RULE

Australian Energy Market Commission

RULE DETERMINATION

NATIONAL ELECTRICITY AMENDMENT (GENERATOR TECHNICAL PERFORMANCE STANDARDS) RULE 2018

PROPONENT

Australian Energy Market Operator

27 SEPTEMBER 2018

INQUIRIES

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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

1 The Commission has made a final rule changing the way that levels of performance are negotiated for equipment connecting to the power system, and improving the technical requirements for 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. The changes commence on 5 October 2018, with transitional arrangements for some connections.

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

Context

3 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.

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

5 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. We have 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.

6 The technical requirements currently set out in the generator access standards in the NER require updating to better address the needs of the power system as it transitions. In some cases, they need to be updated 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 need to be updated 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 final rule

7 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.

8 The NER currently allow 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, the connecting equipment would adversely affect system security or the quality of power supply to other network users. Other mechanisms and 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.

9 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.

10 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 many aspects of the generator access standards in the NER require updating to better address these issues as the power system transitions.

11 In response to these issues, the final 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.

12 A significant number of connection applications are currently before network service providers and AEMO. The final 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. The rule will therefore commence on 5 October 2018, with transitional arrangements ending on 1 February 2019 for projects that had a connection application submitted on the commencement date.

13 A summary of the changes proposed in the draft determination, and the further changes made in the final determination, is provided in Table 1.

Background to the connection process and technical requirements

14 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.

15 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.

16 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.

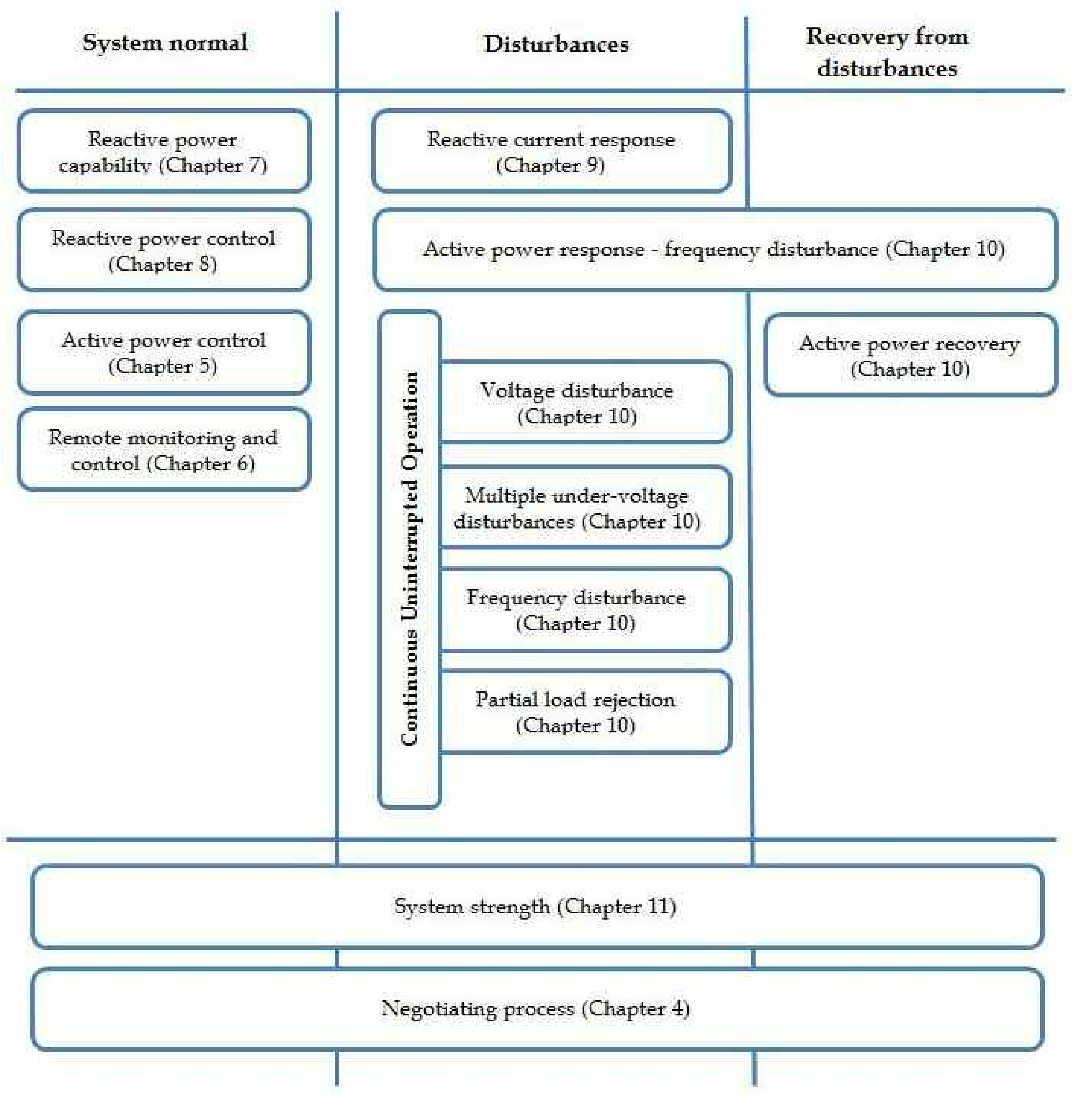
17 Where a negotiated access standard is proposed, the applicant and network service provider negotiate a level of performance for that technical requirement. AEMO advises the network service provider on the negotiation of some access standards, called AEMO advisory matters. The network service provider 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.

18 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.

19 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.

20 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 1.1 below shows the range of technical requirements discussed in this final determination that relate to these power system needs and the Chapter in this final determination that discusses the technical requirement.

Figure 1.1: Technical requirements addressed in this rule change



Assessment of this rule change

21 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.

22 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.

23 The Commission has 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. However, in some specific 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.

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

- submissions from equipment manufacturers, generators and 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.

25 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.

26 On 31 May 2018 the Commission published a draft determination, including a draft rule. The Commission briefed members of its technical working group and industry associations on the contents of the draft rule. The Commission also held a formal stakeholder workshop on the draft rule on 26 June 2018. The Commission received 33 submissions to the draft determination.

27 Throughout the process the Commission has appreciated ongoing support and assistance from AEMO and the technical working group convened to support this rule change. The Commission, AEMO and the technical working group assessed issues and proposed appropriate changes to the technical requirements. AEMO provided updated views on its proposed changes several times during the rule change process, which are published on the AEMC website.

Negotiating process for connections

28 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.

29 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.

30 To address these issues, the final 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.

31 The final 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.

32 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 control

33 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. This can cause 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.

34 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.

35 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.

36 The Commission considers it would not be efficient to require all generating systems to have the capability to provide at least 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.

37 The Commission's final rule however 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 likely to support system security.

38 The Commission agrees with AEMO 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.

39 The final 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 final rule allows for non-scheduled generators to negotiate to a lower level of active power control capability.

40 The Commission agrees with AEMO that power system security and more efficient operation of the power system will be supported where all semi-scheduled and scheduled generating systems have automatic generation control capability. The final rule therefore requires all scheduled and semi-scheduled generating systems to have automatic generation control

capability.

41 The final rule also includes a number of further changes to improve clarity and better reflect what the Commission understands to be actual operational practice.

Remote monitoring and control

42 Remote monitoring capability refers to the real time provision of data to AEMO's control centre related to the status of the generating system or 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.

43 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.

44 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 stakeholders noted that these requirements could impose unnecessary additional costs in certain circumstances. Accordingly, the final 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.

45 The final 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

46 Reactive power capability, and its effective control, is necessary to support the control of 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.

47 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.

48 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 may 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.

49 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. This is because, while network service providers consider the impact on their ability to meet the system standards, AEMO has a separate role through its advisory function to explicitly consider whether a proposed negotiated access standard would adversely affect power system security.

50 The Commission also considers that the current guidance in the access standard for reactive power capability on what circumstances should be taken into account when negotiating is unclear and may result in inefficient outcomes in some cases.

51 To address these issues, the Commission's final rule:

- specifies the access standard for reactive power capability as an AEMO advisory matter, and
- changes the guidance on negotiated access standards to:
  - include reference to the need for the level of reactive power capability to be sufficient to support the security of the power system, and
  - clarify the circumstances that may be taken into account by the parties when negotiating.

Reactive power control

52 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.

53 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 current arrangements need to be changed to better address these challenges for the future, and would also benefit from being simplified and made consistent with the way other access standards are specified.

54 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 final rule:

- changes the requirements for specifying the mode of reactive power control so that:
  - the automatic access standard is the ability to operate in all modes, and switch between them (in accordance with a procedure agreed with AEMO and the network service provider), noting that comissioning and testing of control modes will only occur for those control modes required by AEMO and the network service provider on connection, or at a later time on request, 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.

55 The final 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.

56 The final rule also adjusts the step test stability requirements applying to generating systems operating in the different reactive power control modes to:

- align allowable setting requirements under the minimum access standard for synchronous and asynchronous generating systems operating in voltage control mode, and

- implement a setpoint step response test for evaluating compliance with settling time requirements by generators operating in power factor and reactive power modes.

Reactive current response during disturbances

57 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.

58 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.

59 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.

60 The final 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, largely derived from the arrangements proposed by AEMO, however also providing more flexibility to account for different power system conditions and equipment limitations.

61 The final 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

62 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.

63 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.

64 To address these issues, AEMO proposed changes to the access standards related to requirements of generating systems to maintain continuous uninterrupted operation within defined parameters in response to particular disturbances. This includes access standards related to frequency disturbances, over-voltage and under-voltage disturbances, multiple voltage disturbances (including faults and credible contingencies), 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.

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

- amending the definition of continuous uninterrupted operation to provide greater clarity
- strengthening existing requirements for generating systems to maintain continuous uninterrupted operation for particular voltage and frequency disturbances, especially in light of the changing generation mix
- introducing new requirements for generating systems to maintain continuous uninterrupted operation for certain multiple low voltage disturbances (including guidance in the final determination as to how connecting generators can demonstrate compliance), and
- extending existing requirements to maintain continuous uninterrupted operation for particular partial load rejection events to asynchronous generating systems.

System strength

66 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 as well as 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 have more online synchronous generating systems (because they typically provide more current during faults compared to asynchronous generating systems).

67 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.

68 In its rule change request, AEMO noted that the *Managing power system fault levels rule* 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 further capability from a connecting 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.

69 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.

70 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.

71 The Commission also considers that imposing potential costs or regulatory requirements on a connecting generator in order to help facilitate future connections is contrary to the principles behind the transmission framework in operation in the NEM. 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, to the extent 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.

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

73 Nonetheless, the Commission has made changes to the NER so that connecting generators will be required to register the lowest short circuit ratio at the connection point for which the generating system, including its control systems:

- will be commissioned to maintain stable operation, and
- has the design capability to maintain stable operation.

74 This is designed to assist AEMO, network service providers and connection applicants in developing potentially least cost system strength remediation schemes (required under the *Managing power system fault levels rule*) that may involve the retuning of existing generating systems to operate at lower short circuit ratios.

Consequential changes

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

76 To address these issues the final 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 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 (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.

77 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

78 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 AEMO submitted 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.

79 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 costs and benefits of doing so, and the limitations on the AEMC's rule making powers.

80 The Commission's final rule commences on 5 October 2018. For connection applicants that have submitted a connection enquiry by that date, but not yet submitted a connection application, 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 under the new arrangements.

81 The Commission's final rule also includes a transitional period for connection processes that had a connection application submitted on the date of commencement of the rule.

82 With respect to the transitional period, parties that on 1 February 2019 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 access standards contained in Chapter 5 of the rules in effect immediately before the commencement of the final rule.

83 The Commission's final rule also addresses matters for ongoing connection processes (those that had submitted a connection application by the commencement date) where a full set of access standards is not agreed by 1 February 2019. 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 network service provider can prepare an offer to connect under the new arrangements.

84 The final 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: **Table 1: Comparison of current arrangements, changes under the draft rule and changes under the final rule**

CURRENT ARRANGEMENTS	DRAFT RULE	FINAL RULE
Negotiating process 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.	The draft rule required 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 required 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 •	No substantive changes were made between the draft and final rules. Some minor changes were made to clarify the arrangements for AEMO and network service providers to provide detailed reasons (including that such reasons must be in writing), given the requirement for network service providers to provide detailed reasons to the connection applicant (including any reasons given by AEMO) is a civil penalty provision.

CURRENT ARRANGEMENTS	DRAFT RULE	FINAL RULE
	• 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. 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.	The draft rule: • required all generating systems to have the capability to operate in frequency response mode (subject to energy source availability) • amended 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 • introduced a definition of droop response and makes various clarifying amendments to the automatic access standard • required all semi-scheduled generating systems to have the capability to control active power output to a ramp limit • required all non-scheduled generating systems to have active power control capability, and • required all scheduled and semi-scheduled generating systems to have the capability to receive and respond to AGC signals.	No substantive changes were made between the draft and final rules, except for the following: • allowing for a droop setting outside of the range of 2%-10%, where agreed with the network service provider and AEMO, and • clarifying that the market ancillary service recorded in the performance standards applies for generating systems that connect at the automatic access standard, or under a negotiated access standard where that standard offers measurable amounts of market ancillary services.
Remote monitoring and control	The draft rule amended:	No changes were made between the draft and

CURRENT ARRANGEMENTS	DRAFT RULE	FINAL RULE
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.	• 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.	final rules.
Reactive power capability 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.	The draft rule retained a minimum access standard that did not require reactive power capability, but revised the wording in the minimum access standard to be more consistent with the automatic access standard. The draft rule included a provision specifying the access standard as an AEMO advisory matter. Consistent with this change, the draft rule also provided guidance that the level of reactive power capability should be sufficient to support the security of the power system.	The final rule maintained the position in the draft rule that the minimum access standard does not require reactive power capability, but changed the way the access standard is expressed back to the wording in the existing arrangements. The final rule maintained the provision specifying the access standard as an AEMO advisory matter and including guidance that the level of reactive power capability should be sufficient to support the security of the power system. The final rule also included clearer guidance on what matters may be taken into account when setting the level of reactive power capability in

<table>
<tr><th>CURRENT ARRANGEMENTS</th><th>DRAFT RULE</th><th>FINAL RULE</th></tr>
<tr><td></td><td></td><td>a negotiated access standard.</td></tr>
<tr><td>Reactive power control

The 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 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 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 time for asynchronous generators than are allowed for synchronous generators.</td><td>The draft rule included:
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:
included 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 voltage control using a voltage droop characteristic)</td><td>The final rule is largely consistent with the draft rule, except for the following substantive changes:
including new guidance so it is clear that commissioning and testing of control modes will only occur for those control modes required by AEMO and the network service provider on connection, or at a later time when required
changing the way the performance and accuracy requirements for generating systems operating in reactive power or power factor control modes are specified, and
centering the voltage control setpoint range on a 'target voltage', rather than normal voltage.</td></tr>
</table>

CURRENT ARRANGEMENTS	DRAFT RULE	FINAL RULE
	• included new performance requirements for generating systems operating in reactive power or power factor control modes, and • aligned 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.	The draft rule largely retained existing arrangements for synchronous generating systems, while clarifying the total required response capability for these generators. The draft rule largely incorporated the changes proposed by AEMO specifying the characteristics of reactive current response during disturbances for asynchronous generating systems, including in relation 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 •	The final rule is largely consistent with the draft rule, except for the following substantive changes: • expressing all obligations in the final rule as applying at the generating system level (not the generating unit level) and as applying with reference to changes in connection point voltages (rather than generating unit terminal voltages), while allowing the reactive current contribution and voltage deviation to be measured at other agreed locations • generating systems are required to commence reactive current response within defined voltage ranges, with flexibility provided to shift these ranges where agreed with AEMO and the network service provider

CURRENT ARRANGEMENTS	DRAFT RULE	FINAL RULE
	• ancillary requirements relating to flexibility in the point and method of measurement. The draft rule included additional flexibility in a range of response characteristics to account for equipment limits and power system conditions at the connection point. The draft rule also included a general requirement for the maximum continuous current of the generating system to be available at all times.	• including an exception to the requirement to provide a capacitive reactive current response at certain voltages where the system is not connected through a grid-interfacing transformer • including in the automatic access standard (and removing from the general requirements) a requirement to make the maximum continuous current of a generating system available at all times (for voltages beyond certain thresholds), and taking into account other technical limits for this requirement, and • removing a requirement in the draft rule that limited the consumption of active and reactive current consumption on occurrence of a fault.
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 continuous uninterrupted operation for a range of disturbances, including voltage and frequency disturbances.	The draft rule included changes (that partly reflected AEMO's proposed changes) to better reflect changing power system conditions. This included: • amending the definition of continuous uninterrupted operation to provide greater clarity to network users •	The final rule is largely consistent with the draft rule, except for the following substantive changes: • including a new condition in the minimum access standard to maintain continuous uninterrupted operation for multiple low voltage disturbances, that no more than 3 of the disturbances can occur within 30

CURRENT ARRANGEMENTS	DRAFT RULE	FINAL RULE
	• 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.	seconds, and • removing some ambiguity in the interaction between continuous uninterrupted operation and a generating system's protection systems.
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 commenced in full on 1 July 2018.	The draft rule did not contain a system strength access standard.	The final rule also does not contain a system strength access standard. However, the final rule includes a new requirement for connecting generators to register the lowest short circuit ratio at the connection point for which the generating system, including its control systems: • will be commissioned to maintain stable operation, and • has the design capability to maintain stable operation.
Consequential changes N/A	The draft rule included a number of additional changes that are consequential to making the	No substantive changes were made between the draft and final rules.

CURRENT ARRANGEMENTS	DRAFT RULE	FINAL RULE
	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	The draft rule proposed applying 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, the draft rule allowed for the access standards for the project to be based on the rules that were in force immediately prior to the commencement date. The draft rule also included provisions noting 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	The final rule is largely consistent with the draft rule, except for the following substantive changes: • the final rule will commence on 5 October 2018 • the inclusion of a transitional date of 1 February 2019 for connections that had submitted a connection application by 5 October 2018.

CURRENT ARRANGEMENTS	DRAFT RULE	FINAL RULE
	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 final 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 consequential changes and transitional arrangements in the final rule (Chapters 12 and 13).

To avoid repetition, this final determination focuses mainly on submissions to the draft determination and any changes made in response to those submissions. While summaries of submissions to the consultation paper and the Commission's analysis in the draft determination are provided, readers should refer to the draft determination for more detailed explanations of the reasons underpinning the draft rule, and consequently also much of the final rule.[1]

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 set in accordance with the framework set out in Chapter 5 of the NER.[2] These levels of performance 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.[3] 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:

1 AEMC, *Generator technical performance standards: draft determination*, 31 May 2018, available at www.aemc.gov.au.

2 In particular, see clause S5.2.5 of the NER.

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

- meet the automatic access standard, in which case the equipment will not be denied access because of that technical requirement,[4] or
- propose a negotiated access standard that is at or above the minimum access standard (also, by implication, below the automatic access standard)[5]

- 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.[6] 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,[7] and
- equipment that does not at least meet the minimum access standard will be denied access because of that technical requirement.[8]

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 final determination that relate to these power system needs.

4 "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"

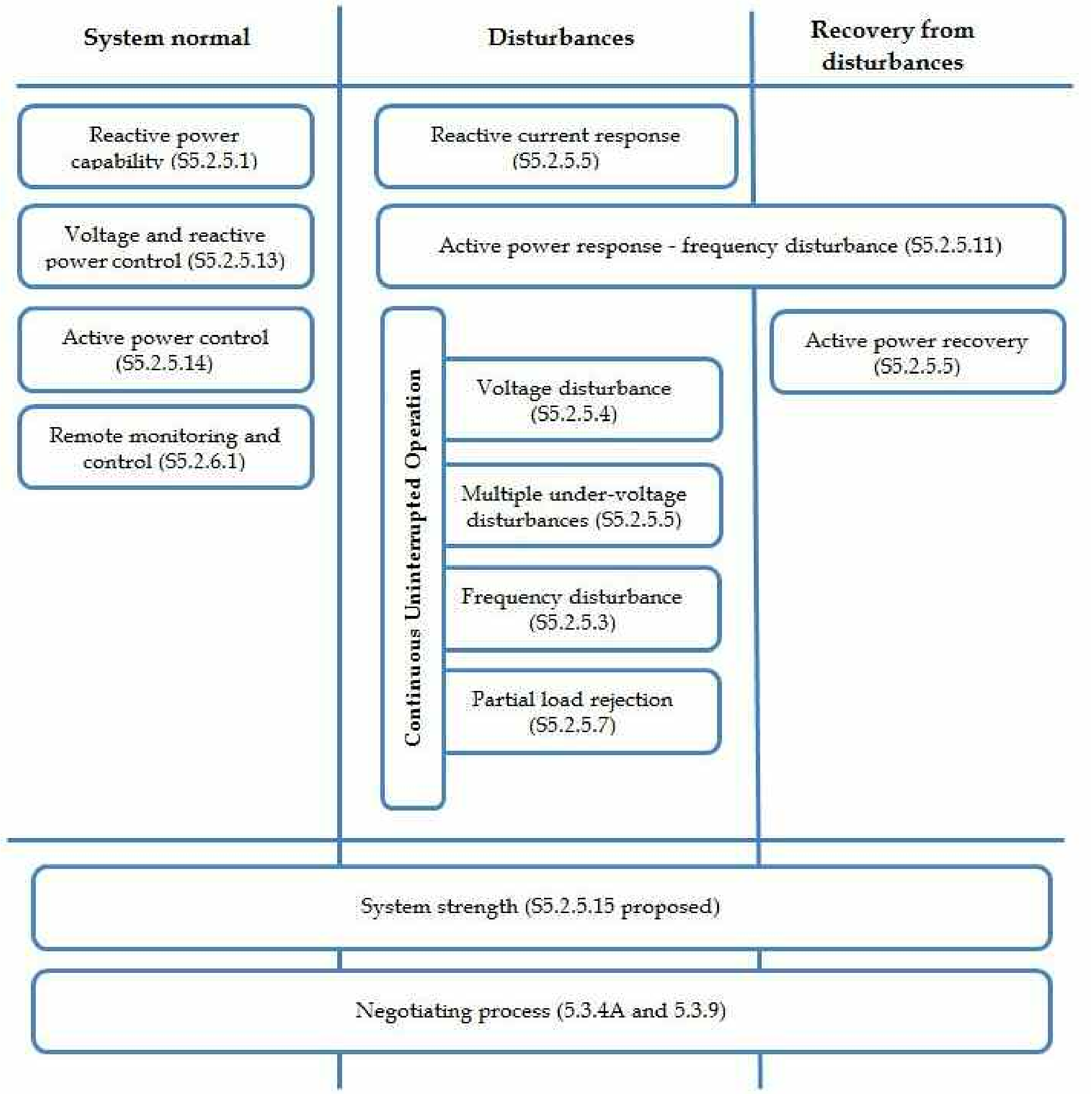
5 "Negotiated access standard" is defined in Chapter 10 of the NER as "in relation to a technical requirement of access for a particular plant, an agreed standard of performance determined in accordance with clause 5.3.4A and identified as a negotiated access standard for that technical requirement in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

6 Note some of the access standards in the NER are specified as AEMO advisory matters. These matters generally relate to AEMO's system security functions under the National Electricity Law (NEL) and any matters in which AEMO has a role in schedules 5.1a, 5.1, 5.2, 5.3 and 5.3a of the NER. 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.

7 See clause 5.3.4A(f)(1), (2) and (4) of the NER.

8 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 its behaviour to actively support the power system, such as by controlling active power or injecting or absorbing 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.[9] 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 formal 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.

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

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.

To assist with its consideration of the rule change request, the Commission convened a technical working group.[10] The technical working group met on 11 December 2017 and on 1 and 2 February 2018.

Throughout its analysis of the issues and the preparation of the draft determination the Commission appreciated the ongoing support and assistance it received from AEMO and the AER. AEMO provided formal updated positions on its proposed changes, responding to concerns raised by stakeholders and the Commission. These formal 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*, which included revised positions on the proposed requirements for continuous uninterrupted operation during multiple low voltage disturbances
- on 9 April 2018 AEMO provided a memorandum to the AEMC setting out a revised position on the injection of current during certain faults, and
- on 13 July 2018 AEMO provided its submission to the draft determination.

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

On 31 May 2018 the Commission published a draft rule and draft determination. The Commission briefed members of its technical working group, the Clean Energy Council, the Australian Energy Council and Energy Networks Australia on the detail of the draft determination. The Commission also held a formal stakeholder workshop on the draft rule on 26 June 2018.

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

The Commission received 33 formal submissions as part of the second round of consultation, most of which were received on time. The Commission considered all issues raised by stakeholders in submissions and conducted a number of follow-up discussions with stakeholders.

2 FINAL RULE DETERMINATION

2.1 The Commission's final rule determination

The Commission's final rule determination is to make a final more preferable rule. The final 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 final more preferable rule are summarised 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 final more preferable rule against the national electricity objective.

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

2.2 Rule-making test

2.2.1 Achieving the national electricity objective

Under the National Electricity Law (NEL), 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).[11] This is the decision making framework that the Commission must apply.

The NEO is:[12]

> 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 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.[13]

11 Section 88 of the NEL.

12 Section 7 of the NEL.

13 See section 91A of the NEL.

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

The Commission considers the final 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 final 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 Chapters 4 to 13.

The final more preferable rule is referred to throughout this final determination as the "final 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 final rule is published with this final rule determination. Its key features are set out below.

The Commission's final rule changes the negotiating process currently in the NER 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:

- clause S5.2.5.11: 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

- clause S5.2.6.1: the requirements for remote monitoring and control of generating system functions related to the control of active and reactive power, to provide for appropriate real time power system management functions where they are needed
- clause S5.2.5.1 and S5.2.5.13: 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
- clause S5.2.5.5: the requirements for generating systems to be able to inject and absorb reactive current during disturbances, so that all generating systems connecting can assist by supporting voltage levels in a predicable way when there are faults on the power system, and
- clauses S5.2.5.3, S5.2.5.4, S5.2.5.5, S5.2.5.7 and Chapter 10: 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 blackouts.

The final rule also includes a number of changes that are necessary or consequential, or corresponding, to the making of the final 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 final 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 final 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. Changes to the access standards are 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 for generators (ultimately passed on 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 would also impose 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 impose an 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 not 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, in some cases, due to differences in inherent physical characteristics of technologies, 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 1: 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 and draft determination
- technical advice from DigSILENT Pacific
- input from industry representatives that have participated in the Commission's technical working group
- 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:

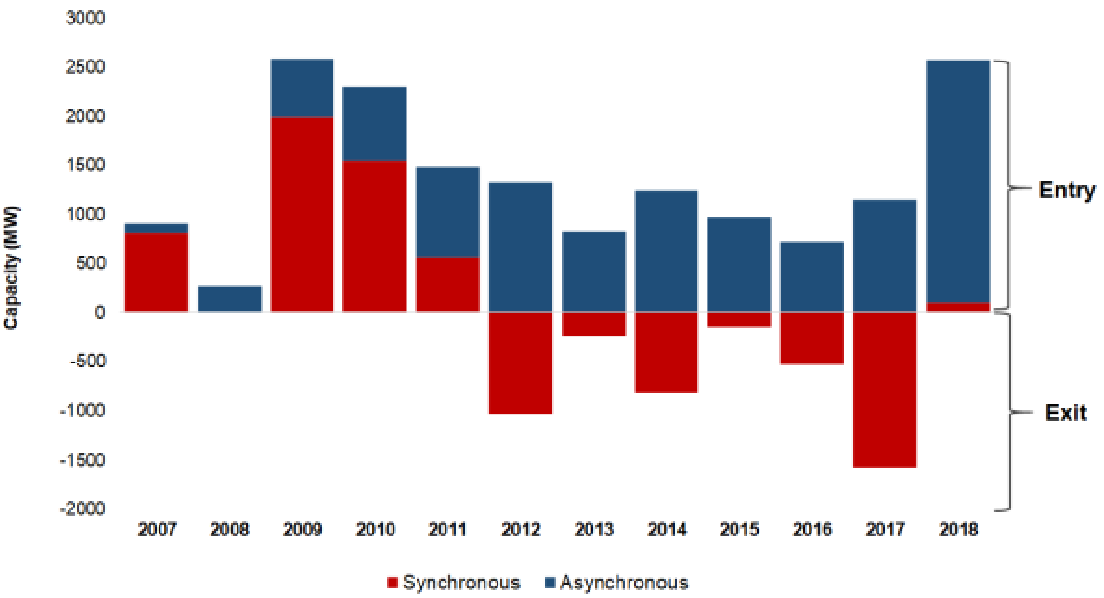
- having certain technical capabilities available while in normal operating conditions
- the need to be able to withstand certain disturbances (including those caused by faults and generation tripping) and provide support to the power system throughout the disturbances, and
- the ability to quickly recover after disturbances to help bring the power system back to normal operating conditions.

It is also important that AEMO and the network service provider are 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 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. While other factors are also having material impacts, this shift in the generation mix towards predominantly asynchronous generation is a key driver of changes in the power system.[15]

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



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

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

15 For example, other factors such as increased variability of generation and changes in levels of intra-day and total minimum and maximum demand are also relevant.

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 in a way that efficiently matches the level of capability of the equipment to the actual needs of the power system, at the time connection.

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.[16]

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.[17] 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.[18]

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."[19] With some parameters, NECA considered the most important requirement for managing the system is to know how plant will react to system disturbances.[20] 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.[21]

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."[22] Put another way, the objective was to "ensure that capabilities and therefore costs are not higher than necessary to meet the defined system requirements."[23]

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

16 NECA, *Review of technical standards, final report*, December 2001, pp. 10-11.
17 ibid, p. 101.
18 ibid.
19 ibid, p. 10.
20 ibid.
21 ibid.
22 ibid, p. 6.
23 ibid.

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 access 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, regardless of where in the power system the connection is proposed. 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 technically 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 inherently 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.[24]

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.[25]

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. There is no 'firm access' to the market for connecting generating systems.[26] Generators have no guarantee that they can export all of their output to the

24 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%2
0for%20publication%20180413.pdf.

25 Clause 5.1A.2 of the NER.

26 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. 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-pape r.aspx

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.

This section will discuss each of these issues in turn.

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 and quality of supply, 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.[27] 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 the technology and location of generating systems changes.

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 future or that are expected to get worse over time.[28] There are a number of implications of this:

27 Rule change request, pp. 5-6; AEMO, submission to the consultation paper, pp. 5-6; and AEMO, submission to the draft determination, pp. 1 and 5-6.

28 The NER do 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.

- the definite, upfront costs of increasing the access standards will be borne by connecting generators but the potential future 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 potential improvements to support system security and quality of supply. Connecting generators may be incurring costs to maintain system security and quality of supply. In the absence of these stricter access standards and negotiating process for generators, costs to meet a similar level of system security and quality of supply could be incurred by AEMO or network service providers.[29]

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.

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.

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

29 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. However, other aspects of system security and quality of supply may be more efficiently planned for and provided by AEMO and network service providers.

access standards to the appropriate levels within that range for any equipment that a participant is seeking to connect at a given connection point.

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 automatic and minimum access standards, as they form the boundaries for the range of allowable outcomes from a 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.

3.4.1 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.

3.4.2 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 (in particular, the system strength at the proposed connection point) that are currently seen across the power system. This is the key distinguishing factor between the automatic and minimum access standards.

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.

3.4.3 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 2: 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 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 Commission's final 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 final rule also includes a new obligation on AEMO and network service providers to provide to the connection applicant detailed reasons in writing 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 final 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
- the Commission's draft determination
- stakeholders' views on the draft determination, and
- the Commission's final rule.

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.

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 connections 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[30]
- 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[31]
- 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[32]

30 Clause 5.3.2 of the NER.

31 Clause 5.3.3 of the NER.

32 Clause 5.3.4 of the NER.

- 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[33]
- offer to connect, where the network service provider makes the offer to the connection applicant, which includes the access standard for each technical requirement,[34] 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.[35]

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.[36]
- Within 20 business days following receipt of the proposed negotiated access standard and all information the connection applicant is required to provide, including under clause S5.2.4 (that is, certain detailed modelling information),[37] AEMO must respond to the network service provider in respect of the AEMO advisory matters.[38]
- Within 30 business days following receipt of the proposed negotiated access standard and all information the connection applicant is required to provide, including under clause S5.2.4, the network service provider must respond to the connection applicant by rejecting or accepting the proposed negotiated access standard.[39]

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:[40]

- 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

33 Clause 5.3.5 of the NER.
34 Clause 5.3.6 of the NER.
35 Clause 5.3.7 of the NER.
36 Clause 5.3.4(c) of the NER.
37 The specific requirement to provide information in clause S5.2.4 applied from 1 July 2018.
38 Clause 5.3.4A(d) of the NER.
39 Clause 5.3.4A(e) of the NER.
40 Clause 5.3.4A(a) and (f) of the NER.

- in AEMO's reasonable opinion, in respect of generating plant,[41] 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.[42] 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.[43]

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 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.[44]
- 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.[45]

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

41 "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".
42 Clause 5.3.4A(g) of the NER.
43 Clause 5.3.4A(i) of the NER.
44 Clause S5.2.1(g) of the NER.
45 For example, clauses S5.2.5.3 and S5.2.5.4 of the NER.

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

On 1 July 2018 a number of changes to the connection process in Chapter 5 of the NER came 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 rule change request was made on the basis of the rules in place at the time it was submitted on 11 August 2017, however these subsequent changes to the NER are also relevant to the issues raised in the rule change request. In particular network service providers are now 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 strength impact assessment in a response to a connection enquiry, following consultation with AEMO.[46]

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,[47] 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.[48]

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 is required under the *Generating system model guidelines rule*, 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.

46 Clause 5.3.4B(a)(1) and (b) of the NER.

47 Clause 5.3.4(g) of the NER.

48 Clause 5.3.4(b)(3) and (4) and clause S5.2.4(b1) 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.[49] 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."[50]

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.[51] 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.[52] 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.[53]

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.[54] 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.[55]

49 Rule change request, p. 19.
50 AEMO, submission to the consultation paper, p. 12.
51 Rule change request, p. 19.
52 ibid.
53 ibid.
54 AEMO, submission to the consultation paper, p. 7.
55 ibid.

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.[56]

4.3.2 AEMO's proposed changes

Seeking to address these concerns, AEMO proposed changes to the negotiating process in the NER to:[57]

- 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)."

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:[58]

- 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 Draft determination

This section sets out the analysis and conclusions of the Commission in its draft determination, including the draft rule.

4.4.1 Stakeholder views

The Commission noted a range of stakeholder views on the current negotiating process and the issues raised by AEMO. This included views from AEMO and networks that connection applicants could better consider the needs of the power system in their connection

56 ibid, p. 9.
57 Rule change request, p. 20.
58 AEMO, submission to the consultation paper, p. 14.

applications, and better support their proposed negotiated access standards with clear information and modelling.

It also included views from generators, connection applicants and consultants that AEMO and network service providers already have too much power in negotiations and can at times abuse that power or fail to adequately provide information to support their decisions.

Further detail on stakeholder views on the rule change request and consultation paper is set out in section 4.4 of the draft determination.

4.4.2 Analysis of the issues

In its draft determination the Commission noted the principal 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. It noted the current process broadly achieves this on a case by case basis by separating 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 considered these roles were appropriate, given the incentives and information each party holds. The Commission considered the outcome of this negotiating process, on a case by case basis, 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 relating to the clarity of the current process, the balance of negotiating power and the information available to parties to the negotiations.

Clarity of the process and its objective

The Commission considered that the current guidance on the appropriate levels of negotiated access standards is not clear and recognised evidence from stakeholders that many connection applicants do not take the existing guidance into account when proposing negotiated access standards. The Commission considered this may result in outcomes that are inconsistent with maintaining power system security at least cost to consumers because an unclear process can result in difficulty reaching an efficient level of performance.

The Commission noted the comments from TasNetworks on the ambiguity regarding whether the objective of negotiations 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.

The Commission considered 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. The Commission noted it is not appropriate to impose the costs of accounting for uncertain future changes to the power system on generating systems connecting today.

Power imbalances and information asymmetries

The Commission noted 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 and who are the ultimate decision makers as to whether or not proposed performance standards are accepted or rejected. Further, some of the information held by AEMO and network service providers 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.

The Commission noted that 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.

The Commission considered there appears to be sufficient data available for connection applicants to use to consider and reasonably determine the level of performance that are likely to be appropriate for local power system conditions and accordingly to make appropriate technology decisions and propose appropriate performance standards. However it found that some connection applicants do not adequately consider the level of performance needed for the power system for other reasons. These reasons included 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 power system conditions at the connection point.

The Commission noted that AEMO and network service providers have an existing ability to address these issues through their ability to reject proposed negotiated access standards, but that some changes are also appropriate to help address the issues.

The Commission also accepted that some network service providers and AEMO can at times provide less information in response to proposed negotiated access standards than is desirable, which can frustrate the negotiation process.

4.4.3 Conclusions

The Commission concluded that:

- 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 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 Commission noted these issues may influence the ability for parties to efficiently agree on negotiated access standards that are appropriate for local network conditions. It noted this could potentially result in situations where the agreed level of performance is lower, or higher, than would be efficient to deliver power system security and quality of supply at lowest cost.

4.4.4 Draft rule to address the issues

The Commission made a draft rule to address the issues identified above. The draft rule included:

- 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:[59]
    - 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 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).[60]

The draft rule also included 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,[61] or

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

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

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

- 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.[62]

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

New obligations for connection applicants

New obligations were included for connection applicants in the draft rule to address the current ambiguity in the guidance on negotiated access standards and evidence that some connection applicants do not take this guidance into account when proposing negotiated access standards. The Commission considered relevant data, information and expertise was available to connection applicants to consider the levels of performance that AEMO and network service providers consider appropriate for the connection. The Commission also considered that the changes that came into effect on 1 July 2018 should further improve the availability of useful information before a connection application is made.

The Commission agreed with AEMO that an overarching objective for negotiations to aim for the automatic access standard is appropriate, which was reflected in the draft rule. The draft rule 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).

The Commission also sought to address the risk of generating systems connecting with levels of performance that are higher, and more costly, than necessary to manage power system security. The draft rule included a 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 power system conditions at the location of the proposed connection, the need to protect the plant from damage, and the commercial and technical feasibility of complying with the automatic access standard. This was included to provide clarity 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 noted that this is consistent with the existing roles and responsibilities of different parties in the negotiating process. It noted that, consistent with their roles and responsibilities, when assessing negotiated access standards AEMO and network service providers do not consider the commercial and technical feasibility of the proposed levels of performance. They principally consider the impact of the proposed connection on power system security and quality of supply.

New obligations for AEMO and network service providers

The Commission noted the views of some stakeholders that when rejecting a proposed negotiated access standard, AEMO and network service providers may in some cases provide

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

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 considered the current negotiating process could be improved through more effective information provision requirements, and included in the draft rule a new obligation on 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
- an adverse effect on 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.

4.5 Stakeholder views on the draft determination

Most stakeholders either largely agreed with the changes proposed by the Commission in its draft rule,[63] or did not comment on them. Network businesses tended to support the new obligations on connection applicants, while connection applicants, generators and consultants tended to support the new obligations on AEMO and network service providers. Some stakeholders commented that an appropriate balance had been struck overall.

Some stakeholders also expressed concerns with parts of the draft rule, and some provided suggestions for further changes. These views are set out below.

4.5.1 Concerns with the draft rule

Stakeholder concerns with the draft rule focussed on the appropriate roles and responsibilities of the parties, the clarity of the new requirements, and a range of other issues.

AEMO's concerns

AEMO considered that the inclusion of the ability for connection applicants to propose a level of performance below the automatic access standard taking into account the "commercial feasibility" of meeting that standard "undermines the need for connection applicants to genuinely aim for the automatic access standard."[64] AEMO argued that, while neither AEMO, nor network service providers are required by clause 5.3.4A(b) of the draft rule to take into account the commercial feasibility of a connection applicant's compliance with an automatic access standard, AEMO is concerned that connection applicants will interpret the rule differently.[65] AEMO considered that, if connection applicants do so, they will give their own

63 Submissions to the draft determination: ENA, p. 4; TasNetwroks, p. 1; Eneflux, p. 3; AGL, p. 2; Clean Energy Council, p. 3; Lloyd's Register, pp. 2-3; Engie, p. 3; Origin Energy, p. 3; SMA, p. 1; WSP, p. 2; Department for Energy and Mining (South Australia), p. 2.

64 AEMO, submission to the draft determination, p. 12.

65 ibid, p. 13.

'commercial feasibility' considerations undue prominence and expect AEMO and network service providers to do likewise when assessing the proposed negotiated access standard.[66] AEMO recommended removing the reference to commercial feasibility and did not comment on any other aspect of the changes to the negotiating process in the draft rule.[67]

Clarity of the draft rule

A number of stakeholders considered the draft rule lacked clarity in some areas, and could benefit from greater prescription.

Advisian stated that the proposed rules are vague with respect to each party's obligations and responsibilities, and proposed that the rule should be improved to "give project proponents more certainty and control over their project risks." The Australian Energy Council suggested the draft rule "implies an obligation on connecting generators to strive for the automatic access standard, while providing little guidance on how technical and commercial decisions by the proponent will be assessed."[68]

SMA considered it would be beneficial to clarify what type of evidence is expected from the connection applicant as part of the new requirements in the negotiating process.[69]

A number of stakeholders were concerned with the level of detail that AEMO and network service providers may be required to provide when giving reasons why a proposed negotiated access standard is not accepted.[70]

The Clean Energy Council suggested the criteria used by AEMO and the network service provider to reject a proposed negotiated standard should be evidence-based, consistently used and transparent.[71]

Canadian Solar suggested that, while rejecting a proposed negotiated standard, AEMO and network service providers should demonstrate clearly why the connecting generator would cause a power system security issue, noting which part of the NER the generator would not be capable of meeting and why.[72]

Eneflux suggested changes to provide greater clarity on the nature of the the obligation on AEMO and network service providers. Eneflux suggested that, in rejecting an access standard the network service provider must:[73]

- clearly identify the system standard or other regulatory requirement that would not be able to be met

66 ibid.

67 ibid.

68 Australian Energy Council, submission to the draft determination, p. 1.

69 SMA, submission to the draft determination, p. 1.

70 Submissions to the draft determination; Energy Networks Australia, p. 4; AGL, p. 2; Eneflux, p. 3; Clean Energy Council, p. 4; Canadian Solar, p. 4.

71 Clean Energy Council, submission to the draft determination, p. 4.

72 Canadian Solar, submission to the draft determination, p. 3.

73 Eneflux, submission to the draft determination, p. 3.

- clearly identify the minimum level of an access standard that would be required to allow the network service provider to meet the relevant system standard or regulatory requirement, and
- clearly identify how a service being requested from the connecting generator could not be more cost effectively provided by a network solution.

SMA considered that network service providers should be required to provide 'evidence' as well as 'reasons' when rejecting a proposed negotiated access standard.[74] SMA also suggested that the reasons provided by AEMO and network service providers should include all relevant technical details necessary for the applicant to reassess their proposal, be specific to the proposed point of connection and project, and relate to system security or reliability.[75]

The Energy Networks Association appeared to consider that network service providers are required to provide 'evidence' when rejecting a proposed negotiated access standard. Although this is not the case, they argued that "the requirement to provide evidence may conflict with confidentiality requirements of other applications seeking to connect in the vicinity," which may be difficult to manage in practice where there are multiple connections to manage in the vicinity.[76]

Civil penalty provision issues

Few stakeholders commented on whether or not clause 5.3.4A(g) should remain a civil penalty clause, given the changes in the nature of the obligations within the clause.

In further consultation the AER considered the provision should remain a civil penalty provision.[77] The AER noted that the provision should include a prescribed timeframe for a response, and that the operation of the civil penalty provision should be limited to the timeframe requirement.[78]

Energy Networks Australia considered there should be a clear link in clause 5.3.4A(g) to the network having received the relevant information from AEMO under clause 5.3.4A(d) and (d1), given the obligation is a civil penalty clause.[79] Energy Networks Australia also noted that clause 5.3.4A(e) should include a new sub clause (3) stating "receipt of all information to be provided by AEMO under 5.3.4A(d) and 5.3.4A(d1)."[80]

Delta Electricity stated that, if the civil penalty clause is to remain, it would seem appropriate that the obligations on network service providers should not be lessened, to support the success of the proposed changes to the negotiating process.[81] Engie considered that a failure to provide detailed reasons should lead to civil penalties.[82]

74 SMA, submission to the draft determination, p. 1.
75 ibid.
76 Energy Networks Association, submission to the draft determination, p. 4.
77 AER, email correspondence to AEMC, 31 July 2018.
78 ibid.
79 Energy Networks Australia, submission to the draft determination, p. 4.
80 ibid.
81 Delta Elecricity, submission to the draft determination, p. 3.
82 Engie, submission to the draft determination, p. 3.

Other issues

While Origin supported the new rule that would require AEMO and network service providers to provide reasons for rejecting a proposed negotiated access standard, it also suggested an additional rule requiring them to specify what adjustments to the connection agreement would be required that would allow the performance standards to be approved.[83] Origin considered this would prevent protracted back and forth negotiations, reducing cost and delay, and also could provide information that would be provided to an independent expert review process (discussed further below).[84]

Lloyd's Register noted that the proposed rule includes the deletion of clause 5.1A.2(d), which provides a general right to request a negotiated access standard below the automatic standard where this does not adversely affect system security or quality of supply.[85] Lloyd's Register considered the provision remained broadly appropriate as a fundamental expression of the NEO.[86] Lloyd's Register also noted that the changes to the negotiating process will add to the already significant costs of analysis and modelling for new connections.[87]

GE Australia considered that the obligation for connection applicants to aim for levels of performance that are as close as practicable to the automatic access standard could lead to more costly connections for other connection applicants that follow, since those later applicants should not have an adverse impact on existing generators' ability to meet their generator performance standards.[88] GE Australia noted that if there were flexibility to adjust some of the performance standards of the existing generators, then a least cost connection could be achieved through coordinating the controls between the existing and proposed connections.[89]

Meridian Energy considered that moving to a regime where the automatic access standard is the expectation for all connecting parties, unless they can demonstrate otherwise, is unlikely to yield the most efficient outcome for consumers given the power system currently operates in a safe and secure manner with numerous parties connected at the level of the minimum access standard.[90]

4.5.2 Further suggested changes

A number of stakeholders, principally connection applicants, generators and consultants, identified further changes they consider could improve the negotiating process.

