impacts on system voltage. The Commission considers that addressing this system security risk relies on all generating systems being capable of controlling active power. Semi-scheduled generating systems clustered in a particular part of the system must all be able to control their active power output, as it is the collective impact of many generating systems rapidly changing their output that triggers the associated instability issues.

The Commission also considers that this issue may become more material over time, if non-scheduled and semi-scheduled generating systems make up the bulk of new connections, and as scheduled generating systems continue to exit.

232 Clause S5.2.5.14 (a) and (b) of the draft rule.

233 Clause S5.2.5.14 (b)(3)(ii) of the draft rule.

Smaller, non-scheduled generating systems are locating in parts of the power system that have not traditionally supported generation. In particular, the variable active power flows of smaller generating systems connecting to low voltage distribution networks may on aggregate have an increasing impact on voltage stability. These smaller generating systems should therefore be required to bring some capability to control active power, to address the risks identified above. As the current limit imposed by AEMO for registration of generating systems as non-scheduled is 5 MW, this effectively forms the lower limit of such obligations.

Costs for generators to meet the mandated capability

The Commission acknowledges that generators may face costs in being required to meet the minimum access standards for active power control. However the Commission considers these costs are either nominal, or can be managed through the negotiating process. The Commission also notes that the active power control capabilities described here are explicitly defined as being dependent on energy source availability, and therefore do not require the installation of battery storage or any other costly equipment to manage variability of energy resources.

Semi-scheduled generating units are generally required to have some capability to control active power, as this is necessary to meet dispatch targets. The Commission understands that for most semi-scheduled units, the ability to control to a ramp limit and a given level may require some additional control software, but that the cost of this at the time of construction should be minimal. Similarly, most semi-scheduled generating systems will already have any required communications channels and SCADA capabilities. The Commission therefore considers that mandating this capability in the minimum access standard for semi-scheduled generating systems is unlikely to impose a material cost burden and therefore should not act as a barrier to entry.

The Commission also notes stakeholder concerns that a mandated minimum access standard for active power control capability might be interpreted as a requirement for the installation of energy storage. The Commission considers that the intention of requiring active power control capability from semi-scheduled generating systems is primarily to control the rapid return to active power output that can occur following a brief interruption to energy source availability. As such, semi-scheduled generating systems would not be required to control a decrease in active power that was due to a decrease in availability of the relevant energy source.

The draft rule therefore includes the words "subject to energy source availability" so that a semi-scheduled generating system will not be required to control its active power output in a way that would require the installation of equipment to manage a sudden drop in wind or solar energy source availability. As such, semi-scheduled generating systems will not be required to install any form of energy storage device to comply with these requirements.

Smaller non-scheduled generating systems may face higher costs to provide active power capability. The Commission understands that for some of these generating systems, control and communications systems may be relatively simple and not able to provide highly accurate or dynamically responsive control of active power. Mandating more onerous active power control capabilities for these generating systems may impose significant additional costs, particularly as this relates to additional communications and remote control equipment. These additional costs could have particular impacts for smaller generating system and could act as an inefficient barrier to entry.

Equally however, it may also be appropriate for non-scheduled generating systems to bring the full suite of active power control capabilities in those parts of the power system where there is a demonstrable system need.

The Commission considers that the negotiating process (discussed in Chapter 4) will allow for appropriate active power control capabilities for non-scheduled generating systems. Where there is a clear system need, the Commission expects that all generating systems, including smaller non-scheduled generating systems, will be required to connect at, or closer to, the more onerous automatic access standard.[234] In other cases, it may be more appropriate for smaller generating systems to connect at a level that is closer to the minimum access standard.[235]

Recognising that in some instances, small non-scheduled generating systems may have a minimal impact on the system, the draft rule reduces the extent of the capability required from those non-scheduled generating systems, whose system impact is such that connection at the minimum access standard may be appropriate. This reflects that for some non-scheduled generating systems, only minimal active power control capability will be necessary to meet system needs.[236] However, as with other connecting generators, the level of capability required from the generating system will be determined through the negotiation process, based on system needs at the connection point.

With respect to non-scheduled generating systems, the draft rule therefore:

- removes the requirement in the minimum access standard for non-scheduled generating systems to have the capability to set a ramp rate in accordance with a verbal instruction from AEMO, and allows for the ramp rate to be set as a single, predetermined value as negotiated between AEMO, the generator and the network service provider.[237] This is intended to reduce operational complexity for smaller non-scheduled generators in ramping active power output within a dispatch interval, and
- removes the requirement for non-scheduled generating systems to be capable of "being upgraded to receive electronic instructions from the control centre and

234 For example, where a smaller generator seeks to connect deep in the distribution network, at a low voltage connection point.

235 For example, where a smaller generator seeks to connect to a meshed part of the transmission network, at a high voltage connection point.

236 The Commission acknowledges that some very small generating systems, potentially down to the threshold set by AEMO for automatic exemption from registration (currently 5 MW), may now be captured by the access standards. the Commission considers it likely that in many instances, these very smallest units are less likely to have a material system impact. The Commission considers it is likely to be appropriate for these generators to propose negotiated access standards closer to the minimum access standard.

237 This capability is currently set out in clause S5.2.5.14(b)(2)(iii) of the NER.

fully implement them within 5 minutes".[238] This is intended to reduce the cost of equipment for small generators by removing the possibility of needing to undertake upgrades to communications equipment.

5.5 Automatic generation control capability

5.5.1 Technical background

The automatic generation control (AGC) system is a centralised control mechanism operated by AEMO that utilises System Control and Data Acquisition SCADA systems.[239]

The AGC is a control program that operates on a four second cycle (eight seconds in Tasmania) to control the output of generating units. It sends data via SCADA to generating units to increase or decrease power generation as needed to match the target output set for the generating unit. AGC monitors generating units' response via SCADA to determine the next set of actions needed.

The AGC system serves two main purposes in the NEM:

- **Energy market dispatch of generating units which are on remote control.** Dispatch targets from each run of the NEM dispatch engine (NEMDE)[240] are delivered to those generating systems who are enabled to receive these signals via AGC.[241] These signals are delivered every four seconds to the generating system. In general, any generating unit not dispatched for regulation FCAS will be ramped linearly from its present operating position to its energy dispatch target.
- **Regulating FCAS dispatch.** The AGC is also used to continuously adjust the output of those generating systems who have offered into regulation FCAS markets. In simple terms, there is a control system in AEMO's energy management system that calculates the number of megawatts required to restore the system frequency to the boundary of the normal operating frequency tolerance band. These small frequency deviations occur as a result of variations in supply and demand during normal operating conditions. Generators enabled to provide regulating FCAS then provide incremental increases or decreases in their active power output, to counter these frequency deviations.

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238 This capability is currently set out in clause S5.2.5.14(b)(2)(iv) of the NER.

239 SCADA provides an interface between AEMO, as power system operator, and the physical processes of generation plant, for the purpose of monitoring and control. SCADA is an integral part of AEMO's Energy Management System. SCADA enables the exchange of real-time data and control commands with Network Service Providers (network service provider) and Generators, for the purposes of real-time monitoring and control of power transmission and distribution systems

240 NEMDE is a program run by AEMO that optimises the dispatch of generation, given generation bids and system constraints. It is operated every five minutes to determine the dispatch targets of scheduled and, when relevant, semi-scheduled generating units.

241 Clause 3.8.21(d) of the NER states that: Where possible, *dispatch instructions* will be issued electronically via the *automatic generation control* system or via an electronic display in the *plant* control room (which may be onsite or offsite) of the *Scheduled Generator*, *Semi-Scheduled Generator* or *Market Participant* (as the case may be).

Importantly, the AGC is primarily a "messenger service" that facilitates the sending of signals to those generating systems participating in the market for regulating FCAS. However, it can also facilitate the sending of dispatch instructions to generating systems. AEMO conducts the actual process of dispatch through NEMDE, in accordance with various principles and requirements established elsewhere in the NER.

The Commission's technical consultants, DigSILENT Pacific, advise that the primary costs of enabling AGC capability are associated with the communication links to carry AGC signals, and the interfaces with generating system controls to allow AGC signals to directly change generating system output. The Commission understands that for larger, scheduled and semi-scheduled units, the incremental costs of AGC capability will therefore be negligible, as larger units have these communications and SCADA capabilities already. DigSILENT estimates that if any additional costs exist associated with delivering AGC capability, they are likely to be less than $100,000.

5.5.2 Current arrangements

Generators are not required to have AGC capability under the NER access standards.

However, as noted above, the NER do explicitly state that AGC is one of the preferred methods for facilitating the communication of dispatch instructions to scheduled and semi scheduled generating systems and market participants:[242]

> “Where possible, *dispatch instructions* will be issued electronically via the *automatic generation control* system or via an electronic display in the *plant* control room (which may be onsite or offsite) of the *Scheduled Generator*, *Semi-Scheduled Generator* or *Market Participant* (as the case may be).”

Generators are free to elect whether they receive their dispatch instructions from the AGC. Where generators decide to do so, the NER require them to comply with AEMO requirements in terms of how the remote dispatch control signals are transmitted to the generating unit.[243]

The NER also specify that where dispatch instructions are sent via the AGC, this should be issued progressively at intervals no longer than five minutes. The NER state that the purpose of this is to facilitate a "prompt and smooth implementation" of dispatch.[244]

The way that generators respond to these dispatch instructions depends on how they have been classified by AEMO. Generators classified as scheduled and semi-scheduled participate in the central dispatch process. This means that at the conclusion of every five minute dispatch period, they are required to meet a specific active power dispatch target as determined by NEMDE.

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242 Clause 3.8.21(d) of the NER.

243 Clause 4.11.1(g) of the NER states that: A *Generator* or *Market Network Service Provider* wishing to receive *dispatch instructions* electronically from *AEMO's automatic generation control system* in clause 3.8.21(d) must comply with *AEMO's* reasonable requirements in respect of how the remote control signals are issued by the *automatic generation control system* and transmitted to the *facility*.

244 Clause 3.8.21(g) of the NER states that "*dispatch instructions* that are issued via the *automatic generation control system* are to be issued progressively at intervals of no more than 5 minutes following re-evaluation of *central dispatch* to achieve a prompt and smooth implementation of the outcomes of each *central dispatch* update.

Scheduled generators are required to meet their dispatch target, subject to limitations including bid in ramp rates. Semi-scheduled generators, which are usually greater than 30 MW in capacity and have intermittent output, must meet the dispatch target under specific conditions, but are otherwise free to generate at any level.[245] Generators classified as non-scheduled are not included in the dispatch process.[246]

5.5.3 Rule change request

AEMO considered that a lack of AGC capability may lead to a lack of regulating FCAS in future.

Specifically, AEMO noted that:[247]

> "Very few semi-scheduled generating units have provided the necessary active power control capabilities required to participate in current arrangements for power system frequency control, and while this is beginning to change, there are no requirements for them to provide this capability, which is fundamental to operating the power system. In this regard, AEMO considers the NER insufficient as there is no requirement for the generating systems to have AGC capability."

AEMO argued that this capability should be mandatory, on the basis that the availability of regulating FCAS was critical to ensure the continued efficient operation of the NEM.

AEMO's rule change request did not refer to the role of AGC in the context of dispatch or any specific system security issue. However, in subsequent discussions, AEMO identified the following issues potentially related to a lack of AGC capability:[248]

- AEMO advised that in recent years, it has observed an increasing number of generators that do not receive dispatch instructions through the AGC, and that these generators are deviating from following a smooth ramp between dispatch targets.[249] To the extent that these generators are deviating from a smooth ramp

245 Clause 4.9.5(a)(6) of the NER specifies that a dispatch instruction to a semi-scheduled generator may specify whether the dispatch interval is a semi-dispatch interval, or a non-semi dispatch interval and the required dispatch level of the semi-scheduled generator. Generally, semi-scheduled generators can be required to meet dispatch targets under certain conditions, such as where AEMO considers this is necessary to meet system constraint limitations. In these conditions, the semi-scheduled unit is sent a signal that requires it to meet the dispatch target. The specific arrangements for how AEMO dispatches semi-scheduled and scheduled generation are set out in: AEMO *System Operating Procedure 3705 - Dispatch*, 14 August 2017, p. 10.

246 Non-scheduled generators are usually generating units or systems where the primary purpose of the generator is for local use and the aggregate sent out generation rarely, if ever, exceeds 30 MW, or the physical and technical attributes of the unit or system make it impracticable for it to participate in central dispatch. The specifics of generator classification are set out in clause 2.2 of the NER and in: AEMO, *Guide to generator classification and exemption*, August 2014.

247 Rule change request, p. 45.

248 These issues were identified in an email from AEMO dated 20 April 2018 and in subsequent phone conversations 24 April 2018.

249 The NER do not explicitly require generators to follow a smooth ramp between dispatch targets. However, as noted above, a general principle in the NER is that dispatch, at least when mediated

at the same time as the frequency is moving away from the nominal 50 Hz, AEMO advised that these deviations could increase the need for regulating FCAS. To the extent that generating systems are not following a smooth ramp to meet their dispatch targets, this could exacerbate any frequency deviation and add to the overall cost of regulating FCAS.

- AEMO also considered that the AGC may be used in future to deliver additional system security benefits, particularly through assisting in emergency management. This could include helping to manage the consequences of non-credible contingencies. Where these more severe contingency events occur, existing contingency FCAS may not be sufficient to prevent a broader frequency deviation and triggering load shedding.[250] AEMO considered that the AGC could be used to "freeze" the dispatch targets of generating systems following occurrence of the non-credible contingency, where those generating systems were following a dispatch target that could worsen the frequency deviation.[251] This could assist in managing the consequences of the non-credible contingency and help to reduce the probability of load shedding.

  AEMO noted that while the AGC has the capability to provide this emergency control response, it is not currently enabled to do so. However, AEMO advised the Commission that it is exploring the possibility of using the AGC in this way to help support system security in future.

AEMO proposed that clause S5.2.5.14 of the NER, which relates to active power control capability, should be amended to include a requirement for all scheduled and semi-scheduled generating systems to have AGC capability.

Specifically, AEMO proposed:

- the removal of the existing restriction of application of clause S5.2.5.14 to generating systems of nameplate capacity greater than 30 MW; and
- addition of a requirement, under both the minimum and automatic access standards, that both scheduled and semi-scheduled generating systems have an active power control system capable of:

  > “receiving and automatically responding to signals delivered from the *AGC*, as updated at a rate of once every four seconds.”

As discussed below, some stakeholders raised concern with the proposed removal of the restriction of application of the clause to generating systems with nameplate

through the AGC, should occur "smoothly". Generators also face various ramping requirements under Chapter 3 of the NER and in the access standards.

250 The purpose of contingency FCAS is to maintain system frequency and avoid load shedding for the occurrence of credible contingency events. However, for more severe non-credible contingency events, contingency FCAS may not be capable of arresting frequency deviations and load shedding may occur.

251 For example, following a non-credible contingency such as the loss of multiple generating units, system frequency will fall. In this instance, the AGC could be used to "arrest" the decrease in active power output from any generator who was following a downward ramping dispatch target. By stopping these generating systems from continuing to follow their downward ramping dispatch trajectory, the AGC could help to minimise the extent of the frequency deviation.

capacity greater than 30 MW. This was on the basis that mandating AGC capability could impose material costs on smaller generating systems.

AEMO have advised that the proposed removal of the size limitation is intended to result in such smaller generating systems being required to meet the access standards for non-scheduled generating systems for limiting active power and ramp limit capability. AEMO advised that their intention is that AGC capability would only be required from larger generating systems that are required to participate in dispatch, namely those that have been classified as scheduled or semi-scheduled units.

5.5.4 Stakeholder views

Stakeholders generally expressed support for the inclusion of AGC capability in the access standards. However, this was subject to various conditions, including that AGC capability only be required from scheduled and semi-scheduled generating systems.

Advisian, TasNetworks and the Clean Energy Council expressed general support for mandating AGC capability from scheduled and semi-scheduled generators, subject to some clarifications.[252]

Various stakeholders cautioned that any application of the requirement for AGC capability could impose disproportionate costs on smaller generators. The CEC stated that requirement for this capability should be clarified on the basis of generator registration class, not capacity.[253] The Australian Sugar Milling Council (SMC) stated that some discretion was necessary to consider the benefit associated with mandating capability, as opposed to the costs of the equipment (particularly communications equipment) necessary to meet this obligation.[254]

Energy Australia suggested that the proposed changes from AEMO appeared to impose obligations for AGC capability on all generators, irrespective of size, potentially down to small scale rooftop PV.[255] TasNetworks also noted that consideration should be given to the management of small non-scheduled generating units/systems wanting to connect to the distribution network, e.g. cumulative impact of small (e.g. 5 MW) generators, and the relatively high cost of control and communication requirements for small generators.[256] Alinta considered that the extension of this requirement to generators of capacity less than 30 MW would "add non-trivial costs in establishing a new connection and is highly likely to be financially unviable for small generators to implement in practise".[257]

AGL questioned how AGC capability would be employed for semi-scheduled units in an operational context, stating that:[258]

252 Submissions to the consultation paper: CEC, p. 31; Advisian, p. 3; TasNetworks, p. 22.

253 Submissions to the consultation paper: CEC, p. 30; ASMC, p. 6.

254 Ibid, p. 7.

255 Energy Australia, submission to the consultation paper, p. 2.

256 TasNetworks, submission to the consultation paper, p. 14.

257 Alinta, submission to the consultation paper, p. 5.

258 AGL, submission to the consultation paper, Annexure A, p. 5.

> "AGL also queries, with respect to control requirements, how AEMO intend to use Automatic Generator Control (AGC) to increase power output for a semi-scheduled generator...given the nature of asynchronous semi-scheduled generating systems, it is likely they will always be running at maximum output. Anything less than this output level impact the operational economics at site."

Stakeholders including the CEC and Tilt Renewables, while generally supportive of the concept of AGC capability, argued that AEMO has demonstrated a preference historically to facilitate dispatch through the market management system, rather than through the AGC. They therefore argued that AEMO should be required to support dispatch via AGC, where generators have requested this.[259]

Hydro Tasmania and Pacific Hydro considered that operational conflicts could exist between AGC mediated dispatch / regulating response and governor mediated frequency response of a generator.[260] Accordingly, Hydro Tasmania suggested that the NER contain a clarification that meeting frequency control requirements should take precedence over meeting active power control requirements. Pacific Hydro also questioned whether increasing the number of generators dispatched through the AGC would improve frequency outcomes in the power system.[261] However, TasNetworks asked that:[262]

> "the AEMC not associate the proposed rule changes with observed frequency control issues currently being investigated as part of the Frequency Control Frameworks Review. TasNetworks believes that the current issues can and will be resolved and are not a justification for seeking to limit future AGC capability from generating systems."

Hydro Tasmania also sought clarification on the reference to a four second AGC update speed in AEMO's proposed drafting, as it understood that AGC update speed in Tasmania was eight seconds.[263]

5.5.5 Analysis and conclusions

Box 5.4 Draft rule

The draft rule changes clause S5.2.5.14 of the NER related to active power control, to:

- introduce a requirement under the automatic and minimum access standards for scheduled and semi-scheduled generating systems (subject to energy source availability) to have the capability to receive and

259 Submissions to the consultation paper: CEC, p. 31; Tilt Renewables, p. 6.

260 Submission to the consultation paper: Hydro Tasmania, p. 14; Pacific Hydro, p.xviii.

261 Ibid, p.xxvii.

262 TasNetworks, submission to the consultation paper, p. 13.

263 Hydro Tasmania, submission to the consultation paper, p. 14.

> automatically respond to signals delivered from the AGC as updated once every four seconds or at a rate as determined by AEMO.[264]

This section sets out:

- the Commission's analysis of the of the issues raised by AEMO, and
- the Commission's draft rule to address any material issues found.

Mandating AGC capability appears likely to support efficient operational and system security outcomes. This includes the potential for more efficient operation of the system, where generators elect to use AGC for the purposes of receiving their dispatch instructions. The Commission also considers that AGC capability may support system security in future.

The Commission considers that these potential system security benefits warrant mandating this capability from all scheduled and semi-scheduled generators.

The draft rule therefore requires scheduled and semi-scheduled generating systems to have the capability to respond to signals delivered from the AGC, under both the automatic and minimum access standard.

In reaching this conclusion, the Commission considered:

- AGC capability and regulating FCAS, and
- current and potential benefits of mandating AGC capability.

AGC capability and regulating FCAS

In its rule change request, AEMO stated that AGC capability should be mandated on the basis that it was necessary to support the continued efficient operation of the power system.[265] This was based on AEMO's view that semi-scheduled units are not investing in AGC capability and may not be able to provide regulating FCAS in future.

AEMO made a similar argument in relation to its proposed changes to S5.2.5.11, on the basis that mandating the capability for all generators to offer one market ancillary service would support future availability of contingency FCAS.

The Commission does not consider that AGC capability should be mandated on the basis of supporting the provision of regulating FCAS.

Generators are best placed to decide whether to invest in FCAS capability. It is also unlikely that mandating AGC capability would deliver more regulating FCAS in future, given that entry into the market for provision of these services remains voluntary.

264 Clause S5.2.5.14(a)(1)(iii), (a)(3)(v), (b)(1)(ii) and (b)(3)(iii) of the draft rule.

265 Rule change request, p. 45.

Benefits of mandating AGC capability

AGC capability may support other system security outcomes, both currently and in future.

As identified by AEMO, these may include helping to minimise the extent of regulating FCAS needed to maintain power system frequency. AEMO have also advised that generating systems with AGC capability may be able to help support emergency management of frequency deviations.

Under existing NER arrangements, operators of generating systems are responsible for meeting their dispatch targets. Furthermore, generating system operators are able to select between various methods of receiving their dispatch targets, including through AEMO's market management system, or through the SCADA based AGC system.[266]

The Commission understands that generators who elect to use the AGC can allow AEMO to directly control the ramping of the generating system, by receiving direct signals to their generating equipment to ramp output from one dispatch interval to the next, to achieve the generator's nominated dispatch target. These signals can be sent as rapidly as every four seconds.

AEMO advised that the AGC co-ordinates the smooth ramping of generating plant[267] between their economic dispatch targets. It does this by sending to the generator a target every four seconds, and adjusting generator output as necessary, which minimises disturbances caused by any target error.[268] AEMO advised that when delivering dispatch instructions for energy services, the AGC facilitates the smooth movement of generation from one level of dispatch to the next, as it allows for monitoring and direct control of the generator's active power output on a four second basis, which allows for minimising system disturbances caused by any sudden step change in active power outputs.

By supporting this smooth ramping of generators, AGC capability may help to reduce the need for regulating services. AEMO advised that:[269]

> "regulating FCAS services are acquired to manage the supply/demand balance where there are small deviations between forecast load and

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266 AEMO's *System Operating Procedure 3705 - Dispatch* states that "where possible, dispatch instructions will be issued electronically via the automatic generation control (AGC) system or the AEMO Electricity Market Management System interfaces." AEMO *System Operating Procedure 3705 - Dispatch* 14 August 2017, p. 9.

267 AEMO state that for generating units on remote control through the AGC: "Dispatch results from the NEMDE run are ramped into the AGC (to prevent any large step change in megawatt output)." AEMO *System Operating Procedure 3705 - Dispatch*, 14 August 2017, p. 10

268 The Commission understands that while a generating systems own control systems have the capability to control active power output, including ramping that output to follow dispatch instructions, these capabilities may not always result in smooth transitions between dispatch targets. AEMO has advised that this may occur as some less sophisticated generator control systems are less effective at adjusting active power output to keep the generator on a smooth ramp between dispatch targets. Furthermore, AEMO have advised that receiving dispatch instructions through systems other than the AGC may result in delays, causing further deviation away from a smooth ramp between dispatch targets.

269 Advice from AEMO, received via email 20 April 2018.

dispatched energy. These services are not necessarily designed to deliver active power balancing where a generator does not meet a dispatch target. Through ongoing monitoring, the AGC system can identify circumstances were an AGC enabled generator is not meeting its dispatch target, and compensates the shortfall by modifying its directions to the generator so that it meets the target; this in turn can prevent frequency excursions and reduce demands on regulation FCAS.

Where AGC's directions fail to illicit a satisfactory response from the generator, the AGC system is aware directly and can if required direct additional regulation FCAS service earlier and thus more efficiently; arresting frequency deviations before they broaden. Without this direct feedback, the AGC system only responds once frequency starts to deviate for a significant period of time."

This relationship between receiving dispatch instructions through the AGC and regulating FCAS is reflected in comments from a number of generators. These stakeholders advised that, in some instances, receiving instructions through the AGC may help to minimise the FCAS "causer pays" penalties associated with deviating from a dispatch target and increasing the need for regulating FCAS.[270] For this reason, several stakeholders have advised that they would prefer to receive dispatch instructions through AGC.[271]

The Commission also notes AEMO's advice that other capabilities of the AGC may be used to support system security in future. As discussed above, AEMO have advised that the AGC may be used in emergency conditions to "arrest" any change in active power output from AGC enabled generators, in order to limit the consequences of a non-credible contingency event.[272] As advised by AEMO, the AGC could be used for the purposes of:[273]

"withholding of dispatch ramping signals to AGC enabled generators where the next target may be counter to power system security needs. This type of capability is under consideration as a mechanism to ensure that all potential capability within the power system is deployed when operating

270 The recovery of AEMO's payments to providers of regulating FCAS is based upon a "causer pays" methodology. Under this framework, market participants are charged according to their contribution to the need for regulating FCAS. A market participant that, through its actions, causes larger deviations in system frequency is charged a proportionately greater amount of money to fund the costs of regulating FCAS. The causer pays methodology is set out in clause 3.15.6A of the NER.

271 In fact, the Commission notes comments from several stakeholders suggesting that despite requests to receive their dispatch instructions through AGC, AEMO has not been able to provide this capability. Stakeholders such as Tilt Renewables and the CEC in fact suggested that AEMO should be explicitly obligated to respond to requests from generators who request to receive dispatch instructions via AGC. the Commission understands that, historically, sending dispatch signals through AGC has been technically complex, but that AEMO now intends to transition towards AGC mediated dispatch wherever possible on the basis of the operational benefits it facilitates.

272 The Commission notes advice from AEMO that this potential application of the AGC would be for emergency conditions, where contingency FCAS has already been called on. As such, it would be used to help minimise load shedding from the use of under frequency load shedding schemes.

273 Advice from AEMO, received via email 20 April 2018.

beyond the technical envelope. This AGC capability could not be considered a formal part of frequency control services – the response time is limited and the outcome is really a 'do no harm' response. Such capability would effectively be utilised only to enhance prospects of surviving a non-credible event, and has the potential to minimise load disruption."

The Commission understands that while the AGC is not currently enabled to provide this capability, it is under active consideration by AEMO. If implemented, the Commission considers that it could potentially provide material benefits to consumers by reducing the probability and extent of load shedding, and potentially the risk of cascading failures, for emergency situations.

The extent of this benefit would depend on the extent to which a majority of the generation fleet actually had AGC capability. The Commission therefore considers that this particular benefit requires that all, or at least a majority of scheduled and semi-scheduled generating systems have AGC capability.

DigSILENT and a number of stakeholders have advised that the costs of providing AGC capability are minimal, at least for scheduled and semi-scheduled generating systems. For these larger units, the SCADA interface and communications equipment needed to support AGC capability are likely to have been installed already. The additional costs of AGC are therefore likely to be nominal.

The Commission considers that AGC capability may support more efficient power system operation and has the potential to support improved system security outcomes in future. Given the very low costs associated with installing this capability for new generating systems, the Commission considers that it should be included in both the automatic and minimum access standard, for scheduled and semi-scheduled generation.

However, smaller non-scheduled generators would potentially face significantly higher costs if required to have AGC capability, mainly due to increased requirements for communications capabilities. In any case, given that currently a key benefit of AGC is related to the sending of dispatch targets to generators, only those generators who participate in central dispatch should be required to have AGC capability. For these reasons, the draft rule includes a requirement for AGC capability from scheduled and semi-scheduled generators only.[274]

The Commission notes comments from Hydro Tasmania regarding the different timeframes for the speed of AGC updates between the mainland and Tasmania. The draft rule therefore refers to a four second update rate, or such other period specified by AEMO as required.

274 The Commission notes concerns from stakeholders regarding the removal of the existing limitation of application of clause S5.2.5.14 to generators with nameplate capacity greater than 30 MW. However, the requirement for AGC capability will only apply to semi-scheduled and scheduled generators, in the specific subclauses of S5.2.5.14 that apply to those generator classification. Generators with nameplate capacity less than 30 MW will be classified as non-scheduled and therefore not captured by the requirement for AGC capability.

6 Remote monitoring and control

Box 6.1 Overview

In its rule change request, AEMO stated that the increasing complexity of the power system and the necessity for faster operational actions has created a need for greater automation and coordination. This automation and coordination can be facilitated where generators have effective remote monitoring and control capabilities.

AEMO therefore proposed requiring under clause S5.2.6.1:

- new remote monitoring capabilities, under both the automatic and minimum access standard, and
- new remote control capabilities, under both the minimum and automatic access standard.

The Commission considers that while most of AEMO's proposed changes to the automatic access standard will support efficient power system operation, the range of capabilities considered will not be required at all connection points. Accordingly, the Commission has made a draft rule that includes most of AEMO's proposed changes in the automatic access standard, but which retains most of the existing minimum access standard, subject to some changes.

The draft rule:

- amends the existing automatic access standard, to allow AEMO to require a number of additional remote monitoring and control capabilities, and
- maintains the current level of the minimum access standard, subject to two changes including:
  - expanding the coverage of the minimum access standard to include non-scheduled generating systems with nameplate capacity of less than 30 MW, and
  - amending the requirements for data provision from semi-scheduled generating systems, to more closely align with what the Commission understands to be modern operational practice for these generating systems.

6.1 Technical background

Remote monitoring capability refers to the real time provision of data to AEMO’s control centre related to the status of the generating unit, supporting auxiliaries and other equipment such as reactive plant. Remote control capability refers to the ability for AEMO to remotely change certain settings in a generating system related to the control of active or reactive power.

These capabilities require the installation of specific monitoring, SCADA and communications equipment. AEMO and some stakeholders have advised that this equipment is becoming standard in modern generating systems, especially for larger scheduled and semi-scheduled generating systems.

6.2 Current arrangements

Clause S5.2.6.1 of the NER sets out the remote monitoring capability requirements. The clause applies to scheduled, semi-scheduled and non-scheduled generating systems and units, however non-scheduled generators with a nameplate capacity of less than 30 MW are currently excluded from these arrangements.[275]

Clause S5.2.6.1 states that this remote monitoring capability is required so that a generator can:

> "transmit to *AEMO's control centres* in real time in accordance with rule 4.11 the quantities that *AEMO* reasonably requires to discharge its *market* and *power system security* functions set out in Chapters 3 and 4."

The automatic access standard then sets out the types of information that AEMO can request be provided through remote monitoring capability, including for:

- generators with a nameplate capacity of 30 MW and over, information on:
  - current, voltage, active power and reactive power in respect of generating unit stators or power conversion systems
  - the status of all switching devices that carry the generation, and
  - tap-changing transformer tap position
- generating systems with a nameplate capacity of less than 30 MW, information on:
  - connected status, tap-changing transformer tap position and voltages
  - active power and reactive power aggregated for groups of identical generating units
  - either the number of identical generating units operating or the operating status of each non-identical generating unit, and
  - active power and reactive power for the generating system
- auxiliary supply systems with capacity of 30 MW and over associated with a generating system or unit, information on active power and reactive power
- reactive power equipment that is part of a generating system but not part of a particular generating unit, its reactive power, and
- wind farms, information on wind speed; wind direction; and ambient temperature.

AEMO is also permitted to ask for any other information required to discharge its market and power system security functions as set out in Chapters 3 and 4 of the NER.

275 This exclusion is expressed in the automatic access standard as applying to generating systems and generating units, whereas for the minimum access standard this exclusion is expressed as applying to generating systems only.

The minimum access standard sets out the following requirements for generating systems to have remote monitoring capability for:

- active power output of the generating unit or generating system (as applicable)
- if connected to a transmission system, the reactive power output of the generating unit or generating system (as applicable), and
- for wind farms, information on number of units operating, wind speed, and wind direction.

Neither the current minimum or automatic access standard contain any requirement for remote control capabilities.

6.3 Rule change request

In its rule change request, AEMO stated that the increasing complexity of the power system and the need for faster real time control actions means that there is a greater need for increased remote monitoring and control capabilities. Greater remote monitoring and control will also deliver more efficient operation of the power system.[276]

Specifically, AEMO advised that:[277]

> "real-time information allows AEMO to specify the technical envelope, to maintain power system security more precisely, and to understand better the real-time ancillary services requirements and capabilities for power system security purposes."

AEMO also advised the Commission that clause S5.2.6.1 of the NER does not currently provide sufficient detail on the information that AEMO may request from a generator and that its proposed changes will provide clarity on what information AEMO may request.[278]

Finally, AEMO advised that additional information on battery storage systems was required to support the integration of these systems into the central dispatch process.[279]

AEMO proposed a number of changes to both the minimum and automatic access standard under clause S5.2.6.1 of the NER.[280] These included:

- Amending both the automatic and minimum access standard to apply to all generating systems, and removing the current specificity of application to

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276 Rule change request, pp. 48-49.

277 Ibid.

278 AEMO advised that some of the additional remote monitoring capability it proposed to be included in the automatic and minimum access standard was intended to clarify the kinds of additional information that it currently has discretion to seek from generators under clause S5.2.6.1(b)(6) of the NER.

279 Rule change request, pp. 48-49.

280 Most of these changes were included in the detailed proposed drafting that was attached to the rule change request.

scheduled, semi- scheduled and non-scheduled (30 MW or greater) units and systems.[281]

- Rearranging the automatic access standard to expand the range of remote monitoring capabilities for all generating systems, to include tap-changing transformer tap position, active power and reactive power, the status of all switching devices, and the number of identical generating units operating or the operating status of each non-identical generating unit.
- Inserting a new requirement under the automatic access standard for all generating systems to provide remote monitoring capability for voltage control setpoint and mode, where applicable.
- Amending the requirement for wind farms to provide specific remote monitoring capabilities, to refer more generally to the data provided by energy conversion models.
- Introducing a new set of remote monitoring capabilities into the automatic access standard, including remote monitoring of:
  - maximum and minimum active power limits and ramp limits for scheduled and semi-scheduled generators
  - the energy available from energy storage systems
  - for any run-back schemes the status and active power, reactive power or other control limit as applicable
  - the mode of operation of the generating unit, turbine control limits, or other information required to reasonably predict the active power response of the generating system to a change in power system frequency at the connection point.
- Introducing a new set of remote control capability requirements, including the capability for remote control of:
  - voltage setpoint and mode
  - for scheduled and semi-scheduled generating systems, AGC control
  - for non-scheduled generating systems, active power limit and ramp limit.
- Amending the minimum access standard to generally replicate the automatic access standard, including the new remote monitoring and control capabilities AEMO had proposed for the automatic access standard. Some minor differences included restricting application of some of the remote monitoring capabilities to larger generating systems or to transmission connected systems.

281 Note that AEMO's proposed drafting retained specific "carve outs" for generating systems with nameplate capacity of less than 30 MW units within the specific sub-clauses of S5.2.6.1.

6.4 Stakeholder views

A number of stakeholders considered that AEMO's proposed changes would impose material costs on connection applicants, particularly for the connection of smaller generating systems.

Advisian stated that AEMO's proposal would impose excessive and expensive technical constraints. This would have the consequence of making new generating systems less competitive with existing ones. Advisian and Pacific Hydro noted that the proposed minimum access standard was essentially the same as the automatic and suggested that the Commission reject the proposed minimum.[282]

Alinta, Origin Energy and Hydro Tasmania noted that requiring these capabilities from existing generators would impose material costs.[283] Hydro Tasmania noted that the costs for existing units to fit the equipment to provide these capabilities would be in the order of $50,000 to $150,000.[284] Origin Energy suggested that the replacement of some legacy equipment could be in excess of $5 million.

The CEC and Pacific Hydro questioned why AEMO required some of the information proposed through the new remote monitoring capabilities. The CEC noted that:[285]

> "the energy available in a battery tells AEMO nothing informative as there may be a range of applications for this energy and capacity. Its discharge or charging cycles would dictate its impact on AEMO's market operations, but may be driven by non-market factors like network support or ancillary services."

The CEC also questioned how the remote control capabilities would be implemented in practice, noting that they may create some concerns around liability implications and how insurances are to capture scenarios where AEMO is controlling plant.[286] The CEC cautioned that there was a need to balance these capabilities with commercial risk. The CEC also questioned how AEMO's control of voltage would interact with network control. Pacific Hydro stated that as voltage control requirements are negotiated with the network service provider to suit local conditions. AEMO should not be requiring control of voltage setpoints into distribution areas.[287]

The CEC, Pacific Hydro and Hydro Tasmania raised concern with the potential cost implications for certain generating systems. In particular, it was noted that these costs could be significant for generating systems with less than 30 MW nameplate capacity. Hydro Tasmania also sought more detail on what information AEMO wanted in regards to run back schemes and energy storage.[288]

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282 Submissions to the consultation paper: Advisian, p. 15; Pacific Hydro, p. xxx.

283 Submissions to the consultation paper; Alinta, p. 4; Origin Energy, p. 10.

284 Hydro Tasmania, submission to the consultation paper, p. 14.

285 CEC, submission to the consultation paper, p. 32.

286 Ibid.

287 Pacific Hydro, submission to the consultation paper, p. xxx.

288 Submissions to the consultation paper: CEC, p. 32; Hydro Tasmania, p. 14; Terrain Solar, p. 6.

AEMO stated that the capabilities being sought were reasonable and that, given such functionality is widely used, should result in minimal additional cost.[289]

6.5 Analysis and conclusions

Box 6.2 Draft rule

The draft rule:

- expands the application of the automatic access standard to include non-scheduled generation with nameplate capacity of less than 30 MW[290]
- amends the application of existing required monitoring capabilities and introduces new monitoring capabilities in the automatic access standard, including:
  - requires a number of monitoring capabilities from all generating systems, including: transformer tap position; active and reactive power of the generating system; status of all switching devices that carry the generation; the number of generating units operating or the status of each non identical generating unit; and a new capability to monitor voltage control setpoint and mode[291]
  - deletes reference to requiring wind farm type generating systems to provide specific information on wind speed and direction and ambient temperature, and replaces this with a more general requirement for semi-scheduled generating systems to have the capability to provide all data as specified in the energy conversion model[292]
  - new requirements for monitoring capabilities for maximum and minimum active power limit and maximum raise and lower ramp rate, and[293]
  - new requirements for monitoring capabilities for status of run back schemes including information on scheme status and active power, reactive power or other control limits as appropriate[294]
  - new requirements for monitoring capabilities for mode of operation of the generating unit, turbine control limits, or other information required to reasonably predict the active power response of a generating system to a change in power system frequency at the connection point[295]

289 AEMO, submission to the consultation paper, p. 27.

290 Clause S5.2.6.1(a)(3) and (a)(4) of the draft rule.

291 Clause S5.2.6.1(b)(1) of the draft rule.

292 Clause S5.2.6.1(b)(5) of the draft rule.

293 Clause S5.2.6.1(b)(6) of the draft rule.

294 Clause S5.2.6.1(b)(7) of the draft rule.

295 Clause S5.2.6.1(b)(8) of the draft rule.

- introduces new remote control capabilities into the automatic access standard, including:
  - control of voltage setpoint and mode (where applicable)[296]
  - AGC (for semi-scheduled and scheduled units),[297]
  - active power limit and ramp limit for non-scheduled generation, to the extent required to manage network flows, and[298]
- amends the minimum access standard to:
  - expands application of the minimum access standard to include non-scheduled generating systems with nameplate capacity of less than 30 MW, and[299]
  - delete current reference to requiring wind farm type generating systems to provide specific information on wind speed and direction and number of units operating, and replaces this with a more general requirement for semi-scheduled generating systems to have the capability to provide all data as specified in the energy conversion model.[300]

This section sets out:

- the Commission's analysis of the of the issues raised by AEMO, and
- the Commission's draft rule to address any material issues found.

6.5.1 Automatic and minimum access standards for remote monitoring and control

The draft rule expands the automatic and minimum access standard to apply to non-scheduled generating systems with a nameplate capacity of less than 30 MW.

The Commission understands that there is an increased penetration of smaller non-scheduled generating systems in certain parts of the power system.[301] These smaller systems may be connecting in parts of the power system with low voltage levels or low levels of system strength, and are likely to have an increasing impact on power system security.

It may therefore be appropriate for these smaller generating systems to provide some level of remote monitoring and control capability.

However, the Commission also notes that these capabilities are unlikely to be needed in all parts of the power system or at all connection points. Furthermore, the Commission

296 Clause S5.2.6.1(b1)(1) of the draft rule.

297 Clause S5.2.6.1(b1)(2) of the draft rule.

298 Clause S5.2.6.1(b1)(3) of the draft rule.

299 Clause S5.2.6.1(c)(3) of the draft rule.

300 Clause S5.2.6.1(d)(3) of the draft rule.

301 Ergon Energy, submission to the consultation paper, p. 8.

also notes stakeholder comments that these capabilities could impose material costs on the connection of smaller generating systems and form a inefficient barrier to entry.

Under AEMO's rule change request, the requirements of the minimum access standard were very similar to those set out in the automatic access standard. The Commission considers that this could result in all generators incurring material costs for remote control and monitoring capabilities, where these may not be needed given power system conditions at the connection point. The appropriate level of performance for the power system conditions at the connection point can then be set between the level in the automatic access standard (discussed below) and the minimum access standard.

For these reasons, the Commission considers that the negotiating process remains the appropriate mechanism to determine the level of capability needed from each generator, on the basis of system needs at the particular connection point. The draft rule therefore retains the existing minimum access standard, subject to a minor change to describe the kinds of data that must be provided by semi-scheduled generating systems.[302] The relevant network service provider, AEMO and the connecting generator may use the negotiation process to determine the appropriate level of capability for a given connection point.

6.5.2 Specific changes to the automatic access standard

The draft rule includes a number of specific changes to the automatic access standard. These changes provide AEMO with more accurate information on generating system status and capabilities. The Commission considers these capabilities will provide AEMO with information necessary to support effective short term forecasting and efficiently and securely operate the power system.

The draft rule also introduces several remote control capabilities. The Commission considers that these remote control capabilities generally support changes made to other parts of the access standards. This includes the changes made to the automatic access standard in clause S5.2.5.13 of the NER, which requires that generating systems have facilities to switch between voltage control modes and have remote control equipment to control the setpoint and mode,[303] and the changes made to the automatic and minimum access standards of S5.2.5.14 of the NER, which require all scheduled and semi-scheduled generating systems to have the capability to respond to AGC signals (which can provide a form of remote control of a generating system for the purposes of dispatch or provision of regulating FCAS).[304]

The format of the existing automatic access standard limits the capabilities that AEMO can request from generators to those that are necessary for AEMO to meet its power system security and market operation obligations under Chapters 3 and 4 of the NER. The Commission is satisfied that each of these new monitoring and control capabilities are capabilities that AEMO could reasonably request to meet these obligations.

The key changes to the automatic access standard are set out below

302 Clause S5.2.6.1(d)(3) of the draft rule.

303 Clause S5.2.5.13(b)(2A) of the draft rule.

304 Clause S5.2.5.14(a)(1)(iii) and (3)(v) and S5.2.5.14(b)(1)(ii) and (3)(iii) of the draft rule.

New monitoring quantities for all sized generators: The draft rule expands the set of matters for which AEMO can request remote monitoring capability from all generators under the automatic access standard, regardless of size.[305] The Commission considers that these quantities, which include transformer tap position, active/reactive power and voltage control setpoint and mode, represent information that AEMO may reasonably ask from all generators, potentially including smaller non-scheduled generators. This information is relevant to operation of the power system and to manage the security of the power system.

However, as discussed above, remote control capabilities for these matters are part of the automatic access standard only and AEMO, the network service provider and the generator can use the negotiation process to decide on the appropriate level of performance to meet a particular system need. Connection applicants may propose negotiated access standards that do not include these capabilities, if the applicant considers that its proposed negotiated access standard is appropriate given system conditions where it wishes to connect.

Clarification of monitoring quantities to be provided by semi-scheduled generators: The draft rule amends existing clauses that specifically relate to data to be provided by wind farms, to instead require semi-scheduled generators to provide mandatory data from energy conversion models.[306] The Commission understands this is a more accurate description of current operational practice. These changes have been made in both the automatic and minimum access standards.

New requirement for active power data: The draft rule sets out a requirement for semi-scheduled and scheduled generating systems to have capability to provide information on active power limits and ramp limits.[307] The Commission understands this information is needed for the purposes of enabling AGC mediated dispatch and regulating FCAS. This requirement has only been introduced into the automatic access standard.

New requirement for run back scheme data: The draft rule sets out a requirement for a generator to provide AEMO with information related to any run-back scheme entered into with the relevant network service provider.[308] These schemes are agreed between generators and network service providers to provide network support services. The Commission understands that the triggering of these schemes can have broader impacts on the power system, and may be relevant to AEMO's operation of the power system and management of power system security. This requirement has only been introduced into the automatic access standard.

New requirement for mode of operation of a generating system: The draft rule sets out a requirement for a generator to provide AEMO with information related to the mode of operation of the generating unit, turbine control limits, or other information required to reasonably predict the active power response of the generating system to a

305 Clause S5.2.6.1(a) and (b) of the draft rule.

306 Clause S5.2.6.1(b)(5) and (d)(3) of the draft rule.

307 Clause S5.2.6.1(b)(6) of the draft rule.

308 Clause S5.2.6.1(b)(7) of the draft rule.

change in power system frequency at the connection point.[309] The Commission understands that this information is necessary for AEMO to manage power system frequency and meet its power system security obligations. This requirement has only been introduced into the automatic access standard.

New remote control capabilities related to voltage control, AGC and active power limits for non-scheduled generation: The draft rule introduces new remote control capabilities for AGC capability and voltage control. These new capabilities reflect the changes made in other parts of the draft rule, including:

- the introduction of a requirement for generators to be capable of remotely switching voltage control modes, under the automatic access standard of S5.2.5.13,[310] and
- the introduction of a requirement for semi-scheduled and scheduled generators to have the capability to receive and respond to signals from AEMO's AGC system, under the automatic and minimum access standards of S5.2.5.14.[311]

This requirement has only been introduced into the automatic access standard.

The Commission considers that these remote control capabilities are therefore justified, on the basis that they are necessary to facilitate the changes made in other parts of the draft rule.

The Commission notes comments from stakeholders regarding potential issues related to the implementation of remote control, particularly for voltage control. The Commission expects that these kinds of operational issues will be addressed by the relevant parties, through the development of procedures that set out how these arrangements will operate in practice. The Commission expects that this will support the safe and efficient operation of the equipment that makes up the power system.

AEMO have advised that the proposal to require remote control capability for non-scheduled generation is designed to address specific instances where the ability of AEMO to remotely control the active power of a non-scheduled generating unit is needed to manage network flows and maintain security of the power system.

The draft rule therefore explicitly states that this remote control capability can only be required where it is needed to manage network flows.[312] This aligns with the active power control capabilities required of non-scheduled generating systems as set out under the automatic access standard in clause S5.2.5.14 of the NER. As with other remote control capabilities, the Commission considers that any operational issues related to how this remote control capability will be exercised should be addressed through the development of operational procedures by the relevant parties.

309 Clause S5.2.6.1(b)(8) of the draft rule.

310 Clause S5.2.6.1(b1)(1) of the draft rule.

311 Clause S5.2.6.1(b1)(2) of the draft rule.

312 Clause S5.2.6.1(b1)(3) of the draft rule.

6.5.3 Proposal for remote monitoring of energy storage facilities

The Commission notes that AEMO's rule change request had proposed a requirement for remote monitoring capability for energy storage systems, to provide information on the available energy of the storage system. The Commission understands that this was proposed to support AEMO's forecasting for the purposes of facilitating a more efficient pre-dispatch and dispatch process.

A key principle underpinning the current dispatch process is that generators are responsible for their own unit pre-commitment decisions. In making these decisions, generators take into account their expectations of likely spot price outcomes as well as their own capability to generate in order to earn revenue from the spot market. Generators structure their pre-dispatch bid and price bands, and their bids into the wholesale market, accordingly.

A key variable factored into this decision making process is a generator's assessment of its own energy source availability. For example, energy constrained generating systems, such open cycle gas turbine generating systems with onsite fuel storage, or small hydro generators, will consider whether they have sufficient fuel available when deciding whether to pre commit to being available for dispatch.

The Commission considers that generators will make the same decisions when considering the available energy from on-site energy storage systems, such as battery storage. The available energy from such energy storage systems will therefore be included in the generator's decision to pre commit, in its pre dispatch bid and price bands and in its final bids into the wholesale market.

The Commission therefore considers AEMO's proposal to require generators to have remote monitoring capability for energy storage facilities is not necessary from the perspective of supporting efficient pre-dispatch and dispatch processes, and could impose unnecessary costs on generators.

7 Reactive power capability

Box 7.1 Overview

The current arrangements in the NER for reactive power capability are contained in S5.2.5.1 and include no minimum capability requirements for the supply or absorption of reactive power at the connection point. AEMO considered these arrangements are not sufficient to maintain power system security at the lowest cost in the context of a power system in transition.

In its rule change request, AEMO proposed a new minimum access standard that would require all generators to have reactive power capability. AEMO's proposed change would require, at a minimum, a connecting generating system to have sufficient reactive power capability to achieve the continuously controllable voltage setpoint range proposed for voltage and reactive power control, discussed in Chapter 8.

The Commission considers the current arrangements, including a minimum access standard that does not require reactive power capability, provide the flexibility to set an appropriate level of performance for the needs of the power system at the lowest cost to consumers. In particular, there is likely to be some circumstances where a reactive power capability is not necessary to maintain the security of the power system or the quality of supply to other network users.

However, the Commission considers that as AEMO doesn't have an advisory function in the current arrangements for reactive power capability, there is a risk that in some cases insufficient capability may be required of a connecting generating system to maintain the security of the power system. This is because AEMO's role in its advisory matters is to explicitly consider whether a proposed negotiated access standard would adversely affect power system security.

To address this issue, the Commission's draft rule includes a provision specifying the access standards for reactive power capability (S5.2.5.1) as an AEMO advisory matter. The draft rule also provides guidance that the level of reactive power capability should be sufficient to support the security of the power system.

7.1 Introduction

This Chapter discusses AEMO's proposed changes to the NER that relate to requirements for connecting generating systems to be capable of injecting and absorbing reactive power under normal operating conditions.

The Chapter sets out:

- technical background introducing reactive power and its function in the power system
- the current arrangements in the NER
- the issues raised by AEMO with the current arrangements and changes proposed to address those issues

- stakeholder views, and
- analysis and conclusions.

7.2 Technical background

Power in alternating current (AC) networks comes in two different types; active power and reactive power. Active power accomplishes useful work at the point of end use through the delivery of energy services (heat, lighting, motion). Reactive power, on the other hand, does not directly deliver energy services to network users. Instead, reactive power is necessary to support the movement of active power through electricity networks and aid its conversion into a useful form. As an example, reactive power is required to energise the magnetic fields inside electric machines which then allow the conversion of active power into mechanical power.

An AC power system (such as the NEM power system) relies on the availability of reactive power to function effectively and stay in a secure operating state. Just as frequency reflects the dynamic balance between active power production and consumption, voltage reflects the dynamic balance between injection and absorption of reactive power. A sustained imbalance in the level of reactive power injection and absorption leads to voltage instability and collapse. By controlling the injection, absorption, and flow of reactive power at all levels in the power system, the voltage profile across the system can be maintained within acceptable limits necessary for the management of power system security, the quality of supply to network users, and the minimisation of transmission losses.

Responsibility for the provision of reactive power services has been traditionally shared between generators, network service providers, and loads. Synchronous generating systems provide reactive power by regulating the excitation of their rotor field.[313] Networks commonly install reactive power equipment, including shunt capacitor banks, Static Volt-ampere Reactive (VAR) Compensator (SVC), and Static Synchronous Compensators (STATCOM), to manage voltages across their networks and facilitate the transfer of active power to network users.[314] Some load also installs reactive capability to maintain their power factor near unity.[315]

AEMO's rule change request sought changes to the access standards relating to reactive power capability and control to address the challenges of a transitioning power system. As the power system transitions, a range of technical factors will influence the need for reactive power services. These include, but are not limited to:

313 The process of generating a magnetic field by means of an electric current is called excitation. An excitation control system involves control of the current and power to the rotor of a synchronous generating unit in order to adjust the magnitude of the rotor field and resulting terminal voltage.

314 SVC and STATCOM are devices that provide fast acting reactive power response through power electronic controlled banks of capacitors and reactors.

315 A unity power factor is one in which all power supplied at the connection point is active power. A load with unity power factor is one which appears as completely resistive from the perspective of the power system. By operating close to unity power factor, a load minimizes the total amount of current (by minimising losses) that needs to be supplied to achieve a given amount of work.

- **connection capacity and location** - as wind and solar energy resources are often located in more remote regions, new generating systems are connecting in weaker parts of the system, remote from other sources of reactive capability
- **generating system retirement** - synchronous generating systems that have traditionally provided large amounts of reactive capability are retiring. As they retire their reactive capability will be lost to the power system. Unless this capability is replaced, either by network or new generating system capability, power system security may be placed at risk, and
- **generating system mix** - synchronous generating systems contribute energy, inertia and short circuit fault current at varying levels. The amount of reactive power needed to influence voltage is determined by the fault level at a connection point. High fault currents are typically associated with improved voltage stability. As the generation mix changes and synchronous generating systems exit the power system, voltage regulation requirements may change due to declining power system fault levels.

Reactive power is denoted Q and has units of Mega Volts-Amperes Reactive (MVAR). It can be either capacitive or inductive in nature:

- capacitive reactive power is associated with the formation of electric fields in the power system and is associated with the injection of positive MVAR. This helps to raise voltages, and
- inductive reactive power is associated with the formation of magnetic fields in the power system and is associated with the absorption of negative MVAR. This helps to lower voltages.

7.3 Current arrangements

This section sets out the current arrangements applying to reactive power capability required from connecting generating systems.

Current arrangements are specified in clause S5.2.5.1 of the NER and include:

- an automatic access standard that requires a generating system to have the capability to supply and absorb continuously at its connection point an amount of reactive power of at least 39.5% of the rated active power of the generating system at:[316]
  - any level of active power output, and
  - any voltage at the connection point within the limits established in clause S5.1a.4 without a contingency event,[317] and
- a minimum access standard that does not require a generating system to have any capability to supply or absorb reactive power at the connection point.[318]

316 Clause S5.2.5.1(a) of the NER.

317 Clause S5.1a.4 of the NER. Note the words "without a contingency event" defines the voltage limits of 90% to 110% of normal voltage.

318 Clause S5.2.5.1(b) of the NER.

In addition to the automatic and minimum access standards, clause S5.2.5.1 of the NER also sets out requirements for a negotiated access standard. In particular, these provisions:[319]

- require the generator and network service providers to ensure that the reactive power capability is sufficient to ensure that all relevant system standards are met before and after credible contingency events under normal and planned outage operating conditions, taking into account at least existing and considered projects
- allow the generator and network service providers to negotiate either a range of reactive power absorption and injection, or a range of power factor, at the connection point within which the plant must be operated, and
- allow the generator and network service providers to negotiate limits that describe how the reactive power capability varies as a function of active power output due to design characteristics of the plant.

The access standards in clause S5.2.5.1 are currently not an AEMO advisory matter.[320]

S5.2.5.1 also provides a connecting generator with flexibility in how it chooses to comply with the required levels of reactive capability. In particular, a connecting generator may install additional equipment at its connection point or another location, compensate the network service provider for the deficit of reactive power within the network, enter into a commercial arrangement with a third party to provide the deficit of reactive power, or agree to operational restrictions if necessary under certain operating conditions, in order to provide the agreed capability.[321]

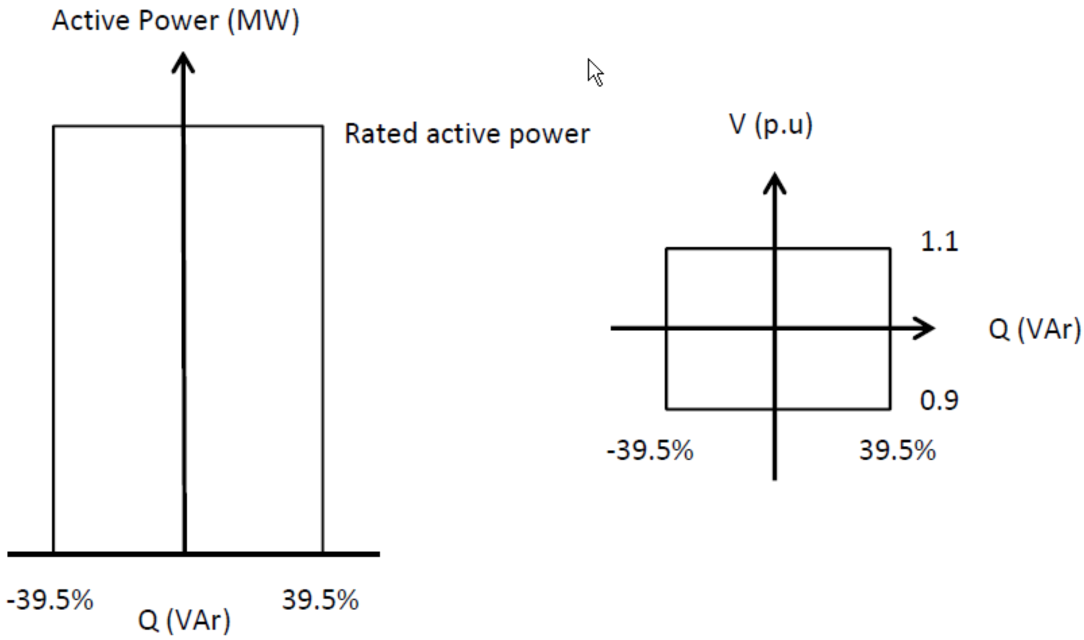
The automatic access standard is characterised by a symmetric requirement for reactive injection and absorption capability (described as Q(VAR) in the figure below) between -39.5% and +39.5% of the rated active power of the generating system at all levels of active power and at all voltages in the continuous operating voltage band, which is between 90% and 110% of normal voltage. This is illustrated in Figure 7.1.

319 Clause S5.2.5.1(c)(1-3) of the NER.

320 AEMO does not have a role in the assessment of negotiated access standards which are not AEMO advisory matters. An AEMO advisory matter is a matter that relates to AEMO's functions under the NEL. For these matters, specified in Schedules 5.1a, 5.1, 5.2, 5.3 and 5.3a, AEMO has a role in the assessment of negotiated access standards.

321 Clause S5.2.5.1(d) of the NER.

Figure 7.1 S5.2.5.1 automatic access standard requirements for reactive capability Q(VAR) presented as a function of active power (MW) and voltage V(p.u).



7.3.1 Related voltage and reactive power control clause (S5.2.5.13)

Reactive capability is used to inject or absorb reactive power for the management of power system voltages and to assist the transfer and utilisation of active power. This is achieved through a combination of the level of reactive power capability set in clause S5.2.5.1 and the way that reactive power is controlled and utilised, which is set under the arrangements in a separate access standard in clause S5.2.5.13 (voltage and reactive power control), discussed in Chapter 8.

The access standards in clause S5.2.5.13 specify how a generating system is required to regulate voltages at its connection point. This includes the mode in which reactive power is controlled, as well as the accuracy and controllability requirements. As such, the access standards in clause S5.2.5.13 effectively set the control capabilities for the delivery of voltage control that is enabled by the amount of reactive power capability set in clause S5.2.5.1.[322]

The voltage control requirements set out in clause S5.2.5.13 are related to, and limited by, the actual reactive capability of a generating system, as specified under S5.2.5.1 and described above. This includes the current guidance that the amount of reactive power capability should be sufficient for the network service provider to meet the system standards, taking into account projects that are existing and considered.[323] Expressed another way, once the amount of reactive capability a generating system is required to

322 NER clause S5.2.5.1 provides for setting the overall quantity of reactive power that is required from a connecting generating system. NER clause S5.2.5.13 then provides for arrangements related to how that reactive power capability is controlled for the management of voltages.

323 Clause S5.2.5.1(c)(1) of the NER.

bring is defined under S5.2.5.1, the way that this reactive power capability is controlled is then defined in S5.2.5.13.

7.4 Rule change request

This section sets out the issues raised by AEMO in its rule change request and the changes proposed to address these issues.

7.4.1 Issues raised by AEMO

In its rule change request, AEMO considered the provision of fully capable voltage control systems as part of a generating system to be essential to the ongoing secure management of the power system. It considered that any lack of reactive power capability and coordinated control of that capability would reduce the power transfer capability of the power system and risk power system stability.[324]

AEMO considered current arrangements for reactive power capability in S5.2.5.1 to be insufficient, particularly the minimum access standard which does not require any reactive power capability from a connecting generating system. AEMO considered the current arrangements may lead to the proliferation of new generating systems that have limited reactive power (S5.2.5.1) and voltage control (S5.2.5.13) capabilities. AEMO considered that, when combined with the withdrawal of existing synchronous generating systems with voltage control capability, power system security and the quality of supply may be placed at risk.[325]

AEMO therefore argued a minimum access standard that requires some level of reactive power capability is required to maintain power system security.[326] AEMO also argued it is particularly inefficient for networks to invest in dedicated assets on grid fringes where many new asynchronous generating systems are proposed for connection.

7.4.2 AEMO's proposed changes

In its rule change request, AEMO proposed amendments to clause S5.2.5.1 to specify a minimum access standard mandating reactive power capability from all connecting generating systems. AEMO’s proposed minimum access standard is:[327]

> “a generating system operating at:
>
> - any level of active power output, greater than 10% of its maximum operating level,[328] and
> - any voltage at the connection point within the limits established in clause S5.1a.4 without a contingency event.[329]

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324 Rule change request, p. 21.

325 Ibid.

326 Ibid.

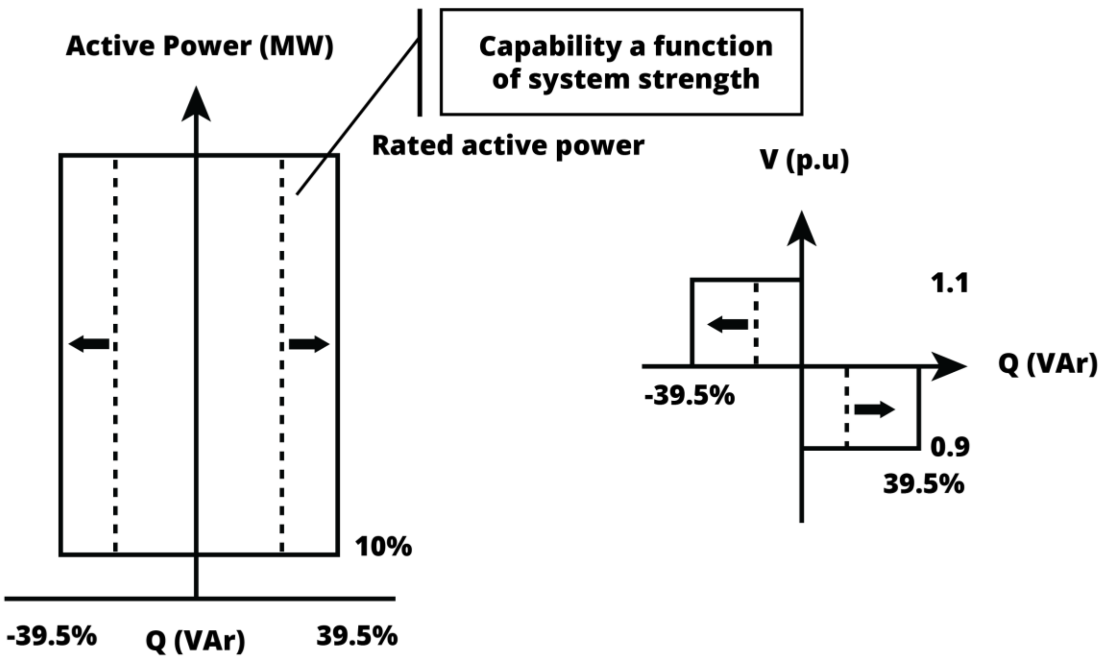
327 Rule change request, p. 22 and AEMO, Generator technical requirements: supplementary material to rule change proposal.

328 The words “greater than 10% of its maximum operating level” were added by way of clarification in AEMO, Generator technical requirements: supplementary material to rule change proposal.

must be capable of supplying and absorbing continuously at its connection point an amount of reactive power of at least the amount required to enable the generating system to achieve the continuously controllable voltage setpoint range specified in its performance standard agreed under S5.2.5.13, and within the limits of the automatic access standard.[330]"

AEMO did not propose changes to the existing automatic access standard or general requirements.[331]

Figure 7.2 AEMO's proposed minimum access standard in the context of the automatic access standard in S5.2.5.1



Subsequent to its rule change proposal, AEMO proposed an amendment to ensure that the requirements for a negotiated access standard in clause S5.2.5.1(c)(1) are consistent with maintaining power system security.[332] This was inserted by way of clarification and does not affect the substance of the provision.

AEMO's proposed minimum access standard for reactive power capability is shown in Figure 7.2 as a function of generating system active power as well as connection point voltage at 100% of rated active power. AEMO's proposed minimum access standard is

329 S5.1a.4 requires maintenance of voltages between 90% and 110% of normal on a continuous basis in the absence of a contingency event.

330 Rule change request, proposed rule, clause S5.2.5.1(b).

331 AEMO's rule change proposal initially referred to a generating system operating at any level of active power output "greater than 10% of its maximum operating level", however that additional wording was subsequently deleted in AEMO, Generator technical requirements: supplementary material to rule change proposal, resulting in no proposed change to the existing automatic access standard for S5.2.5.1.

332 AEMC AEMO, overview of all policy positions workshop, 3 May 2018.

depicted as a dashed line within the envelope set by the automatic access standard.[333] This dashed line will be in a different place for different proposed connections because the position of the line depends on conditions at the connection point, particularly the system strength of the connection point.

AEMO’s proposed minimum access standard is expressed in a different form to the automatic access standard, which is a fixed percentage of rated active power of the generating system. This difference is significant for two reasons:

- the requirement in the proposed minimum access standard to provide reactive power of at least the amount required to achieve the continuously controllable voltage set-point range in S5.2.5.13 would make the reactive capability required from a connecting generating system dependent on fault level at the connection point.[334] The minimum level of reactive capability required from a connecting generating system under AEMO’s proposal would be the level required to achieve AEMO's proposed minimum access standard in S5.2.5.13 (discussed in Chapter 8) to continuously control voltage at the connection point to ± 2% of normal voltage,[335] and
- the proposed minimum access standard is independent of generating system capacity.

In effect, this would mean that a generating system proposed for connection in a strong part of the power system would require a more arduous reactive power capability than one proposed in a weaker part of the power system. In particular in strong parts of the power system the level of reactive power capability required under AEMO’s proposed minimum access standard could potentially be more arduous than the level required under the automatic access standard. Given this, AEMO provided an updated position proposing to cap the minimum access standard requirement at the level of the automatic access standard.[336]

7.5 Stakeholder views

There was significant stakeholder concern about AEMO’s proposed minimum access standard. Generators had particular concerns in the following areas:

- AEMO’s proposed link with S5.2.5.13 would mandate high levels of reactive capability in strong parts of the power system leading to a misalignment of required capability and power system need[337]

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333 Note that the reactive capability depending on connection point voltage is represented as two opposing boxes. This is due to the proposed link with votlage regulation requirements in S5.2.5.13.

334 Generating systems connecting in strong parts of the system, with higher fault levels, would face a greater obligation than generating systems connecting in currently weak parts of the system which have lower fault levels. This is because it requires greater amounts of reactive power to shift voltages in stronger parts of the power system.

335 Rule change request, suggested rule, S5.2.5.13(d)(3)(i).

336 AEMO, Generator technical requirements: supplementary material to rule change proposal, p. 10

337 Submissions to the consultation paper: Advisian, p. 6; Terrain Solar, p. 4; RES, p. 6; First Solar, p. 3; ESCO Pacific, p. 8; Engie, p. 2; Pacific Hydro p. vii.

- AEMO's proposal was either unachievable or could only be achieved at significant additional cost.[338] Advisian in particular considered the requirement to have sufficient reactive power capability to regulate voltage to a specific level to be physically impossible if the generating system is connected to a strong connection point such that it cannot affect system voltage to any significant degree,[339] and
- AEMO's approach was not linked to generating system capacity and thereby places a disproportionate burden on small generators.[340] Edify Energy in particular considered the cost for such to generators to achieve AEMO's proposal to be excessive and create barriers to entry.[341]

Most generators also commented on the importance of flexibility to align the level of reactive power capability required from a connecting generating system with power system conditions at the connection point.[342] They considered this was important because a range of network circumstances are relevant to the reactive power capability needed to meet the system standards. They therefore considered the level of reactive power capability set for a connecting generating system is appropriately managed through negotiation, rather than a minimum requirement.[343] ESCO Pacific provided the example of a generating system that is to be connected to the same substation as a large SVC. Under these circumstances, to meet the minimum requirements proposed by AEMO, the generating system must completely overpower the SVC (requiring a large amount of reactive power capability) before the voltage can be changed.[344]

AEMO's proposal was supported by a number of network businesses,[345] with Powerlink considering that AEMO's proposal provided a framework for efficiently delivering the voltage support and control services required for the current and future operation of the power system.[346] The Commission however notes TasNetworks expressed concern about the practicality of AEMO's proposed link between S5.2.5.1 and S5.2.5.13, which makes the amount of reactive power required under the minimum access standard a function of the fault level at the connection point:[347]

> "While the intent is fully supported, the minimum access standard being proposed requires additional consideration. In TasNetworks view, linking

338 Submissions to the consultation paper: Advisian, p. 6; Terrain Solar, p. 4; First Solar, p. 3; Pacific Hydro, p. 3; Origin Energy, p. 4.

339 Advisian, submission to the consultation paper, p. 6.

340 Submissions to consultation paper: Advisian, p. 6; Terrain Solar, p. 4; First Solar, p. 3; Edify Energy, p. 3.

341 Edify Energy, submission to the consultation paper, p. 3.

342 Submissions to the consultation paper: RES Australia, p. 6; Advisian, p. 6; Terrain Solar, p. 4; First Solar, p. 3; Edify Energy, p. 3; ESCO Pacific, p. 9; Pacific Hydro, p. vii; Alinta, p. 4; CEC, p. 11; GE Australia, p. 8.

343 Submissions to the consultation paper: Engie, p. 2; RES Australia, p. 6;Alinta, p. 4; Edify Energy, p. 3; Pacific Hydro, p. vii; GE Australia, p. 8.

344 ESCO Pacific, submission to the consultation paper, p. 8.

345 Submissions to consultation paper: TransGrid, p. 3; Powerlink, p. 3; Ausgrid, p. 1; ENA, p. 1.

346 Powerlink, submission to the consultation paper, p. 3.

347 TasNetworks, submission to the consultation paper, p. 6.

the minimum required reactive power capability with fault level is a questionable added complication. The fact that the minimum access standard may climb to be equal to the automatic access standard at the strongest locations in the network (where the required additional reactive power may be minimal) suggests an almost perverse outcome."

While the majority of stakeholders did not support AEMO's proposed minimum access standard for clause S5.2.5.1, to be linked to the requirements in clause S5.2.5.13, there was a greater degree of support for a minimum access standard that mandates a minimum level of reactive capability from all generating systems. In addition to network businesses, some generators considered a requirement for all generating systems to provide reactive capability to be acceptable.[348] ESCO Pacific observed:[349]

"ESCO strongly supports AEMO's view that the previous minimum access standard for this clause was inadequate. All generators should be required to provide reactive power to the system."

Some stakeholders noted the potential for a mandated minimum access standard to change the sharing of responsibility between network businesses and generators. A number of stakeholders commented on the shared nature of reactive power and voltage control capability,[350] with some regarding AEMO's proposal as representing a material shift in responsibility from network businesses to generators.[351] Terrain Solar made the following point:[352]

"The proposed changes to S5.2.5.1 and 5.2.5.13 transfer the risk of voltage performance from network service providers to generators who have traditionally not been responsible for regulating voltage and do not receive a regulated revenue base, through ancillary services or otherwise, to provide such services."

Generators expressed a common preference for a commercial procurement approach to sourcing reactive power services over a mandated minimum access standard requiring generating systems to provide reactive power capability.[353] Hydro Tasmania particularly noted the lack of market or commercial opportunities for providing additional reactive power capability.[354] Energy Networks Australia however observed that synchronous generating systems had historically provided reactive power support at minimal or zero cost and had benefited from a more stable network as a result.[355]

348 Submissions to consultation paper: Tilt Renewables, p, 3;ESCO Pacific, p. 8; Hydro Tasmania, p. 5.

349 ESCO Pacific, submission to the consultation paper, p. 8.

350 Submissions to consultation paper: Terrain Solar, p. 4; RES Australia, p. 6; SMA, p. 3; ENA, p. 1.

351 Submissions to consultation paper: Terrain Solar, p. 4; RES Australia, p. 6.

352 Terrain Solar, submission to the consultation paper, p. 4.

353 Submissions to consultation paper: AEC, p. 3; Hydro Tasmania, p. 5; CEC, p. 11; Edify Energy, p. 3 .

354 Hydro Tasmania, submission to the consultation paper, p. 5.

355 ENA, submission to the consultation paper, p. 1.

7.6 Analysis and conclusions

This section sets out:

- the Commission's analysis of the of the issues raised by AEMO, and
- the Commission's draft rule to address any material issues found.

7.6.1 Analysis of the issues

AEMO considered current arrangements for reactive power capability in clause S5.2.5.1 to be insufficient to address the needs of a transitioning power system. In particular AEMO considered the current minimum access standard is not sufficient to address this need as it does not require any reactive power capability from a connecting generating system. To address the issues raised by AEMO, the Commission has considered the:

- allocation of responsibility between generators, network businesses, and AEMO, and
- role of a minimum access standard.

Allocation of responsibility under current arrangements

In its rule change request, AEMO considered the provision of fully capable voltage control systems as part of a generating system to be essential to the ongoing secure management of the power system. It considered that any lack of reactive power capability and coordinated control of that capability would reduce the power transfer capability of the power system and risk power system stability. AEMO therefore considered that reactive capability was required from all generating systems through a minimum access standard which mandates a minimum level of capability from all connecting generators.[356]

Some stakeholders noted the potential for AEMO’s proposal to change the sharing of responsibility between network businesses and generators. A number of stakeholders commented on the shared nature of reactive power and voltage control capability,[357] with Terrain Solar considering proposed changes as transferring the risk of voltage performance from network service providers to generators who have traditionally not been responsible for regulating voltage and do not receive a regulated revenue base, through ancillary services or otherwise, to provide such services.[358]

The Commission agrees with AEMO that sufficient reactive power capability is required to maintain an AC power system in a secure operating state. Amendments to the NER may therefore be justified should existing frameworks be inappropriate to provide the required level of reactive power. Any changes to the allocation of responsibilities between generators, network business, and AEMO however need to be justified by the identification of a clear material gap in current arrangements which may compromise power system security or the quality of supply to end users.

356 Rule change request, p. 21.

357 Submissions to consultation paper: Terrain Solar, p. 4; RES Australia, p. 6; SMA, p. 3; ENA, p. 1.

358 Terrain Solar, submission to the rule change request, p. 4

The NER places primary responsibility for the management of voltage with the network service provider,[359] who is required to design and operate its transmission or distribution network so that connection point voltages fluctuate to an extent that is less than the levels specified in the system standards. This obligation is related to the reactive power flow and the power factor at the connection point being within the limits set out in a corresponding connection agreement.[360] The reactive power capability negotiated under S5.2.5.1 therefore determines the extent to which generating system capabilities contribute to a network service provider's ability to manage voltages according to the requirements in the system standards. Requiring additional reactive capability from connecting generators, beyond the level needed for the network service provider to manage voltages within the system standards, will therefore alter the allocation of responsibility between network businesses and generators.

Generators have obligations for the provision of reactive capability which are contained in S5.2.5.1 and require a generating system to provide reactive power capability sufficient so that all relevant system standards are met before and after credible contingency events, taking into account at least existing and considered projects.[361] Current arrangements do not require a connecting generating system to provide a level of reactive power capability to support the potential and uncertain needs of the power system beyond taking into account existing and considered projects. Existing frameworks account for future changes in power system conditions, beyond the time frame of existing and considered projects, by placing responsibility on network businesses to manage power system implications of circumstances such as generating system retirement, through the NSCAS[362] framework and a network business' regulatory investment tests for transmission and distribution (RIT-T and RIT-D).[363]

AEMO has a role in the dispatch of reactive power to control power system voltages and maintain system security. This includes determining the adequacy of the reactive power capability available in the power system and establishing the limits of power system operating voltage conditions.[364] The NER require AEMO to use its reasonable endeavours to maintain voltage conditions so that the power system remains in a satisfactory operating state.[365] As part of its responsibilities for system security, AEMO has an operational role in dispatching reactive power including:[366]

359 Clause S5.1.5 of the NER.

360 Clause S5.1a.4 of the NER.

361 Clause S5.2.5.1(c)(1) of the NER.

362 Network Support and Control Ancillary Services (NSCAS) are a non-market ancillary service that may be procured by AEMO or transmission network service providers to maintain power system security and reliability, and to maintain or increase the power transfer capability of the transmission network.

363 The purpose of the RIT-T and RIT-D is to identify the network investment option which maximises net economic benefits and, where applicable, meets the relevant jurisdictional or NER based reliability standards.

364 Clause 4.5.1 of the NER.

365 Clause 4.5.1(e) of the NER.

366 Clauses 4.5.1 and 4.5.2 of the NER.

- determining the level of reactive power reserve required to operate the power system
- maintaining an appropriate level of reactive power reserve, and
- dispatching reactive power capabilities to manage power system voltages, and taking all necessary actions, including issuing directions, to return voltage to acceptable limits.

As clause S5.2.5.1 of the NER is not an AEMO advisory matter, AEMO is not explicitly required to provide advice to the network service provider on whether the proposed connection would adversely affect power system security. Reactive capability is therefore directly negotiated between the connection applicant and relevant network service provider, without input from AEMO. While network service providers have information allowing them to understand the reactive power needs of their networks, it is AEMO who is best placed to understand the reactive power needs for over-all system security.

AEMO has expressed concern that their exclusion from negotiation under S5.2.5.1 may result in network service providers agreeing to performance standards do not fully consider system security needs.[367] The Commission agrees that this is a potential risk under the current arrangements. Without AEMO explicitly advising on whether or not a proposed negotiated access standard for reactive power capability would adversely affect power system security, there is a risk that a generating system could connect with a lower capability than is necessary to maintain the power system in a secure state.

Role of the minimum access standard

AEMO considered current arrangements for reactive power capability in S5.2.5.1 to be insufficient, particularly the minimum access standard which does not require any reactive power capability from a connecting generating system. AEMO considered the current arrangements may lead to the proliferation of new generating systems that have limited reactive power (S5.2.5.1) and voltage control (S5.2.5.13) capabilities potentially placing power system security and the quality of supply at risk.[368]

As noted in the Commission's assessment framework, discussed in Chapter 3 for this rule change, mandating a capability in a minimum access standard may be considered necessary where there is a clear system need for a particular capability from all generating systems irrespective of power system conditions at their point of connection. The minimum access standard reflects the lowest level of performance required of a connecting generating system such that it does not adversely affect power system security or the quality of supply to network users, taking into consideration the size, technology and location of the connection.

The current automatic and minimum access standards in S5.2.5.1 allow significant flexibility to set a level of reactive power capability that is appropriate for power system conditions at the connection point, consistent with the current arrangements that share responsibility for voltage control between generating systems, network service

367 AEMO AEMC project call, 15 January 2018.

368 Rule change request, p. 21.

providers and AEMO. This flexibility is provided by the wide range between the automatic access standard, expressed as a percentage of the rated active power of the generating system, and the minimum access standard which is the provision of no capability.

The Commission considers that the appropriate reactive power capability to be set for a connecting generating system is a level that does not affect power system security or the quality of supply to other network users, taking into account existing and considered projects. The Commission notes the views of stakeholders that there are circumstances where these outcomes can be achieved with some generating systems providing no reactive power capability, such as the circumstances cited by ESCO Pacific of a generating systems connecting to the same substation as a large SVC.[369] As a result the Commission does not consider there to be clear system need for a particular capability from all generating systems irrespective of power system conditions at their point of connection.

The Commission also understands that the costs involved in mandating this capability for all generators may be significant. For example, for a typical asynchronous connection it would require increased capital on additional inverter capability, other reactive plant, or reduced revenue through creating active power “headroom” to allow for the provision of greater reactive power capability. In its submission to the consultation paper, Origin Energy noted that additional reactive support (capacitors or reactors) can cost more than $2 million per set.[370] In the absence of a clearly identifiable system need, imposing such costs on all generators irrespective of conditions at the connection point is unlikely to be consistent with maintaining power system security at lowest cost for consumers.

Additional costs may be justified by a clearly identifiable risk to system security or the quality of supply to other network users resulting from the connection of a generating system. However, the risks from insufficient reactive power capability are related to the pooled reactive capabilities from the sum of connected parties within an area of the power system (including all generating system and network capabilities) and not necessarily the reactive capability of a single generating system connecting at a point in the power system.

A single generating system having little or no reactive capability will therefore not automatically increase the risk of voltage instability and collapse, unless there is also insufficient reactive capability available from other nearby sources.

Therefore, the Commission is not able to identify a clear system need justifying a mandated minimum access standard level of reactive power capability from all connecting generators. The Commission’s view is that current settings provide flexibility to account for power system needs at the point of connection, and that a mandated minimum reactive power requirement is likely to result in excess capability and impose costs that are not necessary to meet system needs.

369 ESCO Pacific, submission to the consultation paper, p. 8.

370 Origin Energy, submission to consultation paper, p. 4.

7.6.2 Conclusions

Box 7.2 Draft rule

To address the issues identified above, the Commission's draft rule:

- specifies the access standards for reactive power capability (clause S5.2.5.1) as an AEMO advisory matter[371]
- includes in the access standards for reactive power capability (clause S5.2.5.1) a requirement that a negotiated access standard be consistent with maintaining power system security, taking into account existing and considered projects,[372] and
- amends the minimum access standard so that it remains a requirement to provide no reactive power capability, but is drafted in the same form as the automatic access standard.[373]

This section sets out the Commission's conclusions on:

- the appropriate response to the issues identified above, and
- the changes proposed by AEMO.

Allocation of responsibility for reactive power and voltage control capability

As discussed above, current arrangements specify a bilateral negotiation between a generator and network business that does not include input from AEMO. The Commission considers this to create a risk that some connecting generating systems do not bring enough reactive power capability to support power system security.

The Commission agrees with AEMO that making S5.2.5.1 an AEMO advisory matter would better allow system security considerations to be fully incorporated into the negotiation of reactive capability from connecting generating systems. The Commission notes that the related access standard specifying how the reactive power capability is to be controlled (clause S5.2.5.13) is an AEMO advisory matter. Extending AEMO's oversight to the negotiation of reactive power capability in S5.2.5.1 would therefore also be consistent with AEMO's role in related access standards.

Current arrangements require a negotiated access standard to ensure that the reactive power capability of the generating system is sufficient that all relevant system standards are met before and after credible contingency events under normal and planned outage operating conditions of the power system, taking into account at least existing projects and considered projects.[374] To clearly incorporate power system security considerations into the negotiation of reactive capability under S5.2.5.1, the Commission also recommends adding an additional requirement under this clause that

371 Chapter 10 of the draft rule defines the standards which are AEMO advisory matters.

372 Clause S5.2.5.1(c)(1) of the draft rule.

373 Clause S5.2.5.1(b) of the draft rule.

374 Clause S5.2.5.1(c)(1) of the NER.

a negotiated access standard must be consistent with maintaining power system security, taking into account at least existing projects and considered projects.

Level of the minimum access standard

AEMO proposed a specific minimum access standard to address their identified need for additional reactive power capability to maintain power system security as the power system transitions. AEMO proposed to mandate that, at a minimum, all generating systems have sufficient reactive capability to achieve the minimum access standard of a continuously controllable voltage setpoint range of ± 2% from normal voltage, as proposed for clause S5.2.5.13.

As noted above, the Commission considers that a minimum access standard that does not require the provision of any reactive power capability is appropriate. This is because some parts of the power system may not require any additional reactive power capability to be provided by a connecting generating system, and therefore customers should not pay for that capability. Further, the Commission considers that AEMO's proposed minimum access standard, which requires a minimum amount of reactive capability from a connecting generator sufficient to meet voltage control requirements under S5.2.5.13, is not appropriate.

The Commission notes stakeholder views that AEMO's specific proposed minimum access standard would mandate high levels of reactive capability in strong parts of the power system leading to a misalignment of required capability and power system need. This would impose significant costs on connecting generators that is not justified by power system needs, and place a disproportionate burden on small generating systems thereby creating unnecessary barriers to their connection.

The amount of reactive capability it takes to control voltage to the level proposed for S5.2.5.13 depends on the strength of the system at the connection point. Strong systems, with higher fault levels, require higher amounts of reactive power capability to control voltage than weak parts of the network with lower fault levels. AEMO's proposal would result in a disproportionate amount of reactive capability installed in currently strong parts of the power system. However, the system need for reactive power capability to manage voltage levels is lowest in areas that are strong. Additional reactive power capability installed in such locations is unlikely to be needed to assist with meeting the system standards.

AEMO's proposed requirement would likely also create perverse incentives for generating systems to locate in parts of the power system with lower fault levels, as meeting the proposed requirements to control voltages is easier in these parts of the power system. However, additional connections of asynchronous plant with low reactive power capability would likely exacerbate existing system strength issues in these parts of the system. A requirement that leads to such an outcome is unlikely to be consistent with maintaining power system security at lowest cost.

The amount of reactive capability required under AEMO's proposed minimum access standard is also independent of the capacity of the generating system. While the current automatic access standard references a specific amount of reactive capability linked to the capacity of the generating system, AEMO's proposed minimum access standard would require sufficient reactive capability to at least achieve the continuously controllable voltage range of ± 2% from normal voltage irrespective of the size of the generating system. Such an approach places the same obligation on small generating systems as it does large. Given the significant costs involved providing additional reactive capability, this would likely create unnecessary barriers to the connection of smaller generating systems.

While the Commission does not consider a minimum level of reactive capability to be required under the minimum access standard of S5.2.5.1 the form of the minimum access standard remains important as a means of defining a continuous range over which negotiation occurs. The existing minimum access standard is simply defined as no capability. This is in a different form to the automatic access standard which separately specifies reactive absorption and injection requirements (although both are set at 39.5%). In order to define a clear range over which negotiation occurs the Commission's draft rule expresses the minimum access standard in the same form as the automatic access standard, as separately specifying reactive absorption and injection requirements with both being set at zero capability.[375]

375 Clause S5.2.5.1(b) of the draft rule.

8 Reactive power control

Box 8.1 Overview

AEMO raised concerns that the current arrangements relating to voltage and reactive power control do not provide sufficient reactive power control capabilities for an evolving power system. In its rule change request, AEMO proposed changes to clause S5.2.5.13 relating to:

- the mode of reactive power control a generating system must be capable of operating in
- performance capabilities, and
- the rise and settling times associated with the generating system's response to a step change in voltage of 5%.

The Commission agrees that the changing generation mix in the power system, including increasing penetration of distributed and asynchronous energy sources, presents increasing challenges for controlling voltage on the power system. The Commission considers that in a range of respects the current arrangements are not adequate to address these challenges.

In response to these issues, the Commission's draft rule adopts most of AEMO's proposals but with some changes in how they are implemented. In particular, the Commission's draft rule:

- changes the requirements for specifying the mode of reactive power control so that the automatic access standard is the capability to operate in all modes and switch between them (in accordance with a procedure agreed with AEMO and the network service provider), and the minimum access standard is the capability to either operate in voltage control mode, or otherwise in any other reactive power control mode with the agreement of AEMO and the network service provider
- allows for the mode of reactive power control arrangements to apply irrespective of the connection point voltage and the capacity of the generating system
- introduces a minimum access standard requirement for generating systems to have a voltage control system, where one is required, that:
  - regulates voltage at the connection point (or another agreed location on the power system or within the generating system) to within ±2% of the setpoint, and
  - allows the voltage setpoint to be controllable in the range of at least 98% to 102% of normal voltage at the connection point (or the agreed location)
- clarifies that voltage control can be implemented using a voltage droop characteristic
- introduces new performance requirements for generating systems operating

in reactive power or power factor control modes

- includes a new general requirement in clause S5.2.5.13 that the performance characteristics of any reactive power capability agreed under that clause are to be consistent with the capability determined in clause S5.2.5.1, and
- aligns the rise and settling time requirements for synchronous and asynchronous generating systems under the minimum access standard.

8.1 Introduction

This Chapter discusses AEMO's proposed changes to the NER that relate to requirements for connecting generating systems to control reactive power. That is, the characteristics of how a generating system must control the amount of reactive power capability provided in clause S5.2.5.1, discussed in Chapter 7.

This Chapter discusses proposed changes to the NER related to:

- the mode of reactive power control
- performance capabilities, and
- the characteristics of the generating system's response to a step change in voltage of 5%.

For each of these topics this Chapter sets out:

- the current arrangements in the NER
- the issues raised by AEMO with the current arrangements and changes proposed to address those issues
- stakeholder views, and
- analysis and conclusions.

8.2 Mode of reactive power control

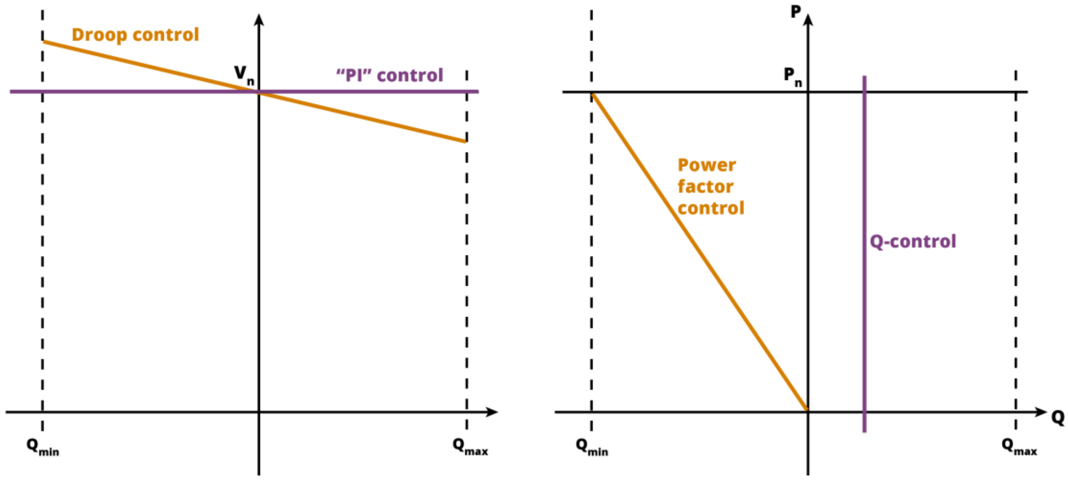
This section discusses AEMO's proposed changes to the arrangements in clause S5.2.5.13 for setting the reactive power control mode of a connecting generating system.

8.2.1 Technical background

A generating system's reactive power capability can be controlled using three basic control modes:

- voltage control mode
- power factor (PF) control mode, and
- reactive power (Q) control mode.

Figure 8.1 Reactive power control modes - voltage control, reactive control, and power factor control



Voltage control mode involves the provision of reactive power to control the voltage at the connection point to a 'setpoint' value (Vn). As shown in Figure 8.1, there are two approaches to voltage control. These are 'PI voltage control' and 'droop voltage control'.

PI voltage control uses the full reactive power capability of the generating system to control the voltage at the connection point to the desired setpoint. The control system achieves this to the extent possible by minimizing the error between the desired voltage setpoint and the measured voltage at the connection point.

Droop voltage control, on the other hand, regulates the generating system's reactive power in proportion to the change in the connection point voltage from the voltage setpoint. In contrast to PI control, Figure 8.1 shows droop control as varying reactive power with connection point voltage according to a defined slope.[376]

While PI voltage control provides for more accurate control of voltage, one of the reasons for using droop control over PI voltage control is that it better allows for the sharing of responsibility for controlling voltage between generating systems and other sources of reactive power operating in close proximity. This is because the control systems of equipment in close proximity operating under PI voltage control can adversely interact, whereas such equipment operating under droop voltage control can better share the burden of providing reactive power to control local voltages.

Unlike voltage control mode (whether PI control or droop control), power factor control mode and reactive power control mode do not control reactive power to support a particular voltage at the connection point. Rather (as shown in Figure 8.1):

- power factor control mode supplies reactive power as a ratio of active power (MW) to apparent power (MVA) at the point of measurement, and

376 In this manner, voltage control via droop seeks to restrain rather than pin voltage at the connection point. The droop expressed in percentage is the offset voltage that would occur if the reactive power (or reactive current) were to change by 100%. Most commonly, the change in reactive power is taken as the rating of the generating system in MVA (or full load current). For a 100 MVA rated generating system, a -4% droop would modify the setpoint by -4% if the reactive power output increases by 100%, or 100 MVAr.

- reactive power control mode supplies a fixed quantity of reactive power (MVAR) independent of changes to the generating system's active power output.

8.2.2 Current arrangements

The requirements under the automatic access standard differ depending on whether the generating system is synchronous or asynchronous (although for the most part, the requirements under each are the same).

The existing automatic access standard in clause S5.2.5.13 requires a generating system to have the capability to operate in voltage control mode, regardless of generating system capacity or connection point voltage. The automatic access standard does not explicitly provide for the capability to operate in the other reactive power control modes.[377]

In contrast, the minimum access standard allows for the capability to operate in the other reactive power control modes (that is, power factor control and reactive power control modes):[378]

- generating systems connecting at a nominal connection point voltage of 100 kV or more are required to have facilities to regulate voltage[379] in a manner that does not prevent the network service provider from achieving the system standards for system stability and voltage levels,[380] and is sufficient for the generating system to achieve certain other performance standards,[381] and
- generating systems connecting at a nominal connection point voltage of less than 100 kV are required to have facilities to regulate one of the reactive power modes (either voltage, reactive power, or power factor) in a manner that does not prevent the network service provider from achieving the system standards for system stability and voltage levels,[382] and is sufficient for the generating system to achieve certain other performance standards.[383]

Also under the existing minimum access standard, a generating system with a nameplate rating of 30 MW or more must have a control system that regulates voltage, power factor or reactive power, as agreed with the network service provider and AEMO.[384] This clause explicitly provides flexibility for generating systems of 30 MW or more to operate in power factor or reactive power control modes. No requirements

377 Clauses S5.2.5.13(b)(4) (asynchronous generating system) and S5.2.5.13(b)(3) (synchronous generating system) of the NER.

378 Clause S5.2.5.13(d)(3) of the NER.

379 While generating systems connecting about 100 kV are required to have facilities to regulate voltage, the Commission notes that this may not preclude the capability to operate in the other control modes.

380 That is, the requirements in clauses S5.1a.3 and S5.1a.4 of the NER.

381 That is, the performance standards agreed in clauses S5.2.5.1, S5.2.5.2, S5.2.5.3, S5.2.5.4, S5.2.5.5, S5.2.5.6 and S5.2.5.12 of the NER.

382 That is, the requirements in clauses S5.1a.3 and S5.1a.4.

383 That is, the performance standards agreed in clauses S5.2.5.1, S5.2.5.2, S5.2.5.3, S5.2.5.4, S5.2.5.5, S5.2.5.6 and S5.2.5.12 of the NER.

384 Clause S5.2.5.13(4)(i), 5(i) of the NER.

are specified for generating systems with a nameplate rating of less than 30 MW. The network service provider and AEMO are not explicitly required to agree to the mode of reactive power control set for generating systems under 30 MW.

The existing minimum access standard requirements are summarized in Table 8.1 below.

Table 8.1 Reactive control mode requirements in the minimum access standard of S5.2.5.13 depending on generating system capacity and connection point voltage

Generating system capacity	Connection point voltage < 100 kV	Connection point voltage ≥ 100 kV
< 30 MW	One of voltage control, reactive power control or power factor control mode.	Voltage control mode is required. The ability to operate in other control modes is not explicitly provided for.
≥ 30 MW	One of voltage control, reactive power control or power factor control mode, with the chosen mode to be agreed with AEMO and the network service provider.	Voltage control mode is required. Additional modes (reactive power control mode or power factor control mode) are provided for where AEMO and network service provider agree.

The existence of the 100 kV threshold divides generating systems between those connected to transmission networks and those connected to distribution networks. the Commission understands that arrangements above and below the 100 kV threshold in the minimum access standard broadly reflect the traditional approach to managing voltage with generating systems connecting at transmission level (100 kV or more) operating in voltage control mode and distribution level (below 100 kV) connections generally operating in power factor or reactive power control modes.

There appears to be some ambiguity in current arrangements regarding the treatment of generating systems under 30 MW. Generating systems under 30 MW connecting to parts of the power system with voltage levels of 100 kV or more are not explicitly provided the same flexibility that is available to larger generating systems to operate in control modes other than voltage control mode. Although not specifically provided for, smaller generating systems may in practice still be able to operate in control modes other than voltage control mode. However, the ambiguity appears to be a matter that could be addressed under this rule change process, which is discussed further below.

8.2.3 Rule change request

In its rule change request, AEMO considered that current arrangements are not adequate to provide for the increased need for voltage control capabilities that it expects will be required as the power system transforms. AEMO was particularly concerned with the voltage control implications of changing power flows arising from high amounts of distributed renewable technologies connecting into distribution networks.[385]

To address these issues, AEMO argued in its rule change request that all new generating systems should be capable of operating in voltage control mode.[386] In addition, AEMO considered that additional flexibility is required for generating systems operating in reactive power control or power factor control modes to be able to switch into voltage control mode in response to changes in power system conditions. AEMO considered that the highly variable power flows that are expected as the power system evolves will require generation that is able to manage reactive power flow, by either operating in or being able to operate in voltage control mode, to ensure that appropriate network voltage profiles are maintained.[387]

In its rule change request, AEMO identified the following specific shortcomings in the current arrangements in clause S5.2.5.13 regarding the mode of reactive power control:[388]

- some generating systems may be connected with only power factor or reactive power control mode, and without voltage control mode, which limits the ability of the generating system to control voltages on the power system as network topography and loading change over time
- the way the automatic access standard and minimum access standard are specified is not consistent, which creates an ambiguity that can lead to difficulties in setting an appropriate negotiated access standard, and
- there is some ambiguity under the minimum access standard regarding the capability and performance requirements for generating systems with a nameplate rating of less than 30 MW, such that voltage control may not be supplied by some embedded generating units. Without this capability, distribution network voltages might not be able to be maintained within operating limits or investment in additional ancillary support plant may be necessary.

To address these issues, in its rule change request AEMO proposed amendments to the minimum access standard in clause S5.2.5.13.[389] AEMO did not propose substantive amendments to the automatic access standard.

Key features of AEMO's proposed changes to the minimum access standard include:

- requiring all connecting generating systems to have voltage control mode capabilities, regardless of connection point voltage or the nameplate capacity rating of the generating system, and
- allowing embedded generating systems to operate in power factor control or reactive power control modes,[390] in a manner that does not prevent the network

385 Rule change request, p. 21.

386 Ibid.

387 Ibid.

388 Ibid.

389 Rule change request, p. 22.

service provider from achieving the system standards for system stability and voltage levels,[391] and is sufficient for the generating system to achieve certain other performance standards.[392]

AEMO's proposed changes also include a new requirement (as part of the negotiated access standard provisions) requiring generating systems with control systems (or excitation control systems) that are operating in power factor control or reactive power control modes (including embedded generating units), to be able to be switched to operation in voltage control mode at any time.[393] This requirement would also include provision for remote control facilities to change the setpoint and mode of control, which is discussed further in Chapter 6.

The changes proposed by AEMO do not contain explicit arrangements for non-embedded generating systems to be able to operate in modes other than voltage control mode (i.e. power factor control or reactive power control modes).[394]

8.2.4 Stakeholder views

Several network businesses agreed with AEMO's view that additional continuous voltage control capability in both transmission and distribution networks is likely to become more important as greater levels of intermittent generation are connected to the power system. TasNetworks and Powerlink particularly noted the integration of large amounts of solar PV as increasing the need for more voltage control capability.[395]

A range of stakeholders however noted that AEMO's proposed minimum access standard appears to remove flexibility for non-embedded generating systems to operate in power factor or reactive power control modes.[396] TasNetworks was concerned this would prevent them from specifying the most appropriate reactive power control mode for the local circumstances within its networks.[397]

> "[T]he move toward more generating systems providing voltage control 'as standard' is an appropriate outcome. It may however not be practical in all cases for a small embedded generating system in a distribution network to implement voltage control and in some cases such control may not be necessary."

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390 Chapter 10 of the NER defines an embedded generating unit as a generating unit connected within a distribution network and not having direct access to the transmission network.

391 That is, the requirements in clauses S5.1a.3 and S5.1a.4 of the NER.

392 That is, the performance standards agreed in clauses S5.2.5.1, S5.2.5.2, S5.2.5.3, S5.2.5.4, S5.2.5.5, S5.2.5.6 and S5.2.5.12 of the NER.

393 Rule change request, clause S5.2.5.13(g) of the proposed rule.

394 Equally however the proposed arrangements do not appear to explicitly preclude non-embedded generating systems from operating in those other control modes.

395 Submissions to the consultation paper: TasNetworks, p. 15; Powerlink, p. 5.

396 Submissions to the consultation paper: Advisian, p. 44; TransGrid, p. 4; Tilt Renewables, p. 3; CEC, p. 11; AGL, p. 4.

397 TasNetworks, submission to the consultation paper, p. 16.

In addition to the value of flexibility at a distribution level, control mode flexibility was also noted as also being important for connections at transmission level. TransGrid observed:[398]

> "There is a need for all generating systems to regulate reactive power and power factor, in addition to providing voltage control facilities."

Some stakeholders also commented on the structure of the existing access standards. Under current arrangements the automatic access standard is one control mode and the minimum access standard includes the ability to operate in other control modes.[399] TransGrid proposed expanding the automatic access standard to include all modes of reactive power control in addition to voltage control mode.[400]

Some concerns were raised with AEMO's proposal to require generating systems operating in power factor control or reactive power control modes to be required to be able to switch to voltage control mode via remote control capability.[401] AGL in particular expressed concern given the possibility of equipment damage if AEMO inappropriately adjusts control modes:[402]

> "AGL does not support AEMO having remote control of the mode of regulation because of the potential damage this may create for generating system infrastructure. The provision of remote control equipment to change the setpoint and mode of regulation should be applicable only where AEMO accept responsibility for the risk to power system security."

8.2.5 Analysis and conclusions

Box 8.2 Draft rule: Mode of reactive power control

The Commission's draft rule:

- amends the automatic access standard so that it requires the capability to operate in all reactive power control modes, and the ability to switch between them in accordance with a procedure agreed with AEMO and the network service provider,[403] and
- amends the minimum access standard so that it requires the capability to operate in either voltage control, or otherwise any other reactive power control mode with the agreement of AEMO and the network service provider.[404]

This section sets out the Commission's analysis and conclusions on the issues raised by AEMO and stakeholders, including:

398 TransGrid, submission to the consultation paper, p. 4.

399 Submissions to the consultation paper: TransGrid, p. 4; Advisian, p. 14.

400 TransGrid, submission to the consultation paper, p. 4.

401 Submissions to the consultation paper: Stanwell, p. 5; AGL, p. 4.

402 AGL, submission to the consultation paper, p. 4.

403 Clause S5.2.5.13(b)(2A) of the draft rule.

404 Clause S5.2.5.13(d)(2A) of the draft rule.

- the need to provide voltage control capability in distribution networks sufficient to maintain system security given a transitioning power system
- the need for sufficient flexibility to specify a mode of reactive power control appropriate to power system conditions at the connection point
- the ability to be able to switch between reactive power control modes, and
- inconsistencies and ambiguities in the existing automatic and minimum access standards.

Voltage control capability in distribution networks

AEMO have significant concerns as to the adequacy of current arrangements to deliver sufficient voltage control capabilities in distribution networks given the integration of distribution level renewable generation and distributed energy resources.[405] AEMO in particular consider current arrangements are ambiguous in relation to the capability and performance requirements for generating systems with a nameplate rating of less than 30 MW, such that voltage control may not be supplied by some embedded generating units.[406]

Existing arrangements require a generating system that is connecting at a location in the power system with a voltage of 100 kV or more to have the capability to operate in voltage control mode.[407] Connections at voltages of less than 100 kV are required to have the capability to operate in one reactive power mode in a manner that does not prevent the network service provider from achieving the system standards related to system stability and voltage levels.[408] This does not require all distribution connected generating systems to have voltage control mode capabilities.[409]

Where a network service provider or AEMO consider it appropriate for a connection at a voltage level below 100 kV to operate in voltage control mode, they have the ability to require this under current arrangements, but only for generating systems with a nameplate rating of 30 MW or more. Current arrangements do not explicitly provide AEMO and the network service provider with an equivalent power for generating systems under 30 MW.[410] This could result in AEMO and network service providers not having a say in the mode of reactive power control for generating systems below 30 MW connecting at voltages below 100 kV.

The Commission agrees with AEMO that current arrangements for generating systems under 30 MW, connecting at voltages under 100 kV are unclear, and may not provide AEMO or the network service provider with the oversight necessary to provide

405 Rule change request, p. 21.

406 Ibid.

407 Clause S5.2.5.13(3)(i) of the NER.

408 Ibid.

409 While distribution connected generating systems may not be required to operate in voltage control mode, current arrangements also do not preclude them from doing so.

410 Clauses S5.2.5.13(4)(i) and (5)(i) of the NER which allow a synchronous or asynchronous generating system to regulate voltage, power factor or reactive power as agreed with the network service provider and AEMO.

sufficient levels of voltage control capability in distribution networks. As voltage control is expected to become more challenging in distribution networks, due to changing power flows from the connection of significant amounts of embedded generation, such current arrangements may not be appropriate for managing voltages in future distribution networks.

To address these issues the Commission's draft rule requires the agreement of AEMO and the network service provider before any connecting generating system is able to operate in a mode other than voltage control mode.[411] This is the case regardless of the size of the connecting generating system and the voltage level at the connection point.

Reactive control mode flexibility

Current arrangements provide flexibility to operate in reactive control modes other than voltage control through the minimum access standard. This flexibility is not limited to distribution level connections but also extends to generating systems connecting at transmission level. Current arrangements for generating systems with a nameplate rating of 30 MW and above connecting to a connection point with a voltage level of 100 kV or above require voltage control mode capability but allow additional modes (reactive power control mode or power factor control mode) where AEMO and the network service provider agree.[412]

AEMO's proposed minimum access standard removes explicit flexibility for non-embedded generating systems to operate in modes other than voltage control.[413] Stakeholders were concerned about the removal of this flexibility to operate in power factor or reactive power modes for connections at transmission level. The Commission notes stakeholder views that flexibility is needed to specify the mode of reactive power control appropriate for power system conditions at the connection point, given surrounding generation and voltage control assets. In particular, TransGrid considered the flexibility to specify the full range of control modes is important for all generating systems.[414]

The Commission agrees with stakeholders that the NER should provide the flexibility to specify any of the reactive power control modes for all connecting generating systems. Such an approach leaves the choice of mode to be decided on the basis of technical studies conducted for the connection, based on the specific power system conditions at the connection point. The Commission considers this approach is preferable to the current arrangements in the NER that pre-determine what is appropriate for a particular connection point based on connection voltage and generating system size. The Commission's draft rule therefore allows any reactive power control mode to be set

411 Clause S5.2.5.13(d)(2A)(ii) of the draft rule.

412 Clauses S5.2.5.13(4)(i) and (5)(i) of the NER which allow a synchronous or asynchronous generating system to regulate voltage, power factor or reactive power as agreed with the network service provider and AEMO.

413 Rule change request, suggested rule, clause S5.2.5.13(d)(3) removed provisions for an synchronous or asynchronous generating system to regulate voltage, power factor or reactive power as agreed with the network service provider and AEMO.

414 TransGrid, submission to the consultation paper, p. 4.

for any connecting generating system, regardless of the size of the generating system or the connection point voltage.[415]

Ability to switch reactive control mode

AEMO proposed requiring embedded generating systems operating in power factor control or reactive power control modes, to be able to be switched to operate in voltage control mode at any time.[416] AEMO considers that fixed power factor control or reactive power control modes may not provide sufficient flexibility for a generating system to continue operating under changed system conditions, including the need to manage highly variable power flows due to intermittent generation and demand response connecting at lower levels of the power system.[417]

Current arrangements in S5.2.5.13 do not provide the flexibility for a connecting generating system that on commissioning will operate in power factor control or reactive power control modes to be required to change mode of operation to voltage control mode at a later time. While the Commission notes the role of Clause 4.14(p) of the NER as a means of renegotiating performance standards, this clause does not provide for switching on operational time scales, as is implied by AEMO's request for the ability to switch modes 'at any time' with remote control equipment to change the setpoint and mode of regulation provided.[418]

While the Commission agrees with AEMO that the capability to switch between reactive power modes would be beneficial, the Commission notes AGL’s concerns regarding the potential for generating system equipment damage given inappropriate switching.[419] The Commission also notes the potential for adverse interactions with network control equipment. However, the Commission considers that these issues, which relate to the operational practices of the relevant parties, should be addressed through the development of procedures that set out how these processes would occur operationally.

From the Commission's survey of equipment manufacturers and subsequent interviews, the Commission understands that the ability to switch reactive power control modes is a standard feature in some larger plant control systems and including this feature should not present an issue for these generating systems. While larger plant may have this feature as standard it may not be standard in smaller plant, and some forms of renewable plant. Requiring the ability to switch reactive power control modes may therefore impose significant costs or could potentially act as an inefficient barrier to entry of certain forms of generation connecting. This would be an inefficient outcome if there was no power system need for the generator to have the ability to switch between voltage control modes. For this reason the Commission considers the ability to switch reactive power control modes should not be required from all connections, but

415 Clauses S5.2.5.13(b)(2A) and S5.2.5.13(d)(2A) of the draft rule.

416 Rule change request, p. 21.

417 Ibid.

418 Rule change request, clause S5.2.5.13(g) of the proposed rule.

419 AGL, submission to the consultation paper, p. 4.

rather should be implemented on agreement between the connection applicant, the network service provider and AEMO.

The Commission's draft rule therefore requires the ability to switch modes under the automatic access standard to be subject to the agreement of all parties on how this may occur, on a case by case basis.[420] This is to allow effective co-ordination and minimize potential risks, such as equipment damage or unintended interactions with other nearby voltage control equipment. The Commission's draft rule does not prescribe arrangements because the range of matters to be considered and potential outcomes will be highly location specific.

Structure of the automatic and minimum access standards

AEMO and a number of stakeholders noted that the current automatic and minimum access standards are not structured in a way that is consistent, leading to ambiguities and difficulties in negotiations.[421] As noted above, the current automatic access standard specifies a single mode capability (voltage control) while the minimum access standard provides for control in a range of modes. Furthermore, only the minimum access standard requirements vary by connection point voltage and generating system capacity.

The general approach used in other access standards is for a minimum access standard to be a subset of the capability required under the automatic access standard. This approach facilitates effective negotiation by reducing the number of variables to be agreed. The current automatic and minimum access standards in S5.2.5.13 are not consistent with this approach with the highest level of capability, in terms of flexibility and modes of operation, being required under the minimum and not the automatic access standard. Stakeholders, such as TransGrid, noted this and recommended the automatic access standard be revised to require facilities from all generating systems to be capable of operation in reactive power and power factor control modes, in addition to voltage control mode.[422]

The existing minimum access standard also segments requirements by connection point voltage and generating system capacity. While this approach may reflect traditional differences in the management of reactive power control in transmission and distribution networks (discussed above), this could give rise to ambiguities under the minimum access standard regarding capability and performance requirements. Furthermore, given the value of flexibility in both transmission and distribution networks, there is no clear functional need for separating requirements by generating system size or voltage level.

For these reasons the Commission considers the existing minimum access standard in S5.2.5.13 is overly complex, difficult to interpret, and inconsistent with the approach taken to setting access standards in other clauses. To address these shortcomings the

420 Clause S5.2.5.13(b)(2A) of the draft rule.

421 AEMO rule change request, p. 21; Submissions to the consultation paper: TransGrid, p. 4; Advisian, p. 14.

422 TransGrid, submission to the consultation paper, p. 4.

Commission's draft rule restructures the automatic and minimum access standard provisions relating to the mode of reactive power control.

Under the Commission's draft rule, the automatic access standard requires the highest level of capability (being all reactive power modes) and the ability to switch between modes.[423] This is consistent with the approach taken to other access standards, where the automatic access standard represents the level of performance that is sufficient for any generating system to connect at any location in the power system. It is also needed to address the risk that a generating system operating in power factor or reactive power control modes should also be capable of being called upon at a later time to operate in voltage control mode where needed to address changed power system conditions.

As noted above, some equipment is unable to operate in all reactive power control modes or to switch between modes. Given this limitation, and identified need for greater flexibility to operate in voltage control mode as the power system transitions, it is appropriate to require the ability to switch between different control modes for the automatic access standard, and not the minimum access standard. This would also allow a network service provider or AEMO to require the ability to switch between control modes under a negotiated access standard where considered appropriate, while allowing the flexibility to operate solely in a control mode other than voltage control mode where this is appropriate given the power system conditions at a generating system's connection point.

The Commission's draft rule includes a minimum access standard that requires a connecting generating system to operate in a single control mode being voltage control mode, or to operate in other control modes as agreed with AEMO and the network service provider.[424] Requiring operation in a single control mode capability is consistent with a minimum access standard that represents the lowest level of capability required of a connecting generating system to meet the needs of the power system. In recognition of the importance of additional voltage control capabilities raised by AEMO, particularly in distribution networks, as the power system transitions, the Commission considers voltage control is an appropriate default mode. However, flexibility is explicitly provided for another more appropriate reactive power control mode to be specified where this is appropriate for power system conditions at the particular connection point.

The automatic and minimum access standards in the draft rule would apply to all generating systems, irrespective of connection point voltage. These access standards, expressed clearly, should allow sufficient flexibility to set the appropriate reactive power control mode arrangements for any generating system proposed for connection at any location in the power system.

The Commission's draft rule would require the connection applicant to obtain agreement with AEMO and the network service provider to specify operation in any mode other than voltage control mode. This would minimize the risk that the mode of operation would adversely impact power system security or the quality of supply to other network users, particularly given the additional clarity that explicitly allows for

423 Clause S5.2.5.13(b)(2A) of the draft rule.

424 Clause S5.2.5.13(d)(2A) of the draft rule.

operation in droop control mode (discussed below). Further, the chosen mode of operation (or modes of operation) would still be required to be sufficient to allow the network service provider to meet its relevant system standard obligations, as well as appropriate to allow the generating system to meet its other relevant performance standards.

8.3 Performance characteristics

This section discusses AEMO's proposed changes to the arrangements in clause S5.2.5.13 for setting the generating system capabilities for operating in reactive power control modes including:

- voltage control mode
- power factor mode, and
- reactive power mode.

8.3.1 Current arrangements

As well as specifying the mode of reactive power control mode, S5.1.5.13 also specifies requirements for how a voltage control system (that is, a control system that regulates reactive power injection and absorption) should behave. In particular it specifies:

- a tolerance 'error band' within which a generating system's voltage control system is required to regulate voltage relative to the defined setpoint, and
- the range over which the voltage setpoint is 'continuously controllable' (without reliance on a tap changing transformer).

These characteristics are only relevant to a voltage control system operating in voltage control mode.

The existing automatic access standard in clause S.5.2.5.13 includes a requirement for a generating system to have an excitation or voltage control system that:[425]

- regulates voltage at the connection point or another agreed location in the power system (including within the generating system) to within 0.5% of its setpoint,[426] and
- allows the voltage setpoint to be continuously controllable in the range of at least 95% to 105% of normal voltage at the connection point (or another agreed location) without reliance on a tap changing transformer.[427]

The existing rule does not include specific accuracy and controllable setpoint range requirements applying to generators operating in power factor or reactive control modes under either the automatic or minimum access standards. The automatic access standard is silent on arrangements for reactive power control modes other than voltage

425 An excitation system (for a synchronous generating system) and a voltage control system (for an asynchronous generating system) both have the function of controlling the reactive power injection or absorption at the generating system terminals.

426 Clauses S5.2.5.13(b)(3)(i) and S5.2.5.13(b)(4)(i) of the NER.

427 Clauses S5.2.5.13(b)(3)(iv) and S5.2.5.13(b)(4)(iii) of the NER.

control mode.[428] The existing minimum access standard requires a generating unit or generating system connecting under 100 kV to have facilities to regulate reactive power or power factor in a manner that does not prevent the Network Service Provider from achieving the requirements of clauses S5.1a.3 and S5.1a.4 and is sufficient to achieve the performance agreed in respect of clauses S5.2.5.1, S5.2.5.2, S5.2.5.3, S5.2.5.4, S5.2.5.5, S5.2.5.6 and S5.2.5.12.[429]

Current requirements for a negotiated access standard in clause S5.2.5.13 require that:[430]

- a generating system that cannot meet the automatic access standard must demonstrate to the network service provider why that standard could not be reasonably achieved and propose a negotiated access standard, and
- the negotiated access standard must be at the highest level that the generating system can reasonably achieve, including by installation of additional dynamic reactive power equipment and through optimizing its control systems.

The requirements for a negotiated access standard for clause S5.2.5.13 therefore bias negotiation towards the automatic access standard.

8.3.2 Rule change request

In its rule change request, AEMO identified a need for increased voltage control capabilities to help maintain system security as the power system transitions. AEMO also considered that the way the existing automatic access standard is specified is not consistent with the way the minimum access standards is specified, creating an ambiguity that can lead to difficulties in setting an appropriate negotiated access standard.[431]

To address these issues AEMO proposed amending the minimum access standard in clause S5.2.5.13 to require synchronous and asynchronous generating systems to have an excitation or voltage control system that:[432]

- regulates voltage at the connection point (or another agreed location on the power system or within the generating system) to within ±2% of the setpoint, and
- allows the voltage setpoint to be continuously controllable in the range of at least 98% to 102% of normal voltage at the connection point (or the agreed location) without reliance on a tap changing transformer.

AEMO's proposal would therefore extend the form of existing requirements under the automatic access standard to the minimum access standard, albeit with lower levels of performance specified. AEMO did not propose amendments to the automatic access standard.

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428 Clause S5.2.5.13(b) of the NER.

429 NER Clause S5.2.5.13(d)(3)(ii) of the NER.

430 Clause S5.2.5.13(e) – (f) of the NER.

431 Rule change request, p. 21.

432 Rule change request, suggested rule, S5.2.5.13(d)(3)(i)(iii).

The minimum voltage control capability requirements proposed by AEMO were designed to complement its other proposed changes to the access standard setting the reactive power capability.[433] This proposal would involve linking the amount of reactive power capability provided to the ability to at least meet the voltage control characteristics set out above at the connection point. As discussed in Chapter 7, the Commission considers this is inappropriate because it would require all connecting generating systems to provide reactive power capability, even where it is not needed to maintain power system security or the quality of supply, and particularly in strong parts of the power system.