Early information

Some stakeholders considered that a requirement for network service providers to provide more information to connection applicants earlier in the connection process, would help

83 Origin Energy, submission to the draft determination, p. 3.
84 ibid.
85 Lloyd's Register, submission to the draft determination, pp. 2-3.
86 ibid.
87 ibid, p. 4.
88 GE Australia, submission to the draft determination, p. 2.
89 ibid.
90 Meridian Energy, submission to the draft determination, p. 1.

applicants prepare their connection applications.[91] GE Australia considered that the requirements for a network service provider's response to a connection enquiry only require the provision of high level information and lack detail on the acceptable levels for negotiated access standards and detailed input data required for connection studies.[92] EnergyAustralia considered that earlier clarification and notification of potential impacts of the proposed connection to the parties would improve the negotiation process.[93]

The Clean Energy Council considered that connection applicants would benefit from receiving adequate and user-friendly information earlier in the negotiation process that clearly identifies what the proposed connection's impact on the network would be.[94] The Council also considered this has the potential to create efficiencies in the negotiation process for all parties by creating shared expectations, which would reduce the likelihood that proposed negotiated access standards are rejected.[95]

WSP noted it would be helpful if network service providers were required to provide details of whether a negotiated access standard would be acceptable, and short reasons as to why, at an early stage, such as in response to a connection enquiry.[96] WSP considered this would assist the applicant to design the plant and plan studies as part of its connection application.[97]

Eneflux and Lloyd's Register also considered that network service providers should be required to provide in response to a connection enquiry, information that is relevant to assessing whether a negotiated standard is appropriate under the new clause 5.3.4A(b2).[98] Lloyd's Register added that, although the network service provider is required to provide standing data to the connection applicant, the applicant also relies on information voluntarily provided by the network service provider to "get on the same page about the studies they need to do for a connection."[99]

Lloyd's Register recommended including new obligations in the NER for the provision of early information, including:[100]

- allowing the connection applicant to request technical data the applicant considers reasonably necessary from the network service provider (in addition to information already provided) for the purpose of preparing reasons and evidence supporting a proposed negotiated access standard, and
- the network service provider must provide the data requested, subject to confidentiality obligations, or else provide details of the evidence that, in the network service provider's

91 Submissions to the draft determination: EnergyAustralia, p. 2; Clean Energy Council, pp. 2-3; WSP, p. 2; Lloyd's Register, p. 4; Eneflux, p. 3; GE Australia, p. 1; AGL, p. 2.

92 GE Australia, submission to the draft determination, p. 1.

93 EnergyAustralia, submission to the draft determination, p. 2.

94 Clean Energy Council, submission to the draft determination, pp. 2-3.

95 ibid.

96 WSP, submission to the draft determination, p. 2.

97 ibid.

98 Submissions to the consultation paper: Lloyd's Register, p. 3; Eneflux, p. 3.

99 Lloyd's Register, submission to the draft determination, p. 4.

100 ibid.

reasonable opinion would adequately demonstrate that the proposed negotiated access standard is appropriate.

AGL considered that a connection applicant should only be expected to provide evidence to demonstrate the appropriateness of a proposed negotiated access standard where this has been requested by the network service provider or AEMO based on an identified system security or local quality of supply issue.[101] AGL noted this would require the network service provider or AEMO identifying the risk, and providing evidence to support it, early in the negotiation process.[102]

Independent dispute resolution

A number of stakeholders suggested that some form of independent dispute resolution should be allowed to manage disagreements on the levels of performance appropriate for connections.[103] Suggestions ranged from binding arbitration, to the extension of the role of the independent engineer to consider matters related to the acceptability of proposed negotiated access standards.[104]

Origin Energy noted it would support the introduction of an independent third party that can arbitrate disputes on negotiated access standards.[105]

EnergyAustralia suggested that an independent expert or dispute resolution avenue should be available to connection applicants to appeal decisions related to acceptance of a proposed negotiated access standard.[106] WSP and the Clean Energy Council agreed with this approach, both also suggesting that an approach similar to the appointment of an independent technical adviser provided for in the *Transmission connection and planning arrangements rule* is appropriate.[107]

Modelling and coordination

A number of stakeholders also commented on the need for greater clarity on the projects that should be taken into account when preparing studies and modelling to support proposed levels of performance for connections.

The Clean Energy Council noted that, under the current arrangements, the connection applicant is required to include committed projects in their studies as part of a connection application.[108] The Council noted its members had provided feedback that AEMO is considering planning models in their decision-making during the negotiation process of a connection application, which they consider is not in line with the requirements on the

101 AGL, submission to the draft determination, p. 2.
102 ibid.
103 Submissions to the draft determination: EnergyAustralia, p. 2; Origin Energy, p. 1; WSP, p. 3; Clean Energy Council, p. 3; Australian Energy Council, pp. 1-2.
104 The independent engineer is a concept introduced by the AEMC's *Transmission connection and planning arrangementsrule*. The independent engineer can be asked to advise on certain technical matters related to the specification of certain connection assets.
105 Origin Energy, submission to the draft determination, p. 1.
106 EnergyAustralia, submission to the draft determination, p. 2.
107 Submissions to the draft determination: WSP, p. 3; Clean Energy Council, p. 3.
108 Clean Energy Council, submission to the draft determination, p. 3.

connection applicant, and allows AEMO to inappropriately enforce their planning power through the generator performance negotiation process.[109] To help address the issue the Clean Energy Council recommended removing the words "at least" from clause S5.2.5.1(c)(1) to ensure that only existing projects and committed projects are required to be assessed by all parties in the negotiation process.[110]

The Australian Energy Council noted that the basis for the network service provider's and AEMO's assessment is the current system model, which does not consider other concurrent or future connection applications which, if successful, may alter the power system's characteristics.[111] The Energy Council noted there is likely difficulty in deciding which generators are most likely to connect, but recommended providing additional guidance on the technical assessment required to be conducted by the network service provider and AEMO in negotiating an access standard.[112]

4.6 Final determination

This section sets out the Commission's views addressing stakeholder comments, and notes any changes from the draft determination.

4.6.1 Removal of commercial feasibility

The changes to the negotiating process set out in the draft rule include a requirement for the connection applicant to propose a level of performance that is as close as practicable to the corresponding automatic access standard, 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.

The Commission does not agree with AEMO that the words "commercial feasibility" should be removed.

Under the process set out in the draft rule, the connection applicant must start at the automatic access standard, and can propose a lower level of performance for a limited number of reasons. If commercial feasibility (in other words, cost) is not able to be used as a reason to propose a lower level of performance, then the levels of performance proposed could conceivably be higher and more costly than necessary to maintain power system security and quality of supply.

As an example, meeting an automatic standard that requires a connection to ride through an event on the power system that lasts 10 seconds may cost $10 million to achieve, while riding through the same event for 8 seconds may cost $5 million to achieve. It is conceivable that meeting the automatic standard may be technically feasible for the equipment and also may not damage the plant or be inconsistent with power system conditions at the proposed

109 ibid.

110 ibid.

111 Australian Energy Council, submission to the draft determination, pp. 1-2.

112 ibid.

location of connection. In this case, if a connection applicant is unable to explicitly propose a level of performance at 8 seconds because it is too expensive to do so, even where that level of performance would not adversely affect power system security or quality of supply, the added cost to the connection (and ultimately consumers) would be $5 million.

Although this is a simplified hypothetical example, it shows why it is appropriate to include the principles underpinning the connection applicant's role in the negotiating process in the NER. The changes set out above for the first time detail in the NER the role of the connection applicant. The Commission considers that a fundamental aspect of the role of the connection applicant is to consider the costs of connection and to try to reduce those costs. Overall, this helps to achieve the goals of delivering a secure, high quality system, at the lowest overall cost to consumers. Removing the words "commercial feasibility" would not clearly articulate in the NER this aspect of the connection applicant's role in the connection process and could end up driving higher costs for consumers.

The Commission also recognises that AEMO and network service providers have different roles in the negotiating process, that reflect their overarching responsibilities. It is for this reason that regardless of the level of performance that a connection applicant proposes in a negotiated access standard, and regardless of the reason for that proposal, AEMO and network service providers are able to reject the proposal where they consider it would adversely affect power system security or quality of supply, among other reasons. As a result, if a connection applicant proposes a lower level of performance because it is not commercially feasible to meet the automatic access standard, AEMO and the network service provider are not required to consider commercial feasibility in their assessment of the proposed negotiated access standard. They appropriately consider only the needs of the power system and retain the ultimate ability to reject a negotiated access standard proposed by a connection applicant.

4.6.2 Early information from network service providers

The Commission noted in its draft determination that, based on evidence provided in submissions and its technical working group, there was sufficient information available to parties early in the connection process for connection applicants to use and analyse to determine the appropriate levels of performance that are likely to be necessary for a connection. It noted that from 1 July 2018 network service providers are required to provide more information to applicants in response to a connection enquiry as a result of new rules on system strength and generating system model guidelines. The Commission also noted that some connection applicants do not make adequate use of this information to assess the appropriate levels of performance for a connection, despite the availability of expert consultants to assist with this.[113] To address this issue the Commission imposed a new obligation on connection applicants to provide evidence and reasons supporting their proposed negotiated access standards, with the aim of requiring connection applicants to better consider the needs of the power system when proposing negotiated access standards.

113 This view was formed based on stakeholder views in submissions, particularly those of AEMO and network businesses, as well as views expressed by a range of different stakeholders in the technical working group.

The Commission has not received in response to the draft determination evidence of specific aspects of data or information that is not available to connection applicants in advance of making a connection application. The Commission also notes that it is always open to connection applicants to engage with network service providers in advance of making a connection application to request information relevant to determining an appropriate level of performance to propose in a negotiated access standard.

The Commission also considers that it is not appropriate to place a significant additional burden on network service providers to provide more detailed information to connection applicants in response to a connection enquiry, or in advance of submitting a connection application. Such an obligation could impose a significant burden to respond in detail to connection enquiries, many of which may not proceed to the connection application stage.

In light of the above, the Commission has not included new requirements on network service providers to provide more information to applicants in response to a connection enquiry.

4.6.3 Consideration of other projects in negotiations

The Commission appreciates that it can be difficult for connection applicants to anticipate which nearby connections may be proceeding to connect and therefore be relevant to consider when determining what state of the power system is appropriate to study when modelling the performance requirements of a connection. As noted above, it is open to connection applicants to engage with network service providers in advance of making a connection application to request information on this.

The Commission notes that the majority of evidence provided to support the view that more clarity should be provided on this issue relates to the negotiation of reactive power capability under clause S5.2.5.1. Stakeholders have advised that the ambiguity in those cases is caused by the wording of the guidance on negotiated access standards under that clause, and the Commission considers it is appropriate to address that ambiguity in the manner set out in Chapter 7.

However, the Commission has not been advised of any equivalent lack of clarity for any of the other access standards. We therefore do not consider it necessary to include further guidance on this matter that relates to the negotiation of all other access standards.

Other more general matters relating to issues arising from the coordination of multiple generators connecting are beign considered in the AEMC's *Review into the coordination of generation and transmission investment*.

4.6.4 Dispute resolution

The Commission considers it is not appropriate to introduce a new form of dispute resolution into the negotiating process in Chapter 5 of the NER.

Firstly, it is not appropriate to include a requirement for arbitration, which would involve all parties submitting to the binding decision of an arbitrator. AEMO and network service providers have clear responsibilities under the NER for power system security and quality of power supply to network users, and it is not appropriate to transfer an important aspect of meeting these responsibilities to a third party arbitrator. AEMO and network service providers are in the best position, including having access to confidential information, which could not appropriately be shared with a third party arbitrator, to assess the needs of the power system.

Secondly, it is not appropriate to extend the responsibilities of the independent engineer to include disputes relating to negotiated access standards. The independent engineer has been implemented to help provide independent expert advice to determine the appropriateness of the connection assets a network service provider proposes are needed for a proposed connection. The need for an independent expert adviser however is limited in negotiations on proposed negotiated access standards, where expert technical advisers are usually already engaged by connection applicants to support the negotiations.

It is also not appropriate for the independent engineer to advise on negotiated access standards due to the structure of the appointment and payment of the independent engineer. The independent engineer is appointed where approved by both the connection applicant and the network service provider, and is paid equally by those parties. This structure however is not appropriate where a dispute on appropriate access standards is often between AEMO and the connection applicant. It is not appropriate for the network service provider to pay for the resolution of such disputes.

There is also nothing under the current arrangements limiting any party or parties from obtaining independent expert advice on the appropriate levels of a negotiated access standard.

4.6.5 Further guidance on the meaning of key terms

The Commission considers it is not appropriate to include further guidance on the meaning of the terms "evidence" or "detailed reasons".

The terms used are relatively clear and capable of interpretation on their ordinary meaning. There is a risk that further defining the terms, as has been suggested by some stakeholders, would provide guidance that is not appropriate for some circumstances that arise that are not able to be anticipated by the Commission.

The intention of the requirement for connection applicants to provide evidence and reasons supporting their proposed negotiated access standards is to clearly identify the reasons why they have not proposed a level of performance at the level of the automatic access standard, and to support the proposed level of performance with evidence in the form of modelling, studies or other information that is appropriate in the context of the particular technical requirement in question.

The intention of the requirement for a network service provider to provide detailed reasons supporting a decision to reject a proposed negotiated access standard (or for AEMO to advice to reject a proposed negotiated access standard) is to require the provision of reasons that are sufficient to:

- identify the aspect of clause 5.3.4A(b) that is the basis on which the proposed negotiated access standard is being rejected

- identify the basis on which that reason has been formed (such as identifying the aspect of AEMO's security obligations or the network service provider's quality of supply obligations that would be adversely affected), and
- identify the specific technical performance parameter that should be changed to address the issue.

This approach should identify the overarching reason for the rejection, the power system need that is not met by the proposed negotiated access standard, and the technical shortcoming of the level of performance proposed for the connection that is the cause of the failure to meet the identified system need. The information provided should be sufficient for the parties to then be in a position to have a meaningful technical discussion to resolve the issue.

The Commission expects these matters can be clearly set out in detailed reasons, without conflicting with confidentiality obligations.

4.6.6 Civil penalty provisions

In the draft determination, the requirement for a network service provider to provide detailed reasons for the rejection of a proposed negotiated access standard, as set out in clause 5.3.4A(g) was maintained as a civil penalty provision.

While the AER considered the clause should remain a civil penalty provision, it considered that it should include a timeframe within which the detailed reasons should be provided, and that the timeframe (rather than the requirement to provide detailed reasons) should be the civil penalty provision. The Commission agrees that a timeframe to provide detailed reasons should be specified as being required to occur at the same time as the decision is made to accept or reject the proposed access standards in clause 5.3.4A(e). This change from the draft rule has been made in the final rule.

The Commission, however, does not agree that the civil penalty provision should be limited to the timeframe in which detailed reasons should be provided. The requirement to provide detailed reasons is an important aspect of changes designed to improve the negotiating process, and should be specified as a civil penalty provision to promote compliance.

The Commission agrees with Energy Networks Australia that, given clause 5.3.4A(g) is a civil penalty provision, the requirement to include the detailed reasons provided by AEMO under clauses 5.3.4A(d) and (d1) should be more clearly linked to the actual receipt of that information from AEMO. The Commission has therefore included in the final rule the words "if any", so it is clear that this aspect of the obligation does not operate where the network service provider has not received any detailed reasons from AEMO. The Commission has also included the requirement that any reasons be provided in writing, to provide greater clarity for all parties and due to the need for clear evidence of compliance with this as a civil penalty provision.

The Commission does not agree with Energy Networks Australia's further suggestion to include in clause 5.3.4A(e) a new sub clause (3) stating "receipt of all information to be provided by AEMO under 5.3.4A(d) and 5.3.4A(d1)". This would effectively restart the clock for a network service provider to assess proposed access standards from the date they receive advice from AEMO. This is not appropriate as assessment by AEMO and the network service provider should occur concurrently. Including the new provision as proposed would likely extend the time for each time a network responds to proposed access standards for a connection by around 20 business days.

The additional time is also unnecessary because there is already scope to extend the time needed to assess performance standards where the further information needs to be provided by the connection applicant for the assessment.[114] This process of requiring more information and restarting the time allowable for AEMO and the network service provider to respond can occur a number of times during the assessment of proposed negotiated access standards for a connection. If the proposed wording is included, additional time would be added each time new information is provided by a connection applicant. The Commission therefore rejects this proposed change because the extra time is not necessary and the added time and cost for connections would likely be significant.

114 See clauses 5.3.4A(d)(2) and (e)(2) of the NER.

5 ACTIVE POWER CONTROL

BOX 3: 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, 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
- all non-scheduled generators to have active power control capabilities.

The Commission considers it would not be efficient to require all generating systems to have the capability to provide at least 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 because actual supply of those services would still be voluntary and market driven. 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.

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.

The final 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 final rule allows for non-scheduled generators to negotiate to a lower level of active power control capability.

> 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 final rule therefore requires all scheduled and semi-scheduled generating systems to have AGC capability.
>
> The final rule also includes a number of further changes to improve clarity and better reflect what the Commission understands to be actual operational practice. These changes were discussed in further detail in Chapter 5 of the draft determination.

5.1 Introduction

This Chapter discusses AEMO's proposed changes to clauses S5.2.5.11 and S5.2.5.14 of the NER, which are the access standards related to a generating system's ability to provide frequency response and active power control respectively. 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
- a summary of the draft determination
- stakeholder views on the draft determination, and
- the Commission's final determination.

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 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]

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 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.

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.

Generating systems use both hardware and control software to control their active power output. This includes control hardware such as rate limiters, hydraulic controls or the ability to change the pitch of turbine blades. Digital governors and control software are also used to control and change the active power output of a generator.

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

- 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,[119] and
- 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

As discussed above, generators can change their active power output as a way to control power system frequency. The capability to automatically adjust active power output in

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 (FCAS). 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 "contingency" 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 FCAS. FCAS is not a NER defined term.

119 The AGC system allows AEMO to continually monitor system frequency and send control signals to change the active power output of the ancillary service generating units that provide regulation services, so frequency is maintained within the normal operating frequency band of 49.85 Hz to 50.15 Hz. The AGC can also be used for the purposes of directly controlling generator output through the process of central dispatch.

response to changes in 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 generating systems. 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:

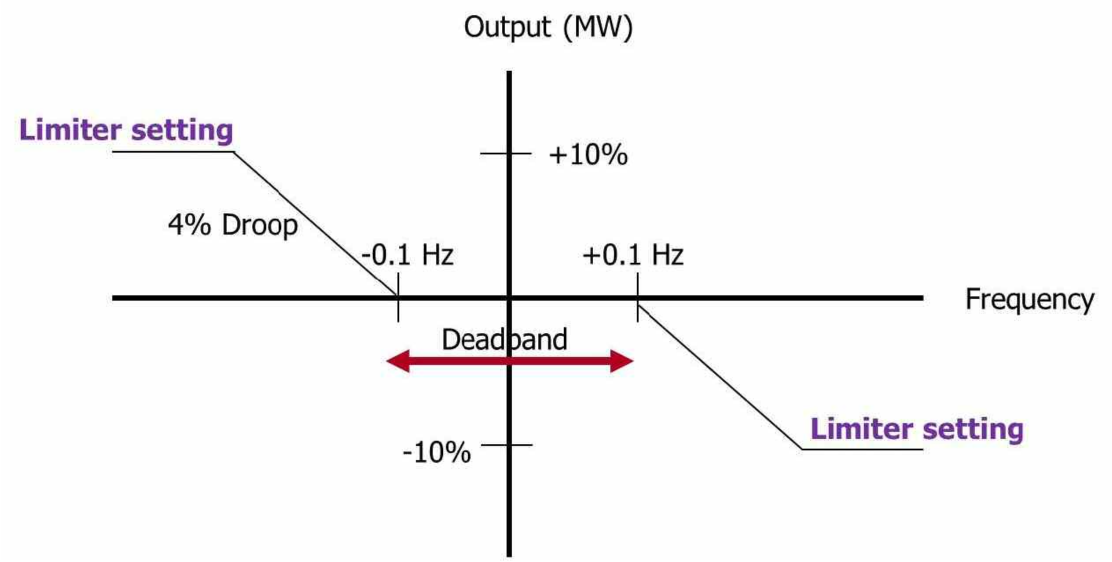
- deadband: the deadband represents the range of power system frequency within which the generating system will not change its active power output
- droop: the droop describes how a generating system will change its active power output in proportion to a change in power system frequency, and
- limit: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

A generalised representation of a proportional frequency control response is in Figure 5.1.

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

Figure 5.1: Droop and deadband



In this diagram:

- the deadband is set to a value of +/- 0.1Hz, on either side of the nominal frequency. In the NEM power system, 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 power system, 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 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 the Market ancillary service specification (MASS).[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.

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.

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.

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.

The automatic access standard requires the generating system 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 a rise in system frequency, and
- 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
- there is no requirement for the generator to be in a position to offer any raise or lower services

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 The 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.

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

- 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.

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. Further to this, AEMO considered that generators may not voluntarily enter the market for the provision of FCAS in the 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]

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]

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

131 Rule change request, pp. 42-43.

132 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.

134 ibid.

135 ibid.

Given these issues, AEMO proposed a change to the minimum access standard, to establish 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's proposed change to the minimum access standard related 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 might be voluntarily used by the generator, or when required to do so by AEMO or the network service provider.[137]

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.[138]

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.[139]

AEMO also proposed that generator frequency response should be specified as a droop type response, once power system frequency moves outside a deadband.[140]

In the proposed rule 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

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. Rule change request, proposed rule, clause S5.2.5.11.

137 ibid, p. 42.

138 ibid, p. 43.

139 Rule change request, p. 43 and proposed rule, clause S5.2.5.11.

140 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
- 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 to clarify that the generator proposing a negotiated access standard must also demonstrate to the network service provider that the proposed level is as close as practicable to the automatic access standard.

The rationale for some of these changes was 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.[141]

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 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.[142]

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 advised that these changes were designed to bring the wording of the clause into line with the rest of the NER.

141 This policy intent was not explicitly stated in the rule change request itself, but reflected in the proposed drafting accompanying the rule change request. Rule change request, proposed rule, clause S5.2.5.11.

142 Rule change request, p. 44.

5.3.4 Draft determination

This section summarises stakeholder views on the consultation paper and the Commission's analysis of the issues and reasons for making the draft rule. A more detailed description of the Commission's analysis can be found in Chapter 5 of the draft determination.

Stakeholder views

A number of submissions to the consultation paper supported AEMO's proposed changes on the basis that this would support system security and help reduce FCAS prices.[143] Others noted that modern generators can generally provide these capabilities, but noted that any subsequent requirements for communications capabilities could impose higher costs for remote generators.[144]

Several stakeholders argued that mandating the capability to participate in FCAS conflicted with fundamental market design principles, particularly that FCAS is provided through a deregulated market framework.[145] It was also suggested the mandating FCAS capability provided no guarantee of actual participation in FCAS markets.[146]

Stakeholders also argued that AEMO's proposed approach conflicted with standard operational practices. For example, it was argued that AEMO's proposed change would effectively require constant derating of the plant or the installation of battery storage, as most renewable generating systems always aim to operate at maximum output.[147]

Stakeholders made a number of general comments on AEMO's other proposed changes, including that any deadband requirements should be included in the frequency operating standards, and that consideration of droop control should take place as part of the frequency control frameworks review.[148]

Finally, it was noted that not all generation types could offer all market ancillary services, and that AEMO's proposal did not recognise other forms of frequency response, such as switched response.[149]

Analysis of the issues

Mandating capability to offer market ancillary services

In the draft determination, the Commission set out its reasoning as to why it considered AEMO's proposal, namely that all generators to have capability to offer one market ancillary service, was not likely to meet the NEO.

A key principle that informed the Commission's assessment was that generators should make the decision as to whether they make the necessary investments, and then make the

143 Submissions to the consultation paper: ENA, p. 7; Advisian, Appendix B, p. iii.
144 ASMC, submission to the consultation paper, p. 6.
145 AGL, submission to the consultation paper, p. 6.
146 CEC, submission to the consultation paper, p. 29.
147 Submissions to the consultation paper: CEC, p. 29; RES Australia, p. 8.
148 Submissions to the consultation paper: GE Australia, p. 17; Origin Energy, p. 2.
149 Submissions to the consultation paper: Advisian, p. 34; Hydro Tasmania, p. 13.

operational decision, to participate in the markets for the provision of frequency control services.

The Commission considered that AEMO's proposed requirement for all generators to have the capability to offer at least one market ancillary service would run contrary to this general principle.

The Commission also considered the materiality of the system security issue identified by AEMO. The Commission found no clear evidence of a shortfall in the supply of FCAS across the power system, in the medium to longer term. As such, there appears to be no pressing reason to mandate that all generating systems are required to invest in the capability to participate in FCAS markets.

The Commission also considered that the proposed changes would not actually increase the supply of FCAS, as the decision to register a generating unit as an ancillary services generating unit, and then to actually offer that unit into the markets for FCAS, remained a voluntary decision for the generator. Mandating capability would therefore not necesarily translate into a generator making this decision.

Finally, the Commission considered that the proposed changes would impose significant additional costs on generators, through increased compliance testing obligations. Ultimately, these costs would be passed on to consumers through higher wholesale energy costs.

On this basis, the Commission decided against the proposal to mandate the capability for all generators to be capable of offering at least one market ancillary service, as set out in AEMO's rule change request.

However, as discussed below, we considered that an alternative requirement, for generators to have the capability to operate in frequency response mode, was likely to meet the NEO.

Requirement for frequency response mode capability

The Commission considered that requiring generating systems to have frequency response mode capability is likely to support improved system security outcomes.

Frequency response mode capability is different to the capability to offer one of the market ancillary services. The former is effectively an inherent characteristic of most modern generating systems and should impose very low to zero costs for generators, whereas the latter requires additional investment, registration and compliance testing, resulting in additional costs.

The Commission considered the extent to which mandating this requirement would impose costs on generators. Advice from our expert consultants DigSILENT Pacific and from industry stakeholders was that frequency response mode capability is typically an inherent capability in most modern synchronous and asynchronous generating systems. Furthermore, the commissioning and compliance testing processes for this capability can be significantly less onerous than for the capability to provide one market ancillary service. AEMO 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 noted that the Reliability Panel, in reviewing and developing the *Template for generator compliance programs,* may include in its considerations the nature of compliance testing appropriate for this capability.[150] The Commission also noted that following completion of this rule change, it will ask the Reliability Panel to review the template, with a view to updating it to reflect the changes made to the access standards.

The Commission considered 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. This was on the basis that requiring a generator to record this capability in its performance standards would help to expedite the process for a generator responding to high FCAS prices to bring new FCAS capability to market. This would support system security by facilitating the rapid delivery of this capability when it is needed to address frequency instability.

Other changes to S5.2.5.11

The Commission in its draft rule also made a number of other changes to the minimum access standard, including:

- allowing for both proportional and switched type frequency responses[151]
- clarifying that the frequency response is subject to energy source availability, and
- allowing for generating systems to provide *either* an increase *or* a decrease in active power in response to a change in power system frequency.

The draft rule also made a number of changes to the form of the automatic access standard and to the general requirements:

- Including a requirement in the automatic access standard for generators to have the capability to be in a position to offer measurable amounts of all market ancillary services for the provision of frequency control. The Commission considered this wording was appropriate to reflect the fact that some generating technologies are capable of offering all types of FCAS, while in other cases, the negotiation process will deliver outcomes that reflect the innate capabilities and limitations of other generating technologies.
- Including a general requirement that, when a generator negotiates performance standards with the relevant network service provider, these performance standards record the market ancillary services that the generator will provide. This was intended to provide certainty regarding when the generator has met the automatic access standard, or a negotiated access standard, for the purposes of commissioning and ongoing compliance.
- Specifying that the capabilities described in the automatic access standard are related to the market ancillary services for the provision of power system frequency control only.

150 See: https://www.aemc.gov.au/markets-reviews-advice/template-for-generator-compliance-programs-review.

151 A proportional frequency response denotes a change in the generator's active power output that is a function of the change in power system frequency. A switched response is a change in active power output that occurs as a single block response, once power system frequency has moved past a trigger threshold.

This is to account for the potential emergence of new market ancillary services in future, which may be designed to meet system needs other than for frequency control.

- Removing a number of references and making a number of changes to specific terms and definitions, in order to provide greater clarity as to the function of clause S5.2.5.11 of the NER.

Lastly, the Commission made a number of changes to specify particular parameters relevant to the provision of frequency control services, including introducing the following:

- generators to be capable of setting a deadband within a range of 0 to +/-1 Hz, with an allowance for different deadbands to be set for either a rise or fall in frequency. This was intended to provide greater clarity for generators as to expected frequency response capability.
- generators to be capable of setting a droop response within the range of 2% to 10%. As with the new deadband requirements, this is intended to provide greater clarity to generators in terms of required response.
- a new definition of droop was introduced, to clarify what this term means in the context of the requirement to set droop within defined ranges.
- any active power frequency response to be provided by a generator with no delay once frequency had moved outside of the deadband. This was 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.
- generators are only required to operate in frequency response mode when enabled for the provision of a relevant market ancillary service. This was 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.

5.3.5 Stakeholder views on the draft determination

Some stakeholders supported the concept of requiring generators to have frequency response capability. Advisian stated that the proposed rule was necessary to provide support to the system to manage frequency deviations and should be implemented in conjunction with an overhaul of FCAS arrangements.[152]

Other stakeholders opposed the concept of mandating frequency response mode capability. AGL suggested that the market is best placed to incentivise cost-efficient frequency control services and that the requirement for all generators to have frequency response mode capability pre-empts decisions being made in the AEMC's Frequency control frameworks review.[153]

152 Advisian, submission to the draft determination, p. 1.

153 AGL, submission to the draft determination, p. 4.

TasNetworks raised issue with the definition of 'capability', and suggested that in the context of S5.2.5.11 the term should be interpreted to mean that a generator could be operated in frequency response mode at any time even if not a registered participant in the FCAS markets, as could occur if directed by AEMO for the purposes of maintaining power system security.[154] Energy Networks Australia stated that it is not clear whether capability refers to a physical capability of the procured generation equipment, or whether it needs to have the capability in the installed equipment which is commissioned, tested, ensures operational compliance with other access standards and is then turned off.[155]

Meridian Energy stated that the inclusion of frequency response mode capability in the minimum access standard would have disproportionate capital cost impacts for smaller generators.[156]

Several stakeholders made specific comments on the new definitions and required ranges of deadband and droop. GE Australia recommended that the minimum deadband be set at 10 mHz to avoid units reacting to grid noise.[157] Pacific Hydro argued that allowing deadbands to be set as wide as +/- 1 Hz could mean that generators would be allowed to have controls that do not respond until after the under frequency load shedding (UFLS) commences, that is, when the frequency falls below 49 Hz.[158] Pacific Hydro suggested allowing deadbands to be set as wide as +/- 1 Hz is meaningless in terms of power system control. Pacific Hydro recommended that the deadband capability be altered to be set within the range of 0 to +/- 0.15 Hz.[159]

AEMO also proposed an alteration to the allowable range of droop settings to be included in S5.2.5.11. AEMO stated that a minimum level of 2% droop may place unnecessary restriction on the operation of battery storage, noting that recent battery storage systems have applied a setting of less than 2%. AEMO therefore recommended altering S5.2.5.11(i)(2) to include an allowance for droop settings to be outside of the range of 2% to 10%, as agreed with the network service provider and AEMO.[160]

5.3.6 Final determination

In relation to frequency control requirements in clause S5.2.5.11 of the NER, the final rule largely resembles the draft rule, other than the introduction of new arrangements to allow droop settings to be negotiated outside of the defined range of 2% to 10%.

In making the final rule, the Commission considered the following issues:

- the costs of mandating frequency response mode capability, and existing arrangements for the provision of FCAS
- the meaning of the term 'capability', and

154 TasNetworks, submission to the draft determination, p. 11.
155 Energy Networks Australia, submission to the draft determination, p. 6.
156 Meridian Energy, submission to the draft determination, p. 2.
157 GE Australia, submission to the draft determination, p. 6.
158 Pacific Hydro, submission to the draft determination, p. 5.
159 ibid.
160 AEMO, submission to the draft determination, p. 15.

- specific changes to the proposed droop and deadband ranges included in the draft rule.

Costs of frequency response capability

The Commission notes comments from AGL and Meridian Energy related to whether mandating frequency response mode capability may impose costs on generators, and any overlap with the broader considerations of frequency control included in the AEMC's *Frequency control frameworks review*.

As identified in the draft determination, advice from AEMO and our technical consultants DigSILENT Pacific is that frequency response mode capability is either an inherent characteristic of most modern generating systems, or can be introduced into control software at a very low upfront cost. We also understand that these costs are unlikely to be significantly different for smaller generating systems, although it is acknowledged they could form a slightly larger proportion of the upfront capital costs of such generators.

The Commission also acknowledges that generators may face some minor costs associated with initial commissioning and ongoing compliance testing processes for these capabilities. While we understand that the extent of these costs should be minimal, they will apply to all generating systems through the minimum access standard.[161]

Nevertheless, the Commission remains of the view that the overall benefits of mandating this capability from all generators are likely to outweigh these costs. These benefits flow from streamlining the process for a generator to respond to FCAS prices and become an FCAS provider, which is likely to become increasingly important as existing FCAS providers retire or choose to change operating patterns. This will have positive impacts for consumers in terms of lower FCAS prices overall, as well as contributing to the secure operation of the power system by bringing new frequency control services online when and where they are needed to support frequency stability.

The Commission also notes comments from stakeholders that mandating this capability is pre-empting positions taken in the *Frequency control frameworks review*. The minimum access standard included in the final rule sets a very general requirement for generators to have a baseline frequency response mode capability. This basic capability does not specify any specific kind of frequency control service, nor does it require any party to actually enter the markets for the provision of frequency control services. As such, we do not consider that the final rule in any way pre-empts or otherwise interferes with the more general considerations of frequency control and FCAS markets in the *Frequency control frameworks review*, or in the AEMC's ongoing investigations into frequency control.[162]

161 Following the publication of this final rule, the Commission will request the Reliability Panel to commence a review of the Template for generator compliance programs. This template typically includes mutliple options for the testing of compliance against the various performance standards, with the generator able to select the option that best suits its needs. In developing the template, the Commission understands that the Panel will give consideration as to how the costs associated with compliance testing can be managed for generators, while maintaining effective compliance self assessment processes.

162 The AEMC completed the *Frequency control frameworks review* on 7 July 2018. A major deliverable of the final report was a work plan, developed collaboratively by the AEMC, AEMO and the AER, detailing actions to be taken by the market bodies, in consultation with stakeholders, to address various freqency control issues identified, and recommendations made, in the final report.

The meaning of capability

The Commission notes comments from stakeholders requesting further clarification regarding the meaning and intent of the term 'capability'.

This term is relevant to a number of other parts of the final rule and will be further addressed in the relevant sections of this final determination. However, this section sets out the Commission's consideration of what this term means generally, as well as how it is intended to apply in clause S5.2.5.11.

The Commission considers that the term 'capability' is a different concept to a requirement to deliver a defined and measured response. A generating system's 'capability' or 'ability to' do something, is a requirement that the generating system be readily able to do that thing. This means, the capability is demonstrated as part of the commissioning process on connection. In the context of S5.2.5.11, this includes the demonstrated capability for a generating system to set its deadband within the range of 0 to +/- 1 Hz, or droop response within the range of 2% to 10%. However, this does not translate into any requirement for a defined response in an operational sense.

The requirement or obligation to deliver that capability, operationally, sits outside of the access standard itself. In the context of S5.2.5.11, this translates to the capabilities of a generator that has registered to participate in FCAS markets to deliver an active power response to changes in system frequency, which meets the specific parameters of the frequency control service that it has agreed to provide. This may include specifically defined deadband and droop settings, as well as other parameters as agreed with AEMO under the framework for the provision of FCAS.

TasNetworks suggested in its submission that the requirement in the minimum access standard for generators to be capable of operating in frequency response mode should be interpreted as requiring the generating system to be capable of *operating at any time* in frequency response mode.[163]

The Commission does not consider this to be an appropriate interpretation of the new requirement. As described above, the Commission has sought to distinguish between the requirement to demonstrate a capability, and the requirement to deliver an actual response, in an operational sense.

The Commission considers that under normal operating conditions, generators should only be required to operate in frequency response mode where they have elected to do so, through making an offer to provide frequency control ancillary services. The final rule therefore explictly states that a generator is required to operate in frequency response mode *only*when it is enabled for the provision of a relevant market ancillary service.[164] As such, while all generators should be capable of demonstrating that they can operate in this mode, the actual delivery of a frequency response will occur only where a generator has made the decision to particpate in the markets for the provision of FCAS.

163 TasNetworks, draft determination submission, p. 11.

164 Clause S5.2.5.11(i)(4) of the final rule.

Despite the above, the Commission has been advised that there are some generators who elect to operate generating systems in frequency response mode at times other than when they are enabled for the provision of FCAS. These generating systems may be operated in this manner due to the characteristics of governor control systems, or to support the ability to provide contingency FCAS. The Commission considers that the drafting of the final rule does not preclude generators from operating their generating systems in this manner. The final rule should therefore not be read to in any way preclude or prevent generators from electing to operate their generating systems in frequency response mode at times other than when they are enabled to provide FCAS.

Specific changes to the proposed droop and deadband ranges included in the draft rule

The Commission notes comments from stakeholders regarding the appropriate settings of droop and deadband. Generally, we consider that the way that droop and deadbands are applied in practice falls outside of the scope of this rule change.

For example, Pacific Hydro's recommendation that all deadbands be set within the range of 0 to +/- 0.15 Hz, speaks more to issues of general operational frequency control, which are being considered in the AEMC's ongoing frequency control work program. Similarly, GE Australia's comments related to the appropriate setting of deadbands to avoid "system noise" need to be similarly considered in an operational context and through processes outside of the scope of this rule change.

AEMO also proposed a change to S5.2.5.11 to allow droop to be set outside of the range of 2% to 10%, where there is agreement between the connection applicant, network service provider and AEMO to do this.[165] The Commission understands that this flexibility will support new technologies, including battery storage, that may be capable of delivering valuable system services with droop characteristics that sit outside of the standard range that is likely to be appropriate for most generating systems. The Commission has therefore accepted AEMO's proposed change and has included it in the final rule.

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 (such as synchronous thermal or hydroelectric generating systems) can directly control active power output. These generating systems can typically increase, decrease and hold steady their output within defined limits,

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

and do so in various ways. For larger generating systems, this may involve equipment such as rate limiters, or operating the generating system in different modes.

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.[166]

5.4.2 Current arrangements

Generators are subject to various requirements 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.[167]
- 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.[168]
- Generating units will generally be expected to ramp linearly from their initial energy output or consumption to their dispatch target.[169]
- The NER also impose FCAS cost liabilities on generators, unless the generator "achieves its dispatch target at a uniform rate".[170]

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

166 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.

167 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). All the relevant NER clauses are: S5.2.5.14(a)(1) (automatic) and S5.2.5.14(b)(1) (minimum) in respect of scheduled generators, and clauses S5.2.5.14(a)(3) (automatic) and S5.2.5.14(b)(3) (minimum) for semi-scheduled generators.

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

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

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

These capabilities are set out in clause S5.2.5.14 of the NER, on the basis of the registration classification of a generating system.[171] 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 generating units or systems:
  - 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.[172]
  - Minimum access standard: equivalent to the automatic access standard but with no requirement for linear ramp capability.[173]
- Semi-scheduled generating units or systems:
  - Automatic access standard: subject to energy source availability,[174] the generating unit or 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.[175]
  - Minimum access standard: the generating system must be able to maintain and change its active power output in accordance with its dispatch instructions.[176]
- Non-scheduled generating units or systems:
  - Automatic access standard: the automatic access standard for non-scheduled generating units or systems is the same as the automatic access standard for semi-scheduled generating systems, *except*that it does not include the requirement for the generating system to ramp its output linearly from one dispatch interval to the next.[177]
  - 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

171 That is, different capabilities are required from scheduled, semi-scheduled and non-scheduled generating systems.

172 Clause S5.2.5.14(a)(1) of the NER.

173 Clause S5.2.5.14(b)(1) of the NER.

174 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.

175 Clause S5.2.5.14(a)(3) of the NER.

176 Clause S5.2.5.14(b)(3) of the NER.

177 Clause S5.2.5.14(a)(2) of the NER.

> 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 in a 5 minute period 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.[178]

A key issue to be noted here is that although the NER require most generating systems to have some capability to control active power output, the extent of these obligations can differ markedly across generation registration classes, different generating system sizes as well as between the relevant minimum and automatic access standards. For example:

- 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,[179] and
- 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 for semi-scheduled units to change active power output in accordance with dispatch instructions (i.e. there is no requirement to control level and rate of change under the minimum access standard).

5.4.3 Rule change request

AEMO stated in its rule change request 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:[180]

- market, non-scheduled generating systems or storage systems 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[181]
- 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 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.

AEMO stated that its concern was that the NER:

178 Clause S5.2.5.14(b)(2) of the NER.

179 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.

180 Rule change request, p. 47.

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

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

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.[182]

Given these issues, AEMO proposed the following changes to clause S5.2.5.14 to:[183]

- 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 application of the existing automatic and minimum access standards to 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 Draft determination

This section summarises stakeholder views on the consultation paper and the Commission's analysis of the issues and the key aspects of the draft rule. A more detailed description of the Commission's analysis can be found in Chapter 5 of the draft determination.

Stakeholder views

A number of stakeholder submissions to the consultation paper were supportive of the concept of requiring some ramp limit capability from all generating systems.[184] However, others raised concerns with the potential for cost impacts of this requirement for smaller generating systems.[185]

Stakeholders also discussed use of the term "subject to energy source availability", as proposed by AEMO in its proposed changes to S5.2.5.14(b)(3). In particular, there was some

182 Rule change request, p. 48.

183 ibid.

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

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

discussion regarding whether the new requirements would be viewed as a requirement for the installation of battery storage.[186]

Analysis of the issues

The Commission decided that the issue raised by AEMO was likely to have a material impact and that changes to the NER were warranted

In the draft determination, the Commission set out its reasoning as to why it considered that generator capability to control active power output was necessary to support voltage and potentially frequency stability.

The Commission noted it understands that increased penetration of dispersed, variable, and price responsive generation has the potential to result in substantial swings in active power flows in some parts of the power system. These swings can be driven by changes in the active power output of different types of generating systems. For intermittent, semi-scheduled generating systems, changes in active power output may be driven by changes in the underlying variable energy source, such as changes in wind speed affecting a wind farm, or a cloud passing over a solar PV generating system. For non-scheduled generating systems that participate in the wholesale market, changes in active power output may be driven by changes in the wholesale market price, where these generators maximise active power output to capture a sudden increase in the wholesale market spot price.

The extent of these changes in active power output are likely to become more significant if penetration rates of non-scheduled and semi-scheduled generating systems continue to grow.[187] As particular types of semi-scheduled generation are likely to co-locate in resource rich areas, these rapid changes may be mirrored across a large number of generating systems located in one part of the power system.

If these rapid changes in active power output are uncontrolled, they can have implications for the management of system stability. Primarily, these sudden changes in active power output can destabilise local system voltages.[188] If large enough, they could also theoretically destabilise overall system frequency stability.[189]

While downward swings may not be easily controlled (such as where a cloud passes over a solar PV generating system), the rate at which the active power output of the generating

186 Submissions to the consultation paper: GE Australia, p. 18; Terrain Solar, p. 6.

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

188 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. If voltage instability cannot be controlled properly, it can propagate across the system and lead to voltage collapse, causing other generators to disconnect and interrupting supply to consumers. 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 particularly material impacts on system voltage.

189 AEMO advised that rapid, uncontrolled swings in active power may 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. 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 very 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.

system is then returned to former levels can be controlled. Such control can help maintain the stability, and hence the security, of the power system.

The Commission therefore considered that system security would 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 extended the coverage of the minimum and automatic access standards to all generating systems, including those with a nameplate capacity less than 30 MW.[190] The draft rule also increased the obligations on semi-scheduled generating systems under the minimum access standard, to require these generating units to have ramp limit capability.[191]

The Commission decided that mandating active power control capability from all generators through the minimum access standard was appropriate to address system security issues

In making its decision, the Commission gave particular consideration to the impacts of mandating active power control through making changes to the minimum access standard of S5.2.5.14.

The Commission considered that requiring the capability to control active power met the general approach set out in the assessment framework to the setting of a minimum access standard. It considered that addressing the system security risks identified above requires all generating systems being capable of controlling active power, and therefore warranted its inclusion in the minimum access standard. This includes semi-scheduled generating systems, as well as non-scheduled generating systems.

The Commission gave particular consideration to the impacts of extending the application of the requirements for active power control capability to smaller, non-scheduled generating systems. We considered that it is important these systems are captured by the requirement to be capable of controlling active power, as they are increasingly likely to locate 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. It is therefore important these smaller generating systems 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.

The Commission considered the cost implications for generators to meet the minimum access standard

Generators may face costs in being required to meet the minimum access standards for active power control in the draft rule. However, in the draft determination, the Commission identified that these costs are either nominal, or can be managed through the negotiating process.

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

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

The Commission noted 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.

The Commission identified that there are very low costs associated with installing equipment, or changing control software, to enable semi-scheduled generating systems to be capable of controlling active power output.[192] Furthermore, to clarify that generators will not face costs associated with installing battery storage, the draft rule also included the term "subject to energy source availability" in reference to the requirement to be capable of controlling active power ramp rates.

Smaller non-scheduled generating systems may face (relatively) higher costs to provide active power capability. In the draft determination, the Commission noted 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 could therefore impose additional costs, particularly as this relates to additional communications and remote control equipment.