On 11 May 2018 AEMO provided additional views as to a set of performance requirements applying to generating units operating in power factor and reactive power mode. These performance characteristics include:[434]

- automatic access standard performance requirements for synchronous and asynchronous generating systems operating in reactive power and power factor regulation modes to:
  - regulate reactive power or power factor at the connection point, or at an agreed location, to within 0.5% of its setpoint, and
  - allow the reactive power or power factor setpoint to be continuously controllable across the reactive power capability range established in clause S5.2.5.1
- minimum access standard performance requirements for synchronous and asynchronous generating systems operating in reactive power and power factor regulation modes to:
  - regulate reactive power or power factor at the connection point, or at an agreed location, to within 2% of its setpoint, and
  - allow the reactive power or power factor setpoint to be continuously controllable across the reactive power capability range established in clause S5.2.5.1

8.3.3 Stakeholder views

Stakeholders raised a number of issues with the current arrangements, as well as AEMO's proposed amendments. Stakeholders were concerned with:

- the treatment of, and scope for, voltage control according to a droop characteristic
- the interpretation of 'controllable setpoint range', and its potential to determine reactive power capability requirements under S5.2.5.1, and
- the exclusion of tap changing from allowable mechanisms to achieve the 'controllable setpoint range'.

A number of stakeholders considered it important for the NER to clearly provide scope for voltage control via a droop characteristic.[435] TasNeworks noted that as many wind

433 Clause S5.2.5.13 of the NER.

434 AEMO, email communication, 11 May 2018

farms (and potentially solar PV farms) regulate voltage at the connection point through a droop characteristic, it would be preferable to remove the specific reference to a voltage control error margin given that it infers 'PI' voltage control.[436]

A range of stakeholders were concerned that a minimum access standard requirement for a 'continuously controllable voltage setpoint range' would give rise to a reactive power capability requirement under S5.2.5.1.[437] This is because being 'continuously' controllable infers reactive power capability must be used to control voltage at the setpoint, rather than other forms of voltage control such as the use of transformer tap changes (which are not able to continuously control to a voltage setpoint range). TransGrid in particular had the following view:[438]

> "TransGrid's interpretation of the [proposed] clause "allows the voltage setpoint to be continuously controllable in the range of at least 95% to 105% of normal voltage at the connection point or the agreed location, without reliance on a tap-changing transformer" is to describe control system capability in terms of voltage setpoint range, rather than generating system reactive power capability required to regulate the agreed location voltage to setpoint voltage range. Therefore, TransGrid suggests removal of the text "without reliance on a tap-changing transformer" from this clause."

Advisian and Pacific Hydro considered AEMO's proposed minimum access standard would be contrary to normal power engineering practice, which regularly uses tap changing transformers to regulate voltage at a generating system's connection point.[439]

Regarding the performance of generating systems operating in reactive power control modes other than voltage control (reactive power and power factor control modes), TransGrid also considered that performance requirements (including settling time, rise time, control accuracy, and setpoint range) and criteria for assessing these parameters should be defined in the NER.[440]

8.3.4 Analysis and conclusions

Box 8.3 Draft rule: Performance characteristics

The Commission's draft rule:

- includes a minimum access standard requirement for synchronous and

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435 Submissions to the consultation paper: TransGrid, p. 4; Powerlink, p. 8; TasNetworks, p . 15; Nordex, p. 7.

436 TasNetworks, submission to the consultation paper, p . 15.

437 Submissions to the consultation paper: TransGrid, p. 3; CEC, p. 11; Nordex, p. 7; Vestas, p. 1; GE Australia, p. 5.

438 TransGrid, submission to the consultation paper, p. 3.

439 Submissions to the consultation paper: Pacific Hydro, p. xxi; Advisian, p. xx.

440 TransGrid, submission to the consultation paper, p. 4.

asynchronous generating systems to have a voltage control system that:

- regulates voltage at the connection point (or another agreed location on the power system or within the generating system) to within ±2% of the setpoint,[441] and
- allows the voltage setpoint to be controllable in the range of at least 98% to 102% of normal voltage at the connection point (or the agreed location)[442]

- includes automatic access standard performance requirements for synchronous and asynchronous generating systems operating in reactive power and power factor regulation modes to:
  - regulate reactive power or power factor at the connection point, or at an agreed location, to within 0.5% of its setpoint,[443] and
  - allow the reactive power or power factor setpoint to be continuously controllable across the reactive power capability range established in clause S5.2.5.1[444]
- includes minimum access standard performance requirements for synchronous and asynchronous generating systems operating in reactive power and power factor regulation modes to:
  - regulate reactive power or power factor at the connection point, or at an agreed location, to within 2% of its setpoint,[445] and
  - allow the reactive power or power factor setpoint to be continuously controllable across the reactive power capability range established in clause S5.2.5.1[446]
- clarifies arrangements allowing voltage regulation strategies including droop control through the specification of a 'droop-adjusted setpoint', in the automatic and minimum access standards,[447] and
- includes a new general requirement in clause S5.2.5.13 that the performance characteristics of any reactive power capability agreed under that clause are to be consistent with the capability determined in clause S5.2.5.1.[448]

This section sets out the Commission's analysis and conclusions on the issues raised by AEMO and stakeholders, including:

441 Clause S5.2.5.13(d)(2B)(i) of the draft rule.

442 Clause S5.2.5.13(d)(2B)(ii) of the draft rule.

443 Clause S5.2.5.13(b)(c1)(1) of the draft rule.

444 Clause S5.2.5.13(c1)(2) of the draft rule.

445 Clause S5.2.5.13(d)(3)(i) of the draft rule.

446 Clause S5.2.5.13(d)(3)(ii) of the draft rule.

447 Clauses S5.2.5.13(b)(2B)(i) and S5.2.5.13(d)(2B)(i) of the draft rule.

448 Clause S5.2.5.13(l) of the draft rule.

- that the performance requirements for voltage control under the existing rule are insufficient and that the existing automatic and minimum access standards are specified inconsistently
- that there is a need to clarify the relationship between S5.2.5.1 and S5.2.5.13 in terms of reactive power capability requirements, and
- that additional clarity is required regarding voltage control via a droop characteristic.

Performance requirements under the automatic access standard

AEMO's original rule change request did not propose amending existing tolerance band and continuous controllable setpoint range performance requirements for under the automatic access standard applying to generating systems operating in modes other than voltage control mode, namely power factor or reactive control modes.

On 11 May 2018 AEMO provided updated views as to a set of specific performance requirements applying to generating systems operating in power factor or reactive control modes under the automatic access standard. AEMO considered that if the Commission was intending to include reactive power control modes other than voltage control in the automatic access standard, more detailed performance characteristics should be specified in the NER applying to those modes.[449]

The Commission considers that the automatic access standard should specify performance requirements applying to generating systems operating in reactive power control modes other than voltage control. This is consistent with the automatic access standard representing the level of performance required of a connection such that it does not adversely affect power system security or the quality of supply to network users, regardless of the size, technology and location of the connection point. The Commission also considers this approach to be more consistent with maintaining power system security while also providing for a clearer negotiation and therefore reduced negotiating costs.

The Commission’s draft rule therefore accepts AEMO’s recommended automatic access standard requirements applying to generating systems operating in mode other than voltage control mode (reactive power and power factor regulation modes). This includes automatic access standard performance requirements for synchronous and asynchronous generating systems operating in reactive power and power factor regulation modes to:

- regulate reactive power or power factor at the connection point, or at an agreed location, to within 0.5% of its setpoint,[450] and
- allow the reactive power or power factor setpoint to be continuously controllable across the reactive power capability range established in clause S5.2.5.1.[451]

449 AEMO-AEMC phone call, 11 May 2018.

450 Clause S5.2.5.13(c1)(1) of the draft rule.

451 Clause S5.2.5.13(c1)(2) of the draft rule.

Performance requirements under the minimum access standard

The Commission acknowledges AEMO's view that there is a need for sufficient voltage control capabilities to manage power system voltages as the power system transitions. As noted above, as more intermittent and distributed energy resources penetrate the power system, and increasingly create reverse power flows and other challenges for voltage control, it is important to have sufficient capabilities available to control voltage where needed. The Commission therefore considers a minimum capability requirement to be appropriate given system needs.

The Commission also agree with AEMO's view that the existing automatic and minimum access standards are not specified in a consistent way. The existing automatic access standard specifies voltage control tolerance and continuously controllable setpoint range requirements, whereas the minimum access standard is silent on these characteristics of voltage control mode response. Current arrangements therefore do not clearly specify a range over which capabilities can be negotiated, which can cause difficulties when setting an appropriate negotiated access standard. The Commission agrees that this is not consistent with arrangements facilitating efficient negotiation, leading to costs of negotiations that are higher than they otherwise could be.

AEMO's proposed minimum access standard is broadly an appropriate way to define the voltage control mode response in a way that is consistent with the automatic access standard, addressing the issues identified above. However, as noted by TransGrid, a requirement to continuously meet the required controllable range requirements without reliance on a tap-changing transformer implies that a connecting generating system would be, at a minimum, required to use reactive power capability to achieve the controllable range requirements. Requiring a reactive power obligation is not consistent with the Commission's view outlined in Chapter 7 that the reactive power capability set in clause S5.2.5.1 should not be linked to a requirement to achieve continuously controllable range requirements in this clause S5.2.5.13.[452] The Commission considers the appropriate role of clause S5.2.5.1 is therefore to determine how much reactive power is needed in a location, and the role of clause S5.2.5.13 is to determine how it will behave where it is needed.

The Commission notes the views of Advisian and Pacific Hydro, who both considered AEMO's proposed minimum access standard precluding the use of tap changing as contrary to normal power engineering practice, where tap changing is used as a means of regulating connection point voltages.

The Commission does not consider a clause restricting the use of tap-changing for voltage regulation purposes to be consistent with the Commission's approach to setting minimum access standards as the lowest level of capability consistent with maintaining power system security. The Commission considers that in some instances, the response characteristics delivered a transformer tap changer may be appropriate for system conditions at a generating system's connection point. The Commission therefore considers it is appropriate to remove from AEMO's proposed minimum access

452 The Commission concluded in Chapter 7 that there are some circumstances where reactive power capability may not be necessary to support power system security or the quality of power supply.

standard the requirement that meeting the controllable range must occur ‘continuously’ and ‘without reliance on a tap-changing transformer’.

The lack of clarity in the relationship between S5.2.5.1 and S5.2.5.13 also stems from the lack of a clear provision in clause S5.2.5.13 noting that the performance characteristics of any reactive power capability are subject to (and therefore do not themselves determine) the need for any such capability set in clause S5.2.5.1. Clarifying the relationship between the two clauses would avoid the potential for the requirements in clause S5.2.5.13 to act as a de-facto reactive power capability requirement.

The Commission’s draft rule changes the minimum access standard in S5.2.5.13 in line with AEMO’s proposal, but allowing the ability to rely on the use of a tap changing transformer to achieve the relevant requirements. It requires synchronous and asynchronous generating systems to have a voltage control system that:[453]

- regulates voltage at the connection point (or another agreed location on the power system or within the generating system) to within ±2% of the setpoint, and
- allows the voltage setpoint to be controllable in the range of at least 98% to 102% of normal voltage at the connection point (or the agreed location).

The Commission’s draft rule also includes a new general requirement in clause S5.2.5.13 that the performance characteristics of any reactive power capability agreed under that clause are to be consistent with the capability determined in clause S5.2.5.1.[454]

Current arrangements require generating units, or generating systems, operating in reactive power control modes other than voltage control (reactive power and power factor modes) to regulate reactive power in a manner that does not prevent the network service provider from achieving their requirements under the system standards,[455] and is sufficient to achieve the performance agreed in respect of related performance standards.[456] The Commission considers these requirements to represent a do-no harm based approach to a minimum access standard for generating system power factor and reactive mode performance characteristics.[457]

Consistent with the Commission's views on minimum access standard arrangements for voltage control, the Commission considers current arrangements do not clearly specify a range over which capabilities can be negotiated. This can therefore cause negotiating costs that are higher than they otherwise could be. As a result, the Commission considers clear minimum access standard arrangements should be specified in a manner which facilitates clear negotiation. The Commission’s draft rule therefore adopts AEMO’s proposed performance requirements for synchronous or asynchronous generator acting in power factor or reactive power control modes to:[458]

453 Clause S5.2.5.13(d)(2B)(i) and (ii) of the draft rule.

454 Clause S5.2.5.13(l) of the draft rule.

455 Clauses S5.1a.3 and S5.1a.4 of the NER.

456 Related performance standards include those agreed under the access standards in clauses S5.2.5.1, S5.2.5.2, S5.2.5.3, S5.2.5.4, S5.2.5.5, S5.2.5.6 and S5.2.5.12 of the NER.

457 Clause S5.2.5.13(d)(3) of the NER.

458 Clause S5.2.5.13(d)(3)(i) and (ii) of the draft rule.

- regulate reactive power or power factor at the connection point, or at an agreed location, to within 2% of its setpoint, and
- allow the reactive power or power factor setpoint to be continuously controllable across the reactive power capability range established in clause S5.2.5.1.

Voltage control via a droop characteristic

Stakeholders considered that current arrangements do not clearly allow for the treatment of voltage control through a reactive power droop characteristic.[459] The existing automatic access standard, and AEMO's proposed minimum access standard, both specify a voltage control tolerance margin and continuously controllable voltage range, but do not specifically refer to a droop control characteristic. TasNetworks considered a requirement to regulate voltage to within a tolerance may be interpreted as precluding the use of a droop response for voltage regulation.[460]

Current practice includes using a droop response characteristic as a common method of control, particularly given a number of generating systems and other voltage control assets located in close proximity. Given that managing nearby voltage control assets in this way is clearly desirable, the Commission considers the lack of clarity in the ability to specify control arrangements to operate using a droop characteristic is an issue that should be addressed.

Providing scope for voltage control through a droop characteristic can be achieved by qualifying the voltage control tolerance band as being in relation to a 'droop adjusted' setpoint. Voltage droop can be implemented by adjusting the voltage control setpoint of a control system that comprises the original setpoint plus an offset calculated in accordance with the droop setting. This 'droop adjustment' may be positive or negative and will have a magnitude in proportion to one of the controlled variables of the generating system, such as reactive power or reactive current. Droop adjustment is described in the formula below.

$$S_{droop} = S_o + D_{Offset}$$

$Where:$

$S_o = Original\ setpoint\ (in\ \%)$

$S_{droop} = Droop\ adjusted\ setpoint\ (in\ \%)$

$D_{Offset} = Droop\ (in\ \%) * Maximum\ reactive\ power\ capacity (in\ \%)/100$

To address this issue the Commission's draft rule amends the existing automatic access standard and includes in the minimum access standard qualification that the voltage control tolerance band is in relation to the droop adjusted setpoint (with that droop adjusted setpoint incorporating any voltage droop agreed with AEMO and the network service provider).[461]

459 Submissions to the consultation paper: TransGrid, p. 4; Powerlink, p. 8; TasNetworks, p . 15; Nordex, p. 7.

460 TasNetworks, submission to the consultation paper, p. 15.

461 Clauses S5.2.5.13(b)(2B)(i) and S5.2.5.13(d)(2B)(i) of the draft rule.

8.4 Step change response

This section discusses AEMO's proposed changes to the arrangements in clause S5.2.5.13 for how a generating system's reactive power control system must respond to a step change in voltage.

8.4.1 Technical background

The reactive power and voltage control provisions in clause S5.2.5.13 specify the requirements for a connecting generating system's reactive power control system response to a 5% step change in voltage.[462] Connecting generating systems are required to meet specified maximum rise and settling times, and to satisfy the requirement to remain 'adequately damped' during any response.[463] The term 'adequately damped' is defined in Chapter 10 of the NER and relates to the magnitude and oscillation frequency of any under-damped generating system response.[464]

Settling time, rise time, and damping behaviour are conceptually illustrated in Figure 8.2 below.

Figure 8.2 Rise and settling time given under-damped and over-damped response to a 5% step change in voltage

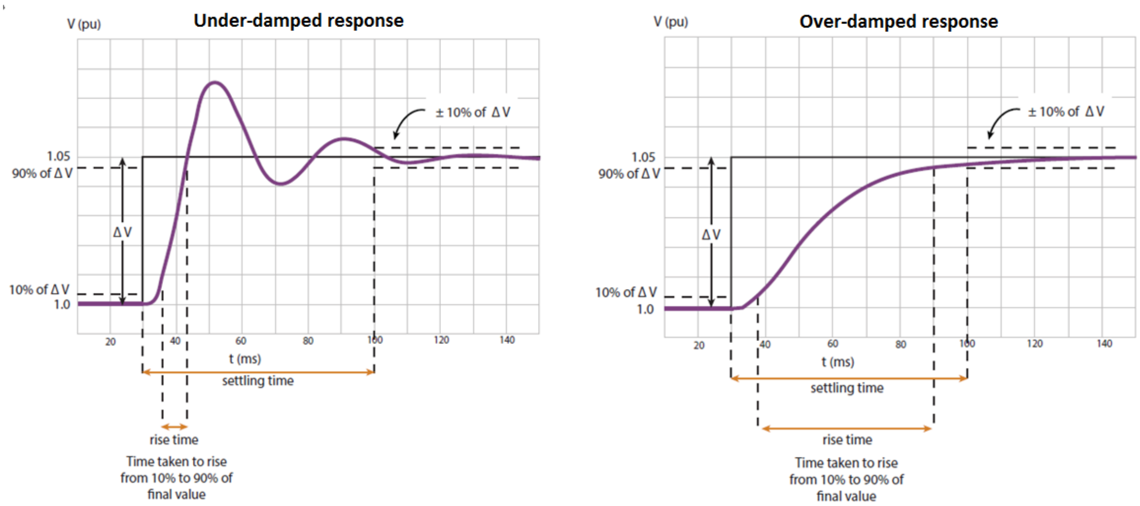


Figure 8.2 shows an under-damped response, which rises quickly (short rise time) but overshoots the target value causing oscillations in connection point voltage which take time to decay until they are within ± 10% of the target value (the settling time). An under-damped response is characterized by oscillations before settling at, or close to, the target value. In contrast, an over-damped response does not overshoot the target

462 Automatic access standard in clause S5.2.5.13(b)(vii) of the NER, minimum access standard in clause S5.2.5.13(d)(4)(iii) and (d)(5)(ii) of the NER.

463 Clause S5.2.5.13(b)(1)(i) and (d)(1)(i) of the NER.

464 Adequately damped means, in relation to a control system, when tested with a step change of a feedback input or corresponding reference, or otherwise observed, any oscillatory response at a frequency of: (a) 0.05 Hz or less, has a damping ratio of at least 0.4; (b) between 0.05 Hz and 0.6 Hz, has a halving time of 5 seconds or less (equivalent to a damping coefficient –0.14 nepers per second or less); and (c) 0.6 Hz or more, has a damping ratio of at least 0.05 in relation to a minimum access standard and a damping ratio of at least 0.1 otherwise.

value, instead rising more slowly but with no oscillation. This illustrates a trade-off between response speed and stability. A fast rise time can be achieved at the cost of an oscillatory response, while a longer rise time can avoid oscillation but at the cost of a slower response.

These characteristics of a generating system's response to a step change in voltage are influenced by the capabilities of the technology, and also by the power system conditions at its connection point. In particular, for a particular level of reactive power response, the extent to which a response is over or under-damped is influenced by the fault level of the connection point. Strong connection points, with high fault levels, will act to further dampen any generating system response while weaker connection points, with low fault levels, will exhibit a faster more oscillatory response.

The system security risks associated with oscillatory behaviour can be significant. Under the right set of circumstances, connection point voltage oscillations may lead to power system stability issues and associated system security risks. The trade-off between speed of response (rise time) and response stability (settling time) therefore needs to be carefully considered given the needs of the power system and conditions at the point of connection. The scale of the system security risks associated with oscillatory behaviour, relative to the risks associated with response speeds, may justify a bias towards allowing a slower response where this is needed to allow for an adequately damped response.

While a generator operating in power factor or reactive power control mode is not controlling reactive power to directly target a voltage setpoint, a synchronous generating system operating in power factor mode will produce a sympathetic reactive power response to a 5% voltage step change. When the step occurs, the plant's control system will respond by controlling reactive power back to the level specified by the target power factor and according to its active power output. While an inverter machine would not experience a sympathetic response in the same manner, it would also see a change in operating conditions which its control system would respond to. The step change test addressed in this section is therefore not specific to generating systems operating in voltage control mode. The Commission considers it equally applicable to generating systems operating in reactive power control modes other than voltage control mode.

8.4.2 Current arrangements

Both the automatic and minimum access standards in clause S5.2.5.13 specify maximum allowable rise and settling times separately for synchronous and asynchronous generating systems in response to a 5% voltage step change.[465]

These are shown in Table 8.2 and Table 8.3, which summarise current arrangements for synchronous and asynchronous generating systems, synchronised to the power system from an operating point where the voltage disturbance would not cause any limiting device to operate, under the automatic and minimum access standards of S5.2.5.13.

465 Note AEMO is not proposing any changes to requirements for synchronous generation.

Table 8.2 Rise times in response to a 5% voltage change

	Synchronous	Asynchronous
Automatic	None specified	2 seconds[466]
Minimum	None specified	None specified

Table 8.3 Settling times in response to a 5% voltage change

	Synchronous	Asynchronous
Automatic	5 seconds[467]	5 seconds[468]
Minimum	5 seconds[469]	7.5 seconds[470]

Requirements for a negotiated access standard in clause S5.2.5.13 require that:[471]

- a generating system that cannot meet the automatic access standard must demonstrate to the network service provider why that standard could not be reasonably achieved and propose a negotiated access standard, and
- the negotiated access standard must be at the highest level that the generating system can reasonably achieve, including by installation of additional dynamic reactive power equipment and through optimizing its control systems.

The current requirements for a negotiated access standard for clause S5.2.5.13 therefore bias negotiation towards the automatic access standard.

8.4.3 Rule change request

In its rule change request, AEMO was concerned that asynchronous generating systems are afforded additional settling time under the minimum access standard. AEMO also considered current arrangements do not require a fast enough stable response to changes in voltage, which they consider will be required to manage more volatile voltage conditions as the power system changes.[472]

To address these issues AEMO proposed in its rule change request the following changes to the minimum access standard in clause S5.2.5.13:[473]

466 Clause S5.2.5.13(b)(4)(vi) of the NER.

467 Clause S5.2.5.13(b)(3)(vii)(B) of the NER.

468 Clause S5.2.5.13(b)(4)(v)(A) of the NER.

469 Clause S5.2.5.13(d)(4)(iii) of the NER.

470 Clause S5.2.5.13(d)(5)(ii) of the NER.

471 Clause S5.2.5.13(e) – (f) of the NER.

472 AEMO AEMC project team call, 30 January 2018.

473 Rule change request, proposed rule, clause S5.2.5.13(d)(5)(ii).

- changing the allowable settling time for asynchronous generating systems from 7.5 seconds to 5 seconds (aligning the requirements with those for synchronous generating systems), and
- introducing a rise time requirement for asynchronous generating systems of 5 seconds, where previously there was no requirement.

AEMO did not propose changes to the arrangements for synchronous generating systems. Therefore, AEMO's proposal would harmonise arrangements for synchronous and asynchronous generation types in setting settling times but introduce a difference between technology types with respect to rise times.

On 11 May 2018 AEMO provided updated views as to recommended performance requirements applying under the automatic access standard to generating systems operating in power factor or reactive power control modes. These updated views included specific arrangements relating to rise and settling time performance. AEMO recommended the following as provisions of the automatic access standard applying to both synchronous and asynchronous generating systems:[474]

- With the generating system connected to the power system, and for a step change in setpoint, or a 5% voltage disturbance:
  - has settling times for active power, reactive power and voltage of less than 5 seconds, from an operating point where the voltage disturbance would not cause any limiting device to operate
  - has settling times for active power, reactive power and voltage of less than 7.5 seconds, when operating into any limiting device from an operating point where a voltage disturbance of 2.5% would just cause the limiting device to operate, and
  - has reactive power rise time of less than 2 seconds.

AEMO does not propose specific rise and settling time requirements under the minimum access standard for generating systems operating in reactive power or power factor control modes.

8.4.4 Stakeholder views

Stakeholders provided limited feedback on AEMO's proposed changes to the step change response requirements in clause S5.2.5.13.

Some stakeholders commented on the need for flexibility in response times to sufficiently address variable power system conditions.[475] TransGrid considered that the proposed reduction in settling time for asynchronous generating systems (from 7.5 seconds to 5 seconds) is problematic in weak system conditions when considered

474 AEMO email communication, 11 May 2018.

475 Submissions to the consultation paper: TransGrid, p. 4; GE Australia, p. 5.

against the need for a response that is adequately damped.[476] GE Australia observed:[477]

> "Reducing the settling time from 7.5s to 5.0s is fine so long as AEMO is able to coordinate and ensure all other voltage controllers in close electrical proximity are appropriately tuned and damped to ensure the reduced settling time could be achieved by the connecting generator. This may be an issue in weak grid areas where the voltage is very sensitive to small changes in reactive power output, hence the flexibility should be available in case a longer settling time is required. "

Respondents to the survey of equipment manufacturers did not raise concerns with the proposal to reduce the allowable settling time for asynchronous generating systems to 5 seconds. One solar PV inverter manufacturer however noted their equipment operates very close to the maximum of 5 seconds due to the speed of power analyser systems it uses, and which are typically used throughout the industry.

Stakeholders did not comment on the proposal to introduce for asynchronous generating systems a rise time of 5 seconds in the minimum access standard.

8.4.5 Analysis and conclusions

Box 8.4 Draft rule: Step change response

The Commission's draft rule:

- retains current arrangements for asynchronous generating system rise and settling times in the minimum access standard in response to a 5% step change in voltage[478]
- increases the allowable settling time in the minimum access standard for synchronous generating systems to 7.5 seconds in response to a 5% step change in voltage which aligns this with the existing requirements for asynchronous generating systems,[479] and
- specifies automatic access standard arrangements for asynchronous and synchronous generators operating in reactive power or power factor control modes to:
  - have settling times for active power, reactive power and voltage of less than 5 seconds, from an operating point where the voltage disturbance would not cause any limiting device to operate[480]
  - have settling times for active power, reactive power and voltage of less than 7.5 seconds, when operating into any limiting device from an

476 TransGrid, submission to the consultation paper, p. 4.

477 GE Australia, submission to the consultation paper, p. 5.

478 Clause S5.2.5.13(d)(5)(ii) of the NER.

479 Clause S5.2.5.13(d)(4)(iii) of the draft rule.

480 Clause S5.2.5.13(c1)(3)(i) of the draft rule.

	operating point where a voltage disturbance of 2.5% would just cause the limiting device to operate,[481] and
—	have a reactive power rise time of less than 2 seconds,[482]

This section sets out the Commission's analysis and conclusions on the issues raised by AEMO and stakeholders. The analysis includes considering whether current arrangements give rise to a material system security issue and whether different requirements for synchronous and asynchronous generating systems are appropriate.

Materiality of system security issues

AEMO considered a faster response to changes in voltage within the normal operating range would benefit power system security, particularly as the power system evolves in a way that the reduction in system strength will generally make controlling voltages more difficult in many parts of the power system.

Current arrangements appear to provide flexibility to specify a level of performance appropriate for the range of conditions applying at different connection points. The Commission considers it is appropriate to retain the flexibility that the current arrangements provide for a slower response where this is justified by the power system conditions at the connection point.

The Commission considers it is appropriate to retain the flexibility that the current arrangements provide for a slower response where this is justified by the power system conditions at the connection point. While a fast response is desirable, a fast response is not preferable when it could lead to oscillatory behaviour in some cases. Where a generating system can provide a faster response than is required under the minimum access standard, the Commission considers the current arrangements, and proposed changes to the negotiation process, bias toward providing as fast a response as possible considering response stability. Further, if AEMO or a network service provider considers a proposed response speed would adversely affect, respectively, power system security or the quality of supply to other network users, they may reject it.

The Commission therefore considers it is appropriate to retain the maximum allowable settling time for asynchronous generating systems at 7.5 seconds. There are cases where the flexibility to specify a longer settling time is desirable, and there is no clearly identified system security need to reduce the settling time from 7.5 to 5 seconds.

Arrangements for different technologies

In addition to the Commission's conclusion that AEMO's proposal does not provide a material system security benefit, the Commission does not see a basis for reducing the settling time or introducing a new settling time limit for asynchronous generating systems. The Commission does however, agree that the arrangements should be harmonised for synchronous and asynchronous generating systems.

481 Clause S5.2.5.13(c1)(3)(ii) of the draft rule.

482 Clause S5.2.5.13(c1)(3)(iii) of the draft rule.

The Commission notes that the need for flexibility identified by stakeholders is not in relation to an issue specific to synchronous or asynchronous generating systems. Instead the need for flexibility in the allowable settling time is related to system conditions, particularly and the challenges of managing weak system conditions. This is a challenge that applies equally to all technologies. As a result the Commission does not consider different arrangements for synchronous and asynchronous generating systems to be justified. Indeed, requirements for synchronous generating systems to have the shorter settling times specified under the current arrangements could limit their ability to connect under weaker power system conditions. The need for longer settling times to account for the power system conditions in some locations therefore also justifies allowing additional settling time for synchronous generating systems.

As discussed in Chapter 3, the Commission considers that it is desirable for the access standards to be expressed in the same way for all technology types, unless there are inherent physical differences between technology types that necessitate different treatment. The Commission does not consider this to be the case in this instance.

The Commission's draft rule therefore requires both synchronous and asynchronous generating systems to meet the same settling time of 7.5 seconds in response to a step change in voltage.[483] This is appropriate because of the value of retaining flexibility to specify longer settling times in some cases, noting that in all cases settling times will be as fast as possible, and also due to the absence of a clearly identifiable system security risk associated with a settling time of 7.5 seconds rather than 5 seconds.

The Commission notes that current arrangements under the automatic access standard are specific to generating systems operating in voltage control mode. Therefore the Commission recognises the gap in the existing automatic access standard applying to rise and settling times for generating systems operating in reactive power control modes other than voltage control. AEMO's views as to rise and settling time requirements applying to generating systems under the automatic access standard apply to both synchronous and asynchronous generating systems as are in line with existing requirements under the automatic access standard for voltage control. For these reasons the Commission considers AEMO's recommendation as clarifying arrangements in a manner which supports power system security. The Commission's draft rule therefore:

- specifies automatic access standard arrangements for asynchronous and synchronous generators operating in reactive power or power factor control modes to:
  - have settling times for active power, reactive power and voltage of less than 5 seconds, from an operating point where the voltage disturbance would not cause any limiting device to operate[484]
  - have settling times for active power, reactive power and voltage of less than 7.5 seconds, when operating into any limiting device from an operating

483 Clauses S5.2.5.13(d)(5)(ii) of the NER and S5.2.5.13(d)(4)(iii) of the draft rule.

484 Clause S5.2.5.13(c1)(3)(i) of the draft rule.

point where a voltage disturbance of 2.5% would just cause the limiting device to operate,[485] and

— have a reactive power rise time of less than 2 seconds.[486]

The arrangements proposed under the minimum access standard applying to synchronous and asynchronous generating systems remain applicable to generating systems operating in all reactive power control modes.

485 Clause S5.2.5.13(c1)(3)(ii) of the draft rule.

486 Clause S5.2.5.13(c1)(3)(iii) of the draft rule.

9 Reactive current response during disturbances

Box 9.1 Overview

AEMO considered that current arrangements in S5.2.5.5 for reactive current response during disturbances are not adequate to address the increasing difficulty of managing voltage levels across the power system caused by the changing generation mix.

To address this risk, AEMO proposed a prescriptive set of reactive current response characteristics that would mostly apply to all connecting generating systems (synchronous and asynchronous). AEMO's proposal specifies requirements for the magnitude of response, response thresholds, response duration, response speed, response limits, as well as a set of supporting requirements related to measurement.

Current arrangements include a specified response for reactive current injection (and not absorption) under the automatic access standard. No other specific response requirements are specified under either the minimum or automatic access standards.

Current arrangements appear to be appropriate for connecting synchronous generating systems that provide a reactive current response during disturbances with characteristics that are inherent to the electro-mechanical nature of the machines. However, current arrangements are not appropriate for connecting asynchronous generating systems. This is because the response of asynchronous generating systems is not inherent and has to be defined (or coded) into the control equipment for the generating system. Without clear definition in the NER to guide how these responses are coded into the control equipment, there is a risk that asynchronous generating systems may not provide sufficient reactive current response (injection or absorption) during disturbances to support the security of the power system.

The Commission's draft rule for asynchronous generating systems broadly reflects the arrangements proposed by AEMO, however providing more flexibility to account for different power system conditions and equipment limitations.

The Commission’s draft rule retains current arrangements for synchronous generating systems as their reactive current response to faults is physically inherent and set by the fundamental design of the generating unit. As a physically inherent response, synchronous generating systems have limited flexibility to alter the reactive current response during disturbances without incurring significant additional cost. The draft rule however includes a new response limit to better align the existing automatic access standard with synchronous generating system capabilities and power system needs.

This Chapter discusses AEMO's proposed changes to the NER that relate to requirements for connecting generating systems to inject or absorb reactive current during certain disturbances.[487] This is distinct from the discussion in Chapter 7 on the amount of reactive power capability required from a connecting generating system, and Chapter 8 on how that reactive power is used during normal operating conditions.

The Chapter sets out:

- technical background
- the current arrangements in the NER
- the issues raised by AEMO with the current arrangements and changes proposed to address those issues
- stakeholder views, and
- analysis and conclusions.

9.1 Technical background

Generating systems can provide fast reactive current injection and absorption to support power system voltages during disturbances, such as those caused by faults and other contingency events. This fast-acting support is important to prevent transient voltage instability and potential collapse, as well as to help the power system recover from the disturbance.

Transient voltage instability and collapse is a major threat to power system operation. It can trigger cascading failures and wide-spread blackouts. Transient voltage instability can be caused by the behaviour and demand for reactive power by some power system elements, such as induction motors, during and immediately following disturbances.

Reactive power (described in Chapter 7) is the product of voltage and reactive current. Under fault conditions voltage can rapidly fall to very low levels. As a result, a generating system is not able to control the amount of reactive power injected or absorbed during a fault, but will still be able to control its injection or absorption of reactive current. It is therefore appropriate for voltage support obligations during disturbances to require a reactive *current* response from a generating system, and inappropriate to require a reactive *power* response because this is outside of the control of the generating system. As a result, obligations to support voltage during disturbances, discussed in this Chapter, are specified in terms of reactive current rather than reactive power.

Synchronous and asynchronous generating systems produce reactive current response during faults in very different ways, due to the physical differences between the technologies. An understanding of those physical differences, and how it translates into different characteristics of reactive current response during disturbances, is required for setting appropriate arrangements in the NER for reactive current response.

487 S5.2.5.5 also deals with other matters during disturbances, such as certain requirements to maintain continuous uninterrupted operation when faced with certain disturbances, discussed in Chapter 10.

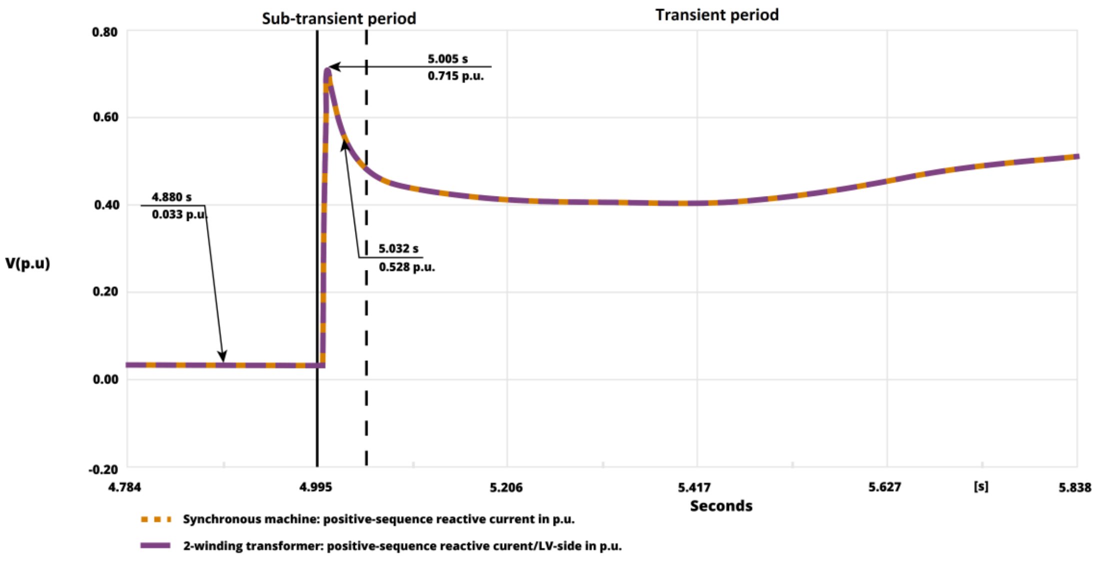
9.1.1 Synchronous generating system response

Reactive current response during disturbances has traditionally been provided by synchronous generating systems as an inherent physical response characteristic of the plant. Synchronous generating systems provide reactive current in response to faults during sub-transient, transient, and steady state time periods as follows:

- *Sub-transient period:* this period is the first few 50 hertz (Hz) cycles after the fault, and is generally limited to 50 milliseconds (ms). During this period a synchronous generating system has an uncontrolled response which produces a very high initial reactive current,
- *Transient period*: this period is between 50 ms and 3 seconds, following the sub transient period. In the transient period the high initial fault currents rapidly decay. The synchronous generating system's automatic voltage regulator is engaged during this period to stabilize the reactive component of the fault current and bring it to its steady state level.[488]
- *Steady-state period*: this is the time period beyond 3 seconds. This period reflects a return to normal operating conditions.

Figure 9.1 illustrates the typical reactive current response from a synchronous generating system during each of these time periods in response to a fault that sees a decline in voltage at the connection point from 100% to 75% of normal voltage.

Figure 9.1 Example of a synchronous generating system reactive current response to a fault at 5 seconds



Faults are limited in duration by protection clearance times in the networks that make up the power system. The system standards in the NER specify fault clearance times

488 A synchronous generating system's automatic voltage regulation system is an element of the generating system's excitation system which controls the current flowing through the rotor windings, the internal EMF of the machine, and by extension the reactive current injected or absorbed by the generating system to affect generating system terminal voltage.

between 80 and 430 ms.[489] Given this, a synchronous generating system's response during the sub-transient and transient time periods is the most relevant to the provision of reactive current response during faults. A synchronous generating system's response following these time-periods however remains important to restoring the power system to normal operating conditions following the clearance of a fault.

As an uncontrolled response, the magnitude of synchronous generating system response during the sub transient and initial transient period is fixed by the design of the plant. The physical design of the generating unit's damper windings, field windings, and rotor body determine the sub transient reactance of the generating system, and is the principal factor affecting the amount of reactive current that is initially injected or absorbed by a synchronous generating system.[490]

There is only very limited ability to tailor the magnitude of reactive current response through plant design. Indeed, redesign of the synchronous generating system to change its reactive current response during disturbances would likely be very costly, could sacrifice other performance characteristics, and in any event would not markedly improve power system security.

This electro-mechanically inherent response of synchronous generating systems is very different to the specifically defined response possible through asynchronous generating system inverter controls.

Asynchronous generating system response

As existing synchronous generating systems retire and are replaced by asynchronous generating systems, important reactive current response during disturbances will be lost unless additional response is provided by other sources, such as asynchronous and inverter based generating systems.

Reactive current response during a disturbance by an inverter connected generating system is controlled by the power electronics used in the inverter and its corresponding control system. Modern inverters are equipped with what are known as 'fault ride through modes' that can provide fast acting reactive current response during disturbances. Fault ride through modes include high-voltage ride through (HVRT) and low-voltage ride through (LVRT) modes. These modes provide reactive current response during disturbances that helps address the risks to system security of short term voltage instability and voltage collapse.[491]

While modern inverter connected plant are capable of providing reactive current response during faults, this inverter controlled response is different to the physical response from a synchronous generating system. Inverter controls require specific

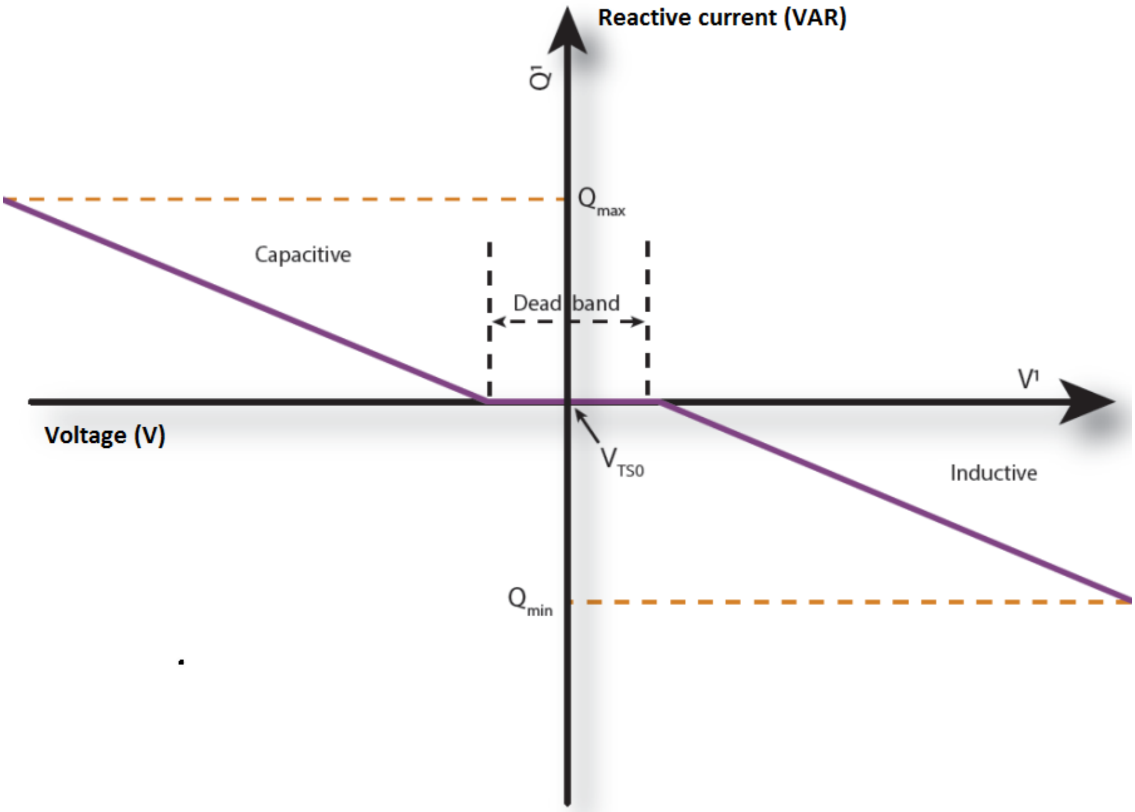
489 The NER specify maximum clearance times for breakers for various nominal voltage levels on the power system, fault locations and for backup protection systems in Table S5.1a.2 in clause S5.1a.8 (Fault clearance times).

490 Reactance is the non-resistive component of impedance in an AC circuit, arising from the effect of inductance or capacitance or both and causing the current to be out of phase with the electromotive force causing it.

491 Lammert G. et al, *Impact of Fault Ride Through and Dynamic Power Support of Photovoltaic Systems on Short Term Voltage Stability*, 2017 IEEE Manchester PowerTech, available from: http://ieeexplore.ieee.org/document/7980926.

settings to determine response characteristics, such as response magnitude, speed and thresholds. As such, the nature of the reactive current response from an asynchronous generating system is fundamentally a property of the settings of its control systems (i.e. the algorithms in the software) rather than an uncontrolled physical reaction to fault conditions due to electro-mechanical characteristics of the equipment (which is the case for synchronous generating systems).

Figure 9.2 Asynchronous generating system control system settings to produce a reactive current response during a fault



Asynchronous generating system control systems provide reactive current response during faults using settings like those illustrated in Figure 9.2. There are four fundamental elements to these settings:

- *The magnitude of the desired response*. This response magnitude is determined by the slope of the reactive injection/absorption curves. It is the amount of reactive current that is injected or absorbed for any measured change in voltage
- *The threshold at which response is triggered.* The response thresholds are the voltage levels that trigger the injection or absorption of reactive current in a 'ride through mode' response. Figure 9.2 shows this as occurring at the edges of a defined 'dead-band'
- *Limits on the maximum level of response.* The maximum response level is the maximum capability to inject or absorb of reactive current which can be required from an asynchronous generator. Figure 9.2 represents these limits as Qmax and Qmin, and

- *Response speed and duration*. While not represented in Figure 9.2, there are also a set of ancillary settings required to define limits on the reactive power response. This includes the required speed of response and the length of time for which response must be sustained.

Each of these four core elements are present in AEMO's proposed changes to the arrangements for reactive current response during disturbances, and are explored in detail in this Chapter.

The reactive current response characteristics of asynchronous generating systems are also affected by the overall generating system control architecture. Control architecture in this sense describes the relationship between generating system level Power Plant Control (PPC) and the local control embedded in inverters at each individual turbine or solar PV module string.

The PPC acts as the 'brain' that centrally co-ordinates the response of each element of the generating system. It does this by reading measurements from the connection point (and other locations within the generating system) and sending instructions (active and reactive power setpoints) out to all the inverters it controls. PPC based control is referred to as 'closed loop'. However, when the generating system goes into 'ride through mode' due to a fault, the central PPC relinquishes control, and each inverter individually takes over control of its own response. In this case each inverter locally measures and responds to changes in voltage. Inverter response is generally implemented as 'open loop' control.

As noted above, a PPC response is generally 'closed loop' in nature, and an individual inverter response is generally 'open loop' in nature:

- *Closed loop* control uses a feedback loop to dynamically re-calibrate the control action. The PPC performs this task. PPC control is generally used under normal operating conditions. It is generally a slower response than an open loop response, however it is also more stable and able to be sustained for longer. The advantage of closed loop is that it adjusts the control action to deliver the required output, and

- *Open loop* control response occurs without reference to a feedback signal from the output. Open loop control can be fast, but in the case of an inverter the response may be limited in duration and stability. HVRT and LVRT responses are generally implemented through an open loop control without PPC co-ordination.

The trade-off between open loop duration limits and closed loop speed limits is an issue explored in section 9.5.4.

An asynchronous generating system's response to fault conditions requires a transition between slower closed loop PPC control (which is used during normal operating conditions but can also be used for some disturbance conditions) and fast open loop inverter control. While there is a range of ways this transition may be implemented, the Commission understands a common approach to be:

- *Prior to a fault*, under normal operating conditions, a generating system's reactive current is managed by the PPC which sends co-ordinating signals to each individual inverter to inject reactive power in response to under voltage or absorb reactive power in response to over voltage. This response is according to the reactive power capability in clause S5.2.5.1 and reactive power control mode in clause S5.2.5.13

- *On the occurrence of a fault* each inverter individually enters ride through mode by passing certain voltage thresholds measured at its inverter terminals. When inverters sense a fault (via a change in voltage) they take over control from the PPC and enter HVRT or LVRT mode, responding according to their open loop control settings, and
- *Once the fault has cleared* and normal operating conditions achieved, each inverter hands control back to the slower PPC which will resume co-ordination of inverter reactive power output to regulate voltage (or act in another reactive power mode as appropriate).

It should be noted that the voltage levels at the inverter terminals, which dictate the inverter response, are generally not the same as the voltage levels at the connection point. The inverter terminal voltage levels will vary relative to the connection point depending on whether the generating system is injecting or absorbing reactive current immediately prior to the fault, and also the transformation ratio of the high voltage to low voltage (HV/LV) transformer, if the connection point is on the HV side of the transformer. This has implications for the setting of reactive current response thresholds and will be considered further in section 9.5.5.

Synchronous and asynchronous generating systems are both able to produce a reactive current response to a fault that supports power system voltages and security. The manner in which each technology achieves this, and therefore certain characteristics of the response, are fundamentally different. These differences and their implications for arrangements under the NER were explored in section 9.1

9.2 Current arrangements

There are currently arrangements covering the provision of reactive current response during disturbances under the automatic access standards in clauses S5.2.5.13 and S5.2.5.5.

The automatic access standard in clause S5.2.5.13 requires a generating system to have a control system that "regulates voltage in a manner that helps to support network voltages during faults and does not prevent the Network Service Provider from achieving the requirements of clause S5.1a.3 and S5.1a.4."[492] No further guidance is provided regarding the manner and extent to which this 'help' is required to be provided.

The minimum access standard in clause S5.2.5.13 does not specify any comparable requirement for the regulation of voltage through the provision of reactive current response during faults.

The automatic access standard in clause S5.2.5.5 requires that a generating system and each of its generating units, in respect of the types of fault listed in the first column in

492 Clause S5.2.5.13(b)(3)(iii) (synchronous generating systems) and clause S5.2.5.13(b)(4)(ii) (asynchronous generating systems) of the NER. Clauses S5.1a.3 and S5.1a.4 set out the system standards to which network service providers are required to plan and operate their networks.

Table 9.1 below, must (subject to any changed power system conditions or energy source availability beyond the generating system's reasonable control) supply to, or absorb from, the network:

- to assist the maintenance of power system voltages during the application of the fault, capacitive reactive current of at least the greater of its pre-disturbance reactive current and 4% of the maximum continuous current of the generating system including all operating generating units (in the absence of a disturbance) for each 1% reduction (from its pre-fault level) of connection point voltage during the fault.[493]

For the minimum access standard in S5.2.5.5, there is no requirement for reactive current injection during faults, although there is a requirement (subject to any changed power system conditions or energy source availability beyond the generating system's reasonable control) to supply or absorb leading or lagging reactive power sufficient to ensure that the connection point voltage is within the range for continuous uninterrupted operation agreed in clause S5.2.5.4 once the faulted element has been disconnected. This is in respect of the types of fault listed in the second column in Table 9.1 below.

Table 9.1 Existing automatic access standard fault types relevant to a generating system's reactive response

Automatic access standard[494]	Minimum access standard[495]
Three phase fault in a transmission system[496]	N/A
Two phase to ground, phase to phase or phase to ground fault in a transmission system[497]	Single phase to ground, phase to phase or two phase to ground fault in a transmission system[498]
Three phase, two phase to ground, phase to phase, or phase to ground fault in a distribution network[499]	Single phase to ground, phase to phase or two phase to ground fault in a distribution network[500]

493 Clause S5.2.5.5(b)(2)(i) of the NER. It should be noted that the existing automatic access standard requirement implies a maximum response magnitude of 400% of the maximum continuous current of the generating system. This is because a generating system is required to manage faults down to 0% of normal voltage.

494 Clause S5.2.5.5(b)(1)(ii-iv) of the NER.

495 Clause S5.2.5.5(c)(1)(ii and iii) of the NER.

496 Cleared by all relevant primary protection systems.

497 Cleared in the longest time expected to be taken for a relevant breaker fail protection system to clear the fault; or if a protection system referred to above is not installed, the greater of the time specified in column 4 of Table S5.1a.2 (or if none is specified, 430 milliseconds) and the longest time expected to be taken for all relevant primary protection systems to clear the fault.

498 Cleared in the longest time expected to be taken for all relevant primary protection systems to clear the fault unless AEMO and the Network Service Provider agree that: the total reduction of generation in the power system due to that fault would not exceed 100 MW; there is unlikely to be an adverse impact on quality of supply to other Network Users; and there is unlikely to be a material adverse impact on power system security.

The current arrangements in both S5.2.5.13 and S5.2.5.5 therefore provide limited detail on the specific reactive current response that is expected of a generating system during a disturbance. This provides a high level of flexibility that is consistent with the need to account for the inherent physical characteristics of the reactive power response from synchronous generating systems.

9.3 Rule change request

9.3.1 Issues raised by AEMO

In its rule change request, AEMO considered that inadequate reactive power support would increase the risk of transient voltage instability and a reduced ability for the power system to recover from disturbances.[501] AEMO further considered sufficient dynamic reactive power support close to each connection point was important to prevent the propagation of voltage dips across the network and to reduce the risk of consequential voltage instability or widespread disconnection of generating systems.[502]

AEMO considered that current arrangements in the access standards in the NER for reactive current injection and reactive current response requirements are insufficient. AEMO states this is because the minimum access standard does not require a generating system to provide any form of reactive power response during a disturbance.[503]

AEMO stated that, without provision of reactive current during disturbances, the faulted part of the power system is at risk of voltage instability and thus losing synchronism with the remainder of the power system.[504] This would mean disturbances could be observed across a wider area, risking the disconnection of more generating systems. In such circumstances, loss of supply may be experienced across a wider area than necessary.[505]

AEMO considered the most efficient way to manage generating system resilience to, and the broader power system security impact of, disturbances, is to source greater reactive current capabilities during disturbances from connecting generating systems.[506] AEMO considered its proposed reactive capabilities (which it proposed should apply to all connecting generating systems) are similar to the inherent response characteristics of synchronous generating systems discussed above. AEMO argued this

499 Cleared in the longest time expected to be taken for the breaker fail protection system to clear the fault; or if a protection system referred to above is not installed, the greater of 430 milliseconds and the longest time expected to be taken for all relevant primary protection systems to clear the fault.

500 Ibid.

501 Rule change request, p. 24.

502 Ibid.

503 Ibid.

504 Ibid.

505 Ibid.

506 Ibid.

capability has not been explicitly required under the existing access standards because it is part of the inherent or assumed behaviour of traditional synchronous generation.[507]

9.3.2 AEMO's proposed changes

AEMO therefore proposed a new set of requirements be included in clause S5.2.5.5 specifying reactive current injection and absorption during disturbances for both synchronous and asynchronous generating systems. The characteristics of these requirements relate to:

- *magnitude of response* (sometimes also referred to as the 'slope', or 'gain' of the response), with requirements that specify how much reactive current to inject or absorb for any given change in voltage
- *response thresholds*, with requirements for when the reactive current response begins and ends
- *response duration*, with requirements for the length over which the response must be sustained
- *response speed*, with requirements for the maximum allowable response rise and settling times
- *response limits*, which specify the maximum response required, and
- *ancillary requirements*, with requirements for the location and method of response measurement and a limit to the reactive active power consumed on occurrence of a fault.

AEMO propose each of the above elements, with the exception of response limits, as applying to both synchronous and asynchronous generating systems. Each of these aspects is described in the sections below.

Response magnitude and thresholds

AEMO's proposal specifies response magnitudes and thresholds for reactive current injection and absorption in both the automatic and minimum access standard in clause S5.2.5.5. They are:

- **Automatic access standard** – Subject to any changed power system conditions or energy source availability beyond the generator's reasonable control, a generating system and each of its generating units, in respect of the types of fault described in subparagraphs (1)(ii) to (iv),[508] must supply to or absorb from the network:
  - to assist the maintenance of power system voltages during the application of the fault:
    1) *capacitive reactive current* in addition to its pre-disturbance level of 4% of the maximum continuous current of the generating system including all operating generating units (in the absence of a

507 Ibid.

508 That is, the faults described in column 1 of Table 9.1 above. See clause S5.2.5.5(b)(1)(ii-iv) of the NER.

disturbance) for each 1% reduction of connection point voltage below 90% of normal voltage, and

2) *inductive reactive current* in addition to its pre-disturbance reactive current and 6% of the maximum continuous current of the generating system including all operating generating units (in the absence of a disturbance) for each 1% increase of connection point voltage above 110% of normal voltage,

— during the disturbance and maintained until the connection point voltage recovers to between 90% and 110% of normal voltage.[509]

- **Minimum access standard** – Subject to any changed power system conditions or energy source availability beyond the generator's reasonable control a generating system and each of its generating units must, in respect of the types of fault described in subparagraphs (c)(1)(ii) and (iii),[510] supply to, or absorb from, the network:

  — to assist the maintenance of power system voltages during the fault:

  1) *capacitive reactive current* in addition to its pre-disturbance level of 2% of the maximum continuous current of the generating system and each of its operating generating units (in the absence of a disturbance) for each 1% reduction of connection point voltage below 90% of normal voltage during the fault, and

  2) *inductive reactive current* in addition to its pre-disturbance reactive current and 6% of the maximum continuous current of the generating system and each of its operating generating units (in the absence of a disturbance) for each 1% increase of connection point voltage above 110% of normal voltage during the disturbance, and

  — during the disturbance and maintained until connection point voltage recovers to between 90% and 110% of normal voltage.[511]

AEMO's proposed response magnitudes for reactive current injection vary between the automatic and minimum access standards (4% and 2% respectively),[512] but the magnitude of reactive current absorption (6%),[513] and the thresholds of response (90% of normal voltage at the connection point for reactive current injection and 110% of normal at the connection point for reactive current absorption) are the same under both

509 Rule change request, proposed rule, clauses S5.2.5.5(b)(2)(i).

510 That is, the faults described in column 2 of Table 9.1 above. See clause S5.2.5.5(c)(1)(ii and iii) of the NER.

511 Rule change request, proposed rule, clauses S5.2.5.5(c)(2)(i).

512 Response as a percentage of the maximum continuous current of the generating system for each 1% decline in connection point voltage.

513 Response as a percentage of the maximum continuous current of the generating system for each 1% increase in connection point voltage.

the automatic and minimum access standard. The response threshold values reflect the boundaries of the continuous operating voltage band.[514]

AEMO considered it is important to have a more aggressive response for reactive current absorption. Over voltages can have severe consequences for equipment connected to the power system and over-voltage requirements for continuous uninterrupted operation only go to 130% of normal voltage. This is less than the scope for under-voltages which can decline to zero at the connection point.[515] AEMO also expressed specific concerns about over-voltage management in certain parts of the NEM, such as in South Australia and Queensland, which they consider justify an aggressive level of reactive current absorption during disturbances.[516]

Response duration

AEMO proposed that reactive current responses under both the automatic and minimum access standards be sustained during the disturbance and maintained until the connection point voltage recovers to between 90% and 110% of normal voltage (the continuous operating voltage range).[517]

AEMO's proposal is an open ended requirement, which effectively makes the over-voltage and under-voltage requirements for continuous uninterrupted operation in clause S5.2.5.4 the response duration limits. In the event of a persistent over or under-voltage event the generating system will be required to sustain response until it is no longer required to maintain continuous uninterrupted operation and accordingly disconnects.[518] The implications of this link to S5.2.5.4 are further considered in section 9.5.4.

Response speed

AEMO proposed specific reactive current injection and absorption response times and characteristics during disturbances, including:

- a rise time of no greater than 30 ms[519]
- a settling time of no greater than 60 ms,[520] and

514 The continuous operating voltage band is defined in S5.1a.4 - Except as a consequence of a contingency event, the voltage of supply at a connection point should not vary by more than 10 percent above or below its normal voltage, provided that the reactive power flow and the power factor at the connection point is within the corresponding limits set out in the connection agreement.

515 130% of normal voltage is the maximum level of continuous uninterrupted operation required for over-voltage under the system standard for power frequency voltage in clause - S5.4a.1.

516 AEMO expressed this concern in an AEMO-AEMC project teleconference on 8 March 2018.

517 Rule change request, proposed rule, clauses S5.2.5.5(b)(2)(i) and S5.2.5.5(c)(2)(i).

518 Clause S5.2.5.4 of the NER specifies the duration over which a generating system must remain in continuous uninterrupted operation with reference to the extent of over or under-voltage at the connection point.

519 Rise time is defined in clause S5.2.5.13(a) of the NER as "in relation to a step response test or simulation of a control system) the time taken for an output quantity to rise from 10% to 90% of the maximum change induced in that quantity by a step change of an input quantity."

- a requirement that the response must be adequately damped.[521]

The rise and settling times relate to the speed of reactive current response and settling at the commencement of a fault while the requirement to remain adequately damped relates to response stability.[522] This is discussed further in section 9.5.4.

Response limits

AEMO proposed the following limits applying to the reactive current response required from asynchronous and synchronous generating systems:[523]

- the maximum continuous current of an *asynchronous* generating system including all operating generating units, and
- 250% of the maximum continuous current of a *synchronous* generating system including all operating generating units.[524]

These limits represent the greatest level of reactive current injection or absorption that can be required from a generating system in response to a disturbance irrespective of further changes in the connection point voltage. AEMO considered the absence of defined limits to maximum reactive response required under the existing automatic access standard implies a maximum required response of 400% of the maximum continuous current of the generating system. AEMO considered this level of response to be unachievable for both synchronous and asynchronous generating systems.[525] This issue is considered further in section 9.5.2.