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

The Commission noted the negotiating process will allow for the appropriate level of active power control capabilities to be determined for non-scheduled generating systems. Where there is a clear system need, the Commission considered 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.[193] 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.[194]

In the draft determination, the Commission decided to expand the application of the requirements for active power control to include non-scheduled generating systems with nameplate capacity less than 30 MW. Recognising that smaller non-scheduled generating systems may face proportionately higher costs to provide this capability, the draft rule reduced 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.[195] This was on the basis that for some non-scheduled generating systems, only minimal active power control capability is likely to be necessary to meet system needs.[196]

192 Semi-scheduled generating systems are already required to exercise some control of their active power, to the extent that they can be required to meet dispatch targets under the minimum access standards.

193 For example, this may be appropriate where a smaller generator seeks to connect at a low voltage, radial part of the distribution network.

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

195 The draft rule removed the requirement from the minimum access standard for non-scheduled generating systems to have the capability to be upgraded to receive electronic instructions from the control centre, as well as allowing for the generating system to set a pre-determined ramp rate where agreed with AEMO and the network service provider.

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.

5.4.5 Stakeholder views on the draft determination

A number of stakeholders made submissions to the draft determination on issues relating to active power control capability.

Ergon Energy and Energex stated that the Commission should clarify the application of the requirements for active power control capability to different generation types.[197]

GE Australia stated that the NER should reflect the fact that ramping in different directions (i.e. ramping from from min or from max generation) should have different ramp rates.[198]

TasNetworks supported the requirement for smaller generating systems to have active power control capability, and noted that an inability to limit the active power response of smaller non-scheduled generating systems with a nameplate capacity of less than 30 MW could result in network voltage control issues and force network operation beyond the technical envelope.[199]

5.4.6 Final rule determination

In relation to active power control, the Commission has made no changes from the draft rule to the final rule.

The Commission acknowledges comments from Ergon Energy and Energex and TasNetworks in relation to the application of active power control capabilities by generation classification and system size. As in the draft rule, the final rule differentiates requirements for active power control capability on the basis of generator registration classification. That is, scheduled, semi-scheduled and non-scheduled generating systems face different requirements, under the automatic and minimum access standards.

The Commission considers that registration classification forms the appropriate basis for the application of these capability requirements for different generators, as opposed to application on the basis of nameplate capacity. While nameplate capacity informs some of the generator registration classifications,[200] other factors are also relevant. The Commission considers that on this basis, the final rule provides adequate clarity as to which generators are required to bring what level of active power control capability.

In relation to the issue raised by GE Australia, the Commission notes that the final rule does not preclude different ramp rates to be set, reflecting whether the change in active power

196 The Commission acknowledged 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 considered it likely that in many instances, these very smallest units are less likely to have a material system impact. The Commission considered it is likely to be appropriate for these generators to propose negotiated access standards closer to the minimum access standard.

197 Ergon Energy and Energex, submission to the draft determination, p. 4.

198 GE Australia, submission to the draft determination, p. 7.

199 TasNetworks, submission to the draft determination, p. 4.

200 Generators classified as non-scheduled are typically in the size range of 5 MW to 30 MW nameplate capacity.

output is from minimum or maximum output. The Commission understands that these ramp rates are determined and applied on an operational timeframe and can be set at whatever value is specified.

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.[201]

The AGC is a control program that operates on a four second cycle (eight seconds in Tasmania) to both monitor and control the output of generating units. It sends data via SCADA networks 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 power system:

- Energy market dispatch of generating units which are on remote control. Dispatch targets from each run of the NEM dispatch engine (NEMDE)[202] are delivered to those generating systems who are enabled to receive these signals via AGC.[203] 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 band, to account for the small frequency deviations that occur as a result of small variations in supply and demand during normal operating conditions. Generators enabled to provide regulating FCAS then receive signals via the AGC to provide incremental increases or decreases in their active power output, to counter these frequency deviations.

Importantly, the AGC acts as a "messenger service" that facilitates the sending of signals to those generating systems participating in the market for regulating FCAS. It can also facilitate the sending of dispatch instructions to those generating systems who have elected to receive their dispatch instructions in this way. AEMO conducts the actual process of dispatch through NEMDE, in accordance with various principles and requirements established elsewhere in the NER.

201 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 and generators, for the purposes of real-time monitoring and control of power transmission and distribution systems

202 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.

203 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).

The Commission's technical consultants, DigSILENT , advised 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 generating systems, the incremental costs of AGC capability are negligible, as larger systems 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 access standards in the NER.

However the NER 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.[204]

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.[205]

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.[206]

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. Scheduled generators are required to meet the dispatch target determined by NEMDE for each dispatch interval, subject to limitations including bid in ramp rates. Semi-scheduled generators, which are usually greater than 30 MW in nameplate capacity and have intermittent output, must meet the dispatch target under specific conditions, but are otherwise free to generate at any level.[207] Generators classified as non-scheduled are not included in the dispatch process.[208]

204 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)."

205 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.

206 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.

207 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.

208 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.

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: "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."[209]

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:[210]

- 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.[211] To the extent that these generators are deviating from a smooth ramp 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.[212] 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.[213] This could assist in managing the consequences of the non-credible contingency and help to reduce the probability of load shedding.

209 Rule change request, p. 45.

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

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

212 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.

213 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.

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.

Given the above, 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 comprised of generating units with a combined 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 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 only intended to result in smaller generating systems being required to meet the part of the access standard related to limiting active power and ramp limit capability. AEMO advised that its 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 Draft determination

This section summarises stakeholder views on the consultation paper and the Commission's analysis of the issues and the key aspects of the draft rule. A more detailed description of the Commission's analysis can be found in Chapter 5 of the draft determination.

Stakeholder views

A number of stakeholders expressed in their submissions to the consultation paper general 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.[214]

Various stakeholders cautioned that any application of the requirement for AGC capability could impose disproportionate costs on smaller generators.[215]

214 Submissions to the consultation paper: CEC, p. 31; Advisian, p. 3; TasNetworks, p. 22.

215 Submissions to the consultation paper: CEC, p. 30; ASMC, p. 6; TasNetworks, p. 14.

Other stakeholders suggested that operational conflicts could exist between AGC mediated dispatch / regulating response and governor mediated frequency response of a generator.[216]

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.[217]

Analysis of the issues

The Commission considered that there were likely to be a number of benefits associated with mandating AGC capability

AGC capability may support other system security outcomes, both currently and in future.

This could include helping to minimise the extent of regulating FCAS needed to maintain power system frequency.

AGC can be used to co-ordinate the smooth ramping of generating plant[218] between 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.[219]

By supporting generators in meeting their dispatch targets in a smooth manner, AGC capability may help to reduce the need for regulating services, with both cost and security benefits for consumers. AEMO advised that:[220]

> regulating FCAS services are acquired to manage the supply/demand balance where there are small deviations between forecast load and 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

216 Submissions to the consultation paper: Hydro Tasmania, p. 14; Pacific Hydro, p. xviii.

217 Hydro Tasmania, submission to the consultation paper, p. 14.

218 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.

219 The Commission understands that while a generating system's 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 - i.e. they may be subject to "target error". 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.

220 Advice from AEMO, received via email 20 April 2018.

> deviate for a significant period of time.

AEMO also advised that generating systems with AGC capability may be able to help support emergency management of frequency deviations.

AEMO 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.[221] As advised by AEMO, the AGC could be used for the purposes of:[222]

> 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 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 considered that if this AGC capability was implemented by AEMO 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 considered that this particular benefit requires that all, or at least a majority of scheduled and semi-scheduled generating systems, have AGC capability.

The Commission also noted that the costs of providing AGC capability appeared to be very low for most scheduled and semi-scheduled generators

The Commission's technical advisers, DigSILENT Pacific, and a number of stakeholders 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 Commission considered that AGC capability may support more efficient power system operation and has the potential to support improved system security outcomes in the future. Given the very low costs associated with installing this capability for new generating systems, the Commission considered that it should be included in both the automatic and minimum access standard for scheduled and semi-scheduled generation.

221 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.

222 Advice from AEMO, received via email 20 April 2018.

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 included a requirement for AGC capability from scheduled and semi-scheduled generators only.[223]

5.5.5 Stakeholder views on the draft determination

WSP commented that requiring AGC capability from smaller generators would impose material costs. WSP suggested that the AEMC consider removing this requirement to receive AGC signals, which could otherwise result in significant cost to smaller generators where they are not required to receive AGC signals.[224]

5.5.6 Final rule determination

In relation to AGC capability, the Commission has made no changes from the draft rule to the final rule.

The Commission notes comments from stakeholders regarding the application of AGC capability to smaller generators, and that mandating this capability could impose proportionately greater costs for these generators.

However, as noted above, the final rule only requires scheduled and semi-scheduled generators to have AGC capability. Most smaller generating systems (i.e. those generating systems with nameplate capacity less than 30 MW) are likely to be classified as non-scheduled and will therefore not be required to have AGC capability.

223 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.

224 WSP, submission to the draft determination, p. 5.

6 REMOTE MONITORING AND CONTROL

BOX 4: 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 new remote control and new remote monitoring capabilities under both the automatic and minimum access standards in clause S5.2.6.1.

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 final rule 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 minor changes.

The final 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 remote monitoring capability requirements for generating systems connecting to the power system. 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.[225]

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 (as applicable)
  - 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 reasonably required to discharge its market and power system security functions as set out in Chapters 3 and 4 of the NER.

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

225 This exclusion is expressed in the automatic access standard as applying to non-scheduled generating systems and generating units, whereas for the minimum access standard this exclusion is expressed as applying to non-scheduled generating systems only. Clauses S5.2.6.1(a)(3) and (4), as well as clauses S5.2.6.1(c)(3).

- 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. It also argued that greater remote monitoring and control will deliver more efficient operation of the power system.[226]

Specifically, AEMO advised that "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."[227]

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.[228]

Finally, AEMO advised that additional information on battery storage systems was required to support the integration of these systems into the central dispatch process.[229]

AEMO proposed a number of changes to both the minimum and automatic access standard under clause S5.2.6.1 of the NER.[230] These included:

- Amending both the automatic and minimum access standard to apply to all generating systems, and removing the current specificity of application to scheduled, semi-scheduled and non-scheduled (30 MW or greater) units and systems.[231]
- 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.

226 Rule change request, pp. 48-49.

227 ibid.

228 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.

229 Rule change request, pp. 48-49.

230 Most of these changes were included in the detailed proposed drafting that was attached to the rule change request.

231 Note that AEMO's proposed drafting retained specific exclusions for generating systems with nameplate capacity of less than 30 MW units within the specific sub-clauses of S5.2.6.1.

- 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 of the scheme, active power, reactive power or any other control limit as applicable, and
  - 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, and
  - 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.

6.4 Draft determination

This section sets out the analysis and conclusions of the Commission in its draft determination, including the draft rule.

6.4.1 Stakeholder views

A number of stakeholders commented on AEMO's proposed changes in their submissions to the consultation paper.

Several stakeholders considered that AEMO's proposed changes would impose material costs on connection applicants, particularly for the connection of smaller generating systems. It was argued these costs would make new generation less competitive than incumbents. Some stakeholders therefore suggested that the AEMC reject AEMO's proposed minimum access standard for remote monitoring and control.[232]

Other stakeholders noted that these requirements could impose material costs if imposed on existing generators, potentially in the order of $50,000 to $5 million.[233]

232 Submissions to the consultation paper: Advisian, p. 15; Pacific Hydro, p. xxx.

233 Submissions to the consultation paper: Alinta, p. 4; Origin Energy, p. 10; Hydro Tasmania, p. 14.

Stakeholders also questioned why AEMO required some of the information proposed through the new remote monitoring capabilities. In particular, it was noted that AEMO did not require information on the energy available in battery storage facilities.[234]

Questions were also raised in terms of how 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.[235]

AEMO stated that the capabilities being sought were reasonable and that, given such functionality is widely used, should result in minimal additional cost.[236]

6.4.2 Analysis of issues

In the draft determination, the Commission considered:

- whether smaller generating systems should be required to have remote monitoring and control capabilities
- the appropriate levels of the automatic and minumum access standards
- what kinds of remote monitoring and control capabilities should be included in the automatic access standard, and
- whether the access standard should explicitly account for the remote monitoring of the energy available in energy storage facilities.

Coverage of non-scheduled generators

The draft rule expanded the coverage of the automatic and minimum access standard of S5.2.6.1 to apply to all non-scheduled generating systems, including those with a nameplate capacity of less than 30 MW.[237]

The Commission considered that this expansion of application was appropriate, on the basis of likely increases in the number of non-scheduled generating systems connecting, potentially in lower voltage parts of the power system where their connection may have more material impacts on voltage stability.[238]

However, as discussed below, the Commission also recognised that the full suite of remote control and monitoring capabilities would not necessarily be required from all generating systems in all locations on the power system. Accordingly, the draft rule maintained the range between the levels of the automatic and minimum access standard, to allow for the appropriate level of capability to be determined through the negotiation process, on a case by case basis.

234 CEC, submission to the consultation paper, p. 32.
235 Pacific Hydro, submission to the consultation paper, p. xxx.
236 AEMO, submission to the consultation paper, p. 27.
237 Clauses S5.2.6.1(a) and (c) of the draft rule.
238 Ergon Energy, submission to the consultation paper, p. 8.

Minimum and automatic access standard

The Commission considered that the suite of remote monitoring and control capabilities as described in the automatic access standard are unlikely to be required in all parts of the power system or at all connection points. The Commission also noted that making the minimum access standard more or less equivalent to the automatic access standard, as proposed by AEMO, could have the effect of imposing materially higher costs on all generators.

The Commission therefore considered that the negotiating process remained 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 retained the existing minimum access standard, subject to a minor change to better describe the kinds of data that must be provided by semi-scheduled generating systems.

Changes to the automatic access standard

The draft rule included a number of specific changes to the automatic access standard. This included specifying a number of additional remote monitoring capabilities that AEMO may request from generators. This included expanding the coverage of existing monitoring capabilities to all generator types, as well as listing several new monitoring capabilities including: clarification of the required remote monitoring capabilities of semi-scheduled generators; active power data; data related to run back schemes and data related to the mode of operation of a generating system.

The draft rule also introduced several remote control capabilities. The Commission considered these remote control capabilities generally supported changes made to other parts of the access standards, such as changes to the automatic access standard in clauses S5.2.5.13 and S5.2.5.14 of the NER related to remote control of voltage setpoint and AGC.

The format of the existing automatic access standard provides guidance on the remote monitoring capabilities that AEMO may request from generators, being 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 was satisfied that each of these new monitoring and control capabilities are capabilities that AEMO could reasonably request to meet these obligations.

The Commission noted comments from stakeholders regarding potential issues related to the implementation of remote control, particularly for voltage control. The Commission expects that any implementation 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.

Remote monitoring capability for energy storage systems

AEMO's rule change request proposed a requirement for remote monitoring capability for energy storage systems, to provide information on the available energy of the storage system. AEMO advised this was intended to support the accuracy and effectiveness of the 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 offer / price bands, and their offers 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 as open cycle gas turbine generating systems with limited 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.

In the draft determination, the Commission considered that generators 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 would therefore be included in the generator's decision to self-commit, in its pre-dispatch offer and price bands and in its final offers to the wholesale market.

The Commission therefore considered that 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.

6.5 Stakeholder views on the draft determination

A number of stakeholders made submissions to the draft determination on issues relating to remote monitoring and control capability.

A key issue raised was the potential impact of increased remote monitoring and control capabilities on the SCADA systems on transmission and distribution networks. A number of network businesses advised that the SCADA communication and processing capabilities of their networks are already under pressure, and that any increase in the volumes of data traffic on these systems, caused by increased remote monitoring and control capabilities, could be problematic and costly to address.

For example, TransGrid noted that it should not be assumed that increased data capability required can be met by all existing SCADA systems immediately. TransGrid noted that, at present, its SCADA hardware and software will reach a maximum limit by 2020. Although it noted that its SCADA systems are currently being reviewed and potentially enhanced, it also advised that industry experience is that 5-10 years is the expected time to complete such a process.[239]

This point was reflected in the submissions of a number of other parties. For example, Energy Networks Australia and TasNetworks noted that while there was likely to be value in

239 TransGrid, submission to the draft determination, p. 9.

increased communications from smart enabled technologies, efforts should be made to limit additional data flows if this was likely to have negative impacts on networks' communications systems.[240]

This issue was also noted by Ergon Energy and Energex, who, along with Energy Networks Australia, suggested that some form of modelling or analysis be undertaken to understand the impact of the new requirements on SCADA systems.[241] The Clean Energy Council cautioned against rapid implementation of any new remote monitoring and control requirements, given the extent of signal congestion currently being experience by network SCADA systems.[242]

Meridian Energy and Advisian questioned whether the new requirements should be imposed on smaller or remotely located generators, given the higher costs potentially faced by these generators, and whether this data was needed on a real time basis for smaller units.[243]

AEMO made a number of comments in its submission to the draft determination:[244]

- AEMO reiterated its argument for the inclusion of remote monitoring capabilities for energy storage facilities on the basis this would allow it greater visibility of the dispatch process and better enable it to manage the consequences of errors made by participants in dispatch. AEMO noted that it has experienced occasions when energy committed in pre-dispatch and dispatch offers has been unavailable in practice. It asserted that having visibility of actual energy in energy storage systems was necessary, as these systems have the capability to be charged or depleted rapidly. AEMO also argued that the provision of a single monitored quantity about the available energy in a storage system should present little more than a marginal additional cost.
- AEMO also noted that its original proposal for clause S5.2.6.1 had included a consolidation of the types of generation to which each of the automatic and minimum access standards applies. It stated that it did not consider that each type of generating unit/system should be listed separately. In line with this, AEMO stated that that minimum access standard should be applied to all generation types, including non-scheduled generating units.[245]

6.6 Final determination

In relation to remote monitoring and control, the Commission has made no changes from the draft rule to the final rule.

In making the final rule, the Commission considered:

240 Submissions to the draft determination: TasNetworks, p. 3; ENA, p. 7.

241 Submissions to the draft determination: Energy Networks Australia, p. 7; Ergon Energy and Energex, p. 4.

242 Clean Energy Council, submission to the draft determination, p. 2.

243 Submissions to the draft determination: Meridian Energy, p. 2; Advisian, p. 2.

244 AEMO, submission to the draft determination, p. 17.

245 AEMO is here referring to the drafting of clause S5.2.6.1(c), which lists all the types of generating units and systems to which the minimum access standard applies. This clause currently only references non-scheduled generating *systems,* **not non-scheduled generating *units.* AEMO consider that the clause should be amended to refer to all generation types, which would have the effect of extending its coverage to non-scheduled generating units.**

- the nature of the SCADA data issues identified by stakeholders, and the extent to which including new remote monitoring and control requirements was likely to exacerbate those issues
- whether smaller non-scheduled generating systems and units should be covered by the minimum access standard of S5.2.6.1, and
- whether the automatic access standard of S5.2.6.1 should include remote monitoring requirements for energy storage.

6.6.1 SCADA data issues

As noted above, several stakeholders considered the new remote monitoring and control capabilities in the draft rule would impact on congestion in the SCADA data communications and processing systems operated by network service providers. A number of stakeholders also raised this as a material issue in the stakeholder workshop that was held in Sydney on 26 June 2018.

The Commission understands that issues relating to congestion on SCADA communications systems are being driven by a number of factors.

Firstly, new generating systems are typically being designed with greater inbuilt monitoring capabilities, and subsequently create larger volumes of data to be carried and processed by SCADA communications systems.

Secondly, the number of new generating systems connecting to the power system has increased in recent years, driving further increases in data flows on SCADA communication systems.

Further, the Commission has been advised that many new generating systems are connecting in parts of the power system that are distant from the fibreoptic communications backbone of the transmission network, where there may be spare bandwidth to support increased data flows.

The Commission appreciates that many network service providers are facing challenges in terms of transmitting and processing increased SCADA data traffic. However, we consider that the kinds of SCADA data that may be required under the new remote monitoring and control capabilities are unlikely to add materially to these already existing issues. The Commission has also been advised that most of the remote monitoring capabilities described are unlikely to require significant bandwidth, even if required to be delivered at four second intervals.

More generally, we understand that network service providers and AEMO are working to manage issues related to the increase in SCADA data traffic on network communication and processing systems. Indeed, the kinds of general issues raised by stakeholders are best addressed through AEMO and industry working together to identify workable solutions, rather than through the access standards in the NER.

The Commission considers AEMO should work proactively with network service providers when determining whether remote monitoring and control quantities are essential, with a view to understanding and minimising the impacts of requiring these capabilities on networks when they negotiate performance standards with connection applicants. In doing so, AEMO should turn its mind to the impacts on SCADA communications systems when requesting additional monitoring data and remote control capabilities from connecting generating systems.

Finally, the Commission notes that clause S5.2.6.1 provides specific guidance to AEMO in terms of what remote monitoring and control capabilities it can reasonably request from connecting generators. Clause S5.2.6.1 identifies that remote monitoring and control capabilities must be sufficient to transmit to and receive from AEMO's control centres the quantities that AEMO *reasonably requires to discharge its market and power system security functions*. More generally, the negotiating process only allows AEMO to request capabilities from generators that are needed for the purposes of maintaining system security.

Given these factors, the Commission considers that, at this stage, to address the issues raised by stakeholders regarding increased data traffic on communications infrastructure it is not necessary to impose any further restrictions or limitations on AEMO's ability to request remote monitoring and control capabilities from generators.

6.6.2 Coverage of smaller generating systems

The Commission notes comments from stakeholders on the potential cost implications for smaller generating systems if they are required to provide levels of remote monitoring and control capability that is closer to the level of the automatic access standard.

These costs may be related to the increased complexity of monitoring and communications equipment that the generator may be required to include in its plant specification. They may also be affected by where in the power system the generating system connects.

Generators connecting in more remote parts of the system may face greater network connection charges, reflecting the costs of delivering necessary communication capabilities in those parts of the power system.

The Commission acknowledges that smaller non-scheduled generating systems could potentially face relatively higher costs if they are required to provide levels of remote monitoring and control capability that are closer to the automatic access standard.

The Commission considers that the negotiating framework forms the appropriate basis to determine what capabilities are required from each generating system, and what costs they should reasonably incur, on the basis of clearly identifed system needs. All connection applicants, including proponents of smaller non-scheduled generating systems, should consider the likely impact of their connection on the power system and account for this in the performance standards they propose to the relevant network service provider.

The Commission has deliberately retained a broad range between the levels of the automatic and minimum access standards in clause S5.2.6.1. Connecting generators, AEMO and the relevant network service provider will need to work together to identify the appropriate level of capability between the automatic and minimum access standard for each connecting generating system on the basis of the principles set out in the negotiating framework.

Other stakeholders raised questions as to whether some of the remote monitoring capabilities would be required to be delivered on a real time basis.

The Commission understands that delivery of many of the remote monitoring and control capabilities referred to in S5.2.6.1 are necessary on a real time basis as these quantities are central to AEMO's ability to effectively operate the power system. Clause S5.2.6.1(a) of the NER therefore refers to the provision of the quantities described in the clause on a real time basis.

The Commission also notes comments from AEMO on the application of clause S5.2.6.1 to each generator registration class, and to non-scheduled generating units.

The Commission considers that, as the coverage of clause S5.2.6.1 has been expanded to include non-scheduled generators with a nameplate capacity of less than 30 MW, it is appropriate for the level of the minimum access standard to be set in a way that accounts for the likely impact of these smaller generating systems on the power system.

We therefore consider it is appropriate for the minimum access standard of S5.2.6.1 to apply to non-scheduled generators at a generating system level, rather than at a generating unit level. This is on the basis that application at the generating system level is likely to be appropriate for some of the smallest non-scheduled generating systems, where these systems have only a minor system impact.

For this reason, the Commission has decided to retain in the final rule the structure of clause S5.2.6.1 as set out in the draft rule, to apply to each generation type by generation registration class, and for the minimum access standard specifically to apply at the generating system level for non-scheduled generators.

6.6.3 Remote monitoring for energy storage

In its submission to the draft determination, AEMO reiterated the rationale for its original proposal that remote monitoring of energy storage facilities should be included in S5.2.6.1.

In subsequent discussions, the Commission understands that AEMO's key concern relates to the potential for the rapid charge and discharge capabilities of battery storage systems to result in unexpected energy spikes or shortfalls that would have the effect of reducing the accuracy of its own pre-dispatch forecasting processes.

AEMO considered that real time monitoring of energy storage systems will allow it to effectively 'confirm' whether the information contained in generator dispatch offers is an accurate reflection of the energy that will actually be available from a generator from any battery storage facilities behind its connection point.

The Commission notes the concerns raised by AEMO. However, we also understand that, at present, there is no direct evidence to suggest that the increased penetration of battery storage systems will translate into increased incidence of generators deviating from their obligations to conform to their dispatch offers, as specified under Chapters 3 and 4 of the NER.[246]

Furthermore, aside from these general requirements to conform to dispatch offers, we note that generators face a number of other disincentives to deviate from their dispatch offers, including the potential for incurring causer pays penalties due to resultant regulating FCAS liabilities caused by their energy deviation.

Real time monitoring of energy levels in battery storage systems may also not necessarily provide AEMO with information that would translate into improved forecasting accuracy. As noted by stakeholder submissions to the consultation paper,[247] it is possible that energy stored in a battery system may be held in reserve for other purposes, such as to meet a network support agreement with the local network service provider. In this case, information on the amount of energy in the battery would not necessarily provide AEMO with any greater transparency in terms of likely dispatch outcomes.

Finally, the Commission notes general comments from stakeholders as to the costs associated with additional monitoring capabilities, including the cost implications for network service providers in dealing with additional data quantities on their SCADA networks.[248] While we acknowledge AEMO's argument that these costs may not be significant, stakeholders have reasonably questioned whether additional costs should be imposed where there is no clear evidence as to the neccessity for the capability.

Generally, the Commission is satisfied that the existing frameworks for self commitment and pre-dispatch are sufficient to provide AEMO with all the tools necessary to support an efficient dispatch process. If, in the future, there is evidence that technology changes are driving a deterioration in the effectiveness of these frameworks, the Commission considers this should be dealt with through a rule change that would consider these frameworks in a holistic manner.

246 Generators are responsible for providing information on the energy volumes that they will provide through the self committment information that they must provide to AEMO. They are then required to meet those self commitment obligations. These obligations are set out in clauses 4.9.6, 4.9.7 and 3.8.17, amongst others.

247 Clean Energy Council, submission to the consultation paper, p. 32.

248 Submissions to the consultation paper: Alinta, p. 4; Origin Energy, p. 10; Hydro Tasmania, p. 14.

7 REACTIVE POWER CAPABILITY

BOX 5: OVERVIEW

The current arrangements in clause S5.2.5.1 of the NER require no minimum capability 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 may 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 does not have an advisory function in the current arrangements for reactive power capability, there is a risk that in some cases the capability required of a connecting generating system may not be sufficient to maintain the security of the power system. This is because, while network service providers consider the impact on their ability to meet the system standards, AEMO has a separate role through its advisory function to explicitly consider whether a proposed negotiated access standard would adversely affect power system security.

The Commission also considers that the current guidance in clause S5.2.5.1 on what circumstances should be taken into account when negotiating is unclear and may result in inefficient outcomes in some cases.

To address these issues, the Commission's final rule:

- specifies clause S5.2.5.1 as an AEMO advisory matter, and
- changes the guidance on negotiated access standards to:
  - include reference to the need for the level of reactive power capability to be sufficient to support the security of the power system, and
  - clarify the circumstances that may be taken into account by the parties when negotiating.

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
- the Commission's draft determination, and
- the Commission's final determination.

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.[249] Networks commonly install reactive power equipment, including shunt capacitor banks, static volt-ampere reactive (VAR) compensator (SVC), and static synchronous compensators (STATCOM), to manage

249 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.

voltages across their networks and facilitate the transfer of active power to network users.[250] Some load also install reactive capability to maintain their power factor near unity.[251]

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:

- 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:

250 SVCs and STATCOMs are devices that provide fast acting reactive power response through power electronic controlled banks of capacitors and reactors.

251 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.

- 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:[252]
  - 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,[253] 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.[254]

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:[255]

- 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 projects 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.[256]

Clause 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 arrangements if necessary under certain operating conditions, in order to provide the agreed capability.[257]

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.

252 Clause S5.2.5.1(a) of the NER.

253 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.

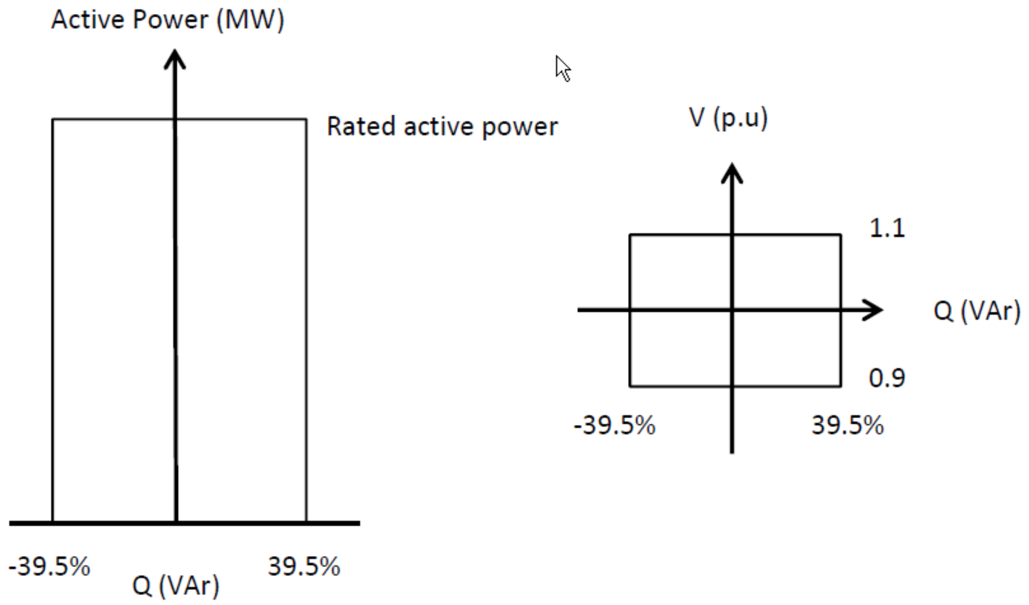
254 Clause S5.2.5.1(b) of the NER.

255 Clause S5.2.5.1(c)(1-3) of the NER.

256 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.

257 Clause S5.2.5.1(d) of the NER.

Figure 7.1: Automatic access standard requirements for reactive capability Q(VAR) as a function of active power (MW) and voltage V(p.u)



Reactive power 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.[258]

The voltage control requirements 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.[259] Expressed another way, once the amount of

258 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.

259 Clause S5.2.5.1(c)(1) of the NER.

reactive capability a generating system is required to 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 full reactive capability 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.[260]

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 reactive capability, power system security and the quality of supply may be placed at risk.[261]

AEMO therefore argued a minimum access standard that requires some level of reactive power capability is required to maintain power system security.[262] 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:[263]

"a generating system operating at:

- any level of active power output, greater than 10% of its maximum operating level,[264] and
- any voltage at the connection point within the limits established in clause S5.1a.4 without a contingency event[265]

260 Rule change request, p. 21.

261 ibid.

262 ibid.

263 Rule change request, p. 22 and AEMO, Generator technical requirements: supplementary material to rule change proposal.

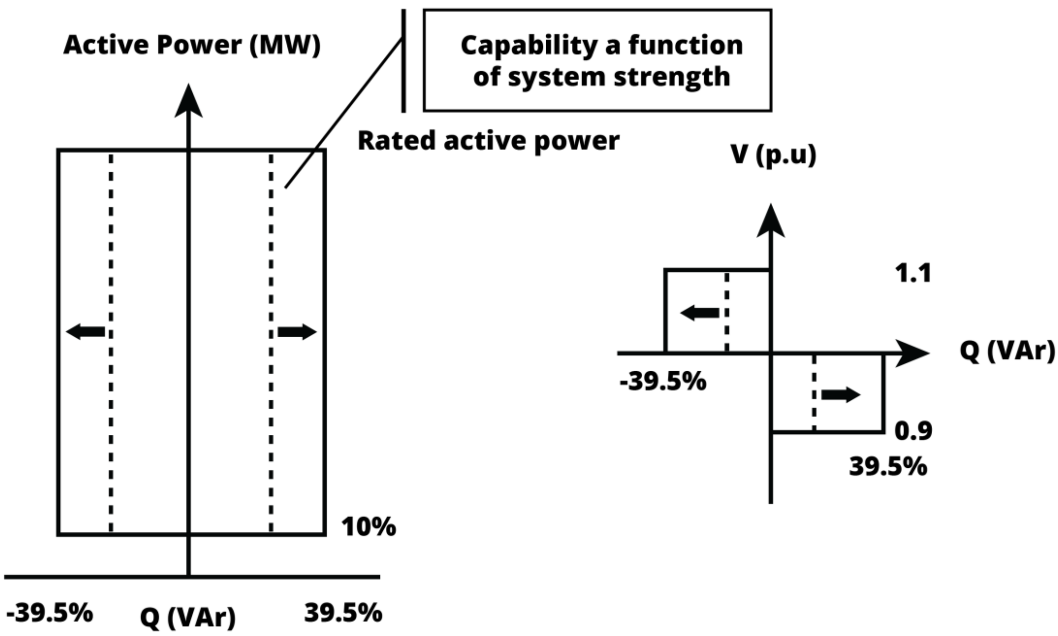
264 The words "greater than 10% of its maximum operating level" were added by way of clarification in AEMO, Generator technical requirements: supplementary material to rule change proposal.

265 S5.1a.4 requires maintenance of voltages between 90% and 110% of normal on a continuous basis in the absence of a contingency event.

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."[266]

AEMO did not propose changes to the existing automatic access standard or general requirements.[267]

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.[268] This was inserted by way of clarification and did not affect the substance of the provision.

266 Rule change request, proposed rule, clause S5.2.5.1(b).

267 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.

268 AEMC AEMO, overview of all policy positions workshop, 3 May 2018.

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 depicted as a dashed line within the envelope set by the automatic access standard.[269] 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 was 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.[270] 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,[271] and
- the proposed minimum access standard is independent of generating system capacity.

Greater amounts of reactive power are required to shift the voltage in parts of the power system with high fault currents - or 'strong' parts of the system. The effect of this is 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.[272]

7.5 Stakeholder views

In response to the rule change request, stakeholders were mostly concerned about AEMO's proposed minimum access standard. Generators had particular concerns that AEMO's proposed approach:

269 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.

270 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.

271 Rule change request, suggested rule, S5.2.5.13(d)(3)(i).

272 AEMO, Supplementary material to the rule change proposal, October 2017, p. 5, available at www.aemc.gov.au.

- included a link with clause S5.2.5.13 that would mandate high levels of reactive power capability in strong parts of the power system, with the outcome that the required capability is not aligned with the power system need[273]
- was either unachievable or could only be achieved at significant additional cost,[274] particularly where a connection point is in a strong part of the power system,[275] and
- is not linked to generating system capacity, placing a disproportionate burden on small generators.[276]

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.[277] 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.[278]

A number of network businesses supported AEMO's proposal.[279] Powerlink considered the proposal provided a framework for efficiently delivering the voltage support and control services required for the current and future operation of the power system.

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.[280]

While the majority of stakeholders did not support AEMO's proposed minimum access standard, there was some 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.[281]

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,[282] with some regarding AEMO's proposal as representing a material shift in responsibility from network businesses to generators.[283]

273 Submissions to the consultation paper: Advisian, p. 6; Terrain Solar, p. 4; RES Australia, p. 6; First Solar, p. 3; ESCO Pacific, p. 8; Engie, p. 2; Pacific Hydro p. vii.

274 Submissions to the consultation paper: Advisian, p. 6; Terrain Solar, p. 4; First Solar, p. 3; Pacific Hydro, p. 3; Origin Energy, p. 4.

275 Advisian, submission to the consultation paper, p. 6.

276 Submissions to consultation paper: Advisian, p. 6; Terrain Solar, p. 4; First Solar, p. 3; Edify Energy, p. 3.

277 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.

278 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.

279 Submissions to consultation paper: TransGrid, p. 3; Powerlink, p. 3; Ausgrid, p. 1; ENA, p. 1.

280 TasNetworks, submission to the consultation paper, p. 6.

281 Submissions to consultation paper: Tilt Renewables, p, 3; ESCO Pacific, p. 8; Hydro Tasmania, p. 5.

282 Submissions to consultation paper: Terrain Solar, p. 4; RES Australia, p. 6; SMA, p. 3; ENA, p. 1.

283 Submissions to consultation paper: Terrain Solar, p. 4; RES Australia, p. 6.

More detailed discussion of stakeholder views on the rule change request is provided in section 7.5 of the draft determination.

7.6 Draft determination

The Commission noted in the draft determination that it agreed with AEMO that sufficient reactive power capability is required to maintain an AC power system in a secure operating state. It considered that changes to the NER may be justified where existing frameworks can be shown to not efficiently provide the required level of reactive power.

7.6.1 Existing frameworks for reactive power capability

The NER place primary responsibility for the management of voltage with the network service provider,[284] who is required to design and operate its transmission or distribution network so that connection point voltages fluctuate only within 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.[285]

The reactive power capability negotiated under clause S5.2.5.1 is based on the extent to which a connecting generating system's reactive capabilities contribute to a network service provider's ability to manage voltages according to the requirements in the system standards. Clause S5.2.5.1 requires the provision of reactive power capability by the generator sufficient for the network service provider to meet all relevant system standards before and after credible contingency events, taking into account at least existing projects and considered projects.[286]

Current arrangements therefore do not require a connecting generating system to provide a level of reactive power capability to support the potential needs of the power system, beyond taking into account existing projects and considered projects. Existing frameworks account for future changes in power system conditions, beyond the time frame of existing projects and considered projects, by placing responsibility on network businesses to manage power system implications of circumstances such as generating system retirement, through a network business' regulatory investment tests for transmission and distribution (RIT-T and RIT-D),[287] AEMO's functions as transmission planner and its publication of the National Transmission Network Development Plan (NTNDP), and through the Network Support and Control Ancillary Services (NSCAS) framework.[288]

AEMO also 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

284 Clause S5.1.5 of the NER.

285 Clause S5.1a.4 of the NER.

286 Clause S5.2.5.1(c)(1) of the NER.

287 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.

288 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.

operating voltage conditions.[289] The NER require AEMO to use its reasonable endeavours to maintain voltage conditions so that the power system remains in a satisfactory operating state.[290] As part of its responsibilities for system security, AEMO has an operational role in dispatching reactive power including:[291]

- 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.

The Commission also noted in its draft determination that clause S5.2.5.1 is not an AEMO advisory matter. As a result, AEMO is not explicitly required to provide advice to network service providers on whether a proposed connection would adversely affect power system security. The Commission considered that without the ability for AEMO to advise on the level of reactive power capability needed for a connection, there is a risk that insufficient capability is provided to address system security needs.

7.6.2 Level 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.

The Commission noted in its draft determination that it considered 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 projects and considered projects.

The Commission also considered that the existing arrangements broadly remain appropriate. That is, arrangements that 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 providers and AEMO. As this flexibility is provided by the range between the automatic access standard and the minimum access standard, the Commission considered a minimum access standard requiring no reactive power capability remains appropriate.

The Commission considered this was consistent with a minimum access standard that 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.

In arriving at this conclusion, the Commission noted the views of stakeholders that there may be circumstances where a generating system may not need to provide reactive power

289 Clause 4.5.1 of the NER.

290 Clause 4.5.1(e) of the NER.

291 Clauses 4.5.1 and 4.5.2 of the NER.

capability, such as a generating system connecting to the same substation as a large SVC.[292] The Commission therefore did not consider there to be a clear system need for a particular level of reactive power capability from all generating systems, irrespective of power system conditions at their point of connection.

The Commission also noted that the costs of mandating the minimum level of reactive power capability for all generators, as proposed by AEMO, could be significant. 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.

The Commission considered that a single generating system having little or no reactive capability would not automatically increase the risk of voltage instability and collapse, unless there is also insufficient reactive capability available from other nearby sources. The Commission considered it is the role of the negotiating framework to set an appropriate level of reactive power capability on a case by case basis.

7.6.3 Draft rule

To address the issues identified above, the Commission made a draft rule:

- specifying the access standard for reactive power capability in clause S5.2.5.1 as an AEMO advisory matter[293]
- including in the access standard for reactive power capability a requirement that a negotiated access standard be consistent with maintaining power system security, taking into account existing projects and considered projects,[294] and
- changing 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.[295]

The Commission considered that making clause 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 noted 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 would therefore be consistent with AEMO's responsibility for power system security, and its role in related access standards.

The Commission considered a further amendment was also needed to clearly incorporate power system security considerations in the assessment of proposed negotiated access standards under clause S5.2.5.1. The draft rule therefore included further guidance in the access standard that a negotiated access standard must be consistent with maintaining power system security, taking into account at least existing projects and considered projects.

292 ESCO Pacific, submission to the consultation paper, p. 8.

293 Chapter 10 of the draft rule defines the standards that are AEMO advisory matters.

294 Clause S5.2.5.1(c)(1) of the draft rule.

295 Clause S5.2.5.1(b) of the draft rule.

This was consistent with existing guidance for network service providers relating to their assessment and the need to maintain quality of power supply to other network users.

The Commission rejected AEMO's proposed minimum access standard that would have required, at a minimum, all generating systems to 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. This was rejected because it would have required significantly more reactive capability than was needed in many situations. Furthermore, the Commission found that the level of the current minimum access standard, being no capability, may be appropriate in some situations.

While the Commission did not consider a minimum level of reactive power capability to be required, the draft rule changed the minimum access standard to more clearly define a continuous range over which negotiation can occur. To achieve this, the draft rule sought to express the minimum access standard in the same form as the automatic access standard. The minimum access standard in the draft rule was "a generating system operating at any voltage at the connection point within the limits established under clause S5.1a.4 without a contingency event, must be capable of supplying and absorbing continuously at its connection point an amount of reactive power of at least the amount equal to zero."[296]

7.7 Stakeholder views on the draft rule

Stakeholders commented on the level of the minimum access standard, the way the minimum access standard was expressed in the draft rule, and the need for further clarity in the guidance for negotiations on this access standard.

The few stakeholders that commented on this matter supported the decision to include clause S5.2.5.1 as an AEMO advisory matter.

7.7.1 Level of the minimum access standard

Most stakeholders did not comment on the draft rule maintaining a minimum access standard that does not require a specific level of reactive power capability. Those that did comment were generally supportive of the draft rule.[297] Lloyd's Register particularly supported the recognition that circumstances exist where the provision of reactive power capability is immaterial to system security or to quality of supply.[298] Origin Energy and Lloyd's Register both commented that the appropriate level of reactive power capability will depend on the particular network and location within that network of the generator's connection point.[299]

AEMO did not support the draft rule retaining a minimum access standard that did not specify a minimum reactive power capability, and proposed an alternative approach.[300] AEMO stated

296 Clause S5.2.5.1(b) of the draft rule.

297 Submissions to the draft determination: AGL, p. 3; Origin Energy, p. 3; Meridian Energy, p. 2; Lloyd's Register, p. 5; Ergon Energy and Energex, p. 4.

298 Lloyd's Register, submission to the draft determination, p. 5.

299 Submissions to the draft determination: Origin Energy, p. 3; Lloyd's Register, p. 5.

300 AEMO, submission to the draft determination, pp. 19-20.

that the AEMC had determined that it is preferable to rely on voltage (reactive power) control and support services that can be delivered by existing generation and network plant.[301]

AEMO considered that increasing asynchronous generator connections strongly influences network voltages due to changes in power flows. AEMO considered the effects of this must be mitigated using dynamic voltage control or reactive power plant, and cannot be adequately managed with plant typically used by networks.[302] AEMO considered that reliance on existing reactive power capabilities and network capabilities is not a practical approach to the management of voltage into the future.

AEMO noted there is rarely a case where no capability is required, and therefore proposed that a more practical approach would be to require all connecting generators to deliver reactive power capability, unless the capability is not required by AEMO and the network service provider.[303] AEMO therefore proposed a minimum access standard that would result in a power factor of 0.99, and provide the capability to influence the voltage at the connection point by around 5% with a short-circuit ratio of 3.[304]

AEMO proposed the minimum access standard should read: "Unless AEMO and the Network Service Provider agree that a lesser reactive power capability is acceptable at the connection point of a generating system, the minimum access standard is a generating system operating at any voltage at the connection point within the limits established under clause S5.1a.4 without a contingency event, must be capable of supplying and absorbing continuously at its connection point an amount of reactive power of at least the amount equal to the product of the rated active power of the generating system and 0.143."[305]

7.7.2 Expression of the minimum access standard

A number of stakeholders commented that the changes to the wording in the minimum access standard created uncertainty and potentially limited flexibility.

A number of stakeholders commented that the changes implied a requirement for a "unity power factor", which is not equivalent to requiring no capability.[306] Essential Energy noted that the changes to align the drafting of the automatic and minimum access standards appear to have included a requirement for a generator to provide the capability of cancelling any inherent reactive power drawn by its connection assets, to be zero at the generator connection point.[307]

TransGrid also noted that the changes would reduce the flexibility available to allow a range of solutions including a generator to connect with a fixed (non-zero) power factor, that could

301 ibid, p. 19.

302 ibid.

303 ibid.

304 ibid.

305 ibid, p. 20.

306 Submissions to the draft determination: Ergon and Energex, p. 4; Essential Energy, p. 2; Nordex, p. 8; TransGrid, p. 3; Tilt Renewables, p. 1.

307 Essential Energy, submission to the draft determination, p. 2.

be leading or lagging reactive power.[308] Lloyd's Register noted the changes may be difficult or confusing to interpret.[309]

7.7.3 Clarity in guidance for negotiations

A number of stakeholders raised concerns that there is insufficient guidance in clause S5.2.5.1 regarding how much reactive power capability is needed from a connecting generating system, and how the responsibility for the control of voltage is to be shared between network service providers and connecting generators.