AEMO's proposed limits, at 250% (for synchronous generating systems), and 100% (for asynchronous generating systems), are illustrated in Figure 9.3 respectively. Issues associated with AEMO's proposed response limits are discussed in section 9.5.2.

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520 Settling time is defined in clause S5.2.5.13(a) of the NER as "in relation to a step response test or simulation of a control system) the time measured from initiation of a step change in an input quantity to the time when the magnitude of error between the output quantity and its final settling value remains less than 10% of: (1) if the sustained change in the quantity is less than half of the maximum change in that output quantity, the maximum change induced in that output quantity; or (2) the sustained change induced in that output quantity.

521 'Adequately damped' is defined in Chapter 10 of the NER as "in relation to a control system, when tested with a step change of a feedback input or corresponding reference, or otherwise observed, any oscillatory response at a frequency of: (a) 0.05 Hz or less, has a damping ratio of at least 0.4; (b) between 0.05 Hz and 0.6 Hz, has a halving time of 5 seconds or less (equivalent to a damping coefficient -0.14 nepers per second or less); and (c) 0.6 Hz or more, has a damping ratio of at least 0.05 in relation to a minimum access standard and a damping ratio of at least 0.1 otherwise.

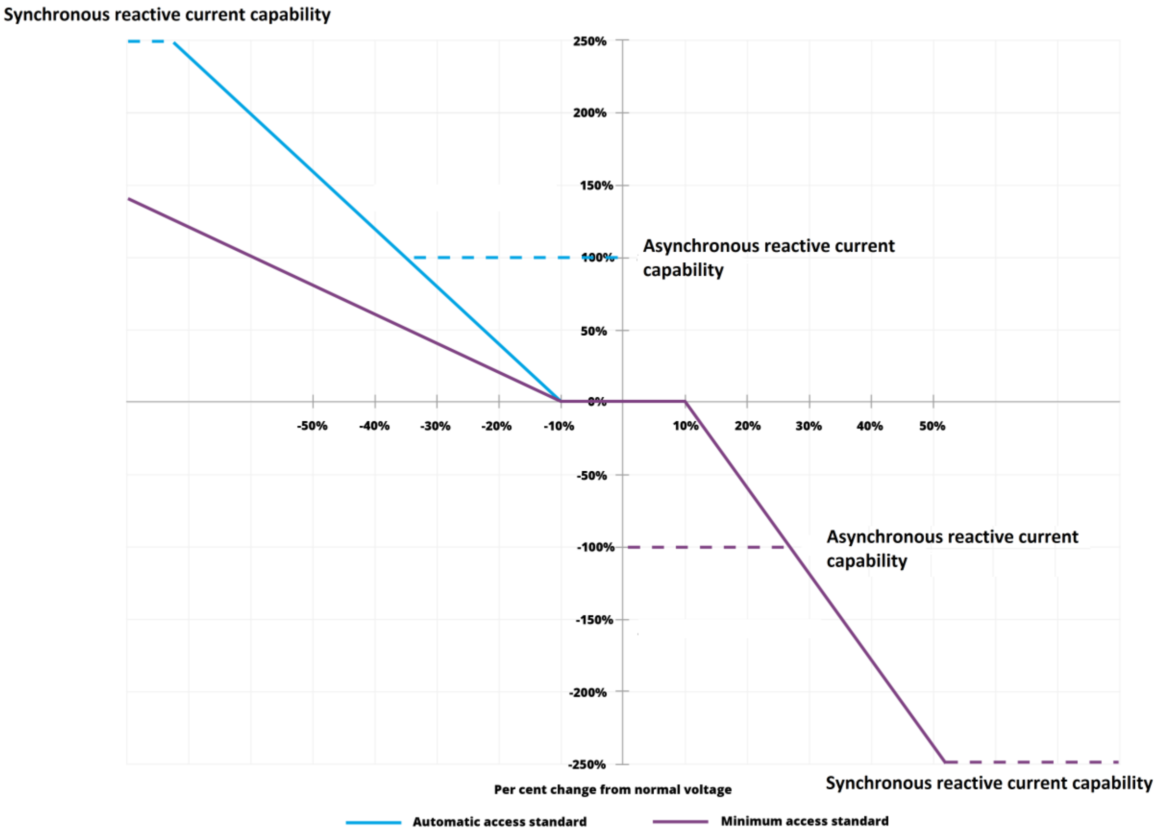
522 The Commission notes under AEMO's proposed amendments, the definitions of rise time and settling time are proposed to be moved from clause S5.2.5.13 to the Chapter 10 glossary (given the term is proposed to be used in both clauses S5.2.5.5 and S5.2.5.13). AEMO also proposes amending the definitions of rise time and settling time to replace the words "in relation to a step response test or simulation of a control system" with "in relation to a control system".

523 These limits are proposed as 'general requirements' applying to all registered performance standards registered in clause S5.2.5.5 rather than provisions specific to the automatic or minimum access standard.

524 Rule change request, proposed rule, clause S5.2.5.5(i)(i)(A and B).

525 Advice provided to the Commission by AEMO, 3 May 2018.

Figure 9.3 AEMO's proposed synchronous and asynchronous generating system reactive current response capability requirements



In addition to the reactive current response limits shown above, AEMO proposed a requirement limiting the consumption of active and reactive power immediately on the occurrence of a fault. This requirement limits active and reactive power consumption immediately upon the occurrence of the fault to 5% of the maximum continuous current of the generating system, and is limited to the duration of the rise time for reactive power and 20 ms for active power.[526] Further discussion is provided in section 9.5.6.

Additional requirements related to measurement

AEMO proposed a set of additional requirements relating to the location and method of measuring reactive current response. AEMO proposed:

- the reactive current contribution required may be calculated using phase to phase, phase to ground, or sequence components of voltage.[527] When using sequence components, the ratio of negative-sequence to positive-sequence current injection

526 Rule change request, proposed rule, clause S5.2.5.5(i)(v) and (vi).

527 Generally the voltages (or currents) in a three phase power system are balanced with the voltages in each phase being equal in magnitude and displaced by 120 degrees. However, unbalanced voltages can occur during fault (except three phase faults). The analysis of the voltages and current that occur during unbalanced conditions is usually undertaken using sequence components where the voltages and currents in the three phases are converted into an equivalent set of positive, negative and zero sequence components of voltage.

must be agreed with AEMO and the Network Service Provider for various types of voltage disturbances,[528] and

- the reactive current contribution and voltage deviation described may be measured at the applicable low-voltage terminals of the generating units or reactive plant within a generating system.[529]

Issues regarding the location and method of measurement are discussed in section 9.5.7.

AEMO's updated position on the maintenance of total current during a fault

On 9 April 2018, AEMO proposed an additional general requirement to account for active current injection during faults. AEMO noted examples where the active current from a generating system drops to zero during faults, even for shallow voltage disturbances. AEMO considered this situation to represent a risk to system security and therefore proposed the following general requirement in S5.2.5.5 for active current injection during faults:[530]

> "Notwithstanding the amount of reactive current injected/absorbed during voltage disturbances, the maximum continuous current of the generating system including all operating generating units (in the absence of a disturbance) must be available at all times."

Issues regarding the maintenance of active current during a fault are discussed in section 9.5.8.

9.4 Stakeholder views

Stakeholders commented on a range of issues with AEMO's proposed reactive current response requirements during disturbances, including:

- their applicability to synchronous generating system response
- whether they are achievable for asynchronous and synchronous generating systems
- whether they provide sufficient flexibility to account for power system conditions at the connection point, and
- the need to account for additional equipment limits.

9.4.1 Applicability to synchronous generating systems

AEMO's proposed requirements for reactive current response during disturbances would apply equally to synchronous and asynchronous generating systems. Several stakeholders questioned whether these requirements were appropriate for synchronous generating systems, given the continuous, physically inherent nature of synchronous

528 Rule change request, proposed rule, clause S5.2.5.5(i)(iii) .

529 Rule change request, proposed rule, clause S5.2.5.5(i)(ii).

530 AEMO, Generator technical requirements: supplementary material to Rule change proposal, May 2018.

generating system reactive current response, relative to the controlled response from asynchronous generating systems.[531]

Hydro Tasmania noted that during a disturbance the nature of the reactive current response of synchronous generating systems is an inherent design characteristic, and as a result is not as flexible as the response of asynchronous generating systems.[532] Powerlink considered a different compliance assessment method should be required for synchronous generating units, given their different response dynamics.[533]

Achievability of AEMO's proposed requirement

Stakeholder submissions indicated that the magnitude of AEMO's proposed reactive current response requirements were set at a high level, but are generally achievable by asynchronous generating systems.[534] Four respondents to the Commission's survey of equipment manufacturers who build asynchronous plant noted that the automatic access standard could be met under certain circumstances, and three noted the minimum access standard could be met under certain circumstances. The responses were generally qualified on the need for sufficient flexibility to align the magnitude of response with power system conditions at the connection point, rather than the underlying ability of the equipment to achieve AEMO's proposed response magnitude slopes.

Some stakeholders had significant concerns with the ability of synchronous generating systems to meet AEMO's proposed automatic or minimum access standards. Powerlink noted that recently connected synchronous generating systems in Queensland were unlikely to be able to meet AEMO's proposed minimum access standard.[535] A respondent to the Commission's survey of equipment manufacturers noted that AEMO's proposals may not be achievable for all types of synchronous generating systems. In particular, the respondent noted there was a limit to reactive current injection for air-cooled gas turbines common in peaking power plant.

A number of stakeholders identified an additional limit that AEMO had not considered in its rule change request.[536] These stakeholders noted that some inverter connected generating systems cannot sustain reactive current injection where there is a very low voltage experienced at the connection point (that is, under deep fault conditions). Nordex (a wind turbine manufacturer) observed that other jurisdictions specifically accounted for this in their grid codes:[537]

> "In Germany, the settling times for deep voltage dips down to a residual voltage below 10% of nominal voltage (for asymmetrical and symmetrical faults) are actually excluded from the evaluation. Especially for deep symmetrical voltage dips, it is hard to get the correct reference value for

531 Submissions to the consultation paper: Hydro Tasmania, p. 12; Powerlink, p. 7.

532 Hydro Tasmania, submission to consultation paper, p. 12.

533 Powerlink, submission to consultation paper, p. 7.

534 Submissions to consultation paper: Pacific Hydro, p. xii; Advisian p. 31.

535 Powerlink, submission to consultation paper, p. 7.

536 Submissions to the consultation paper: Nordex, p. 6; Tilt Renewables, p. 4; Vestas, p. 2.

537 Nordex, submission to consultation paper, p. 6.

reactive and active current as the phase angle can't be determined during the deep voltage dips."

One respondent to the Commission's survey of equipment manufacturers also noted that for inverter connected plant there is a trade-off between response speed and the ability to sustain a reactive current response until the voltage recovers to within the continuous operating voltage band, under some circumstances. This manufacturer indicated that while open loop LVRT/HVRT response can be very fast, this response is time limited and not suitable for periods longer than approximately 2 seconds. Therefore, if the duration of a voltage deviation is longer than this, an open loop inverter response will be insufficient and a PPC based response will be required.

Some stakeholders also considered AEMO's proposed requirement limiting consumption of active and reactive power on the commencement of a fault to 5% of the maximum continuous current rating of the generating system to be challenging to meet under some circumstances.[538] Alinta considered this requirement should be considered on a case by case basis, having regard to the specific needs of the power system at the point of connection.[539] Some stakeholders considered a negotiation range, achieved by including a minimum access standard, was necessary to account for equipment limitations.[540] GE Power suggested this minimum access standard should limit any positive sequence active current consumption exchange immediately upon the occurrence of a fault to 10% of the maximum continuous current of the generating system, limited to a duration of 60 ms.[541]

Arrangements accounting for variation in connection point condition

A key concern raised by stakeholders was that AEMO's proposal was overly prescriptive and did not provide sufficient flexibility to allow a reactive current response that is suitable to the power system conditions at the connection point.[542] Stakeholder concerns included the potential for instability arising from inappropriate magnitude, speed, and threshold of response due to requirements that are not flexible enough to account for the range of different power system conditions that can occur at the connection point.

Stakeholders considered an overly prescriptive requirement for the magnitude of response risks instability where that response is inappropriate for the power system conditions at the connection point. It was argued this is particularly the case in locations with poor system strength.[543] Vestas noted that to account for the need for flexibility in response there must be a distinction between having the capability and applying capability specific response magnitude in site specific cases.[544]

538 Submissions to the consultation paper: Clean Energy Council, p. 14; GE Power, p. 9; Alinta, p. 4.

539 Alinta, submission to the consultation paper, p. 4.

540 Submissions to the consultation paper: GE Power, p. 9; Clean Energy Council, p. 14.

541 GE Power, submission to the consultation paper, p. 9.

542 Submissions to the consultation paper: Vestas, p. 2; ESCO Pacific, p. 11; SMA, p. 6.

543 Vestas, submission to consultation paper p. 2.

544 Ibid.

In addition to flexibility in the magnitude of response, stakeholders also considered flexibility in the speed of response to be an important consideration in order to account for power system conditions at the connection point. Some stakeholders considered that compliance with the rise and settling times proposed by AEMO, while also maintaining an adequately damped response, would be challenging, particularly under weak grid conditions.[545]

Nordex noted that while AEMO's proposed rise and settling times were consistent with the relevant German (VDE) standard, AEMO had omitted a 20 ms cycle for the initial detection of the fault, which is provided for in Germany through supplementary guidelines.[546] In the absence of this 20 ms detection cycle, Nordex considered that AEMO's proposed response times would be reduced to 10 ms rise time and 40 ms settling time.[547]

In addition to response magnitude and speed, stakeholders questioned AEMO's proposed use of the continuous operating voltage band boundaries (90% to 110% of normal) as the thresholds for generating system response.[548] The Clean Energy Council considered that typically reactive current injection setting thresholds are further outside the continuous operating band than proposed by AEMO (ie +/- 15% or more). The Clean Energy Council considered that there needs to be some gap to allow for transition and hysteresis between the continuous operating mode (typically voltage control but not always) and inverter ride-through/grid support modes.[549] In this regard, TransGrid proposed:[550]

> "that voltage threshold of 90% connection point voltage in the minimum standard should include flexibility to select within a range of e.g. 80-90% and voltage threshold of 110% connection point voltage in the minimum standard should include flexibility to select within a range of e.g. 110-120%."

9.5 Analysis and conclusions

This section considers AEMO and stakeholder views, expert technical advice and the Commission's analysis in making recommendations on:

- whether there is a need to change the current arrangements for reactive current injection during disturbances
- whether it is appropriate to apply any new requirements to both synchronous and asynchronous equipment, and

545 Submissions to the consultation paper: Alinta, p. 4; ESCO Pacific, p. 9.

546 German technical guideline called "TG 8 - Certification of the Electrical Characteristics of Power Generating Units and Systems in Low-, Medium-, High- and Extra-High Voltage Grids"; http://www.wind-fgw.de/shop/technical-guidelines/? lang=en). These guidelines are also focussing on the time which is needed for detecting the fault and are adding another 20 ms as a dead-time to the original grid code requirement.

547 Nordex, submission to the consultation paper, p. 5.

548 Submissions to consultation paper: TransGrid, p. 5; Vestas, p. 2; CEC, p. 14.

549 CEC, submission to consultation paper, p. 14.

550 TransGrid, submission to consultation paper, p. 5.

- the appropriate characteristics of those requirements, including:
  - *magnitude* of response
  - *response speed* (rise and settling times)
  - *response duration* (including the interaction with the requirements to for continuous uninterrupted operation)
  - *response thresholds* (the boundaries for when a response begins)
  - *response limits* (including limits on total response magnitude and on reactive and active power consumption on occurrence of a fault), and
  - certain matters relating to *measurement*.

9.5.1 The need to change current arrangements

Reactive current response during disturbances has traditionally been provided by synchronous generating systems. As the reactive current injection and absorption response provided by a synchronous generating system is an inherent physical characteristic of the plant, its provision was inherent in traditional power systems. As existing synchronous generating systems retire, the inherent physical reactive current response to disturbances they provide will be lost to the power system. Unless that response is replaced with other adequately performing reactive current response, the risk of voltage collapse under fault conditions will increase, and power system security may deteriorate.

Given the inherent physical response of synchronous generating systems, there was previously not a need for a prescriptive set of requirements in the NER describing the characteristics of a reactive current response under fault conditions. Synchronous generating systems always brought their physically inherent level of this response to the power system when they connected.

Reactive current response from inverter connected generating systems, on the other hand, is not physically inherent to the plant. While asynchronous generating systems are capable of fast reactive current response in HVRT/LVRT modes, that response is determined by control systems and their settings. Similarly, the slower PPC reactive current response is also determined by centralised control systems and their settings. There is therefore significant flexibility in the settings that determine the nature of the response provided by asynchronous generating systems.

To address this issue, the draft rule includes specific requirements that specify the characteristics of response from asynchronous generating systems. Without addressing this issue there is a risk that the reactive current response from connecting asynchronous generating systems will not be adequate or appropriate to maintain power system security.

9.5.2 Application of new arrangements to synchronous generating systems

Box 9.2 Draft rule: Applicability to synchronous generating systems[551]

The Commission's draft rule:

- retains current arrangements under both the automatic and minimum access standards for synchronous generating systems for reactive current response during disturbances (subject to the introduction of a new response limit for synchronous generating systems discussed below and with some drafting changes to add clarity),[552] and
- introduces new arrangements under both the automatic and minimum access standards for asynchronous generating systems that define the characteristics of their reactive current response during disturbances.[553]

The requirements for asynchronous generating systems in the draft rule (set out in more detail below) broadly reflect the arrangements proposed by AEMO, including the same principal features of slope of response, response thresholds, speed and duration of response. However, for the reasons set out below, the draft rule also provides additional flexibility accounting for different power system conditions and equipment limitations.

AEMO's proposed requirements apply to all technologies, synchronous and asynchronous. In proposing requirements related to reactive current response during a fault that apply to all generating systems, AEMO considered its requirements reflect the inherent response characteristics provided by synchronous generating systems.[554]

A number of stakeholders however considered that inherent differences between asynchronous and synchronous generating system response dynamics justify specifying reactive current requirements differently under the NER.[555] In particular, the Commission notes Powerlink's view that synchronous generating system response dynamics would require a different compliance method and that recently connected synchronous generating systems in Queensland were unlikely to meet AEMO's proposed minimum access standard.[556]

Synchronous generating system magnitude of response is a feature of the fundamental design of the generating unit. The magnitude of initial response during the sub-transient periods is determined by the sub-transient reactance of the generating system. This reactance arises from electro-mechanical characteristics of the generating system itself including its physical geometry and construction. The Commission

551 Proposed drafting at clauses S5.2.5.5(b)(2) and (c)(2) makes clear that the requirements apply to both wholly-synchronous generating systems and individual synchronous generating units within any generating system.

552 Clauses S5.2.5.5(b)(2) and S5.2.5.5(c)(2) of the draft rule.

553 Clauses S5.2.5.5(b)(3) to (5) and S5.2.5.5(c)(3) to (5) of the draft rule.

554 Rule change request, p. 24.

555 Submissions to consultation paper: Hydro Tasmania, p. 12; Powerlink, p. 7.

556 Powerlink, submission to consultation paper, p. 7.

understands there to be limited flexibility to specify physical generating system characteristics for the purpose of tuning reactive current response during fault events, without incurring significant additional cost. In addition to cost, it is likely impractical to design a synchronous plant expressly for the purpose of achieving a specific level of reactive fault current.

In contrast, the response from an asynchronous generating system is a function of control system architecture and settings which can be readily configured, with certain characteristics that are supported by that architecture. Asynchronous generating system reactive current response dynamics involve the transition between two distinct modes of control, closed loop PPC and open loop inverter ride through modes. Therefore, arrangements are needed to specify the manner and speed at which that transition occurs, as well as the characteristics of response when in the different modes. AEMO's proposal in particular proposes a transition to ride through modes at fixed voltage thresholds according to a specified response speed. Neither of these factors is relevant to, nor effectively describes, the reactive current response of a synchronous generating system.

Synchronous generating systems respond instantaneously and continuously in response to the fault. The dynamics of that response involves a very high initial reactive current during the sub-transient period, which then naturally declines until the generating system's automatic voltage regulator takes over, stabilising the reactive current and bringing it to its steady state value. Synchronous generating systems are therefore not able to sustain a response in the same manner as asynchronous generating systems. AEMO's proposal to require reactive current to be sustained, potentially for the durations described in S5.2.5.4, is therefore not likely to be achievable for synchronous generating systems.

AEMO's proposed requirements for reactive current response during a disturbance reflect the control architecture and consequent response characteristics of asynchronous generating systems. We do not however consider their proposed requirements to reflect the inherent response provided by synchronous generating systems.

Considerations of technology neutrality

Given the inherent physical differences in reactive current response from synchronous and asynchronous generating systems, the Commission considers in this case it is appropriate that separate requirements are set out in the NER for the different technology types. This section considers this in the context of the principle of technology neutrality.

Technology neutrality is an important consideration in this rule change. As discussed in Chapter 8 (relating to reactive power response to a step change in voltage), technology neutrality does not mean treating all technology types the same in setting the access standards, but rather, technology neutrality means that all technology types should have an equal opportunity to enter the market, subject to system security requirements.

The Commission considers that, where possible, it is appropriate for the access standards to be expressed in the same way for all technology types. However, in this case, it is not appropriate to express the access standards in the same terms for all technologies. Given the inherently different physical responses from synchronous and asynchronous technologies (discussed in detail above) it is necessary in this case to specify different requirements to reflect these physical differences. The technology-specific arrangements are necessary to make sure that the access standards for reactive current response to a fault do not create an inefficient barrier to entry for one technology or another. As noted by stakeholder submissions,[557] arrangements proposed by AEMO had the potential to creating barriers to entry for synchronous generating systems in circumstances where the entry of these generating systems wouldn't cause system security issues.

The Commission also notes that stakeholders have not argued that the current arrangements in clause S5.2.5.5 for reactive current response during a disturbance are inappropriate for synchronous generating systems or when applied to synchronous generating systems lead to outcomes that pose a risk to power system security. Rather, the Commission notes that AEMO's proposed changes have been justified by the need to define requirements that better specify the reactive current response characteristics during disturbances given a power system in transition to higher penetrations of asynchronous generation.[558]

In this context, the assessment of technology neutrality should focus on neutrality of outcomes (i.e. the impact on system security) rather than the neutrality of inputs (i.e. the words used in the access standards). Neutrality of outcomes means that different types of generating systems should be required to have the same outcomes in terms of their impact on system security, even if doing so requires different access standards to be set out in the NER for different types of systems. As a result of the inherent physical differences in reactive current response from synchronous and asynchronous generating systems, it is not possible to draft a single access standard that applies to both synchronous and asynchronous generating systems and delivers appropriate systems security outcomes from both types of systems.

Given this, the Commission does not consider it appropriate to change the current arrangements for synchronous generating systems (other than as discussed immediately below). However, the Commission considers that new arrangements are needed to define the characteristics of the response required from asynchronous generating systems, given there is a clear system security need given the transition of the power system to higher penetrations of asynchronous generation.

Clarifying current arrangements for synchronous generating systems

One element of the changes proposed by AEMO included a minimum reactive current response capability from a synchronous generating system set at 250% of the maximum continuous current of the generating system.[559] The current automatic access standard, which specifies a reactive current injection of 4% of the maximum continuous current of the generating system for each 1% change in voltage, implies that at a voltage level of 0% at the connection point the reactive current injection required from the generating

557 Powerlink, submission to consultation paper, p. 7.

558 Rule change request, p. 9.

559 Rule change request, proposed rule, clause S5.2.5.5(i)(i)(B).

system should be 400% of its maximum current capacity.[560] AEMO considered this requirement to be unachievable for generating systems connecting in the NEM and proposed synchronous generating systems provide a reactive current contribution which may be limited to 250% of the maximum continuous current of the generating system.[561]

The Commission considers current arrangements which imply a reactive current response capability of 400% to be inappropriate and understand AEMO's proposed capability requirement for 250% of the maximum continuous current of the synchronous generating system to be achievable and provide a response consistent with maintaining power system security.

The Commission's draft rule clarifies current arrangements for synchronous generating systems through a general requirement which specifies the reactive current contribution from a synchronous generating system may be limited to 250% of the maximum continuous current of the synchronous generating system, including all operating synchronous generating units, and the synchronous generating units with a generating system.[562]

As the major changes to reactive current response in the draft rule only apply to asynchronous generating systems, the analysis in the following sections is specific to requirements for asynchronous generating systems.

9.5.3 Response magnitude

Box 9.3 Draft rule: Response magnitude

The Commission's draft rule specifies the following as automatic and minimum access standard requirements applying to asynchronous generating systems for reactive current injection and absorption in response to faults:[563]

- Automatic access standard - facilities capable of a reactive current response of 4% of the maximum continuous rated current of the generating system for each 1% reduction in voltage at the generating unit terminals below the applicable under-voltage response threshold;[564] and 6% of the maximum continuous rated current of the generating system for each 1% increase in the voltage at the generating unit terminals above the over-voltage response threshold.[565]
- Minimum access standard - facilities capable of a reactive current response of 2% of the maximum continuous rated current of the generating system

560 Clause S5.2.5.5(b)(2)(i) of the NER.

561 Rule change request, proposed rule, clause S5.2.5.5(i)(i)(B).

562 Clauses S5.2.5.5(j) and (k) of the draft rule.

563 Clauses S5.2.5.5(b)(3) and (c)(3) of the draft rule make it clear that the requirements apply to both wholly-asynchronous generating systems and individual asynchronous generating units within any generating system.

564 Clause S5.2.5.5(b)(3)(i)(A) of the draft rule.

565 Clause S5.2.5.5(b)(3)(i)(B) of the draft rule.

for each 1% increase or reduction (as the case may be) in the voltage at the generating unit terminals relative to the over or under-voltage response thresholds.[566]

The automatic and minimum access standard magnitude of response requirements occur in respect of voltages above and below the generating unit terminal threshold ranges addressed in section 9.5.5.

Both the negotiated capability and the specific reactive current response set within the negotiated capability are to be recorded in the generator performance standards.[567]

The Commission's draft rule also includes the following exceptions to the requirement to provide reactive current response under deep fault conditions:

- under the automatic access standard, reactive current injection is not required for all generating unit terminal voltages lower than 5% of nominal voltage,[568] and
- under the minimum access standard, reactive current injection is required for all generating unit terminal voltages greater than 20% of nominal voltage.[569]

Requirement versus capability

Stakeholders were generally concerned that the magnitude of any reactive current injection or absorption during a disturbance, as determined by the slope of response, should be appropriate for power system conditions at the connection point. Stakeholders considered an overly prescriptive magnitude of response risks instability where that response is inappropriate for the conditions at the connection point.[570] It was argued this is particularly the case in locations with poor system strength.[571] Vestas noted that to account for the need for flexibility in response there must be a distinction between having the capability and applying the capability in a site specific case.[572]

It was unclear to some stakeholders whether AEMO's proposal was to require a specific magnitude of response, or a capability to provide response to a certain level within which a specific response would be set in accordance with conditions at the connection point. The main concern expressed by stakeholders was that a requirement to provide a specific response that is inappropriate for the connection point may lead to voltage instability, creating risks to power system security.

566 Clauses S5.2.5.5(c)(3)(i)(A) and (B) of the draft rule.

567 Clauses S5.2.5.5(b)(3)(i) and S5.2.5.5(c)(3)(i) of the draft rule.

568 Clause S5.2.5.5(b)(3)(i)(A) of the draft rule.

569 Clause S5.2.5.5(c)(3)(i)(A) of the draft rule.

570 Submissions to the consultation paper: SMA, p. 6; Vestas, p. 2; ESCO Pacific, p. 11; Origin Energy, p. 2.

571 Vestas, submission to consultation paper, p. 2.

572 Ibid.

If obligations in the NER are specified as a requirement to provide a specific response, the minimum access standard constrains the ability to set a response that is appropriate for the conditions at the connection point. AEMO has proposed a minimum access standard with limited negotiating flexibility, particularly for reactive current absorption (addressed below). The Commission understands that situations exist where very low reactive current response may be appropriate for particular connection points. A minimum access standard that acts as a capability, within which a specific setting is specified, would provide additional flexibility to account for a full range of system conditions.

On further discussion with AEMO the Commission understands that AEMO considers a clear requirement to provide a specific reactive current response to be important as an obligation facilitating both compliance and power system security outcomes. Once an appropriate magnitude of response is determined for the connection point it should act as a requirement to provide that specific level of response. This appears to be an appropriate approach in practice, however it is not clear in the proposed changes that this was the intended approach.

In order to provide the flexibility to set the magnitude of response at a level that is appropriate for conditions at any connection point, while also providing clear compliance obligations, the Commission considers the arrangements in the NER should be specified as requiring generating system facilities capable of providing a specific magnitude of response. Within the bounds set by this capability, a specific magnitude of response, appropriate to the connection point, may be determined. The Commission also agrees with AEMO's view that a specific response magnitude that is appropriate for the conditions at the connection point, once determined, should be recorded in the generating system's performance standards. The Commission considers this will facilitate more effective compliance by providing clear obligations in the generating system's performance standards. The Commission also agrees that the current arrangements for the alteration of performance standards (in clause 4.14(p)) provide sufficient flexibility for any party to instigate a change to the levels of performance set, if appropriate to do so, at a later time.

Automatic access standard requirements

AEMO proposed the following automatic access standard for response magnitude.[573]

	Reactive injection	Reactive absorption
Automatic access standard	4%	6%

AEMO's proposed automatic access standard is based on the requirements adopted in the Essential Services Commission of South Australia's (ESCOSA) generating system

573 Response as a percentage of the maximum continuous current of the generating system, including all operating generating units (in the absence of a disturbance) for each 1% change in connection point voltage.

licensing guidelines.[574] The ESCOSA licensing requirements were set on the basis of advice from AEMO that also informs the proposed response magnitudes in AEMO's rule change request. AEMO's proposed automatic access standard was considered by ESCOSA to be appropriate for South Australia, given the challenge of managing over-voltages due to the operation of special protection schemes being implemented in that state.[575] The Commission therefore accepts AEMO's view there are circumstances where a reactive current response during a fault in line with AEMO's automatic access standard is required to maintain power system security in certain parts of the power system.

Stakeholders indicated that AEMO's proposal for the magnitudes of reactive current response were challenging yet achievable for asynchronous generating systems. Four out of five respondents to the survey of equipment manufacturers that build asynchronous plant indicated their equipment was able to comply with AEMO's proposed automatic access standard. While some indicated that some additional equipment may be required, in particular solar PV generating systems,[576] the greatest source of concern was that flexibility needs to be provided to tailor the response to power system conditions at the connection point (discussed below). Given this, it does not appear that there are any particular technology limitations for asynchronous generating systems preventing them from achieving AEMO's proposed automatic access standard requirements.

The Commission's general approach to setting automatic access standards is that they should reflect the level of performance required of a connection so that it will not adversely affect power system security or the quality of supply to other network users, regardless of the size, technology and location of the connection. Consistent with this approach, the Commission considers it is appropriate to set the levels of performance for reactive current response during a disturbance for asynchronous generating systems in the automatic access standard at the levels of capability proposed by AEMO.

This does not mean that the levels noted in the automatic access standard are appropriate for the conditions at all connection points, rather, those levels represent the limits of the capability required of asynchronous generating systems connecting at the level of the automatic access standard. Both the capability and the required level of performance appropriate for the connection point are to be recorded in a generating system's performance standards.

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574 ESCOSA, *Inquiry into the licensing arrangements for generators in South Australia – Final Report*, p. 27. Available from: https://www.escosa.sa.gov.au/projects-and-publications/projects/inquiries/inquiry-into-licensing-arrangements-for-inverter-connected-generators.

575 Ibid, p. 25.

576 SMA, submission to consultation paper, p. 6.

Minimum access standard requirement

AEMO proposes the following minimum access standard for response magnitude.[577]

	Reactive injection	Reactive absorption
Minimum access standard	2%	6%

The Commission's approach to setting minimum access standards is that they should reflect the lowest level of performance required of a connection so that it does not adversely affect power system security or the quality of supply to other network users, taking into consideration the size, technology and location of the connection. A minimum access standard should therefore be set where a clearly identifiable system need exists and an inappropriately low level of capability from a connecting generating system may risk system security or the quality of supply.

A power system experiencing fault conditions is under stress and potentially in an emergency situation. When the power system is in such a state, every generating system needs to have the capability to respond at an appropriate level in order to support the voltage at its particular connection point. Therefore the Commission considers there to be an identifiable system security need justifying a minimum access standard for reactive current response during faults under S5.2.5.5.

Should a generator not provide a reactive current response at an appropriate level, it may increase the extent and severity of the voltage disturbance experienced by other generating systems. This may result in a cascading outage leading to voltage collapse. In this regard, the system security considerations associated with supplying reactive current response during fault conditions are more aligned with those for generators remaining in continuous uninterrupted operation rather than the injection and absorption of reactive power under steady state conditions as in S5.2.5.1 and S5.2.5.13.[578]

AEMO’s proposed minimum access standard for reactive current injection of 2% is lower than the proposed automatic access standard. The proposed minimum level is aligned with German requirements and is at a level that stakeholders considered would be achievable. The Commission agrees AEMO’s proposed minimum access standard for reactive current injection magnitude of response to be an appropriate level of capability for all asynchronous generating systems to support power system voltages under fault conditions.

In contrast, AEMO’s proposed minimum access standard for reactive current absorption, which is the same as the automatic access standard, is not appropriate. While a level of reactive current absorption of 6% during a fault may be appropriate to maintain system security for certain connection points in the power system, it is

577 Response as a percentage of the maximum continuous current of the generating system, including all operating generating units (in the absence of a disturbance) for each 1% change in connection point voltage.

578 The ability of a generating system to withstand a disturbance is technically referred to as its ability to maintain 'continuous uninterrupted operation', which is defined in Chapter 10 of the NER.

unlikely to be appropriate as a lowest level of capability required from all asynchronous generating systems in order to maintain system security across all regions in the power system. If implemented, AEMO's proposed minimum access standard would require a level of capability that is not justified by system need, and would therefore not be consistent with maintaining system security at lowest cost.

German reactive current absorption requirements for reactive absorption are set at 2%, in line with AEMO's proposed minimum access standard requirement for reactive current injection.[579] The Commission considers 2% reactive current absorption in response to over voltages to be a reasonable minimum capability requirement that is appropriate as a lowest level of capability required from all asynchronous generating systems.

This does not mean that the levels noted in the minimum access standard are appropriate for the conditions at all connection points, rather, those levels represent the limits of the capability required of asynchronous generating systems connecting at the level of the minimum access standard. As a settable capability, the minimum access standard would provide scope to set a lower reactive current response if that is appropriate for the power system. This extends to circumstances where very low, or no response may be justified.[580] Both the capability and the required level of performance appropriate for the connection point are to be recorded in a generating system's performance standards.

Point of reference - connection point or generator terminals

AEMO propose the requirement to either inject or absorb reactive current for each 1% change in connection point voltage. As introduced in the technical introduction, existing technical practice is for asynchronous generating systems to provide reactive current response as part of their inverter ride through capabilities. We understand standard equipment capabilities are for ride through to occur in relation to voltages at the inverter terminals rather than the connection point.

There will be a difference between inverter terminal and connection point voltages due to reactive current flows combined with the impedance of the transformers and lines between the inverter terminals and connection point. This difference makes it challenging for an inverter based ride through response to accurately respond to changes in connection point voltages. As a result, the Commission's draft rule requires reactive current response in relation to changes in voltage at the generating unit terminals rather than at the connection point. The Commission notes this approach to be consistent with the Commission's understanding of existing technical practice.

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579 Tennet TSO GmbH, *Grid code – extra high voltage, 1 November 2015,* available from: https://www.tennet.eu/fileadmin/user_upload/The_Electricity_Market/German_Market/Grid_customers/tennet-NAR2015eng.pdf.

580 On 11 may 2018, AEMO provided information regarding the reactive current response requirements from asynchronous generators currently connected in weak locations in the NEM. This information shows that existing generation, connecting at very weak connection points, are providing a reactive current response of less than 2% for each 1% decline in connection point voltages. The Commission is also aware that a reactive current injection level of zero may be appropriate for some distribution connection points where classical over-current protection is applied.

Further discussion on the use of the generating unit terminals as the point of reference is provided in section 9.5.5.

While the Commission's draft rule specifies the response as occurring at the terminals of an asynchronous generating unit, there may be future circumstances where the connection point is the most appropriate point of reference. The Commission therefore agrees with AEMO that there should be flexibility to measure response at a range of locations. To allow for circumstances where equipment capabilities allow for accurate response to connection point voltage, the Commission proposes a flexibility clause further assessed in section 9.5.7.

Exceptions to response requirements under deep fault conditions

Several stakeholders noted the inability of modern inverter connected plant to sustain a response under very deep fault conditions.[581] Submissions from, Nordex, Tilt Renewables, and Vestas all observed that the modern asynchronous generating units they are currently installing/manufacturing may not be able to sustain a reactive current response below generating terminal voltage levels of 20% of normal voltage.[582] These technical limits for inverter connected plant are accounted for in international grid codes. For example, the Commission understands the German grid code provides an exemption for compliance with settling time requirements where the connection point voltage falls below 10% of normal.[583]

AEMO's proposed changes do not allow for asynchronous generating systems to cease providing reactive current support during disturbances where the connection point voltage is very low. Given the limitations of many asynchronous generating systems, it is important to include such limitations to reduce the risk of creating unnecessary barriers to the connection of some technologies.

A generator experiencing very deep fault conditions is unlikely to create material system security vulnerability by ceasing reactive current injection. Faults that result in very low voltages for a generating system are likely to have occurred at, or very close to, the connection point. Sustaining reactive current injection given faults at, or close to, the connection point will have limited impact on broader power system voltages during the fault. In this case the response of surrounding generating systems will be more important for supporting power system voltages than response from the generating system experiencing the deep fault.

Following discussions with the Commission, AEMO assessed declared capabilities of various wind turbine and solar PV inverter manufacturers. AEMO found that, of the technologies assessed, the minimum generating unit terminal voltage levels for which reactive injection can be sustained ranges from 5% to 20%.[584] Given the uncertainty in the relationship between connection point and generating system terminal voltages (discussed in more detail in section 9.5.5) the Commission considers the generating

581 Submissions to the consultation paper: Nordex, p. 6; Tilt Renewables, p. 4; Vestas, p. 2.

582 Ibid.

583 Nordex, submission to consultation paper, p. 6.

584 Advice provided to the Commission by AEMO, 7 May 2018.

system terminals the appropriate location for specifying voltages over which reactive injection must be sustained.

While a generator experiencing very deep fault conditions is unlikely to create a material system security vulnerability by ceasing reactive current injection, the extent of any impact will be reduced by the ability to sustain injection to voltages close to zero. The Commission's draft rule therefore includes an automatic access standard requiring the capability to sustain reactive current injection to 5% of normal voltage at the generating system terminals, and a minimum access standard of 20% of normal voltage at the generating system terminals.[585] This approach will allow the flexibility for some asynchronous generating systems that can sustain reactive current injection at very low residual voltages to do so, and for AEMO and network service providers to require this level of performance where required to avoid adverse impacts on power system security.

9.5.4 Response speed and duration

Box 9.4 Draft rule: Response speed and duration

The Commission's draft rule includes new automatic and minimum access standard requirements requiring a reactive current response from asynchronous generating systems that:[586]

- is maintained until the connection point voltage recovers to between 90% and 110% of normal voltage
- has a rise time of no greater than 40 ms
- has a settling time of no greater than 70 ms, and
- provides a response which is adequately damped.

The Commission's draft rule includes the following exceptions in the minimum access standard to the duration and speed of response requirements for asynchronous generating systems:

- for under-voltage - as an exception to the response duration requirement, allow a response duration limit of 2 seconds in respect of all voltages below the under-voltage response threshold,[587] and
- for over-voltage - as an exception to the speed of response requirements, where a duration of greater than 2 seconds is required, the reactive current rise time must be as soon as practicable, and in any event, no longer than 180 milliseconds.[588]

585 Clause S5.2.5.5(b)(3)(i)(A) of the draft rule.

586 Clauses S5.2.5.5(b)(4) and S5.2.5.5(c)(4) of the draft rule.

587 Clause S5.2.5.5(c)(3)(i) of the draft rule.

588 Clause S5.2.5.5(c)(4) of the draft rule.

Automatic access standard

Current arrangements in clause S5.2.5.5 for reactive current response during a disturbance do not specify explicit requirements for the duration or speed of the response. While this may be appropriate for synchronous generating systems, given the inherent physical response they provide right across the voltage spectrum, the duration and speed of response from asynchronous generating systems is determined by inverter and control system characteristics. In order to provide a response from asynchronous generating systems that is appropriate for the secure operation of the power system, there is therefore a need to specify required response speed and duration parameters, including rise and settling times.

AEMO proposed a requirement for reactive current response to be maintained until voltage levels at the connection point recover to within 90% and 110% of normal voltage.[589] Where a power system disturbance leads to a persistent voltage deviation, the over and under-voltage duration requirements for continuous uninterrupted operation specified in S5.2.5.4 implicitly become the duration limit for which reactive current response must be sustained.[590] Put another way, the generating system would have to maintain a reactive current response for as long as it is required to continue operating in the face of a persistent under or over voltage event.

The Commission considers a requirement for an asynchronous generating system to sustain a reactive current response for as long as it is required to continue operating to be beneficial for maintaining power system security given serious and persistent fault conditions. Consistent with the Commission's approach to setting automatic access standards, as the level of performance required of a connection so that it will not adversely affect power system security or the quality of supply to other network users, regardless of the size, technology and location of the connection, the Commission considers it is appropriate to accept AEMO's proposed duration requirement as an element of the automatic access standard.

The Commission is however aware of certain asynchronous generating system equipment limits relevant to a requirement to sustain reactive current response for long durations. Flexibility accounting for these limitations is proposed under the minimum access standard, discussed in the following section.

Fast response is a generally desirable property when managing short duration power system events, such as faults. AEMO considered that speed of response is critical given the very short duration within which response is valuable for system security. However, while desirable, the speed of response also needs to be consistent with response stability, which is affected by power system conditions at the connection point. An inappropriately fast response in weak system conditions may result in

589 Rule change request, proposed rule, clauses S5.2.5.5(b)(2)(i) and S5.2.5.5(c)(2)(i).

590 S5.2.5.4 – generating system response to voltage disturbance, specifies the duration of withstand during which a generating system is required to maintain continuous uninterrupted operation as a function of voltages at the connection point.

oscillatory, potentially unstable voltages that may be detrimental to power system security.[591]

The value of the rise and settling times in response to a fault depend on the magnitude of the reactive current response given connection point conditions. Section 9.5.3 describes how the draft rule specifies reactive current response magnitudes as a capability, within which a response requirement appropriate to conditions at the connection point are to be set. This approach provides the flexibility to set a magnitude of response to avoid inappropriate oscillation given the fast response proposed by AEMO.

The Commission considers that response stability can be effectively managed (given specified rise and settling times) with the flexibility afforded under arrangements for response magnitude. With this flexibility, the connection applicant, together with AEMO and the network service provider, can set an appropriate response magnitude for the power system conditions at the connection point, thereby prioritising a fast response that is appropriate for the management of short duration fault events.

In its rule change request, AEMO proposed a response rise time of no greater than 30 ms, and a settling time of no greater than 60 ms. The Commission's survey of equipment manufacturers suggests that AEMO's proposed rise and settling time requirements are generally achievable by asynchronous plant. AEMO's proposed response speed requirements are also broadly aligned with requirements that apply in Germany, which require a rise time of within 20 ms.[592] German requirements however provide for an additional 20 ms cycle in which to detect the fault and respond.[593] This additional 20 ms brings the allowable rise time, when measured from fault occurrence, to 40 ms which is 10 ms above AEMO's proposal for the NEM.

In order to prevent barriers to the connection of plant that cannot achieve the response speeds proposed by AEMO (such as equipment designed primarily to meet other requirements specified overseas), the Commission's draft rule sets a rise time of 40 ms and settling time of 70 ms, with the response to be adequately damped.[594]

591 This issue of response stability given generating system response to step change was discussed in Chapter 8. In that Chapter the Commission considered an emphasis on response stability to be warranted given the power system security risks of an oscillatory response.

592 Tennet TSO GmbH, *Grid code – extra high voltage, 1 November 2015,* available from: https://www.tennet.eu/fileadmin/user_upload/The_Electricity_Market/German_Market/Grid_customers/tennet-NAR2015eng.pdf

593 As noted by Nordex in its submission, German technical guideline called "TG 8 - Certification of the Electrical Characteristics of Power Generating Units and Systems in Low-, Medium-, High- and Extra-High Voltage Grids"; http://www.wind-fgw.de/shop/technical-guidelines/? lang=en). These guidelines are also focusing on the time which is needed for detecting the fault and are adding another 20 ms as a dead-time to the original grid code requirement.

594 Clauses S5.2.5.5(b)(4) and S5.2.5.5(c)(4) of the draft rule - An allowable settling time of 70ms is less than the shortest protection clearance times in Table S5.1a.2 of the NER which specifies 80ms as the critical protection clearance time for connections at 400 kV and above.

Minimum access standard - response speed and duration limits

Where a power system disturbance leads to a persistent voltage deviation, the over and under-voltage duration requirements for continuous uninterrupted operation specified in S5.2.5.4[595] implicitly become the duration limit for which reactive current response must be sustained.

The Commission understands that some inverters will have difficulty complying with a requirement to sustain a reactive current response sufficient to achieve the duration requirements for continuous interrupted operation specified in S5.2.5.4. The HVRT and LVRT modes of some inverters are limited to a response duration of 2 seconds.[596] While asynchronous generating systems can respond for longer durations when response is coordinated by the PPC acting as the 'central brain' controller (as discussed in section 9.1), the speed of such a response is limited by the speed of the power analyser sampling rate (the equipment that processes data from the connection point).[597] PPC based response is therefore able to sustain a stable response for a long duration but unable to achieve the AEMO's speed of response requirements.

Fast HVRT/LVRT inverter response is therefore unlikely to meet all of the draft rule duration requirements for continuous uninterrupted operation, discussed in Chapter 10. The shaded area in Figure 9.4 illustrates the extent to which a two second reactive current response limit would be insufficient to achieve the requirements to maintain continuous uninterrupted operation for various voltage disturbance bands in clause S5.2.5.4. A two second inverter response from an asynchronous generating system would be insufficient to meet three of the voltage bands, including the requirements for 80% to 90% of normal voltage (requiring continuous uninterrupted operation for up to 10 seconds), 110% to 115% of normal voltage (up to 20 minutes) and 115% to 120% of normal voltage (up to 20 seconds).[598]

595 S5.2.5.4 – generating system response to voltage disturbance, specifies the duration of withstand during which a generating system is required to maintain continuous uninterrupted operation as a function of voltages at the connection point.

596 Based on information provided in confidential original equipment manufacturer submission.

597 IEC 61000-4-30, *Electromagnetic compatibility (EMC) - Part 4-30: Testing and measurement techniques - Power quality measurement methods*, Available from: https://webstore.iec.ch/publication/21844.

598 Rule change request, p. 30; AEMO, submission to consultation paper, p. 20.

Figure 9.4 **Comparison between a 2 second inverter response limit and the over and under voltage duration requirements for continuous uninterrupted operation in S5.2.5.4**

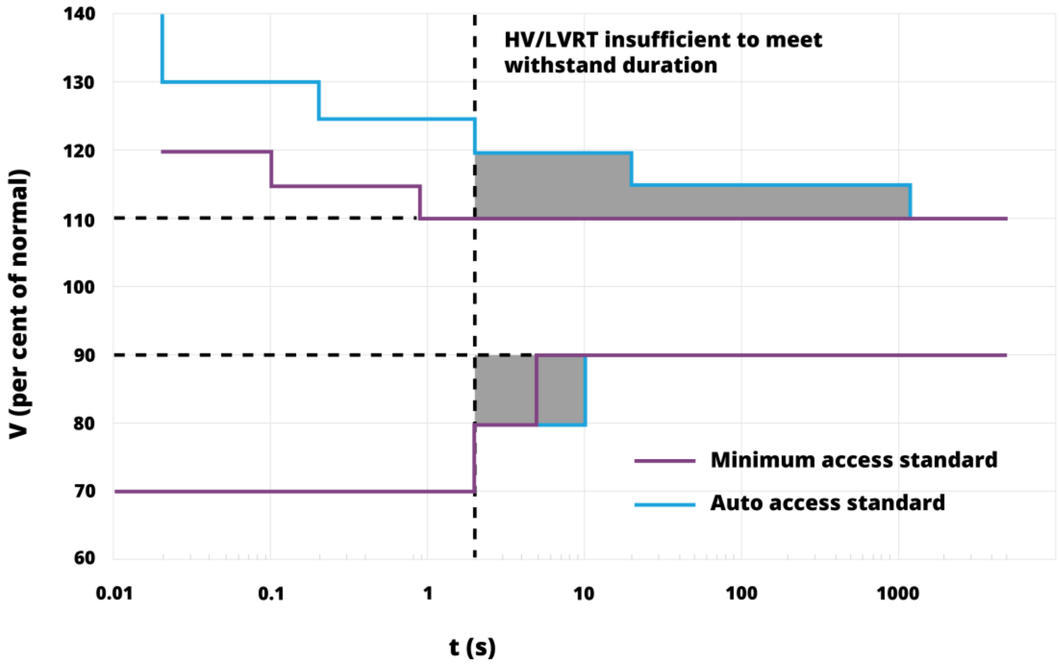


Figure 9.4 shows that while both the automatic and minimum access standard duration requirements for continuous interrupted operation are unachievable for voltages between 80% and 90%, only the automatic access standard is unachievable for over-voltages between 110% and 120% of normal. Therefore, the inverter response duration limit of two seconds only binds for a continuous uninterrupted duration requirement under S5.2.5.4 of more than 2 seconds.

To help resolve this conflict, the Commission sought AEMO's views on the relative importance of reactive current response speed and response duration in each of these voltage ranges.[599] For under-voltage, AEMO considered that power system security is most challenged by events that are deep and short (usually caused by a fault in the power system). For these events, response speed was considered more important than the ability to sustain a response for a duration of greater than two seconds. A two second response duration, limited by the capabilities of an inverter's HVRT/LVRT mode, was therefore considered unlikely to adversely affect power system security for such events.

AEMO was however concerned with the system security risks from over-voltages that exhibited a low rise but were longer in duration. For such events, reactive current response speed may, under certain circumstances, be less important than response duration.[600] For fast and short over-voltage events however, a fast reactive current response was still considered by AEMO to be preferred over a slower and more

599 Advice provided to the Commission by AEMO, 8 March 2018.

600 Ibid.

sustained response, given the importance of maintaining over-voltages to within acceptable limits.[601]

The Commission's survey of equipment manufacturers highlighted that inverter based reactive current absorption capabilities are relatively immature. As a result, the Commission has not been able to obtain a fastest possible rise and settling time for PPC based response required to sustain a stable response for greater than 2 seconds. In further discussions on this issue, AEMO provided an indicative PPC response rise time of 180 ms.[602] In the absence of any contradictory evidence, the Commission accepts AEMO's views in this regard.

The Commission's draft rule therefore provides flexibility accounting for equipment capability limits, and the trade-off between reactive current response speed and duration for different voltage bands, under the minimum access standard for reactive current response in clause S5.2.5.5 as follows:

- For all under-voltage events (that is, below the under-voltage threshold discussed in section 9.5.5), it is appropriate to prioritise speed of reactive current response over duration of reactive current response. The draft rule therefore requires a response duration limit under the minimum access standard of at least 2 seconds in recognition of inverter capability limits.[603]
- For over-voltage, it is appropriate to provide flexibility under the minimum access standard to allow duration of reactive current response to be prioritised over speed where appropriate. The minimum access standard draft rule therefore requires that, to the extent that a duration for continuous uninterrupted operation under S5.2.5.4 is set in excess of 2 seconds, the reactive current response rise time to be as fast as practicable and no longer than 180 ms. This flexibility intends to allow response to initially occur via PPC before transition into HVRT mode.[604]

9.5.5 Response thresholds

Box 9.5 Draft rule: Response thresholds

The Commission's draft rule introduces a general requirement for reactive current response during disturbances to:

- establish a range within which thresholds for activation of the reactive current contribution are set:[605]
  - reactive current response thresholds must be set within 85% and 112% of the nominal voltage, with the actual thresholds to be agreed between AEMO and the network service provider, and

601 The Commission notes that under Clause S5.1a.4 of the NER the system standard and AEMO's proposed requirements for continuous uninterrupted operation in S5.2.5.4 the maximum permissible over-voltages are 130% of normal.

602 Advice provided to the Commission by AEMO, 3 May 2018.

603 Clause S5.2.5.5(c)(2)(i) of the draft rule.

604 Clause S5.2.5.5(c)(4) of the draft rule.

605 Clause S5.2.5.5(c)(4) of the draft rule.

- the threshold for under-voltage reactive current injection to be set within the range of 85% to 90% of nominal voltage, and the threshold for over-voltage reactive current absorption to be set within 110% to 112% of nominal voltage, and

- specify that:
  - the thresholds for activation of the reactive current contributions must be recorded in the performance standards,[606] and
  - the voltage thresholds for reactive current response are to be defined at the generating unit terminals.[607]

Inverter terminals versus connection point

As described in the technical background in section 9.1 the voltage thresholds at which an asynchronous generating system commences injecting or absorbing reactive current are implemented in the ride through settings in each inverter. Therefore, each individual inverter enters LVRT or HVRT modes based on the voltage measured at its terminals, rather than at the connection point.

This makes implementing AEMO's proposed changes, which specify a reactive current response when voltage reaches certain thresholds at the connection point, challenging for inverter based technologies. The challenge arises because of the difference between voltage levels at the connection point and at the terminals of the inverters (which is the measurement that the individual inverters comprising the asynchronous generating system are responding to). This difference is illustrated in Figure 9.5.

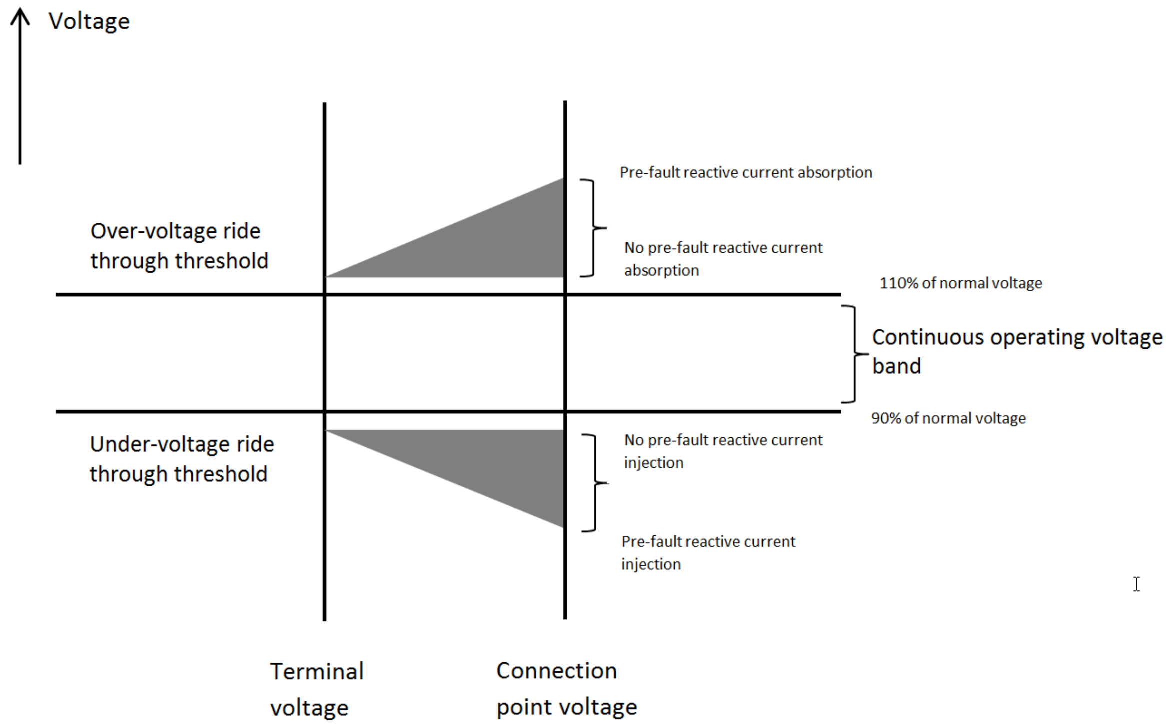
The difference between voltage at the terminal and connection point changes significantly depending on whether the generating system was injecting or absorbing reactive power immediately prior to the fault. If a generating system was injecting reactive power immediately prior to a fault, the voltage level at the inverter terminals will be higher than at the connection point on occurrence of the fault. If a generating system was absorbing reactive power immediately prior to a fault, the voltage level at the inverter terminal will be lower than at the connection point on occurrence of the fault. Furthermore, a generator cannot predict whether its generating system will be injecting or absorbing reactive power immediately prior to a fault.

As a result, a voltage at the inverter could correspond to a range of different voltage levels at the connection point on occurrence of the fault, depending on a range of factors including the magnitude of any reactive power response immediately prior to the fault (described above), the length of the feeder between the individual inverter and the connection point and, the transformer impedance and tap-position.

606 Ibid.

607 Ibid.

Figure 9.5 **Conceptual illustration of the range of connection point voltages triggering a ride through given pre-fault reactive current flows**



As a generating system is not able to control the difference between the voltage seen at the terminals and connection point on occurrence of the fault, the Commission does not consider it appropriate to specify the connection point as the default point at which thresholds are specified for reactive current response. Doing so could lead to uncertainty and compliance risks that are not appropriate to be borne by a party not able to address those risks.

The Commission's draft rule therefore specifies the voltage thresholds triggering a reactive current response at the terminals of the generating units or reactive plant making up the asynchronous generating system.[608]

Threshold levels and flexibility

AEMO proposed the boundaries of the continuous operating voltage band (90% to 110% of normal voltage), measured at the connection point, as the thresholds for reactive current response. Stakeholders identified a range of issues with the use of the continuous operating band boundaries in this way.[609] The Clean Energy Council considered reactive current injection and absorption response thresholds should be set at least 15% outside of the continuous operating band at the connection point.[610] TransGrid proposed response threshold ranges of 80-90% and 110-120% of normal voltage at the connection point specified within which response may occur.[611]

608 Clause S5.2.5.5(c)(4) of the draft rule.

609 Submissions to consultation paper: TransGrid, p. 5; Vestas, p. 2; Clean Energy Council, p. 14.

610 Clean Energy Council, submission to the consultation paper, p. 14.

611 TransGrid, submission to the consultation paper, p. 5.

Voltage levels seen at the inverter terminals (where the Commission has concluded this requirement should be specified), can be expected on occasion to approach the edge of the continuous operating voltage band in response to normal changes in reactive power, load, generation, and overall network conditions. Given in particular the uncertainty in the relationship between the voltage seen by the inverter in triggering reactive current response, and the voltage at the connection point (described above), there may be circumstances where reactive current response thresholds set at the boundaries of the continuous operating voltage band (being 90% and 110% of normal) result in inappropriate response in the absence of a fault.

Inappropriate reactive current response in the absence of a fault may lead to adverse outcomes. Inappropriate reactive current response can lead to behaviour that is referred to as ‘hunting’, which involves the control system oscillating, or bouncing back and forth, between ride through and PPC control modes. Hunting may lead to power quality deterioration and system security risks if the plant or other connected plant becomes unstable as a result of repeated oscillations. The Commission therefore accepts stakeholder views that reactive current response thresholds should be able to be set outside of the continuous operating band to prevent such outcomes where appropriate.[612]

AEMO proposed in subsequent discussions with the Commission the inclusion of additional flexibility in the range of voltages over which reactive current response may occur. AEMO proposed:[613]

> “Where the reactive current contribution and voltage deviation is measured at the low-voltage terminals of the generating units or reactive plant, a threshold for activation of the reactive current contribution must be agreed with AEMO and the Network Service Provider and must be within the limits of 85% and 112% of the nominal voltage at the low-voltage terminals.”

AEMO's further views appear to allow for specification of thresholds at the inverter terminals, and provide scope for thresholds to be set outside the continuous operating voltage band, reducing the potential for inappropriate reactive current response to occur.

The Commission considers that it is appropriate for connecting generating systems to have the flexibility to set reactive current response thresholds at the terminals at levels that do not risk inappropriate response under normal operating conditions. Although the Commission notes the submissions of TransGrid and the Clean Energy Council, the Commission accepts AEMO's updated view that this flexibility is appropriately provided for with response thresholds of as low as 85% of normal voltage, and as high as 112%, set at the terminals of the inverter or reactive plant.

The Commission notes that these arrangements are proposed to be set as general requirements in clause S5.2.5.5, with specific response thresholds to be recorded in the performance standards for the connecting generating system.

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612 Clean Energy Council, submission to consultation paper, p. 14.

613 Advice provided to the Commission by AEMO, 2 May 2018.

9.5.6 AEMO's proposed response limits

Box 9.6 Draft rule: Response limits

The Commission's draft rule contains a number of limits relating to active and reactive current response, including:

- an automatic access standard requirement, reflecting the general requirement proposed by AEMO, that any active current consumption immediately upon the occurrence of a fault must not exceed 5% of the maximum continuous current of the generating system, and is limited to 20 ms
- a minimum access standard that limits the consumption of active current on the occurrence of a fault so that it must not exceed 10% of the maximum continuous current of the generating system, limited to a duration of 60 ms, and
- a general requirement as proposed by AEMO, that any reactive current consumption immediately upon the occurrence of a fault must not exceed 5% of the maximum continuous current of the generating system, and is limited to the duration of rise time.

Active and reactive current consumption limits

AEMO proposed that active and reactive power consumption immediately upon occurrence of the fault must not exceed 5% of the maximum continuous current of the generating system. AEMO is seeking to address an issue that arose in the SA system black event in 2016. AEMO's investigation found that consumption of active and reactive current on occurrence of the faults by a number of asynchronous generating systems increased the overall severity of the disturbances.[614]

The Commission understands that inverter-based plant can take time to 'reorient' itself on the occurrence of fault. That is, time for the generating system's control systems to assess power system conditions and react to them appropriately. During this period a generating system may consume active and reactive power, potentially exacerbating the disturbance to the power system. Generating systems that can quickly re-orient themselves, limiting active and reactive current consumption, improve power system security by better contributing to recovery from the disturbance.

GE Power and the Clean Energy Council however considered that in certain conditions, depending on the severity of the fault, the requirement proposed by AEMO would not be able to be achieved by some asynchronous generating systems.[615] They considered that flexibility should be provided in a minimum access standard, allowing for consumption of active current on occurrence of a fault of up to 10% of the maximum continuous current of the generating system and limited to a duration of 60 ms.[616] The

614 AEMO, *Black System South Australia 28 September 2016: Final report*, p. 246.

615 Submissions to the consultation paper: GE Power, p. 9; Clean Energy Council, p. 14.

616 GE Power, submission to consultation paper, p, 9.

Commission notes that GE Power is not proposing a minimum access standard requirement for reactive current consumption on fault occurrence.

The Commission also considers that AEMO's proposed approach, without flexibility, may inadvertently create barriers to entry. A general requirement (applying to all connecting generating systems) for consumption of active and reactive current on occurrence of a fault of no more than 5% of the maximum continuous current of the generating system, could limit the ability of some asynchronous generating systems to connect in some locations, even where this would not adversely impact power system security. The impact of such unnecessary barriers to entry would be to reduce competition for the provision of certain equipment, and as a result potentially increase costs for consumers.

The Commission considers it is appropriate to include limits on the active and reactive current consumption by an asynchronous generating system immediately upon the occurrence of a fault to reduce risks to power system security during power system disturbances. However, in doing so, flexibility should also be provided to limit the risk of creating unnecessary barriers to entry, allowing for the connection of equipment with lower levels of performance where this would not cause harm to the power system. The Commission's draft rule therefore:

- includes an automatic access standard requirement, reflecting the general requirement proposed by AEMO, that any active current consumption immediately upon the occurrence of a fault must not exceed 5% of the maximum continuous current of the generating system, and is limited to 20 ms[617]
- includes a minimum access standard that limits the consumption of active current on the occurrence of a fault so that it must not exceed 10% of the maximum continuous current of the generating system, limited to a duration of 60 ms,[618] and
- includes a general requirement (reflecting that proposed by AEMO) that any reactive current consumption immediately upon the occurrence of a fault must not exceed 5% of the maximum continuous current of the generating system, and is limited to the duration of rise time.[619]

617 Clause S5.2.5.5(b)(3) of the draft rule.

618 Clause S5.2.5.5(c)(3) of the draft rule.

619 The Commission notes that AEMO has proposed a requirement to limit active and reactive power to a percentage of the maximum continuous current of the generating system. The Commission understands that AEMO chose to frame the obligation in terms of power in order to facilitate measurement.

Total response capability

The second of AEMO's proposed general response requirements is for an asynchronous generating system to be capable of providing a reactive current response capability of at least the maximum continuous current rating of the generating system (including all operating generating units).[620]

Stakeholders did not raise any issues with AEMO's proposed requirements for asynchronous generating systems. The Commission understands this level to be achievable for asynchronous generating systems without the installation of additional equipment, so long as active power can be sacrificed to provide the required reactive current response (further considered in section 9.5.8). Consistent with other characteristics of an asynchronous generating system's reactive current response during disturbances, the Commission considers it is appropriate to define the reactive current magnitude level that an asynchronous generating system must be capable of responding to.

The Commission's draft rule therefore includes AEMO's proposed general requirement that the total reactive current contribution from an asynchronous generating system may be limited to the maximum continuous current of the generating system.[621]

9.5.7 Arrangements relating to measurement

Box 9.7 Draft rule: Arrangements relating to measurement

To provide clarity and flexibility as to the method and point of measurement for reactive current response, the Commission's draft rule:

- allows the reactive current contribution required (under Clause S5.2.5.5(b)(2) or Clause S5.2.5.5(c)(2)) to be with reference to the phase-to–phase, phase-to-ground or sequence components of voltages[622]
- requires that the ratio of the negative sequence to positive sequence components of the reactive current contribution must be agreed with AEMO and the network service provider for the relevant faults listed in the automatic and minimum access standard of S5.2.5.5,[623] and
- allows the reactive current contribution and voltage deviation to be measured at the connection point (with the agreement of AEMO and the network service provider).[624]

620 AEMO's proposal also proposed a requirement synchronous generating systems to be capable of providing a reactive current response of at least 250% maximum continuous current rating of the generating system (including all operating generating units).

621 Clause S5.2.5.5(i)(1) of the draft rule.

622 Clause S5.2.5.5(i)(3) of the draft rule.

623 Clause S5.2.5.5(i)(2) of the draft rule.

624 Clause S5.2.5.5(i)(2) of the draft rule.

AEMO has proposed two general requirements relating to the method and location of reactive current response measurement. These are:

- a requirement to agree the ratio of the negative sequence to positive sequence components of the reactive current contribution when using sequence components to calculate reactive current contribution, and
- flexibility in the point of measurement for the response.

Ratio of negative-sequence to positive-sequence current injection

AEMO proposed the following as a general requirement on the measurement and calculation of reactive current response due to a fault:

- the reactive current contribution required may be calculated using phase to phase, phase to ground, or sequence components of voltage. When using sequence components, the ratio of negative-sequence to positive-sequence current injection must be agreed with AEMO and the network service provider for various types of voltage disturbances.[625]

AEMO's proposed requirement has two elements, the first is to allow flexibility in the approach to measuring reactive current and the second to require agreement to the ratio between negative and positive sequence currents for various, undefined, types of voltage disturbances.

AEMO provided further clarification on the appropriate approach, which is set out below:[626]

> "the reactive current contribution required (under Clause S5.2.5.5(b)(2) or Clause S5.2.5.5(c)(2)) can be with reference to the phase-to–phase, phase-to-ground or sequence components of voltages. The ratio of the negative sequence to positive sequence components of the reactive current contribution must be agreed with AEMO and the network service provider for various types of voltage disturbances."

Generally the voltage levels (or current levels) in a three phase power system are balanced with the voltages in each phase being equal in magnitude and displaced by 120 degrees. However, unbalanced voltages can occur during faults (except three phase faults). The analysis of the voltage and current levels that occur during unbalanced conditions is usually undertaken using sequence components, where the voltages and currents in the three phases are converted into an equivalent set of positive, negative and zero sequence components.[627] A clearly specified method of calculating balanced and un-balanced voltages during faults is necessary to determine the relevant level of reactive current injection or absorption required from the generating system under any arrangements for reactive current injection during fault conditions. AEMO noted the 'various types of voltage disturbances' referred to in their proposal as involving the

625 Rule change request, proposed rule, clause S5.2.5.5(i)(iii).

626 Advice provided to the Commission by AEMO, 26 April 2018.

627 Unbalanced faults are faults that are not evenly applied to all phases and include single phase to ground, two phase to ground, and phase to phase faults.

relevant faults listed in the automatic and minimum access standard of S5.2.5.5 and set out in Table 9.1 above.[628]

AEMO's proposal provides flexibility to account for the various approaches used by manufactures to model generating system response to fault conditions. The Commission agrees this is an appropriate approach. The Commission's draft rule therefore implements AEMO's proposed changes, as updated on 26 April 2018, as a general requirement for which the ratio of negative to positive sequence components must be agreed, including reference to the types of faults listed in Table 9.1 above.[629]

Flexibility in point of response measurement

AEMO's proposal is for measurement of the voltage deviation and subsequent reactive current response to occur at the connection point. However, AEMO also proposed that other locations may be used for this measurement. Specifically, AEMO proposed as a general requirement:[630]

> "the reactive current contribution and voltage deviation described may be measured at the applicable low-voltage terminals of the generating units or reactive plant within a generating system."

The Commission's survey of equipment manufacturers indicated that current technical practice is for inverters under HVRT/LVRT modes to respond to voltage levels measured at the inverter terminals, rather than voltages at the connection point. While AEMO's proposed requirement provides flexibility in terms of measurement, the Commission's draft rule is to require a reactive current response in respect of the generating unit (inverter) terminal voltage rather than the connection point.[631] This reflects a different default point of obligation to that proposed by AEMO. The Commission however considers that flexibility should remain for reactive current contribution and voltage deviation to be measured at either the connection point where appropriate.

The Commission's draft rule therefore includes the changes proposed by AEMO allowing for flexibility in the point of measurement. That flexibility however is to measure the reactive current contribution and voltage deviation at the connection point (as agreed with AEMO and the network service provider) rather than at the generating unit terminals.

628 AEMO – AEMC project team phone conference, 13 April 2018.

629 Clause S5.2.5.5(i)(3) of the draft rule.

630 Rule change request, proposed rule, clauses S5.2.5.5(i)(iv).

631 Clauses S5.2.5.5(b)(3) and S5.2.5.5(c)(3) of the draft rule.

9.5.8 AEMO's proposal relating to total current during a fault

Box 9.8 Draft rule: Total current during a fault

The Commission's draft rule:

- requires an asynchronous generating system to have the capability to maintain total current (both active and reactive) during a disturbance at the maximum continuous current of the generating system including all operating generating units (in the absence of a disturbance) at all times,[632] and
- includes additional guidance providing for AEMO and the network service provider to impose limits on active current injection where required to maintain system security and the quality of supply to other network users.[633]

On 9 April 2018, AEMO requested an additional general requirement for the maximum continuous current of the generating system to be available at all times.[634] AEMO noted that, prior to submitting this additional request, their proposed changes to S5.2.5.5 related solely to reactive current response during a fault. AEMO considers system security needs as justifying additional requirements specifying active current injection during faults. To address this risk, AEMO propose the following as an additional general requirement:[635]

> "Notwithstanding the amount of reactive current injected/absorbed during voltage disturbances, the maximum continuous current of the generating system including all operating generating units (in the absence of a disturbance) must be available at all times."

A requirement to maintain the maximum continuous current of the generating system defines the level of active current injection through the relationship between active and reactive current in a current limited asynchronous generating system. Figure 9.6 illustrates this relationship showing reactive current on the horizontal axis and active current on the vertical axis. Total current is represented by the hypotenuse of the triangle formed by the corresponding active and reactive components.

632 Clause S5.2.5.5(i)(6) of the draft rule.

633 Ibid.

634 AEMO, Generator technical requirements: supplementary material to Rule change proposal, May 2018.

635 Ibid. AEMO's use of maximum continuous current of the generating system relates to the total active and reactive current from the generating system.

Figure 9.6 **Active and reactive components of total current for an asynchronous generating system given shallow and deep faults**

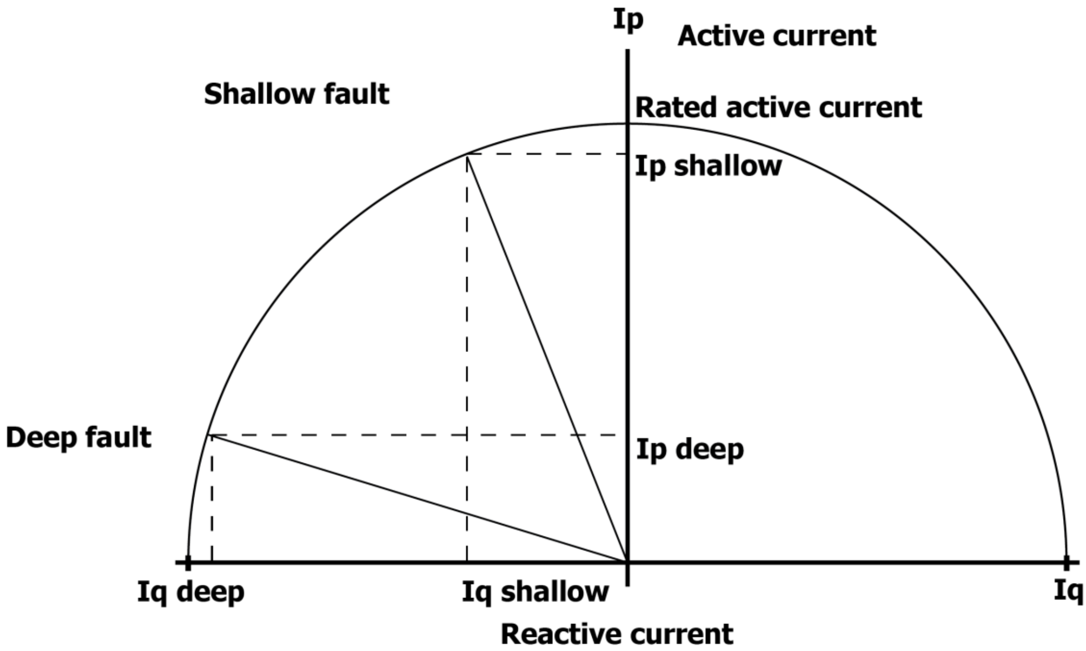

Figure 9.6 shows two hypothetical operating points to illustrate how the ratio of active and reactive current changes depending on the depth of a fault and corresponding level of injected reactive current. While the amount of active current declines with greater levels of reactive current, significant levels of active current are still injected for moderate faults in order to maintain total current at the maximum continuous current of the generating system. AEMO noted it is aware of examples in the power system where the active current of the generating system drops to zero during faults, even for shallow disturbances with a 10% - 20% voltage dip at the connection point. AEMO consider this to be a risk to power system security justifying their proposed requirement.[636]

If generators in part of the power system are exposed to faults that produce a collective decline in active current, an active power deficit will result producing a corresponding decline in power system frequency. This active power deficit occurs both during the fault and in the period immediately following as active current is recovered. To the extent that this deficit in active power can be compensated through network (including interconnector) flows, any consequential decline in frequency will be distributed across the wider power system. Should a fault in part of the power system produce an active power deficit that is greater than is able to be managed by the capacity of network connections in neighbouring areas, there is a risk to power system security from separation and islanding. This risk is most acute in areas of the power system prone to separation, including South Australia and north Queensland.

Maintaining active current injection during faults minimises any active power deficit arising, and therefore reduces the risk of islanding from a set of serious fault events in some parts of the power system. While there are system security benefits from

636 Ibid.

maintaining active current during faults, the Commission notes that this should not occur at the expense of reactive current injection. The most immediate power system security need given fault conditions is to support voltage by injecting reactive current. Even though AEMO's proposal implies a relationship between active and reactive current (as described above) the Commission considers explicit priority should be given to reactive current injection under any arrangements.

AEMO presented information from four manufacturers, three wind and one solar, showing that each was able to maintain total current of at least 100% of the maximum continuous current of the generating system. AEMO therefore consider their requirement as generally achievable by asynchronous generating systems. The Commission's draft rule incorporates AEMO's proposed general requirement on the basis that maintaining active current during a fault minimises the active power deficit arising from fault conditions and therefore enhances system security.

There may, however be circumstances where active current injection during faults is unsuitable for the power system conditions at a connection point. In particular, the Commission understands that in a part of the power system that is weak and with a low X to R ratio,[637] a high level of active power injection during a fault can cause voltage instability. To provide flexibility to account for circumstances where it is appropriate to limit the level of active current injection the draft rule also provides guidance allowing for AEMO and the network service provider to limit on active current injection where required to maintain system security and stability, and for those limits to be recorded in the performance standards for the generating system.

637 X to R ratio is the ratio of the system reactance to the system resistance. It relates to the total impedance of the circuit from the generating system, through the transmission system, transformers, conductors, to a reference point.

10 Continuous uninterrupted operation

Box 10.1 Overview

As part of its rule change request, AEMO considered that asynchronous generating systems, which are increasingly connecting to the power system, may not have adequate capability to maintain operation in response to particular voltage and frequency disturbances in the power system. In addition, AEMO considered that this change in the generation mix may lead to more frequent and severe disturbances in the power system, such as frequency disturbances caused by reductions in system inertia, as well as voltage disturbances caused by reductions in system strength. AEMO considered that without clearly specified capabilities for generating systems to maintain operation in response to such disturbances the power system would need to be operated more conservatively, including by reducing interconnector flows and implementing constraints on generation.

To address these issues, AEMO proposed changes to the access standards in Schedule 5.2 to the NER related to requirements of generating systems to maintain continuous uninterrupted operation in response to particular disturbances. This includes access standards related to frequency disturbances (clause S5.2.5.3), over-voltage and under-voltage disturbances (clause S5.2.5.4), multiple voltage disturbances (currently no explicit requirement), active power recovery following a disturbance (clause S5.2.5.5), as well as load rejection (clause S5.2.5.7). In addition, AEMO proposed amendments to the definition of continuous uninterrupted operation in Chapter 10 of the NER.

After considering stakeholder views, expert technical advice and the Commission's own assessment of the issues raised in the rule change request, the Commission's draft rule largely implements AEMO's proposed changes to the NER. This includes amending the definition of continuous uninterrupted operation in Chapter 10 of the NER to provide greater clarity to network users, strengthening existing requirements for generating systems to maintain continuous uninterrupted operation for particular disturbances, introducing a new requirement for generating systems to maintain continuous uninterrupted operation for multiple voltage disturbances, as well as extending the existing requirement to maintain continuous uninterrupted operation for particular partial load rejection events to asynchronous generating systems.

10.1 Introduction

This Chapter discusses AEMO's proposed changes to the NER that relate to requirements for connecting generating systems to be capable of continuous uninterrupted operation during and following various power system disturbances.[638]

638 Note that, for the access standards discussed in this Chapter, the general term “generating system” specifically relates to the phrase “generating system and each of its generating units” in the NER,

This Chapter first provides technical background to the access standards related to continuous uninterrupted operation, and then discusses proposed changes to the NER related to:[639]

- the definition of continuous uninterrupted operation (Chapter 10 of the NER)
- over-voltage and under-voltage disturbances (clause S5.2.5.4)
- multiple under-voltage disturbances (clause S5.2.5.5)
- active power recovery time following a disturbance (clause S5.2.5.5)
- partial load rejection (clause S5.2.5.7), and
- frequency disturbances (clause S5.2.5.3).

For each of these topics this Chapter sets out:

- the current arrangements in the NER
- the issues raised by AEMO with the current arrangements and changes proposed to address those issues
- stakeholder views, and
- analysis and conclusions.

10.2 Technical background

It is important for the security of the power system that generating systems have the ability to keep operating in response to disturbances caused by network faults or generating systems and other equipment disconnecting or disconnecting. Such capabilities are important because a generating system that is unable to continue operating during and after (i.e. maintain 'continuous uninterrupted operation' for) a disturbance at its connection point will disconnect, which may increase the extent and severity of the disturbance experienced by other generating systems.[640] A cascading outage can occur when this increase in the size of the disturbance due to one generating system disconnecting increases the risk of the remaining generating systems also disconnecting.[641] In an extreme case a cascading outage can lead to a major supply disruption,[642] or even a black system event.[643]

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unless specified otherwise. One exception to this is S5.2.5.7, which AEMO has proposed to apply to generating systems only, and not individual generating units.

639 See clauses S5.2.5.3, S5.2.5.4, S5.2.5.5 and S5.2.5.7 of the NER.

640 The ability of a generating system to 'withstand' a disturbance is technically referred to as its ability to maintain 'continuous uninterrupted operation', which is defined in Chapter 10 of the NER.

641 Cascading outage is defined in Chapter 10 of the NER as “the occurrence of an uncontrollable succession of outages, each of which is initiated by conditions (e.g. instability or overloading) arising or made worse as a result of the event preceding it.”

642 Major supply disruption is defined in Chapter 10 of the NER as “the unplanned absence of voltage on a part of the transmission system affecting one or more power stations and which leads to a loss of supply to one or more loads.”

643 Black system is defined in Chapter 10 of the NER as “the absence of voltage on all or a significant part of the transmission system or within a region during a major supply disruption affecting a significant number of customers.”

AEMO and network service providers plan and operate the power system so that the system frequency and network voltages are kept within the system standards, at least for credible contingencies.[644] The access standards that require a generating system to maintain continuous uninterrupted operation for certain disturbances (such as changes in frequency) generally align with the corresponding system standards. However, sometimes the access standards require generating systems to maintain continuous uninterrupted operation for disturbances that are more arduous than those likely to be caused by single credible contingencies. An example of this is the requirement to maintain continuous uninterrupted operation for frequency disturbances under the automatic access standard for clause S5.2.5.3 of the NER. This additional capability over and above that required for single credible contingencies is desirable for limiting the risk of a cascading outage following more severe contingencies. This is appropriate given the significant costs that can result from a severe cascading outage.

Some access standards (such as reactive power response during a disturbance) at clauses S5.2.5.4 and S5.2.5.5) are designed to help keep the power system within the limits around which connected generating systems are designed to maintain continuous uninterrupted operation. As such, there is often a close interaction between continuous uninterrupted operation capabilities, and other capabilities required under other access standards. For example, one access standard might require a generating system to maintain voltage at the connection point within a certain range, and a corresponding access standard might aim to limit the risk of generating systems disconnecting if network voltages leave that range by requiring those generators to maintain continuous uninterrupted operation.

10.2.1 Factors relevant to the assessment of continuous uninterrupted operation access standards

Generally, generating systems that can maintain continuous uninterrupted operation for more severe disturbances cost more than those with lower capabilities. In some cases the additional cost will be negligible, but in others it can be more substantial, especially when the costs are aggregated across all generating systems connecting to the power system. Consistent with the assessment framework presented in Chapter 3, the assessment of whether to increase or introduce any capabilities to maintain continuous uninterrupted operation should balance:

- the benefits of increased capability in terms of the reduced likelihood of cascading outage, major supply disruptions and black system events, and
- the cost of providing the additional (or new) capability to maintain continuous uninterrupted operation.

It is important that the capability that is required by connecting generating systems through the minimum access standard is likely to be equal to or higher than that required to maintain continuous uninterrupted operation for a credible contingency.

644 The system standard for the allowable power system frequency ranges for different contingencies is set out in the Frequency Operating Standards as determined by the Reliability Panel. The system standard for the allowable levels of the network voltages is set out in clause S5.1a.4 of the NER.

For example, the current mainland frequency operating standards require that the frequency be kept in the range of 49 Hz to 51 Hz following a credible network contingency,[645] while the continuous uninterrupted operation capabilities require generating systems to operate for short periods out to 47 Hz to 52 Hz during frequency disturbances.[646]

This capability exceeds what is required for a single credible contingency and provides the power system with an ability to cope with relatively severe frequency disturbances, without experiencing cascading outages that may otherwise lead to a black system event.

This capability to maintain continuous uninterrupted operation following relatively severe disturbances may require investment in additional equipment or control systems, increasing costs for generating systems. However, these costs should be compared with the potential costs that can result from cascading outages and black system events. For example, the South Australian black system event in 2016, which was caused by a cascading outage, is estimated to have cost the South Australian economy $450 million.[647]

10.2.2 Role of the minimum access standards for continuous uninterrupted operation

The level of the minimum access standards for requirements to maintain continuous uninterrupted operation has a very important impact on the risk of a cascading outage. This is because generating systems with the lowest capabilities for continuous uninterrupted operation would be more likely to disconnect first for a given disturbance and hence may increase the size of the disturbance to which remaining generating systems would be exposed.

To illustrate this concept, an analogy can be made by reference to the minimum specified strength of mooring ropes used to hold an ocean liner in place on a wharf. The ability to hold the ocean liner in place is determined by the combined strength of all of the ropes. However, if the minimum strength of any particular rope is too low, that rope may break, leading to the others bearing a greater load, increasing the likelihood of a cascading failure of the remaining ropes and the ocean liner floating away. The same logic applies to the role of a minimum access standard for a continuous uninterrupted operation requirement in the power system. All generating systems need to have sufficient capability in order to limit the risk of a cascading outage. Having some generators with lower or no capabilities in this case is not appropriate.

This is quite different to a minimum access standard for reactive power capabilities and requirements.[648] The power system needs some reactive power capabilities in an area

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645 A less tight range of 49.5Hz to 50.5Hz applies for generator or load contingencies.

646 The full ranges are 47Hz to 49Hz and 51Hz to 52Hz, being the mainland extreme frequency excursion tolerance limit for multiple contingency events. The specifics of these ranges are established in the Frequency Operating Standard, which are determined by the Reliability Panel.

647 Parliament of South Australia, Report of the select committee on the state-wide electricity blackout and subsequent power outages, 28 November 2017, p. 12.

648 Clauses S5.2.5.1(a) and (b) provide the automatic and minimum access standards for reactive power capability.

or region to satisfy the respective system standards, but it does not need each and every generating system to provide the reactive power capabilities.

10.3 Continuous uninterrupted operation definition

This section sets out AEMO's proposed changes to the definition of 'continuous uninterrupted operation' in Chapter 10 of the NER.

10.3.1 Current arrangements

'Continuous uninterrupted operation' is a term defined in Chapter 10 of the NER and used to refer to the ability of a generating system (or operating generating unit) to remain connected (although not necessarily at full performance or normal operation) to support the power system during a disturbance and return to normal operation once the disturbance has resolved. Continuous uninterrupted operation is currently defined as:[649]

> "In respect of a *generating system* or operating *generating unit* operating immediately prior to a *power system* disturbance, not *disconnecting* from the *power system* except under its *performance standards* established under clauses S5.2.5.8 and S5.2.5.9 and, after clearance of any electrical fault that caused the disturbance, only substantially varying its *active power* and *reactive power* required by its *performance standards* established under clauses S5.2.5.11, S5.2.5.13 and S5.2.5.14, with all essential auxiliary and *reactive plant* remaining in service, and responding so as to not exacerbate or prolong the disturbance or cause a subsequent disturbance for other *connected plant*."

10.3.2 Rule change request

It its rule change request, AEMO considered that the definition of continuous uninterrupted operation needed to be reviewed to include existing and proposed requirements in clause S5.2.5.5 of the NER.[650] The current definition does not explicitly mention requirements in clause S5.2.5.5.

AEMO therefore proposed the following changes to the definition of continuous uninterrupted operation:[651]

> In respect of a *generating system* or operating *generating unit* operating immediately prior to a *power system* disturbance, not *disconnecting* from the *power system* except under its *performance standards* established under clauses S5.2.5.8 and S5.2.5.9 and, <u>during the disturbance and </u>after clearance of any electrical fault that caused the disturbance, <u>not </u>~~only substantially~~ varying~~ its~~ *active power* <u>or </u>~~and~~ *reactive power* <u>unless </u>required by its *performance standards* established under clauses <u>S5.2.5.5,</u> S5.2.5.11, S5.2.5.13 and S5.2.5.14, with all essential auxiliary and *reactive plant* remaining in service, and responding so

649 Chapter 10 of the NER.

650 Rule change request, p. 25.

651 Rule change request, p. 87. Note, text proposed to be removed is struck through, and proposed new text is underlined.

as ~~to~~ not to exacerbate or prolong the disturbance or cause a subsequent disturbance for other *connected plant*.

AEMO proposed replacing the phrase "only substantially varying" with "not varying". AEMO advised the Commission that this was designed to prevent any variation of active and reactive power after clearance of a fault, unless required or permitted by a generating system's performance standards. AEMO's proposed definition, therefore, removes the requirement that, after the clearance of any electrical fault, a generating system should only 'substantially' vary its active power and reactive power as required by its performance standards.

This change appears to represent a reduction in the level of flexibility available to a generating system to manage unavoidable (or insubstantial) variations in active and reactive power under such conditions. AEMO advised the Commission that this was due to ambiguity in the phrase "only substantially varying" leading to differing interpretations of the definition of continuous uninterrupted operation by stakeholders.[652]

10.3.3 Stakeholder views

Many stakeholders identified specific aspects of the proposed changes to the definition of continuous uninterrupted operation that could result in outcomes that are unworkable or have unintended consequences. Several network businesses also considered that the proposed definition removed uncertainty in how the definition is interpreted.[653]

Advisian considered that the proposed changes appear to prevent a generating system from responding during a transient event,[654] which may be required to control the voltage or frequency at the connection point.[655] Advisian, the Australian Energy Council and Pacific Hydro further considered that synchronous generating systems would not be able to comply with the proposed changes due to their inherent response to transient events in the power system.[656] Transient events can sometimes cause changes to the output of active or reactive power for short periods as a result of a generating system being synchronised to the power system voltage and frequency.

RES Australia considered that the response of a generating system following a fault should give priority to the recovery of the reactive power over the active power, and this appears contrary to the requirements for continuous uninterrupted operation proposed by AEMO.[657] RES Australia instead considered that the definition should allow a reduction in active power to facilitate an increase in reactive power (contributing to the recovery of voltage) for a specified period following a disturbance.

652 Advice provided to the Commission by AEMO, 3 May 2018.

653 Submissions to the consultation paper: Energy Networks Australia, p. 8; Ergon-Energex, p. 8, TasNetworks, p. 17; Transgrid, p. 6.

654 A transient event is a relatively short-lived change in voltage and/or frequency.

655 Advisian, submission to the consultation paper, p. iv.

656 Submissions to the consultation paper: Advisian, p. iv; Australian Energy Council, p. 2; Pacific Hydro, p. 11.

657 RES Australia, submission to the consultation paper, p. 8.

Terrain Solar considered that removing the ability for a generating system to "only substantially" vary its active and reactive power under particular other performance standards, would remove flexibility for generators to "negotiate reasonable technical outcomes."[658] This is because the variation in the active or reactive power output of a generating system may not always present a material risk to system security, and thus variation of its output should not necessarily mean that the generating system should not be connected.

Origin Energy considered that a clear definition of 'disturbance' would be valuable as it would better define the limits within which a generating system is expected to perform, and that AEMO should make an allowance for units to vary their reactive power.[659] The Commission notes that while 'disturbance' is not defined in the NER, its meaning within each access standard that it appears is related to specific voltage or frequency conditions that occur as a result of the disturbance, as outlined in the relevant access standard.

Stakeholders did not discuss the cost impacts of AEMO's proposed changes to the definition of continuous uninterrupted operation.

10.3.4 Updated AEMO position

Following initial stakeholder feedback, AEMO suggested some changes to the definition it proposed in the rule change request. The revised definition, including AEMO's suggested changes, is set out below.[660]

> In respect of a *generating system* or operating *generating unit* operating immediately prior to a *power system* disturbance:
>
> (a) not disconnecting from the *power system* except under its *performance standards* established under clauses S5.2.5.8 and S5.2.5.9 ~~and~~;
>
> (b) during the disturbance contributing reactive current as required by its *performance standards* established in clause S5.2.5.5; and
>
> (c) after clearance of any electrical fault that caused the disturbance, not ~~only substantially~~ varying ~~its~~ *active power* or ~~and~~ *reactive power* unless required by its *performance standards* established under clauses S5.2.5.11, S5.2.5.13 and S5.2.5.14,
>
> with all essential auxiliary and *reactive plant* remaining in service, and responding so as ~~to~~ not to exacerbate or prolong the disturbance or cause a subsequent disturbance for other *connected plant*.[661]

658 Terrain Solar, submission to the consultation paper, p. 7.

659 Origin, submission to the consultation paper, p. 10.

660 AEMO, Supplementary material to rule change proposal, October 2017, p. 11, available at www.aemc.gov.au. Note that, text proposed to be removed is struck through, and proposed new text is underlined.

661 Note this is different to the version provided in AEMO's submission to the consultation paper, which contained errors in the underlining and strike-through text that did not accurately describe the proposed changes to the current arrangements.

AEMO considered that active and reactive power must be maintained when the voltage is between 90% and 110% of normal voltage following a disturbance so as not to exacerbate, prolong or cause a subsequent disturbance for other connected plant. AEMO proposed a change to the definition of continuous uninterrupted operation to ensure that the reactive current injection requirement proposed by AEMO in clause S5.2.5.5 of the NER is explicitly captured. This requirement in the updated definition would apply during a disturbance, and not after, to mirror the requirements in clause S5.2.5.5 to supply or absorb reactive current during a fault.

AEMO advised the Commission that the proposed minimum access standard in clause S5.2.5.4 and definition of continuous uninterrupted operation proposed in its rule change request had been interpreted by some stakeholders as a requirement that active power not vary for disturbances that cause the voltage at the connection point to reduce down to 70% of normal voltage. It is instead AEMO's intention that a generating system be able to respond to disturbances that cause the voltage to go outside the normal operating range (90 – 110% of normal voltage) by varying active power in accordance with its performance standards. AEMO's latest amendment (set out above) to the proposed definition for continuous uninterrupted operation clarifies that generating systems are not required to manage their active power during the presence of a fault.

10.3.5 Analysis and conclusions

Box 10.2 Draft rule

To address the issues identified above, the Commission's draft rule makes the following changes to the definition of 'continuous uninterrupted operation' in Chapter 10 of the NER:

- allowing variation of active and reactive current injection or absorption during a fault as required in clause S5.2.5.5
- allowing variation of active power output and reactive power injection or absorption after the clearance of a fault as required or permitted in clause S5.2.5.5
- specifying the contribution of active current, as well as reactive current, as required or permitted by performance standards established in clause S5.2.5.5, and
- qualifying the requirement not to exacerbate or prolong the disturbance or cause a subsequent disturbance for other connected plant, where this is required or permitted by relevant performance standards.

This section sets out:

- the Commission's analysis of the of the issues raised by AEMO, and
- the Commission's draft rule to address any material issues found.

The updated proposal to the definition of continuous uninterrupted operation was discussed at the 1 February 2018 meeting of the technical working group convened to support this rule change request. There was general agreement at this meeting that the updated definition addressed most of the issues raised by stakeholders with the changes initially proposed in the rule change request.

One area of continuing concern was the replacement of “only substantially varying its active and reactive power …” with “not varying active power or reactive power …”, which would require generating systems to not vary active and reactive power in response to a disturbance at all, unless required or permitted by certain other performance standards. More specifically, under AEMO’s original proposed definition, active or reactive power must not be varied unless necessary in meeting the requirements of (or otherwise permitted by) the performance standards under clauses S5.2.5.11, S5.2.5.13 and S5.2.5.14 for reactive power or voltage control, and for active power or frequency control.

Placing an obligation on generating systems to ‘not vary’ active or reactive power after the clearance of the fault that caused the disturbance, except when meeting certain other voltage or frequency control obligations, may restrict the connection of generating systems that do not have such a capability. This would occur even if the performance of the connecting generating system during a disturbance does not cause a power system security issue. It may be unreasonable for a generating system to be prevented from varying its active or reactive power (outside of requirements in other performance standards) following a fault due to unexpected or natural changes in generating system performance that are outside of the control of the operator, but are nonetheless an insubstantial variation with minimal impact on the power system. For example, there may be situations where not varying active power would be unreasonable, such as following a nearby three-phase fault that reduces voltage at the connection point to almost zero.

Placing an obligation on generating systems to ‘not vary’ active or reactive power after clearance of a fault, as described above, may also create a inefficient barrier to entry for generating equipment that does not have this capability, even though such equipment may not present a risk to power system security. This may increase costs for connection applicants by reducing competition in the supply of generation equipment, or creating additional compliance costs.

In submissions to the consultation paper, stakeholders generally agreed that removing the flexibility allowed under the current definition could have negative effects and is not justified.

The Commission’s draft rule therefore amends the definition of continuous uninterrupted operation in Chapter 10 of the NER to allow for variation of reactive current injection or absorption during a fault as required in clause S5.2.5.5, and to allow for reasonable variation of active power output and reactive power injection or absorption after the clearance of a fault as required in clause S5.2.5.5.

The rule also qualifies the additional requirement not to exacerbate or prolong the disturbance or cause a subsequent disturbance for other connected plant, where this is required or permitted by relevant performance standards.

The definition of continuous uninterrupted operation in the draft rule also specifies in part (b) the contribution of active current, as well as reactive current, as required or permitted in clause S5.2.5.5. This is in accordance with the new general requirement in the draft rule, which requires the maximum continuous current of a generation system including all operating generating units to be available at all times (discussed in Chapter 9).

The amended definition of continuous uninterrupted operation in the draft rule will contribute to the NEO by providing greater clarity and certainty to network users as to the specific requirements of continuous uninterrupted operation. This will contribute to the security of the power system by minimising risks associated with inappropriate interpretation of the definition of continuous uninterrupted operation. These changes are not likely to result in additional costs.

10.4 Voltage disturbance capability

This section discusses AEMO's proposed changes to the requirements for connecting generating systems to maintain continuous uninterrupted operation during over-voltage and under-voltage disturbances in the power system.

10.4.1 Current arrangements

The system standards in the NER outline how voltages throughout the power system are required to be within the range of 90% to 110% of their normal values, except as a consequence of a credible contingency.[662] However, following a disturbance to the power system, such as a voltage or frequency change resulting from a contingency, the voltage magnitude at one or more locations in the power system may be outside this normal range.

Clause S5.2.5.4 of the NER sets out the capabilities for continuous uninterrupted operation during voltage disturbances that connecting generating systems are required to provide. These capabilities are necessary to minimise the risk that voltage disturbances propagate throughout the power system, potentially leading to a cascading outage. The clause includes both an automatic and a minimum access standard.

The ability of different generating systems to maintain continuous uninterrupted operation for voltages outside the normal range depends on a number of factors, including the technology that is used. The cost in meeting these access standards will likely vary between generating systems as a result.

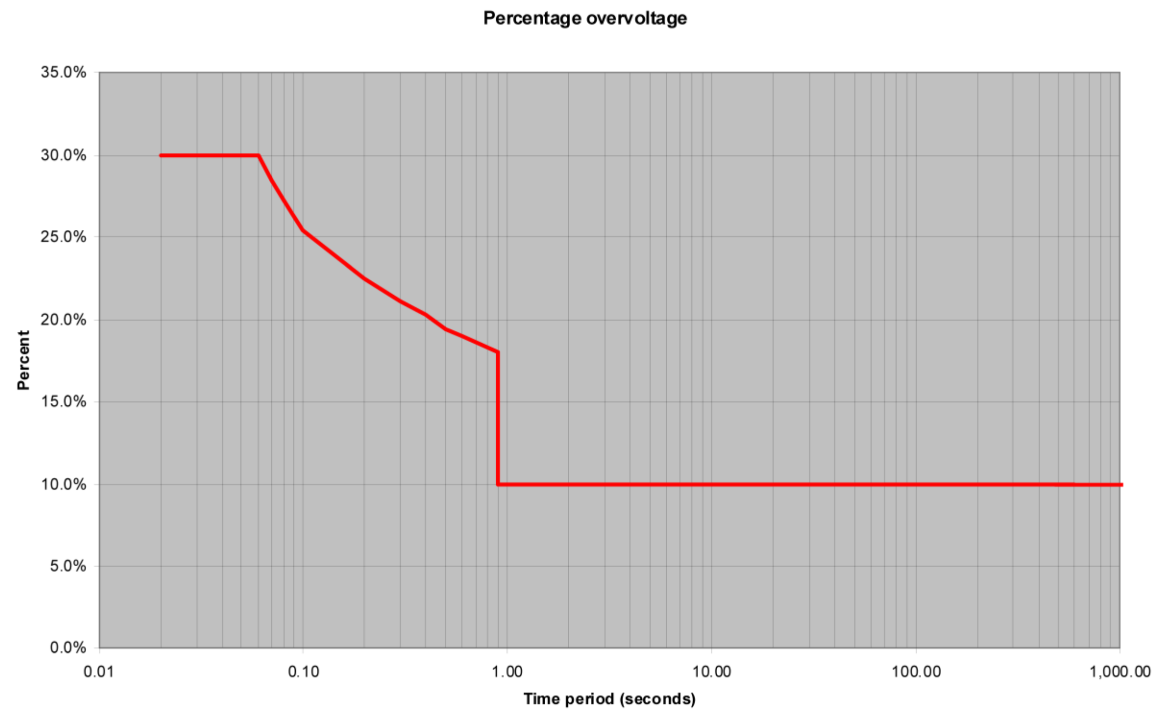
10.4.2 Over-voltage requirements

The automatic access standard for maintaining continuous uninterrupted operation during over-voltage (i.e. above 110% of normal voltage) disturbances is linked to the

662 See clause S5.1a.4 of the NER. Chapter 10 of the NER also defines the normal voltage as "in respect of a connection point, its nominal voltage or such other voltage up to 10% higher or lower than nominal voltage, as approved by AEMO, for that connection point at the request of the Network Service Provider who provides connection to the power system." Chapter 10 of the NER also defines nominal voltage as "the design voltage level, nominated for a particular location on the power system, such that power lines and circuits that are electrically connected other than through transformers have the same nominal voltage regardless of operating voltage and normal voltage."

system standard for voltage magnitude in clause S5.1a.4.[663] That is, to meet the automatic access standard, 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 (i.e. not exceed) the duration and voltage levels contained in the figure provided in clause S5.1a.4 of the NER (Figure 10.1 below).

Figure 10.1 Current voltage level and duration requirements in clause S5.1a.4.



The automatic access standard operates in conjunction with the requirement that each network service provider plan and design its network and voltage control equipment so that voltages within its network are kept within the levels shown in Figure 10.1 above,[664] as a consequence of a credible contingency event, or a protected event.[665] Therefore, following any credible contingency event or protected event, all the generating systems in the network that meet the automatic access standard would be expected to maintain continuous uninterrupted operation.

663 The system standard for the voltage magnitude in clause S5.1a.4 is referred to as the standard for power frequency voltage. This refers to the component of voltage at the frequency of the power system, which is initially 50Hz. The voltage in the power system may also include small components of voltage at other frequencies, known as harmonics. The standards for these components of voltage are set out in clause S5.1a.6, which refers to levels defined in an Australian Standard.

664 Clause S5.1.4 of the NER. Schedule S5.1 of the NER outlines network performance requirements to be provided or co-ordinated by network service providers.

665 A protected event is defined in clause 4.2.3(f) of the NER as “a non-credible contingency event that the Reliability Panel has declared as a protected event in clause 8.8.4, where that declaration has come into effect and has not been revoked. Protected events are a category of non-credible contingency event”. AEMO is able to use a combination of ex-ante solutions, such as the purchase of frequency control ancillary services, with some controlled load shedding, to limit the consequences of protected events.

The minimum access standard for over-voltage capability does not require a generating system be able to maintain continuous uninterrupted operation above 110% of the normal voltage. In addition, the requirement to maintain continuous uninterrupted operation between 90% and 110% of the normal voltage does not apply if the ratio of the voltage magnitude as a percentage of the normal voltage, and the frequency as a percentage of 50Hz, exceeds:

- a value of 1.15 for more than two minutes, or
- a value of 1.1 for more than 10 minutes.[666]

Under-voltage requirements

To meet the under-voltage (i.e. below 90% of normal voltage) automatic access standard in clause S5.2.5.4 a generating system must be capable of continuous uninterrupted operation where a power system disturbance causes the voltage at the connection point to vary:

- between 70% and 80% of the normal voltage for at least 2 seconds, and
- between 80% and 90% of the normal voltage for at least 10 seconds.

The minimum access standard for continuous uninterrupted operation during under-voltage disturbances does not require a generating system be able to maintain continuous uninterrupted operation below 90% of the normal voltage.

Negotiated access standard for voltage disturbance

The negotiated access standard for voltage disturbance is an AEMO advisory matter.[667]

Under the current NER, a negotiated access standard for voltage disturbance requires a generating system and each of its generating units to be capable of meeting the automatic access standard for over-voltage and under-voltage, except where AEMO and the network service provider agree that:

- the negotiated access standard is as close as practicable to the automatic access standard, while respecting the need to protect the plant from damage
- the generating plant that would be disconnected as a result of any voltage excursion within levels specified by the automatic access standard is not more than 100 MW, or a greater limit based on what AEMO and the network service provider both consider to be reasonable in the circumstances, and
- there would not be a material adverse impact on the quality of supply to other network users or power system security.

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666 The voltage generated by a synchronous generating unit is proportional to the speed, or frequency, and the strength of the magnetic field produced by the rotor. Some synchronous generating units would risk damage due to excessive magnetic flux if required to operate at a too high a voltage level for a given frequency.

667 While the process of negotiating performance standards is between a network service provider and the connection applicant, AEMO is required to approve some of the negotiated access standards, known as AEMO advisory matters. These are typically related to matters of system security and stability, which fall within AEMO's remit as system operator.

10.4.3 Rule change request

AEMO considered that changes in the generation mix are increasing the difficulty of managing voltages in the power system. It also considered that temporary over-voltages in future may exceed the existing system standard, and by extension, the existing automatic access standard for connecting generating systems.[668] AEMO noted this is consistent with observations following the recent network separation events in South Australia, including the black system event of 28 September 2016. AEMO also considered that the risk of higher temporary over-voltages has increased following the implementation of the special protections scheme intended to manage the stable separation of South Australia following a separation event.

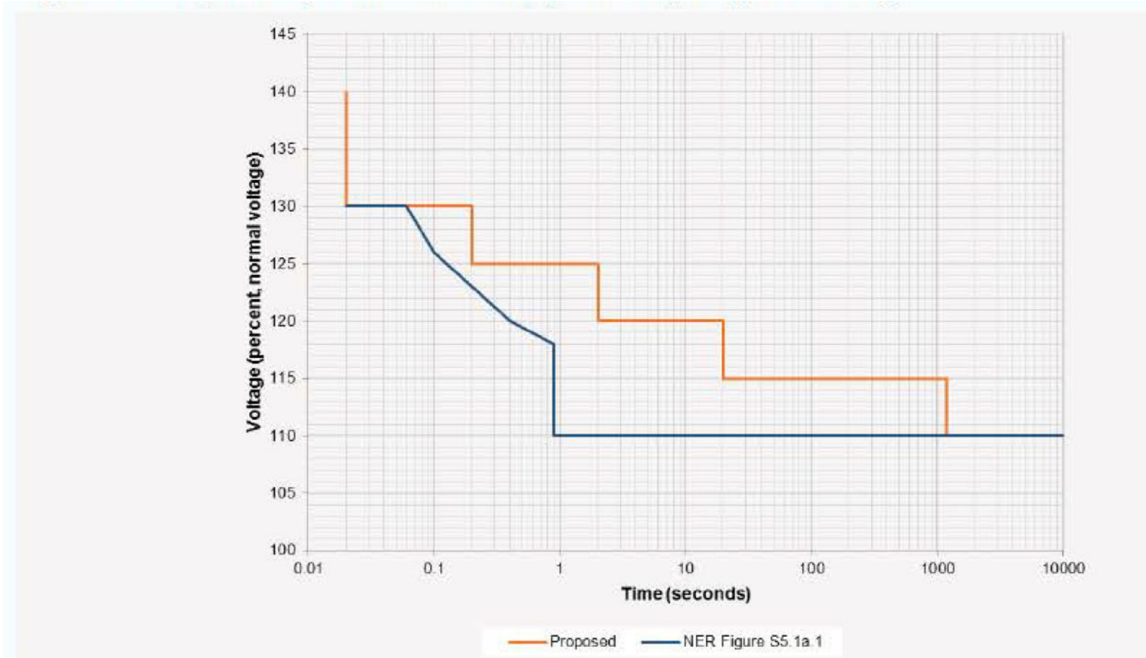
In its rule change request, AEMO proposed a number of changes aimed at addressing these issues,[669] including proposing changes to the requirements for connecting generating systems to maintain continuous uninterrupted operation for certain voltage levels and durations at the connection point.

In particular, AEMO proposed increasing the voltage level and duration requirements in the system standard in clause S5.1a.4 of the NER to the levels shown in Figure 10.2 below. This change would flow through to the automatic access standard in clause S5.2.5.4, which has the same over-voltage requirements as those in the system standard in clause S5.1a.4 of the NER. AEMO proposed amending the minimum access standard in clause S5.2.5.4 such that the over-voltage requirements also mirrored those in the system standard in clause S5.1a.4.

668 Rule change request, p. 30.

669 The other proposed changes include changes to the requirements for connecting generating systems to maintain continuous uninterrupted operation for certain faults (addressed later in this Chapter), and requirements to inject or absorb reactive power or current to help control voltage levels on the power system (addressed in Chapters 7 to 9).

Figure 10.2 AEMO's proposed voltage level and duration requirements for clause S5.1a.4.[670]



Note that, while Figure 10.2 does not show the over-voltage requirements for the first 20 milliseconds (ms) of a disturbance, in AEMO's rule change request it recommended that the requirement to be capable of continuous uninterrupted operation for over-voltages be capped at 140% of the normal voltage for this period.[671]

Based on research by CIGRE Working Group 33.10, AEMO considered that existing network equipment would be able to meet the proposed new system standard for over-voltage, in particular, the proposed requirement for operation within limits of 115% of normal voltage for up to 1200 seconds (20 minutes).[672]

AEMO did not propose changes to the automatic access standard for under-voltage disturbances.

AEMO also proposed significant changes to the minimum access standard for under-voltage disturbances so that it would be equivalent to the automatic access standard, except that:

- the duration of the requirement to maintain continuous uninterrupted operation between 80% and 90% of normal voltage would be 5 seconds (rather than 10 seconds), and
- the requirement to maintain continuous uninterrupted operation between 90% and 110% of normal voltage does not apply if the ratio of the voltage magnitude as a percentage of normal voltage, and the frequency as a percentage of 50 Hz,

670 Rule change request, p. 33.

671 Rule change request, p. 33.

672 CIGRE Working Group 33.10, Temporary over-voltage withstand characteristics of extra high voltage equipment, August 1998, available at https://e-cigre.org/publication/ELT_179_3-temporary-over-voltage-withstand-characteristics-of-extra-high-voltage-equipment.

exceeds 1.15 for more than 2 minutes or 1.1 for more than 10 minutes (noting this exception is in the current arrangements for the minimum access standard).

10.4.4 Stakeholder views

Some stakeholders supported the view that increased requirements would provide a necessary benefit to power system security. However, the majority of stakeholders considered that the voltage disturbance requirements proposed by AEMO in its rule change request were too arduous, particularly the requirements under the minimum access standard.

Energy Networks Australia agreed that the changes proposed by AEMO would increase the capability of new connecting generating systems to maintain continuous uninterrupted operation for voltage disturbances, which would also increase the ability of the power system to remain secure during more severe contingencies.[673]

Many stakeholders considered that the proposed increases to the levels and associated durations of the over-voltage requirements for the system standard in clause S5.1a.4 may increase the risk of damage to existing network and generation equipment.[674]

RES Australia and SMA indicated that the proposed requirement to maintain continuous uninterrupted operation for an over-voltage disturbance of 140% of the normal voltage would add approximately 50% to the cost of the transistors used in inverters, which make up about 30% of the total inverter price (a total price increase of about 15%).[675] Similarly, GE Australia and Advisian considered that the proposed over-voltage requirements may exceed international inverter standards.[676]

Stanwell and Terrain Solar considered that the control of voltage on the network is the responsibility of network service providers and that the proposed changes to the voltage disturbance access standards appear to represent a transfer of responsibility from network service providers to connection applicants.[677]

10.4.5 Updated AEMO position

Following feedback received during a stakeholder workshop on this rule change request held on 12 October 2017, AEMO updated its views on its proposed changes to S5.2.5.4 of the NER. AEMO's updated views were set out in its submission to the consultation paper.[678] AEMO suggested:[679]

- retaining the existing system standard for over-voltage requirements in clause S5.1a.4 so that the limits within which network service providers are obliged to

673 Energy Networks Australia, submission to the consultation paper, p. 6.

674 Submissions to the consultation paper: Alinta Energy, p. 4; Ausgrid, p. 2; Energy Networks Australia, p. 6; Ergon-Energex, p. 5; GE Australia, p. 13; Origin Energy, p. 2; Tilt Renewables, p. 5.

675 Submissions to the consultation paper: RES Australia, pp. 4-5; SMA, p. 1.

676 Submissions to the consultation paper: GE Australia, p. 2; Advisian, p. 11.

677 Submissions to the consultation paper: Stanwell, p. 3; Terrain Solar, p. 5.

678 AEMO, submission to the consultation paper, pp. 19-20.

679 Ibid at p. 19.

manage their networks would not risk exposing existing equipment to over-voltages that are greater than they are designed to operate at

- retaining the levels and durations originally proposed for the automatic access standard for over-voltage requirements,[680] and
- revising the proposed minimum access standard for over-voltage disturbances to require a less stringent requirement compared to the automatic access standard, both in terms of the level and duration of the over-voltages, in order to recognise the limited capability of some generating systems.

The Commission notes that the automatic access standard is more arduous than the respective system standard for over-voltages. This means that if a contingency occurs that is more severe than a credible contingency, the voltage may exceed the system standard, but a generating system registered under the automatic access standard would be required to maintain continuous uninterrupted operation beyond that threshold and until the voltage exceeds the updated automatic access standard.

AEMO's updated position on the automatic access standard would require a connecting generating system and each of its generating units to 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. over 130% of normal voltage for a period of at least 0.02 seconds
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 seconds
4. 115% to 120% of normal voltage for a period of at least 20 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.

The Commission understands that the requirement for over-voltages up to 115% of normal voltage for as long as 20 minutes is to account for prolonged over-voltages that require system operator intervention to return the voltage to the normal voltage range. This is in excess of the system standards in clause S5.1a.4, which means that if an over-voltage that followed the profile in the automatic access standard occurred, the risk of damage to network and customer-connected equipment may be increased.

AEMO's updated position on the minimum access standard would require a connecting generating system and each of its generating units to 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. 115% to 120% of normal voltage for a period of at least 0.1 seconds

680 Note that the updated automatic access standard for over-voltage capability is silent on the requirements for the first 20 ms of the disturbance, which is consistent with the existing system standard.

2. 110% to 115% of normal voltage for a period of at least 0.9 seconds
3. 90% to 110% of normal voltage continuously, provided the ratio of the voltage magnitude as a percentage of normal voltage to the frequency in percentage of 50Hz does not exceed 1.15 for more than 2 minutes or 1.1 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.

The Commission understands that AEMO's updated position intends that time spent in voltage bands further from normal voltage is included in the count of the time spent in voltage bands closer to normal voltage. For example, in the case of an under-voltage disturbance under the automatic access standard, if the voltage is between 70% and 80% of normal voltage for 1.5 seconds, then the generating system must be capable of continuous uninterrupted operation between 80% and 90% of normal voltage for a further 8.5 seconds before it can disconnect, making a total of 10 seconds.

Stakeholders did not have an opportunity to provide feedback in submissions on AEMO's updated position because the amendments were provided in AEMO's submission to the consultation paper. However, as discussed below, the technical working group did have an opportunity to consider the updated proposal at a meeting held on 1 February 2018.

10.4.6 Analysis and conclusions

This section sets out:

- the Commission's analysis of the of the issues raised by AEMO, and
- the Commission's draft rule to address any material issues found.

10.4.7 Analysis of the issues

Following a power system disturbance, such as that caused by a fault, the loss of an interconnector or large generating unit, there can be periods of over-voltage or under-voltage outside the range of 90% to 110% of normal voltage. This can cause generating systems to change their active or reactive power output, or even disconnect, which would likely increase the severity of the disturbance and risk a cascading outage. Therefore, to reduce the risk of cascading outages, all generating systems need to be capable of continuous uninterrupted operation for voltage disturbances that can be reasonably expected to occur.

Such voltage disturbances are likely to become more frequent and severe where synchronous generation retires from the power system and asynchronous generation connects in its place. It is likely this will continue to occur, particularly in locations with high quality renewable energy resources. This may cause voltage disturbances to become more frequent and severe because such changes in the generation mix can lead to reductions in system strength (as discussed in Chapter 11), which causes voltage levels to be less stable in some parts of the network and more prone to large deviations from normal voltage following a disturbance. As such, there is a need for connecting generating systems to have greater capability for continuous uninterrupted operation during voltage disturbances.

Conclusions

Box 10.3 Draft rule

To address the issues identified above, the Commission has made a draft rule that changes clause S5.2.5.4 of the NER to implement the updated proposed changes set out by AEMO in its submission to the consultation paper.[681]

The automatic access standard would require a connecting generating system and each of its generating units to be capable of continuous uninterrupted operation where a power system disturbance causes the voltage at the connection point to vary within the following ranges:[682]

1. over 130% of normal voltage for a period of at least 0.02 seconds
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 seconds
4. 115% to 120% of normal voltage for a period of at least 20 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.

The minimum access standard would require a connecting generating system to be capable of continuous uninterrupted operation where a power system disturbance causes the voltage at the connection point to vary within the following ranges:[683]

1. 115% to 120% of normal voltage for a period of at least 0.1 seconds
2. 110% to 115% of normal voltage for a period of at least 0.9 seconds
3. 90% to 110% of normal voltage continuously, provided the ratio of the voltage to the frequency (as measured at the connection point and expressed as a percentage of normal voltage and a percentage of 50Hz frequency, respectively) does not exceed 1.15 for more than 2 minutes or 1.1 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.

The Commission notes that time spent in voltage bands further from normal voltage is included in the calculation of the time spent in voltage bands closer to

681 AEMO, submission to the consultation paper, pp. 19-20.

682 Clause S5.2.5.4(a) of the draft rule.

683 Clause S5.2.5.4(b) of the draft rule.

normal voltage.

The Commission considered a range of evidence in addressing the issues outlined above.

AEMO's updated position on its proposed automatic and minimum access standards for voltage disturbances was discussed with a number of stakeholders at a technical working group meeting on 1 February 2018. Stakeholders at the meeting generally agreed that:

- the majority of asynchronous generating systems would be able to meet the automatic access standard
- the requirement in the automatic access standard for a generating system to be capable of continuous uninterrupted operation for voltage levels of between 110% and 115% of normal voltage for 20 minutes is arduous, in effect being a steady state requirement,[684] and
- the auxiliary loads of new synchronous generating units can be designed to operate under the updated under-voltage requirements proposed by AEMO.