Advisian noted the existing and proposed rules are vague with respect to each party's obligations and responsibilities, which can make negotiations more difficult.[310]

Some stakeholders expressed concerns that under the draft rule AEMO and network service providers are able to require reactive power capabilities where a clear need cannot be demonstrated.

A number of stakeholders noted that the negotiation of reactive power capability should adhere to a shallow connections framework. AGL noted that applying more stringent requirements on connecting generators may undermine the 'do no harm' principle, potentially misplacing commercial and operational risk.[311]

Renew Estate and Wirsol noted that generators are being asked to fill the reactive power capability gap that was previously the responsibility of network service providers.[312] They considered the decision of whether to approve a set of generator performance standards or not should be based only on the current committed generation, and not on an assumption of further generators connecting in the future or on the planning decisions of network service providers.[313] Eneflux noted that in recent years it had encountered a material number of instances where it considered network service providers had arbitrarily request automatic or close to automatic access standards, resulting in either increased project costs or projects becoming unviable.[314] In follow up correspondence it was noted that these examples relate principally to the negotiation of reactive power capability under clause S5.2.5.1.[315]

Canadian Solar considered that a connecting generating system should do what is in its reasonable control to do no harm to the power system, and network service providers and AEMO should focus on their planning and other functions.[316]

308 TransGrid, submission to the draft determination, p. 3.
309 Lloyd's Register, submission to the draft determination, p. 5.
310 Advisian, submission to the draft determination, p. 1.
311 AGL, submission to the draft determination, p. 2.
312 Renew Estate and Wirsol, submission to the draft determination, p. 2.
313 ibid.
314 Eneflux, submission to the draft determination, p. 3.
315 Eneflux, email to AEMC, 17 August 2018.
316 Canadian Solar, submission to the draft determination, p. 1.

The Australian Energy Council noted the uncertainty on the assessment of performance against the current system model and additional or concurrent connections, suggesting that further guidance could be included in the rules on the technical assessment required.[317]

As noted in Chapter 4 on the negotiating process, the Clean Energy Council was concerned that AEMO is innapropriately considering planning models in its consideration of negotiated access standards.[318] The Clean Energy Council appears to have been principally concerned with the negotiation of reactive power capability, and to address the issue proposed removing the words "at least" from clause S5.2.5.1(c)(1) to ensure that only existing projects and committed projects are required to be assessed.[319] Tilt Renewables also proposed removing the words "at least" from the clause because it considers those words are being used by network service providers to require reactive power capability at a level that is much higher than required.[320] Tilt argues that network service providers are considering all future generation (committed and unplanned) that might one day be connected to the power system.[321]

7.8 Final determination

This section sets out the Commission's analysis of the issues raised by stakeholders with the draft rule, and any changes in the final rule to address them.

7.8.1 Level of the minimum access standard

The Commission's final rule retains a minimum access standard in clause S5.2.5.1 that does not require a connecting generating system to provide reactive power capability.

Most stakeholders supported this, however AEMO suggested that the access standard should set a default minimum level of reactive power capability from all connecting generating systems, while allowing a lower level of capability to be set where AEMO and the network service provider agree this is acceptable.

The Commission does not consider it is appropriate to set a default level of reactive power capability with the ability to set a lower amount where AEMO and the network service provider agree. The automatic and minimum access standards should set the highest and lowest required levels of performance needed across the power system. It is the role of the negotiating process to set the appropriate level of performance within that range for the individual connection. Creating a new minimum access standard, set at a level that can be reduced, would risk undermining the effectiveness of the negotiating process in achieving the level of performance that is needed to maintain power system security and quality of supply at an efficient cost for consumers.

317 Australian Energy Council, submission to the draft determination, p. 1.

318 Clean Energy Council, submission to the draft determination, p. 3.

319 ibid.

320 Tilt Renewables, submission to the draft determination, pp. 1-2.

321 ibid.

The Commission's final rule therefore maintains a minimum access standard that does not require a connecting generating system to provide reactive power capability.

7.8.2 Expression of the minimum access standard

In the draft rule the Commission changed the way the minimum access standard for clause S5.2.5.1 was specified so that it was better aligned with the automatic access standard and could therefore provide a clearer path for negotiating a level of performance, while retaining a minimum requirement to not provide any reactive power capability.

The Commission accepts the views of stakeholders that the changes to the expression of the minimum access standard do not achieve a minimum requriement of no reactive power capability, but rather could imply a positive obligation to control the reactive power at the connection point to a level that represents unity power factor. The Commission also appreciates that the changes could limit flexibility in how a negotiated access standard may be specified in a generator's performance standards, which may create a barrier to the connection of some technologies. Neither of these outcomes was intended, and as such the Commission considers it appropriate to reverse the changes proposed in the draft rule.

The final rule therefore does not make a change to the minimum access standard in clause S5.2.5.1.

7.8.3 Clarifying the guidance for negotiations

The Commission's final rule includes guidance to clarify the matters that may be taken into account when setting a negotiated access standard for clause S5.2.5.1.

Context

As described in Chapter 3, the NER set out a connections framework based on the principle that new connections should do no harm to the power system, or in other words, pay for the impact of their connection on the power system and no more. This is also sometimes referred to as a 'shallow' connection framework. In this framework:

- generators have a right to negotiate a connection to the transmission network, paying for the costs of the services provided to them (but not the right to earn revenue in the wholesale market)
- network service providers have to meet jurisdictionally-set reliability standards, reflecting a balance between the cost of building and maintaining networks and the value consumers place on reliability
- end-use customers pay for costs incurred by the network service providers in providing shared services from which they benefit, reflected in the fees paid by those customers, which are regulated by the AER
- AEMO provides an independent strategic view as national transmission planner, which transmission businesses use as they plan their networks, and

- augmentation and replacement decisions relating to the network are subject to cost-benefit tests (regulatory investment tests) so network investments create a net market benefit for consumers.

The level of reactive power capability required from a connecting generating system under clause S5.2.5.1 should be consistent with this framework. Further, the amount of reactive power capability required of connecting generators also needs to be consistent with the NER framework for voltage control in the power system.

Under this framework network service providers are ultimately responsible for voltage control on their networks. Schedule 5.1 of the NER requires network service providers to provide network services (as set out in their connection agreements) that observe and apply the relevant system standards, including relating to voltage control.

AEMO's role as national transmission planner requires it annually to publish the NTNDP. The NTNDP considers the projected capabilities of the national transmission system, and the network support and control ancillary services (NSCAS) required to support the existing and future capabilities of the system, under a range of scenarios.

Taking this information into account, network service providers consider where and when certain investments are required to maintain quality of supply, including meeting their voltage control obligations under Schedule 5.1. AEMO may also declare an NSCAS gap to address a system security need, including reactive power capability.

Analysis and conclusions

The negotiation of the level of reactive power capability that a connecting generator is required to connect with occurs under clause S5.2.5.1. Current arrangements require network service providers to assess the appropriate amount of reactive power capability required, taking into account "at least existing projects and *considered projects*".

The term 'considered projects' refers only to transmission and distribution network augmentation projects, and not to other nearby generation projects.[322] The term 'existing projects' is not defined in the NER. In stakeholder consultation following the draft determination, a range of views have been expressed on the potential meaning of the term. Some considered that, when considered in its context, the term is limited to existing transmission and distribution network projects. Others consider it also refers to new connections and potentially also the retirement of existing equipment.

The draft rule specified clause S5.2.5.1 as an AEMO advisory matter. This has been broadly accepted by stakeholders and has not changed in the final rule. Under the final rule, negotiations of the level of reactive power capability to be provided by a connecting generator will therefore require AEMO to advise on the level of capability needed for power system security.

Stakeholders have clearly raised concerns that the current arrangements may allow network service providers (and under the draft rule, AEMO) to require more reactive power capability

322 See definition of *'considered project'* in Chapter 10 of the NER.

than is appropriate under a shallow connection framework. This is because the term "existing projects" and the words "at least" allow a wide discretion to determine what matters should be taken into account when determining the level of reactive power capability required for the connection. Stakeholders considered the uncertainty and discretion allows networks to require uncertain future events to be taken into account when determining the level of reactive capability a generator is required to provide, which they consider is not appropriate under a shallow connections framework. Specific examples have been provided confidentially to the AEMC, including the example of one generator being asked to provide enough reactive power capability to accommodate the retirement of a nearby synchronous generator, expected to occur in the early 2030s.

The Commission accepts that cases such as these may arise because the guidance in clause S5.2.5.1 on the circumstances that may be taken into account in negotiations is not clear. The phrase, "at least existing projects and *considered projects,*" does not provide clear guidance on the extent of future events that may be included in the consideration of the level of reactive power that a generator can be required to provide on the basis of doing no harm to power system security and quality of supply. This lack of clarity could result in circumstances where, when determining the reactive capability a generator should provide, inappropriate consideration might be given to future power system conditions and generator connections or retirements that would fall outside of the range consistent with the philosophy of the shallow connection framework.

Indeed, in discussions with network service providers facilitated by Energy Networks Australia, one network noted it considered it appropriate to take into account a network's Transmission Annual Planning Report, which is a document identifying future network needs in the short, medium and longer terms.[323]

The Commission considers that uncertain future connections, existing generator retirement decisions or the decisions of existing generators or loads to change operating patterns in an unexpected way, are not appropriate matters to be considered when determining the level of reactive capability required of a connecting generator. However, the existing guidance does not clearly specify whether these kinds of events and power system conditions can be considered. Nor does the existing guidance clearly specify how the different operating states of the existing power system should be taken into account.

This is a material issue because under the current arrangements there is a risk that cost and risk are not efficiently allocated to the relevant parties. The ambiguity in the guidance for negotiations gives rise to a risk that generators are required to provide surplus reactive power capabilities, which can be very costly, in order to address a risk that would be more appropriately and efficiently faced by network service providers in the execution of their obligations to plan their networks to meet the system standards, including in relation to voltage control. Indeed, a number of different parties have a role in the control of voltage on the power system, and clearer guidance is needed on where one party's responsibilities end and another party's responsibilities begin.

323 Energy Networks Australia, teleconference with ENA members, 7 September 2018.

It is not appropriate for a connecting generator to pay for the provision of reactive power capability to account for uncertain future events. This is appropriately provided for by other arrangements within the NER for the control of voltage. For example:

- the ability to address short term uncertainties that create immediate risks to power system security due to insufficient reactive power capability being available (such as a sudden change in the operating patterns of a major load or the sudden exit of a synchronous generating system) is accounted for through the ability of networks to plan for such circumstances, as well as through the powers of AEMO to direct market participants, apply constraints, or even create a longer term solution by declaring an NSCAS gap, and
- the ability to address longer term uncertainties that create voltage control challenges (such as the transition of the power system to include greater penetrations of distributed energy, or the closure of a synchronous generating system that has been foreshadowed to the market) is accounted for through network and AEMO planning processes.

Customers ultimately pay for reactive power capability, regardless of whether it is provided by a connecting generator or provided or procured by a network service provider. The Commission however considers it is appropriate for uncertain future events to be accounted for in the planning decisions of network service providers, and subjected to regulatory investment tests, rather than required from connecting generators where the costs are not subjected to the same level of scrutiny.

The Commission considers it is therefore appropriate to clarify the nature of the future events that should be taken into account when negotiating the level of reactive power capability that is required from a connecting generating system. The current guidance is clearly inadequate and could lead to inefficient outcomes. However, while the Commission considers it appropriate to clarify the guidance for all parties, it also considers that it is appropriate that some discretion still rests with AEMO and the network service provider to determine the appropriate matters to take into account when setting the level of reactive power capability required of a connection. This discretion is appropriate given the information those parties hold (some of which may be confidential) and their ultimate responsibility under the NER for maintaining power system security and quality of supply.

The Commission's final rule therefore includes the new guidance that the level of reactive power capability required of the connection should be set, taking into account "existing *power system* conditions, *considered projects* and any other project for the connection of a *Network User* in relation to which:

- there is an existing *Connection Agreement*, or
- *the Network Service Provider* and *AEMO* reasonably consider the *Network User* will connect to the power system."

The new guidance clarifies that it is not appropriate for parties to take into account generator retirements or uncertain future changes in the operation of the power system when negotiating the level of reactive power capability that is required from a connecting generating system.

The new guidance explicitly requires parties to take into account existing power system conditions. This is appropriate as all parties should be required to turn their minds to the way the power system operates currently. There is some scope for AEMO and the network service provider to exercise appropriate discretion to consider what reasonable operational scenarios the connecting generating system may face at the time of connection. This may include taking into account the operating patterns of existing loads, nearby generation and network plant that can be reasonably expected at the time of connection. However, it is not appropriate for connecting generators to be asked to account for uncertain future operating scenarios, such as an increased penetration of distributed generation in the medium term, or the retirement or changed operating behaviour of a significant nearby source of reactive capability. It is the role of network service providers and AEMO to address those matters through their planning processes and system operation functions as described above.

The parties are also directed explicitly to take into account the connection of network users where there is a connection agreement in place, or where the network service provider and AEMO reasonably consider the network user will connect. This is because the amount of reactive power capability required of a connecting generating system should take into account the best information about the circumstances that the plant will connect to. It will not be appropriate for AEMO and network service providers to require all connecting network users to be taken into account, as smaller connections in some categories of network user will have very little impact on the appropriate level of reactive power capability for the connecting generating system. However, it is appropriate that AEMO and network service providers have the discretion to determine which network user connections are significant and should be taken into account, regardless of which category of network user the connection relates to.

Some stakeholders have suggested that it may be appropriate for generators to provide reactive power capability because it is cheaper for them to provide it than for network service providers to provide. Indeed, in certain circumstances, it may be that it is cheaper for reactive power support to be provided by a generator, rather than specific assets built by a network service provider.

However, existing arrangements allow for such additional reactive power capability to be provided by a generator where this is the most efficient solution. Where a need is identified and a regulatory investment test met, the network service provider can obtain reactive power capability from generators efficiently through network support agreements. Importantly, where networks are required to plan and procure only enough reactive power capability to meet their obligations to maintian the quality of supply, their procurement of this capability should be disciplined and subject to regulatory oversight, reducing the overall costs to consumers.

8 REACTIVE POWER CONTROL

BOX 6: OVERVIEW

AEMO raised concerns that current arrangements relating to voltage and reactive power control do not provide sufficient voltage control capabilities for an evolving power system. In its rule change request, AEMO proposed changes relating to:

- the mode of reactive power control in which a generating system must be capable of operating, to require additional voltage control capabilities
- performance requirements under the minimum access standard for generators operating in voltage control mode, and
- adjusting allowable settling times associated with an asynchronous generating system's response to a setpoint 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 a range of improvements can be made to current arrangements to address the issues AEMO raised. To address these issues, the Commission's final rule:

- changes the requirements for specifying the mode of reactive power control so that:
  - the automatic access standard is the ability to operate in all modes, and switch between them (in accordance with a procedure agreed with AEMO and the network service provider), noting that commissioning and testing of control modes will only occur for those control modes required by AEMO and the network service provider on connection, or at a later time on request, 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 provide
- 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 final 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.

The final rule also adjusts the step test stability requirements applying to generating systems operating in the different reactive power control modes to:

- align allowable setting requirements under the minimum access standard for synchronous and asynchronous generating systems operating in voltage control mode, and
- implement a setpoint step response test for evaluating compliance with settling time requirements by generators operating in power factor and reactive power modes.

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 under clause S5.2.5.1, as discussed in Chapter 7.

This Chapter discusses proposed changes to the NER related to:

- the mode of reactive power control
- voltage control mode 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
- the Commission's draft determination
- stakeholder views on the draft determination, and
- the Commission's final determination.

8.2 Mode of reactive power control

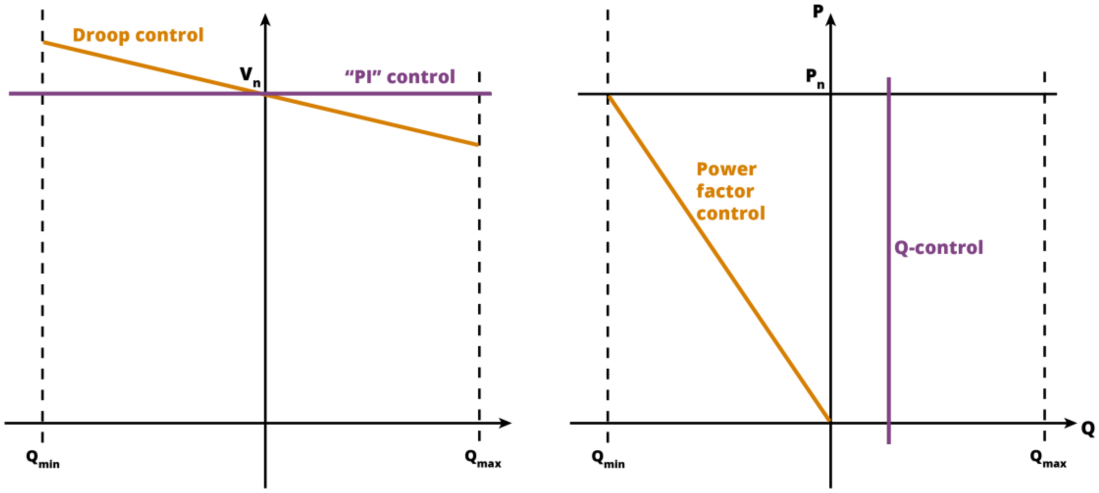
This section discusses AEMO's proposed changes to the arrangements in clause S5.2.5.13 for setting the reactive power control mode of a connecting generating system.

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 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.[324]

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

324 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.

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 to maintain a constant ratio of active power (MW) to apparent power (MVA) at the point of measurement, and
- 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 a control system that operates in voltage control mode, regardless of generating system capacity or connection point voltage. The automatic access standard does not explicitly require the generating system to operate in the other reactive power control modes.[325]

In contrast, the minimum access standard allows for the generating system to operate in the other reactive power control modes (that is, power factor control and reactive power control modes):[326]

- generating systems connecting at a nominal connection point voltage of 100 kV or more are required to have facilities to regulate voltage[327] in a manner that does not prevent the network service provider from achieving the system standards for system stability and voltage levels,[328] and is sufficient for the generating system to achieve the performance agreed in certain other performance standards,[329] 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

325 Clauses S5.2.5.13(b)(4) (asynchronous generating system) and S5.2.5.13(b)(3) (synchronous generating system) of the NER.

326 Clauses S5.2.5.13(d)(3) to (5) of the NER.

327 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.

328 That is, the requirements in clauses S5.1a.3 and S5.1a.4 of the NER.

329 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.

levels,[330] and is sufficient for the generating system to achieve the performance agreed in certain other performance standards.[331]

Also under the existing minimum access standard, a generating system with a combined 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.[332] 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 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 summarised 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

330 That is, the requirements in clauses S5.1a.3 and S5.1a.4.

331 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.

332 Clause S5.2.5.13(4)(i), 5(i) of the NER.

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.[333]

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.[334] 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.[335]

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:[336]

- 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 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 ability, distribution network voltages might not be able to be maintained within operating limits or investment in additional ancillary support plant may be necessary.

333 Rule change request, p. 21.
334 ibid.
335 ibid.
336 ibid.

To address these issues, in its rule change request AEMO proposed amendments to the minimum access standard in clause S5.2.5.13.[337] 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,[338] in a manner that does not prevent the network service provider from achieving the system standards for system stability and voltage levels,[339] and is sufficient for the generating system to achieve certain other performance standards.[340]

AEMO's proposed changes also included 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.[341] 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).[342]

8.2.4 The draft determination

To address the material issues raised by AEMO, the Commission made a draft rule that:

- amends the automatic access standard so that it requires the ability 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,[343] and
- amends the minimum access standard so that it requires the generating system to operate in either voltage control, or otherwise any other reactive power control mode with the agreement of AEMO and the network service provider.[344]

Reactive control mode flexibility

AEMO proposed changes to the minimum access standard that appeared to remove any flexibility to operate in modes of reactive power control other than voltage control for non-

337 Rule change request, p. 22.

338 Chapter 10 of the NER defines an embedded generating unit as a generating unit connected within a distribution network and not having direct connection to the transmission network.

339 That is, the requirements in clauses S5.1a.3 and S5.1a.4 of the NER.

340 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.

341 Rule change request, clause S5.2.5.13(g) of the proposed rule.

342 Equally however the proposed arrangements do not appear to explicitly preclude non-embedded generating systems from operating in those other control modes.

343 Clause S5.2.5.13(b)(2A) of the draft rule.

344 Clause S5.2.5.13(d)(2A) of the draft rule.

embedded generating systems.[345] Stakeholders were concerned about the removal of this flexibility to operate in power factor or reactive power modes for connections at transmission level.[346]

The Commission however accepted 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, the Commission accepted TransGrid's view that flexibility to specify the full range of control modes is important for all generating systems, including those connecting at transmission level. The Commission's draft rule therefore allowed any reactive power control mode to be set for any connecting generating system, regardless of the size of the generating system or the connection point voltage.[347]

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.[348] AEMO considered 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.[349]

While stakeholders did not object to the idea of switching control modes on an operational timescale, 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. Stakeholders were concerned that inappropriate remote switching may risk plant damage if conducted inappropriately.[350]

While the Commission agreed with AEMO that the ability to switch between reactive power modes would be beneficial, the Commission noted AGL's concerns regarding the potential for generating system equipment damage given inappropriate switching.[351] However, the Commission considered that these issues, which relate to the operational practices of the relevant parties, should be addressed through the development of procedures, agreed to by all parties, that set out how these processes would occur operationally.

The Commission understands that while larger plant may have the ability to switch modes it may not be standard in some smaller, 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. For this reason the

345 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.

346 Submissions to the consultation paper: Advisian, p. 44; TransGrid, p. 4; Tilt Renewables, p. 3; CEC, p. 11; AGL, p. 4.

347 Clauses S5.2.5.13(b)(2A) and S5.2.5.13(d)(2A) of the draft rule.

348 Rule change request, p. 21.

349 ibid.

350 Submissions to the consultation paper: Stanwell, p. 5; AGL, p. 4.

351 AGL, submission to the consultation paper, p. 4.

Commission considered the ability to switch reactive power control modes should not be required from all connections, but would be appropriate as an element of the automatic access standard.

The Commission's draft rule therefore required the ability to switch reactive power control 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.[352] The Commission considered this approach was appropriate to allow effective co-ordination and minimise potential risks, such as equipment damage or unintended interactions with other nearby voltage control equipment. The Commission's draft rule did not prescribe arrangements because the range of matters to be considered and potential outcomes will be highly location specific.

Voltage control capability in distribution networks

The Commission agreed with AEMO that current arrangements for generating systems under 30 MW, connecting at voltages under 100 kV are unclear and have the potential to result in sub-optimal amounts of voltage control ability in distribution networks. 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. The Commission found 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.

To address these issues the minimum access standard in the Commission's draft rule required 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.[353] The requirement applies irrespective of the size of the generating system or voltage at the connection point.

Structure of the automatic and minimum access standards

The existing automatic access standard specifies a single mode requirement (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.[354]

In the draft determination the Commission noted it considers the existing minimum access standard in S5.2.5.13 to be overly complex, difficult to interpret, and inconsistent with the approach taken to setting generator access standards in other clauses. To address these shortcomings the Commission's draft rule restructured 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 required the highest level of ability (being all reactive power modes) and the ability to switch between modes.[355] This is

352 Clause S5.2.5.13(b)(2A) of the draft rule.

353 Clause S5.2.5.13(d)(2A)(ii) of the draft rule.

354 Clauses S5.2.5.13(b)(3) to (4) and S5.2.5.13(d)(3) to (5) of the NER.

355 Clause S5.2.5.13(b)(2A) of the draft rule.

consistent with the approach taken to other generator 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.

This is also needed to address the situation where a generating system operating in power factor or reactive power control modes is called upon at a later point in time to operate in voltage control mode, where this is needed to address changed power system conditions.

The Commission's draft rule included a minimum access standard that required 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.[356] Requiring operation in a single control mode is consistent with a minimum access standard that represents the lowest level of ability required of a connecting generating system to meet the needs of the power system.

The automatic and minimum access standards in the draft rule would apply to all generating systems, irrespective of connection point voltage. These generator 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 also required the connection applicant to obtain agreement from AEMO and the network service provider to specify operation in any mode other than voltage control mode. This would minimise 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 operation in droop control mode (discussed below).

8.2.5 Stakeholder views on the draft determination

Stakeholders generally supported the Commission's draft automatic and minimum access standard requirements applying to modes of reactive power control in clause S5.2.5.13.[357] Stakeholders however had a number of concerns, including:

- the time, cost, and complexity associated with the technical studies required to commission multiple reactive control modes required to connect at the automatic access standard
- that a requirement to switch in accordance with an agreed procedure was insufficient to prevent inappropriate switching by either AEMO or the network service provider, and
- whether a requirement for switchable multi-mode ability was justified for small generating systems in distribution networks.

Stakeholders raised concerns over the additional costs and complexity required for a generating system to be designed and commissioned for the operation of each mode of reactive power control. These views were expressed by generators and network businesses who were concerned that a significantly higher number of technical studies needed to be

356 Clause S5.2.5.13(d)(2A) of the draft rule.

357 Submissions to the draft determination: AGL, p. 3; Ergon and Energex, p. 5; Essential Energy p. 2; TasNetworks, p. 4; Energy Networks Australia, p. 2.

performed for a generating system to be demonstrated through the commissioning process to have 'the ability to' operate in each reactive power control mode.[358]

The number of additional technical studies required to commission multiple modes of operation were not limited to three (one for each mode) but also potentially required a large additional number to study interactions between nearby generating systems that may also operate in multiple modes. A clear view was expressed by stakeholders that a requirement for all modes of reactive power control to be commissioned on connection to the power system would add significant additional time, cost, and complexity to the connection process.

Energy Networks Australia considered a requirement to have the ability to operate in different reactive power control modes, is unclear regarding whether the generating system's ability must be commissioned and tested, ensuring operational compliance with other generator access standards.[359] Energy Networks Australia suggested the option to require testing and commissioning of alternate modes be performed at a future date when those modes are needed.[360]

Some stakeholders were also concerned that the requirement in the draft rule to switch between modes of reactive power control in accordance with an agreed procedure was insufficient to prevent inappropriate switching and manage the risks of adverse control system interactions.[361] Pacific Hydro was concerned this requirement gives rise to the potential for equipment damage, given AEMO or the network service provider may be able to 'remotely' switch the control of a generating system from voltage to power factor or reactive control.[362] ElectraNet however noted that the requirement to switch from power factor to voltage control has been an SA technical license condition since 2010, for which switching is managed through a Transmission Connection Agreements and Operating Protocols agreed with connecting generators.[363] These protocols include the right for ElectraNet to change the reactive control mode and applicable setpoint at any time.[364] TasNetworks also noted their experience with automated voltage control schemes in Tasmania as indicating that it is possible to mitigate such risks through an appropriate procedure.[365]

Some stakeholders also questioned whether an automatic access standard that requires multiple modes of operation was justified for small generating systems in distribution networks,[366] or in regions of the power system where local conditions make it unlikely there will be a benefit from the ability to switch modes.[367]

358 Submissions to the draft determination: Renew Estate and Wirsol, p. 3; SMA, p. 2, Pacific Hydro, p. 7; CitiPower, p. 1; Ergon Energy and Energex, p. 4.

359 Energy Networks Australia, submission to the draft determination, p. 2.

360 ibid.

361 Submissions to the draft determination: AEC, p. 2; Ergon and Energex, p. 4; Essential Energy, p. 1; Pacific Hydro, p. 7.

362 Pacific Hydro, submission to the draft determination, p. 7.

363 ESCOSA, 2010 Licence conditions for wind generators, final decision, p. 49.

364 ElectraNet, submission to the draft determination, p. 2.

365 TasNetworks, submission to the draft determination, p. 5.

366 Meridian Energy, submission to the draft determination, p. 4.

367 Energy Networks Australia, submission to the draft determination, p. 7.

8.2.6 Final determination

This section sets out the Commission's analysis and conclusions in response to stakeholder views on the draft determination, as well as any changes between the draft and final rules.

The ability to operate in multiple control modes

The Commission's final rule includes changes to clarify that, where a connecting generating system is to be capable of operation in more than one reactive power control mode, it is not required to commission all of its control modes on connection to the power system, and may be able to do so at a later date.[368]

The Commission accepts stakeholders' concerns regarding the time, cost, and complexity associated with the technical studies required to commission all three modes of operation on connection to the power system. Indeed, a large number of technical studies may be required to commission a generating system in multiple modes of operation, particularly where other nearby generating systems are also commissioned to operate in multiple modes of operation. The additional time, cost, and complexity associated with such a large number of technical studies may not be warranted in most cases at the time of connection.

The Commission considers that the ability to operate in multiple modes and be able to switch between them is only likely to be valuable in certain circumstances and in certain areas of the power system. It is not appropriate to be required as a general ability across the power system, particularly given the additional costs and complexity this would likely result in.

There are however some circumstances where the ability to operate in multiple modes of reactive power control, and switch between those modes, is desirable. The Commission considers it is appropriate that this ability, being a level of performance that is sufficient for connection at any location in the power system, should be in the automatic access standard.[369]

Changes to the draft rule are required to address the concerns regarding the cost and complexity of conducting additional studies. The Commission agrees with Energy Networks Australia's suggestion of deferring modelling, testing, and commissioning to the point where multiple modes are justified by circumstances in the power system. The final rule therefore requires network service providers to initially nominate one, or more, primary modes of operation to be fully tested and commissioned as part of the connection process. The testing and commissioning of other modes of reactive power control may be requested by the network service provider and AEMO at a later time if and when that other mode is required.[370]

The Commission considers that the ability to operate in modes, other than those nominated to be tested in commissioning at the time of connection, could be demonstrated on the basis of manufacturer or design specifications of the equipment (including through certification by

368 Clause S5.2.5.13(h) of the final rule.

369 Clause S5.2.5.13(b)(2A) of the final rule.

370 Clause S5.2.5.13(h) of the final rule.

the equipment manufacturer from a type test), or via other means acceptable to AEMO and the network service provider.

Compared with the requirements in the draft rule, the final rule should reduce the number of technical studies that are required prior to connection and therefore reduce the potential for time and costs to be incurred from commissioning modes of reactive power control that are not justified by power system conditions.

The minimum access standard is the same as the minimum access standard in the draft rule. It requires operation in one reactive power control mode, as agreed, and is likely to be appropriate for the connection of generating systems in areas of the power system that are unlikely to require generating systems to be able to operate in multiple modes of operation in order to maintain system security or the quality of supply. However, the final rule makes this minimum access standard applicable for any generating systems of any size and location where it is appropriate for that generating system to operate in a single mode.[371] Generally, we consider that the changes to the negotiating process are likely to facilitate generators having the appropriate control mode ability to meet power system needs, as a connection applicant is now clearly able to propose a negotiated access standard taking into account the power system conditions at the proposed location of connection.

Switching procedure

The draft rule included a requirement for switching to occur in accordance with a procedure agreed with AEMO and the network service provider.[372] The Commission notes stakeholder concerns that switching may occur inappropriately leading to the risk of equipment damage.[373]

The Commission however considers the requirement set out in the draft rule remains appropriate as it requires agreement from all parties,[374] including the connection applicant, network service provider, and AEMO, and does not restrict the matters that may be considered, or the process by which switching can occur.

The Commission does not wish to pre-judge or limit the factors that can be taken into account by the parties when developing these procedures. We consider that relevant risks and issues will be identified and addressed by affected stakeholders on a case by case basis. This approach leaves it open to AEMO, network service providers, and connection applicants to consider the conditions on which they consider switching between modes is able to safely occur. Requiring agreement by all parties provides for arrangements that will satisfy each party that their interests will be protected in any decision to switch, or pre-agreed protocol for switching.

371 Clause S5.2.5.13(d)(2A) of the final rule.

372 Clause S5.2.5.13(b)(2A) of the draft rule.

373 Submissions to the draft determination: AEC, p. 2; Ergon and Energex, p. 4; Essential Energy, p. 1; Pacific Hydro, p. 7.

374 Clause S5.2.5.13(b)(2A) of the draft rule.

The Commission notes the experience in South Australia where the *2010 Licence Conditions for Wind Generators* required new facilities to be able to switch between control modes.[375] ElectraNet manage switching through Transmission Connection Agreements and Operating Protocols agreed with connecting generators.[376] The experience in South Australia suggests that any risks of inappropriate switching can be managed, and network service providers and connection applicants in other jurisdictions can learn from the procedures currently in place there.

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 to control voltage at the connection point) should behave. In particular it specifies:

- an accuracy 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:[377]

- 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,[378] 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.[379]

375 ESCOSA, Licence conditions for wind generators - May 2010, p. 17. Available at, https://www.escosa.sa.gov.au/ArticleDocuments/800/100430-LicenceConditionsWindGenerators-FinalDecision.pdf.aspx?Embed=Y

376 ElectraNet, Submission to the draft determination, p. 2.

377 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.

378 Clauses S5.2.5.13(b)(3)(i) and S5.2.5.13(b)(4)(i) of the NER.

379 Clauses S5.2.5.13(b)(3)(iv) and S5.2.5.13(b)(4)(iii) of the NER.

The existing rule does not include specific accuracy and controllable setpoint range requirements applying to generating systems 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 control mode.[380] The existing minimum access standard requires a generating unit or generating system connecting under 100 kV to have facilities to regulate voltage, 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.[381]

Current requirements for a negotiated access standard in clause S5.2.5.13 require that:[382]

- 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 optimising 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 standard is specified, creating an ambiguity that can lead to difficulties in setting an appropriate negotiated access standard.[383]

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:[384]

- 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

380 Clause S5.2.5.13(b) of the NER.

381 Clause S5.2.5.13(d)(3)(ii) of the NER.

382 Clauses S5.2.5.13(e) to (f) of the NER.

383 Rule change request, p. 21.

384 Rule change request, proposed rule, S5.2.5.13(d)(3)(i)(iii).

performance specified. AEMO did not propose amendments to the automatic access standard.

The minimum voltage control requirements proposed by AEMO were designed to complement its other proposed changes to the access standard setting the reactive power capability.[385] 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 a set of performance requirements it considered should apply to generating systems operating in power factor and reactive power modes. These performance characteristics included:[386]

- 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, and
- 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 Draft determination

In relation to the performance characteristics for reactive power control, the Commission's draft rule:

- included a minimum access standard requirement for synchronous and 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,[387] 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)[388]

385 Clause S5.2.5.13 of the NER.

386 AEMO, email correspondence, 11 May 2018.

387 Clause S5.2.5.13(d)(2B)(i) of the draft rule.

388 Clause S5.2.5.13(d)(2B)(ii) of the draft rule.

- included 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, at an agreed location on the power system or within the generating system, to within 0.5% of its setpoint,[389] 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[390]
- included 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, at an agreed location on the power system or within the power system, to within 2% of its setpoint,[391] 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[392]
- clarified arrangements allowing voltage regulation strategies including droop control through the specification of a 'droop-adjusted setpoint', in the automatic and minimum access standards,[393] and
- included 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.[394]

This section summarises the Commission's analysis and conclusions from the draft determination on the issues raised by AEMO and stakeholders.

Performance requirements under the automatic access standard

Existing arrangements only specify performance requirements for generating systems operating in voltage control mode, as that is the sole mode required under the existing automatic access standard.[395] AEMO's original rule change request did not propose changes to this, and therefore did not propose performance requirements under the automatic access standard applying to generating systems operating in modes other than voltage control mode, namely power factor or reactive control modes.

As discussed above, the draft rule included in the automatic access standard the requriement to be able to operate in all three reactive power control modes. In its draft determination the Commission therefore considered that the automatic access standard should specify

389 Clause S5.2.5.13(b)(c1)(1) of the draft rule.
390 Clause S5.2.5.13(c1)(2) of the draft rule.
391 Clause S5.2.5.13(d)(3)(i) of the draft rule.
392 Clause S5.2.5.13(d)(3)(ii) of the draft rule.
393 Clauses S5.2.5.13(b)(2B)(i) and S5.2.5.13(d)(2B)(i) of the draft rule.
394 Clause S5.2.5.13(l) of the draft rule.
395 Clause S5.2.5.13(b) of the NER.

performance requirements applying to generating systems operating in reactive power control modes other than voltage control.

In ongoing discussions during the development of the draft rule, AEMO recommended automatic access standard requirements applying to generating systems operating in modes other than voltage control mode (reactive power and power factor regulation modes), that the AEMC included in its draft rule. These included 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, at an agreed location on the power system or within the generating system, to within 0.5% of its setpoint,[396] 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.[397]

Performance requirements under the minimum access standard

The Commission noted in its draft determination that 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 considered a minimum requirement for generating systems operating in voltage control mode to be appropriate, given future system needs.

In the draft determination the Commission agreed 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. 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, which can lead to difficulties in negotiations.

The Commission considered AEMO's proposed minimum access standard is broadly an appropriate way to define the voltage control mode response. However, the Commission also agreed with stakeholder concerns that 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 have a certain level of reactive power capability to achieve this level of performance.

In making the draft rule the Commission decided against including AEMO's proposal that the minimum access standard should require generators to be capable of meeting the controllable range 'continuously' and 'without reliance on a tap-changing transformer'. The Commission considered that in some instances, the response characteristics delivered by a transformer tap changer may be appropriate for system conditions at a generating system's connection point.

396 Clause S5.2.5.13(c1)(1) of the draft rule.

397 Clause S5.2.5.13(c1)(2) of the draft rule.

More generally, the Commission considered that requiring a continuously controllable reactive power obligation is not consistent with the Commission's view that the reactive power capability set in clause S5.2.5.1 should not be determined by the continuously controllable voltage setpoint range requirements in this clause S5.2.5.13, and that a minimum requirement of no capability is appropriate. The Commission considered the appropriate role of clause S5.2.5.1 is 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 draft rule therefore required synchronous and asynchronous generating systems under the minimum access standard to have a voltage control system that:[398]

- 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 also considered it appropriate to clarify the relationship between S5.2.5.1 and S5.2.5.13. The Commission's draft rule therefore included 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.[399]

Consistent with the Commission's changes to the automatic access standard in the draft rule, including performance characteristics for reactive power and power factor control modes, the Commission considered it is appropriate to include performance characteristics for those modes in the minimum access standard to more clearly specify a range over which capabilities can be negotiated. The Commission's draft rule therefore adopted AEMO's proposed performance requirements for a synchronous or asynchronous generating systems acting in power factor or reactive power control modes to:[400]

- regulate reactive power or power factor at the connection point, at an agreed location on the power system or within the generating system, 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 responding to the consultation paper considered that current arrangements do not clearly allow for the treatment of voltage control through a reactive power droop characteristic.[401] The existing automatic access standard, and AEMO's proposed minimum access standard, both specified a voltage control accuracy tolerance and continuously controllable voltage range, but did not specifically refer to a droop control characteristic.

Current practice includes using a droop characteristic as a common method of control, particularly given a number of generating systems and other voltage control assets located in

398 Clause S5.2.5.13(d)(2B) of the draft rule.

399 Clause S5.2.5.13(l) of the draft rule.

400 Clause S5.2.5.13(d)(3)(i) and (ii) of the draft rule.

401 Submissions to the consultation paper: TransGrid, p. 4; Powerlink, p. 8; TasNetworks, p. 15; Nordex, p. 7.

close proximity. Given that managing nearby voltage control assets in this way is clearly desirable, the Commission considered the lack of clarity in the ability to specify control arrangements to operate using a droop characteristic to be an issue that should be addressed.

The Commission's draft rule provided scope in the automatic and minimum access standards for voltage control through a droop characteristic by qualifying the voltage control accuracy tolerance band as being in relation to a 'droop adjusted' setpoint.[402] 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.

8.3.4 Stakeholder views on the draft determination

Stakeholders identified a number of issues related to performance requirements specified in clause S5.2.5.13 of the draft rule.

A number of stakeholders considered the way that control tolerance requirements for generating systems operating in power factor and reactive power control modes were expressed in the draft rule was not appropriate.[403] Specifically, the specification of a control tolerance as a percentage of setpoint was considered to be inappropriate as the accuracy range would become infeasibly small as a reactive power setpoint approached zero.[404] Stakeholders put forward a range of alternative approaches, including expressing the acceptable tolerance ranges as a percentage of rated MVAr and rated system MVA, or power factor setpoint. TasNetworks put forward a specific proposal for generators operating in reactive power control mode to regulate reactive power to within:[405]

- for the automatic access standard, ±4% of the rated MVA of the generating system, and
- for the minimum access standard, ±8% of the rated MVA of the generating system.

With the corresponding for generating systems operating in power factor control mode to regulate power factor to:

- for the automatic access standard, ±0.02 of its power factor setpoint, and
- for the minimum access standard, ±0.04 of its power factor setpoint.

TasNetworks, Ergon Energy and Energex recommended changing the continuously controllable voltage setpoint range from being centred on normal voltage, to instead being centred on an independently flexible target, or agreed, voltage defined for the connection point.[406] This change was recommended to provide flexibility to address circumstances where network operating voltages are outside the continuously controllable voltage setpoint range of ±5% of normal voltage. Stakeholders considered the definition of normal voltage, and its

402 Clause S5.2.5.13(b)(2B) of the draft rule.

403 Submissions to the draft determination: Nordex, p. 2; TasNetworks, p. 5; TransGrid, p. 3; Lloyd's Register, p. 6; AEMO, p. 22.

404 Nordex, submission to the draft determination, p. 2.

405 TasNetworks, submission to the draft determination, p. 5.

406 Submissions to the draft determination: TasNetowrks, p. 11; Ergon Energy and Energex, p. 5.

link to the over voltage requirements for continuous uninterrupted operation in S5.2.5.4, as making its adjustment difficult if not impossible in many circumstances.[407]

Several stakeholders commented on the draft rule changes providing for a voltage control setpoint to be droop-adjusted.[408] In particular, the draft rule had replaced an existing provision allowing reactive current compensation with an explicit arrangement for droop. Lloyd's Register noted that reactive current compensation provided a function different to droop which was still required by the power system. Lloyd's Register therefore recommended re-including the provision relating to reactive current compensation in clause S5.2.5.13.[409] TransGrid also noted this omission and requested the inclusion of reactive current compensation along with droop.[410]

Nordex and TransGrid also raised concerns with the existing requirement for asynchronous generating systems to have a power system stabiliser. TransGrid noted the functional requirements specified for power system stabiliser were specific to synchronous machines and recommended that requirements be separately specified in the automatic access standard for asynchronous machines.[411] Nordex noted that wind generating systems do not commonly have power system stabilisers and requested the removal of the provision.[412]

TransGrid also considered the draft rule is still not sufficiently clear about the relationship between clauses S5.2.5.13 and S5.2.5.1. TransGrid considered that if the Commission's purpose is not for S5.2.5.13 requirements to drive reactive capability under clause S5.2.5.1, then the text within subclause S5.2.5.13 (l) should be changed from "must be consistent with" to "are subject to".[413]

8.3.5 Final determination

This section sets out the Commission's analysis and conclusions in response to stakeholder views on the draft determination, as well as any changes between the draft and final rules.

Automatic and minimum access standard requirements for power factor and reactive mode control tolerance

The draft rule included control accuracy requirements for generating systems operating in power factor and reactive power control modes.[414] These reflected performance requirements under the existing rule for generating systems operating in voltage control mode and were specified in terms of an allowable percentage of a power factor or reactive power setpoint.

Stakeholders considered that required accuracy or tolerance should be expressed in fixed values of MVAr or as a percentage of some other fixed value (rated active or reactive power), and not as a percentage of the setpoint itself. The Commission agrees with stakeholders that

407 ibid.

408 Submissions to the draft determination: Lloyd's Register, p. 6; TransGrid, p. 3.

409 Loyd's Register, submission to the draft determination, p. 6.

410 TransGrid, submission to the draft determination, p. 3.

411 ibid.

412 Nordex, submission to the draft determiantion, p. 19.

413 TransGrid, submission to the rule change request, p. 3.

414 Clause S5.2.5.13(c1) and S5.2.5.13(d)(3) of the draft rule.

a tolerance that is expressed as a percentage of the reactive power setpoint is impractical as the tolerance would collapse to zero when the reactive power setpoint is close to 0 MVAr. This is clearly an unachievable requirement. The Commission's final rule therefore defines control accuracy requirements for generating systems operating in power factor or reactive power control modes as a requirement to control to a percentage of a set amount of reactive power (MVAr).

As not all generating systems have defined reactive power (MVAr) rating, the Commission has elected to express control tolerance requirements as an amount of reactive power (MVAr) corresponding to a fixed percentage of plant MVA rating. All plant have a MVA rating and this approach would see the allowable tolerance vary with the size of the plant.

The Commission considers that for consistency, reactive power and power factor regulation accuracy requirements should be defined that are comparable to the established access standards for voltage control which is to regulate voltage at the connection point to within 0.5% of the setpoint.[415] The MVAr accuracy required to regulate voltage at the connection point to within 0.5% of the setpoint however depends on the fault level of the connection point. A generating system connected at a weak location will be required to have tighter control of its reactive power than a generator connected at a strong location. Therefore the amount of reactive power (MVAr) corresponding to a fixed percentage of plant MVA rating can vary widely depending on connection point conditions.

Noting that generators operating in power factor or reactive power control modes are unlikely to be connected in locations where power system conditions are particularly weak, and following discussions with AEMO, the Commission considers tighter requirements to be required than those put forward by TasNetworks. The automatic access standard in the Commission's final rule is for the control tolerance requirements for generating systems operating in power factor or reactive power control modes with levels of performance broadly corresponds to the existing automatic access standard requirements for voltage control under relatively weak power system conditions.[416] The minimum access standard broadly corresponds to a level of performance that is achievable by generating systems connected in stronger locations.