The Commission also considered AEMO's comparison of its original proposed over-voltage requirements with those specified in the grid codes for Hydro Quebec (where there is a high penetration of wind energy) and parts of Europe (through the European Network of Transmission System Operators for Electricity – ENTSOE).[685] Table 10.1 below compares AEMO's updated over-voltage requirements with those specified in the grid codes for Hydro Quebec and ENTSOE.

Table 10.1 Comparison of NEM and international requirements for generating systems to maintain operation during over-voltage disturbances.

	Temporary over-voltage (% of normal voltage)					
		110-115	**115-120**	**120-125**	**125-130**	**Over 130**
Duration (seconds)	Europe (ENTSOE)	Continuous up to 118%, 1200-3600 (20-60 min) thereafter				
	Hydro Quebec	300 (5 min)	30	2	0.1	0.1 (130% - 140%)
	AEMO updated proposal (automatic)	1200 (20 min)	20	2	0.2	0.02 (over 130%)

684 A steady state requirement is one that must be sustained indefinitely, as opposed to a transient requirement, which may be more arduous, but only needs to be sustained for a limited period.

685 Rule change request, p. 32.

	AEMO updated proposal (minimum)	0.9	0.1	Nil	Nil	Nil

AEMO’s updated position on over-voltage requirements for the minimum access standard is less arduous than those for the international jurisdictions listed above. The requirements proposed under the automatic access standard are similar to, more arduous than or sometimes less stringent than the international grid codes listed, depending on the over-voltage range examined. In particular, AEMO’s proposed requirement for 110-115% over-voltage under the automatic access standard is noticeably more arduous than that in Hydro Quebec (20 minute duration compared to 5 minute), but less than the ENTSOE requirement (continuous up to 118%). The Commission considers that generator access standards in the NER are relatively unique compared to international standards in providing a negotiation range between different levels of performance.

Analysis of AEMO's proposed changes has also been informed by a survey of equipment manufacturers conducted by DigSILENT Pacific on behalf of the Commission.[686] As part of the survey, an inverter manufacturer indicated that it had compared the over-voltage requirements from 28 countries and concluded that the proposed over-voltage standards represented the highest overall of all countries. DigSILENT Pacific also advised that “the proposed automatic access standard appears to be higher than most other jurisdictions and higher than the International Electrotechnical Commission standard for rotating machines,” and that this point was raised by multiple survey respondents.[687]

In terms of equipment capability, the eight manufacturers (covering both synchronous and asynchronous technologies) that responded to the survey considered that their equipment could meet the updated proposed minimum access standard in clause S5.2.5.4 of the NER.

For the updated proposed over-voltage requirements, most claimed that their equipment could readily meet the minimum access standard (i.e. at little or no additional cost using ‘off-the-shelf’ equipment), while two respondents indicated that their equipment could readily meet the automatic access standard, and four respondents claimed that their equipment could meet it with some modification to the equipment (i.e. a likely material, but manageable additional cost). For the updated proposed under-voltage requirements, all but one respondent claimed that their equipment could meet the automatic access standard at little or no additional cost.

Reasons varied as to why the four respondents above claimed that they could not readily meet AEMO’s updated position on the over-voltage requirements for the automatic access standard. Some claimed that inverter settings would need to be adjusted, while others claimed that new products would require development. One respondent considered that gas turbines would require additional equipment, such as

686 DigSILENT Pacific, Survey of Original Equipment Manufacturers, Draft report (confidential), March 2018.

687 Ibid.

oversized step-up transformers or capacitor banks. An inverter manufacturer claimed that their equipment may not be able to meet AEMO's updated proposed requirement under the automatic access standard to maintain continuous uninterrupted operation for 115% to 120% of normal voltage for a period of at least 20 seconds. This respondent noted that previous models had this capability, but that it may not be worth redesigning current models for Australian-specific access standards given the relatively small size of the Australian market.

One manufacturer of synchronous generating units claimed that their larger sized generating units may not be able to meet the over-voltage requirements under the proposed automatic access standard. This respondent also claimed that their equipment would not be able to meet the under-voltage requirements under the proposed automatic access standard; however the Commission understands this may have been due to a misunderstanding about AEMO's proposed requirements for active power output during under-voltage events, which was discussed earlier in section 10.3 on AEMO's proposed changes to the definition of continuous uninterrupted operation.

While it appears that AEMO's updated proposed over-voltage requirements under the automatic access standard are relatively stringent, both relative to international standards and the capability of equipment available in the Australian market, it is important to note that not all connecting generating systems need to meet the automatic access standard. Instead, the negotiating process allows an appropriate balance to be achieved between the needs of the power system at a connection point, and the technical capabilities and cost of a connecting generating system.

While it is expected that different manufacturers can guarantee different levels of capability, the Commission notes that there are still several manufacturers available from all of the technology types surveyed that can guarantee their equipment can meet over-voltage and under-voltage requirements for AEMO's updated proposed automatic access standards for S5.2.5.4 of the NER, and most equipment manufacturers can guarantee their equipment can meet the requirements of the proposed minimum access standard.

The Commission has therefore made a draft rule that aligns with the updated position set out by AEMO in its submission to the consultation paper. The draft rule balances:

- the need to reduce the risk of cascading outages by requiring all generating systems to be capable of continuous uninterrupted operation for the over-voltage and under-voltage disturbances that can reasonably be expected to occur in the power system, and
- the capability of and associated costs for the majority of generating systems connecting to the power system in meeting the access standards in clause S5.2.5.4 of the NER.

The Commission considers, based on the advice of stakeholders, DigSILENT Pacific and the technical working group for this rule change, that the minimum access standard can be met by synchronous generating units. The Commission also considers that asynchronous generating systems can generally meet the automatic access standard without significant modifications, which is likely to be particularly important in weaker locations. It is therefore unlikely that the arrangements set out in the Commission's draft rule would lead to significant cost increases for connection applicants or represent a barrier to entry.

The Commission notes that some manufacturers are concerned that it may be expensive to meet the requirement in the draft rule for the automatic access standard for generating systems to be capable of continuous uninterrupted operation for voltages of between 110% and 115% for as long as 20 minutes. However, the Commission considers that:

- the minimum access standard is much lower, so a reduced requirement can be negotiated when the cost is high and the requirement is not needed for system security, and
- as is discussed in Chapter 9, the inverter controls are only required to operate in an open-loop mode for voltages above 120% of normal, with the slower acting closed-loop power plant controller used to control the reactive power absorption for voltages below 120% of normal.

The voltage disturbance requirements set out in the draft rule:

- would likely lead to an improvement to the security of the power system that is necessary (as discussed earlier) by increasing the ability of new connecting generating systems to maintain continuous uninterrupted operation for over-voltages and under-voltages, thus reducing the likelihood of cascading outages
- are designed such that the automatic access standard could be met by most asynchronous generating systems and the minimum access standard could be met by most synchronous generating systems at little or no additional cost
- provide a suitable negotiation range to accommodate for the connection of generating systems at locations where the capability required in the automatic access standard is not necessary due to relatively high system strength, or other factors related to local network conditions, and
- are expressed without reference to a specific technology.

The changes to clause S5.2.5.4 of NER in the Commission's draft rule will likely improve the security of the power system, and hence are likely to contribute to the NEO, by allowing for greater capability amongst generating systems to maintain continuous uninterrupted operation for voltage disturbances in the power system that are likely to become more severe and more frequent as the generation mix changes. The flexibility provided by the negotiable range for this access standard allows connection applicants to agree on a level of capability that is appropriate for each connection. This means that it is likely that the system security benefits associated with the draft rule will outweigh any associated costs.

10.5 Multiple voltage disturbance capability

This section discusses AEMO's proposed changes to the requirements in the access standards in clause S5.2.5.5 for connecting generating systems to maintain continuous uninterrupted operation for multiple voltage disturbances in the power system.

10.5.1 Current arrangements

Clause S5.2.5.5 of the NER requires generating systems to be capable of continuous uninterrupted operation for a disturbance (or multiple disturbances) caused by specified events, including credible contingencies and particular types of faults in the power system.[688] This requirement is important because faults in the power system can cause disturbances to the voltage at the connection points of generating systems. A cascading outage in the power system could occur if one or more generating systems disconnect or do not respond quickly enough following these voltage disturbances, progressively increasing the risk of other generating systems disconnecting.

The current requirements for generating systems to maintain continuous uninterrupted operation for disturbances under the automatic and minimum access standards are very similar. This reflects the importance of all generating systems having the capability to maintain continuous uninterrupted operation for the contingencies and faults that can occur in the power system. The main differences between the automatic and minimum access standards are that:

- the automatic access standard requires generating systems to maintain continuous uninterrupted operation for more severe three phase faults, while the minimum access standard only considers single phase to ground, phase to phase faults and two phase to ground faults, and
- the automatic access standard requires generating systems to maintain continuous uninterrupted operation for faults that are cleared by breaker fail protection,[689] while the minimum access standard only considers faults that are cleared by a primary protection system.

The minimum access standard can only apply when the total reduction of generation in the power system does not exceed 100 MW.

The current arrangements in clause S5.2.5.5 of the NER do not explicitly specify the requirements for continuous uninterrupted operation following 'multiple' disturbances within a relatively short period of time. However, the Commission has been advised by AEMO and other stakeholders that the current requirements have been interpreted as a

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688 Clause S5.2.5.5 also sets out requirements following these events in terms of reactive current injection and absorption. This is addressed in Chapter 9.

689 The primary protection system is designed to detect and clear a fault within the times prescribed within clause S5.1a.8 of the NER. In most cases the primary protection system operates correctly and the fault is cleared when the circuit breakers operate and isolate the element of the power system that is experiencing the fault. However, if one or more of the circuit breakers that clear the fault fail to operate within the intended time then a slower acting backup protection system will also detect the fault and attempt to clear the fault. This backup protection system, often referred to as circuit breaker fail protection, is usually less discriminating as to the fault location and may remove from service elements in addition to the faulted element.

requirement for generating systems to maintain continuous uninterrupted operation for multiple disturbances.

10.5.2 Rule change request

In its rule change request, AEMO considered that all types of generating systems need to be resilient to successive disturbances, and considered that the level of this capability was a significant factor in the South Australian black system event of 28 September 2016.[690] Further, they noted that the access standards do not explicitly require a generating system to maintain continuous uninterrupted operation for multiple disturbances.[691]

Consequently, AEMO proposed changes to the automatic and minimum access standards that would require generating systems to be capable of continuous uninterrupted operation during and following a specified number of disturbances. AEMO's proposed changes would require generating systems to maintain continuous uninterrupted operation for up to 15 disturbances within any five-minute period for certain contingency and fault events, provided that none of the events would disconnect the generating unit from the power system by removing network elements from service. The proposed obligation would also be limited to an accumulated time below 90% voltage of 1.8 and 1.0 seconds for the automatic and minimum access standards respectively.

To inform the development of this proposal AEMO surveyed a number of inverter manufacturers to assess how their inverters would respond to some of the disturbances that preceded the South Australian black system event.[692] In each case, AEMO considered that the inverters would be compliant with the proposed standards, except for one where compliance was unclear.

10.5.3 Stakeholder views

The majority of stakeholders considered that the changes proposed by AEMO were too arduous and were not clearly expressed, thus creating uncertainty for connection applicants.

AGL, the Clean Energy Council, GE Australia, TasNetworks and Terrain Solar considered that basing the access standards for multiple voltage disturbances on the South Australia black system event would be excessive, given the exceptional circumstances surrounding the event.[693]

Similarly, Advisian, AGL and ESCO Pacific considered that 15 faults within five minutes would be very unlikely to occur as this would need to be associated with multiple transmission line outages. This could mean generating systems become part of a separated (islanded) system with multiple network elements disconnected, in which

690 Rule change request, p. 27.

691 Ibid.

692 Rule change request, p. 29.

693 Submissions to the consultation paper: AGL, p. 3; Clean Energy Council, p. 17, GE Australia, pp. 10-11; TasNetworks, p. 4; Terrain Solar, p. 1.

case these generating systems would be unlikely to be able to maintain continuous uninterrupted operation.[694]

Engie considered that the minimum access standard should be lower than that proposed by AEMO to allow room for negotiation where a generating system is unable to meet the high proposed multiple disturbance requirements.[695]

Advisian, GE Australia, Hydro Tasmania, Pacific Hydro and Stanwell considered that it was unlikely that synchronous generating units would be capable of continuous uninterrupted operation for 15 faults within five minutes.[696] This is because each fault would cause the affected generating units to participate in a transient stability event, with the risk that the generating unit would lose synchronism with the power system before 15 faults would have occurred. Advisian further considered that the synchronous generating units exposed to too many faults in a short period would be required to accelerate or decelerate at extreme torque, depending on the timing of the faults, and this may lead to damage to the generating unit's shaft.[697] Advisian also considered that types 1, 2 and 3 wind turbines would also be exposed to mechanical oscillations that would lead to damage in extreme cases of multiple disturbances.[698] AGL and Pacific Hydro considered that most synchronous machines can maintain continuous uninterrupted operation for six or seven faults, but not all generating systems could maintain continuous uninterrupted operation for 15 faults.[699]

Advisian, Hydro Tasmania and TasNetworks considered that the proposal is unclear as it does not define the timing of the 15 disturbances within a five-minute period.[700] For example, the 15 faults could all occur close together or be evenly distributed across the five-minute period. This could potentially require a very large number of combinations of faults and power system conditions to be modelled before a connection applicant can provide evidence that its connecting generating system would meet the proposed requirements. More generally, GE Power and GE Australia (in separate submissions) questioned how compliance with the proposed access standard could be tested.[701]

Ergon, Energex and TransGrid considered that the accumulated fault times of 1.8 and 1.0 seconds would not be practical when a generating system is exposed to some

694 Submissions to the consultation paper: Advisian, p. 6, AGL, p. 5; ECSO Pacific, p. 8.

695 Engie, submission to the consultation paper, p. 3.

696 Submissions to the consultation paper: Advisian, p. 12; GE Australia, p. 1; Hydro Tasmania, p. 12; Pacific Hydro, p. 4; Stanwell, p. 4.

697 Advisian, submission to the consultation paper, p. xii.

698 Advisian, submission to the consultation paper, p. xii. Type 3 wind turbines comprise the majority of wind turbines in the power system and have mechanical systems that are, to a degree, influenced by disturbances to power system voltage. Type 4 wind turbines, which are inverter-connected, experience minimal impact on the generator or mechanical drive train from power system voltage disturbances. These turbines are expected to make up an increasing proportion of new connections, especially for the largest wind farm projects. See AEMO, Wind turbine plant capabilities report, 2013, pp. 17-18.

699 Submissions to the consultation paper: AGL, p. 5; Pacific Hydro, p. 4.

700 Submissions to the consultation paper: Advisian, p. 6; Hydro Tasmania, p. 12; TasNetworks, p. 7.

701 Submissions to the consultation paper: GE Power, p. 2; GE Australia, p. 11; SMA, p. 4.

distribution network faults that can take up to two seconds to clear.[702] ESCO Pacific considered that the minimum access standard requirement of an accumulated fault time of one second with 15 faults equates to an average fault duration of 66.7 ms, which is shorter than the shortest fault clearing times required in the NER.[703]

ESCO Pacific considered that a better approach to developing the multiple disturbance requirements would be for AEMO to determine, on a case by case basis, the capability required from a connecting generating system in relation to other generating systems in that particular area or region.[704]

10.5.4 Updated AEMO position

AEMO updated its position on the proposed requirements for multiple disturbances following stakeholder feedback and additional power system modelling it conducted. The updated position was provided to the Commission and published on the AEMC website in March 2018. The updated proposed requirements are outlined in Table 10.2 below.[705] The AEMC received informal feedback on AEMO's updated proposal from some stakeholders, with the greatest concern being that the zero minimum time between successive faults under the automatic access standard may not be difficult to achieve, or reflect likely system conditions.

Table 10.2 AEMO's updated requirements for multiple disturbances.

Criteria	Automatic access standard	Minimum access standard
Total number of disturbances within five minutes	15	6
Sliding window reset time	5 minutes	30 minutes[706]
Accumulated disturbance duration[707]	1800 milliseconds	1000 milliseconds
Sum of $\Delta V \times \Delta t$[708]	1.0 pu seconds[709]	0.5 pu seconds
Number of deep disturbances[710]	6	3

702 Submissions to the consultation paper: Ergon and Energex, p. 6; TasNetworks, p. 5.

703 ESCO Pacific, submission to the consultation paper, p. 9.

704 Ibid.

705 AEMO, Multiple voltage disturbance ride-through capability: Justification of AEMO's proposal, March 2018, available at www.aemc.gov.au.

706 This means that the generating system must be capable of continuous uninterrupted operation for the same number of voltage disturbances within a five-minute interval. However, no further capability for continuous uninterrupted operation is required until the 30-minute interval expires.

707 Accumulated disturbance duration is the cumulative amount of time in milliseconds where the connection point voltage is below 90%.

708 Sum of $\Delta V \times \Delta t$ (pu second) is the time integral of voltage difference between 90% voltage and the connection point voltage when the connection point voltage is lower than 90%.

709 1 per unit (pu) voltage is equivalent to 100% voltage.

Criteria	Automatic access standard	Minimum access standard
Minimum time difference between successive disturbances	No restriction[711]	200 milliseconds[712]
Type of disturbances to be considered	• One disturbance cleared by a *breaker fail protection system* • One long-duration shallow disturbance, e.g. 80% residual voltage for 2 seconds as per S5.2.5.4 of the NER • One deep three-phase disturbance (or two deep three-phase disturbances in parts of network where a three-phase auto-reclosing is permitted) • Remaining disturbances are unbalanced • An unsuccessful auto-reclosure event is counted as two disturbances	• One disturbance cleared by a *breaker fail protection system*[713] • One long-duration shallow disturbance, e.g. 80% residual voltage for 2 seconds as per S5.2.5.4 of the NER • All disturbances are unbalanced • An unsuccessful auto-reclosure event is counted as two disturbances
Proposed access standards intended for	Asynchronous generation (Automatic and below)	Synchronous generation (Minimum and above)

Calculation of the value of $\Delta V \times \Delta t$ (pu seconds) is illustrated in Figure 10.3 below.[714]

710 Voltage at the connection point voltage drops below 50% of the normal value.

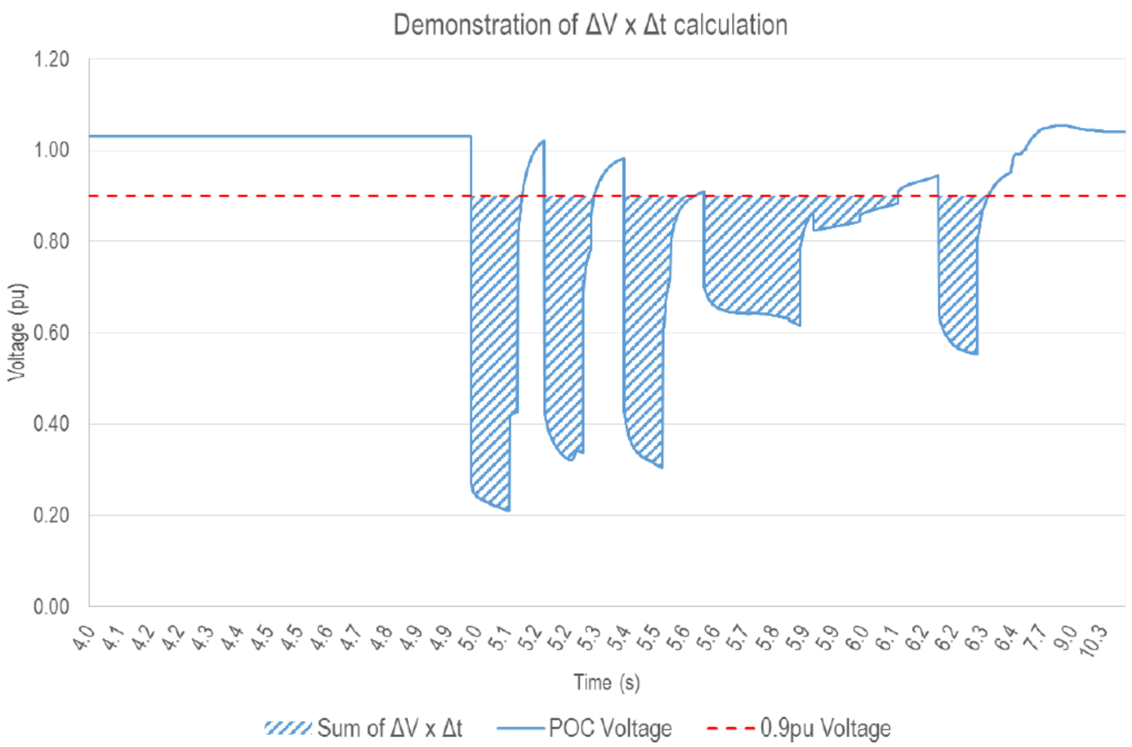
711 Meaning that two successive disturbances can occur one after another with practically zero time difference.

712 AEMO's original proposal provided for no restriction; however this was subsequently updated to 200 milliseconds.

713 Breaker fail protection system is defined in Chapter 10 of the NER as "a protection system that protects a facility against the non-operation of a circuit breaker that is required to open to clear a fault."

714 AEMO, Multiple voltage disturbance ride-through capability: Justification of AEMO's proposal, March 2018, p. 10, available at www.aemc.gov.au.

Figure 10.3 Illustration of a sum of ΔV x Δt.



In Figure 10.3 the blue curved line is a hypothetical voltage profile at the connection point and the red dashed horizontal line indicates 90% of the normal voltage. The shaded area is defined as the sum of ΔV x Δt for a given connection point voltage profile and is measured in per unit seconds (pu seconds).[715]

Under AEMO's updated position on the proposed changes to S5.2.5.5, a generating system and each of its generating units would be required to maintain continuous uninterrupted operation unless one of the following conditions are exceeded first:

- the number of disturbances in five minutes and the sliding window reset time exceeds the relevant obligation (15 for the automatic access standard or 6 for the minimum access standard)
- the number of deep disturbances (voltage at the connection point drops below 50% of the normal value) in five minutes exceeds the relevant obligation (six for the automatic access standard or three for the minimum access standard)
- the accumulated disturbance duration exceeds the relevant obligation (1.8 s for the automatic access standard or 1.0 s for the minimum access standard), and
- the sum of ΔV x Δt exceeds the relevant obligation (1.0 pu.s for the automatic access standard and 0.5 pu.s for the minimum access standard).

In addition, AEMO has suggested that generating systems be capable of continuous uninterrupted operation for a number of other fault types outlined in Table 10.2.

715 ΔV is an incremental change in voltage at the connection point and Δt is an incremental change in time since the voltage drops below 90% of normal voltage.

10.5.5 Analysis and conclusions

This section sets out:

- the Commission's analysis of the of the issues raised by AEMO, and
- the Commission's draft rule to address any material issues found.

10.5.6 Analysis of the issues

As was demonstrated from the South Australian black system event on 28 September 2016, multiple voltages disturbances within a short period of time can contribute to cascading outages.[716] As discussed earlier, voltage disturbances in the power system have the potential to become more common and severe as changes in the generation mix (from predominantly synchronous generation to a greater share of asynchronous generation) cause reductions in system strength across some parts of the power system.

AEMO noted in its rule change request and further report supporting its proposed multiple disturbance requirements that it considered the maximum number of faults within 2-, 30- and 120-minute intervals recorded in the South Australian, Queensland and New South Wales transmission and distribution networks over the period 2006 to 2016.[717] This analysis is summarised in Table 10.3 below.[718]

Table 10.3 Number of faults recorded over different time periods in transmission and distribution networks by jurisdiction.

State	Network	Time period (minutes)		
		2	30	120
SA	Transmission	5	11	16
NSW	Transmission	7	105	224
QLD	Transmission	4	9	13
SA	Distribution	7	18	18
NSW	Distribution	0	5	18
QLD	Distribution	4	9	13

Figure 10.4 below summarises these results graphically, with the two outliers for NSW (105 and 224 faults) removed for clarity.

716 Rule change request, p. 27.

717 Rule change request, p. 29, and AEMO, *Multiple voltage disturbance ride-through capability: Justification of AEMO's proposal*, March 2018, pp. 10-12.

718 Numbers for Queensland are for disturbances in both transmission and distribution networks.

Figure 10.4 **Number of faults recorded over different time periods in transmission and distribution networks by jurisdiction from 2006-16 (outliers removed).**

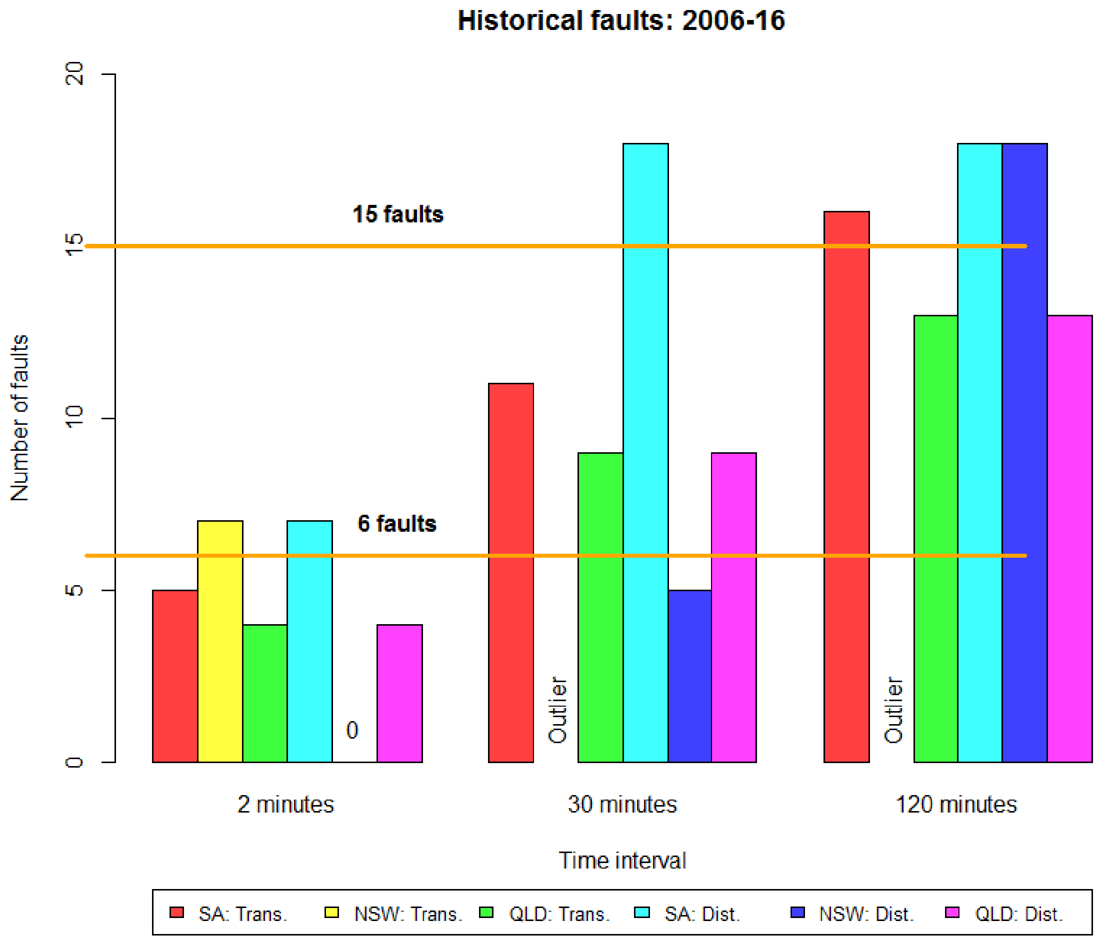


Table 10.3 and Figure 10.4 show that the requirements under AEMO's proposed minimum access standard for multiple voltage disturbances (six disturbances in five minutes, with a 30-minute sliding window reset time) is comparable with the number of faults experienced on various transmission and distribution networks in a two-minute period (between four and seven faults). Historically, these occurrences of a high number of faults within a short period have not typically caused cascading outage or major supply disruption, as the severity of the faults depends on their proximity to generating systems, the depth of the resulting voltage disturbance, and the performance of any affected generating systems.

AEMO's proposed requirement under the automatic access standard (15 disturbances in five minutes, with a five minute sliding window reset time) is comparable to the number of faults experienced on transmission and distribution networks over periods from 30 minutes (SA distribution network) up to 120 minutes (NSW and SA distribution networks, and SA transmission network). A requirement to maintain continuous operation for 15 disturbances in five minutes would therefore be relatively arduous compared to the number of faults experienced in equivalent time periods historically, with the exception of the outlier measurements for NSW included in Table 10.3, but excluded from Figure 10.4.

The current automatic and minimum access standards do not explicitly specify requirements to be capable of continuous uninterrupted operation for multiple disturbances. The changes proposed by AEMO would provide greater certainty for connection applicants regarding the capabilities they would need to provide for multiple voltage disturbances. The changes would also provide AEMO with greater certainty regarding its ability to maintain the power system in a secure operating state. This is particularly important for AEMO to understand the capability of synchronous generating units, and some asynchronous generating systems, to be able to maintain continuous uninterrupted operation for too many disturbances within a short period of time.

As discussed above, voltage disturbances in the power system have the potential to become more common and severe, and current arrangements do not provide sufficient clarity as to the requirements of generating systems to maintain continuous uninterrupted operation for multiple voltage disturbances. There is therefore a need to provide greater clarity in the NER as to these requirements.

Conclusions

Box 10.4 Draft rule

To address the issues identified above, the Commission's draft rule adopts AEMO's updated position on requirements for multiple voltage disturbances in clause S5.2.5.5(b) and S5.2.5.5(c). The draft rule is based on Table 10.2, drafted into a more suitable form. Specific requirements under the draft rule include a requirement for a generating system and each of its generating units to remain in continuous uninterrupted operation for:

- up to 15 disturbances under the automatic access standard,[719] or up to 6 six disturbances under the minimum access standard,[720] within any five minute period
- up to six deep disturbances[721] under the automatic access standard,[722] or up to three deep disturbances under the minimum access standard,[723] within any five minute period, and
- specific faults outlined in the draft rule for S5.2.5.5.[724]

These requirements are subject to a number of provisions outlined in the draft rule, which should be reviewed by stakeholders along with this draft

719 Clause S5.2.5.5(b)(1A) of the draft rule.

720 Clause S5.2.5.5(c)(1A) of the draft rule.

721 A deep disturbance occurs where voltage at the connection point drops below 50% of normal voltage.

722 Clause S5.2.5.5(b)(1A)(I) of the draft rule.

723 Clause S5.2.5.5(c)(1A)(I) of the draft rule.

724 Clause S5.2.5.5(b)(1), S5.2.5.5(b)(1A), S5.2.5.5(c)(1) and S5.2.5.5(c)(1A) of the draft rule.

determination.

The Commission considered a range of evidence in addressing the issues outlined above.

One such consideration was the response of different technologies to multiple voltage disturbances. Synchronous generating systems often do not have explicit protection systems that would disconnect a generating unit when it is exposed to multiple disturbances, but would have pole slipping protection to disconnect when they detect they are losing synchronism with the power system. Therefore, a series of faults occurring near a synchronous machine could disrupt its operation if pole slipping is detected.

Some asynchronous generating systems, such as type 3 wind turbines, maintain continuous uninterrupted operation for a limited number of disturbances to limit the temperature of the under-voltage protection system. This operates by monitoring or modelling the temperature of the associated devices, (such as dump resistors), or by using a counter that disconnects the turbine following a pre-determined number of disturbances. Other asynchronous generating systems do not require this type of protection and can maintain uninterrupted operation for effectively an unlimited number of disturbances.

The Commission also considered a range of equivalent multiple disturbance requirements internationally:

- Germany requires generating systems to maintain operation for four voltage disturbances over a total duration of two seconds[725]
- wind farms in Denmark must maintain operation for two faults within two minutes and six faults in five minutes,[726] and
- in the UK, there is a requirement that wind farms maintain operation for five faults in five minutes and 25 faults in 24 hours.[727]

These requirements are all subject to different definitions of a fault or disturbance in each jurisdiction. Broadly, AEMO's updated position on the minimum access standard requirements for multiple disturbances in clause S5.2.5.5 of the NER is similar to those for Denmark and the UK. AEMO's updated position on the automatic access standard requirements is more arduous than those above.

In addition, several manufacturers were consulted on AEMO's updated position in follow up interviews as part of the survey of equipment manufacturers conducted by DigSILENT Pacific on behalf of the Commission.

Key results included that four out of five respondents claimed that their equipment could readily meet the updated minimum access standard (i.e. at little or no additional

725 VDE, VDE-AR-N 4120:2015-01: Technical requirements for the connection and operation of customer installations to the high-voltage network, October 2015, available at www.shop.vde.com.

726 Section 3.3.4 of Energinet.dk, Technical Regulation 3.2.5 for wind power plants with a power output above 11kW, July 2016, available at www.en.energinet.dk.

727 National Grid, Grid Code – Connection Conditions – CC.A.7.2.3.2, available at https://www.nationalgrid.com/uk/electricity/codes/grid-code?code-documents.

cost using ‘off-the-shelf’ equipment), and five out of six respondents claimed that their equipment could readily meet, or meet with modification (i.e. a likely material, but manageable additional cost), the updated automatic access standard.

No respondents claimed that their equipment could not meet the updated minimum or automatic access standards under any circumstances. Some respondents considered that compliance would depend on certain power system conditions at the connection point, such as whether voltage and frequency at the connection point are within the physical limits of inverters, the level of mechanical stress on gas and wind turbine drive trains, as well as the thermal capacity of the resistor used to ‘dump’ energy into during a disturbance. Several manufacturers considered, however, that they would need to conduct further analysis to confirm that their equipment could comply with AEMO's updated position, especially given that the requirements now comprise more detailed fault definitions and compliance criteria.

AEMO also proposed in its rule change request to remove a statement in clause S5.2.5.4(c)(2) allowing for the negotiation with AEMO and the network service provider of a limit to the size of generating plant that would be disconnected (currently 100 MW) as a result of any voltage excursion within levels specified by the automatic access standard.[728] AEMO did not provide a reason for this proposed change in its rule change request. In its supplementary advice, AEMO proposed leaving this statement in the clause in order to preserve a level of flexibility for connection applicants to negotiate a limit greater than 100 MW.[729] The Commission is satisfied that this level of flexibility is necessary. This would allow for situations where a reduction in generation of more than 100 MW, either from a single generator or multiple generators affected by the same disturbance, would not pose a material risk to system security.

AEMO’s updated proposal to relax the time difference between successive faults to 200 ms introduces some room for negotiation where a connecting generating system may not be able meet the requirement of adjacent disturbances, where this does not introduce a material risk to system security.

Overall, AEMO’s proposed requirements for multiple disturbances have been updated considerably and iteratively by AEMO following additional power system modelling and feedback from stakeholders as part of the Commission's consultation on the rule change request. Findings from the survey of equipment manufacturers also indicated that the refined requirements would generally be within the capabilities of a variety of generation technologies at manageable cost. The Commission therefore considers it is appropriate to include in its draft rule AEMO’s updated position on the proposed requirements in clause S5.2.5.5.

The draft rule will likely improve the security of the national electricity system, and hence contribute to the NEO, by allowing for greater capability amongst generating systems to maintain continuous uninterrupted operation for voltage disturbances in the power system that are becoming more likely as the generation mix changes. The flexibility provided by the negotiable range for this access standard allows parties to

728 Rule change request, p. 70.

729 AEMO, Supplementary material to rule change proposal, October 2017, pp. 10-11, available at www.aemc.gov.au.

agree on a level of capability that is appropriate for each connection. This means that it is likely that the system security benefits associated with the draft rule will outweigh any associated costs.

10.6 Active power recovery capability

This section discusses AEMO's proposed changes to the requirements in clause S5.2.5.5(b)(2) and S5.2.5.5(c)(2) related to active power recovery time.

10.6.1 Current arrangements

To meet the existing automatic access standard for voltage disturbances (clause S5.2.5.5), a connecting generating system must, subject to any changed power system conditions or energy source availability beyond the generator's reasonable control, be capable of returning to 95% of the pre-fault active power output within 100 ms following disconnection of a faulted element.

The existing minimum access standard does not contain an equivalent requirement. That is, it requires continuous uninterrupted operation during and after the disturbance, but does not specify a time period in which active power must be recovered, nor does it specify the level of active power (as a percentage of the pre-fault level) that must be recovered.

Continuous uninterrupted operation requires that, after the clearance of the electrical fault that caused the disturbance (note this is the same point as 'disconnection of the faulted element'), the generating system can only substantially vary its active or reactive power as required or permitted by its performance standards established in clause S5.2.5.11, S5.2.5.13, S5.2.5.14, as well as S5.2.5.5 included under this draft rule and discussed above.

10.6.2 Rule change request

In its rule change request, AEMO considered that synchronous generating units can generally recover their active power output within a few hundred milliseconds, but asynchronous generating systems can take as long as one second to recover.[730] AEMO considered that if a large proportion of the generating systems in a part of the power system take a long time to recover active power output, this could lead to:

- voltage instability
- increased active power swings across interconnectors, leading to an increased risk of interconnector protection systems operating, potentially triggering a cascading outage, and
- the need for constraints on the affected generation to limit the potential risk of islanding of a region.

In its rule change request, AEMO considered that the continued connection of significant numbers of generating systems that cannot meet the automatic access

730 Rule change request, p. 34.

standard requirements, and for which there is no clear minimum access standard obligation, will place the security of the power system at risk.

AEMO recommended amending the minimum access standard for active power recovery following a disturbance to introduce a new time limit for active power recovery to one second. That is, a connecting generating system must be capable of returning to 95% of the pre-disturbance active power output within one second following disconnection of the faulted element.

10.6.3 Stakeholder views

A number of stakeholders raised concerns with AEMO's proposed changes to S5.2.5.5 for active power recovery time.

GE Australia was concerned that not all asynchronous generating systems would be able to meet the minimum access standard for active power recovery to 95% of pre-disturbance output within 1 second of disconnection of the faulted element due to limitations on active power recovery time in weak parts of the system.[731]

Energy Networks Australia proposed that the minimum access standard should be "1 second or as otherwise agreed by AEMO and the network service provider".[732] It considered that this would provide flexibility for the network service provider and AEMO to agree to a lower active power recovery time where this did not introduce a material risk to system security.

The Clean Energy Council was concerned that the obligation to return to 95% of the pre-disturbance active power output within 1 second needs to consider energy source availability for semi-scheduled generating systems, namely, solar PV and wind generating systems.[733] Similarly, Hydro Tasmania was concerned that the obligation to recover active power also needs to allow for the response of the generating system to any frequency disturbances associated with the disturbance.[734]

10.6.4 Analysis and conclusions

This section sets out:

- the Commission's analysis of the of the issues raised by AEMO, and
- the Commission's draft rule to address any material issues found.

10.6.5 Analysis of the issues

The current minimum access standard in clause S5.2.5.5 of the NER does not specify an active power recovery time. It is therefore unclear what the minimum requirements for a generating system are for recovering active power following the clearance of the fault.

It is generally preferable for the active power output of a generating system to recover as quickly as possible after the disconnection of a faulted element. However, in some

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731 GE Australia, submission to the consultation paper, p. 14.

732 Energy Networks Australia, submission to the consultation paper, p. 6.

733 Clean Energy Council, submission to the consultation paper, p. 25.

734 Hydro Tasmania, submission to the consultation paper, p. 12.

cases a rapid recovery of active power may not be possible due to local power system conditions or equipment limitations. This will not necessarily adversely affect power system security. This will depend on the circumstances, and the nature of the active power recovery capabilities of other generating systems in the area. Given this, the Commission does not consider that a system security issue is created by having a minimum access standard that does not specify a minimum active power recovery time as AEMO has proposed.

However, the current minimum access standard does not require recovery of active power after the disconnection of the faulted element, at which point in time the active power output of the generating system may be close to zero. If the generating system is also required to not substantially vary its active power output from this point in time (as per the definition of continuous uninterrupted operation), the generating system could in some circumstances not be required to not recover active power at all. This could exacerbate frequency issues if there is no active power recovery.

The Commission therefore considers it is appropriate to introduce a minimum access standard for active power recovery time to address situations where a connecting generating system could connect under current arrangements without any active power recovery requirements.

Conclusions

Box 10.5 Draft rule

To address the issues identified above, the Commission's draft rule includes a new minimum access standard for voltage disturbances (clause S5.2.5.5) that requires a connecting generating system to be capable of returning to 95% of the pre-fault active power output within a period of time, after clearance of the fault, that is agreed by the connection applicant with AEMO and the network service provider.[735]

For clarity, the draft rule also replaces references to "disconnection of the faulted element" with "clearance of the fault" for consistency, and given that generators may not be in a position to determine whether a particular element of the generating system has been disconnected.[736]

No material changes have been made to the active power recovery time requirement under the automatic access standard in clause S5.2.5.5 of the NER.[737]

The Commission considers that, while introducing arrangements to address the issues outlined above, it is also important to maintain flexibility. The flexibility is needed in particular to account for circumstances where active power recovery may be more difficult in distribution networks with long fault clearance times, as advised by some

735 S5.2.5.5(c)(3)(ii) of the draft rule.

736 S5.2.5.5(b)(3)(ii) and S5.2.5.5(c)(3)(ii) of the draft rule.

737 Clause S5.2.5.5(b)(3)(ii) of the draft rule.

stakeholders.[738] In these situations, it may be necessary to allow for an active power recovery time greater than the one second proposed by AEMO.

The Commission therefore considers it is appropriate to introduce a minimum access standard that clearly requires the recovery of active power, but has enough flexibility to account for the local power system conditions and the capabilities of some connecting generating systems. The Commission's draft rule therefore includes a minimum access standard that requires a connecting generating system to be capable of returning to 95% of the pre-fault active power output within a period of time, after clearance of the fault, that is agreed by the connection applicant with AEMO and the network service provider.

The Commission also considered a number of international jurisdictions that have active power recovery requirements, including:

- in the UK, generating systems are required to recover 90% of active power within 500 ms[739]
- in Ireland, generating systems are required to recover 90% of active power within 500 ms for faults up to 140 ms in duration or one second recovery for longer faults,[740] and
- in Germany, generating systems are required to return active power to the original value before the fault with a gradient of between 10-20% rated power per second, which implies a recovery time of up to (but likely less than) 10 seconds.[741]

AEMO's proposed changes to the minimum access standard in clause S5.2.5.5 of the NER are therefore broadly similar to, or less stringent than, equivalent standards in other jurisdictions.

The proposed access standard for active power recovery capability was explored further at the technical working group meeting on 1 February 2018. Some members of the group indicated that the ability of a generating system to meet this standard can depend on factors outside of its control, for example, where the system strength is low and where the generating system is exposed to long fault clearing times in some distribution networks.

AEMO advised the Commission that relatively long duration fault clearing times may cause a generator to go into a "hibernation" mode, whereby active power recovery is more difficult compared to that following shorter duration faults.[742]

As part of the survey of equipment manufacturers conducted on behalf of the Commission by DigSILENT Pacific, five out of six respondents indicated that their equipment could readily meet the proposed minimum access standard under all

738 Submissions to the consultation paper: Ergon and Energex, p. 6; TasNetworks, p. 5.

739 National Grid, Grid Code – Connection Conditions – CC.6.3.15, available at https://www.nationalgrid.com/uk/electricity/codes/grid-code?code-documents.

740 EirGrid Grid Code section WFPS1.4.2, Version 6, June 2015, available at http://www.eirgridgroup.com/site-files/library/EirGrid/GridCodeVersion6.pdf.

741 TenneT, Grid Code – High and extra high voltage, 1 November 2015, p. 18, available at: https://www.tennet.eu.

742 Advice provided to the Commission by AEMO, 3 May, 2018.

conditions (i.e. at little or no additional cost using 'off-the-shelf' equipment).[743] One wind turbine manufacturer indicated that compliance with the proposed minimum access standard would be more difficult under low system strength conditions.

Given that all equipment manufacturers surveyed could meet the level of the proposed minimum access standard under most power system conditions, it is likely that the updated negotiating process set out in the draft rule (see Chapter 4) would result in levels of performance that are generally at or exceed the level of AEMO's proposed minimum access standard. However, in cases where an active power recovery time of less than one second is not achievable under the circumstances, and would not adversely affect power system security, the flexibility to be able to connect generating systems with longer allowed active recovery times under these circumstances could reduce the costs of connection may be an efficient outcome.

The Commission's draft rule will likely improve the security of the national electricity system, and hence contribute to the NEO, by requiring capability of generating systems to return to an appropriate level of active power following a fault in order to avoid frequency collapse. However, the draft rule also strikes an efficient balance by allowing for the negotiation of an active power recovery time that balances both system security needs at the connection point of a connecting generating system and actual system conditions at the connection point to determine the appropriate active power recovery time.

10.7 Partial load rejection capability

This section discusses AEMO's proposed changes to the requirements in clause S5.2.5.7 of the NER for generating units to maintain continuous uninterrupted operation following reductions in load on the power system.

10.7.1 Current arrangements

Partial load rejection refers to the ability of a generating system to maintain continuous uninterrupted operation in the event of a loss of a significant amount of end use load. Partial load rejection is related to other continuous uninterrupted operation requirements because the loss of a large proportion of load leads to voltage and frequency disturbances that generating systems are also required to maintain continuous uninterrupted operation for these disturbances under other access standards.

The automatic access standard in clause S5.2.5.7 of the NER requires that a generating unit be capable of continuous uninterrupted operation during and following a power system load reduction of 30% from its pre-disturbance level, or an equivalent impact from separation of part of the power system in less than ten seconds, provided that the loading level remains above the minimum load (that is, minimum sent out generation for continuous stable operation).[744]

743 This included two solar PV inverter manufacturers, two synchronous generating system manufacturers and one wind turbine manufacturer.

744 Clause S5.2.5.7(a) of the NER.

The current minimum access standard is similarly worded, but requires continuous uninterrupted operation for a power system load reduction of 5%.

The current access standard explicitly states that clause S5.2.5.7 does not apply to asynchronous generating units, and therefore, current requirements apply only to synchronous generating units.

10.7.2 Rule change request

In its rule change request, AEMO noted that asynchronous generating systems are exempt from the existing access standard.[745] AEMO considered that this is not sufficient to maintain the power system in a secure operating state as the power system evolves to comprise higher penetrations of asynchronous generating systems.

AEMO proposed to remove the provision in clause S5.2.5.7 that limits the access standard to synchronous generating units. This removal would extend the application of the automatic and minimum access standards to all generating systems, both synchronous and asynchronous.

AEMO also proposed an amendment to specify the requirement for a 'generating system', rather than a 'generating unit' under both the automatic access standard and minimum access standard.

10.7.3 Stakeholder views

A large number of stakeholders supported or did not raise objections to proposed changes to this access standard. Reasons for this included that the proposed access standard would result in improved system security, would result in minimal commercial and operational risk and is within the capability of asynchronous generation technology.[746]

By contrast, ESCO Pacific considered that it was not clear what additional benefit the proposed changes would provide that would not be provided by other existing access standards (and the changes proposed to them).[747] Similarly, Energy Networks Australia considered that because partial load rejection may impact frequency and voltage, the proposed access standard should be incorporated into other access standards that address these characteristics.[748] Advisian and Pacific Hydro likewise considered that partial load rejection should be addressed as a system frequency issue.[749]

745 Rule change request, p. 35.

746 Submissions to the consultation paper: AGL, p. 5; Hydro Tasmania, p. 13; Pacific Hydro, p. 12; Powerlink, p. 7; Tesla, p. 3; Transgrid; p. 5.

747 ESCO Pacific, submission to the consultation paper, p. 9. This is a reference to the performance standards under clauses S5.2.5.3 (rate of change of frequency capability), S5.2.5.4 (generating system response to voltage disturbances) and S5.2.5.11 (frequency control).

748 Energy Networks Australia, submission to the consultation paper, p. 9.

749 Submissions to the consultation paper: Advisian, p. v, Pacific Hydro, p. vi.

Some stakeholders considered that meeting the proposed access standard would not create significant costs for connecting generating systems.[750] Specifically, Origin Energy claimed that meeting the standard may require a control system change for a generating system costing in the order of $50,000.[751]

10.7.4 Analysis and conclusions

This section sets out:

- the Commission's analysis of the of the issues raised by AEMO, and
- the Commission's draft rule to address any material issues found.

10.7.5 Analysis of the issues

The power system is currently experiencing a significant increase in the penetration of asynchronous generation. It remains important that all generating systems provide some level of partial load rejection capability to avoid the risk of cascading outages caused by the loss of a significant proportion of load. It is also important that asynchronous generation provides this capability as it continues to make up an increasing share of the generation mix. The Commission agrees with AEMO the current access standard for partial load rejection excluding asynchronous generation is not sufficient to address the needs of the power system, and this should be addressed.

Conclusions

Box 10.6 Draft rule

To address the issues identified above, the Commission's draft rule amends the access standards for partial load rejection (clause S5.2.5.7) so that they apply to both synchronous and asynchronous generating systems.[752]

The Commission considered a range of evidence in addressing the issues outlined above.

As part of the survey of equipment manufacturers conducted on behalf of the Commission, five out of six respondents claimed that their equipment could readily meet both the proposed automatic and minimum access standards (i.e. at little or no additional cost using 'off-the-shelf' equipment).[753] One wind turbine manufacturer claimed that their equipment could only meet the standard to the extent that a partial load rejection does not lead to a disturbance that exceeds the ability of the generating system to maintain continuous uninterrupted operation for frequency and voltage disturbances. the Commission notes that in the event a loss of load causes a disturbance

750 Submissions to the consultation paper: Origin Energy, p. 8; Pacific Hydro, p. xvii.

751 Origin Energy, submission to the consultation paper, p. 8.

752 Clause S5.2.5.7(b) of the NER, which excluded asynchronous generating units from application of this access standard, has been deleted in the draft rule.

753 Included two inverter manufacturers, one wind turbine manufacturer and two gas turbine manufacturers.

to frequency and voltage that exceeds the requirements of other access standards, the other access standards would allow the generating system to disconnect.

The technical working group for the rule change request did not identify any major concerns with the proposed access standard.

There was both general stakeholder support and lack of opposition to the proposal to extend S5.2.5.7 to asynchronous generation, while results from the survey of equipment manufacturers suggest that meeting the levels of performance for partial load rejection set in the existing automatic and minimum access standards is largely within the capability of asynchronous generating systems. The Commission agrees with the approach proposed by AEMO to amend the current requirements so they also apply to asynchronous generating systems.

Consistent with the Commission's approach to technology neutrality used throughout this rule change, there are not any inherent physical differences between technology types in this instance that would justify setting different standards based on technology type.

Although some stakeholders raised concerns that this access standard duplicates requirements in other access standards, such as continuous uninterrupted operation requirements related to frequency and voltage, the Commission considers that, on balance, the partial load rejection arrangements should be retained. The Commission has not been provided with substantive evidence that other continuous uninterrupted operation requirements completely cover the circumstances addressed by the partial load rejection access standard, or that the costs of the current arrangements are significant. AEMO has also advised the Commission it does not consider it appropriate to remove the requirements in their entirety without significant review and power system modelling to determine whether there any system security issues could arise from their removal.

The Commission's draft rule also replaces the term 'generating unit' in clause S5.2.5.7 with the term 'generating system'.[754] This is consistent with the approach across other generator access standards in specifying compliance in terms of the 'generating system'. It also reflects the increasing connection of large wind generating systems made up of dozens of small turbines (in which case it is too arduous to classify all turbines as generating units), compared to connections of generating systems comprised of a handful of large synchronous generating units. This approach increases the flexibility to find the least cost way to achieve compliance behind the connection point. For example, compliance by a generating system could be achieved by using auxiliary equipment to compensate for part of the system that may not be able to be used if compliance was required from each generating unit.

The Commission's draft rule will likely improve power system security, and contribute to the NEO, by requiring sufficient partial load rejection capability from both

754 Generating unit is defined in Chapter 10 of the NER as "the plant used in the production of electricity and all related equipment essential to its functioning as a single entity. Generating system is defined as for Chapter 5 of the NER as "system comprising one or more generating units and includes auxiliary or reactive plant that is located on the generator's side of the connection point and is necessary for the generating system to meet its performance standards."

synchronous and asynchronous generating systems as the generation mix in the power system changes. The change is unlikely to result in any significant additional costs for connecting generating systems, and is generally within the technical capability of existing technologies.

10.8 Frequency disturbance capability

This section discusses AEMO's proposed changes to the requirements in clause S5.2.5.3 of the NER for generating systems to maintain continuous uninterrupted operation for disturbances to the frequency of the power system.

10.8.1 Current arrangements

A secure power system requires connected generating systems to be able to maintain continuous uninterrupted operation during frequency disturbances caused by an imbalance between the supply of, and demand for, active power. The ability for generating systems to remain connected to the power system following a rapid change in frequency is typically limited to a given rate of change of frequency (RoCoF).[755] The ability of a generating system to maintain continuous uninterrupted operation for different levels of RoCoF varies by technology type. Some technologies are typically, but not always, able to maintain continuous uninterrupted operation for higher levels of RoCoF, relative to others. For example, certain synchronous generation technologies, including combined cycle gas turbines, generally have limited ability to maintain continuous uninterrupted operation for frequency disturbances compared to asynchronous, inverter-connected generation technologies, which are not electrically or mechanically linked to power system frequency, and consequently, are less affected by frequency disturbances.

Clause S5.2.5.3 of the NER specifies the range and duration of frequencies for which a generating system and each of its generating units (regardless of whether synchronous or asynchronous) are required to maintain continuous uninterrupted operation. The existing automatic access standard requires a generating system to maintain continuous uninterrupted operation unless the RoCoF is outside the range of ±4 Hz/s for more than 0.25 seconds (or such a range as determined by the Reliability Panel from time to time). The minimum access standard sets the requirement at ±1 Hz/s for more than 1 second (or such a range as determined by the Reliability Panel from time to time).

10.8.2 Rule change request

While clause S5.2.5.3 includes a requirement to maintain continuous uninterrupted operation for certain levels of RoCoF, AEMO considered these requirements were insufficient to cope with increasing RoCoF levels experienced in the power system, which over time could lead to an increased risk of cascading outage if generating systems disconnect following a disturbance.[756]

755 RoCoF relates to how fast frequency changes immediately following a contingency event. System inertia (traditionally provided by the spinning mass in synchronous generating systems) has the effect of reducing RoCoF.

756 Rule change request, p. 37.

AEMO considered that there are fundamental differences in the ability of different technology types to maintain continuous uninterrupted operation for relatively high levels of RoCoF. Specifically, it considered that synchronous generating systems are susceptible to severe damage and must be able to disconnect to protect the generating system, whereas asynchronous generating systems are less susceptible to this kind of damage. AEMO considered that this difference should be recognised in order to maintain a secure power system, without creating an unreasonable inefficient barrier to entry for synchronous generating systems.[757]

AEMO proposed addressing this issue by amending the access standards in clause S5.2.5.3 to require asynchronous generating systems to be capable of continuous uninterrupted operation for higher levels of RoCoF, while providing synchronous generating systems with the flexibility to negotiate a performance standard that reflects their physical equipment capabilities. Specifically, AEMO's rule change request included the following:

- asynchronous generating systems must meet the automatic access standard (and no lower) in which continuous uninterrupted operation must be maintained up to a RoCoF of ±4 Hz/s for 250 ms, and ±3 Hz/s for 1 second, and
- synchronous generating systems would be able to meet the minimum access standard (or higher) in which continuous uninterrupted operation must be maintained up to ±2 Hz/s for 250 ms, and ±1 Hz/s for 1 second.

Compared to the existing requirements, the additional requirements in the proposed access standards correspond to lower levels of RoCoF, and for longer durations.

10.8.3 Stakeholder views

Stakeholders expressed a range of views on the proposed amendments to the access standard. Several stakeholders considered that the proposed changes to the automatic access standard may imply that generating systems would need to maintain continuous uninterrupted operation outside of the extreme frequency excursion tolerance limit of 47 Hz or 52 Hz (for the NEM mainland) if a RoCoF of 3 Hz/s was sustained for a full second.[758] The Commission notes the current access standard specifies that a generating system does not need to be capable of maintaining continuous uninterrupted operation outside of the extreme frequency excursion tolerance limit. AEMO has not proposed changing this.

One feature of the proposed changes to the access standard is the differentiation between synchronous generating systems (which would be allowed to negotiate a performance standard in the full range from the minimum access standard to the automatic access standard) and asynchronous generating systems (which must meet the automatic access standard and would not be able to negotiate an access standard). AGL questioned the rationale behind a technologically-specific approach to the access standards, while other stakeholders argued that the proposal was against the principle

757 Ibid.

758 Submissions to the consultation paper: Advisian, p. ix; ESCO Pacific, p. 8, Origin Energy, p. 9; Pacific Hydro, p. ix.

of technology neutrality that has traditionally underpinned the design of the generator access standards.[759]

Other stakeholders considered that, even if a significant number of asynchronous generating systems met the more demanding automatic access standard, the ability of the power system to maintain continuous uninterrupted operation for RoCoF events may be limited to the level specified in the minimum access standard for synchronous generating systems. These stakeholders claimed that there may be a risk that the disconnection of synchronous generating systems (if the limit specified in the minimum is surpassed during a disturbance) may lead to an increase in RoCoF that exceeds the limit specified in the automatic access standard.[760] In this way, it is considered the ability of the power system to remain in a secure operating state during frequency disturbances would be determined predominantly by generating systems with a capability at the minimum access standard for synchronous generating systems.

GE Australia considered that the level of ±4 Hz/s specified in the proposed automatic access standard may be close to the design limits of single shaft heavy duty gas turbines.[761] Origin Energy commented that the level of ±3 Hz/s was “aggressive”, but did not identify any inherent technological barriers.[762]

10.8.4 Analysis and conclusions

This section sets out:

- the Commission's analysis of the of the issues raised by AEMO, and
- the Commission's draft rule to address any material issues found.

10.8.5 Analysis of the issues

Increases in the amounts of asynchronous generation and decreases in the amount of synchronous generation in the power system is reducing levels of system inertia such that the RoCoF following future disturbances is likely to be larger than levels historically experienced. This change in the generation mix also means that it will be increasingly important for asynchronous generating systems to have the capability to maintain continuous uninterrupted operation for frequency disturbances, which is required to help restore the power system to a satisfactory operating state following a major disturbance.

The Commission notes that there may be interactions between the access standards in clause S5.2.5.3 and requirements under the *Managing the rate of change of power system frequency rule* to commence on 1 July 2018.[763] The Managing the rate of change of power system frequency rule requires transmission network service providers to procure, as determined by AEMO, minimum levels of inertia or procure other services that reduce

759 Submissions to the consultation paper: AGL, p. 6; Advisian, p. 12; Pacific Hydro, p. ix; SMA, p. 2.

760 Submissions to the consultation paper: Clean Energy Council, p. 26; TasNetworks, p. 11.

761 GE Australia, submission to the consultation paper, p. 15.

762 Origin Energy, submission to the consultation paper, p. 9.

763 AEMC, *Managing the rate of change of power system frequency*, Final determination, 19 September 2017, available at www.aemc.gov.au.

the minimum level of inertia required, when a shortfall in inertia exists or is likely to exist in the future for an electrical sub-network that becomes islanded. This would provide:

- time for frequency control ancillary services to respond and recover the frequency to normal operating levels
- time for emergency frequency control schemes to operate effectively, and
- a higher probability of generators remaining online following the occurrence of the contingency event.[764]

The *Managing the rate of change of power system frequency rule* and the access standards in clause S5.2.5.3 of the NER serve different functions. The *Managing the rate of change of power system frequency rule* allows AEMO, through the transmission network service provider, to maintain sufficient inertia in an electrical sub-network so that it could continue to operate in a secure operating state should it become islanded, following a credible or non-credible contingency. Complimentary to this, the access standards in clause S5.2.5.3 of the NER require generating systems to maintain continuous uninterrupted operation for major frequency disturbances, such as a separation of a sub-network, so that the disturbance is not exacerbated into a cascading outage. As such, the access standards in clause S5.2.5.3 address the performance of generating systems during power system events, whereas the *Managing the rate of change of power system frequency rule* addresses the operating state of a sub-network following such events.