The Commission's final rule therefore includes the following requirements for generating systems operating in reactive power control mode to regulate reactive power to within:

- automatic access standard: MVAr within 2% of generating system MVA rating,[417] and
- minimum access standard: MVAr within 5% of generating system MVA rating.[418]

The Commission's final rule also includes the following accuracy requirements for generating systems operating in power factor control mode to regulate reactive power to within:

415 Clause S5.2.5.13(b)(2B)(i) of the final rule.

416 Relatively weak system conditions are taken as approximately corresponding to a SCR of 3.

417 Clause S5.2.5.13(c1)(1)(i) of the final rule.

418 Clause S5.2.5.13(d)(3)(i)(A) of the final rule.

- automatic access standard: power factor corresponding to MVAr within 2% of generating system MVA rating,[419] and
- minimum access standard: power factor corresponding to MVAr within 5% of generating system MVA rating.[420]

Target voltage as the centre of the continuously controllable voltage set point range

The draft rule retained existing arrangements that centred the continuously controllable voltage setpoint range in clause S5.2.5.13 on 'normal voltage' at the connection point. Specifically, the automatic access standard required a voltage control system to allow the voltage setpoint to be continuously controllable on the range of at least 95% to 105% of normal voltage at the connection point or other agreed location.[421] The minimum access standard required a voltage control system that allows the voltage setpoint to be set between 98% and 102% of normal voltage at the connection point or other agreed location.[422]

The Commission accepts evidence from stakeholders that there are circumstances where normal network operating voltages may be outside the continuously controllable voltage control setpoint range required under the automatic access standard. The Commission understands that some network locations ordinarily operate at voltages greater than 105% of normal voltage. Existing arrangements could therefore see no effective voltage control capabilities provided by generating systems connecting at such locations.

When making its draft determination, the Commission considered that the ability to adjust normal voltage at a connection point by ±10% relative to nominal voltage levels provided sufficient flexibility to reflect network operating conditions.

The Commission however agrees with TasNetworks' observation that the ability to adjust normal voltage provides very little practical flexibility, as adjusting normal voltage higher to reflect network operating voltages would also increase the absolute level of over-voltages for which a generating system is required to maintain continuous uninterrupted operation.[423] Significantly, for this reason, currently all points in the power system have normal voltage set at nominal voltage.[424]

Target voltage is an existing concept present in the NER. Clause S5.1.4 of the NER allows a network service provider to determine a minimum access standard for the voltage of supply at the connection point.[425] This provision allows for a target voltage to be determined and recorded in a relevant connection agreement.[426] Unlike normal voltage, target voltage is not relevant to any of the other access standards that are relevant to the final rule. It therefore

419 Clause S5.2.5.13(c1)(1)(ii) of the final rule.
420 Clause S5.2.5.13(d)(3)(i)(B) of the final rule.
421 Clause S5.2.5.13(b)(2B)(iii) of the draft rule.
422 Clause S5.2.5.13(d)(2B)(ii) of the draft rule.
423 Clauses S5.2.5.4(a) to (b) of the NER.
424 TasNetowrks, Submission to the draft rule, p. 11.
425 Clause S5.1.4(b) to (c) of the NER.
426 Clause S5.1.4 of the NER.

offers flexibility to act as the centre of the continuously controllable voltage setpoint range, without any flow on implications in other areas of the final rule.

The Commission therefore considers it appropriate to centre the continuously controllable voltage setpoint range on an independent target voltage, referenced to clause S5.1.4 of the NER, which can be adjusted independently of normal voltage to reflect network operating voltages.

While a network service provider can determine a target voltage under the provisions in S5.1.4 for magnitude of power frequency voltage at a connection point, the Commission understands that target voltages are seldom determined under this clause and may impose additional requirements on network service providers. As the Commission does not intend to the new requirement in clause S5.2.5.13 to trigger any additional requirements on network service providers under clause S5.1.4, the final rule specifically refers to the target voltage as determined by the Network Service Provider in accordance with clause S5.1.4(c) and recorded in the connection agreement in accordance with clause S5.1.4. This approach does not reference the requirements of S5.1.4(b) which require a network service provider to determine a minimum access standard for the voltage of supply in order to declare a target voltage for the purpose of S5.2.5.13.

Droop and reactive current compensation

The draft rule included explicit provision for the voltage control tolerance range to be 'droop adjusted'.[427] This provision was included to address stakeholder concerns that existing, and proposed arrangements were ambiguous as to the treatment of droop.[428] In including this requirement, the Commission elected to replace an existing provision allowing 'reactive current compensation' on the basis that this provision was effectively captured within the concept of a droop adjusted setpoint.

TransGrid and Lloyd's Register requested the re-inclusion of the provision for reactive current compensation considering it necessary in addition to droop.[429] The Commission understands that reactive current compensation is related to droop, except with a slope of the opposite polarity. Its function is to compensate for the voltage drop across the generating system's step-up transformer in a way that allows the high voltage side of the transformer to act as the control point.

The Commission therefore agrees with TransGrid and Lloyd's Register that reactive current compensation should be re-included alongside provision for droop in the final rule. The final rule therefore requires the regulation of voltage to allow the setpoint to be value-adjusted to incorporate any voltage droop or reactive current compensation agreed with AEMO and the network service provider.[430]

Power system stabiliser requirements and asynchronous generating systems

427 Clauses S5.2.5.13(b)(2B)(i) and S5.2.5.13(d)(2B)(i) of the draft rule.

428 Submissions to the consultation paper: TransGrid, p. 4; Powerlink, p. 8; TasNetworks, p . 15; Nordex, p. 7.

429 Submissions to the draft determination: Loyd's register, p. 6; TransGrid, p. 3.

430 Clauses S5.2.5.13(b)(2B)(i) and S5.2.5.13(d)(2B)(i) of the final rule.

The automatic access standard in the draft rule retained an existing requirement for generating systems to have a power system stabiliser satisfying a set of specific functional requirements.[431] The Commission understands that this requirement has been an area of confusion in the past and notes TransGrid's observation that the functional requirements specified in the current rule are specific to synchronous generating systems.[432]

The Commission is aware that while power system stabilisers for synchronous generating systems address the damping of local electromagnetic oscillation modes which do not exist in asynchronous generating systems, power system stabilisers on synchronous generating systems can also be used to damp low frequency inter-area oscillations. Asynchronous generating systems are also capable of modulating voltage or active power to provide a power system service, damping low frequency inter-area oscillations in a manner similar to that provided by a synchronous machine's power system stabiliser. While noting Nordex's submission that the control system elements required to provide these functions are not typically provided as part of asynchronous generator control systems,[433] the Commission understands that the additional control system requirements for asynchronous generating systems to damp inter-area oscillations are modest.

Given the power system security benefits of oscillation damping ability in the power system, the Commission considers it appropriate to retain an automatic access standard requirement for asynchronous generating systems to have an ability to damp power system oscillations. This ability will remain valuable for power system security as the existing synchronous generating systems, which provide this service through their power system stabilisers, retire.

As a power system stabiliser is a concept in the rules that has a functional specification specific to asynchronous generating systems, the Commission considers that additional clarity is required regarding performance characteristics applying to asynchronous generating system power oscillation damping capabilities. To clarify existing arrangements, the automatic access standard of the final rule separately specifies requirements for synchronous and asynchronous generating systems in this area and clarifies asynchronous generating system requirements as being to provide power oscillation damping rather than power system stabiliser capability.[434]

The final rule retains existing arrangements for synchronous generating systems,[435] while requiring AEMO to develop, consult, and publish a new functional requirement for power oscillation damping performance specific to asynchronous generating systems.[436] In order to account for the period required for AEMO to develop and consult on power oscillation damping capabilities, the Commission's final rule retains the existing rule functional description as applying during the transitional period prior to AEMO publishing characteristics applying to asynchronous power oscillation damping.[437]

431 Clause S5.2.5.13(b)(2B)(v) of the draft rule.

432 TransGrid, submission to the draft determination, p. 3.

433 Nordex, submission to the draft determiantion, p. 19.

434 Clauses S5.2.5.13(b)(3)(ix) and S5.2.5.13(b)(4)(vii) of the final rule.

435 Clause S5.2.5.13(b)(3)(ix) of the final rule.

436 Clause S5.2.5.13(b)(4)(vii)(B) of the final rule.

437 Clause S5.2.5.13(b)(4)(vii)(A) of the final rule.

Further clarifying the relationship between clauses S5.2.5.1 and S5.2.5.13

The draft determination included a general requirement that sought to clarify that the requirements of clause S5.2.5.13 should not be used to determine an amount of reactive power capability under clause S5.2.5.1. This general requirement was that the performance characteristics of any reactive power control capability under clause S5.2.5.13 'be consistent with' the reactive power capability agreed with AEMO and the network service provider under S5.2.5.1.[438]

TransGrid considered this choice of words to be insufficient to prevent S5.2.5.13 requirements being used to determine requirements under S5.2.5.1 and recommended that the text within clause S5.2.5.13(l) be changed to make the performance under clause S5.2.5.13 'subject to' the reactive power capability established under clause S5.2.5.1.[439]

The Commission accepts stakeholder views that the use of term 'consistent with', does not clearly express the intention that clause S5.2.5.13 should not be used to obtain a level of reactive power capability, but rather should be used to specify the control requirements for the capability that is required under clause S5.2.5.1. To clarify this, the Commission's final rule replaces the general requirement in the draft rule with a qualification in the automatic and minimum access standard requirements for voltage control setpoint range, making them 'subject to' the reactive power capability established under S5.2.5.1.[440] We consider this more accurately reflects the intention noted above.

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.[441] 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.[442] 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.[443]

438 Clause S5.2.5.13(l) of the draft rule.

439 TransGrid, submission to the draft determination, p. 3.

440 Clauses S5.2.5.13(b)(2B)(iii) and S5.2.5.13(d)(2B)(ii) of the final rule.

441 Automatic access standard in clause S5.2.5.13(b)(3)(vii) of the NER, minimum access standard in clause S5.2.5.13(d)(4)(iii) and (d)(5)(ii) of the NER.

442 Clause S5.2.5.13(b)(1)(i) and (d)(1)(i) of the NER.

443 "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.

Settling time, rise time, and damping behaviour are conceptually illustrated in Figure 8.2 below.

Figure 8.2: Rise and settling times for a 5% step change in voltage

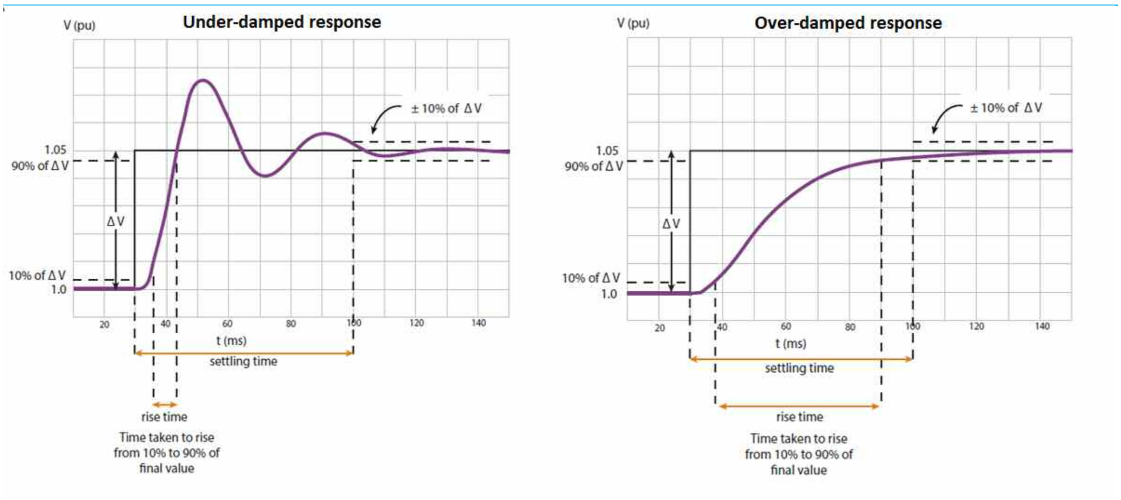


Figure 8.2 shows an under-damped response, which rises quickly (short rise time) but overshoots the target value causing oscillations in connection point voltage which take time to decay until they are within ± 10% of the target value (the settling time). An under-damped response is characterised by oscillations before settling at, or close to, the target value.

In contrast, an over-damped response does not overshoot the target 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 generating system 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 to which its control system would respond. 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.[444]

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.

Table 8.2: Rise times in response to a 5% voltage change

	SYNCHRONOUS	ASYNCHRONOUS
Automatic	None specified	2 seconds[445]
Minimum	None specified	None specified

Table 8.3: Settling times in response to a 5% voltage change

	SYNCHRONOUS	ASYNCHRONOUS
Automatic	5 seconds[446]	5 seconds[447]
Minimum	5 seconds[448]	7.5 seconds[449]

444 Note AEMO did not propose any changes to requirements for synchronous generation.
445 Clause S5.2.5.13(b)(4)(vi) of the NER.
446 Clause S5.2.5.13(b)(3)(vii)(B) of the NER.
447 Clause S5.2.5.13(b)(4)(v)(A) of the NER.
448 Clause S5.2.5.13(d)(4)(iii) of the NER.
449 Clause S5.2.5.13(d)(5)(ii) of the NER.

Requirements for a negotiated access standard in clause S5.2.5.13 require that:[450]

- 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 optimising 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.[451]

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:[452]

- 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 was to harmonise arrangements for synchronous and asynchronous generation types in setting settling times, but introduce a difference between technology types with respect to rise times.

In further consultation AEMO provided updated views on 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.[453] With the generating system connected to the power system, and for a step change in setpoint, or a 5% voltage disturbance:

450 Clauses S5.2.5.13(e) to (f) of the NER.
451 AEMO AEMC project team call, 30 January 2018.
452 Rule change request, proposed rule, clause S5.2.5.13(d)(5)(ii).
453 AEMO, email correspondence, 11 May 2018.

- 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 did 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 Draft determination

The Commission made a draft rule that:

- retained current arrangements for asynchronous generating system rise and settling times in the minimum access standard in response to a 5% step change in voltage[454]
- increased 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 to align with the existing requirements for asynchronous generating systems,[455] and
- specified automatic access standard arrangements for asynchronous and synchronous generating systems 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[456]
  - 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 point where a voltage disturbance of 2.5% would just cause the limiting device to operate,[457] and
  - have a reactive power rise time of less than 2 second.[458]

This section summarises the Commission's analysis and conclusions in the draft determination on the issues raised by AEMO and stakeholders. The analysis included considering whether current arrangements give rise to a material system security issue and whether different requirements for synchronous and asynchronous generating systems are appropriate.

System security justification

AEMO considered a faster response to changes in voltage within the normal operating range would benefit power system security.[459] This is particularly the case given likely reductions in

454 Clause S5.2.5.13(d)(5)(ii) of the draft rule.
455 Clause S5.2.5.13(d)(4)(iii) of the draft rule.
456 Clause S5.2.5.13(c1)(3)(i) of the draft rule.
457 Clause S5.2.5.13(c1)(3)(ii) of the draft rule.
458 Clause S5.2.5.13(c1)(3)(iii) of the draft rule.
459 AEMO-AEMC phone conference, 7 March 2018.

system strength associated with a transitioning power system which will make controlling voltages more difficult in many parts of the power system. AEMO's proposed reduction in allowable settling time for asynchronous generating systems under the minimum access standard would however reduce the flexibility available to determine a reactive power response suitable for very weak connection points. Some stakeholders expressed concerns that a reduction in the allowable settling times would reduce the flexibility to maintain stable operation given variable power system conditions.[460]

The Commission agreed with stakeholders that it is appropriate to retain the flexibility in current arrangements to 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 or unstable behaviour in some cases. Requirements that provide insufficient flexibility to set a settling time that allows for a stable response may lead to system security risks associated with oscillatory and potentially unstable generator responses.

Where a generating system can provide a faster response than is required under the minimum access standard, the Commission considered current arrangements, and proposed changes to the negotiation process, require generators to achieve as fast a response as possible considering response stability. Further, the Commission noted that 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 did not consider there to be material system security justification for reducing allowable minimum access standard settling times for asynchronous generating systems. The Commission's draft rule therefore retained the maximum allowable settling time applying in the minimum access standard for asynchronous generating systems at 7.5 seconds.[461]

Minimum access standard requirements for different technologies

In addition to the Commission's view that there was an insufficient system security justification for accepting AEMO's proposal, the Commission also did not consider there to be a justification for different arrangements applying to synchronous and asynchronous generating systems.

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 the challenge of maintaining a stable response under weak system conditions. This is a challenge that applies equally to all technologies. As a result, the Commission did not consider different minimum access settling time arrangements for synchronous and asynchronous generating systems were justified.

460 Submissions to the consultation paper: TransGrid, p. 4; GE Australia, p. 5.

461 Clause S5.2.5.13(d)(4)(iii) of the draft rule.

In the absence of a clearly identifiable system security risk associated with a settling time of 7.5 seconds rather than 5 seconds, and noting that in all cases settling times should be as fast as possible, the Commission's draft rule required both synchronous and asynchronous generating systems to meet the same minimum access standard settling time of 7.5 seconds in response to a 5% step change in voltage setpoint.[462] The Commission considered this is appropriate because of the value of retaining flexibility to specify longer settling times in some cases.

Arrangements for generating systems operating in power factor and reactive control modes

The Commission also noted that current arrangements under the automatic access standard are specific to generating systems operating in voltage control mode. With the inclusion of power factor and reactive control modes in the automatic access standard, the Commission recognised there was gap in the existing automatic access standard applying to rise and settling times for generating systems operating in these control modes. Following discussion with AEMO on this matter, AEMO proposed that step response requirements (allowable rise and settling times) for generating systems operating in power factor or reactive power control modes be significantly aligned with those applying to generating systems operating in voltage control mode. As the requirement to respond in a manner that is stable applies irrespective of the mode of reactive power control, the Commission accepted AEMO's recommendation that allowable rise and settling times for generating systems operating in power factor and reactive power control modes be aligned with those applying to generating systems operating in voltage control. The Commission's draft rule therefore:

- specified automatic access standard arrangements for asynchronous and synchronous generating systems 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[463]
  - 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 point where a voltage disturbance of 2.5% would just cause the limiting device to operate,[464] and
  - have a reactive power rise time of less than 2 seconds.[465]

8.4.5 Stakeholder views on draft determination

No stakeholder submissions were received on the issue of aligning allowable settling times for synchronous and asynchronous generating systems at 7.5 seconds under the minimum access standard.

462 Clauses S5.2.5.13(d)(5)(ii) of the NER and S5.2.5.13(d)(4)(iii) of the draft rule.
463 Clause S5.2.5.13(c1)(3)(i) of the draft rule.
464 Clause S5.2.5.13(c1)(3)(ii) of the draft rule.
465 Clause S5.2.5.13(c1)(3)(iii) of the draft rule.

TransGrid was the only stakeholder to comment on the inclusion in the draft rule of a 5% system voltage step test requirement for generating systems operating in power factor or reactive power control modes. TransGrid noted that reactive power rise time does not bear any meaning for a 5% voltage disturbance with respect to reactive power or power factor control modes. TransGrid further suggested deleting clause S5.2.5.13(c1)(3) of the draft rule, which is the requirement for compliance to be assessed on the basis of a 5% system voltage step test. Instead TransGrid proposed and compliance be evaluated on the basis of a setpoint step test.[466]

8.4.6 Final determination

This section sets out the Commission's analysis and conclusions in response to stakeholder views on the draft determination, as well as any changes between the draft and final rules.

A generating system needs to remain stable and have reasonable performance given changes in system voltage. A 5% voltage step test allows generating system performance and stability to be assessed for a reasonable system voltage disturbance. The Commission considers a 5% voltage disturbance test remains relevant to generating systems operating in power factor or reactive power control modes. It should however be noted that as generating systems operating in power factor or reactive power modes do not have voltage setpoints, the final rule does not specify this test to be in respect of a 5% change in voltage setpoint, but instead as a 5% voltage disturbance at the connection point, or other agreed location.[467]

The Commission appreciates that inducing a power system voltage step of 5% for the purposes of testing may be onerous, or impractical for network service providers to achieve, under certain circumstances. The Commission therefore agrees with TransGrid and the final rule implements a power factor, or reactive power setpoint step test as an alternative option to a 5% voltage disturbance test. This setpoint test involves a step in the power factor or reactive power setpoint equivalent to 50% of the reactive power capability negotiated under clause S5.2.5.1.[468] The settling times specified for active power and reactive power remain unchanged from the draft rule at 5 seconds (when the generating system response occurs from an operating point where the voltage disturbance would not cause any limiting device to operate), and 7.5 seconds (when the generating system response occurs from an operating point where a voltage disturbance of 2.5% would just cause a limiting device to operate).[469] The Commission has determined that the final rule will provide the network service provider with the discretion to choose the test it considers appropriate in the circumstances.[470]

The draft rule specified an automatic access standard reactive power rise time requirement, for a 5% step change in the voltage, of less than 2 seconds for generating systems operating in power factor or reactive control modes.[471] The Commission's final rule removes this requirement.

466 TransGrid, submission to the draft determination, p. 3.

467 Clause S5.2.5.13(c1)(3) of the final rule.

468 ibid.

469 Clauses S5.2.5.13(c1)(3)(i) to (ii) of the draft rule.

470 Clause S5.2.5.13(c1)(3) of the final rule.

471 Clause S5.2.5.13(c1)(3)(iii) of the draft rule.

A reactive power rise time requirement is less meaningful for generating systems operating in power factor or reactive power control modes. Unlike generating systems operating in voltage control, for which voltage setpoint changes are common and necessary for power system operational reasons, setpoint changes for generating systems operating in power factor or reactive control modes are generally not undertaken on operational time scales. The reactive power rise time response is therefore not material from a power system security or quality of supply perspective for generating systems operating in power factor or reactive control modes. Rather, it is appropriate that rise time flexibility be maximised by making settling time stability the main focus of any requirement for generating systems operating in reactive power or power factor modes. The Commission's final rule therefore removes the automatic access standard requirement for a reactive power rise time of less than 2 seconds for generating systems operating in power factor or reactive control modes.[472]

472 Clause S5.2.5.13(c1)(3) of the final rule.

9 REACTIVE CURRENT RESPONSE DURING DISTURBANCES

> **BOX 7: OVERVIEW**
>
> In its rule change request AEMO considered that current arrangements in clause 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 specified 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.
>
> The Commission's final rule for asynchronous generating systems substantially reflects the arrangements in the draft rule. The final rule also introduces new arrangements for asynchronous generating systems, largely derived from the arrangements proposed by AEMO, however also providing more flexibility to account for different power system conditions and equipment limitations.
>
> The Commission's final 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 final 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 sets out the Commission's final determination on reactive current response requirements during disturbances. These requirements are distinct from those 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
- AEMO's rule change request
- the Commission's draft determination
- stakeholder views on the Commission's draft determination, and
- the Commission's final determination.

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 instability and potential voltage collapse, as well as to help the power system recover from the disturbance.

Transient instability and voltage collapse is a major threat to power system operation. It can trigger cascading failures and wide-spread blackouts. Voltage collapse 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's response cannot be characterised in terms of reactive power injected or absorbed, but can be characterised in terms of the amount 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.

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:

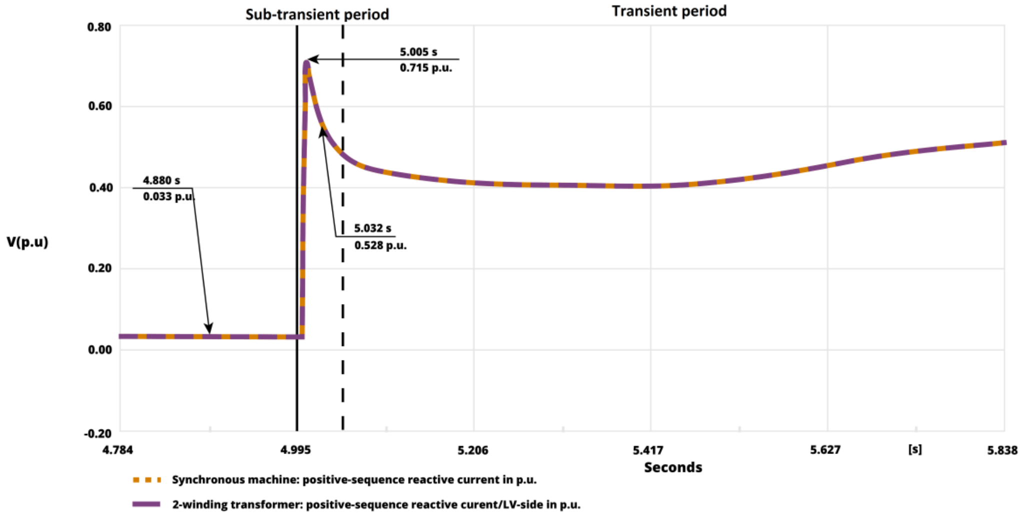
- *Sub-transient period:* this period is the first few 50 hertz (Hz) cycles after the fault, and is generally limited to 50 milliseconds (ms). During this period a synchronous generating system has an uncontrolled response which produces a very high initial reactive current,
- *Transient period:* this period is between 50 ms and 3 seconds, following the sub transient period. In the transient period the high initial fault current rapidly decays. The synchronous generating system's automatic voltage regulator is engaged during this period to stabilise the reactive component of the fault current and bring it to its steady state level.[473]

473 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 electromotive force of the machine, and by extension the reactive current injected or absorbed by the generating system to affect generating system terminal voltage.

- *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



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 maximum allowable fault clearance times between 80 and 430 ms.[474] 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 beyond 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.[475]

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

474 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).

475 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.

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.

9.1.2 Asynchronous generation system response

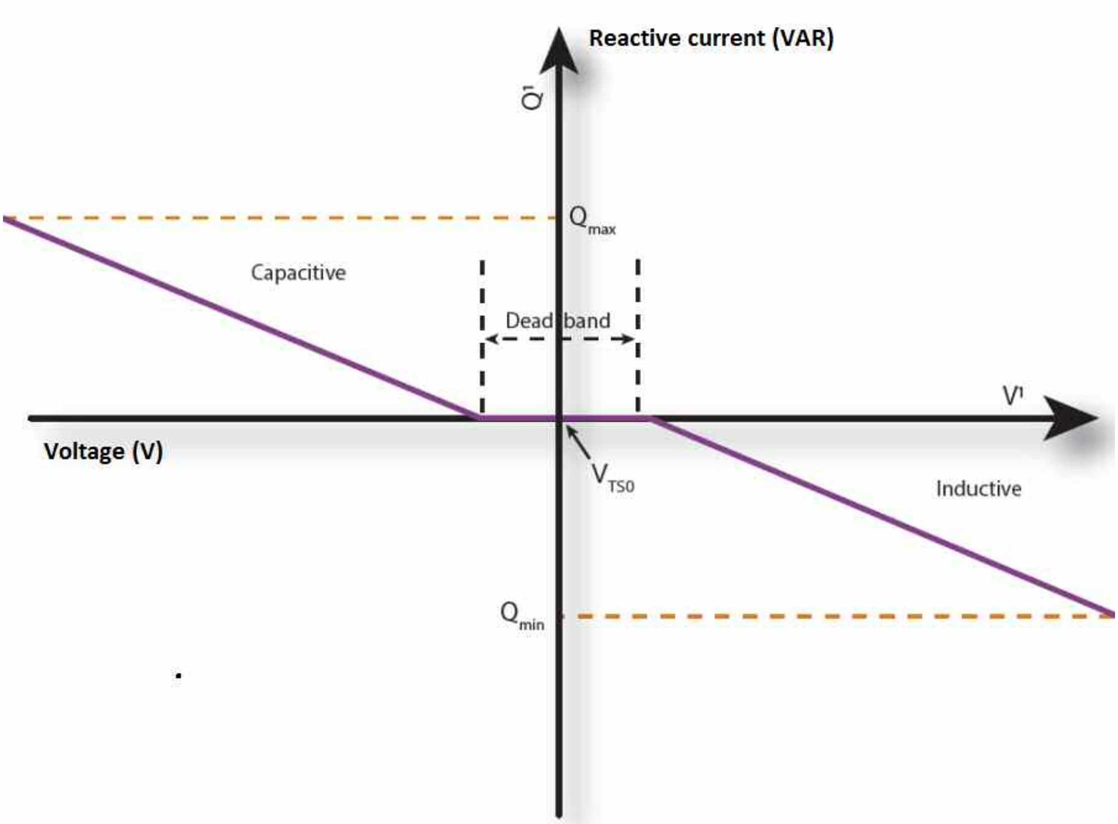
As existing synchronous generating systems retire and are replaced by asynchronous generating systems, important reactive current response during disturbances will be lost unless additional response is provided by other sources, such as asynchronous and inverter based generating systems.

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.[476]

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 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).

476 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.

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 reactive current which can be required from an asynchronous generator. Figure 9.2 represents these limits as Q_{max} and Q_{min}.
- *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.
- *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 9.6.

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).

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 9.6.

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 standard 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 clauses S5.1a.3 and S5.1a.4."[477] 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 Table 9.1, must (subject to any changed power system conditions or energy source availability beyond the Generator'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

477 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.

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.[478]

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 Generator'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.

Table 9.1: Existing automatic access standard fault types relevant to a generating system's reactive current response

AUTOMATIC ACCESS STANDARD[479]	MINIMUM ACCESS STANDARD[480]
Three phase fault in a transmission system[481]	N/A
Two phase to ground, phase to phase or phase to ground fault in a transmission system[482]	Single phase to ground, phase to phase or two phase to ground fault in a transmission system[483]
Three phase, two phase to ground, phase to phase, or phase to ground fault in a distribution network[484]	Single phase to ground, phase to phase or two phase to ground fault in a distribution network[485]

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.

478 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.

479 Clauses S5.2.5.5(b)(1)(ii) to (iv) of the NER.

480 Clauses S5.2.5.5(c)(1)(ii) and (iii) of the NER.

481 Cleared by all relevant primary protection systems.

482 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.

483 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.

484 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.

485 ibid.

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.[486] 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.[487]

AEMO considered that current arrangements in the generator access standards in the NER for reactive current injection and reactive current response requirements are insufficient. AEMO stated this is because the minimum access standard does not require a generating system to provide any form of reactive power response during a disturbance.[488]

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.[489] 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.[490]

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.[491] AEMO also 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 capability has not been explicitly required under the existing generator access standards because it is part of the inherent or assumed behaviour of traditional synchronous generation.[492]

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

486 Rule change request, p. 24.
487 ibid.
488 ibid.
489 ibid.
490 ibid.
491 ibid.
492 ibid.

- *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 and active power consumed on occurrence of a fault.

AEMO proposed 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 specified 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),[493] must supply to or absorb from the network:
  - to assist the maintenance of power system voltages during the application of the fault:
    - — *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 disturbance) for each 1% reduction of connection point voltage below 90% of normal voltage, and
    - — *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, and
  - during the disturbance and maintained until the connection point voltage recovers to between 90% and 110% of normal voltage.[494]
- **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),[495] supply to, or absorb from, the network:
  - to assist the maintenance of power system voltages during the fault:

493 Clauses S5.2.5.5(b)(1)(ii) to (iv) of the NER.
494 Rule change request, proposed rule, clause S5.2.5.5(b)(2)(i).
495 Clauses S5.2.5.5(c)(1)(ii) and (iii) of the NER.

- — *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
- — *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.[496]

AEMO's proposed response magnitudes for reactive current injection vary between the automatic and minimum access standards (4% and 2% respectively),[497] but the magnitude of reactive current absorption (6%),[498] 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 the automatic and minimum access standard. The response threshold values reflect the boundaries of the continuous operating voltage band.[499]

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.[500] 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.[501]

Response duration

AEMO proposed that reactive current responses under both the automatic and minimum access standards be sustained during the disturbance and be maintained until the connection point voltage recovers to between 90% and 110% of normal voltage (the continuous operating voltage range).[502]

496 Rule change request, proposed rule, clause S5.2.5.5(c)(2)(i).

497 Response as a percentage of the maximum continuous current of the generating system for each 1% decline in connection point voltage.

498 Response as a percentage of the maximum continuous current of the generating system for each 1% increase in connection point voltage.

499 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.

500 130% 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.

501 AEMO expressed this concern in an AEMO-AEMC project teleconference on 8 March 2018.

502 Rule change request, clauses S5.2.5.5(b)(2)(i) and S5.2.5.5(c)(2)(i) of the proposed rule.

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.[503]

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[504]
- a settling time of no greater than 60 ms,[505] and
- a requirement that the response must be adequately damped.[506]

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.[507]

Response limits

AEMO proposed the following limits applying to the reactive current response required from asynchronous and synchronous generating systems:[508]

- 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.[509]

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

503 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.

504 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."

505 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.

506 '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.

507 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".

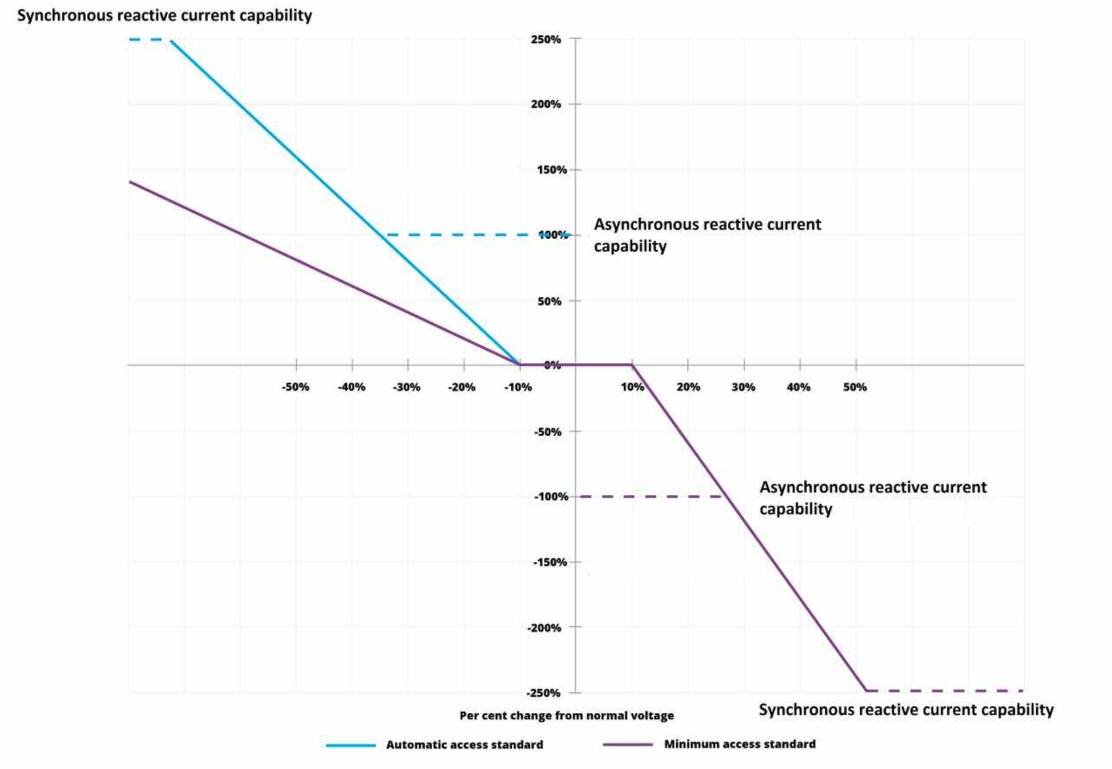
508 These limits are proposed as 'general requirements' applying to all registered performance standards registered in clause S5.2.5.5 rather than provisions specific to the automatic or minimum access standard.

509 Rule change request, proposed rule, clauses S5.2.5.5(i)(i)(A) to (B).

maximum reactive current 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.[510]

AEMO's proposed limits, at 250% (for synchronous generating systems), and 100% (for asynchronous generating systems), are illustrated in Figure 9.3 respectively.

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.[511]

510 Advice provided to the Commission by AEMO, 3 May 2018.

511 Rule change request, proposed rule, clauses S5.2.5.5(i)(v) and (vi).

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.[512] 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,[513] 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.[514]

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:[515]

> 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.

AEMC analysis and conclusions

The following sections summarise the Commission's analysis and conclusions in the draft determination, and set out stakeholder views and the Commission's final determination on:

- whether it is appropriate to apply any new requirements to both synchronous and asynchronous equipment, and
- the appropriate characteristics of those requirements, including:
  - magnitude of the reactive current response
  - response speed and duration
  - response thresholds
  - response limits
  - arrangements relating to measurement, and
  - maintaining total current during a fault.

512 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.

513 Rule change request, proposed rule, clause S5.2.5.5(i)(iii) of the proposed rule.

514 Rule change request, proposed rule, clause S5.2.5.5(i)(ii).

515 AEMO, Generator technical requirements: supplementary material to Rule change proposal, May 2018.

9.4 Arrangements for different technologies

This section sets out the Commission's draft and final determinations on the structure of the arrangements for reactive current response for different technologies in clause S5.2.5.5.

9.4.1 Draft determination

The Commission's draft rule:

- retained current arrangements for synchronous generating systems under both the automatic and minimum access standards 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),[516] and
- introduced new arrangements for asynchronous generating systems under both the automatic and minimum access standards that define the characteristics of their reactive current response during disturbances.[517]

The need for change

The Commission in its draft determination noted that 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 historically no 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 most asynchronous inverter connected generating systems, on the other hand, is not physically inherent to the plant. While asynchronous generating systems are capable of providing reactive current response, that response is determined by 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 Commission's draft rule included specific requirements that specify the response from asynchronous generating systems. The Commission noted there was a need to address this issue due to the risk that the reactive current response from connecting

516 Clauses S5.2.5.5(b)(2) and S5.2.5.5(c)(2) of the draft rule.

517 Clauses S5.2.5.5(b)(3) to (5) and S5.2.5.5(c)(3) to (5) of the draft rule.

asynchronous generating systems would not be adequate or appropriate to maintain power system security.

Application of new arrangements to synchronous generating systems

AEMO's proposed requirements applied 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.[518]

The Commission however agreed with a number of stakeholders that considered inherent differences between asynchronous and synchronous generating system response dynamics justify specifying reactive current requirements differently under the NER.[519] As discussed in section 9.1, synchronous generating system magnitude of response reflects the fundamental electro-mechanical characteristics of the generating system itself including its physical geometry and construction.

The Commission understood there to be limited flexibility to specify physical generating system characteristics for the purpose of achieving a specific level of reactive current response during fault events, without incurring significant additional cost. In addition to cost, the Commission considered it likely to be 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. Therefore, the Commission considered that new arrangements are needed in clause S5.2.5.5 of the NER to specify the manner and speed at which that response occurs, as well as the characteristics of that response, for asynchronous generators.

The Commission considered AEMO's proposed requirements to reflect the control architecture and consequent response characteristics of asynchronous generating systems. The Commission considered, for a range of specific technical reasons, that AEMO's proposed requirements are not appropriate for synchronous generating systems and may present a barrier to the connection of some types of synchronous generating systems.

Considerations of technology neutrality

Given the inherent physical differences in reactive current response from synchronous and asynchronous generating systems, the Commission considered it appropriate for separate requirements to be set out in the NER for the different technology types. This section considers this decision in the context of the principle of technology neutrality.

Importantly, technology neutrality does not mean treating all technology types the same in setting the generator access standards, but rather, technology neutrality means that all

518 Rule change request, p. 24.

519 Submissions to consultation paper: Hydro Tasmania, p. 12; Powerlink, p. 7.

technology types should have an equal opportunity to enter the market, subject to system security requirements.

Where possible, it is preferable for the generator access standards to be expressed in the same way for all technology types. However, it is not always appropriate to express the standards in the same terms for all technologies. In this case, given the inherently different physical responses from synchronous and asynchronous technologies (discussed in detail above), the Commission considered it it necessary to specify different requirements for each technology type in the draft rule. The Commission considered it necessary in this case for technology-specific arrangements 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.

The Commission did not consider it appropriate to change existing arrangements for synchronous generating systems (other than as discussed immediately below). However, the Commission considered that new arrangements were 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 AEMO's proposed changes included a minimum reactive current response capability from a synchronous generating system set at 250% of the maximum continuous current of the generating system.[520] 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 connection point voltage, implies that at a voltage level of 0%, the reactive current injection required from a generating system should be 400% of its maximum current capacity.[521] AEMO considered this requirement to be unachievable and proposed that synchronous generating systems provide a reactive current contribution which may be limited to 250% of the maximum continuous current of the generating system.[522]

The Commission agreed with AEMO and the draft rule therefore clarified current arrangements for synchronous generating systems through a general requirement specifying that 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.[523]

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.

520 Rule change request, proposed rule, clause S5.2.5.5(i)(i)(B).

521 Clause S5.2.5.5(b)(2)(i) of the NER.

522 Rule change request, proposed rule, clause S5.2.5.5(i)(i)(B).

523 Clauses S5.2.5.5(j) and (k) of the draft rule.

9.4.2 Stakeholder views on the draft determination

No stakeholders other than AEMO expressed a view on the Commission's draft rule to retain existing arrangements for synchronous generating systems while imposing a specific set of arrangements applying to asynchronous generating systems.

AEMO recognised the inherent differences in the manner in which synchronous and asynchronous generating plant respond to disturbances, but considered there to be little merit in segregating the requirements for synchronous and asynchronous generating systems to the extent proposed by the Commission.[524] AEMO particularly argued a clear minimum access standard level of performance was required for synchronous generating systems. In particular, AEMO was concerned that future synchronous technologies will offer a lower level of the previously delivered 'inherent' response and that it is no longer sufficient to assume the synchronous generating system capability delivered in the past will be maintained or delivered in the future. AEMO was concerned that, in the absence of a defined minimum access standard, connection applicants proposing to connect synchronous generating systems will give little consideration to meeting an appropriate negotiated level of performance where the automatic access standard cannot be met.[525]

9.4.3 Final determination

The Commission's final rule retains existing arrangements for synchronous generating systems (subject to clarification on the minimum reactive current response capability) and imposes a new set of arrangements specifically applying to asynchronous generating systems. These arrangements are largely the same as those in the draft rule, with changes in some areas, as discussed in the following sections.[526]

While the Commission notes AEMO's concerns regarding the risk of some synchronous generating technologies not delivering a significant level of response, the Commission does not consider a defined minimum access standard level of performance to be warranted as changes to the negotiating process will adequately address the risk of synchronous generating systems connecting with inappropriate levels of performance. The changes to the negotiating process will apply to all generation types, both synchronous and asynchronous, and require connection applicants to achieve automatic access standard levels of performance or justify why it is not appropriate for the connection to achieve that level of performance. AEMO and network service providers will also retain their ability to reject a proposed negotiated access standard where they consider it would adversely affect power system security or quality of power supply for network users. The Commission views these arrangements as addressing AEMO's concerns that the absence of a defined minimum access standard for synchronous generators may result in connection applicants proposing to connect synchronous generating systems giving little consideration to achieving an appropriate negotiated level of performance.

524 AEMO, submission to the draft determination, p. 7.

525 ibid.

526 Clauses S5.2.5.5(b)(2) and S5.2.5.5(c)(2) of the final rule

9.5 Response magnitude

This section sets out the Commission's draft and final determinations on the response magnitude for reactive current response in clause S5.2.5.5.

9.5.1 Draft determination

The Commission's draft rule specified the following automatic and minimum reactive current injection and absorption generator access standards applying to asynchronous generating systems:[527]

- Automatic access standard - facilities capable of a reactive current response of 4% of the maximum continuous current of the generating system for each 1% reduction in voltage at the generating unit terminals below the applicable under-voltage response threshold;[528] 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.[529]
- Minimum access standard - facilities capable of a reactive current response of 2% of the maximum continuous rated current of the generating system 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.[530]

The Commission's draft rule required both the negotiated capability range and the specific reactive current response set within the negotiated capability range to be recorded in the generator performance standards.[531]

The Commission's draft rule also included 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,[532] and
- under the minimum access standard, reactive current injection is required for all generating unit terminal voltages greater than 20% of nominal voltage.[533]

Requirement versus capability

Stakeholders were concerned that AEMO's proposal was unclear as to whether the magnitude of any reactive current injection or absorption during a disturbance, as determined by the slope of response, allowed a response appropriate to power system conditions at the connection point. Stakeholders were particularly concerned that an overly prescriptive

527 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.

528 Clause S5.2.5.5(b)(3)(i)(A) of the draft rule.

529 Clause S5.2.5.5(b)(3)(i)(B) of the draft rule.

530 Clauses S5.2.5.5(c)(3)(i)(A) and S5.2.5.5(c)(3)(i)(B) of the draft rule.

531 Clauses S5.2.5.5(b)(3)(i) and S5.2.5.5(c)(3)(i) of the draft rule.

532 Clause S5.2.5.5(b)(3)(i)(A) of the draft rule.

533 ibid.

magnitude of response risked instability where that response is inappropriate for the conditions at the connection point.[534]

The Commission noted it understood that situations exist where very low reactive current response may be appropriate for particular connection points. 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's draft rule defined the automatic and minimum access standard as a capability requirement within which a specific magnitude of response, appropriate to the connection point, is determined. In order to provide clear compliance requirements, the draft rule required the specific magnitude of response to be recorded in the generating system's performance standards.

Automatic access standard requirements

AEMO proposed an automatic access standard with response magnitudes of 4% for reactive current injection and 6% for reactive current absorption.[535]

AEMO's proposed automatic access standard was based on the requirements adopted in the Essential Services Commission of South Australia's (ESCOSA) generating system licensing guidelines.[536] The ESCOSA licensing requirements were set on the basis of advice from AEMO that also informed the response magnitudes in AEMO's rule change request. AEMO's proposed automatic access standard was considered by ESCOSA to be appropriate for managing the adverse circumstances in South Australia, particularly the challenge of managing over-voltages due to the operation of special protection schemes being implemented in that state.[537]

Stakeholders indicated that AEMO's proposed 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 additional equipment may be required, in particular for solar PV generating systems,[538] 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).

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

534 Submissions to the consultation paper: SMA, p. 6; Vestas, p. 2; ESCO Pacific, p. 11; Origin Energy, p. 2.

535 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.

536 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.

537 ibid, p. 25.

538 SMA, submission to consultation paper, p. 6.

considered it is appropriate to set the asynchronous generating system automatic access standard levels of reactive current response capability at the levels of proposed by AEMO.