In practice, the levels and durations of RoCoF specified in the access standards in clause S5.2.5.3 of the NER likely correspond to those experienced during a severe non-credible contingency.

Conclusions

Box 10.7 Draft rule

To address the issues identified above, the Commission's draft rule:

- amends the access standards in clause S5.2.5.3 of the NER to include AEMO's proposed additional RoCoF levels (±3 Hz/s for more than 1 second in the automatic access standard, and ±2 Hz/s for more than 250 milliseconds in the minimum access standard),[765] and
- does not adopt AEMO's proposal to include specific reference to synchronous or asynchronous generating systems, but instead allows for a negotiation range between the automatic and minimum access standard for any connecting generating system.

The Commission considered a range of evidence in addressing the issues outlined above.

764 Ibid, pp. 19-20.

765 Clause S5.2.5.3(b) and S5.2.5.3(c) of the draft rule.

The survey of equipment manufacturers conducted by DigSILENT Pacific on behalf of the Commission was a key input to the Commission's draft rule. As part of this survey, five out of eight respondents (including both synchronous and asynchronous generating system manufacturers) claimed that their equipment could readily meet the proposed automatic access standard (i.e. at little or no additional cost using 'off-the-shelf' equipment),[766] and all claimed their equipment could achieve the proposed minimum access standard.

Specifically, one inverter manufacturer claimed that their inverters are tested at RoCoF levels up to ±4.5 Hz/s (which exceeds the RoCoF level in AEMO's proposed automatic access standard). The additional requirements proposed by AEMO correspond to lower levels of RoCoF than those specified in the existing access standard, but include longer periods that continuous uninterrupted operation must be maintained for. It is the longer periods over which continuous uninterrupted operation must be maintained that represent the greater technical challenge for synchronous generating systems in particular, due to these systems having a strong electrical and mechanical interaction with the power system compared to asynchronous generating systems.

One inverter manufacturer claimed that additional equipment would be required to detect the proposed RoCoF levels in the automatic access standard, whilst a manufacturer of heavy duty gas turbines claimed that meeting the automatic access standard would be limited by technical limits of the gas compressor system.

The technical working group convened for this rule change did not identify any major concerns with AEMO's proposed changes.

The Commission also considered a number of international jurisdictions that have grid codes specifying active or proposed RoCoF requirements for generating systems. These are summarised in Table 10.4 below.[767]

Table 10.4 Comparison of international requirements to maintain continuous uninterrupted operation in response to frequency disturbances.

Region	Requirement (±Hz/s)	Duration	Status
Denmark	2.5	80-100 ms	Active
Finland	2	1.25 s	Active
Ireland	0.5	Continuous	Active
Ireland	1	500 ms	Approved for implementation
Spain	2	NA	Proposal

766 Included two solar PV inverter manufacturers, two wind turbine manufacturers and one gas turbine manufacturer.

767 Adapted from Ciaran Roberts, Review of international grid codes, Lawrence Berkeley National Laboratory, February 2018, p. 29, available at https://www.ferc.gov/industries/electric/indus-act/reliability.asp.

These requirements are generally in line with the minimum access standard proposed by AEMO, noting that it is difficult to compare these requirements given the differences between both the RoCoF magnitude and duration specified in different requirements. The automatic access standard proposed by AEMO is more stringent (i.e. generating systems will be required to maintain continuous uninterrupted operation for a relatively high RoCoF) compared to these international grid codes; however the generator access standards in the NER are relatively unique in providing a negotiation range between different levels of performance.

As discussed above, the Commission considers there are benefits in revising the RoCoF requirements specified in clause S5.2.5.3 of the NER to better reflect the changing needs of the power system. The levels proposed by AEMO are generally supported by stakeholders and within the capabilities of equipment available on the Australian market.

The Commission does not consider it appropriate to require asynchronous generating systems to meet the automatic access standard, without the ability to negotiate a performance standard that is below the automatic access standard but may be suitable for that connection at a given location in the power system. AEMO and stakeholders have not identified a clear system security need for one type of technology to provide a greater level of capability than another. Instead, it is appropriate to allow for a negotiable range between the automatic and minimum access standard for all connecting generating systems. This avoids the risk of creating an arrangement that is an unnecessary inefficient barrier to entry for some types of generating systems. That is, an arrangement that requires a higher level of performance from asynchronous generating systems would provide no flexibility to allow the connection of an asynchronous generating system that can deliver a level of capability that is close to, but does not exactly meet the automatic access standard, even where providing a slightly lower capability would not adversely affect power system security or the quality of supply to other network users.

The draft rule addresses this issue by not specifying requirements for synchronous and asynchronous generating systems separately, but rather allowing any generating system and each of its generating units to negotiate an appropriate performance standard at or between the automatic and minimum access standard through the negotiation process.

However, the Commission considers that the likely practical outcome of the changes to clause S5.2.5.3 of the NER set out in the draft rule will be that asynchronous generating systems will generally connect at the level of the automatic access standard in any event. This is because stakeholders and equipment manufacturers advised the Commission that asynchronous generating systems can generally achieve those levels of performance. The changes to the negotiating process set out in the draft rule and outlined in Chapter 4 are likely to result in generating systems providing capabilities at the levels specified in the automatic access standard, particularly where equipment can readily meet that level of performance.

The Commission's draft rule will likely benefit the security of supply of electricity and the national electricity system by allowing generating systems to maintain continuous uninterrupted operation for frequency disturbances in the power system that are becoming more likely as the generation mix changes. This is necessary to reduce the risk of cascading outages caused by frequency collapse. While meeting the automatic access standard in the draft rule may be challenging for some equipment, the ability to propose a level of capability between the minimum and automatic access standards should balance system security needs and costs.

11 System strength

Box 11.1 Overview

System strength is deteriorating in some parts of the network. There is a risk to power system security due to multiple generating systems disconnecting if system strength reduces below the levels for which generating systems can maintain continuous uninterrupted operation.

In its rule change request, AEMO noted that the *Managing power system fault levels rule* recently made by the Commission allows a network service provider to make sure that a generating system must be capable of operating correctly down to the lowest expected system strength at the connection point.[768] However, AEMO also considered that the *Managing power system fault levels rule* does not allow network service providers to require further capability from a generating system to make efficient use of the available system strength in an area and minimise costs for the connection of generating systems in the future.

AEMO proposed addressing this issue by introducing a new minimum access standard (with no corresponding automatic access standard) that would require a generating system and each of its generating units to be capable of continuous uninterrupted operation for a short circuit ratio of 3.0 at the connection point.[769]

The Commission considers that the framework for managing system strength created by the *Managing power system fault levels rule* is likely to be sufficient to address the risks to power system security from reductions in system strength. In addition, the Commission considers that imposing costs or regulatory requirements on connecting generators in order to increase access for potential connecting generators in future is contrary to the principles behind the transmission framework in operation in the NEM. The Commission also considers that there is insufficient certainty as to the magnitude of potential incremental costs on all connecting generators today as well as the magnitude of potential avoided costs for connecting generators and network service providers in future.

This issue could be reconsidered in future reviews of the generator technical performance standards once the *Managing power system fault levels rule* has been fully implemented and more information is available on the costs and benefits of a system security access standard.

The Commission has therefore made a draft rule that does not contain a system strength access standard.

768 Rule change request, p. 39.

769 Ibid, pp. 39-40.

11.1 Introduction

This Chapter sets out and considers:

- technical background and key concepts regarding system strength
- the current arrangements in the NER related to system strength
- the issues raised by AEMO with the current arrangements and changes proposed to address those issues
- stakeholder views, and
- analysis and conclusions.

11.2 Technical background

This section explains technical concepts related to system strength.

System strength is related to the ability of the power system to maintain voltage in response to faults, changes in generation and load, as well as network switching events. It is related to a number of characteristics that contribute to the ability of a power system to remain stable under normal conditions and return to steady-state conditions following a disturbance.[770]

Power system stability is defined by AEMO as "the ability of the electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical or electrical disturbance, with system variables bounded so that practically the entire power system remains intact."[771]

By way of analogy, the strength of a network is like the tension in an elastic sheet: a tight sheet (strong network) will not change shape significantly (voltage will deviate less) if the sheet is poked from the top or bottom (reactive power injected or absorbed). A loose and flexible sheet (weak system) will deform more significantly (voltage will deviate more) when the sheet is poked. This is because voltage is more sensitive to changes in reactive power under weak system conditions.[772]

System strength is described and measured in a number of different ways. Some important concepts for understanding system strength are:

- **Fault current:** the current that flows into a fault in response to the drop in voltage at the fault before it is isolated. Synchronous generating systems or synchronous condensers can typically provide 2-3 times the rated current capacity for a short period in response to a fault. Asynchronous generation does not typically provide as much fault current (typically 20-30 per cent above rated capacity).

770 AEMO, Power system requirements, March 2018, available at www.aemo.com.au.

771 AEMO, Power system stability guidelines, 25 May 2012, p. 5, available at www.aemo.com.au.

772 Active power can also affect network voltage, but typically not to the same degree as an equivalent amount of reactive power.

- **Fault level:** the product of the pre-fault nominal voltage (measured in kilovolts – kV – between a pair of phases), the fault current in each phase for a three phase fault at the location (measured in kiloamperes – kA), and the square root of 3.[773] Three phase fault level (often referred to as fault level) is measured in megavolt-amperes. Strong networks are characterised by a high fault level as a result of high fault current and/or high voltage. Fault level is sometimes referred to as system strength.
- **Short circuit ratio (SCR):** the ratio of the three phase fault level at the connection points for a generating system to the maximum operating level of the generating system (in MW).[774] Strong systems are typically regarded as having a high SCR (> 5) and weak systems as having a low SCR (< 3).[775]
- **X/R ratio:** the ratio of reactance (X) to resistance (R) at a point in the network.[776]

Strong parts of the power system are typically characterised by, among other factors, a relatively high penetration of synchronous generation (supplying high fault current) and strong interconnection (which helps to distribute fault current throughout the network). These features act to produce relatively stable voltage levels on the power system.

Weak parts of the power system, in terms of generation, are often characterised by relatively low penetration of synchronous generation and often have a relatively high penetration of asynchronous (including inverter-connected) generation. Such systems experience voltage disturbances that are deeper, more widespread and longer lasting, because network voltages are more sensitive to changes in reactive power and faults.[777] Weak system conditions can lead to:

- difficulty in controlling voltage on the network under both steady-state and disturbance conditions
- difficulty in maintaining stability of synchronous and asynchronous generating systems (due to the voltage instability), and
- malfunction of network and generator protection systems as a result of there being insufficient fault current to detect the occurrence of a fault.

773 Chapter 10 of the NER.

774 AEMO, submission to the consultation paper, p. 21.

775 Cigre Working Group B4.62, Connection of wind farms to weak AC networks, December 2016, available at www.b4.cigre.org.

776 Reactance is the opposition to changes in current and voltage by inductors and capacitors in AC circuits, whereas resistance is the physical opposition to current in any circuit as a result of the properties of the conducting material.

777 AEMO, National Transmission Development Plan for the National Electricity Market, December 2016, p. 68.

11.3 Current arrangements

This section sets out current arrangements in the NER related to system strength.

There is currently no explicit system strength access standard as part of the generator access standards in Schedule 5.2 to the NER. The Commission understands that there is also no directly comparable standard internationally.

The *Managing power system fault levels rule* made by the Commission on 19 September 2017, is relevant to AEMO's proposed system strength access standard.[778] Part of that rule commenced on 17 November 2017, and the remaining parts will commence on 1 July 2018. The final rule has the following key aspects:[779]

- an obligation on AEMO to develop and publish a system strength requirements methodology that sets out the process it will use to determine the system strength requirements for each region. When developing the methodology, AEMO must take into account, among other things, the maximum load shedding or generation shedding expected to occur on the occurrence of any credible contingency event or protected event affecting the region,[780] as well as any resulting risk of cascading outages and the stability of the region following any such credible contingency event or protected event[781]
- when AEMO specifies the system strength requirements for a region, it must define this in terms of the fault level nodes in the region (being the location on the transmission network for which the three phase fault level must be maintained at or above a level determined by AEMO) and for each fault level node, it must define the minimum three phase fault level[782]
- where there is, or is likely to be, a three phase fault level shortfall in any region,[783] AEMO must publish and give notice to the relevant system strength service providers of the assessment and notice of the date that system strength services must be made available. Under the *Managing power system fault levels rule*, the system strength service provider is the transmission network service provider for the region, or if there is more than one transmission network service provider, the jurisdictional planning body for the relevant jurisdiction. In Victoria, the obligation is placed on AEMO through its role as the jurisdictional planning body

778 National Electricity Market Amendment (Managing power system fault levels) Rule 2017 No. 10.

779 AEMC, *Managing power system fault levels* rule change, Final determination, p. iii-iv.

780 Clause 4.2.3(f) of the NER states that a protected event means a non-credible contingency event that the Reliability Panel has declared to be a protected event in clause 8.8.4, where that declaration has come into effect and has not been revoked. Protected events are a category of non-credible contingency event.

781 Clause 5.20.7 of the NER (as in force from 1 July 2018).

782 Three phase fault level is defined in Chapter 10 of the NER as, measured in MVA at a location on a transmission network or a distribution network, the product of the pre-fault nominal voltage (measured in kV between a pair of phases), the fault current in each phase for a three phase fault at the location (measured in kA), and the square root of 3.

783 Fault level shortfall is defined in Chapter 10 of the NER (as in force from 1 July 2018) as a shortfall in the three phase fault level typically provided at a fault level node in a region (having regard to typical patterns of dispatched generation in central dispatch) compared to the minimum three phase fault level most recently determined by AEMO for the fault level node.

- an obligation on the system strength service provider to make system strength services available to AEMO if AEMO has declared a fault level shortfall. AEMO can enable the system strength services provided by the relevant system strength service provider in order to maintain the power system in a secure operating state
- AEMO must develop system strength impact assessment guidelines that set out a methodology to be used by network service providers and generators when assessing the impact of a new generating system connection on system strength, and
- new connecting generators are required to 'do no harm' to the level of system strength necessary to maintain the security of the power system, in relation to the impact of the connection of the generating system on the ability of the power system to maintain stability and for nearby generating systems to maintain stable operation. The network service provider makes this assessment in accordance with AEMO's system strength impact assessment guidelines.[784]

Any harm that would be caused by the connection of a proposed generating system must be mitigated by the connection applicant at its own expense, either through a scheme implemented by the connection applicant (a system strength remediation scheme), or through investment in a transmission or distribution network by the network service provider (system strength connection works).

The relationship between these requirements and the proposed minimum access standard is discussed in section 11.6 below.

11.4 Rule change request

In its rule change request, AEMO considered that a system strength access standard is required due to projected deterioration of system strength across parts of the power system. Without such a standard, AEMO expects greater risk of generating system instability and disconnection during power system disturbances, lost load as a result of inappropriate operation of network equipment, as well as public safety hazards if faults are not cleared properly on the power system.[785]

AEMO considered that the proposed access standard requiring continuous uninterrupted operation under low system strength conditions would be complementary to the new obligations under the *Managing power system fault levels rule*.[786] It considered the introduction of its proposed access standard would protect against a scenario where a generating system connecting in a relatively strong part of the network with inferior equipment may increase the cost of connection for future connecting generators. The incumbent generating system that does not have sufficiently high system strength capability is more prone to instability or disconnection, and therefore makes it more difficult for incoming generators to satisfy their 'do no harm' obligations under the *Managing power system fault levels rule*.

784 AEMO, System strength impact assessment guidelines, First stage consultation, 5 March 2018, available at https://www.aemo.com.au/Stakeholder-Consultation.

785 Rule change request, pp. 39-40.

786 Rule change request, p. 39.

In this scenario, AEMO considered that the proposed access standard would reduce the need for, or extent of, system strength remediation schemes and connection works if the earlier connecting generator was required to have a minimum level of capability to maintain continuous uninterrupted operation under low system strength conditions. AEMO therefore considered that its proposed system strength access standard may minimise costs for connecting generators and system strength service providers (and by extension, consumers) in future under the *Managing power system fault levels rule* framework.[787]

AEMO also advised the Commission that, in the absence of the proposed system strength access standard, AEMO may be required to specify more fault level nodes, with more onerous (i.e. higher) minimum three phase fault level requirements, in order that sufficient three phase fault level is available to electrically remote generating systems connected to weak parts of the power system. AEMO considered that this would significantly increase costs under the *Managing power system fault levels rule*.

AEMO also cited a recommendation made by the Commission in the *System security market frameworks review* to "consider requiring inverters and related items of plant within a connecting party's generating system to be capable of operating correctly down to specified system strength levels."[788] The Commission notes that this recommendation required further consideration of the need for minimum requirements for generating systems to be able to operate at specified levels of system strength. The consideration of this issue as part of this rule change therefore satisfies this recommendation.

To address the issues raised in its rule change request, AEMO proposed introducing a new access standard, comprised of a minimum access standard only, that would require connecting generating systems and units to be capable of continuous uninterrupted operation for relatively low levels of system strength.[789]

The minimum access standard proposed by AEMO was:[790]

> "a *generating system* and each of its *generating units* must be capable of *continuous uninterrupted operation* for a *short circuit ratio* of 3.0 at the *connection point*."

AEMO's proposed access standard intended to use a definition of short circuit ratio that had been made in the *Managing power system fault levels draft rule*.[791] However, this definition was not included in the final rule. In its submission to the consultation paper AEMO proposed including the following definition of short circuit ratio in Chapter 10 of the NER:[792]

787 Rule change request, p. 39.

788 AEMC, *System security market frameworks review*, Final report, p. 25.

789 Rule change request, p. 39.

790 This is the access standard proposed in AEMO's submission to the consultation paper (p. 21), without the X/R ratio requirement, as per subsequent advice from AEMO.

791 AEMC, *Managing power system fault levels draft rule*, p. 21, available at www.aemc.gov.au.

792 AEMO, submission to the consultation paper, p. 21.

> "for 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)."

AEMO did not propose a corresponding automatic access standard or any general requirements for this access standard. AEMO argued that providing a negotiable range between an automatic and minimum access standard for system strength is not practical as this would require costly and time-consuming tuning of generating system settings and demonstration studies. AEMO therefore proposed a single minimum access standard.[793]

As is the case with all access standards, connection applicants would not be able to negotiate a lower capability (i.e. an SCR higher than 3.0) than that specified in the minimum access standard. The absence of a corresponding automatic access standard would allow for the network service provider or AEMO, where appropriate, to reject a proposed negotiated access standard unless it met a higher capability (i.e. an SCR lower than 3.0).

AEMO's submission to the consultation paper suggested the proposed minimum access standard should also include a requirement to maintain continuous uninterrupted operation down to an X/R ratio of 3.0.[794] This would operate in addition to the requirement to maintain continuous uninterrupted operation for an SCR of 3.0.[795] However, this suggestion has since been revoked by AEMO, leaving its position unchanged from the proposal outlined above.

AEMO's submission to the consultation paper suggested specifying the access standard as an AEMO advisory matter.[796] This was not proposed in the rule change request. AEMO's submission did not provide an argument as to why the access standard should be specified as an AEMO advisory matter.

The proposed system strength access standard would require generating systems to maintain continuous uninterrupted operation for specified levels of system strength. Continuous uninterrupted operation is currently defined in Chapter 10 of the NER as follows:

> "In respect of a *generating system* or operating *generating unit* operating immediately prior to a *power system* disturbance, not *disconnecting* from the *power system* except under its *performance standards* established in clauses S5.2.5.8 and S5.2.5.9 and, after clearance of any electrical fault that caused the disturbance, only substantially varying its *active power* and *reactive power* required by its *performance standards* established in clauses S5.2.5.11, S5.2.5.13 and S5.2.5.14, with all essential auxiliary and *reactive plant*

793 Rule change request, p. 40.

794 AEMO, submission to the consultation paper, p. 21.

795 Discussed as part of a meeting with AEMO, 24 January 2018.

796 While the process of negotiating generator access standards is principally between a network service provider and the connection applicant, AEMO may advise the network service provider to reject a negotiated access standard for certain standards that are AEMO advisory matters. AEMO advisory matters typically relate to system security and stability, which fall within AEMO's remit as system operator.

remaining in service, and responding so as to not exacerbate or prolong the disturbance or cause a subsequent disturbance for other *connected plant*. "

AEMO has also proposed changes to the definition of continuous uninterrupted operation, which are addressed in Chapter 10 of this draft determination.

11.5 Stakeholder views

This section outlines stakeholder views on the proposed system strength access standard proposed in AEMO's rule change request. The Commission received submissions regarding this proposed access standard from a range of stakeholders, including project developers, generators, network businesses, equipment manufacturers and consultants, as well as industry and market bodies.

11.5.1 Materiality of issues raised by AEMO

Several stakeholders explicitly supported, or did not express opposition to, the proposed system strength access standard, including network service providers, generators and an inverter and battery manufacturer.[797] Few stakeholders commented in detail on the materiality of system strength reductions across the power system or the need for generating systems to be capable of continuous uninterrupted operation in response to current and projected reductions in system strength across parts of the network. TasNetworks, however, argued that "a new technical requirement to specifically address system strength is necessary given the dominance of power electronically [including inverter] controlled generating technologies that are being connected to the power system en masse."[798]

A number of stakeholders also explicitly opposed the proposed access standard in its current form, or disagreed that there is a need for a system strength standard to be implemented. This included owners and developers of primarily asynchronous (but also some synchronous) generating systems, as well as consultants.[799]

Some stakeholders questioned the analysis underpinning the proposed changes. Advisian argued that "the whole issue of 'system strength' needs to be critically examined…the necessary requirement for system strength as promulgated by various authorities needs to be clarified and the recent statements debunked if necessary."[800] Pacific Hydro likewise argued that "many of the issues on system strength being discussed in the industry require further work and thorough investigation and more work on this issue should be carried out."[801]

797 Submissions to the consultation paper: Alinta Energy, p. 3; Energy Networks Australia, p. 6; Ergon-Energex, p. 6; Origin Energy, p. 9; TasNetworks, p. 9; Tesla, p. 3; TransGrid, p. 2.

798 TasNetworks, submission to the consultation paper, p. 4.

799 Submissions to the consultation paper: Advisian, p. xxix; AGL, p. 6; Australian Sugar Milling Council, p. 5; Clean Energy Council, p. 27; Edify Energy, p. 4; EnergyAustralia, p. 1-2; ESCO Pacific, p. 9; Pacific Hydro, p. 9; WSP, p. 5.

800 Advisian, submission to the consultation paper, p. xxix.

801 Pacific Hydro, submission to the consultation paper, p. iii.

11.5.2 Interactions with *Managing power system fault levels rule*

Several stakeholders considered that the Commission should closely consider the proposed system strength access standard in the context of the *Managing power system fault levels rule*.[802] Most stakeholders did not provide analysis as to whether the proposed access standard is required given obligations under the *Managing power system fault levels rule*, however TasNetworks commented that "while the *Managing power system fault levels* rule change has included the concept of 'do no harm', there is nothing yet which prevents the consumption of existing network hosting capability up to the point to which 'harm' commences."[803] TasNetworks further argued that the proposed access standard would address their concern by "more equitably sharing the available network hosting capacity, and in doing so, better managing the future need for system strength services."[804]

11.5.3 Equipment capability and the potential costs of the proposed access standard

Stakeholders differed on whether generating equipment, particularly inverter-connected generating systems, would be capable of meeting the proposed access standard. Overall, few stakeholders identified specific equipment that would not be capable of meeting the proposed access standard. Several stakeholders, primarily network businesses, some manufacturers and a project developer, claimed that meeting the proposed access standard would generally be within the physical capability of new generating systems, including those containing solar PV inverters and wind turbines.[805] Specifically, SMA commented that its inverters are able to operate down to an SCR of 2.0, which they claimed was among the highest capability they were aware of.[806]

Nordex considered that, in general, wind turbines can operate at an SCR of 3.0, but that this is nearing the physical limits for wind turbines and could create stability issues.[807] Nordex instead proposed an alternative approach in which a maximum allowable range of SCR over a time frame is specified in a generator performance standard.

Several stakeholders, mostly generators, project developers and consultants, claimed that it would be difficult for some inverters to meet the proposed access standard.[808] Some claimed the proposed access standard would result in higher costs for project

802 Submissions to the consultation paper: ElectraNet, p. 2; Energy Networks Australia, p. 2; Meridian Energy, p. 2; TasNetworks, p. 10; Transgrid, p. 2.

803 TasNetworks, submission to the consultation paper, p. 10.

804 Ibid.

805 Submissions to the consultation paper: Ergon-Energex, p. 6; Nordex, p. 7; Powerlink, p. 6; RES Australia, p. 7; SMA, p. 7; Tesla, p. 3; TasNetworks, p. 9.

806 SMA, submission to the consultation paper, p. 7.

807 Nordex, Submission on consultation paper, p. 7.

808 Submissions to the consultation paper: Advisian, p. xxix; AGL, p. 6; ESCO Pacific, p. 9; Pacific Hydro, p. 9; WSP, p. 5.

developers,[809] and could limit the equipment available in the Australian inverter market.[810]

Some stakeholders also considered that it may be difficult for some types of synchronous generating systems to meet the proposed access standard, but no detail was provided as to the reasons for this.[811]

11.6 Analysis and conclusions

Box 11.2 Draft rule

The Commission’s draft rule does not include a system strength access standard as proposed by AEMO.

This section sets out:

- the Commission's analysis of the of the issues raised by AEMO, and
- the Commission's draft rule to address any material issues found.

Parts of the power system have become weaker largely because connecting asynchronous generating systems have consumed more available fault level than they contribute, and the retirement of synchronous generating systems has caused material reductions in available fault level. This trend is likely to continue.

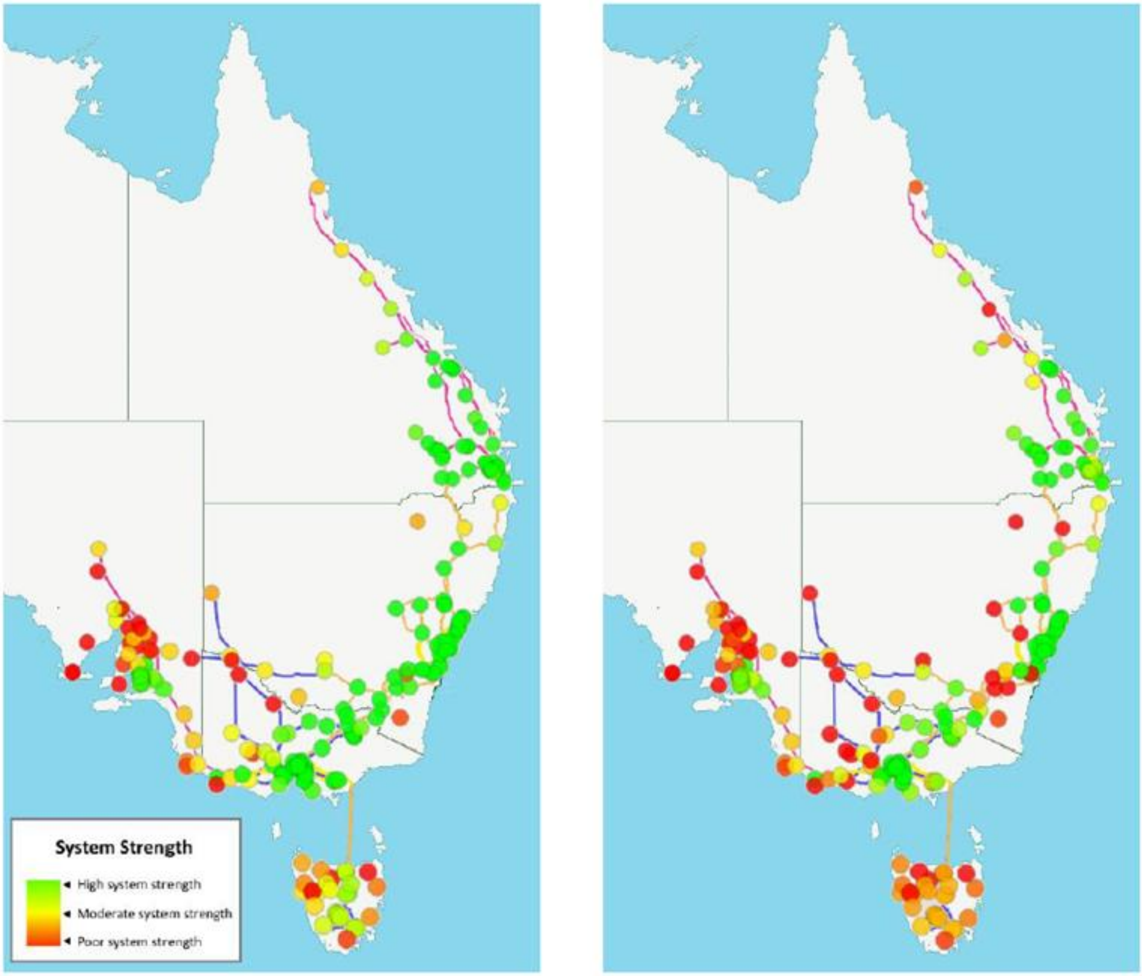
Figure 11.1 below shows the estimated aggregate SCR (a method of calculating SCR that takes into account multiple nearby generating systems) calculated by AEMO for different parts of the power system. It is apparent from Figure 11.1 that system strength is projected to deteriorate across parts of South Australia, Tasmania, Southern NSW and Western Victoria between 2016-17 and 2035-36.

809 Submissions to the consultation paper: Edify Energy, p. 4; EnergyAustralia, p. 1.

810 Submissions to the consultation paper: Clean Energy Council, p. 27; Edify Energy, p. 4.

811 Submissions to the consultation paper: Advisian, p. xxix; Australian Sugar Milling Council, p. 4.

Figure 11.1 AEMO assessment of power system strength in 2016-17 and projections for 2035-36.[812]



Since Figure 11.1 was published in December 2016, AEMO conducted further modelling that took into account revised estimates of new asynchronous generating system connections in Queensland. AEMO has projected from this modelling that system strength is likely to become poor across large parts of Queensland, particularly the south-east (previously projected to remain relatively strong) as a result of expected connection of solar PV generating systems.[813] Network participants in the technical working group for this rule change request also advised that system strength in these parts of Queensland is reducing faster than expected.[814]

AEMO advised that a significant proportion of active connection applications (approximately 100) have calculated SCR values at 3.0 or below, and a handful have values approaching 1.0.[815] AEMO considered that whilst it may not be appropriate to require all generating systems to be capable of continuous uninterrupted operation for

812 AEMO, National transmission network development plan, December 2016, p. 67.

813 Advice provided to the Commission from AEMO, 12 February 2018.

814 Advice provided to the Commission by the technical working group, 1 February 2018.

815 Ibid.

an SCR of 1.0, there is value in this capability for an SCR of 3.0 given the increasing prevalence of connections at these levels.[816]

The Commission considers there is sufficient evidence to suggest system strength is deteriorating in some parts of the power system. There are material risks to power system security if the connection of new asynchronous generating systems occurs without assessment of their ability to be capable of continuous uninterrupted operation for relatively low system strength conditions.

However, the Commission recently made the *Managing power system fault levels rule* to address the system security risks associated with reductions in system strength. Part of the rule commenced on 17 November 2017, and the remaining parts of the rule will commence on 1 July 2018.[817] In order to identify a system security issue that remains to be addressed, there would need to be clear evidence that the *Managing power system fault levels rule* does not effectively address the system security issues raised by AEMO in its rule change request. The following sections outline why the Commission considers there is likely to be no residual system security issue given requirements under the *Managing power system fault levels rule*.

11.6.1 System security assessment

Assessing the potential system security benefits in implementing AEMO's proposed access standard requires consideration of the *Managing power system fault levels rule*, described in section 11.3 above.

The *Managing power system fault levels rule* requires system strength service providers to procure system strength services to provide, at fault level nodes, the level of system strength determined by AEMO to be reasonably sufficient for the power system to be maintained in a secure operating state. Further, connecting generators are required to remediate any reductions in three phase fault level below the minimum required level for the relevant fault level node that are likely to be caused by the connection of the generating system. This is because a reduction in three phase fault level below the minimum required level for a node caused by a connecting generating system would likely adversely affect power system security, which would constitute 'harm' by that generating system.[818]

As part of the *Managing power system fault levels rule*, AEMO is also required to produce a system strength requirements methodology for determining the location and extent of fault level nodes and the minimum three phase fault level for each node. When

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816 Advice provided to the Commission from AEMO, 12 February 2018.

817 AEMO published the *Interim system strength impact assessment guidelines* (used to assess the potential level of harm to power system security from a connecting generating system) on 17 November 2017 and is expected to publish the final guidelines by 1 July 2018. AEMO must also publish, by 30 June 2018, a system strength requirements methodology (which, among other things, specifies how AEMO assesses minimum three phase fault level requirements) and determine the appropriate location of fault level nodes and corresponding minimum three phase fault level requirements for each node.

818 Clause 5.3.4B of the *Managing power system fault levels* specifies that an adverse system strength impact that will result from the connection of a generating system must be remedied or avoided through either a system strength remediation scheme or system strength connection works (both defined in Chapter 10 of the NER under the final rule).

producing the methodology, AEMO is required to consider a number of factors, including:[819]

- the combination of three phase fault levels at each fault level node in the region that could reasonably be considered to be sufficient for the power system to be in a secure operating state, which includes levels expected following any credible contingency or protected event
- the maximum load shedding or generation shedding expected to occur on the occurrence of any credible contingency or protected event affecting the stability of the region
- the stability of the region following any credible contingency or protected event
- the risk of cascading outages as a result of load shedding, or generating system or market network service provider disconnecting as a result of a credible contingency event or protected event
- additional contribution to three phase fault level needed to account for the possible loss or unavailability of a synchronous generating unit or other facility or service that materially contributes to the three phase fault level at the node
- the stability of any equipment that is materially contributing to the three phase fault level or inertia within the region, and
- any other matters as AEMO considers appropriate.

System strength service providers are therefore required to maintain three phase fault levels that would not only allow AEMO to return the power system to a secure operating state following a credible contingency or protected event, but also the maximum load shedding or generation shedding expected to occur on the occurrence of such as event. The Commission considers that the *Managing power system fault levels rule* provides AEMO the ability to maintain system security for relatively severe events, and that increasing AEMO's ability to maintain power system security is not necessary. Given the already broad scope of impacts on system strength that AEMO must consider, the Commission therefore considers that the *Managing power system fault levels rule* provides AEMO with sufficient ability to address power system security issues related to low system strength.

In addition, the 'do no harm' requirement under the *Managing power system fault levels rule*, described in section 11.3, will likely incentivise the installation of generating systems that are capable of continuous uninterrupted operation for the lowest expected three phase fault level at the connection point. This is because connection applicants would be provided with the minimum three phase fault level, as determined by the network service provider, for the relevant connection point, prior to connection of the proposed generating system.[820] In addition, as part of the system strength impact assessment, the network service provider would calculate the minimum aggregate SCR or available three phase fault level expected after connection of the proposed generating system, and compare this to the minimum SCR or three phase fault level for which the

819 Clause 5.20.7(b) (as in force from 1 July 2018) in the *Managing power system fault levels rule*.

820 Clause 5.3.3(b5)(1) of the NER, in the *Managing power system fault levels rule*.

generating system is capable of stably operating at, provided by the connection applicant.[821]

It follows that a connection applicant proposing the connection of a generating system that is capable of continuous uninterrupted operation for the lowest expected level of system strength at the connection point is likely to minimise or eliminate costs under the 'do no harm' requirement of the *Managing power system fault levels rule*, as well as facilitate a timely connection application process. This is because failure of a connection applicant to guarantee continuous uninterrupted operation at these levels of system strength may impact on the ability of a nearby generating system or the power system to maintain stability, depending on characteristics such as size and location of the connecting generating system. In the absence of this capability, a connection applicant is likely to require a more detailed, costly and lengthy system strength impact assessment, and may incur greater costs in remediating an adverse system strength impact that their generating system causes.

As described above, AEMO has the ability to address power system security issues related to system strength under the *Managing power system fault levels rule*. There are not likely to be any residual system security issues that are not addressed by the intended outcomes of the *Managing power system fault levels rule*. AEMO's proposed system strength access standard therefore would not provide an additional benefit to AEMO's ability to manage power system security.

Finally, the Commission considers that it would be premature to introduce a system strength access standard at this time, given that the *Managing power system fault levels rule* has not yet fully commenced. AEMO is yet to publish both the final system strength impact assessment guidelines and the system strength requirements methodology, which will clarify how the *Managing power system fault levels rule* will be implemented. As such, the Commission considers there is currently no identifiable system security need to introduce an access standard requiring generating systems to maintain continuous uninterrupted operation under low system strength conditions. In Chapter 12 the Commission describes its draft rule to introduce a requirement for AEMO to review the access standards in the NER at least every five years. The Commission considers these reviews will provide an appropriate opportunity to consider the need for a system strength access standard in future.

11.6.2 Cost assessment

As well as system security impacts, the Commission has considered potential costs and potential avoided costs in implementing AEMO's proposed system strength access standard. AEMO considered in its rule change request that, in terms of the *Managing power system fault levels rule*, “an additional complementary requirement is needed to ensure the long-term cost to consumers is minimised”.[822] This argument was supported by TasNetworks, which argued that access standards should aim to

821 AEMO, System strength impact assessment guidelines, First stage consultation, 5 March 2018, p. 14, available at https://www.aemo.com.au/Stakeholder-Consultation/.

822 Rule change request, p. 39.

maximise the sharing of available network hosting capacity between current and future connection applicants.[823]

AEMO specifically highlighted in its rule change request the need to address a scenario in which an asynchronous generating system connects to a part of the network that is expected to remain strong for a long time, and where there are few existing asynchronous generating systems.[824] AEMO considered that, in this scenario, there may be little incentive for the generator or network service provider to seek to maximise the ability of the generating system to operate stably if the system strength reduces in future as a result of the retirement of synchronous generating systems or further connection of asynchronous generating systems.

AEMO considered that, under the *Managing power system fault levels rule*, any future generating system connecting nearby would bear the cost of ensuring the existing generating system remains stable, and that had the first generating system been required to have the capability to operate down to a minimum level of system strength (i.e. through AEMO's proposed access standard), the cost associated with connecting future generating systems would be reduced.[825]

Imposing costs or regulatory requirements on connecting generators in order to help facilitate future connections is contrary to the principles of the transmission framework in operation in the NEM, as outlined by the Commission as part of the *Coordination of generation and transmission investment review*.[826] Under the current transmission framework, generators are only required to bear the cost directly related to their connection at the time of their connection. This means that connecting generators do not bear a responsibility for future developments, assuming that a connecting generator does not create a system security issue for future connections. As described above, there are not likely to be any residual system security issues that are not addressed by the intended outcomes of the *Managing power system fault levels rule*.

Matters relating to the coordination of generation and efficient use of and investment in network capacity are being considered as part of the AEMC’s *Coordination of generation and transmission investment review*. This review will consider issues regarding the efficient connection of generation, and the regulatory changes that may be required to facilitate the connection of large amounts of new generation which may need to locate in areas that are at the edges of the existing network, in new renewable energy zones. The Commission welcomes stakeholder feedback on these issues as part of that review.

The Commission considers that there is insufficient certainty as to the magnitude of potential incremental costs on all connecting generators today as well as the magnitude of potential avoided costs for connecting generators and network service providers in future. These incremental costs today, and the potential for avoided costs in future, are explored in further detail below.

823 TasNetworks, submission to the consultation paper, p. 10.

824 Rule change request, p. 39.

825 Ibid.

826 AEMC, *Coordination of generation and transmission investment*, Discussion paper, p. 23, available at www.aemc.gov.au.

Assessment of equipment capabilities and current costs in meeting AEMO’s proposed access standard was informed by a survey of equipment manufacturers in the Australian market conducted by DigSILENT Pacific on behalf of the AEMC.[827] As part of this survey, one solar PV inverter manufacturer and one wind turbine manufacturer claimed that their equipment could readily meet AEMO’s proposed access standard (i.e. at little or no additional cost using ‘off-the-shelf’ equipment). One wind turbine manufacturer and two gas turbine manufacturers claimed that their equipment could meet the standard with modification of the generating system, such as modification of control system software or transformer design (i.e. a likely material, but manageable additional cost). One solar PV inverter manufacturer claimed that they could only guarantee compliance down to a SCR of 5.0 and another highlighted that, while they could guarantee compliance at the inverter terminals, they could not guarantee compliance at the generating system connection point, where AEMO's proposed system strength access standard is specified. This was due to likely consumption of available three phase fault level by auxiliary plant between the connection point and terminals of a generating unit.

While these responses from manufacturers indicate that some can guarantee compliance with the proposed minimum access standard at minimal cost, it appears that others would face material costs, or would be unable to guarantee performance, to comply with AEMO’s proposed access standard. This may exclude potentially lower-cost manufacturers or models of equipment from the market, resulting in increased costs due to reduced competition. Increased costs could also result from the need to modify generating systems in order to guarantee compliance with the proposed access standard.

The Commission also notes that responses from manufacturers are based on the proposed minimum access standard with an SCR of 3.0. However, AEMO's proposed access standard does not include an automatic access standard and as a result would enable AEMO or a network service provider to reject a proposed negotiated access standard unless it corresponded to a higher capability (i.e. an SCR lower than 3.0). This could be difficult for a larger range of equipment to meet and therefore impose costs on a larger number of generating systems.

Introducing the proposed access standard could also result in upfront and ongoing compliance costs through the need to conduct power system studies and control system modification for generating systems. This would likely result in a marginal increase in costs for individual connecting generating systems that would be multiplied across most or all connecting generating systems in future. In aggregate, the cost could be significant.

The Commission acknowledges that mandating this capability from all generating systems could reduce the need for, or extent of, system strength remediation schemes and connection works paid for by future connecting generators as part of their ‘do no harm’ obligations. It could also reduce the need for investment by system strength service providers in equipment and processes to maintain minimum three phase fault levels as part of their obligations under the *Managing power system fault levels rule*. While

827 Advice provided to the Commission by DigSILENT Pacific, 5 March 2018.

these avoided costs could be significant, the Commission has not received sufficient evidence as to whether they may be realised, and if so, where they would occur and over what timeframes.

11.6.3 Conclusions

The proposed system strength access standard does not provide a clear additional system security benefit given the role of the *Managing power system fault levels rule*. While the Commission accepts there may be some avoided future costs in implementing the proposed system access standard, given the current stage of implementation of the *Managing power system fault levels rule* there is insufficient evidence to suggest that these avoided costs would materialise. In addition, connecting generators should not be asked to bear costs or comply with obligations that would reduce costs for future generators applying to connect to the network.

The Commission considers that implementing AEMO's proposed system strength access standard would not promote the NEO given uncertainty in relation to future benefits and a lack of an identifiable system security benefit from implementing the proposed access standard.

The Commission has therefore made a draft rule that does not implement AEMO’s proposed system strength access standard.

12 Consequential changes and other matters

Box 12.1 Overview

The rule change request and stakeholder submissions raised a number of issues that relate to the implementation of this draft rule. Some of the matters raised relate to changes that are necessary or consequential, or corresponding, to the making of this draft rule. The matters raised relate to:

- the regular review of the access standards in the NER
- the review of the template for generator compliance programs
- provision of information on the register of performance standards to the AER, and
- the process to renegotiate a generator's performance standards when equipment is altered.

To address these issues the Commission's draft rule:

- introduces a framework for AEMO to review the access standards in the NER at least every 5 years, in accordance with a defined process and set of objective
- introduces clear obligations for AEMO to provide the AER with an up-to-date copy of the register of generator performance standards (including the corresponding performance standards) annually and on request, or a copy of certain performance standards relevant to specified plant on request, and
- for the existing arrangements for renegotiating certain of a generator's performance standards when equipment is altered:
  - clarifies the application of the arrangements
  - allows applicants to negotiate between the level of their existing agreed performance standard and the automatic access standard, and
  - includes new references to specific access standards that are deemed to be affected (and therefore must be renegotiated) when altering certain listed equipment.

In addition, immediately following the making of any final rule, the Commission will request the Reliability Panel to review the template for generator compliance programs for consistency with the new access standards.

12.1 Introduction

This Chapter discusses matters raised by AEMO, other stakeholders and the Commission as being necessary or consequential, or corresponding, to the making of the draft rule. The matters include:

- regular review of the access standards in the NER

- review of the template for generator compliance programs
- provision of information on the register of performance standards to the AER, and
- arrangements for the renegotiation of certain performance standards upon the alteration of generating equipment.

For each of these, the sections below set out:

- the background to and stakeholder views on the matter, and
- the Commission's analysis and conclusions.

12.2 Regular review of access standards

This section sets out the issues raised regarding regular review of access standards, including stakeholder feedback, and provides analysis and conclusions on the issue.

12.2.1 Background and stakeholder views

The rule change request focuses on changes to the access standards for connecting generating systems (Schedule 5.2).[828] It does not propose changes to the access standards for connecting customers (Schedule 5.3) and market network services (Schedule 5.3a). However, the rule change request also proposes changes to the process to negotiate access standards, which apply to the negotiation of access standards for connection applicants,[829] including connecting generating systems, customers and market network service providers. The last time the generator access standards were reviewed in detail was in 2006 and 2007, when a number of changes were made to accommodate the connection of asynchronous generating systems.

The current arrangements in the NER do not prescribe a process for the regular review of access standards. However, one of the functions of the Reliability Panel is to monitor, review and publish a report on the implementation of automatic access standards and minimum access standards as performance standards in terms of whether:[830]

- their application is causing, or is likely to cause, a material adverse effect on power system security, and
- the automatic access standards and minimum access standards should be amended or removed.

In its rule change request, AEMO noted that recommendation 2.1 in the *Independent review into the future security of the national electricity market*, led by Dr Alan Finkel AO, states that a comprehensive review of the connection standards should be undertaken every 3 years.[831] That is, a review of the access standards for generators, customers and

828 Although AEMO may have reviewed all of the generator access standards, they have not proposed changes to all of them. As such, not all of the generator access standards have been considered in this rule change.

829 "Connection applicant" is defined in Chapter 10 of the NER as “a person who wants to establish or modify a connection to a transmission network or distribution network and/or wishes to receive network services and who makes a connection enquiry as described in clause 5.3.2 or clause 5.3A.5.”

830 Clause 8.8.1(a)(7) of the NER.

831 Rule change request, p. 12.

market network service providers. AEMO agreed with the need for regular reviews and noted it will undertake them as recommended, but did not see the need to amend the NER to give effect to the reviews.[832] AEMO again noted in its submission to the consultation paper that it supports "the need for technical standards to undergo regular review to accommodate future needs, improvements in technology and to maintain alignment with international practice."[833]

In its submission to the consultation paper, the AER suggested that a requirement should be introduced in the NER, or other arrangement, to review the access standards at least every 5 years.[834] The AER considered this is appropriate due to the fast pace at which new technologies are emerging and because the current access standards have not been reviewed since 2007.[835] It therefore considered a regular review of the access standards would proactively ensure the standards reflect the evolving power system.[836]

Ergon and Energex noted they consider that generator access standards should be subject to regular review given the rapid changes in the generation mix.[837] No other stakeholders commented on matters relating to the regular review of technical standards.

12.2.2 Analysis and conclusions

Box 12.2 Draft rule

The Commission's draft rule introduces a new clause 5.2.6A of the NER setting out a requirement for AEMO to review the access standards in the NER at least once every 5 years, in accordance with a process and set of objectives defined in the NER. Under this process:

- 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 every five years (and more frequently if AEMO considers necessary) to assess whether those requirements should be amended, having regard to:[838]
  - the NEO
  - the need to achieve and maintain power system security
  - changes in power system conditions, and
  - changes in technology and capabilities of the equipment that makes

832 Rule change request, p. 13.

833 AEMO, submission to the consultation paper, pp. 5-6.

834 AER, submission to the consultation paper, p. 2.

835 Ibid.

836 Ibid.

837 Ergon and Energex, submission to the consultation paper, p. 4.

838 Clause 5.2.6A(a) of the draft rule.

up the power system

- when conducting the review AEMO must consult widely, including with registered participants and the Reliability Panel,[839] and
- in conducting the review AEMO must publish on its website:[840]
  - — an approach paper, setting out the scope of the review, the issues to be consulted on and the date by which a draft report will be published
  - — a draft report setting out any recommendations for any amendments to the technical requirements and the reasons for them, calling for submissions on the issues identified and publishing the submissions, subject to obligations of confidentiality, and
  - — a final report within 12 months of the publication of the approach paper, setting out AEMO's recommendations for any amendments to the technical requirements.

The Commission agrees with AEMO and the AER that a regular review of the access standards would enable the access standards be adapted to respond to evolving power system conditions, as issues arise and are better understood.

The Commission also agrees with the AER that a framework for regular reviews should be provided for in the NER. Access standards are used to set the performance of equipment connecting to the power system, and as such are a critical element of the overall system security framework in the NER. Given the importance of the access standards, and the ongoing changes in the power system, the Commission considers it is appropriate to set a framework in the NER to provide a high level of certainty that these reviews will be conducted on an ongoing basis, and provide stakeholders with clarity on when and how the reviews will occur. In addition, the Commission considers it is appropriate to set out a framework in the NER that governs the scope, timing and outcome of the review to provide transparency and to place appropriate parameters on how the reviews will be undertaken.

The existing functions of the Reliability Panel allow it to monitor, review and publish a report on the implementation of automatic access standards and minimum access standards as performance standards. While this function could be used for the regular review of access standards in the NER, the Commission considers the appropriate market body to conduct the reviews is AEMO. AEMO is best placed to undertake the reviews given its role as system operator and its advisory role in the negotiation of access standards that are AEMO advisory matters.

However, the Commission also considers it is appropriate that the Reliability Panel should continue to play a role in the review of access standards, both in consultation with AEMO as part of the regular reviews, and by retaining its existing functions so that it may monitor and review any matters related to the access standards it considers appropriate.

839 Clause 5.2.6A(b) of the draft rule.

840 Clauses 5.2.6A(c) to (e) of the draft rule.

Although the Finkel review and AEMO's rule change request suggest that regular reviews of access standards should occur every three years, the Commission considers that this is likely to be too frequent. In order to conduct a thorough and informed review of the access standards, it is likely to be appropriate to gain some experience with new connections complying with any arrangements that changed under a previous review. For this reason the Commission considers five yearly reviews to be an appropriate timeframe, noting that any urgent issues can always be addressed through a rule change request at any time.

It is appropriate that AEMO be able to exercise its discretion to set the scope of these reviews to address the most pressing needs of the power system. For example, at the discretion of AEMO, one review may focus on generator access standards, and the next review may focus on access standards for customers. This flexibility for AEMO to determine the scope of reviews should also be accompanied with discretion to conduct more frequent reviews if appropriate to address different matters.

The Commission's draft rule therefore requires that a review must occur at a *minimum* of once every five years, but leaving the option for AEMO to conduct a review sooner if it considers it is needed. The Commission's draft rule also introduces a review framework that is not prescriptive, allowing AEMO to exercise its discretion to determine the scope and focus of any given review.

The Commission also considers it appropriate that the framework set some parameters for the review, including overall timing and transparency measures such as the obligation to consult widely and publish reports and submissions. This should provide an appropriate balance between certainty of a review occurring in a transparent way, and providing enough flexibility for AEMO to conduct the review when it considers appropriate, and to tailor the focus of the review in a manner considered necessary at the time.

It is necessary also to clearly articulate the objective of the reviews to provide AEMO with some guidance on the principles that should be taken into account in the review process. This guidance should provide both AEMO and stakeholders engaging in the review process with a clear objective for the appropriate outcomes of a review. The Commission considers the appropriate objective of the reviews is to assess whether the technical requirements in the NER that are the subject of the review should be amended, having regard to the NEO, the need to achieve and maintain power system security, changes in power system conditions, and changes in technology and capabilities of the equipment that makes up the power system.

12.3 Review of template for generator compliance

This section sets out the issues raised regarding the need to update the template for generator compliance obligations, including any stakeholder feedback, and provides analysis and conclusions on the issue.

12.3.1 Background and stakeholder views

Generators must ensure that their plant meets or exceeds their performance standards, and must also institute and maintain a compliance program to manage compliance with performance standards.[841] The compliance program must be implemented within 6 months of when AEMO notifies the participant of the registration of its performance standards, or within 6 months of the relevant plant commencing operation.[842]

The compliance program must be consistent with the template for generator compliance programs, which is set by the Reliability Panel.[843] Further, participants must modify their compliance programs to be consistent with any amendments made to the template for generator compliance programs within 6 months of amendments to the template being published, or another date determined by the Reliability Panel.[844]

One of the functions of the Reliability Panel is to determine, modify as necessary, and publish, the template for generator compliance programs.[845]

The Reliability Panel must conduct a review of the template for generator compliance programs at least every five years (from the date of the previous five yearly review) or at such other times as the AEMC may request.[846] Following such a review, the Reliability Panel may amend the template for generator compliance programs in accordance with its report to the AEMC. The last review of the template was completed in June 2015, and therefore, the next scheduled review would be in 2020.

In its submission to the consultation paper, the AER suggested that any change to particular access standards should also result in the review of the template for generator compliance programs published by the Reliability Panel.[847]

This issue was not raised by AEMO in its rule change request or submission. No other stakeholder submissions raised this issue.

12.3.2 Analysis and conclusions

The draft rule includes a number of material changes to the access standards that apply to generators connecting to the power system. This includes new requirements that do not appear to be captured under the current template for generator compliance, such as a new requirement to maintain continuous uninterrupted operation when faced with multiple faults.

There does not however appear to be an urgent need to update the template for generator compliance programs concurrently with the commencement of the draft rule, if it is ultimately made as a final rule. This is because any changes to the generator access standards are likely to take some time to flow through to generating systems being commissioned, partly due to the nature of the transitional arrangements discussed in Chapter 13, and also because of the time to build and commission a generating system. Further, as noted above, the requirement for a compliance program to be in place begins within 6 months of when AEMO notifies the participant of the

841 Clauses 4.15(a) and (b) of the NER.

842 Clause 4.15(b) of the NER.

843 Clause 4.15(c) of the NER.

844 Ibid.

845 Clause 8.8.1(a)(2b) of the NER.

846 Clause 8.8.3(ba) of the NER.

847 AER, submission to the consultation paper, p. 2.

registration of performance standards, or within 6 months of the relevant plant commencing operation. This should allow enough time for the Reliability Panel to conduct a review of the template for generator compliance after a final determination is made under this rule change request.

The next five yearly review is due to occur in 2020, however this will be too late to implement the necessary changes to the template to account for this rule change. It would therefore be appropriate to use the mechanism in the current rules for the AEMC to request the Reliability Panel to conduct a review of the template out of sequence with the usual five yearly review process.[848] The approach would be for the AEMC to send a letter to the Panel at the conclusion of the rule change, requesting the Panel to review the template in accordance with terms of reference set by the AEMC. A new provision would not be required in the NER to give effect to this, as the current clause 8.8.3 already provides for this.

The Commission therefore notes that following the conclusion of this rule change, if a final rule is made making changes to the generator access standards in the NER, it will request the Reliability Panel to review the template. The request will be made in accordance with clause 8.8.3(ba) of the NER, which allows the Commission to request the Panel to review the template outside of the five yearly cycle.

12.4 Register of performance standards

This section sets out the issues raised regarding the register of performance standards kept by AEMO, including stakeholder feedback, and provides analysis and conclusions on the issue.

12.4.1 Background and stakeholder views

Network service providers and registered participants (including generators) must notify AEMO of the details of the performance standards that form part of the terms and conditions of a connection agreement within 20 business days of its execution.[849] AEMO must establish and maintain a register of performance standards, as advised by registered participants following the execution of their connection agreements.[850]

There is currently no requirement in the NER for AEMO to notify the AER of the details of performance standards, or to provide the register of performance standards to the AER. The Commission understands that in practice AEMO shares this information with the AER on an ad hoc basis, when requested.

In its submission to the consultation paper, the AER suggested that there should be a requirement for AEMO to provide the AER with a consolidated copy of controlled versions of all registered generator performance standards at least annually or, within five business days, a copy of any amended generator performance standards, or generator performance standards that are formally requested by the AER.[851] The AER

848 Clause 8.8.3(ba) of the NER.

849 Clause 5.3.7(g)(1) of the NER.

850 Clause 4.14(n) of the NER.

851 AER, submission to the consultation paper, p. 2.

considered this would assist it with considering matters relating to the generator performance standards more promptly and effectively, particularly regarding the non-compliance reporting regime,[852] and the AER's function to review and determine the appropriateness of rectification periods set by AEMO under that reporting process.[853]

12.4.2 Analysis and conclusions

Box 12.3 Draft rule

The Commission's draft rule includes changes to clause 4.14 of the NER, which require:

- AEMO to establish and maintain the register of performance standard, as advised by registered participants following both execution of the connection agreement and after any variation to a connection agreement[854]
- AEMO to provide to the AER by 1 July each year, an up-to-date copy of the register of performance standards (including a copy of the corresponding performance standards),[855] and
- where the AER makes a request (that it considers is required for the performance or exercise of its functions):[856]
  - AEMO to provide to the AER, within 10 business days, an up-to-date copy of the register of performance standards (current as at the date of the AER's request), including a copy of the corresponding performance standards, and
  - AEMO to provide to the AER, within 5 business days, a copy of the performance standards relating to specified plant.

The Commission considers it is preferable to have clear information provision requirements in the NER to support the timely investigation of non-compliance issues, which is a critical function of the AER. A clear requirement would likely assist all relevant organisations to plan and allocate resources for the purposes of providing this information in a timely manner.

The Commission also considers that clear requirements for information provision are necessary given the AER's role in reviewing and determining the appropriateness of rectification periods set by AEMO. If a request is made, the AER must within 30 business days review and either accept the rectification period determined by AEMO or

852 AER, submission to the consultation paper, p. 2. See also clause 4.15(f) of the NER.

853 Clauses 4.15(n) and (o) of the NER. A rectification period is the period of time determined by AEMO for a registered participant to rectify a breach of performance standards. The rectification period is determined in clause 4.15(i) of the NER.

854 Clause 4.14(n) of the draft rule.

855 Clause 4.14(n1) of the draft rule.

856 Clauses 4.14(n2) and (n3) of the draft rule.

determine a new rectification period, giving reasons.[857] Given the requirement for the AER to respond within a short period of time, it is appropriate for the AER to have available an up-to-date copy of the register of performance standards, and the ability to quickly obtain a copy of particular performance standards, within a defined timeframe.

The Commission's draft rule therefore introduces requirements for AEMO to provide an up-to-date copy of the register of performance standards (including the corresponding performance standards) to the AER annually by 1 July or within 10 business days of a request. It also allows the AER to request a copy of performance standards relating to specified plant, requiring AEMO to provide the particular performance standards to the AER within 5 business days of such a request. To make a request the AER must consider in its reasonable opinion that the request is required for the performance or exercise of its functions.

12.5 Alteration of plant and renegotiation of performance standards

This section sets out issues identified regarding the alteration of existing plant, including stakeholder feedback, and provides analysis and conclusions on the issue.