Minimum access standard requirement

AEMO proposed a minimum access standard with response magnitudes of 2% for reactive current injection and 6% for reactive current absorption.[539]

The Commission considered in its draft determination that 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. Should a generating system 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. The Commission considered that, consistent with the assessment framework for setting a minimum access standard, it is appropriate that all generating systems connecting to the power system be capable of providing reactive current support during disturbances.

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 achievable. The Commission considered these levels to be appropriate and included in the draft rule AEMO's proposed minimum access standard for the magnitude of reactive current injection response from asynchronous generating systems.

In contrast, the Commission did not consider AEMO's proposed minimum access standard for reactive current absorption, which was the same as the proposed automatic access standard, to be appropriate. The Commission did not consider it to represent a lowest level of capability required from all asynchronous generating systems required to maintain system security across all regions in the power system. The Commission considered that implementing such a requirement would require capability that is not justified by the needs of the power system, 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.[540] The Commission therefore considered 2% reactive current absorption in response to over-voltages to be a reasonable minimum capability required from all asynchronous generating systems.

Point of reference - connection point or generating system terminals

AEMO proposed the requirement to either inject or absorb reactive current for each 1% change in connection point voltage.[541] As introduced in the technical introduction, existing

539 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.

540 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.

541 AEMO, rule change request, p. 26.

practice is for asynchronous generating systems to provide reactive current response as part of their inverter ride through mode capabilities. We understand that standard equipment capabilities are for ride through to occur in relation to voltages measured at the inverter terminals, rather than the connection point. As a result, the Commission's draft rule required a reactive current response in relation to changes in voltage at the generating unit terminals rather than at the connection point.[542]

While the Commission's draft rule specified the response as occurring at the terminals of an asynchronous generating unit, the Commission also recognised there may be circumstances where the connection point is the most appropriate point of reference. The Commission therefore included in the draft rule a mechanism for parties to be able to set the magnitude of response requirement as an obligation at the connection point, discussed further in section 9.7.[543]

Exceptions to response requirements under deep fault conditions

In the draft determination the Commission accepted the views of several stakeholders who noted that some modern inverter connected plant is unable to sustain a response under very deep fault conditions.[544] These technical limits for inverter connected plant are accounted for in international grid codes, such as the German grid code.[545]

The Commission noted that a generating system experiencing very deep fault conditions is unlikely to create a 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 for a generating system, In such circumstances, 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. Given the limitations of many asynchronous generating systems, as indicated by stakeholders, and the lack of significant system security risk, the Commission's draft determination included these limits to reduce the risk of creating unnecessary barriers to the connection of some asynchronous technologies.

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 ranged from 5% to 20%.[546] The Commission's draft rule therefore included an automatic access standard requiring the capability to sustain reactive current injection down to 5% of nominal voltage at the generating unit terminals, and a minimum access standard requiring the capability to sustain reactive current injection down to 20% of nominal voltage at the generating unit terminals.[547]

542 Clauses S5.2.5.5(b)(3)(i) and S5.2.5.5(c)(3)(i) of the draft rule.

543 Clause S5.2.5.5(i)(2) of the draft rule.

544 Submissions to the consultation paper: Nordex, p. 6; Tilt Renewables, p. 4; Vestas, p. 2.

545 Nordex, submission to consultation paper, p. 6.

546 AEMO, email correspondence to the AEMC, 7 May 2018.

547 Clause S5.2.5.5(b)(3)(i)(A) of the draft rule.

9.5.2 Stakeholder views on the draft determination

Most stakeholders supported, or did not comment on, the response magnitude levels for asynchronous generating systems in the Commission's draft rule.[548] A number of stakeholders however questioned the use of the generating unit terminals as the point of obligation.[549] TransGrid expressed a preference for defining the obligation at the connection point,[550] while Lloyd's Register suggested that the response be clarified as being deemed to apply at either the generating system's connection point or the aggregate reactive current measured at all generating unit terminals and at the terminals of all dynamic reactive power equipment.[551] Stakeholders also noted the inconsistency created by placing the obligation to respond at the generating unit terminal voltages given the requirement to sustain a response until the connection point returned to within the continuous operating voltage at the connection point.[552]

Some stakeholders also indicated that additional clarity was required regarding the intention that the response magnitude required be defined as a plant capability within which a specific response level would be set appropriate to the local power system conditions.[553] These stakeholders reiterated the risk of instability associated with the automatic or minimum access standard being interpreted as a requirement to provide a specific level of reactive current response, rather than a plant capability. Lloyd's Register in particular requested that the Commission clarify that generator access standards for reactive current injection and absorption act as requirements to demonstrate unit capability only, with the actual current injection levels to be negotiated with the network service provider and AEMO on a site specific basis.[554]

9.5.3 Final determination

This section sets out the Commission's analysis and conclusions in response to stakeholder views on the draft determination, as well as any changes between the draft and final rules.

Point of obligation - connection point or generating system terminals

The Commission's final rule imposes the obligation for a reactive current response at the connection point. This is a change from the draft rule, which imposed the obligation at the generating unit terminals.[555]

The Commission agrees with stakeholders regarding the inconsistency created by specifying the requirement for reactive current response magnitude at the generating unit terminals, and other requirements that place obligations at the connection point.[556] Specifically the

548 Submissions to the draft determination: TasNetworks, p. 6; AGL, p. 3; ENA p. 8.

549 Submissions to the draft determination: TransGrid, p. 6; Lloyd's Register, p. 7.

550 TransGrid, submission to the draft determination, p. 6.

551 Lloyd's Register, submission to the draft determination, p. 7.

552 Submissions to the draft determination: TasNetworks, p. 8; TransGrid, p. 6; Lloyd's Register, p. 7.

553 Submissions to the draft determination: Advisian, p. 2; Eneflux, p. 5; SMA, p. 2; Lloyd's Register, p. 7.

554 Lloyd's Register, submission to the draft determination, p. 7.

555 Clauses S5.2.5.5(b)(3)(i) and S5.2.5.5(c)(3)(i) of the final rule.

556 In particular the requirement to sustain reactive response until the voltage at the connection point returns to within the continuous operating voltage band.

Commission considers that mixing these two points of reference to be unclear and likely to create confusion.

The Commission notes that the general approach taken across access standards in the NER is to place obligations at the connection point. This approach provides greater certainty for AEMO and network service providers regarding the performance of the power system. It also allows the connection applicant to make decisions behind the connection point, such as on plant design and operation, to meet the obligation at the connection point. Requirements defined at the generating unit terminals therefore risk inappropriately restricting the design and operational options available to connection applicants.

The Commission also notes the additional costs of high speed metering on each generating unit within a generating system required to demonstrate compliance with an obligation defined at the generating unit terminals. The Commission therefore considers the costs of compliance with an obligation at the generating unit terminals, together with the benefits outlined above for defining the obligation at the connection point, justify the obligations for reactive current respond being defined at the connection point.

Clarifying magnitude of reactive current response capabilities

The final rule clarifies that the obligation is for the generating system to be capable of a range of magnitudes of reactive current response, as well as a requirement for the generating system to meet a specific reactive current response. Given stakeholder support, the Commission's final rule also retains the magnitude of response capabilities for asynchronous generating systems proposed in the draft rule.[557]

The primary concern raised by stakeholders was the risk of the automatic or minimum access standard response magnitudes being prescriptively applied in inappropriate circumstances. Stakeholders noted that even the minimum access standard level of response may be excessive under weak fault level conditions, requiring investment in auxiliary reactive plant such as static VAR compensators or synchronous condensers.[558]

Some stakeholders appear not to have appreciated the Commission's intent in the draft rule that a capability negotiated between the minimum and automatic access standards define the upper end of a response capability range within which a specific response, appropriate for the connection point, could be set. The flexibility to set the specific response (within the negotiated range) at a level appropriate to the connection extends to a setting of no response. The draft rule contained the requirement to record the specific response as a separate clause to the magnitude of response requirements, which may have made the Commission's intent unclear.[559]

The final rule clarifies that the generating system must have facilities capable of supplying and absorbing from the network reactive current sufficient to meet the negotiated level, with the performance standards to record the actual response, appropriate to the connection point, as agreed with AEMO and the network service provider. For clarity, the final rule

557 Clauses S5.2.5.5(b)(3)(i) and 5.2.5.5(c)(3)(i) of the final rule.

558 Submissions to the draft determination: Advisian, p. 2; Eneflux, p. 5; SMA, p. 2; Lloyd's Register, p. 7.

559 Clauses S5.2.5.5(c)(5) and S5.2.5.5(b)(5) of the draft rule.

incorporates these requirements within the relevant clauses that outline the required reactive current response (instead of as a separate general requirement).[560]

Exceptions to response requirements under deep fault conditions

Consistent with the change to the point of obligation, the final rule also adjusts the exception to response requirements for deep faults. In the draft rule these exceptions were specified in terms of voltage levels at the generating unit terminals, and in the final rule they are specified at the connection point.

The adjustment specifies equivalent levels of voltage at the connection point to those that were specified in the draft rule as being measured at the unit terminals, accounting for likely impedances between the generating unit terminals and connection point and levels of reactive current injection required at low voltage levels. The Commission's final rule exempts asynchronous generating systems from the requirement to sustain reactive current injection:[561]

- under the automatic access standard, for voltages of 0% or lower of normal voltage at the connection point, and
- under the minimum access standard, for voltages of 15% or lower of normal voltage at the connection point.

The Commission is also aware that some generating systems do not have grid transformers between the generating unit terminals and the connection point.[562] For these circumstances, the final rule retains the arrangements currently in the draft rule as, in the absence of a transformer acting as an impedance, generating unit terminal voltages will substantially correspond to connection point voltages in the absence of a grid transformer. The final rule exempts asynchronous generating systems for which there is no grid transformer from the requirement to sustain reactive current injection:[563]

- under the automatic access standard, for voltages of 5% or lower of normal voltage at the connection point, and
- under the minimum access standard, for voltages of 20% or lower of normal voltage at the connection point.

9.6 Response speed and duration

This section sets out the Commission's draft and final determinations on the response speed and duration for reactive current response in clause S5.2.5.5.

560 Clauses S5.2.5.5(b)(3)(i) and S5.2.5.5(c)(3)(i) of the final rule.

561 Clauses S5.2.5.5(b)(5) and S5.2.5.5(c)(5) of the final rule.

562 The Commission understands that connection other than through a grid transformer is uncommon. The Commission however considers that such circumstances should still be accounted for in the rules.

563 ibid.

9.6.1 Draft determination

The Commission's draft rule included new automatic and minimum access standard requirements requiring a reactive current response from asynchronous generating systems that:[564]

- 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 also included 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,[565] 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.[566]

In its draft determination the Commission included explicit requirements for the duration and speed of the reactive current response, recognising that it is important to specify these requirements for asynchronous generating systems that do not respond inherently.

Automatic access standard

The Commission recognised that a fast response is a generally desirable property when managing faults, but that the speed of response also needs to be consistent with response stability, which is affected by power system conditions at the connection point. The Commission considered 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 appropriate response magnitude can be set for conditions at the connection point, thereby prioritising a fast response that is appropriate for the management of short duration fault events.

The Commission's draft rule included a requirement under the automatic access standard for asynchronous generating systems to respond with a 40 ms rise time and 70 ms settling time while remaining adequately damped.[567] This aligned the requirements with those applying in Germany.[568]

564 Clauses S5.2.5.5(b)(4) and S5.2.5.5(c)(4) of the draft rule.

565 Clause S5.2.5.5(c)(3)(i) of the draft rule.

566 Clause S5.2.5.5(c)(4) of the draft rule.

567 Clause S5.2.5.5(b)(4) of the draft rule.

568 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

Regarding the duration of required response, 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.[569] The Commission agreed this was appropriate and included this as an automatic access standard requirement of the draft rule.[570] However the Commission also noted that expressing the duration limit in this open ended way effectively makes the over and under-voltage duration requirements for continuous uninterrupted operation specified in S5.2.5.4 the duration limit for which reactive current response must be sustained.[571]

The Commission considered 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.

Minimum access standard

While the Commission's draft determination accepted the requirements for continuous uninterrupted operation as appropriate limits for the duration of response required under the automatic access standard, the Commission included lower requirements to account for the response duration limits of operation in HVRT and LVRT modes of some inverters, which can be limited to around two seconds.

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. This includes requirements for the voltage bands 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).[572]

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). PPC based response is therefore able to sustain a stable response for a long duration but unable to achieve the speed of response requirements under the automatic access standard.

The Commission was not able to obtain advice on what the fastest possible rise and settling time for PPC based response was, that also sustained 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.[573] In the absence of any contradictory evidence, the Commission accepted AEMO's view. The Commission's minimum access standard in its draft rule provided the

569 Rule change request, proposed rule, clauses S5.2.5.5(b)(2)(i) and S5.2.5.5(c)(2)(i).

570 Clause S5.2.5.5(b)(3)(i) of the draft rule.

571 Clause 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.

572 Rule change request, p. 30; AEMO, submission to consultation paper, p. 20.

573 AEMO, email correspondence to the AEMC, 3 May 2018.

following flexibility, accounting for the trade-off between reactive current response speed given equipment capability limits:

- For all under-voltage events (that is, below the under-voltage threshold), speed of reactive current response is prioritised over duration of reactive current response. The draft rule therefore required an asynchronous generating system to sustain a reactive current response for at least two seconds in recognition of inverter response/stability limits.[574]
- 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 under the draft rule therefore required that, to the extent that a duration for continuous uninterrupted operation under S5.2.5.4 is required 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 was intended to allow response to initially occur via PPC before transition into HVRT mode.[575]

9.6.2 Stakeholder views on the draft determination

Nordex and Lloyd's Register both commented on the achievability of the proposed 70ms settling time requirement.[576] Lloyd's Register suggested that the proposed rise and settling time requirements be removed from the minimum access standard to allow a lower rise or settling time to be negotiated where meeting the minimum access standard requirements in the draft rule would involve significant extra cost for additional reactive plant.

Ergon Energy and Energex requested clarification that the 180 ms applies from the end of the initial 2 second fault response such that the total allowable time is 2.18 seconds.[577] TasNetworks considered the draft rule did not reflect the Commission's stated policy intent. TasNetworks suggested clarifying that the reactive current response must be sustained for not less than 2 seconds while the generating system and each of its generating units remains connected to the network.[578]

9.6.3 Final determination

This section sets out the Commission's analysis and conclusions in response to stakeholder views on the draft determination, as well as any changes between the draft and final rules.

Speed of response in the minimum access standard

The final rule removes the 180 ms threshold from the minimum access standard requiring that asynchronous generating units respond as soon as practicable where a response duration of greater than 2 seconds is required.

574 Clause S5.2.5.5(c)(4) of the draft rule.
575 ibid.
576 Submissions to the draft determination: Lloyd's Register, p. 7; Nordex, p. 14.
577 Ergon Energy and Energex, submission to the draft determination, p. 5.
578 TasNetworks, submission to the draft determination, p. 8.

No objections were raised with the duration and speed of response requirements proposed in the draft rule's automatic access standard. Stakeholders' concerns on the draft rule speed of response requirements involved the minimum access standard and its interpretation. Lloyd's Register suggested that the proposed rise and settling time requirements be removed from the minimum access standard[579] and Ergon Energy and Energex requested clarification regarding the 180 ms rise time limit in the minimum access standard for reactive current absorption of greater than 2 seconds.[580]

The Commission considers a fast, yet stable, response to be the primary objective given the system security risks associated with short duration fault events. For this reason, it considers the minimum access standard requirement for a fast rise time of 40 ms and settling time of 70 ms to remain appropriate where that response can be provided stably. For circumstances where power system security is better served by a longer response, rather than a faster response, the minimum access standard in the draft rule provided an exception to the speed of response requirements. Should a response of greater than 2 seconds be required, a fast inverter ride through response would be inappropriate, thereby necessitating a slower PPC response. This exception accounts for the HVRT and LVRT response stability limits in certain inverter designs.

While the Commission considers these provisions to remain appropriate, it also understands that there is significant uncertainty as to the response speed possible from different PPC designs. Given the requirement to respond as fast as practicable, and the range of potential technology options and associated response speeds, the Commission has removed the 180 ms rise time limit in the minimum access standard in the final rule.

The Commission does not consider the removal of this limit to pose a risk to system security, given the requirement to respond as soon as practicable and the requirements under the negotiating process. The Commission considers the removal of this requirement should reduce the potential for confusion, remove the potential for barriers to specific technologies and provide flexibility for a wider range of possible technical solutions.

9.7 Response thresholds

This section sets out the Commission's draft and final determinations on the voltages for which reactive current response is required to commence under clause S5.2.5.5.

9.7.1 Draft determination

The Commission's draft rule introduced a general requirement for reactive current response during disturbances which:

- established a range within which thresholds for activation of the reactive current contribution are set:[581]

579 Lloyd's Register, submission to the draft determination, p. 7.

580 Ergon Energy and Energex, submission to the draft determination, p. 5.

581 Clause S5.2.5.5(i)(4) of the draft rule.

  - 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
  - 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
- specified that:
  - the thresholds for activation of the reactive current contributions must be recorded in the performance standards,[582] and
  - the voltage thresholds for reactive current response are to be defined at the generating unit terminals.[583]

Point of reference - connection point or generating unit terminals

The Commission considered in its draft determination that the reactive current response should commence at voltages referenced to the generating unit terminals rather than the 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 generating unit. Therefore, each individual generating unit enters LVRT or HVRT modes based on the voltage measured at its terminals, rather than at the connection point.

This made AEMO's proposed changes, which required a reactive current response to commence when voltage reached certain specific threshold voltages at the connection point,[584] infeasible for most asynchronous generating systems. The infeasibility arises due to the difference between voltage at the terminal and connection point which changes significantly depending on inverter tap positions and pre-fault reactive power flows both of which are outside the generator's direct control.

As an asynchronous 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 did 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.

As a specific response threshold voltage is implemented at the generating unit terminals, the Commission's draft rule placed the obligation to trigger a reactive current response at the terminals of the generating units or reactive plant making up the asynchronous generating system.[585]

582 ibid.
583 ibid.
584 Rule change request, p. 25.
585 Clauses S5.2.5.5(b)(3)(i) and S5.2.5.5(c)(3)(i) of the draft rule.

Flexibility in threshold level settings

The Commission's draft rule provided flexibility to set the reactive current response thresholds at generating unit voltages outside the boundaries of the continuous operating voltage band.[586] This flexibility was needed to address the uncertainty in the relationship between the voltage seen by the generating unit triggering reactive current response, and the voltage at the connection point, discussed above. The Commission noted that this issue can cause inappropriate reactive current response that may lead to adverse outcomes, including unstable operation and potentially risks to system security.

AEMO had proposed the boundaries of the continuous operating voltage band (90% to 110% of normal voltage), measured at the connection point, as the single specific thresholds at which reactive current response must commence.[587] A number of stakeholders suggested defining ranges in which the thresholds for reactive current response can be set. 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. TransGrid proposed response threshold ranges of 80-90% and 110-120% of normal voltage at the connection point specified within which response may occur.[588]

The Commission's draft determination reflected a subsequent proposal by AEMO to allow thresholds for activation of the reactive current contribution (to be agreed with AEMO and the network service provider) to be within the limits of 85% and 112% of the nominal voltage at the generating unit terminals.[589] The Commission accepted AEMO's view that the need for flexibility is appropriately provided for with those response thresholds. The draft rule implemented these arrangements 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.[590]

9.7.2 Stakeholder views on the draft determination

Stakeholders expressed a strong view that the reactive current response threshold ranges in the draft rule provided insufficient flexibility to avoid response instability and response within the continuous operating voltage band.[591] Huawei considered that the proposed ranges were insufficient to prevent dynamic instability associated with 'hunting', arguing that the allowable range from 85% to 112% is too narrow, especially for generating systems with low SCR or generating large amounts of reactive power.[592] TransGrid reiterated the view expressed in its submission to the consultation paper. While not objecting to smaller ranges as part of an automatic access standard, TransGrid considered the minimum access standard should allow for a wider response within the range 80% to 90% and 110% to 120%.[593]

586 Clauses S5.2.5.5(b)(3)(i) and (c)(3)(i) of the draft rule.
587 Rule change request, p. 25.
588 Submissions to the consultation paper: TransGrid, p. 5; Vestas, p. 2; CEC, p. 14.
589 AEMO, email correspondence to AEMC, 2 May 2018.
590 Clause S5.2.5.5(i)(4) of the draft rule.
591 Submissions to the draft determination: Nordex, p. 18; Huawei, p. 2; TransGrid, p. 6; Eneflux, p. 5; Lloyd's Register, p. 8.
592 Huawei, submission to the draft determination, p. 2.
593 TransGrid, submission to the draft determination, p. 6.

9.7.3 Final determination

This section sets out the Commission’s analysis and conclusions in response to stakeholder views on the draft determination, as well as any changes between the draft and final rules.

Response commencement ranges

The final rule sets out minimum and automatic access standard requirements for connection point voltage ranges within which a generating system must commence its reactive current response to over or under-voltage disturbances.[594]

The difference between voltage levels at the connection point (where the final rule requires a response) and the generating unit terminals is uncertain. This uncertainty arises due to a range of factors. These factors include those within the generator’s control, such as the transformer design impendences, and those outside the generator’s control, such as pre-fault network voltages, transformer tap positions, and pre-fault reactive power flows. Therefore, a specific generating unit terminal voltage will correspond to a range of connection point voltages, depending on the conditions at the commencement of the fault.

Most asynchronous generating systems commence reactive current response at specific generating unit terminal voltages. As a result, for the final rule to define an obligation to commence reactive current response according to connection point voltages, uncertainty in the relationship between the unit terminals and connection point voltages must be accounted for. This involves establishing a range of connection point voltages within which a generating system must commence its response rather than requiring a response to commence at a specific generating unit terminal voltage, as in the draft rule.

Generators can make design choices that minimise uncertainty in its connection point response by installing low impedance transformers or potentially implementing adaptive control systems. Design choices such as these involve additional costs, but reduce the connection point voltage range required to produce a stable response, while also avoiding response within the continuous operating voltage band. The Commission has therefore included in its final rule an automatic access standard, with a relatively narrow range within which a generating system must commence its reactive current response, for circumstances where system security and quality of supply considerations justify such additional costs.

The Commission has also included in its final rule a minimum access standard that provides the flexibility for more conventional, lower cost equipment to connect in parts of the power system where system security considerations do not justify a narrow response range. The greater level of flexibility under the minimum access standard reflects the ranges proposed by TransGrid in its submissions to the consultation paper and draft determination.[595] The Commission considers the range suggested by TransGrid to represent an appropriate level of capability to account for the needs of the power system in some locations, and an achievable capability for standard equipment.

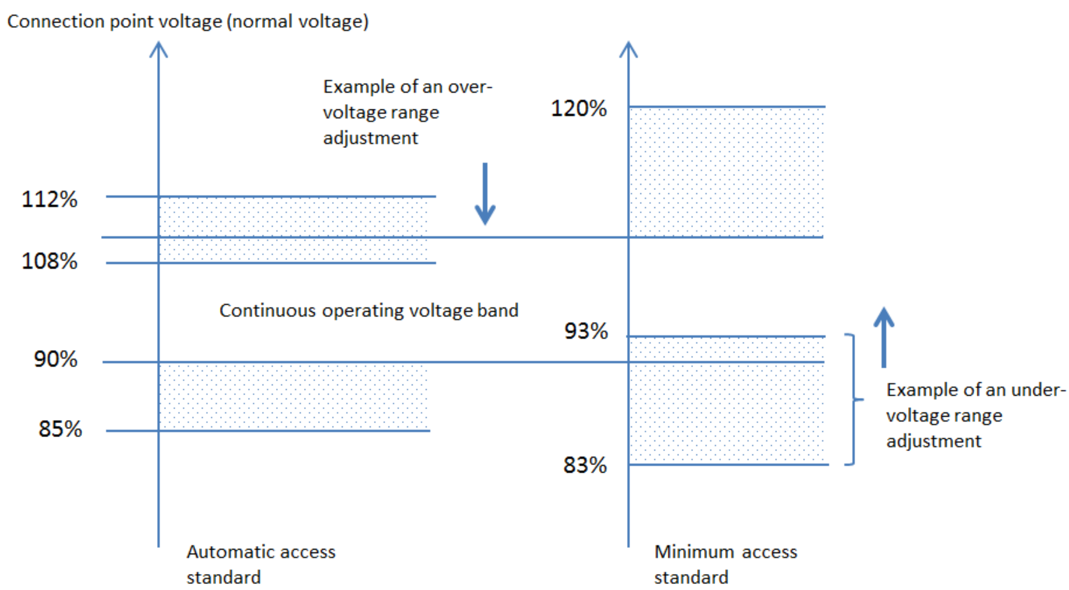
594 Clauses S5.2.5.5(b)(4) and S5.2.5.5(b)(4) of the final rule.

595 TransGrid, submission to the draft determination, p. 6.

Under the final rule, over voltage and under voltage connection point ranges are defined within which a generator must commence its reactive current response. These ranges are conceptually illustrated in Figure 9.4 and involve an inner response boundary at which a generator may commence its reactive current response and an outer response boundary by which a generator must have commenced its response. The Commission's final rule includes requirements for an asynchronous generating system to:

- under the automatic access standard:[596]
  - for under voltage response, commence reactive current response between a connection point voltage of 85% and 90% of normal voltage,[597] and
  - for over voltage response, commence reactive current response between a connection point voltage of 110% and 115% of normal voltage, and
- under the minimum access standard:[598]
  - for under voltage response, commence reactive current response between a connection point voltage of 80% and 90% of normal voltage, and
  - for over voltage response, commence reactive current response between a connection point voltage of 110% and 120% of normal voltage.

Figure 9.4: Reactive current response commencement ranges



The connection point response ranges specified in the Commission's final rule are of the same width for both over and under-voltage. This is a departure from the approach put

596 Clause S5.2.5.5(b)(4) of the final rule.

597 Note that the final rule references the requirement to commence a reactive current response to normal voltage as the requirement is in respect of connection point voltages.

598 Clause S5.2.5.5(c)(4) of the final rule.

forward by AEMO, and incorporated in the draft rule, which required a response range closer to the over-voltage edge of the continuous operating voltage band at 110% than it did for the under-voltage edge of the continuous operating voltage band at 90%.[599]

While the Commission acknowledges AEMO's concerns regarding the need to manage over-voltage conditions in certain parts of the power system, an asymmetric requirement that provides a narrower range in which to commence response for over-voltages, as set out in the draft rule, is not appropriate. This is because the factors that determine the required width of the connection point voltage ranges are largely symmetrical for voltages above the continuous operating voltage band and voltages below it. These factors include the relevant impedances and voltage changes associated with pre-fault reactive power flows which are the same for over and under-voltage conditions.

The Commission considers it is not appropriate to address this issue by narrowing the voltage range for response only for over-voltages, which would lead to significant additional costs and would also in effect narrow the actual response range for under voltages. However, the Commission considers it is appropriate to address the need to quickly manage over-voltage conditions by providing for the flexibility to adjust where the response ranges commence and end, as set out below.

Adjustment of the commencement point for response ranges

The final rule provides flexibility to adjust the connection point voltage ranges within which a generating system must commence its reactive current response to over or under voltage disturbances (where AEMO and the network service provider agree), while keeping the width of the ranges the same (that is, *Δ* 5% in the case of the automatic access standard, and *Δ* 10% in the case of the minimum access standard).[600]

The final rule specifies reactive current response commencement ranges that commence at thresholds that align with the boundaries of the continuous operating voltage bands; being 110% for over voltages and 90% for under voltages. These inner boundaries are set recognising that reactive current response within the continuous operating voltage band is generally undesirable due to the risk of inappropriate response dynamics, such as hunting. However, there are circumstances where some response within the band may be justified if it provides system security benefits in other areas and avoids inappropriate response dynamics. In such circumstances, the final rule provides flexibility to shift the ranges subject to agreement by all parties. This could potentially include shifting the inner boundaries of the commencement ranges to sit within the continuous operating voltage band, or outside of this band.

The Commission understands that AEMO is concerned about the need to manage risks associated with over-voltage conditions in certain areas of the power system. As a result there may be a system security justification for allowing reactive current absorption to commence prior to the connection point voltage reaching the upper boundary of the

599 Clause S5.2.5.5(i)(4) of the draft rule. The draft rule provided scope for generators to implement generating unit terminal votlage thresholds between 110 - 112% for voltage voltages and 85-90% for under voltages.

600 Clauses S5.2.5.5(b)(4) and S5.2.5.5(c)(4) of the final rule.

continuous operating voltage band at 110% of normal voltage. The flexibility to adjust the commencement of the over voltage response range lower, into the continuous operating voltage band, may provide AEMO with the scope to better manage such over-voltage risks.

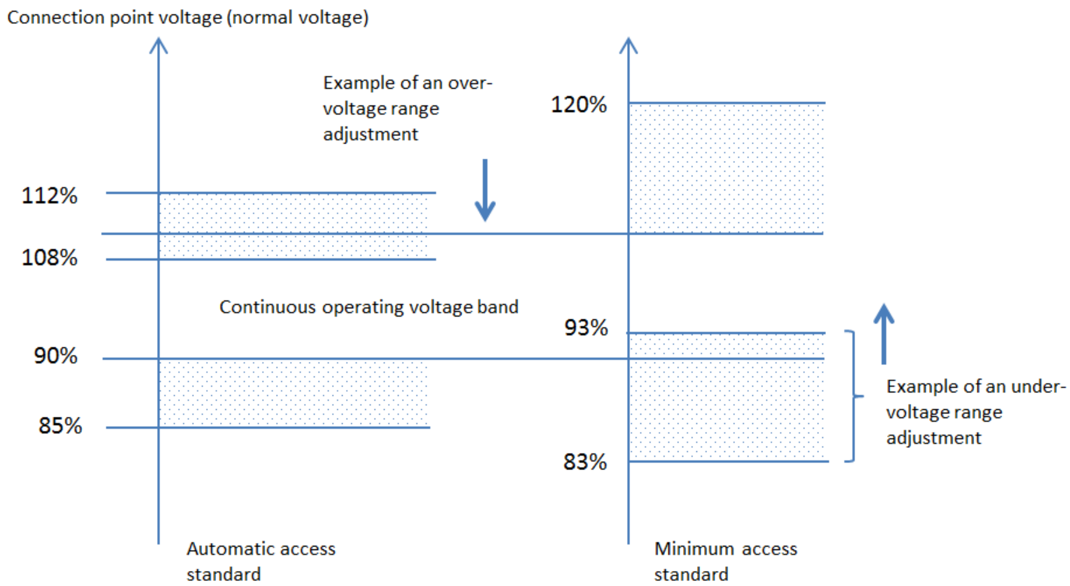
There are also other drivers for the need to include the flexibility to vary the point at which the reactive current response commences. The Commission understands that some connection points have operating voltages as high as 107% of normal. At such locations, generating systems could experience large step changes in voltage (e.g. around 17%) following a fault that causes a drop in voltage, prior to commencing a reactive current response during a fault if the under voltage inner response boundary is set at 90% of normal voltage at the connection point. For such generating systems, likely transformer tap-positions would lead to an undesirably low voltage (in this example, as low as 83% of normal voltage at the connection point) at which the generating system commences its reactive current response to a fault. In such circumstances, system security may be best served by adjusting the under voltage response commencement range into the continuous operating voltage band in order to minimise the voltage step prior to response commencing.

The Commission's final rule therefore allows the reactive current response commencement ranges to be adjusted as agreed with the network service provider and AEMO.[601] The final rule does not place conditions on, or restrict this flexibility, except that the total range between the upper and lower bounds of the high or low voltage response ranges remains the same, being *Δ* 5% for the automatic access standard and *Δ* 10% for the minimum standard. Adjustment can therefore involve shifting the over and under-voltage response ranges together or independently of one another (depending on the underlying issue driving the need to shift where the response can commence) and is conceptually illustrated in Figure 9.5.

The Commission has provided this flexibility in recognition that the range of factors that determine the appropriate points at which the commencement of a reactive current response should occur, is appropriately assessed on a case by case basis. Requiring all parties to agree with any adjustment to the point at which a response commences will incorporate each party's perspectives and responsibilities, including AEMO's system security considerations, the network service provider's quality of supply considerations, and the connection applicant's perspective in considering equipment capability, protection and cost. The Commission considers the requirement for all parties to agree should effectively manage any risks associated with adjustment on a case by case basis, driven by the underlying circumstances of the connection.

601 Clauses S5.2.5.5(b)(4) and S5.2.5.5(c)(4) of the final rule.

Figure 9.5: **Examples of reactive current response commencement range adjustment**



9.8 Response limits

This section sets out the Commission's draft and final determinations on certain response limits for reactive current response in clause S5.2.5.5.

9.8.1 Draft determination

The Commission's draft rule contained 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[602]
- a minimum access standard that limited 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[603]
- 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

602 Clause S5.2.5.5(b)(3) of the draft rule.
603 Clause S5.2.5.5(c)(3) of the draft rule.

continuous current of the generating system, and is limited to the duration of rise time,[604] and

- a general requirement, as proposed by AEMO, that an asynchronous generating system may be limited to providing a reactive current response of the maximum continuous current of the generating system, including its operating asynchronous generating units.[605]

Active and reactive current consumption limits

The Commission's draft rule included limits on the level of active and reactive current that could be consumed at the commencement of a fault. 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's investigation of the South Australian system black event in 2016 identified unexpected consumption of reactive current on occurrence of the faults by several asynchronous generating systems which AEMO considered to have increased the overall severity of the disturbances.[606]

The Commission accepted AEMO's proposal for limits to be applied given it understood that inverter-based plant can take time to 'reorient' itself on the occurrence of fault. That is, time for the control systems to assess power system conditions and react to them appropriately. 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.[607] 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.[608]

The Commission considered that AEMO's proposed approach, without flexibility, may inadvertently create unnecessary barriers to entry. The draft rule therefore imposed limits on the active and reactive current consumption by an asynchronous generating system immediately upon the occurrence of a fault but also provided flexibility to limit the risk of creating unnecessary barriers to entry and allow 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:

- included an automatic access standard requirement, reflecting the general requirement proposed by AEMO, that any active current consumption immediately upon the

604 Clause S5.2.5.5(i)(5) of the draft rule.

605 ibid.

606 AEMO, Black System South Australia 28 September 2016: Final report, p. 246.

607 Submissions to the consultation paper: GE Power, p. 9; Clean Energy Council, p. 14.

608 GE Power, submission to consultation paper, p, 9.

occurrence of a fault must not exceed 5% of the maximum continuous current of the generating system, and is limited to 20 ms[609]

- included 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,[610] and
- included 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.[611]

Total response capability

The Commission's draft rule included AEMO's proposed limit to the maximum reactive current response an asynchronous generating system must be capable of. AEMO proposed a general response requirement for an asynchronous generating system to be limited to providing a reactive current response of at least the maximum continuous current rating of the generating system (including all operating generating units).[612]

Stakeholders did not raise any issues with AEMO's proposed requirements for asynchronous generating systems. The Commission noted in its draft determination that it understood 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. Consistent with other characteristics of an asynchronous generating system's reactive current response during disturbances, the Commission considered it was 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 included 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, including its operating asynchronous generating units.[613]

9.8.2 Stakeholder views on the draft determination

No stakeholder views were received on the total response capability limits for asynchronous generating systems in the draft rule.

Nordex however indicated that the draft rule limits to the reactive and active current consumption on occurrence of a fault would create unnecessary barriers to the connection of Type 3 wind. Nordex requested substantially more flexibility to allow reactive current consumption of up to 15% of the maximum continuous current of the generating system and

609 Clause S5.2.5.5(b)(3) of the draft rule.

610 Clause S5.2.5.5(c)(3) of the draft rule.

611 Clause S5.2.5.5(i)(5) of the draft rule.

612 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).

613 Clause S5.2.5.5(i)(1) of the draft rule.

active current of up to 20% of the maximum continuous current if the wind turbine is operating in sub-synchronous mode. Nordex considered the direct connection of the Type 3 wind turbine stator to the grid involved fundamental physical factors justifying this additional flexibility.[614]

9.8.3 Final determination

The Commission's final rule does not impose an explicit requirement limiting the level of active and reactive current that may be consumed on occurrence of a fault. The Commission considers further information is required identifying the nature of the issue, before imposing an explicit requirement in this area, noting also that other access standards provide some protection against system security issues that may arise due to active and reactive current consumption on occurrence of a fault.[615]

The draft rule included AEMO's proposal as an automatic access standard but also included a minimum access standard for active current in response to stakeholder concerns about the achievability of AEMO's proposal as a general requirement.[616]

Although this requirement limiting active and reactive power consumption was included in the draft determination, the Commission has since undertaken further consultation and examination of the issue. These further investigations have been inconclusive on the nature of the technical issue being addressed.

The Commission is aware of isolated examples of equipment that has been shown to consume reactive or active current on occurrence of a fault under certain circumstances.[617] The Commission has received conflicting information from equipment manufacturers, suggesting that this issue may not necessarily be fundamental to all Type 3 wind generating systems, as suggested by Nordex. Given the availability and quality of the information available to the Commission at this point, the Commission is unable to confidently establish the underlying technical issues that cause the consumption of active or reactive current on occurrence of a fault, and the materiality of these issues in isolation or in aggregate.

Furthermore, the Commission lacks sufficient information to establish whether active and reactive current consumption on occurrence of a fault is a widespread issue, leading to material system security risks. AEMO's investigation of the South Australian black system event noted unexpected reactive current consumption measured at three wind farms.[618] However, no other active or reactive current consumption was reported on commencement of any of the faults leading to the South Australian black system event.

614 Nordex, submission to the draft determination, p. 12.

615 Obligations that include a requirement to maintain continuous uninterrupted operation require a generating system to not exacerbate or prolong a disturbance.

616 Clauses S5.2.5.5(b)(3)(i) and S5.2.5.5(c)(3)(i) of the draft rule. The Commission notes that accepting Nordex's submission as a minimum access standard would further increase the levels of allowable active and reactive current consumption significantly from the levels in the draft rule minimum access standard. To incorporate Nordex's request, allowable reactive current consumption would increase by three times, and allowable active current consumption would double from the level included in the minimum access standard in the draft determination.

617 Information supplied on a commercial in confidence basis.

618 AEMO, system black report , Appendix X, p. 245 - Unexpected reactive power responses were recorded for Hornsdale, North Brown Hill, and The Bluff wind farms.

The kind of phenomenon that was identified by AEMO was also highly transient, involving time scales on the order of 20 ms or one 50 Hz cycle in duration. The Commission understands that this kind of highly transient active and reactive current consumption is not expected to lead to the system security risks associated with longer duration events.

The Commission acknowledges that active and reactive current consumption on occurrence of a fault may prolong or exacerbate a disturbance. However, the Commission also considers it not appropriate to impose a specific obligation without a clear understanding of the technical issues and materiality of the system security risks that need to be addressed.

The Commission notes that existing obligations to maintain continuous uninterrupted operation require generating systems not to exacerbate or prolong disturbances.[619] While this provision is not specific to active or reactive current consumption on occurrence of a fault, it provides a mechanism to prevent the connection of a generating system that would, on occurrence of a fault, consume active or reactive current in a manner that would exacerbate or prolong a disturbance. The Commission therefore considers existing arrangements provide AEMO with the ability to deny the connection of equipment that poses a clear risk to the power system due to its behaviour during a disturbance. Any specific limits to consumption of active and reactive power on occurrence of a fault should only be implemented when there is clear evidence of the technical factors present, and the system security issues they give rise to.

9.9 Arrangements relating to measurement

This section sets out the Commission's draft and final determinations on certain arrangements relating to measurement for reactive current response requirements in clause S5.2.5.5.

9.9.1 Draft determination

To provide clarity and flexibility as to the method and point of measurement for reactive current response, the Commission's draft rule:

- allowed the reactive current contribution required to be with reference to the phase-to–phase, phase-to-ground or sequence components of voltages[620]
- required 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,[621] and
- allowed the reactive current contribution and voltage deviation to be measured at the connection point (with the agreement of AEMO and the network service provider), rather than at the generating unit terminals.[622]

619 See definition of continuous uninterrupted operation in Chapter 10 of the NER.

620 Clauses S5.2.5.5(i)(3) of the draft rule.

621 ibid.

622 ibid.

Ratio of negative-sequence to positive-sequence current injection

The Commission's draft rule provided flexibility in the approaches available to measuring voltage and current. AEMO proposed allowing the reactive current contribution required to be calculated with reference to the phase-to–phase, phase-to-ground or sequence components of voltages. However, when using sequence components, AEMO proposed that 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.[623]

AEMO's proposed requirement had two elements, the first was to allow flexibility in the approach to measuring reactive current, and the second was to require agreement to the ratio between negative and positive sequence currents for various, undefined, types of voltage disturbances. The Commission agreed with AEMO's proposal to provide flexibility to account for the various approaches used by manufactures to model generating system response to fault conditions. The Commission's draft rule therefore implemented the proposed changes as a general requirement for which the ratio of negative to positive sequence components must be agreed.[624]

Flexibility in point of response measurement

The Commission's draft rule provided that the reactive current response was to be measured at the generating unit terminals, with the flexibility to measure the response at the connection point rather than at the generating unit terminals.[625] AEMO's proposal was 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 the following as a general requirement:[626]

"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. The Commission however considered 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 included the changes proposed by AEMO allowing for flexibility in the point of measurement.[627]

623 Rule change request, proposed rule, clause S5.2.5.5(i)(iii).

624 Clause S5.2.5.5(i)(3) of the draft rule.

625 Clause S5.2.5.5(i)(2) of the draft rule.

626 Rule change request, proposed rule, clause S5.2.5.5(i) and (iv).

627 Clause S5.2.5.5(i)(2) of the draft rule.

9.9.2 Stakeholder views on the draft determination

No stakeholder submissions were received on the issue of measurement flexibility in the point of measurement or on the draft determination's requirements relating to negative and positive sequence current injection.

9.9.3 Final determination

The Commission's final rule retains the provisions in the draft rule relating to measurement.[628]

9.10 Maintaining current during a fault

This section sets out the Commission's draft and final determinations on arrangements relating to maintaining current during faults for reactive current response requirements in clause S5.2.5.5.

9.10.1 Draft determination

The Commission's draft rule:

- required 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,[629] and
- included 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.[630]

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.[631] AEMO noted that, prior to submitting this additional request, their proposed changes to clause S5.2.5.5 related solely to reactive current response during a fault. AEMO considered system security needs to justify additional requirements for active current injection during faults. To address this risk, AEMO proposed the following as an additional general requirement:[632]

> 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.

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% to

628 Clause S5.2.5.5(3)(i) of the final rule.
629 Clause S5.2.5.5(i)(6) of the draft rule.
630 ibid.
631 AEMO, Generator technical requirements: supplementary material to Rule change proposal, May 2018.
632 ibid. AEMO's use of maximum continuous current of the generating system relates to the total active and reactive current from the generating system.

20% voltage dip at the connection point. AEMO considered this to be a risk to power system security justifying their proposed requirement.[633]

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 maintaining active current during faults, the Commission noted that this should not occur at the expense of reactive current injection or be imposed in certain circumstances where active current injection may lead to instability. In particular, the Commission understood that in a part of the power system that is weak and with a low X to R ratio,[634] a high level of active power injection during a fault can cause voltage instability. While the draft rule implemented the requirement proposed by AEMO, the draft rule also provided guidance allowing for AEMO and the network service provider to limit active current injection where required to maintain system security and the quality of supply, and for those limits to be recorded in the performance standards for the generating system.[635]

9.10.2 Stakeholder views on Draft Determination

TasNetworks strongly supported the proposed requirement in the absence of alternative advice that it is not readily achievable.[636] SMA however expressed a strong view that the requirement was unrealistic, unachievable, and neglected the current technical capabilities of asynchronous generating systems.[637]

Other stakeholders raised a number of matters relating to temperature dependence and maximum continuous current availability given generation levels. Pacific Hydro observed that the maximum current available will depend on the level of generation prior to the fault indicating that maximum 'continuous' current cannot be 'available at all times'.[638] TransGrid noted that a generating system's maximum continuous current rating (active and reactive) is a function of temperature, suggesting the addition of a general requirement for a connection applicant to record any condition, such as temperature, under which the proposed reactive capability is specified.[639]

9.10.3 Final Determination

This section sets out the Commission's analysis and conclusions in response to stakeholder views on the draft determination, as well as any changes between the draft and final rules.

Clarification of over and under-voltage performance requirements

633 ibid.

634 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.

635 Clause S5.2.5.5(i)(6) of the draft rule.

636 TasNetworks, submission to the draft determination, p. 7.

637 SMA, submission to the draft determination, p. 3.

638 Pacific Hydro, submission to the draft determination, p. 4.

639 TransGrid, submission to the draft determination, p. 6.

The draft rule included a requirement to maintain the maximum continuous current of the generating system.[640] However, we are now aware a requirement expressed in this way could result in the apparent power exceeding the rating of the plant in over-voltage conditions. As a result it is necessary to make the requirement subject to the plant apparent power rating, given over-voltage conditions. This will allow the generating system to reduce its current response so that it is not required to exceed plant power ratings. The final rule therefore requires, for over-voltages above 115% of normal voltage at the connection point, the generating system to provide reactive current sufficient to maintain rated apparent power of the generating system, rather than to maintain maximum continuous current. The final rule retains the requirement to maintain maximum continuous current for under-voltage conditions.[641]

The Commission also agrees with the observations of TransGrid and Pacific Hydro that the current required to maintain rated apparent power or maximum continuous current, considering nominal voltage at the connection point, is a function of pre-fault generating levels and ambient temperature conditions. Therefore, the Commission's final rule changes the requirement so that it is subject to energy source availability and thermal performance characteristics.[642] This will be complemented by a general requirement to record any known condition, such as temperature, under which the proposed reactive capability is specified.[643]

Implementation as part of the automatic access standard

The draft determination included AEMO's proposal as a general requirement for a generating system to make the maximum continuous current of the generating system available at all times.[644] The proposal for the inclusion of this requirement was received not long before the publication of the draft determination, leaving little opportunity for stakeholder engagement. Furthermore, the proposal was received after the completion of the Commission's survey of equipment manufacturers.