12.5.1 Background and issues

A generator that proposes to alter a generating system must follow a process in the NER that requires the performance standards for the generating system to be updated to reflect any new levels of performance.[858] The process is triggered where a generator proposes to alter a generating system (that is connected or has performance standards accepted by AEMO) in a manner that will affect the performance of the generating system relative to any of the technical requirements set out in, among other things, clause S5.2.5 which includes the access standards for generators.[859]

Where this threshold is triggered, the generator is required to notify AEMO, and for each technical requirement for which the proposed alteration to the equipment will affect the level of performance, propose amendments to its performance standards.[860] Where a negotiated access standard will be determined, the process followed to negotiate is the usual process for negotiation in clause 5.3.4A of the NER.[861] This process requires that a negotiated access standard must be no less onerous than the minimum access standard.[862]

An issue could arise where equipment that is part of an existing generating system is sought to be altered and cannot meet a relevant minimum access standard, particularly

857 Clause 4.15(o) of the NER.

858 Clause 5.3.9(a) of the NER.

859 Clause 5.3.9(a) of the NER.

860 Clause 5.3.9(b) of the NER. Note the clause refers to the requirement for a generator to propose amendments to the "access standards". This should be a reference to a proposal to amend the performance standards for the relevant generating system (given that the access standards are the levels of performance set out in Schedules to Chapter 5 in the NER). The Commission's draft rule clarifies this matter.

861 Clause 5.3.9(c) of the NER.

862 Clause 5.3.4A(b)(1) of the NER.

where the access standards have changed under a final rule. This is because the generator cannot commission its altered generating system unless it has received notice that the network service provider and AEMO (where relevant to an AEMO advisory matter) are satisfied that each amended performance standard either:

- meets the requirements of the corresponding automatic access standard, or
- meets the requirements for a negotiated access standard (i.e. is no less than the corresponding minimum access standard).[863]

Under current arrangements there is therefore a risk that a generator could be restricted from being re-commissioned following the alteration of plant because it cannot meet the new minimum access standard. This could occur even though the purpose of the alteration may be to extend the life of a generator or improve its performance, which would be a desirable outcome for system security, reliability and the prices paid by customers for electricity. The Commission understands that in practice this risk is partly mitigated by a pragmatic approach generally taken in these circumstances by generators, AEMO and network service providers. Regardless, a perception that this risk is present may still form a barrier to efficient investment in the upgrade of equipment.

A further issue identified is that it does not appear to be clear when the process to update the performance standards due to the alteration of equipment is triggered. The threshold for the application of the clause is where a generator is proposing to alter a generating system in a manner that 'will affect the performance of the generating system relative to the technical requirements'.[864] This leaves some room for discretion and ambiguity.

A table is set out later in the clause that specifies the access standards (in Column 2) in relation to which a generator must propose amended performance standards to the network service provider for particular types of equipment alterations (in Column 1).[865] However, the alteration of equipment specified in Column 1 of the table does not explicitly trigger the application of the clause (in clause 5.3.9(a)). As a result, a generator may alter equipment listed Column 1 of the table, and, if it considers it will not affect the performance of the generating system relative to the technical requirements, is not obliged to inform AEMO of the alteration to the plant and propose new performance standards.

In its rule change request, AEMO proposed the inclusion of two new access standards in the table described above that must be renegotiated for certain equipment alterations, being:

- when a voltage control system is altered, requiring the renegotiation of the performance standard set in clause S5.2.5.7 (partial load rejection withstand capability), and

863 Clause 5.3.10 of the NER.

864 The 'technical requirements' include the generator access standards in Schedule 5.2 to the NER. See clauses 5.3.9(b)(3) and (d) of the NER.

865 Clause 5.3.9(d) of the NER.

- when a protection system is altered, requiring the renegotiation of the performance standard set in clause S5.2.5.10 (protection to disconnect for unstable operation).

AEMO's rule change request also proposed to fix a historical typographical error in the same table in clause 5.3.9, noting that when the auxiliary supplies are altered the performance standard set in clause S5.2.7 should be renegotiated, and not the currently referred to clause S5.2.8 (which was the numbering for the current S5.2.7 in a previous version of the rules).

TasNetworks also suggested that the performance standards set in clause S5.2.5.1 (reactive power capability) should be required to be renegotiated when a generator alters its excitation control system or voltage control system.[866] It considered this is appropriate because 'limiters' may be incorporated into the control systems that directly impact on the reactive capability of the generating unit or generating system as determined at the connection point.[867]

12.5.2 Analysis and conclusions

Box 12.4 Draft rule

The Commission's draft rule includes changes to clauses 5.3.4A and 5.3.9 of the NER that:

- allow a generator altering its generating system to submit a negotiated access standard between the automatic access standard and the generator's existing performance standard[868]
- clarify that the types of equipment alterations set out in Column 1 of the table at clause 5.3.9(d) are deemed to trigger both the application of all of the requirements in clause 5.3.9 and to specify the access standards for which amendments to corresponding performance standards must be proposed (unless AEMO and the network service provider otherwise agree),[869] and
- include the two clause references proposed by AEMO into the table in clause 5.3.9(d) and rectify the erroneous reference identified by AEMO in the table.[870]

This section sets out:

- the Commission's analysis of the of the issues raised by AEMO, and
- the Commission's draft rule to address any material issues found.

The Commission's draft rule addresses the ambiguity in the application of the arrangements for renegotiation of performance standards on alteration of certain

866 TasNetworks, submission to the consultation paper, p. 19.

867 Ibid.

868 Clause 5.3.4A(b)(1A) of the draft rule.

869 Clause 5.3.9(d) of the draft rule.

870 Clause 5.3.9(d) of the draft rule.

equipment, the risk that generators may avoid efficient investment in upgrading their equipment due to a perceived risk that the equipment may not be re-commissioned, and the need to update the table referring to access standards relevant to particular alterations of equipment.

Application of clause 5.3.9

The Commission considers that the appropriate role of clause 5.3.9 is to make sure that, where generators upgrade or alter their equipment, any change in the performance of the generating system is captured in updated performance standards registered with AEMO. This is because it is essential that AEMO is aware of the performance of equipment connected to the power system, and any changes to that performance.

Given the importance of the requirements in clause 5.3.9, it is critical that the application of the clause is clear to all parties. As noted above, the current arrangements do not provide this clarity. The Commission's draft rule therefore addresses this issue by making it clear that any of the alterations set out in Column 1 of the table in clause 5.3.9(d) are deemed to affect the performance of the generating systems relative to the technical requirements set out in Column 2 of the table, and thus trigger the application of the whole clause under 5.3.9(a).

The Commission considers this is likely to result in AEMO having better information on the performance of equipment that is connected to the power system, so it is able to more efficiently exercise its functions in managing power system security.

Potential barriers to investment

As noted above, the Commission considers there is a material risk that a generator may be deterred from investing to upgrade equipment given that current arrangements would require that any performance standards that are renegotiated must be set within the range provided by the automatic access standard and minimum access standard, as at the time the renegotiation occurs. If the altered equipment would be unable to meet a minimum access standard (including for example as amended by a final rule made under this rule change) the generating system may be at risk of being unable to be re-commissioned in clause 5.3.10 of the NER.

A number of stakeholders appear to agree that this risk is present, or at least consider that compliance with the new requirements would be prohibitively expensive for existing equipment.[871] EnergyAustralia considered that, given the age and technical capability of some plant, clause 5.3.9 may prohibit upgrades as the costs of retrofitting equipment to meet the new standards would be too high, preventing the potential positive effects of such investments for system security.[872] Origin Energy considered the risk may hasten the retirement of plant that would otherwise be upgraded and continue service.[873]

871 Submissions to the consultation paper: Hydro Tasmania, p. 1; EnergyAustralia, p. 2; Meridian Energy, p. 6; Australian Sugar Milling Council, p. 8; Origin Energy, pp. 4-5; Pacific Hydro, p. 12.

872 EnergyAustralia, submission to the consultation paper, pp. 2-3.

873 Origin Energy, submission to the consultation paper, p. 4.

A number of stakeholders suggested alternative arrangements to address this issue.[874] Hydro Tasmania recommended limiting the application of any changed standards to connecting generating systems to avoid imposing unnecessary obligations on existing ones.[875] It also recommended that any new access standards should recognise legacy issues when being applied to generating systems that are undergoing modifications.[876] Meridian Energy suggested including a general requirement for a generator altering its equipment to negotiate in good faith with the relevant network service provider and AEMO to identify technical improvements that enhance AEMO's ability to operate the power system in a more secure state.[877] This is consistent with the view of Origin Energy that the overall aim of negotiations triggered by clause 5.3.9 should not be to bring the performance standards up to the levels of the automatic access standards, but to have a pragmatic discussion between all parties to come to a reasonable agreement on what the unit can perform to, within reasonable costs.[878]

Although the Commission considers current arrangements may create a potential barrier to efficient investment in the upgrade of equipment, the Commission does not agree that existing equipment should be exempt from any new rules. The Commission considers that existing generating systems, when their equipment is upgraded, should be required to update their performance standards to reflect any improved levels of performance that result from the upgrade. It is appropriate that the content and expression of the updated performance standards reflects the rules at the time.

Accordingly, the Commission's draft rule addresses the risk that alterations to equipment result in the generating systems being unable to be re-commissioned. The draft rule includes new provisions in the negotiating process that make it clear that when a negotiation of performance standards relates to the alteration of equipment in clause 5.3.9, the negotiating range is between the automatic access standard and the generator's corresponding existing performance standard (rather than the corresponding minimum access standard in the NER).

These changes remove the potential barrier to efficient investment in upgrading equipment, while allowing parties to pragmatically agree new relevant performance standards under the changed negotiating process. This is likely to result in more efficient investment in upgrading generating systems connected to the power system.

New access standard references

The table in clause 5.3.9(d) lists the access standards in relation to which performance standards must be renegotiated for particular kinds of alterations of equipment. It deems that specific alterations to equipment will affect the performance of the generating system relative to certain technical requirements (including the generator access standards), and should therefore trigger the requirements in clause 5.3.9. AEMO

874 See for example, Hydro Tasmania, submission to the consultation paper, p. 1.

875 Hydro Tasmania, submission to the consultation paper, p. 7.

876 Hydro Tasmania, submission to the consultation paper, p. 7.

877 Meridian Energy, submission to the consultation paper, p. 6.

878 Origin Energy, submission to the consultation paper, pp. 4-5.

considers that clauses S5.2.5.7 and S5.2.5.10 should be included in the table, and that a reference to clause S5.2.8 should be changed to S5.2.7, as noted above.

Few stakeholders commented on these proposed changes. Energy Networks Australia (ENA), TasNetworks, and Ergon and Energex agreed with AEMO that the access standards should be included.[879]

Requirements to maintain continuous uninterrupted operation in the face of partial load rejection events, set out in clause S5.2.5.7, currently do not apply to asynchronous generating systems. As described in section 10.7, the Commission's draft rule amends clause S5.2.5.7 on partial load rejection to apply the existing requirements to asynchronous generating systems. It is therefore appropriate to include the requirement to renegotiate the performance standard set in clause S5.2.5.7 where the voltage control system of an asynchronous generating system is altered. This also reflects the arrangements for the alteration of synchronous generating systems. Performance standards set in clause S5.2.5.7 must be renegotiated when the excitation control system of a synchronous generating system (which is analogous to a voltage control system in an asynchronous generator) is altered. ENA agreed that the changes will bring the requirements for asynchronous generators into line with requirements for synchronous generators.[880]

Clause S5.2.5.10 relates to the performance of a generator's protection system when tripping due to unstable operation. It is a clear omission in the current arrangements that an alteration to a generator's protection system does not trigger a requirement to renegotiate the performance standard set in clause 5.2.5.10. The Commission also agrees with AEMO that the reference in the table in clause 5.3.9(d) to clause S5.2.8 is erroneous, and should be replaced with a reference to clause S5.2.7.

The Commission's draft rule therefore amends the table in clause 5.3.9(d) to include the changes proposed by AEMO.

The Commission does not consider that further clauses need to be included in clause 5.3.9. In particular, the Commission does not agree with the changes suggested by TasNetworks that clause S5.2.5.1 be included. This clause relates to how much reactive power capability is required from a connecting generator for the particular location in the network. Under the Commission's draft rule the minimum access standard in clause S5.2.5.1 does not require the provision of any reactive power capability because, in some locations in the power system, no capability is needed from a connection. The Commission consider it is not the role of a connecting generator to account for the reactive power capability that may be required in the future, which is more appropriately the responsibility of networks. Including a requirement to renegotiate performance in clause S5.2.5.1 when a generator alters its excitation or voltage control system could change this balance of responsibilities in some cases.

The Commission considers it is appropriate for a generator to comply with its original agreed level of performance under S5.2.5.1 both before and after an alteration of an excitation or voltage control system. Furthermore, if a network requires additional

879 Submissions to the consultation paper: ENA, p. 9; TasNetwroks, p. 19; Ergon and Energex, p. 9.

880 ENA, submission to the consultation paper, p. 9.

reactive power capabilities to meet its obligations at later date, it can at that time follow the relevant processes to procure those services on a commercial basis.

The Commission notes that TasNetworks is principally concerned that an altered excitation or voltage control system may have 'limiters' that make it unable to meet certain levels of performance. It is not clear whether this refers to an inability to meet existing agreed performance standards, or an inability to meet the new minimum access standard proposed by AEMO (which is not included in the draft rule). Regardless, the Commission considers that an alteration to a generating system should not result in a reduction in performance, which is reflected in the draft rule requiring that a renegotiation of performance standards triggered by clause 5.3.9 is between the existing agreed performance standard and the corresponding automatic access standard. This would not allow a generator to negotiate a lower level of performance than it has already agreed.

However, if an alteration of equipment did result in lower levels of performance, this could result in a non-compliance with performance standards. As a last resort, the non-compliance could be resolved by reducing the level of performance set in the performance standards in accordance with the process in clause 4.14 of the NER. This existing process would address the issue raised by TasNetworks in the appropriate way, as a compliance issue.

13 Transitional arrangements

Box 13.1 Overview

In its rule change request, AEMO was concerned that if the final rule is not promptly implemented with effective transitional arrangements, a large number of generating systems (assets with a 20 year life) may be connected under current arrangements that AEMO considered to be outdated. AEMO therefore proposed transitional arrangements that would apply any amending rule to all connection applications not finalised by 11 August 2017 (the date they made the rule change request) and to create a mechanism to change certain performance standards agreed between 11 August 2017 and the date the rule is made.

The Commission agrees that if all of the generating systems with existing connection applications currently under consideration by AEMO and network service providers are able to proceed to connection under the current rules, a significant number of generating systems would be connected under arrangements that the Commission considers should be changed to better support the security of the power system. It is therefore appropriate to implement the new rule as quickly as is feasible, having regard to limitations on the AEMC's rule making powers.

The Commission's draft rule therefore includes transitional arrangements that:

- provide that the final rule would commence on the date that is 8 weeks after the date of the final determination, and
- for negotiations that on the date of commencement have a full set of access standards agreed for a proposed connection, allows for the access standards for the project to be based on the rules that were in force immediately prior to the commencement date.

Parties that have a full set of access standards agreed for the proposed connection prior to an offer to connect, have an offer to connect, or have entered into a connection agreement, are able to proceed to be commissioned in accordance with the rules as they were in effect immediately before the commencement of the final rule.

The Commission's draft rule also addresses matters for connection processes where a full set of access standards is not yet agreed as at the date the final rule commences. For these connection processes the network service provider is required to:

- notify the connection applicant that the new arrangements apply to their connection process, and
- to the extent necessary, provide the connection applicant with any further information relevant to the proposed plant (e.g. details of the relevant access standards), and written notice of any further information to be provided by the connection applicant to the network service provider so that the connection applicant can prepare an application to connect, or so that the

network service provider can prepare an offer to connect, under the new arrangements.

The draft rule does not allow the network service provider to charge an additional fee relating to a connection enquiry or application to connect, however the network service provider may still recover reasonable costs of work done relating to the connection and to facilitate the implementation of the new arrangements. The network service provider may also extend certain time periods to allow for additional time taken in excess of the period allowed in the preliminary program that is necessary to take account of the new arrangements.

13.1 Introduction

All changes to the NER must commence from the date the rule is made, or from a later date specified in the relevant notice or amending rule.[881] This can be as simple as specifying that the new rules commence on the date the rule is made, or at some later date. For other more complex changes to the NER, such as those set out in the draft rule, detailed transitional arrangements are required.

This Chapter sets out the Commission's approach to transitional arrangements for:

- the commencement of a final rule, including determining which connection processes should not be affected by a final rule, and
- arrangements for connection processes that will be affected by a final rule.

For each of these issues, where relevant, this Chapter sets out:

- issues raised by AEMO
- stakeholder views, and
- analysis and conclusions.

13.2 Rule change request

In its rule change request AEMO argued that applying the amending rule to all negotiations from 11 August 2017 (the date it submitted the rule change request) is imperative to ensure the ongoing security of the power system.[882] AEMO argued that failing to do so would mean that assets with long life-cycles may be connected under current arrangements that AEMO considered do not ensure the capabilities required for the future power system.[883] AEMO considered this was particularly important given the large number of connection applications currently under consideration by AEMO and network service providers.

To address this issue AEMO proposed in its rule change request:

881 Section 104 of the National Electricity Law (NEL). The date the rule is made is the date the notice is published in the South Australian Government Gazette.

882 Rule change request, p. 7.

883 Ibid.

1. applying the final rule from 11 August 2017 for all connection applications made before the date the new rule is made, where the performance standards were not finalised by 11 August 2017, and
2. for any performance standard finalised on or after 11 August 2017 that is below the level of the minimum access standard set out in the new rule:
   (a) applying the new minimum access standard to the exclusion of the agreed performance standard from the date the new rule commences, and
   (b) requiring the network service provider and the connection applicant to negotiate an amendment to the performance standard to ensure it is consistent with the new rule, with AEMO to provide advice to the network service provider on any relevant AEMO advisory matters.

AEMO also proposed allowing it to provide exemptions from the requirements to renegotiate any performance standards finalised after 11 August 2017 where it considers that the performance standard will not adversely affect power system security.

There are some limitations on the AEMC's rule making powers that constrain the Commission's ability to make the transitional arrangements proposed by AEMO in its rule change request. The Commission does not have the power to make retroactive rules;[884] that is, rules that are expressed to commence on a date before the rule is made and gazetted. It appears that this is the intended effect of the transitional arrangements proposed by AEMO that are described in paragraph (1) above.

In addition, rules made by the Commission that have certain types of retrospective effect (retrospective rules) will be invalid. That applies to rules that repeal or amend an existing rule in a manner that affects existing rights and liabilities in any of the ways described in paragraphs (a)-(e) of clause 33(1) of Schedule 2 to the National Electricity Law (NEL). The central consideration for retrospective rules is identifying which existing rights are protected from being affected by the repeal or amendment of an existing rule. While it is clear that a rule that affects existing rights or liabilities in the ways described in paragraphs (a)-(e) of clause 33(1) of Schedule 2 to the NEL will be invalid, it is not always clear whether a particular amendment to the NER has such an effect. It will depend on the circumstances of each case, and in particular on the precise nature of the rule and the nature of the rights and liabilities it affects. These considerations are relevant to the transitional arrangements proposed by AEMO that are described in paragraph (2) above.

The Commission must also take into account the constitutional limitations on making laws in the Northern Territory and the ACT under the Commonwealth self-government Acts that apply to those territories.[885] If a provision of the NER affects an acquisition of

884 Section 104 of the NEL provides that a rule made commences operation on the day the relevant notice is published or on any day after that day, provided for in the relevant notice or the rule. This prevents the AEMC from making a rule that commences operation before the day the rule is published.

885 Electricity (National Scheme) Act 1997 (ACT), s 5; National Electricity (Northern Territory) (National Uniform Legislation) Act (NT), s 6.

property otherwise than on just terms,[886] that provision will be invalid and not operate as a law of the Northern Territory and the ACT. For example, a rule change that affects contractual rights without provision for compensation could amount to an acquisition of property other than on just terms and be invalid in the Northern Territory and the ACT on that basis.

13.3 Stakeholder views

Most stakeholders opposed AEMO's proposed transitional arrangements, however some network businesses expressed their general support for a rapid transition to any new arrangements.

There was some support from network businesses for AEMO's view that a large proportion of proposed connections under current arrangements could impact the future security of the power system.[887] Ergon and Energex considered the large proportion of projects in the pipeline connecting under the existing rules could create technical issues over time.[888] TasNetworks noted it is currently managing an unprecedented level of connection activity and that it is critical that any changes to the access standards are applied to as many of them as possible.[889]

Some stakeholders however questioned whether there was a system security need for the rapid transition to any new arrangements, as proposed by AEMO.[890]Terrain Solar and the CEC considered that AEMO had not effectively prosecuted the case or provided real evidence that the rule is urgent.[891] The CEC noted that although AEMO argues the urgency stems from the 20 GW of currently proposed generation across the power system, other AEMO predictions of likely new capacity include a need for approximately 12 GW to meet unserved energy by 2027, and a predicted 5 GW by 2019 set out in the draft integrated grid plan.[892]

Many stakeholders considered that the transitional arrangements proposed by AEMO could significantly impact existing and planned investments.[893] AGL considered the proposal could render existing generating systems unviable.[894] First Solar considered the uncertainty created by such transitional arrangements could lead to project developers over-specifying equipment to account for potential future changes to the NER, pushing up the cost of developments and power prices.[895]

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886 In this sense, "property" is a broad term that encompasses more than just tangible real property (land) and personal property, but also extends to contractual rights: Mutual Pools & Staff Pty Ltd v The Commonwealth (1994) 179 CLR 155 at 172.

887 Submissions to the consultation paper: ENA, p. 12; Ergon and Energex, p. 12; TasNetworks, p. 2.

888 Ergon and Energex, submission to the consultation paper, p. 12.

889 TasNetworks, submission to the consultation paper, pp. 22-23.

890 Submissions to the consultation paper: AGL p. 8; CEC p. 2; Terrain Solar, p. 2.

891 Submissions to the consultation paper: Terrain Solar, p. 2; CEC, p. 2.

892 CEC, submission to the consultation paper, p. 2.

893 Submissions to the consultation paper: Alinta Energy, p. 3; AGL, p. 8; EnergyAustralia, p. 3; ESCO Pacific, p. 4; First Solar, p. 1; Origin Energy, p. 3; RES Australia, p. 10; Terrain Solar, p. 2.

894 AGL, submission to the consultation paper, p. 8.

895 First Solar, submission to the consultation paper, p. 1.

Many stakeholders also noted that impacting existing investments by retroactively applying a new rule would affect the perception of risk in the sector, and therefore the ability to obtain finance for projects in the future.[896] The CEC noted that such changes undermine investor confidence and would therefore not further the NEO.[897] It noted that project finance is negotiated having regard to the specific yield expectations that are based on the design agreed to in the performance standards, and late or retroactive changes to these could undermine agreed finance terms.[898] Edify Energy also noted the proposed transitional arrangements would impact the 'bankability' of projects and future investment in the sector.[899]

Network businesses also appeared to agree there is a need to balance the potential risks to system security with the need to minimise impacts on existing investments to avoid undermining investor confidence.[900] ENA suggested that for this reason it would be reasonable that some transitional period is provided for that is fair, transparent and predictable.[901] Ergon and Energex considered the transitional arrangements should balance the need for swift implementation of the new standards against the potential impact on project proponents, who may be required to redesign equipment.[902]

Some stakeholders suggested arrangements for the transition and implementation of any new rules. ENA considered a clear milestone for commencement (such as agreed generator performance standards) would be crucial to any transitional arrangements, and that consideration should be given to the potential risks of even a fraction of existing connection enquiries being allowed to connect without being affected by any new rules.[903] Ergon and Energex also considered that if access standards have been agreed, it would be appropriate for the project to be allowed to connect without being affected by any new rules.[904]

Some stakeholders considered that projects in earlier stages in the connection process should be allowed to connect without being affected by any new rules. First Solar considered that any transitional arrangements should avoid impacting advanced stage projects to avoid negative impacts on projects and investment certainty.[905] It suggested that any new rules should not apply to any party that has submitted a complete application for connection.[906]

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896 Submissions to the consultation paper: Edify Energy, p. 2; CEC, p. 5; EnergyAustralia, p. 3; ESCO Pacific, p. 5; First Solar, p. 1; Origin Energy, p. 3; Terrain Solar, p. 2.

897 CEC, submission to the consultation paper, p. 5.

898 Ibid.

899 Edify Energy, submission to the consultation paper, p. 2.

900 Submissions to the consultation paper: ENA, p. 12; Ergon and Energex, p. 12; Powerlink, p. 3.

901 ENA, submission to the consultation paper, p. 12.

902 Ergon and Energex, submission to the consultation paper, p. 12.

903 ENA, submission to the consultation paper, p. 12.

904 Ergon and Energex, submission to the consultation paper, p. 13.

905 First Solar, submission to the consultation paper, p. 1.

906 Ibid.

13.4 AEMO's updated position

AEMO's submission to the consultation paper provided further information on the urgency underpinning the need for a rapid transition to new arrangements, as well as further views on the appropriate approach to transitional arrangements.[907]

The AEMC's consultation paper requested detailed information on the nature of the system security threat addressed by the transitional arrangements proposed in AEMO's rule change request.[908] In response, AEMO encouraged the AEMC to consider the 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 may arise from any single project being connected under the existing framework.[909]

AEMO provided some general views supporting the need for a rapid transition to any new arrangements. AEMO noted the need, through the introduction of appropriate technical standards, to quickly address the increasing uncertainty resulting from the rapid transformation of the energy market that is increasingly driven by intermittent energy supply.[910] AEMO also noted that to maintain power system security, it invokes constraint equations on the power system to ensure the system remains within its technical envelope. AEMO considered that the higher the performance standards of the generating fleet, the less likely it is that AEMO would need to constrain the operation of the power system in the future.[911] Lastly, AEMO argued that allowing a large number of existing connection applications to connect without being affected by any new rules may trigger further state specific arrangements to address these projects in the interim.[912]

AEMO's submission provided further views on the appropriate transitional arrangements for any new rules. It recommended a new rule be applied from the date of the final determination, with the new arrangements to apply to all negotiations of performance standards in clause 5.3.4A from this date.[913] AEMO considered that:[914]

- for any project where AEMO has advised (as required by the NER) the relevant network service provider on the appropriateness of a proposed negotiated access standard, and a negotiated access standard that is acceptable to AEMO and the network service provider has been provided to a connection applicant as part of an offer to connect, the new rule should not apply, and
- for any project where a negotiated access standard has not been accepted by AEMO and the network service provider, the new rule should apply.

907 AEMO, submission to the consultation paper, pp. 15-17.

908 AEMC, *Generator technical performance standards: consultation paper*, p 48.

909 AEMO, submission to the consultation paper, p. 15.

910 Ibid.

911 Ibid.

912 Ibid.

913 Ibid, p. 16.

914 Ibid.

13.5 Analysis and conclusions

Box 13.2 Draft rule

The Commission's draft rule includes transitional arrangements in Chapter 11 of the NER that:

- provide that the final rule would commence on the date that is 8 weeks after the date of the final determination,[915] and
- for negotiations that on the date of commencement have a full set of access standards agreed for a proposed connection, allows for the access standards for the project to be based on the rules that were in force immediately prior to the commencement date.[916]

The draft rule creates a framework for determining whether a full set of access standards was agreed for a proposed connection as at the date of commencement. The process would require that where, in the reasonable opinion of the network service provider and AEMO, all access standards relevant to a plant are agreed access standards as at the commencement date, then the network service provider must:

- within 10 business days from a request by the connection applicant, provide written confirmation to the connection applicant that all access standards relevant to the plant are agreed access standards as at the commencement date;[917] and
- otherwise, use its best endeavours to provide, within 10 business days from the commencement date, written confirmation to the relevant connection applicant that all access standards relevant to the plant are agreed access standards as at the commencement date.[918]

Where some of those access standards (that were agreed as at the commencement date) are subject to certain conditions being satisfied, the network service provider is required to identify those access standards that have conditions attached in its written confirmation to the connection applicant.[919] If any conditions are subsequently unable to be satisfied, then the full set of access standards will be taken to have not been agreed, and the new arrangements will then apply to the negotiation.[920]

The draft rule also addresses matters for connection applicants that do not have a full set of access standards agreed on the date the final rule commences. Under these arrangements, from the commencement date the network service provider

915 Clause 11.107.1 of the draft rule (definition of commencement date).

916 Clause 11.107.3(g) of the draft rule.

917 Clause 11.107.3(e)(1) of the draft rule.

918 Clause 11.107.3(e)(2) of the draft rule.

919 Clause 11.107.3(e)(1)(b) and 11.107.3(e)(2) of the draft rule.

920 Clause 11.107.3(f) of the draft rule.

must (in consultation with AEMO):

- where a connection applicant has made a connection enquiry but not yet made an application to connect, within 10 business days:[921]
  - use its reasonable endeavours to provide written notification to the connection applicant that the existing connection enquiry will be treated as a connection enquiry under the new arrangements, and
  - within a further 20 business days, in consultation with AEMO and where necessary, provide the connection applicant with any further information relevant to the proposed plant, and written notice of any further information to be provided by the connection applicant to the network service provider, to enable the connection applicant to submit an application to connect under the new arrangements, and
- where a connection applicant has made an application to connect but not yet received an offer to connect (and did not have a full set of access standards agreed with AEMO and the network service provider on the commencement date):[922]
  - within 10 business days, use its reasonable endeavours to provide written notification to the connection applicant that the existing application to connect will be treated as an application to connect under the new arrangements, and
  - within a further 20 business days, in consultation with AEMO and where necessary, provide the connection applicant with any further information relevant to the proposed plant (including details of the relevant access standards), and written notice of any further information to be provided by the connection applicant to the network service provider, to enable the network service provider to prepare an offer to connect under the new arrangements.

The draft rule does not allow the network service provider to charge any additional fees or charges relating to a connection enquiry or application to connect, however the network service provider may still recover reasonable costs of work done relating to the connection and to facilitate the implementation of the new arrangements.[923] The network service provider may also extend certain time periods to allow for additional time taken in excess of the period allowed in the preliminary program that is necessary to take account of the new arrangements.[924]

This section sets out the Commission's analysis and conclusions on the transitional arrangements for the draft rule.

921 Clause 11.107.2(b)(3) of the draft rule.

922 Clause 11.107.3(b)(3) of the draft rule.

923 Clauses 11.107.2(c) and 11.107.3(c) of the draft rule.

924 Clause 11.107.3(d) of the draft rule.

13.5.1 Commencement and application of a final rule

The power system is transforming. Recent experience of large numbers of connections of asynchronous generating systems, including significant numbers in some areas, has highlighted the need to update the generator access standards in the NER. The draft rule includes changes to the negotiating process and generator access standards in the NER so they are flexible and resilient to whichever technology mix eventuates. Some of the changes represent a significant departure from current arrangements; for example, new requirements to maintain continuous uninterrupted operation in the face of multiple low voltage disturbances.

Given that some of the changes are significant, and they are generally made to address identified threats to system security as the power system transforms, it is appropriate for any new arrangements to come into effect quickly. However, the Commission accepts stakeholder views that applying the new arrangements to some projects could impact financial commitments made based on performance standards that have already been agreed. The Commission notes that affecting such investments has the potential to undermine the confidence investors and financiers have in generation projects. This could in turn add to the perception of risk in such projects, increasing costs (which are ultimately borne by consumers).

It would not be appropriate to require all connection applicants, even where they have agreed all access standards for a connection, to renegotiate their performance under new arrangements. The likely system security benefit of doing so would be marginal, while the costs of renegotiating (including modelling and consultant costs) could be significant. Furthermore, some connection applicants may be very close to reaching agreement on all access standards for a connection. The costs of requiring these connection applicants (of which there is unlikely to be many) to renegotiate all of their access standards under a new rule would also be likely to outweigh the benefits. It is therefore appropriate to balance the system security need to transition in the new arrangements relatively quickly, with the need to maintain investment certainty and minimise costs for connecting parties.

To achieve this balance, the Commission considers it is important that the transitional arrangements commence as soon as possible, taking into account the impacts for connection applicants that are partway through the connection process. These matters are discussed separately below.

Commencement date

There is a risk that in the period of time between the Commission making this draft rule and the publication of a final determination, connection applicants may not be able to effectively assess the technical requirements their equipment will be likely to be required to meet under a final rule. This could affect their ability to plan the commercial arrangements for connection (such as the entry into contracts with equipment suppliers), as well as affecting the level of risk that financial stakeholders perceive to be present for their projects.

Although the Commission considers there are appropriate measures that connection applicants can take to manage these risks, they should also be mitigated to some extent through setting an appropriate commencement date for any final rule. Accordingly, the Commission considers that it is appropriate for the final rule to commence on a date shortly after the final rule determination is published. For connections where the parties are close to reaching agreement on all access standards for a connection, this short period of time will allow:

- the connection applicant, AEMO and the network service provider to assess the implications of the final rule, and
- if the connection applicant decides to pursue agreement on access standards under the current arrangements, the preparation, submission and consideration by the network service provider (and where relevant, AEMO) of any revised negotiated access standards.

The Commission considers the length of this period of time between publication of a final determination and commencement of a final rule should balance the benefits of reducing the risks faced by the limited number of parties that are close to reaching agreement on all access standards for a connection, and the impact of such connections on the efficient management of the power system in a secure state. The limited number of such connections is not likely to pose material risks to the efficient management of the power system or to system security, particularly given that under current arrangements AEMO and network service providers have an ability to reject a proposed negotiated access standard if in their view it would adversely affect power system security or the quality of supply to other network users.

The Commission therefore considers that an appropriate date for the commencement of a final rule is the date that is 8 weeks after the date of publication of the final rule determination. This should provide sufficient time for each party to consider the implications of the new arrangements, prepare and submit revised negotiated access standards, and time for AEMO and network service providers to consider and respond to any revised negotiated access standards.

Application to ongoing connection processes

There is no clearly defined milestone under the existing connections process in the NER that the Commission considers is appropriate to be used as the point beyond which current ongoing connection processes should proceed under the rules in force immediately prior to the commencement date. The rules-based milestones in the connection process are, in order, connection enquiry, connection application, offer to connect and signed connection agreement. Access standards are negotiated after the connection application, and must be agreed before an offer to connect is made. However, a lot of time can elapse between connection application and offer to connect. As a result, there are many projects for which a connection application has been lodged, but an offer to connect has not been made.[925]

925 The application to connect and offer to connect are defined stages in the connection process set out in rule 5.3 of the NER. However, there are many aspects to the connection process that sit outside of the process prescribed in the NER and for which there are no defined stages in the NER. The time period between application to connect and offer to connect can be lengthy and a number of different decisions can be made during this time.

The practical implication of the above is that, if all parties that have lodged a connection application (but do not yet have an offer to connect or signed connection agreement) are able to connect under the rules that were in force immediately prior to the commencement date, a significant number of generating systems may connect under those arrangements. This could adversely affect the efficient management of the security of the power system. Conversely, if it were required that a project must have an offer to connect or connection application to be able to proceed under the rules that were in force immediately prior to the commencement date, some projects that have already agreed or are close to agreement on all access standards would likely be adversely impacted. This could increase costs of these connections and potentially have a broader impact on investment certainty in the energy industry, with cost increases that are ultimately borne by consumers.

Given this, the Commission considers it is appropriate that the new arrangements under a final rule should apply to all ongoing connection processes where a full set of access standards has not yet been agreed.[926] It is appropriate to require *all* access standards to be agreed for a connection (not just some), because application of the existing rules to some agreed performance standards, and the new rules to the standards that are not yet agreed, would risk the creation of gaps in the performance standards for connecting equipment, or other unintended consequences.

The Commission considers this approach strikes the right balance between implementing the new arrangements quickly enough to address the risks to the efficient management of system security, and providing investment certainty.

Under the NER, a connection agreement and an offer to connect can only occur after agreement is reached on all access standards. The transitional arrangements in the draft rule therefore allow for all connections with an offer to connect or connection agreement to proceed with performance standards based on the rules that were in force immediately prior to the commencement date

Some connection applicants that have not yet received an offer to connect may still have agreed all access standards with the network service provider. For these connections, the transitional arrangements in the draft rule create a mechanism to confirm that the access standards are indeed agreed. Under the proposed mechanism, where a network service provider and AEMO reasonably consider all access standards relevant to a plant are agreed access standards as at the commencement date, the network service provider must use its reasonable endeavours to notify the connection applicant of this within 10 business days of the commencement date. The requirement is to use reasonable endeavours because contact information for connection applicants can change as personnel move on or as projects are sold to new owners. The transitional arrangements also require a network service provider to confirm to a connection application within 10 business days of a request whether or not the applicant had a full set of access standards agreed as at the commencement date.

The Commission is aware that where a full set of access standards is agreed for a connection, the validity of the agreement may be subject to the occurrence of some other

926 Note, the new rules would apply to any renegotiation of performance standards at a later date in clause 5.3.9.

matter, such as an offer to connect or connection application being finalised within a period of time or the provision of further information. In these circumstances, under the transitional arrangements in the draft rule the network service provider would be required to identify those access standards that have conditions attached in its written confirmation to the connection applicant. If any conditions are subsequently unable to be satisfied, then the full set of access standards would be taken to have not been agreed, and the new arrangements would then apply to the negotiations.

Where, before the commencement date, a generator is proposing to modify a generating system in clause 5.3.9 (and has advised AEMO in accordance with that provision), then the parties will be able to proceed under the current arrangements, unless otherwise agreed or where AEMO (in its reasonable opinion, in respect of one of its advisory matters) considers there to be an adverse impact on power system security.

13.5.2 Arrangements for connection processes that will be affected by a final rule

The Commission also considers it is appropriate to provide some guidance for ongoing connection processes that will be affected by a final rule. For example, some connection applicants will have submitted a connection enquiry and received a response from the network service provider setting out, among other things, the automatic and minimum access standards that are relevant to the connection and other guidance on the information needed to support a connection application. As a final rule would apply to these connection processes, it would be important for the response by the network service provider to be updated to avoid the risk of connection applications being prepared on the basis of potentially outdated information.

The circumstances will likely be even more complex for connection applicants that have submitted a connection application but not yet agreed a full set of access standards. In this case (in which a final rule would also apply) the connection application will likely have notified the network service provider that the connection will meet certain automatic access standards, and may have also proposed some negotiated access standards. The application will also have been supported by data, modelling and other information required under the NER.

To address each of these circumstances, the Commission considers an appropriate balance should be struck between the need to efficiently achieve and maintain system security, and the costs for connection applicants that are partway through the connection process. It is therefore appropriate that the transitional arrangements applying to connection processes where a full set of access standards are not agreed as at the commencement date minimise the work that must be redone by all parties to the connection process (particularly costly power system studies and modelling) and minimise the additional time taken to connect. Furthermore, the Commission considers that it would not be appropriate to set out highly prescriptive transitional arrangements for these ongoing connection processes, as doing so would increase the risk that the transitional arrangements are not appropriate for the many different circumstances (some of which cannot reasonably be anticipated by the Commission) that could apply for connections.

For this reason, the transitional arrangements in the Commission's draft rule include requirements for network service providers to consider circumstances of each ongoing connection process and communicate to the connection applicant the appropriate actions to take to address the application of any final rule. Under this process the network service provider must (in consultation with AEMO):

- notify the connection applicant that the new arrangements apply to their connection process
- provide the connection applicant with any further information relevant to the proposed plant (e.g. details of the relevant access standards), and
- provide written notice of any further information to be provided by the connection applicant to the network service provider so that the connection applicant can prepare an application to connect, or so that the network service provider can prepare an offer to connect, under the new arrangements.

The Commission considers it is appropriate for the network service provider to manage the process to transition to the new arrangements on a case by case basis, as they are the party that plays the central role (liaising with AEMO, the connection applicant and other affected network service providers) under the existing connections process. The Commission considers that under this process there should be limited risk that an ongoing connection process will be significantly affected by the transition to the new rules. For example, a connection that had proposed certain levels of performance under the arrangements in place before the final rule is made, may be required to update the wording of, or other information supporting, the proposed negotiated access standard, however in each case the level of performance required is the level that AEMO and the network service provider consider would not adversely affect power system security or the quality of supply.

The Commission considers these transitional arrangements should have, in most cases, a limited impact on levels of performance already agreed for certain technical requirements. Both before and after the commencement of any final rule, the level of performance that must be accepted by the network service provider is the level that would not adversely affect power system security or the quality of supply. In most cases this level of performance is unlikely to be affected by the commencement of a final rule.

The Commission also considers it is appropriate that network service providers are able to charge the reasonable costs of the additional work done to support the transition to the new arrangements, but that they are not able to recover any other fees related to a connection enquiry or application to connect. The network service provider may also extend certain time periods to allow for additional time taken in excess of the period allowed in the preliminary program that is necessary to take account of the new arrangements.

Abbreviations

AC	Alternating Current
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AGC	Automatic Generation Control
ARENA	Australian Renewable Energy Agency
ASMC	Australian Sugar Milling Council
CEC	Clean Energy Council
Commission	See AEMC
ENA	Energy Networks Australia
ESCOSA	Essential Services Commission of South Australia
FCAS	Frequency Control Ancillary Services
FFR	Fast Frequency Response
HVRT	High voltage ride-through
LVRT	Low voltage ride-through
MASS	Market Ancillary Services Specification
MCE	Ministerial Council on Energy
MVA	Megavolt-ampere
MVAR	Megavolt-ampere Reactive
MW	Megawatt
MWh	Megawatt Hour
NECA	National Energy Code Administration
NEL	National Electricity Law
NEM	National Electricity Market
NEMDE	National Electricity Market Dispatch Engine
NEO	National Electricity Objective
NER	National Electricity Rules
NSCAS	Network Support and Control Ancillary Services
PPC	Power Plant Control
PV	Photovoltaic

RIT-D	Regulatory Investment Test – Distribution
RIT-T	Regulatory Investment Test – Transmission
RoCoF	Rate of Change of Frequency
SCADA	Supervisory Control and Data Acquisition
SCR	Short Circuit Ratio
STATCOM	Static Synchronous Compensator
SVC	Static Var Compensator
VAR	Volt-ampere Reactive

A Summary of other issues raised in submissions

This appendix sets out the issues raised in the first round of consultation on this rule change request and the AEMC's response to each issue. If an issue raised in a submission has been discussed in the main body of this document, it has not been included in this table.

Stakeholders	Comment	AEMC Response
Negotiation process - Clause 5.3.4A		
SMA, pp. 2-3	The access standards need to use less ambiguous language than, for example, "practicable", "reasonable under the circumstances", "proportional", "sufficiently rapidly", "sufficient period", "measurable amounts" and "AEMO's reasonable opinion".	These phrases are still broadly appropriate within the context of the negotiation process. It is important that the access standards retain a degree of flexibility to negotiate an appropriate outcome given the circumstances of the connection, and are not applied in a manner that is too prescriptive.
ESCO Pacific, p. 7; Ergon and Energex, p. 10; Clean Energy Council, p. 27	An updated guide to how performance standards should be assessed and tested would be valuable to the industry and would provide a starting point for performance standard assessment.	The draft rule includes more guidance to parties in the negotiation process. Furthermore, the Commission will request the Reliability Panel to review the template for generator compliance programs for consistency with the access standards in the draft rule.
Tilt Renewables, p. 2	AEMO’s proposed clause 5.3.4A(c1) should be changed to require, when seeking a negotiated access standard, the connection applicant to “…provide with that proposal, evidence (to AEMO’s and the Network Service Provider’s reasonable satisfaction) that there is no system security and no power quality degradation associated with not meeting the automatic access standard”, avoiding the “as close as practicable” wording, yet ensuring a level of engineering assessment is performed.	Clause S5.3.4A of the draft rule specifies the various requirements of connecting generators in providing evidence to AEMO and the network service provider to support a proposed negotiated access standard.
Active power control – Clause S5.2.5.11		

Stakeholders	Comment	AEMC Response
Hydro Tasmania, p. 13	There is a need to provide clarity around the potential conflicts between clause S5.2.5.14 and clause S5.2.5.11, particularly as this relates to the interaction between governor response and AGC response. The active power control access standards should have a clause that excludes meeting that standard if it conflicts with the frequency control response.	The Commission understands that there may be a relationship between these two differently mediated forms of frequency control. This issue is out of the scope of this rule change. Broader questions of frequency control are being considered in the AEMC's *Frequency control frameworks review*.
Clean Energy Council, p. 31	Commercial drivers for plant design require clarity on the operational limitations of the plant. The NER therefore needs to clearly set out how ramp rate limitations may be applied.	The Commission notes stakeholder concerns as to how ramp rate capabilities may be applied in practice. However, as noted by AEMO in its rule change request, these operational considerations are addressed through the power system and market operations processes set out in Chapters 3 and 4 of the NER. As the focus of this rule change is on capabilities, rather than operational processes, these issues are out of scope.
Pacific Hydro, p. xix	The phrase "relatively stable" is present in the minimum access standard, whereas it is absent from the automatic access standard. Some wording should be added to include the intent of "relatively stable" in both sections to avoid generators being non-compliant during power swing conditions. A clear definition of what "relatively stable" means should be provided… if generating systems (wind farms or solar farms) are obligated to meet the automatic access standard it would be unreasonable to expect frequency control without "relatively stable input energy".	The Commission considers that this term does not require clarification on the basis that as it is used in the minimum access standard, and therefore forms a reasonable lower boundary to inform negotiation of access standards. In proposing negotiated access standards, a connection applicant is able to account for commercial and technical feasibility in complying with the automatic access standard. This may include the extent to which frequency control can be provided by a generator with a variable energy source.
	Remote monitoring and control – Clause S5.2.6.1	
Hydro Tasmania, p. 15	Does the proposed requirement to report megawatt hour (MWh) of energy storage apply to hydro	The Commission has not included AEMO's proposal for information on energy available in energy storage devices in the draft rule.

Stakeholders	Comment	AEMC Response
	generators, noting that there are various other reporting mechanisms for energy availability? With the complexity of an interconnected hydro scheme, how would this even be defined? Hydro Tasmania is a participant in a number of special protection schemes whereby generation can be reduced in certain conditions. Are such schemes considered runback schemes? If so, would it be the network service provider who should supply data to AEMO given that they run the schemes?	Questions related to whether a specific scheme can be classified as a run back scheme can be determined with AEMO as part of the process of negotiating performance standards.
GE Australia, p. 5	What due diligence is required from the generator to accept the set point request and pass through to the controller?	Requirements of scheduled generators and semi-scheduled generators in receiving instructions from AEMO are outlined in clause 4.9.4 of the NER. Generators are expected to act in accordance with dispatch instructions, including those for voltage control system setpoint, unless in the generator's reasonable opinion, public safety would otherwise be threatened or there would be a material risk of damaging equipment or the environment. Clause 4.11 of the NER then sets out obligations as they relate to remote control and monitoring devices installed in accordance with Schedule 5.2 to the NER.
Transgrid, p. 6	Network service providers should also have remote control and monitoring requirements.	The remote control and monitoring requirements specified in clause S5.2.6.1 of the NER are currently designed to support AEMO in its market and power system security functions. The Commission considers that expansion of the application of this clause would fall outside of the scope of this rule change request.
Reactive power capability – Clause S5.2.5.1		
Hydro Tasmania, p. 10	Flexibility should remain in the rules that allows active power to be reduced should reactive power be required. Consideration should be given to the option of operating units at unity power factor in the event of high water storage and inflow conditions. MVA rating limits mean that energy would need to be	The draft rule retains the level of performance required under the current minimum access standard, retaining the flexibility to reduce active power to achieve a level of reactive power where required.

Stakeholders	Comment	AEMC Response
	spilt and would not be available to the market should the existing requirement to provide reactive power capability be on a continuous basis.	
RES Australia, p. 6	The minimum access standard should be modified to require an amount of reactive power capability that can be provided for a small marginal cost. A body of work should be undertaken to quantify this amount for a broad range of technologies.	The draft rule does not include a requirement for reactive power capability above 0% of rated active power under the minimum access standard in clause S5.2.5.1. Under the negotiated access standard in clause S5.2.5.1, an amount of reactive power absorption and supply capability must be negotiated sufficient to ensure that all relevant system standards are met before and after credible contingency events under normal and planned outage operating conditions of the power system, taking into account at least existing projects and considered projects.
Voltage and reactive power control – Clause S5.2.5.13		
Hydro Tasmania, p. 14	The minimum access standard in clause S5.2.5.13 makes no reference to the frequency and limiters on voltage regulation which would be active to ensure that the flux (V/Hz) limits of the plant are not exceeded. This function should be recognised in the minimum access standard.	The minimum access standard in clause S5.2.5.13 includes a requirement for limiting devices to ensure that a voltage disturbance does not cause the generating unit to disconnect at the limits of its operating capability. This applies to both synchronous and asynchronous generating units.
Powerlink, p. 8	There should be more specific detail regarding what represents a critical mode in respect of the automatic access standard in clause S5.2.5.13.	The automatic access standard in clause S5.2.5.13 requires that the operation of a generating system does not degrade the damping of any critical mode of oscillation of the power system. Power system modes of oscillation relate to small signal stability and depend on power system characteristics that can be expected to change over time. An automatic access standard that is not specific to the modes considered provides flexibility for those modes to be assessed on an ongoing basis.
TasNetworks, p. 16	A new term “target voltage” should be defined to address circumstances where network service providers operate busses at voltages elevated relative to their nominal voltages. It would be	Network service providers are able to define voltages different to nominal voltages in parts of their network. This flexibility is provided through the ability to set 'normal' voltages and is embedded in existing access standard arrangements which reference voltages relative to normal, rather than

Stakeholders	Comment	AEMC Response
	preferable to nominate an agreed voltage control range in terms of a 'delta' around an agreed target voltage. A definition for target voltage could be the average (50th percentile) operating voltage for a nominated location within the power system.	nominal, voltage levels.
Reactive current response during faults – Clause S5.2.5.5		
Clean Energy Council, p. 15	Only one slope setting should be required for both capacity and inductive modes of operation.	AEMO considered it important to have a more aggressive response for reactive current absorption because over-voltage requirements for continuous uninterrupted operation only go to 130% of normal voltage. This is less than the scope for under-voltages which can decline to zero at the connection point. AEMO also expressed specific concerns about over-voltage management in certain parts of the NEM, such as in South Australia and Queensland, which they considered justify an aggressive level of reactive current absorption during disturbances. In the Commission's draft rule, the minimum access standard is expressed as a single slope setting for both reactive injective and inductive modes of operation. In addition, a negotiated access standard may have a single slope setting for both reactive current injection and absorption.
Continuous uninterrupted operation: Voltage disturbance – Clause S5.2.5.5		
TasNetworks, p. 5	The proposed changes to the over-voltage withstand capability curve be implemented as a generator connection requirement rather than as changes to the system standards. Although modifications should be made to the figure in the future, the proposed changes could not be applied as operational limits without a detailed audit of existing network and generator protection settings as well as a review of existing plant capabilities.	The Commission's draft rule does not change the system standard for over-voltages in S5.1a.4 of the NER, but instead changes the requirements under the automatic and minimum access standards in clause S5.2.5.4. This mean that the new requirements in S5.2.5.4 will not affect existing network equipment and generating systems, unless a re-negotiation of generator performance standards occurs in clause S5.3.9 of the NER.
Continuous uninterrupted operation: Multiple voltage disturbances – Clause S5.2.5.5		

Stakeholders	Comment	AEMC Response
Nordex, p. 5	An alternative option would be that a generating system and each of its generating units must remain in continuous uninterrupted operation for up to fifteen disturbances within any five minute period, but limited to: - 2 faults within 15 s in case of symmetrical faults - 3 faults within 15 s in case of a two-Phase fault - 4 faults within 15 s in case of a one-Phase fault.	Clause S5.2.5.5 of the Commission's draft rule specifies a number of different requirements to maintain continuous uninterrupted operation in response to voltage disturbances, including multiple disturbances, caused by different fault types.
System strength - S5.2.5.15		
Clean Energy Council, p. 27	The NER should align with the revised ESCOSA licence conditions, including the inclusion of the reactance-to-resistance (X/R) ratio, as this would make the NER requirements more meaningful and easier to assess.	The Commission has decided not to make AEMO's proposed system strength access standard, on the basis that, given the *Managing power system fault levels rule*, there is likely no additional system security issue that requires the establishment of a system strength access standard. The proposed system strength access standard would also be contrary to the open access regime for generator connection.
EnergyAustralia, p. 2	System strength could be procured through a market mechanism.	Other sources of system strength services will be made available through the *Managing power system fault levels rule*, which commences in full on 1 July, 2018.
Transitional arrangements		
First Solar, p. 2	The current proposed transitional arrangements are ambiguous around the definition of "finalised" and it is not clear whether this means when registered with AEMO (upon commissioning), or agreed to by AEMO in the form of a clause 5.2.4A letter, which is needed to start construction.	The process to determine whether a full set of generator performance standards has been agreed is set out in the draft transitional rule and includes a requirement for network service providers to provide confirmation to those parties with agreed performance standards.
Other issues		

Stakeholders	Comment	AEMC Response
Australian Energy Regulator, p. 1	International standards may provide useful guidance in conjunction with state based technical and regulatory requirements and instruments that are relevant to this rule change request.	The Commission considered equivalent access standards in other jurisdictions as part of this rule change request. These are discussed in a number of Chapters of this draft determination.
Australian Energy Regulator, p. 2	A new disclosure obligation should be introduced in the NER requiring generators to provide AEMO with all relevant information about their generating systems' capabilities and settings, for the purposes of generator connection and registration of performance standards.	Existing arrangements require connecting generators to provide sufficient information to AEMO on the performance of their equipment, including under clauses S5.2.5.8 and S5.2.4 of the NER. Recent changes under the *Generating system model guidelines rule* also allows AEMO to obtain the information it considers appropriate on commissioning and registration of a generating system.
Australian Energy Regulator, p. 2	Guidelines should be published on the non-compliance framework for generator performance standards, and that the ability to resolve non-compliance by reducing the level of performance in a generator performance standard should be removed.	The non-compliance framework is complex and deals with a wide variety of non-compliance matters that arise and proceed in a variety of ways, depending on the individual circumstances of the case. These varied circumstances of non-compliance do not lend themselves to resolution through a prescribed process under guidelines. It is also appropriate to retain the ability to, as a last resort, lower a generator's performance standards due to a non-compliance to allow for more efficient negotiations to set levels of performance, and to allow an efficient outcome where a generator continuing to operate following a non-compliance does not affect power system security or the quality of power supply.
Transgrid, p. 6	Clause S5.2.5.2 (Quality of electricity generated) and clause S5.2.5.6 (Quality of electricity generated and continuous uninterrupted operation): The NER refers to older versions of Australian/IEC standards, which now have updated versions. TransGrid proposes that clause S5.2.5.2 should be amended to reflect the latest version of the Australian/IEC standards.	AEMO did not raise issues in its rule change request related to S5.2.5.2 or S5.2.5.6 of the NER. The Commission will consult further on whether these changes are appropriate and will also further consider whether these matters are outside of the scope of this rule change request.
Transgrid, pp. 6-7	Clause S5.2.5.8 of the NER (Protection of	AEMO did not raise issues in its rule change request related to S5.2.5.8 of the

Stakeholders	Comment	AEMC Response
	generating systems from power system disturbances) should be considered as part of the rule change request.	NER. The Commission considers changes to these clauses to be outside of the scope of this rule change request.
Australian Sugar Milling Council, pp. 3,9; Edify Energy, p. 3; EnergyAustralia, p. 2; Energy Networks Australia, p. 8; ENGIE, p. 1; First Solar, pp. 2-4; Hydro Tasmania, p. 5; Meridian Energy, p. 2; Terrain Solar, p. 6	System security services and capabilities should also be sourced through other voluntary market mechanisms, such as ancillary services markets. Doing so may, in some circumstances, be more efficient than imposing requirements on connecting generators through the access standards in Schedule 5.2 to the NER.	The Commission considers that system security can be maintained through a combination of mechanisms, including market mechanisms and requirements in the NER, such as generator access standards. Some system security capabilities are required from most or all connecting generators, such as capabilities to maintain continuous uninterrupted operation for disturbances, whilst others relate to 'pooled' resources that can be sourced efficiently from a selection of generating systems through a market mechanism, such as frequency control through the Frequency Control Ancillary Services markets. Services can, in some situations, be provided most efficiently by network service providers. Broader questions regarding changes to or the introduction of ways to procure system security services are outside of the scope of this rule change request.
Tesla Motors Australia, p. 2	Precinct scale energy hubs with the appropriate technical capabilities could address some of the network concerns that AEMO has flagged.	This issue is beyond scope of the rule change request, but is being considered as part of the AEMC's *Review of coordination of generation and transmission investment*. This review is considering options for clustering new generators in zones to reduce the costs of new transmission infrastructure needed to connect these generators to the grid.

B Legal requirements under the NEL

This appendix sets out the relevant legal requirements under the NEL for the AEMC to make this draft rule determination.

B.1 Draft rule determination

In accordance with section 99 of the NEL the Commission has made this draft rule determination in relation to the rule proposed by AEMO.

The Commission's reasons for making this draft rule determination are set out in section 2.4.

A copy of the more preferable draft rule is attached to and published with this draft rule determination. Its key features are also described in section 2.4.

B.2 Power to make the rule

The Commission is satisfied that the more preferable draft rule falls within the subject matter about which the Commission may make rules. The more preferable draft rule falls within section 34 of the NEL as it relates to the operation of the national electricity system for the purposes of the safety, security and reliability of that system and also relates to the activities of persons (including Registered participants) participating in the national electricity market or involved in the operation of the national electricity system. Further, the more preferable draft rule falls within the matters set out in Schedule 1 to the NEL as it relates to the operation of generation, transmission and distribution systems (items 10 to 12), reviews conducted by or on behalf of, among others, AEMO (item 33) and reporting or disclosing information to the AER (item 34B).

B.3 Commission's considerations

In assessing the rule change request the Commission considered:

- it's powers under the NEL to make the rule
- the rule change request
- submissions received during first round consultation, and
- the Commission's analysis as to the ways in which the proposed rule will or is likely to, contribute to the NEO.

There is no relevant Ministerial Council on Energy (MCE) statement of policy principles for this rule change request.[927]

The Commission may only make a rule that has effect with respect to an adoptive jurisdiction if satisfied that the proposed rule is compatible with the proper performance of Australian Energy Market Operator (AEMO)'s declared network

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927 Under section 33 of the NEL the AEMC must have regard to any relevant MCE statement of policy principles in making a rule. The MCE is referenced in the AEMC's governing legislation and is a legally enduring body comprising the Federal, State and Territory Ministers responsible for Energy. On 1 July 2011 the MCE was amalgamated with the Ministerial Council on Mineral and Petroleum Resources. The amalgamated council is now called the COAG Energy Council.

functions.[928] The more preferable draft rule is compatible with AEMO's declared network functions because it is unrelated to them and therefore it does not affect the performance of these functions.

B.4 Civil penalties

The Commission's draft rule amends the following rules of the NER that are currently classified as civil penalty provisions under the NER Schedule 1 of the National Electricity (South Australia) Regulations:

- clause 5.3.4A(c)
- clause 5.3.4A(e)
- clause 5.3.4A(f)
- clause 5.3.4A(g), and
- clause 5.3.9(h).

The Commission considers that clauses 5.3.4A(c), (e), (f) and 5.3.9(h) should continue to be classified as civil penalty provisions and therefore does not propose to recommend any change to their classification to the COAG Energy Council. With respect to clause 5.3.4A(g), the Commission is still considering whether this provision should continue to be classified as a civil penalty provision and will seek stakeholder feedback on this.

The Commission does not consider any other provisions of the draft rule should be classified as civil penalty provisions.

B.5 Application in the Northern Territory

From 1 July 2016, the National Electricity Rules (NER), as amended from time to time, apply in the Northern Territory, subject to derogations set out in Regulations made under the NT legislation adopting the NEL.[929] Under those Regulations, only certain parts of the NER have been adopted in the NT.[930] As the proposed rule relates to parts of the NER that currently do not apply in the Northern Territory, the Commission has not assessed the proposed rule against additional elements required by Northern Territory legislation.[931] However, the proposed rule relates to parts of the NER that will apply in the Northern Territory from 1 July 2019.

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928 Section 91(8) of the NEL.

929 National Electricity (Northern Territory) (National Uniform Legislation) (Modifications) Regulations.

930 For the version of the NER that applies in the Northern Territory, refer to: http://www.aemc.gov.au/Energy-Rules/National-electricity-rules/National-Electricity-Rules-(Northern-Territory).

931 National Electricity (Northern Territory) (National Uniform Legislation) Act 2015.