As there was limited and inconclusive feedback from stakeholders on the need for, and issues with, this requirement in the draft rule, the Commission does not consider there is sufficient information available to impose a general requirement to make the maximum continuous current of the generating system available at all times without risking the creation of unnecessary barriers to connection.

The Commission recognises the potential system security benefits of generating systems that can make the maximum continuous current of the generating system available at all times during faults, and notes TasNetworks' strong support for the proposed requirement. 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. The system security benefits of this capability are therefore meaningful in certain regions of the power system such as South Australia and Tasmania. This benefit

640 Clause S5.2.5.5(i)(6) of the draft rule.
641 Clause S5.2.5.5(b)(6) of the final rule.
642 Clause S5.2.5.5(b)(6) of the final rule.
643 Clause S5.2.5.5(i)(4) of the final rule.
644 Clause S5.2.5.5(i)(6) of the draft rule.

however must be balanced against the risk of creating unnecessary barriers to the connection of some types of generating plant in regions where such performance is not required to maintain system security or quality of power supply.

The Commission's final rule therefore includes this requirement as an element of the automatic access standard for asynchronous generating systems, rather than as a general requirement. The negotiating process under the final rule requires connection applicants to propose levels of performance that are as close as practicable to the level of the automatic access standard requirement and justify why a lower level of performance is needed. AEMO and network service providers are able to reject the proposed levels of performance where they consider it would adversely affect power system security or quality of supply to network users. Implementing this requirement as an element of the automatic access standard would therefore provide scope for AEMO and network service providers to require the maximum continuous current of a generating system available at all times where justified by system security and quality of power supply considerations, without creating unnecessary barriers to connection where these issues are not present.

10 CONTINUOUS UNINTERRUPTED OPERATION

BOX 8: 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 disturbances (currently no explicit requirement), active power recovery following a disturbance (clause S5.2.5.5), as well as partial 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 final 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 disturbances, as well as extending the existing requirement to maintain continuous uninterrupted operation for 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.[645]

645 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, 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.

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:[646]

- the definition of continuous uninterrupted operation (Chapter 10 of the NER)
- over-voltage and under-voltage disturbances (clause S5.2.5.4)
- multiple 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 on both the rule change request and draft determination, and
- the Commission's final determination.

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, including those caused by network 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 (i.e. maintain 'continuous uninterrupted operation') a disturbance at its connection point will disconnect, which may increase the extent and severity of the disturbance experienced by other generating systems.[647] A cascading outage can occur when an increase in the size of a disturbance due to one generating system disconnecting increases the risk of the remaining generating systems also disconnecting.[648] In an extreme case a cascading outage can lead to a major supply disruption,[649] or even a black system event.[650]

Generally, the access standards for generators to maintain continuous uninterrupted operation are more arduous than the system standards that are applied to network service providers and AEMO. System standards are based around maintenance of the power system within defined limits following credible contingency events. The access standards for the continuous uninterrupted operation of generators are based around the generator surviving more severe, lower probability non-credible contingency events.

646 See clauses S5.2.5.3, S5.2.5.4, S5.2.5.5 and S5.2.5.7 of the NER.

647 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.

648 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."

649 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."

650 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. These system standards generally require the system to be maintained within defined limits following credible contingencies.[651]

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 a close relationship between continuous uninterrupted operation capabilities, and capabilities required under other access standards that aim to limit the likelihood or severity of disturbances. 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.

651 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.

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.

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,[652] while the continuous uninterrupted operation capabilities require generating systems to operate for short periods out to 47 Hz to 52 Hz during frequency disturbances.[653]

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.

If generating systems can only withstand a credible contingency then a major supply disruption due to cascading failure could occur as a result of a non-credible contingency that is only marginally more severe than a credible contingency. Such an outcome would not be acceptable as this could happen too often. Conversely, it is acceptable for a generating system to not maintain continuous uninterrupted operation for relatively extreme non-credible contingencies as these are very rare and it would be expensive to impose the cost of such high withstand capabilities. 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.[654]

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 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

652 A tighter range of 49.5Hz to 50.5Hz applies for generator or load contingencies.

653 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.

654 Parliament of South Australia, Report of the select committee on the state-wide electricity blackout and subsequent power outages, 28 November 2017, p. 12.

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 is not appropriate.

This is quite different to the minimum access standards for various other requirements, which do not necessarily require all generators to bring a basic level of capability. A good example are the access standards relating to reactive power capabilities and requirements.[655] The power system needs some reactive power capabilities in an area to satisfy the respective system standards in that area, 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 and the Commission's draft and final rules related 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 follows:[656]

> 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

Issues raised by AEMO and AEMO's proposed changes

In 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.[657] The current definition does not explicitly mention requirements in clause S5.2.5.5.

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655 Clauses S5.2.5.1(a) and (b) provide the automatic and minimum access standards for reactive power capability.

656 Chapter 10 of the NER.

657 Rule change request, p. 25.

AEMO therefore proposed the following changes to the definition of continuous uninterrupted operation:[658]

> 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, during the disturbance and 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 S5.2.5.5, 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*.

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, would remove 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.[659]

10.3.3 Draft determination

Stakeholder views on the rule change request

Several network businesses considered that the proposed definition removed uncertainty in how the definition is interpreted.[660]

Some stakeholders considered that some generating systems would not be able to comply with the requirement to not vary active or reactive power, unless required by performance standards, due to their inherent response to transient events in the power system.[661]

Further detail on stakeholder views on the rule change request and consultation paper is set out in section 10.3.3 of the draft determination.[662]

658 Rule change request, p. 87. Note, text proposed to be removed is struck through, and proposed new text is underlined.

659 Advice provided to the Commission by AEMO, 3 May 2018.

660 Submissions to the consultation paper: Energy Networks Australia, p. 8; Ergon-Energex, p. 8, TasNetworks, p. 17; Transgrid, p. 6.

661 Submissions to the consultation paper: Advisian, p. iv; Australian Energy Council, p. 2; Pacific Hydro, p. 11; Terrain Solar, p. 7.

662 AEC, *Generator technical performance standards: draft determination*, 31 May 2018, pp. 192-93, available at aemc.gov.au.

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:[663]

> 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 S5.2.5.5, 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.

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. AEMO's updated position also aimed to clarify that generating systems are not required to manage their active power during the presence of a fault.

Analysis

The Commission considered it appropriate to provide greater clarity and certainty to network users as to the specific requirements of continuous uninterrupted operation. This would contribute to the security of the power system by minimising risks associated with inappropriate interpretation of the term.

The draft determination noted some stakeholders were concerned with the replacement of "only substantially varying" with "not varying", 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. The Commission considered it would 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, but are nonetheless an insubstantial variation with minimal impact on the power system. The Commission instead considered it appropriate to allow for reasonable variation of active power output and reactive power injection or absorption after the clearance of a fault.

663 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. Note also 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.

The Commission also considered it appropriate to specify the contribution of active and reactive current as required or permitted in clause S5.2.5.5 during a disturbance. This is in accordance with a 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 of the draft determination).

Draft rule

The Commission made changes to the definition of 'continuous uninterrupted operation' in Chapter 10 of the draft rule to:

- allow variation of active and reactive current injection or absorption during a fault as required in clause S5.2.5.5
- allow variation of active power and reactive power injection or absorption after the clearance of a fault as required or permitted in clause S5.2.5.5
- specify 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
- qualify 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.

10.3.4 Stakeholder views on the draft determination

Stakeholders did not raise major issues with the definition of continuous uninterrupted operation in Chapter 10 of the draft rule.

Delta Electricity and Origin Energy supported the retention of "only substantially varying" in part (c) of the definition to allow for immaterial variations in active and reactive power that do not exacerbate or prolong a disturbance or cause a subsequent disturbance.[664] SMA considered that it would be beneficial to specify what "substantially varying" means under the definition (e.g. 1-2%).[665]

Stakeholders also raised material issues related to the implementation and operation of the definition of continuous uninterrupted operation as part of specific access standards in Schedule 5.2 of the NER. These will be discussed in the sections of this Chapter relevant to those access standards.

10.3.5 Final determination

The definition of continuous uninterrupted operation in Chapter 10 of the final rule is the same as that in the draft rule, except the phrase "so as to" has been removed from part (d) of the definition to improve clarity, and "exacerbate" is replaced with "exacerbating" for grammatical reasons.

664 Submissions to the draft determination: Delta Electricity, p. 7; Origin Energy, p. 1.

665 SMA, Submission to the draft determination, p. 3.

A change has also been made to S5.2.5.8 (Protection of generating systems from power system disturbances) in the final rule due to ambiguity as to the relationship between the definition of continuous uninterrupted operation, clause S5.2.5.8 and clause S5.2.5.10.

Under the definition of continuous uninterrupted operation, a generating system can disconnect if it is permitted to do so under a performance standard established under clause S5.2.5.8 (as well as clause S5.2.5.9). Clause S5.2.5.8 in turn specifies that a generating system may be automatically disconnected where permitted under S5.2.5.10 due to a failure of the generating plant. The Commission has removed the phrase "due to a failure of the generating plant" from clause S5.2.5.8(e)(4) to clarify that it is appropriate for a generating plant to disconnect if any of the conditions specified in clause S5.2.5.10 (e.g. conditions that would lead to pole slip, or unstable active power, reactive power or voltage at the connection point) are detected, regardless of whether or not a failure of the generating plant occurs. This change removes the ambiguity in determining whether or not a failure of the generating plant has occurred, and also recognises the increased risk that generating systems may need to disconnect due the occurrence of particular multiple voltage disturbances. AEMO advised the Commission that it was in favour of this change.[666]

10.4 Voltage disturbances

This section discusses AEMO's proposed changes and the Commission's draft and final rules related to 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.[667] 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.

666 Advice from AEMO via email, 17/08/18.

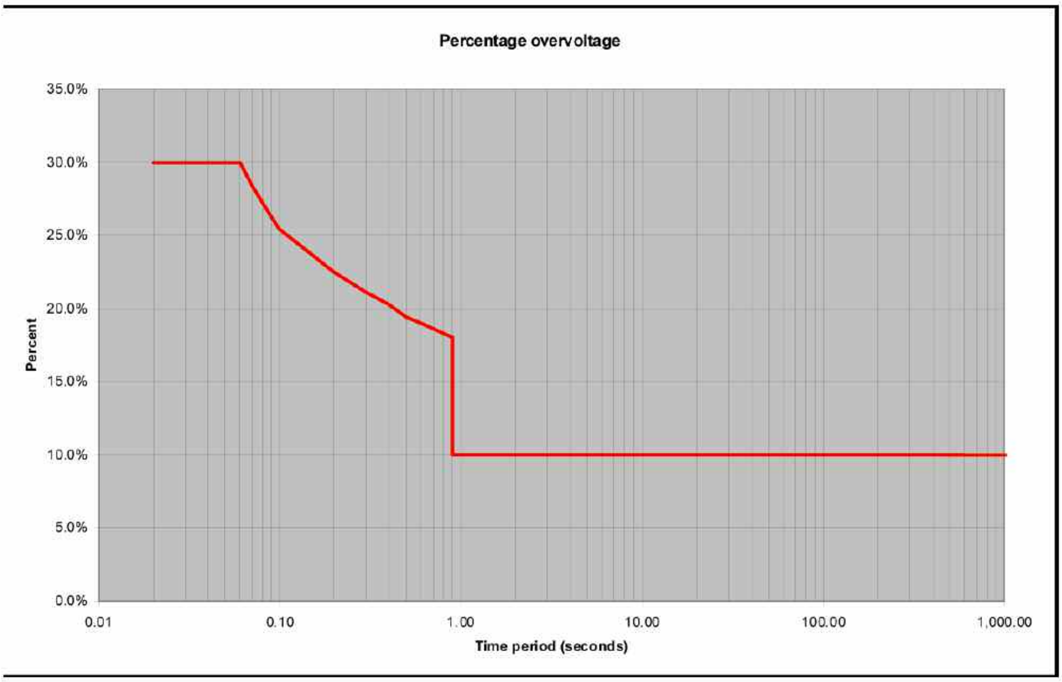
667 See clause S5.1a.4 of the NER.

Over-voltage requirements

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."

The automatic access standard for maintaining continuous uninterrupted operation during over-voltage (i.e. above 110% of normal voltage) disturbances is linked to the system standard for voltage magnitude in clause S5.1a.4.[668] 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 durations 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.



668 Clause S5.2.5.4(a)(1) of the NER.

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,[669] as a consequence of a credible contingency event, or a protected event.[670] 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.

The minimum access standard for over-voltage capability does not require a generating system to 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 50 Hz, exceeds:

- a value of 1.15 for more than two minutes, or
- a value of 1.1 for more than 10 minutes.[671]

Under-voltage requirements

To meet the under-voltage (i.e. below 90% of normal voltage) requirements under the 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.[672]

Under current arrangements, a negotiated access standard for voltage disturbance requires a generating system and each of its generating units to be capable of meeting the automatic

669 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.

670 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.

671 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.

672 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.

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 be no material adverse impact on the quality of supply to other network users or power system security.

10.4.2 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.[673] 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.

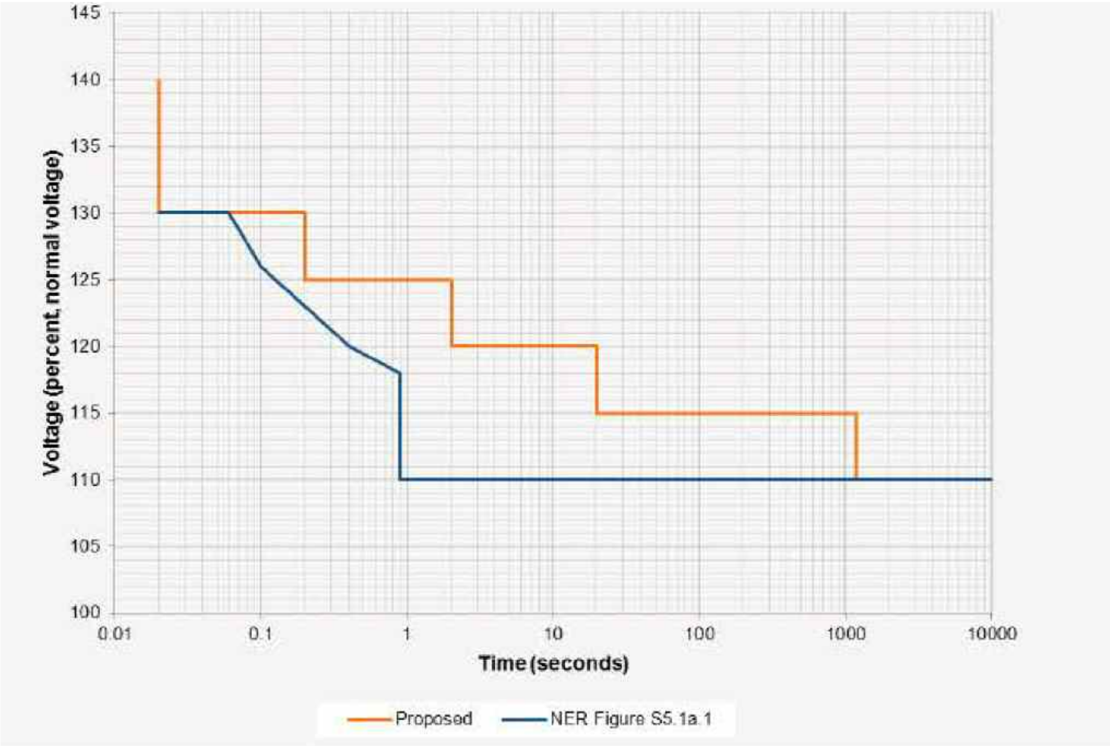
In its rule change request, AEMO proposed a number of changes aimed at addressing these issues,[674] including proposing changes to the requirements for connecting generating systems to maintain continuous uninterrupted operation for certain voltage levels and durations at the connection point.

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.

673 Rule change request, p. 33.

674 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.

Figure 10.2: AEMO's proposed voltage level and duration requirements for clause S5.1a.4.



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.

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).[675]

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

675 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).

- 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, 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).

10.4.3 Draft determination

Stakeholder views on the rule change request

Some stakeholders supported the view that increased requirements would provide a necessary benefit to power system security.[676] However, the majority of stakeholders considered that the voltage disturbance requirements proposed by AEMO in its rule change request were too arduous, particularly AEMO's proposed over-voltage requirements.[677]

Some stakeholders 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.[678]

Further detail on stakeholder views on the rule change request and consultation paper is set out in section 10.4.3 of the draft determination.

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.[679] AEMO suggested:[680]

- 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 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,[681] 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.

676 Energy Networks Australia, submission to the consultation paper, p. 6.

677 Submissions to the consultation paper: Alinta Energy, p. 4; Ausgrid, p. 2; Energy Networks Australia, p. 6; Ergon Energy and Energex, p. 5; GE Australia, p. 13; Origin Energy, p. 2; Tilt Renewables, p. 5.

678 Submissions to the consultation paper: Stanwell, p. 3; Terrain Solar, p. 5.

679 AEMO, submission to the consultation paper, pp. 19-20.

680 ibid at p. 19.

681 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.

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 understood that the requirement for over-voltages up to 115% of normal voltage for as long as 20 minutes was to account for prolonged over-voltages that require system operator intervention to return the voltage to the normal voltage range.

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
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 50 Hz 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 understood that AEMO's updated position intended that the total time spent in each voltage band is cumulative; that is, the time spent further from normal voltage is added to the count of the time spent in voltage bands closer to normal voltage.

Analysis

The Commission noted in its draft determination that 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, 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, the Commission considered there was a need for connecting generating systems to have greater capability for continuous uninterrupted operation during voltage disturbances.

The draft determination included analysis of a range of evidence, including input from stakeholders, advice from its expert consultants DigSILENT Pacific and the technical working group for this rule change, results from a survey of equipment manufacturers and a review of arrangements in other jurisdictions.

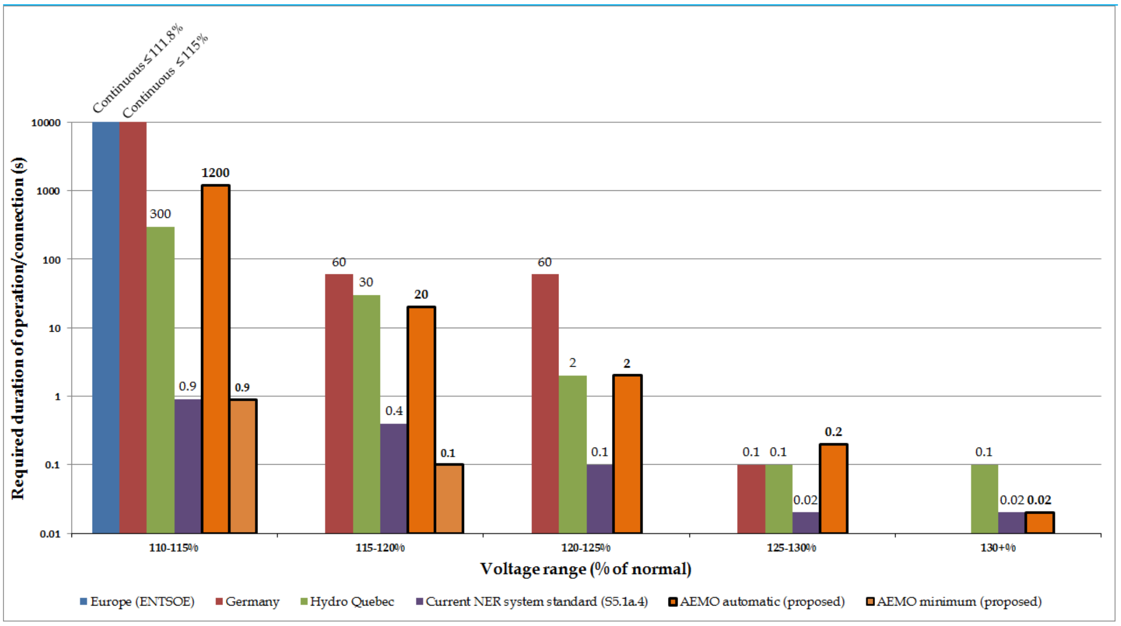
As part of the manufacturer survey, the eight manufacturers (covering both synchronous and asynchronous technologies) that responded considered that their equipment could readily meet the updated proposed minimum access standard in clause S5.2.5.4 of the NER.

- 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. The Commission considered from this evidence that AEMO's proposed minimum access standard could be met by synchronous generating units, and that that asynchronous generating systems could generally meet AEMO's proposed automatic access standard without significant modifications.

The Commission also undertook analysis into equivalent requirements in international jurisdictions, as shown in Figure 10.3 below.[682]

682 Adapted from analysis provided by AEMO in its rule change request, pp. 31-32.

Figure 10.3: Comparison of over-voltage disturbance requirements in international jurisdictions.



From its analysis, including that illustrated in Figure 10.3, the Commission considered that AEMO's proposed over-voltage requirements in the proposed automatic access standard were comparable, and in many cases less arduous, than standards in other jurisdictions. Generator access standards in the NER are also relatively unique compared to international standards in providing a negotiable range between different levels of performance and the Commission also considered that this was appropriate as the lower minimum access standard provides a negotiating range to account for system locations that would not necessitate the level of performance required under the automatic access standard.

Further analysis of the issues identified by AEMO and AEMO's proposed changes to the NER is set out in section 10.4.5 of the draft determination.

Draft rule

The Commission made a draft rule to change 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.[683]

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:[684]

1. over 130% of normal voltage for a period of at least 0.02 seconds

683 AEMO, submission to the consultation paper, pp. 19-20.

684 Clause S5.2.5.4(a) of the draft rule.

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 including all operating 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:[685]

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 voltage to 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 times specified above are measured from the point at which voltage at the connection point first varies above 110% of normal voltage for the over-voltage requirements, or below 90% normal voltage for under-voltage requirements, and resets when voltage returns to the 90% - 110% voltage band.

10.4.4 Stakeholder views on the draft determination

In submissions to the draft determination, stakeholders raised a number of concerns with both the drafting of clause S5.2.5.4 in the draft rule and principles underpinning changes to clause S5.2.5.4.

Some stakeholders considered that over-voltage requirements in S5.2.5.4 should continue to mirror the system standard for allowable levels of network voltages set out in clause S5.1a.4 of the NER.[686] This is in contrast to over-voltage requirements in the draft rule, which generally exceed the system standard in the NER. Similarly, Ergon Energy and Energex considered that the requirements in S5.2.5.4 would require generating systems to assist the network in extreme conditions for extended periods of time.[687]

685 Clause S5.2.5.4(b) of the draft rule.

686 Submissions to the draft determination: Clean Energy Council, p. 4; Tilt Renewables, p. 5.

687 Ergon Energy and Energex, Submission to the draft determination, p. 6.

Some stakeholders recommended that a limit on the over-voltage requirements above 130% be introduced, as the draft rule is currently silent on this. [688] Huawei considered that generating inductive reactive power at voltages above 130% is hazardous to inverters.[689]

Some stakeholders considered that generating systems should not be required to maintain continuous uninterrupted operation for voltage disturbances if there is a step change in voltage above a specified magnitude within the 90% - 110% normal voltage range.[690] WSP considered that designing for a step change greater than 10% will have a direct impact on capital cost for projects.[691] TransGrid noted that they plan and operate their network so that a step change in voltage post tripping of a major network element (e.g. a transmission line) is limited to a maximum of 10%.

10.4.5 Final determination

The Commission considers it appropriate that the requirements in clause S5.2.5.4 be more arduous than the system standard in clause S5.1a.4 of the NER, which is designed for credible contingencies. As discussed in section 10.2, it is important that the capability that is required by connecting generating systems is likely to be equal to or higher than that required to maintain continuous uninterrupted operation for a credible contingency. If generating systems can only withstand a credible contingency then a major supply disruption due to cascading failure could occur as a result of a non-credible contingency that is only marginally more severe than a credible contingency. Such an outcome occurring too often, resulting in significant costs for consumers, would not be acceptable.

The final rule in respect of clause S5.2.5.4 has not changed materially from the draft rule. The Commission considers that the voltage disturbance requirements in clause S5.2.5.4 of the final rule allow for an appropriate capability to be negotiated that strikes a balance between power system security and quality of supply on the one hand, and the technical limits of a generating system, the local power system conditions and commercial feasibility of meeting the automatic access standard, on the other hand.

Over-voltage limit

The Commission recognises that the automatic access standard in clause S5.2.5.4 of the draft rule was silent for voltages over 130% of normal voltage at the connection point for the first 20 ms after a disturbance. This allows for transient voltage spikes (e.g. considerably higher than 130% of normal voltage due to lightning) for which generating systems should maintain continuous uninterrupted operation, in line with other Australian and international equipment standards. These capabilities are recorded as part of the connection agreement. The Commission also recognises that within the first 20 ms after a disturbance, there is little ability to accurately measure voltage levels.

688 Submissions to the draft determination: Ergon Energy and Energex, p. 5; Huawei, p. 2.; Tilt Renewables, p. 5; WSP, p. 3.

689 Huawei, submission to the draft determination, p. 2.

690 Submissions to the draft determination: Transgrid, p. 5; WSP, p. 3.

691 WSP, submission to the draft determination, p. 3.

The final rule therefore maintains the requirement for voltages over 130% within the first 20 ms after a disturbance.

Voltage step changes

To address the concerns raised by stakeholders, the Commission considered the option of introducing an allowance for generating systems to not maintain continuous uninterrupted operation for step changes in voltage greater than a specified amount.

After also considering advice from AEMO on this matter, the Commission considers that a sufficiently large voltage step change would likely result in a generating system being allowed to disconnect under certain other access standards, such as clause S5.2.5.10, due to the risk of pole slipping for a synchronous generating system, or voltage instability at the connection point for either a synchronous or an asynchronous generating system, as assessed in accordance with the guidelines for power system stability established under clause 4.3.4(h).

As such, an additional voltage step change allowance in clause S5.2.5.4 would not likely have an additional benefit.

T(ov) and T(uv)

The final rule changes the wording used in the draft rule to define T(ov) and T(uv) in S5.2.5.4(a) (automatic access standard) and S5.2.5.4(b) (minimum access standard) to clarify that there can be multiple points in time for which the voltage leaves the 90% - 110% normal voltage band. It also makes it clearer that an under-voltage or over-voltage event ends when the voltage at the connection point re-enters the 90% - 110% normal voltage band.

110% - 115% normal voltage

The final rule retains the requirement in the automatic access standard in clause S5.2.5.4 to maintain continuous uninterrupted operation for at least 20 minutes for voltage levels between 110% and 115% of normal voltage. The Commission considers that this is an appropriate length of time for the automatic access standard given that, as per additional advice provided by AEMO,[692] at least 15 minutes is required by system operators to manually respond to over-voltages on the network that are not resolved by automatic measures. The Commission notes that this requirement is comparable to that in Europe through the European Network of Transmission System Operators for Electricity (continuous operation up to and including 111.8%, and operation for 20 - 60 minutes between 111.8% - 115%),[693] as well as a specific requirement in Germany requiring continuous operation in the 110% - 11.8% voltage range.[694]

692 AEMO email correspondence, 23 August 2018.

693 ENTSO-E, *Commission Regulation establishing a network code on requirements for grid connection of generators*," 14 April 2016, available at https://www.entsoe.eu/network_codes/rfg/.

694 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.

10.5 Multiple disturbances

This section discusses AEMO's proposed changes and the Commission's draft and final rules related to requirements in clause S5.2.5.5 for connecting generating systems to maintain continuous uninterrupted operation for multiple disturbances in the power system.

10.5.1 Current arrangements

Clause S5.2.5.5 of the NER currently requires generating systems to be capable of continuous uninterrupted operation for a disturbance (or multiple disturbances) caused by specific events, including credible contingencies and particular types of faults in the power system.[695] 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 disturbances 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
- the automatic access standard requires generating systems to maintain continuous uninterrupted operation for faults that are cleared by breaker fail protection,[696] while the minimum access standard only considers faults that are cleared by a primary protection system, and
- the minimum access standard can only apply when the total reduction of generation in the power system due to the fault would 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 (i.e. those that occur with little or no time gap between them). However, the Commission has been advised by AEMO and other stakeholders that the current requirements have been

695 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.

696 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.

interpreted as a requirement for generating systems to maintain continuous uninterrupted operation for multiple disturbances.

Whilst S5.2.5.5 references a number of specific fault types, the clause is worded such that the requirement is to maintain continuous uninterrupted operation for particular disturbances. A disturbance relates to the effect (usually in terms of voltage and/or frequency) of an event on the power system 'seen' at the connection point of a generating system. Faults are likely to lead to disturbances at a nearby connection point, but disturbances can also be caused by other events that aren't faults on the network, including the tripping of a generating system or load.

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.[697] Further, they noted that the access standards do not explicitly require a generating system to maintain continuous uninterrupted operation for multiple disturbances.[698]

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% normal 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.[699] 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 Draft determination

Stakeholder views on the rule change request

A number of stakeholders considered that the changes proposed by AEMO were too arduous and were not clearly expressed, thus creating uncertainty for connection applicants.[700]

697 Rule change request, p. 27.

698 ibid.

699 Rule change request, p. 29.

700 Submissions to the consultation paper: Advisian, p. 6; AGL, p. 3; Clean Energy Council, p. 17; Engie, p. 3; ECSO Pacific, p. 8; GE Australia, pp. 10-11; TasNetworks, p. 4; Terrain Solar, p. 1.

Some stakeholders highlighted potential technical challenges for synchronous generating systems and older wind turbines in complying with AEMO's proposed requirements, particularly those in the automatic access standard.[701]

Advisian, Hydro Tasmania and TasNetworks considered that the proposal was unclear as it did not define the timing of the 15 disturbances within a five-minute period.[702] More generally, GE Power and GE Australia (in separate submissions) questioned how compliance with the proposed access standard could be tested.[703]

Further detail on stakeholder views on the rule change request and consultation paper is set out in section 10.5.3 of the draft determination.

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 proposed requirements are outlined in Table 10.1 below.[704]

Table 10.1: 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[705]
Accumulated disturbance duration[706]	1800 milliseconds	1000 milliseconds
Sum of ΔV x Δt[707]	1.0 pu seconds[708]	0.5 pu seconds
Number of deep disturbances[709]	6	3
Minimum time difference between successive	No restriction[710]	200 milliseconds[711]

701 Submissions to the consultation paper: Advisian, p. 12; AGL, p. 5; GE Australia, p. 1; Hydro Tasmania, p. 12; Pacific Hydro, p. 4; Stanwell, p. 4.

702 Submissions to the consultation paper: Advisian, p. 6; Hydro Tasmania, p. 12; TasNetworks, p. 7.

703 Submissions to the consultation paper: GE Power, p. 2; GE Australia, p. 11; SMA, p. 4.

704 AEMO, Multiple voltage disturbance ride-through capability: Justification of AEMO's proposal, March 2018, available at www.aemc.gov.au.

705 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.

706 Accumulated disturbance duration is the cumulative amount of time in milliseconds where the connection point voltage is below 90%.

707 Sum of ΔV x Δt (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%.

708 1 per unit (pu) voltage is equivalent to 100% voltage.

709 Voltage at the connection point voltage drops below 50% of the normal value.

CRITERIA	AUTOMATIC ACCESS STANDARD	MINIMUM ACCESS STANDARD
Type of disturbances considered	• One disturbance cleared by a breaker fail protection system[712] • One long-duration shallow disturbance, e.g. 80% residual voltage for 2 seconds as per clause 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 • One long-duration shallow disturbance, e.g. 80% residual voltage for 2 seconds as per clause S5.2.5.4 of the NER • All disturbances are unbalanced • An unsuccessful auto-reclosure event is counted as two disturbances
Technology that proposed access standard is intended for	Asynchronous generation (automatic access standard and below)	Synchronous generation (minimum access standard and above)

Calculation of the value of $\Delta V \times \Delta t$ (pu seconds) is illustrated in Figure 10.4 below.[713]

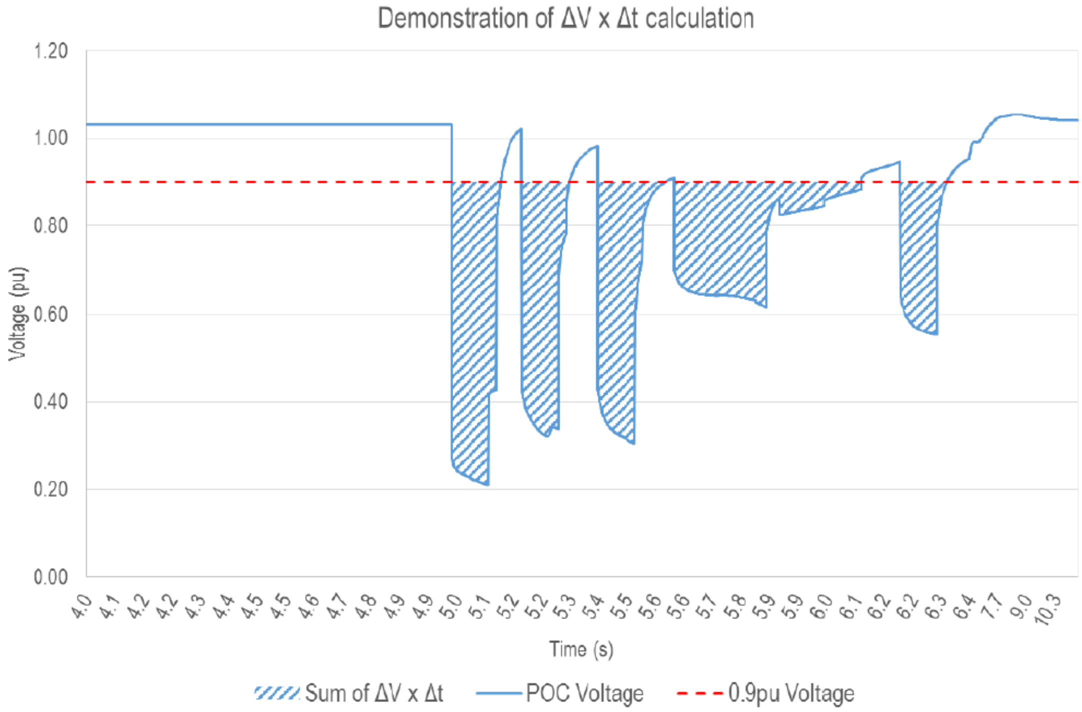
710 Meaning that two successive disturbances can occur one after another with practically zero time difference.

711 AEMO's original proposal provided for no restriction; however this was subsequently updated to 200 milliseconds.

712 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."

713 AEMO, Multiple voltage disturbance ride-through capability: Justification of AEMO's proposal, March 2018, p. 10, available at www.aemc.gov.au.

Figure 10.4: Illustration of a sum of ΔV x Δt.



In Figure 10.4 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).[714]

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)

714 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.

- 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 suggested that generating systems be capable of continuous uninterrupted operation for a number of other fault types outlined in Table 10.1.

Analysis

The Commission noted in its draft determination that multiple voltage disturbances within a short period of time can contribute to cascading outages, as was demonstrated from the South Australian black system event on 28 September 2016.[715] 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. It was also noted that current arrangements do not provide sufficient clarity as to the requirements for generating systems to maintain continuous uninterrupted operation for multiple disturbances.

The draft determination included analysis of a range of evidence, including advice of stakeholders, DigSILENT Pacific and the technical working group for this rule change, results from a survey of equipment manufacturers, a review of arrangements in other jurisdictions, as well as analysis of historically recorded occurrences of multiple faults.

The Commission considered that AEMO's updated position on the minimum access standard requirements for multiple disturbances in clause S5.2.5.5 of the NER was similar to those for Denmark and the UK. The Commission considered that AEMO's updated position on the automatic access standard requirements was more arduous than the international jurisdictions considered, but noted that generator access standards in the NER are relatively unique compared to international standards in providing a negotiation range between different levels of performance.

As part of the manufacturer survey, four out of five respondents (including manufacturers of both synchronous and asynchronous generating systems and units) claimed that their equipment could readily meet the updated minimum access standard (i.e. at little or no additional 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.

The Commission considered from this evidence that AEMO's proposed requirements for multiple disturbances would be appropriate for the maintenance of system security and would generally be within the capabilities of a variety of generation technologies at manageable cost. The Commission therefore considered it is appropriate to incorporate in its draft rule AEMO's updated position on the proposed requirements in clause S5.2.5.5.

715 Rule change request, p. 27.

Further analysis of the issues identified by AEMO and AEMO's proposed changes to the NER is set out in section 10.4.5 of the draft determination.[716]

Draft rule

To address the issues identified above, the Commission's draft rule adopted AEMO's updated position on requirements for multiple disturbances in clause S5.2.5.5(b) and S5.2.5.5(c). The draft rule was based on Table 10.1, drafted into a more suitable form for inclusion as an access standard in the NER. Specific requirements under the draft rule included 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,[717] or up to 6 six disturbances under the minimum access standard,[718] within any five minute period
- up to six deep disturbances[719] under the automatic access standard,[720] or up to three deep disturbances under the minimum access standard,[721] within any five minute period, and
- specific types of faults, as outlined in the draft rule for S5.2.5.5.[722]

These requirements were subject to a number of provisions outlined in the draft rule, including the accumulated disturbance duration (below 90% of normal voltage), the sum of $\Delta V \times \Delta t$, the number of deep disturbances, and the time difference between successive disturbances.

The Commission considered that the draft rule would likely improve the security of the power system, and hence contribute to the NEO, by allowing for greater capability among generating systems to maintain continuous uninterrupted operation for multiple voltage disturbances that are becoming more likely as the generation mix changes. The Commission also considered the flexibility provided by the negotiable range for this access standard would allow parties to agree on a level of capability that is appropriate for each connection.

10.5.4 Stakeholder views on the draft determination

Several stakeholders, including developers, generators and network businesses, considered that additional guidance was required as to how compliance can be demonstrated during negotiation of performance standards for the multiple disturbance requirements in clause S5.2.5.5.[723] This includes guidance as to the appropriate combinations of disturbances that connection applicants should model for their proposed generating system, given that there

716 AEMC, *Generator technical performance standards: draft determination*, 31 May 2018, pp. 214-18, available at www.aemc.com.au.

717 Clause S5.2.5.5(b)(1A) of the draft rule.

718 Clause S5.2.5.5(c)(1A) of the draft rule.

719 A deep disturbance occurs where voltage at the connection point drops below 50% of normal voltage.

720 Clause S5.2.5.5(b)(1A)(I) of the draft rule.

721 Clause S5.2.5.5(c)(1A)(I) of the draft rule.

722 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.

723 Submissions to the draft determination: Advisian, p. 3; AGL, p. 2; Clean Energy Council, p. 5; Energy Networks Australia, p. 8; Ergon Energy and Energex, p. 6; GE Australia, p. 2; Lloyd's Register, p. 10; Pacific Hydro, p. 3; Renew Estate and Wirsol, p. 3; SMA, p. 3; Tilt Renewables, p. 7.

are a significant number of possible combinations with different voltage depth, duration and order. These stakeholders considered that demonstrating compliance may require prohibitively time consuming and costly studies due to the potentially large number of disturbance combinations and network configurations that would need to be modelled. For example, Lloyd's Register considered that "the set of all credible study scenarios for 'qualifying' multiple disturbances is so large that to exhaustively test all would be impractical. There is no readily identifiable subset of 'most onerous' scenarios where a positive result would reasonably imply positive results for all 'in between' cases."[724]

Some stakeholders repeated concerns about physical stresses that may be experienced by synchronous generators and type 3 wind turbines in maintaining continuous uninterrupted operation for the number and combination of voltage disturbances specified in clause S5.2.5.5 of the draft rule.[725] This could include mechanical oscillation, shaft torsional stresses and excessive heat generation. Pacific Hydro considered that most of the disturbances listed in clause S5.2.5.5 will remove a network element from service, in which case a generating system may not be required to maintain continuous uninterrupted for a successive fault.[726] Nordex proposed that the minimum access standard in clause S5.2.5.5(c)(1A) be amended to further limit the distribution of the disturbances to three within 30 seconds.[727]

WSP and Pacific Hydro proposed additional conditions under which generating systems should not be required to maintain continuous uninterrupted operation, including situations where the generating system's active power, reactive power or voltage at the connection point become unstable, or where there is a material reduction in system strength as a result of network elements or synchronous generating units being removed from service.[728]

The Clean Energy Council and Tilt Renewables considered that an alternative to demonstrating compliance for multiple disturbances is to have an equipment or plant standard.[729] The Clean Energy Council considered that this "could be either a type test with actual hardware connected in the factory, or a hardware in the loop test based on actual equipment controls and simulated network voltages."[730]

Some stakeholders sought clarification as to how different voltages on each of the three phases would be considered during voltage disturbances.[731]

TransGrid noted that the minimum access standard currently does not include faults cleared by breaker fail protection so recommended that S5.2.5.5(c)(1A)(ii) of the draft rule should be deleted.[732]

724 Lloyd's Register, submission to the draft determination, p. 10.

725 Submissions to the draft determination: AGL, p. 3; Clean Energy Council, p. 5; GE Australia, p. 5; Nordex, p. 11; Origin Energy, p. 2.

726 Pacific Hydro, submission to the draft determination, p. 2.

727 Nordex, submission to the draft determination, p. 11.

728 Submissions to the draft determination: WSP, p. 4; Pacific Hydro, p. 4.

729 Submissions to the draft determination: Clean Energy Council, p. 5; Tilt Renewables, pp. 7-8.

730 Clean Energy Council, submission to the draft determination, p. 5.

731 Submissions to the draft determination: TransGrid, p. 8; Tilt Renewables, p. 7.

732 TransGrid, submission to the draft determination, p.7

Stakeholders also provided a number of detailed suggestions for and sought clarification on the drafting of the multiple disturbance requirements in S5.2.5.5. These comments are addressed in the table in Appendix A.

10.5.5 Final determination

The final rule with respect to the requirements for multiple disturbances in clauses S5.2.5.5(b) and S5.2.5.5(c) has not changed from the draft rule, excluding some drafting clarifications and the deletion of subparagraph (c)(1A)(ii) (discussed below). The Commission considers that the multiple voltage disturbance requirements in clause S5.2.5.5 of the final rule would likely contribute to maintaining system security at the lowest costs to consumers.

The Commission accepts that the requirements in the automatic access standard are relatively stringent, especially compared to equivalent requirements in international jurisdictions, however the Commission considers that the negotiation process allows for an appropriate capability to be negotiated that strikes a balance between power system security and quality of supply on the one hand, and the technical limits of the generating system, the local power system conditions and commercial feasibility of meeting the automatic access standard, on the other hand.[733] The Commission also notes that a similar requirement has been enforced in South Australia by ESCOSA since August 2017 without creating a barrier to entry for new connecting generators.[734]

The Commission accepts stakeholder views that additional guidance is required on how a connection applicant would demonstrate the ability of their proposed generating system to comply with the multiple voltage disturbance requirements. AEMO has advised the Commission that it will be updating its *Guidelines for assessment of generator proposed performance standards* to include details of its approach to assessment of clause S5.2.5.5. This update will provide information about critical combinations of disturbances for which compliance will need to be demonstrated by connection applicants. In addition, AEMO and the network service provider can advise connection applicants at the time of connection enquiry as to specific scenarios for which compliance should be demonstrated, taking into account power system conditions at the proposed connection point.

The Commission also accepts stakeholders' views that the physical stresses that may be experienced by type 3 wind turbines, and by some synchronous generators, in maintaining continuous uninterrupted operation for the number and combination of voltage disturbances specified in clause S5.2.5.5 of the draft rule could be excessive.

In particular, the Commission recognises that the minimum access standard requirement in the draft rule to maintain operation in the face of up to six disturbances, with as little as 200 ms between them, could cause damage to these types of equipment. To address this issue the final rule restricts the timing of the disturbances under the minimum access standard in clause S5.2.5.5(c)(1A) so that a maximum of three of the six disturbances can occur within a 30 second period. This restriction would allow the mechanical oscillations caused by up to

733 Clause 5.3.4A(b1) of the final rule.

734 ESCOSA, *2017 mdel licence conditions for new generators*, 17 August 2017, p. 3, available at www.escosa.sa.gov.au.

three closely spaced disturbances to be damped, thus restoring the generating system's ability to maintain operation in the face of further voltage disturbances without damage.

The Commission considers that this restriction on the timing of the disturbances removes a potenital barrier to synchronous generating units and type 3 wind turbnines, which will not materially affect system security as the probability of more than 3 disturbances within a 30 second period is considered low.

In terms of monitoring compliance on an ongoing basis, the Commission considers that a suitable approach can be achieved through existing compliance obligations and the *Template for generator compliance programs*.[735] The Reliability Panel will consider these matters when it reviews the template following the publication of this final determination (as outlined in Chapter 12 of this final determination). The Reliability Panel's review should include consideration of the high speed monitoring requirements needed to provide reliable information for the assessment of compliance on the occurrence of a multiple fault event.

Without binding the nature of any compliance action that may be taken following the occurrence of a multiple disturbance event, the AER has confirmed that an appropriate approach to assessment of compliance would be to apply the measured voltage profile to the generator system models provided for assessment on connection with respect to relevant parts of clause S5.2.5.5. This could involve a situation where a generating system has not maintained continuous uninterrupted operation, but where a model of its generating system survives the disturbance in a model simulation run. In this circumstance, it may be appropriate to take compliance action.[736]

The final rule does not contain the requirement in clause S5.2.5.5(c)(1A)(ii) of the draft rule, under the minimum access standard, for continuous uninterrupted operation for up to one disturbance cleared by a breaker fail protection system or similar back-up protection system. The Commission considers that this requirement was appropriate for the automatic access standard but is not appropriate for the minimum access standard as considering the operation of breaker fail protection is currently excluded from the minimum access standard. The Commission also considers that excluding the operating of breaker fail protection from the minimum access standards would provide flexibility for its inclusion under a negotiated access standard, should AEMO or the network service provider consider it is necessary for system security.

The Commission has provided the discussion above to give stakeholders greater certainty on the nature of the obligation to maintain continuous uninterrupted operation in the face of certain multiple fault events, particularly relating to the assessment of performance on connection and ongoing compliance matters. The Commission's final rule, however, remains largely unchanged from the draft rule.

735 AEMC Reliability Panel, *Template for generator compliance programs*, 18 June 2015, available at www.aemc.gov.au.

736 The processes used for assessing compliance with performance standards is at the discretion of the AER.

10.6 Active power recovery

This section discusses AEMO's proposed changes and the Commission's draft and final rules related to requirements in clause S5.2.5.5(b)(2) and S5.2.5.5(c)(2) for active power recovery.

10.6.1 Current arrangements

To meet the existing automatic access standard for voltage disturbances (clause S5.2.5.5), a connecting generating system (and each of its generating units) 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.[737]

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.[738] 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 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

737 Clause 5.2.5.5(b)(2)(iii) of the NER.
738 Rule change request, p. 34.

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 Draft determination

Stakeholder views on the rule change request

A number of stakeholders raised concerns with AEMO's proposed changes to S5.2.5.5 for active power recovery time. These mainly related to the ability of synchronous generating systems to return to 95% active power within 1 second, as well as the ability of renewable energy systems to recover to previous levels of active power if there is a change in energy source availability (i.e. sun and wind).

Further detail on stakeholder views on the rule change request and consultation paper is set out in section 10.6.3 of the draft determination.

Analysis

The draft determination noted 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.

The Commission considered it was 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 cases a rapid recovery of active power may not be possible due to local power system conditions (especially low system strength) or equipment limitations. This would not necessarily adversely affect power system security. Given this, the Commission considered that a system security issue was created by having a minimum access standard that does not specify a minimum active power recovery time, as AEMO had proposed.

The Commission considered it appropriate to introduce a minimum access standard for active power recovery time to address situations where a connecting generating system could otherwise connect under current arrangements without any active power recovery requirements. The Commission considered it 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.

Further analysis of the issues identified by AEMO and AEMO's proposed changes to the NER is set out in section 10.6.4 of the draft determination.

Draft rule

To address the issues identified above, the Commission's draft rule included a new requirement in the minimum access standard for clause S5.2.5.5 in which an asynchronous generating system must 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.[739]

The Commission considered the draft rule would likely improve the security of the national electricity system, and hence contribute to the NEO, by requiring 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 allowed 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.

10.6.4 Stakeholder views on the draft determination

AEMO recommended that the active power recovery requirements imposed on asynchronous generating systems be applied to synchronous generating systems in the minimum access standard.[740] AEMO considered it reasonable that all generating systems contribute to the recovery of the power system from disturbances. For each generating system that offers no support, additional support must be sourced from other connected generating systems.[741]

Ergon Energy and Energex expressed support for the ability under the minimum access standard in clause S5.2.5.5 to negotiate an active power recovery time reflecting local power system conditions.[742]

GE Australia considered that the requirement under the automatic access standard to recover at least 95% of pre-fault active power within 100 ms after clearance of the fault was too short, and recommended extending this value to at least 1 second.[743] GE Australia also recommended adding a provision to allow active power oscillations to occur during recovery following fault clearance, as long as they are adequately damped and the total active energy delivered during the period of the oscillations is at least that which would have been delivered if the active power was constant.[744]

Stakeholders did not comment on the level of the active power recovery requirements in the minimum access standard, which is an active power recovery time that is agreed by all parties.

10.6.5 Final determination

The Commission agrees that the minimum access standard for active power recovery in clause S5.2.5.5 should also apply to synchronous generating systems, and therefore should be included in clause S5.2.5.5(c)(2). Its failure to be included was an oversight in the draft rule, rather than a policy position that it should not apply to synchronous generating systems. The Commission still considers it appropriate to introduce a minimum access standard that

739 Clause S5.2.5.5(c)(3)(ii) of the draft rule.

740 AEMO, submission to the draft determination, p. 26.

741 ibid.

742 Ergon Energy and Energex, submission to the draft determination, p. 6.

743 GE Australia, submission to the draft determination, p. 6.

744 ibid.

clearly requires the recovery of active power from all generating systems, regardless of technology. In the final rule, the Commission has addressed this issue by modifying clause S5.2.5.5(c)(2) to include the same active power recovery time requirement as that in S5.2.5.5(c)(3)(ii), meaning the requirement applies to both synchronous and asynchronous generating systems, as well as those comprised of combinations of synchronous and asynchronous generating units.

10.7 Partial load rejection

This section discusses AEMO's proposed changes and the Commission's draft and final rules related to 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 may lead to simultaneous voltage and frequency disturbances. Generating systems are required to maintain continuous uninterrupted operation for discrete voltage and frequency disturbances under other access standards, including clause S5.2.5.3 (frequency disturbances) and S5.2.5.4 (voltage disturbances).

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 10 seconds, provided that the loading level remains above the minimum load (that is, minimum sent out generation for continuous stable operation).[745]

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.[746] 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

745 Clause S5.2.5.7(a) of the NER.

746 Rule change request, p. 35.

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 Draft determination

Stakeholder views on the rule change request

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.[747] Some stakeholders questioned whether S5.2.5.7 has an additional benefit over other access standards (S5.2.5.3 and S5.2.5.4 in particular).[748]

Further detail on stakeholder views on the rule change request and consultation paper is set out in section 10.7.2 of the draft determination.

Analysis

The draft determination noted 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 agreed with AEMO that the exclusion of asynchronous generating systems from clause S5.2.5.7 does not sufficiently address the needs of the power system, and that this should be addressed.

Further analysis of the issues identified by AEMO and AEMO's proposed changes to the NER is set out in section 10.6.4 of the draft determination.

Draft rule

To address the issues identified above, the Commission's draft rule amended clause S5.2.5.7 so that it would apply to both synchronous and asynchronous generating systems.[749]

The Commission considered that the draft rule would likely improve power system security, and contribute to the NEO, by requiring sufficient partial load rejection capability from both synchronous and asynchronous generating systems as the generation mix in the power system changes. The change was considered unlikely to result in any significant additional

747 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.

748 Submissions to the consultation paper: ESCO PAcific, p. 9; Energy Networks Australia, p. 9.

749 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.

costs for connecting generating systems, and would generally be within the technical capability of existing technologies.

10.7.4 Stakeholder views on the draft determination

Several stakeholders considered that S5.2.5.7 should not be applied to asynchronous generating systems because they do not respond to changes in load in the same way that synchronous generating systems do.[750] Specifically, Tilt Renewables considered that the wording of clause S5.2.5.7 was designed to describe how a thermal unit should trip to house load,[751] in which generating units can disconnect from the transmission network following a major supply disruption and continue to supply their own auxiliaries or an isolated segment of system load.[752] Though Lloyd's Register supported the extension of S5.2.5.7 to asynchronous generating systems, it considered that asynchronous generating systems "are in general not designed to operate islanded with a passive load" and that "load rejection can in practice only be studied where the generating system operates in parallel with a 'slack' synchronous generator or with a full NEM system model."[753] Pacific Hydro considered that asynchronous generating units cannot control frequency in isolation and are required to disconnect when islanded with local load following a load rejection.[754]

In terms of compliance, Lloyd's Register expressed concern about the practicality of testing the partial load rejection capability of asynchronous generating systems in pre-connection studies, and suggested that where study evidence is provided and demonstrates successful continuous uninterrupted operation when total system load is reduced by the required amount, this should be taken as evidence of compliance.[755]

10.7.5 Final determination

The Commission recognises that asynchronous generating systems do not respond to changes in load in the same way as synchronous generating systems. However, the ability to maintain continuous uninterrupted operation for the load rejection events in clause S5.2.5.7 is an important capability that needs to be provided by all generating systems, especially from asynchronous generating systems as they make up an increasing share of the generation mix. Remaining silent on the requirement to comply with clause S5.2.5.7 for asynchronous generating systems creates the risk that the control systems of asynchronous generating systems are set by operators in such a way that they do not maintain continuous uninterrupted operation if particular load rejection events are detected, which could result in insufficient generation to manage power system security.

The Commission recognises that, as part of the *Technical standards for wind generation and other generator connections* rule change in 2006-07, AEMO (then NEMMCO) requested that

750 Submissisons to the draft determination: Canadian Solar, p. 3; GE Australia, p. 6; Lloyd's Register, p. 12; Pacific Hydro, p. 5; Tilt Renewables, p. 8.

751 Tilt Renewables, Submission to the consultation paper, p. 8.

752 AEMO, *SRAS Guidelines*, 5 September 2014, p. 5, available at www.aemo.com.au.

753 Lloyd's Register, submission to the draft determination, p. 12.

754 Pacific Hydro, submission to the consultation paper, p. 4.

755 Lloyd's Register, submission to the draft determination, p. 12.

the access standard for partial load rejection be removed in its entirety because it was "not directly applicable to asynchronous generation and covered by other technical requirements".[756] As part of the final rule for that rule change request, the Commission kept clause S5.2.5.7, but restricted it to synchronous generating systems.[757] In reaching this view the Commission considered that the likely costs of compliance would be small (and may only require changing settings on certain control systems) whereas the benefits in reducing the probability of cascading failure would likely be great.

Nonetheless, the penetration of asynchronous generating systems in the NEM at the time of the *Technical standards for wind generation and other generator connections* rule change was considerably lower than at present. There is therefore now a much greater need to require compliance with S5.2.5.7 from asynchronous generating systems, as the absence of this requirement could magnify the relatively small power system security risks associated with exempting asynchronous generating systems from clause S5.2.5.7 when they made up a smaller proportion of the generation mix.

As such, the final rule contains a requirement for asynchronous generating systems to comply with clause S5.2.5.7, along with the existing requirement for synchronous generating systems.

The Commission considers that compliance for asynchronous generating systems can be demonstrated through generating system modelling that would be undertaken as part of the connection application.

10.8 Frequency disturbances

This section discusses AEMO's proposed changes and the Commission's draft and final rules related to requirements in clause S5.2.5.3 of the NER for generating systems to maintain continuous uninterrupted operation during 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).[758] 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

756 NEMMCO, *Technical standards for wind generation and other generator connections* rule change request, Appendix A, p. 7, available at www.aemc.gov.au.

757 AEMC, *Technical standards for wind generation and other generator connections: final determination*, pp. 51-52, available at www.aemc.gov.au.

758 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.

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).[759] 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).[760] The automatic and minimum access standards also specify requirements to maintain continuous uninterrupted operation for different frequency bands (for example, the normal operating frequency band).

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.[761]

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.[762]

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

759 Clause S5.2.5.3(b) of the NER.
760 Clause S5.2.5.3(c) of the NER.
761 Rule change request, p. 37.
762 ibid.

- 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 Draft determination

Stakeholder views on the rule change request

Stakeholders expressed a range of views on the proposed amendments to the access standard.

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 of technology neutrality that has traditionally underpinned the design of the generator access standards.[763]

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.[764]

Further detail on stakeholder views on the rule change request and consultation paper is set out in section 10.8.3 of the draft determination.

Analysis

The draft determination noted that 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. The Commission considered 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 draft determination included analysis of a range of evidence, including advice of stakeholders, DigSILENT Pacific and the technical working group for this rule change, results from a survey of equipment manufacturers and a review of arrangements in other jurisdictions. The Commission considered from this evidence that the RoCoF levels and

763 Submissions to the consultation paper: AGL, p. 6; Advisian, p. 12; Pacific Hydro, p. ix; SMA, p. 2.

764 Submissions to the consultation paper: Clean Energy Council, p. 26; TasNetworks, p. 11.

durations proposed by AEMO are generally supported by stakeholders and within the capabilities of equipment available on the Australian market. The Commission also considered that AEMO's proposed requirements in the minimum access standard were generally in line with international requirements. While the automatic access standard proposed by AEMO was more stringent compared to international requirements, the Commission considered that the negotiation process would allow for a level of capability to be provided that is appropriate to the technological limits of the proposed generating system.

The Commission did 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. There was no clear system security need identified for one type of technology to provide a greater level of capability than another.

Further analysis of the issues identified by AEMO and AEMO's proposed changes to the NER is set out in section 10.4.5 of the draft determination.

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 ms 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 the draft rule would likely benefit the security of supply of electricity and the national electricity system by requiring 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 Commission considered the ability to propose a level of capability between the minimum and automatic access standards would allow for a balance between system security needs and costs on generators to be achieved.

10.8.4 Stakeholder views on the draft determination

In its submission to the draft determination, GE Australia considered that it would have to undertake studies to identify specific limits for their technologies in a particular grid configuration in order to determine compliance with the requirements in the draft rule.[766]

TransGrid considered that the inclusion of additional RoCoF limits and durations in the draft rule would instead have the effect of loosening the requirements in both the automatic and

765 Clause S5.2.5.3(b) and S5.2.5.3(c) of the draft rule.

766 GE Australia, submission to the draft determination, p. 4.

minimum access standards by allowing additional conditions where continuous uninterrupted operation is not required.[767]

10.8.5 Final determination

The Commission did not receive material evidence to suggest that the RoCoF levels (in Hz/s) and durations (in seconds) in the draft rule for S5.2.5.3 would not be appropriate.

The Commission notes the concerns of TransGrid above, but considers that the additional RoCoF levels and durations in the draft rule do not loosen requirements, but rather provide additional conditions for which generating systems and units must maintain continuous uninterrupted operation, which were not previously captured. These conditions are not necessarily more or less onerous, as it is difficult to compare the combined effects of RoCoF level and duration, but rather represent different types and ranges of power system disturbances. The RoCoF levels and durations in the final rule are therefore unchanged from those in the draft rule.

The negotiated access standard in clause S5.2.5.3(d) of the final rule reverts to using some of the original wording in the NER. The Commission considered that the requirement in the draft rule that a negotiated access standard "must require that the *frequency* would be unlikely to fall below the lower bound of the operational frequency tolerance band as a result of over-frequency tripping of *generating units*" implies a level of certainty that may not be possible, given potential effects on frequency outside of the control of a connecting generator. Clause S5.2.5.3(d) of the final rule now reads "a *negotiated access standard* can be accepted by the *Network Service Provider* provided that *AEMO* and the *Network Service Provider* agree that the *frequency* would be unlikely to fall below the lower bound of the operational frequency tolerance band as a result of over-frequency tripping of *generating units*".

767 TransGrid, submission to the draft determination, p. 5.

11 SYSTEM STRENGTH

BOX 9: OVERVIEW

System strength is deteriorating in some parts of the network. There is a risk to power system security due to the mal-operation of network protection systems and 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* made by the Commission in September 2017 addresses the system security risks associated with deteriorating system strength levels, but 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.

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.

Further to this, the proposed system strength access standard would impose potential costs or regulatory requirements on connecting generators in order to increase access for potential connecting generators. This runs contrary to the principles behind the shallow connection framework in operation in the NEM power system.

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 the future. The Commission has therefore made a final rule that does not contain a system strength access standard.

Nonetheless, the Commission has made changes to Schedule 5.5.4 of the NER such that connecting generators will be required to register the lowest short circuit ratio at the connection point for which the generating system, including its control systems:

- will be commissioned to maintain stable operation, and
- has the design capability to maintain stable operation.

This is designed to assist AEMO, network service providers and connection applicants in developing potentially least cost system strength remediation schemes (required under the *Managing power system fault levels rule*) that may involve the retuning of existing generating systems to operate at lower short circuit ratios.

11.1 Introduction

This Chapter sets out:

- 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 on the draft determination, and
- the final determination.

11.2 Technical background

This section explains technical concepts related to system strength.

System strength reflects 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.[768]

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."[769]

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.[770]

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 a 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).
- **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.[771] Three phase fault

768 AEMO, *Power system requirements*, March 2018, available at www.aemo.com.au.

769 AEMO, Power system stability guidelines, 25 May 2012, p. 5, available at www.aemo.com.au.

770 Active power can also affect network voltage, but typically not to the same degree as an equivalent amount of reactive power.

771 See definition of *three phase fault level* in Chapter 10 of the NER.

level (often referred to as fault level) is measured in megavolt-amperes (MVA). 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 interchangeably with system strength.

- **Short circuit ratio (SCR)**: the ratio of the three phase fault level at the connection point for a generating system to the maximum operating level of the generating system (in MW).[772] Strong systems are typically regarded as having a high SCR (> 5) and weak systems as having a low SCR (< 3).[773]
- **X/R ratio:** the ratio of reactance (X) to resistance (R) at a point in the network.[774]

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 may 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.[775] 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.

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 and commenced on 1 July 2018) is relevant to AEMO's proposed system strength access standard.[776] The final rule has the following key aspects:[777]

772 AEMO, submission to the consultation paper, p. 21.

773 Cigre Working Group B4.62, *Connection of wind farms to weak AC networks*, December 2016, available at www.b4.cigre.org.

774 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.

775 AEMO, *National Transmission Development Plan for the National Electricity Market*, December 2016, p. 68, available at www.aemo.com.au.

776 National Electricity Market Amendment (Managing power system fault levels) Rule 2017 No. 10.

777 AEMC, *Managing power system fault levels rule change:* final determination, p. iii-iv, available at www.aemc.gov.au.

- 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,[778] any resulting risk of cascading outages, as well as the stability of the region following any such credible contingency event or protected event[779]
- 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[780]
- where there is, or is likely to be, a three phase fault level shortfall in any region,[781] AEMO must publish and give notice to the relevant system strength service providers of the assessment and the date that system strength services must be made available.[782] 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.[783] In Victoria, the obligation is placed on AEMO through its role as the jurisdictional planning body
- an obligation on the system strength service provider to make system strength services available[784] to AEMO if AEMO has declared a fault level shortfall.[785] 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,[786] 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

778 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.

779 Clauses 5.20C.1 and 5.20.7 of the NER.

780 Clause 5.20.7(b)(1) of the NER. See also the definition of three phase fault level in chapter 10 of the NER.

781 Fault level shortfall is defined in Chapter 10 of the NER 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.

782 Clause 5.20C.2(d) of the NER.

783 Clause 5.20C.3(a) of the NER.

784 Under the transitional arrangements in clause 11.101.4(b)(2), the date by which the system strength service provider must ensure the availability of system strength services in accordance with new clause 5.20C.3(b), which must not be earlier than 1 July 2019 unless an earlier date is agreed with the system strength service provider.

785 Clause 5.20C.3(b) of the NER.

786 Clause 4.6.6(a) of the NER.

stability, and for nearby generating systems to maintain stable operation.[787] The network service provider makes this assessment in accordance with AEMO's system strength impact assessment guidelines.[788]

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 11.5.2 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.[789]

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*.[790] 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*.

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.[791]

787 Clauses 5.2.5(d) and 5.3.4B(g) of the NER.

788 AEMO, *System strength impact assessment guidelines*, 28 June 2018, available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/System-Security-Market-Frameworks-Review.

789 Rule change request, pp. 39-40.

790 Rule change request, p. 39.

791 Rule change request, p. 39.

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."[792] 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 that 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.[793]

The minimum access standard proposed by AEMO was:[794]

> 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 final rule*.[795] 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:[796]

> 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.[797]

792 AEMC, *System security market frameworks review: final report*, p. 25.

793 Rule change request, p. 39.

794 This is the access standard proposed in AEMO's submission to the consultation paper (p. 21), without an X/R ratio requirement which was proposed in subsequent advice from AEMO and later advised that it was no longer recommended.

795 AEMC, *Managing power system fault levels draft rule*, p. 21, available at www.aemc.gov.au.

796 AEMO, submission to the consultation paper, p. 21.

797 Rule change request, p. 40.

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 specifying the access standard as an AEMO advisory matter.[798] 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.

AEMO also proposed changes to the definition of continuous uninterrupted operation, which are addressed in Chapter 10 of this final determination.

11.5 Draft determination

This section sets out the analysis and conclusions of the Commission in its draft determination, including the draft rule.

11.5.1 Stakeholder views on the rule change request

The Commission considered a range of stakeholder views on current arrangements and issues raised by AEMO related to system strength. 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.[799] These stakeholders largely considered that there was a need to prevent the connection of generating systems with inferior system strength capability, and that connecting generating systems would likely have the innate capability required to comply with AEMO's proposed system strength access standard.

A number of stakeholders also explicitly opposed AEMO's proposed system strength access standard, including owners and developers of primarily asynchronous (but also some synchronous) generating systems, as well as consultants.[800] These stakeholders generally considered there was not a system security need for a system strength access standard to be implemented, or raised issues with the proposed access standard in its current form (e.g. the use of short circuit ratio as a metric).

798 While the process of negotiating generator access standards is primarily 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.

799 Submissions to the consultation paper: Alinta Energy, p. 3; Energy Networks Australia, p. 6; Ergon Energy and Energex, p. 6; Origin Energy, p. 9; TasNetworks, p. 9; Tesla, p. 3; TransGrid, p. 2.

800 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.

Stakeholders differed on whether generating equipment, particularly inverter-connected generating systems, would be capable of meeting the proposed access standard. Several stakeholders also considered that the Commission should closely consider the proposed system strength access standard in the context of the *Managing power system fault levels rule*.[801]

Further detail on stakeholder views on the rule change request and consultation paper is set out in section 11.5 of the final determination.

11.5.2 Analysis of the issues

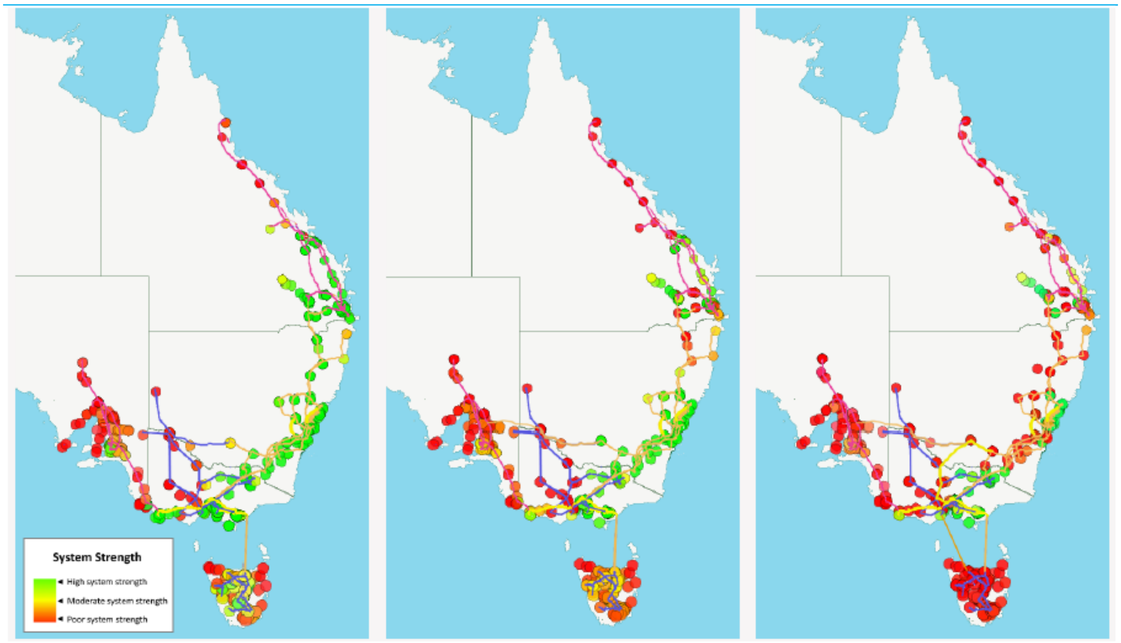
The Commission noted in its draft determination that parts of the power system have become weaker, largely because connecting asynchronous generating systems have effectively 'consumed' more available fault level than they contribute, and the retirement of synchronous generating systems has caused material reductions in available fault level. This trend is likely to continue.

Figure 11.1 below shows the projected weighted short circuit ratio (a method of calculating short circuit ratio that takes into account interactions between nearby inverter-connected generation) calculated by AEMO for different parts of the power system for years 2018-19, 2028-29 and 2038-39, if no remediation of system strength is undertaken. It is apparent from Figure 11.1 that system strength is projected to deteriorate across large parts of the NEM if not remediated.[802]

801 Submissions to the consultation paper: ElectraNet, p. 2; Energy Networks Australia, p. 2; Meridian Energy, p. 2; TasNetworks, p. 10; TransGrid, p. 2.

802 AEMO, Integrated System Plan for the National Electricity Market, July 2018, p. 73, available at www.aemo.com.au.

Figure 11.1: AEMO projections of system strength for 2018-19, 2028-29 and 2038-39 (without remediation)



The Commission considered there was sufficient evidence to suggest system strength risks deteriorating in some parts of the power system. The Commission also considered that there are material risks to power system security if the connection of new asynchronous generating systems occurs without *some form* of assessment of their ability to maintain continuous uninterrupted operation for relatively low system strength conditions.

System security assessment

Overall, the Commission considered that, as part of the existing *Managing power system fault levels rule*, AEMO has the ability to maintain system security, accounting for changes to available fault current in the power system due to changes in the generation, allowing it to effectively deal with the consequences of relatively severe power system events. Imposing additional system strength requirements on generators through the access standards was therefore considered not necessary from a system security perspective.

The Commission also considered that 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 proposed connection point. This is because a connection applicant proposing the connection of a generating system with this capability is likely to minimise or eliminate costs under the 'do no harm' obligation in the *Managing power system fault levels rule*, as well as facilitate a shorter and lower cost connection application process. Failure of a connection applicant to provide this capability 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. This may lead to the requirement for a more detailed, costly and lengthy system strength impact assessment, as well as greater costs in remediating any adverse system strength impact.

Cost assessment

In its rule change request, AEMO considered that, under the *Managing power system fault levels rule*, future generating systems would bear the cost of ensuring existing generating systems remain stable, and that had earlier generating systems been required to have the capability to operate down to a minimum level of system strength, the cost associated with connecting future generating systems would be reduced.[803]

In response to this, the Commission acknowledged that implementing AEMO's proposed system strength access standard could potentially 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. In addition, AEMO's proposed system strength access standard could reduce the need for investment by system strength service providers in equipment and processes to maintain minimum three phase fault levels.

However, the Commission also considered that there is insufficient certainty as to the magnitude of potential incremental costs on all connecting generators today, as measured against the magnitude of potential avoided costs for connecting generators and network service providers in the future.

While the Commission's survey of equipment manufacturers indicated that some could guarantee compliance with the proposed minimum access standard at minimal cost, it appeared that others would face material costs, or would be unable to guarantee performance, to comply with AEMO's proposed access standard.

The Commission also noted that, under the current shallow connection framework in the NEM, generators are only required to bear the cost or comply with regulations directly related to their connection, at the time they connect. 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.

However, the Commission also noted that matters relating to the coordination of generation, and the long term efficient utilisation of and investment in network capacity, are being considered as part of the AEMC's *Coordination of generation and transmission investment review*.[804] This review is considering 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.

803 Rule change request, p. 39.

804 AEMC, Coordination of generation and transmission investment, Stage 2 discussion paper, available at www.aemc.gov.au.

11.5.3 Conclusions

The Commission concluded 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 considered that it would be premature to introduce a system strength access standard at this time, given the *Managing power system fault levels rule* has only recently commenced. In Chapter 12 the Commission describes its final 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.

The Commission's draft rule therefore did not include a system strength access standard as proposed by AEMO.

11.6 Stakeholder views on the draft determination

A number of stakeholders supported the Commission in not including a system strength access standard in its draft rule. This included project developers, generators, distribution network service providers and consultants.[805] Reasons given for this included that the framework created under the *Managing power system fault levels rule* would be sufficient for managing system security issues related to system strength, and that related issues of long-term efficient utilisation of the network should instead be addressed through the *Coordination of Generation and Transmission Investment* review.

In its submission, AEMO considered that a system strength access standard was not proposed as a system security measure, but as a complementary measure to the *Managing power system fault levels rule* providing quality of supply ("resilience") and cost efficiency benefits in the long-term interests of consumers.[806] AEMO considered that the Commission should reconsider the inclusion of a minimum system strength access standard as part of the *Coordination of Generation and Transmission Investment review.*[807]

TasNetworks and Energy Networks Australia considered that the *Managing power system fault levels rule* does not sufficiently address issues related to system strength.[808] TasNetworks maintained support for a system strength access standard and considered that "equity issues pertaining to future generation access" should be further assessed given the potential for AEMO's *Integrated System Plan* and associated recommendations around renewable energy zones to "shape future generation colocation and impact the hosting capacity of specific parts of the network."[809]

805 Submissions to the draft determination: Advisian, p. 4; AGL, p. 3; Ergon Energy and Energex, p. 6; Essential Energy, p. 2; Lloyd's Register, p. 12; Meridian Energy, p. 3.

806 AEMO, submission to the draft determination, p. 28.

807 ibid.

808 Submission to the draft determination: Energy Networks Australia, p. 9; TasNetworks, p. 9.

809 TasNetworks, submission to the draft determination, p. 9.

TasNetworks proposed alternative drafting for AEMO's proposed system strength access standard that would require the capability to maintain continuous uninterrupted operation for any short circuit ratio down to a maximum of 3.0 at the connection point when the minimum fault level required for stable operation of a proposed generating system is more than 10% of the available fault level that exists at the proposed connection point prior to the connection of the generating system, or any short circuit ratio when the minimum fault level required is less than 10% of the available fault level.[810] TasNetworks considered that this approach would minimise costs for smaller generating systems, while ensuring reasonable capability would be provided by larger (particularly asynchronous) generators that effectively 'consume' more of the available fault level.

Eneflux considered that AEMO's proposed system strength access standard has high potential to result in the need for additional equipment, including synchronous condensers or STATCOMs.[811]

AEMO considered that even without a system strength access standard, there is a need to include information with a connection agreement relating to the minimum and maximum short circuit ratio at a connection point for which a proposed generating system has been designed to meet its performance standards. They considered this information may allow for system strength remediation schemes to be designed that involve the retuning of generating systems as the most efficient outcome.[812] Ergon Energy and Energex likewise supported the recording of minimum SCR of fault level capabilities of connecting generating systems in order to improve the connection process for future connections.[813]

11.7 Final determination

Under the existing transmission framework in the NEM, generators should only be required to bear the cost or comply with regulations directly related to their connection at the time of the connection. Requiring generators to incur costs today to meet a system strength access standard, on the basis that this will benefit other generators tomorrow, would run contrary to this principle.

The Commission also considers that the *Managing power system fault levels rule* is effectively designed to require sufficient fault level to be made available across the majority of the network in order for AEMO to maintain the power system in a secure operating state. This includes the fault level required to account for credible contingencies, as well as longer term changes in the generation mix.

In addition, the *Managing power system fault levels rule* also requires connecting generating systems to mitigate any adverse impacts they are likely to have on system strength in the vicinity of their connection. These adverse impacts could include the likely failure of a generating system to operate stably down to the lowest expected fault level at the proposed

810 ibid.

811 Eneflux, submission to the draft determination, p. 5.

812 AEMO, submission to the draft determination, p. 28.

813 Ergon Energy and Energex, submission to the draft determination, p. 6.

connection point. As described in section 11.5.2, the Commission considers that this minimum fault level reflects the level expected due to relatively severe power system events (potentially more severe than a credible contingency) and expected changes in the generation mix, regardless of how strong the connection point is under current conditions. In this way, it is unlikely that asynchronous generating systems connecting in relatively strong parts of the network (an increasingly rare occurrence) will be able to 'free ride' by not providing sufficient system strength capability.

The Commission's final rule therefore does not include a system strength access standard.

The Commission notes that AEMO recently published its inaugural *Integrated System Plan* (ISP), a cost-based engineering optimisation plan that forecasts the overall transmission system requirements for the National Electricity Market (NEM) over the next 20 years. As part of the ISP, AEMO identified Renewable Energy Zones (REZs) across the NEM where abundant renewable energy resources overlap with locations where the transmission network is strong and has sufficient additional capacity for further generator connections. In terms of system strength, AEMO notes in the ISP that "clustering of renewable generation in a REZ could provide an important opportunity for the local [transmission network service provider] to take steps to most efficiently and economically address system strength issues over the development of the REZ area, rather than connection by connection."[814] AEMO further considered that "in the absence of improving system strength across a REZ, renewable generator capabilities and protection design could need to be updated to accommodate further decreases in system strength in some areas of the network."

Recording of system strength capability

Despite not implementing a system strength access standard, the Commission considers there is value in requiring the system strength capability of a connecting generator to be recorded at the time its connection is negotiated. Recording this capability for all connecting generators would mean that, as generators continue to connect in future, AEMO and network service providers will likely have a better idea of the level of system strength required to maintain stability for existing generators, and therefore have a better idea of potential stability impacts that connecting generators may have on existing generators or the power system more broadly

The Commission considers that the system strength capability of a proposed generating system is likely to be known by connection applicants in any case, at little or no additional cost, from manufacturer information or modelling of the proposed generating system conducted by the applicant as part of the connection application. This information would also likely be required as part of the system strength impact assessment that must be undertaken for a proposed generating system.

Accordingly, the final rule contains a provision in Schedule 5.5.4 of the NER (Network Plant and Apparatus Setting Data) that connection applicants may, at the discretion of the network service provider (in accordance with clause S5.5.1), need to provide in the technical

814 AEMO, *Integrated System Plan*, p. 73, available at www.aemo.com.au.

specification in the connection agreement, the lowest short circuit ratio at the connection point for which the generating system, including its control systems (i) will be commissioned to maintain stable operation and (ii) has the design capability to maintain stable operation. As per clause S5.5.1, this information may be made available to AEMO and to other network service providers by the network service provider for the new connection at the appropriate time.

12 CONSEQUENTIAL CHANGES AND OTHER MATTERS

BOX 10: OVERVIEW

The rule change request and stakeholder submissions raised a number of issues that relate to the implementation of this final rule. Some of the matters raised relate to changes that are necessary or consequential, or corresponding, to the making of this final rule.

To address these issues the Commission's final 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
- 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, after the making of this final rule, the Commission will ask 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 first round stakeholder views on the matter
- the Commission's draft determination, and

- stakeholder views on the draft determination and the Commission's final rule.

12.2 Regular review of access standards

This section sets out the issues raised regarding regular review of access standards, including stakeholder feedback and the Commission's draft determination and final rule.

12.2.1 Background and first round stakeholder views

The rule change request focused on changes to the access standards for connecting generating systems (Schedule 5.2).[815] It did not propose changes to the access standards for connecting customers (Schedule 5.3) and market network service providers (Schedule 5.3a). However, the rule change request proposed changes to the process to negotiate access standards, which apply to the negotiation of access standards for connection applicants,[816] 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 the 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:[817]

- 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.[818] That is, a review of the access standards for generators, customers and 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.[819] 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."[820]

815 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.

816 "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."

817 Clause 8.8.1(a)(7) of the NER.

818 Rule change request, p. 12.

819 Rule change request, p. 13.

820 AEMO, submission to the consultation paper, pp. 5-6.

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.[821] 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.[822] It therefore considered a regular review of the access standards would proactively ensure the standards reflect the evolving power system.[823]

Ergon and Energex noted they consider that generator access standards should be subject to regular review given the rapid changes in the generation mix.[824] No other stakeholders commented on matters relating to the regular review of technical standards.

12.2.2 Draft determination

The Commission made a draft rule to introduce 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:[825]
  - 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
- when conducting the review AEMO must consult widely, including with registered participants and the Reliability Panel,[826] and
- in conducting the review AEMO must publish on its website:[827]
  - an approach paper, setting out the scope of the review, the issues and technical requirements 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.

821 AER, submission to the consultation paper, p. 2.
822 ibid.
823 ibid.
824 Ergon Energy and Energex, submission to the consultation paper, p. 4.
825 Clause 5.2.6A(a) of the draft rule.
826 Clause 5.2.6A(b) of the draft rule.
827 Clauses 5.2.6A(c) to (e) of the draft rule.

The Commission considered that a regular review of the access standards would enable the access standards to be adapted to respond to evolving power system conditions, as issues arise and are better understood.

The Commission considered 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 considered 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.

The Commission considered the appropriate market body to conduct the reviews is AEMO, 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 considered it is appropriate that the Reliability Panel should continue to play a role in the review of access standards, 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.

Although the Finkel review and AEMO's rule change request suggested that regular reviews of access standards should occur every three years, the Commission considered that five yearly reviews are an appropriate timeframe, noting that any urgent issues can always be addressed through a specific rule change request at any time.

The Commission considered it is appropriate that AEMO be able to exercise its discretion to set the scope of the reviews to address the most pressing needs of the power system, also to allow AEMO the flexibility to conduct more frequent reviews if appropriate to address different matters.

The draft rule also set some parameters for the review, including overall timing and transparency measures such as the obligation to consult widely and publish reports and submissions. The Commission considered this appropriate to provide 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.

12.2.3 Final determination

Few stakeholders commented on the draft rule to introduce a process for the regular review of access standards. AEMO did not comment. Those that did comment were supportive. Energy Networks Australia, Ergon and Energex, TasNetworks and Hydro Tasmania all agreed that a regular review process as proposed is reasonable and appropriate.[828]

The Commission's final rule on the process for the regular review of access standards is unchanged from the draft rule.

828 Submissions to the draft determination: Ergon Energy and Energex, p. 6; Energy Networks Australia, p. 9; TasNetworks, p. 1; Hydro Tasmania, p. 2.

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 stakeholder feedback and the Commission's draft and final determinations.

12.3.1 Background and first round 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.[829] 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.[830]

The compliance program must be consistent with the template for generator compliance programs, which is set by the Reliability Panel.[831] 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.[832]

One of the functions of the Reliability Panel is to determine, modify as necessary, and publish, the template for generator compliance programs.[833]

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.[834] 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.[835]

This issue was not raised by AEMO in its rule change request or submission. No other stakeholder submissions raised this issue.

12.3.2 Draft determination

The Commission noted in the draft determination 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 for generator compliance programs.

829 Clauses 4.15(a) and (b) of the NER.
830 Clause 4.15(b) of the NER.
831 Clause 4.15(c) of the NER.
832 ibid.
833 Clause 8.8.1(a)(2b) of the NER.
834 Clause 8.8.3(ba) of the NER.
835 AER, submission to the consultation paper, p. 2.

The Commission noted the request will be made in accordance with clause 8.8.3(ba) of the NER, which allows it to request the Panel to review the template outside of the five yearly cycle.

The Commission considered this is appropriate because the draft rule (and now the final rule) include a number of material changes to the access standards that apply to generators connecting to the power system, the next five yearly review is too far away, and there is sufficient time for the Reliability Panel to conduct a review following completion of the rule change request.

12.3.3 Final determination

No stakeholders commented on the Commission's proposal to request the Reliability Panel to review the template for generator compliance programs on completion of this rule change. The Commission's approach therefore remains as outlined in the draft determination.

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 the Commission's draft determination and final rule.

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.[836] AEMO must establish and maintain a register of performance standards, as advised by registered participants following the execution of their connection agreements.[837]

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.[838] The AER considered this would assist with considering matters relating to the generator performance standards more promptly and effectively, particularly regarding the non-compliance reporting regime,[839] and the AER's

836 Clause 5.3.7(g) of the NER.

837 Clause 4.14(n) of the NER.

838 AER, submission to the consultation paper, p. 2. See also clause 4.15(f) of the NER.

839 ibid.

function to review and determine the appropriateness of rectification periods set by AEMO under that reporting process.[840]

12.4.2 Draft determination

The Commission made a draft rule including new requirements for AEMO to provide information on the register of performance standards to the AER. The draft rule required:

- AEMO to establish and maintain a register of performance standards, as advised by registered participants following both execution of the connection agreement and after any variation to a connection agreement[841]
- 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),[842] and
- where the AER makes a request (that it considers is required for the performance or exercise of its functions):[843]
  - 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,

  or such other time periods as the AER may agree.

The Commission made the draft rule as 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. The Commission considered it is particularly important here due to 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 determine a new rectification period, giving reasons.[844] Given the requirement for the AER to respond within a short period of time, the Commission considered 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.

12.4.3 Final determination

The only stakeholder comment on this part of the draft rule was Energy Networks Australia, which helpfully noted a typographical error.[845] It noted that the references in the draft rule in clause 4.14(n3) to (n1) and (n2), should in fact be references to 4.14(n2)(1) and (n2)(2).[846]

840 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.

841 Clause 4.14(n) of the draft rule.

842 Clause 4.14(n1) of the draft rule.

843 Clauses 4.14(n2) and (n3) of the draft rule.

844 Clause 4.15(o) of the NER.

845 Energy Networks Australia, submission to the draft determination, p. 9.

The Commission agrees with the comment made by Energy Networks Australia and has made this change in the final rule. In all other respects the final rule including new requirements for AEMO to provide information on the register of performance standards to the AER is the same as the draft rule.

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 the Commission's draft determination and final rule.

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.[847] 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 either 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), or have an adverse system strength impact or adversely affect network capability, power system security, quality or reliability of supply, inter-regional power transfer capability or the use of a network by another network user.[848]

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.[849] Where a negotiated access standard will be amended under clause 5.3.9, the process followed to negotiate is the usual process for negotiation in clause 5.3.4A of the NER.[850] This process requires that a negotiated access standard must be no less onerous than the minimum access standard.[851]

In the draft determination, the Commission identified that 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 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

846 ibid.

847 Clause 5.3.9(a) of the NER.

848 Clause 5.3.9(a) of the NER.

849 Clause 5.3.9(b) of the NER. Note the clause refers to the requirement for a generator to propose amendments to the "automatic access standards" or "negotiated access standard". 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 final rule clarifies this matter.

850 Clause 5.3.9(c) of the NER.

851 Clause 5.3.4A(b)(1) of the NER.

- meets the requirements for a negotiated access standard (which includes a requirement that it be no less than the corresponding minimum access standard).[852]

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. In practice this risk is partly mitigated by a pragmatic approach generally taken in these circumstances by generators, AEMO and network service providers, however even a perception that this risk is present may still form a barrier to efficient investment in the upgrade of equipment.

A further issue identified was 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 relevant 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'.[853] 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).[854] 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 in 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
- 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

852 Clause 5.3.10 of the NER.

853 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.

854 Clause 5.3.9(d) of the NER.

control system or voltage control system.[855] 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.[856]

12.5.2 Draft determination

The Commission's draft rule included changes to clarify the application of clause 5.3.9, address the issue raised regarding the potential barrier to upgrading existing plant, and included changes to the access standard references in the table in clause 5.3.9(d). The draft rule:

- allowed a generator altering its generating system to submit a negotiated access standard between the automatic access standard and the generator's existing performance standard[857]
- clarified that alterations to the types of equipment 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),[858] and
- included 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.[859]

Application of clause 5.3.9

The Commission considered 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. The Commission's draft rule therefore sought to clarify that alterations to any of the equipment set out in Column 1 of the table in clause 5.3.9(d) are deemed to affect the performance of the generating system 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).

Potential barriers to investment

The Commission agreed that current arrangements create 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

855 TasNetworks, submission to the consultation paper, p. 19.
856 ibid.
857 Clause 5.3.4A(b)(1A) of the draft rule.
858 Clause 5.3.9(d) of the draft rule.
859 Clause 5.3.9(d) of the draft rule.

range provided by the automatic access standard and minimum access standard, as at the time the renegotiation occurs.

The Commission's draft rule sought to address this risk by including 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).

The Commission considered 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. AEMO considered 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.

The Commission agreed with AEMO and included in its draft rule amendments to the table in clause 5.3.9(d) to include the changes proposed by AEMO.

The Commission did not consider that further clauses need to be included in clause 5.3.9. In particular, the Commission did not agree with the changes suggested by TasNetworks that clause S5.2.5.1 be included. While acknowledging the issue raised by TasNetworks, the Commission considered 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 risk changing this balance of responsibilities in some cases. Accordingly, the Commission considered 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.

12.5.3 Final determination

This section sets out stakeholder views on the draft determination, and the Commission's final rule.

Stakeholder views on the draft determination

Stakeholders were generally supportive of the changes proposed to clause 5.3.9 set out in the draft rule. A range of stakeholders particularly supported the ability to negotiate between the level of the existing performance level and the automatic access standard as an appropriate change.[860]

Most stakeholder concern related to the amendments to clarify the application of clause 5.3.9 by including that alterations to the equipment listed in the first column in the table in clause

860 Submissions to the draft determination: Ergon Energy and Energex, p. 6; TasNetworks, p. 10; Meridian Energy, p. 4; Hydro Tasmania, p. 2; EnergyAustralia, p. 2.

5.3.9(d), will for the purposes of the application of the whole clause be deemed to affect the performance of the equipment relative to certain access standards.

The Australian Energy Council noted that caution should be taken about increasing demands for providing power system models when making minor plant changes.[861] The Council noted that the increased detail required in carrying out this modelling will act to delay some needed upgrades, to little benefit.[862] The Council proposed that modelling work for minor upgrades be minimised, suggesting that this can be achieved by providing more guidance within clause 5.3.9(d) about the materiality of equipment changes that would trigger an assessment of a generating system's performance.[863]

AGL sought clarification on whether the requirement to renegotiate access standards under clause 5.3.9 under the draft rule is intended to be a "firm obligation".[864] AGL also encouraged the Commission to explore whether generators would be exposed to unfavourable negotiating situations where their current performance standard sits in between the revised automatic and minimum access standard, and, as a result of the rule, a generator's negotiating range is reduced.[865]

Delta Electricity considered that the interpretation of the application of clause 5.3.9 hinges on the word "alter", noting that many "like for like" changes ought not to alter the system, in which case the obligations under clause 5.3.9 would not apply.[866] The AER agreed with this view in further consultation, but considered that for an abundance of caution the rule should more explicitly state that "like for like" alterations may be made without triggering clause 5.3.9.[867]

Although generally supporting the changes, Hydro Tasmania was concerned that where a new technical requirement is introduced for which there is not an existing generator performance standard, there may be some uncertainty regarding the nature of the obligation to negotiate between the level of the existing performance standard and the automatic access standard.[868] Hydro Tasmania considered that it may be in this case there is no existing performance standard to act as a "fall back", potentially requiring the generator to meet the new requirement at prohibitive cost.[869]

Millmerran Power remained concerned that future plant upgrades could lead to a requirement for additional and expensive modelling and significant plant modifications.[870] Millmerran Power noted that some changes in minimum access standards could not be met by a synchronous generator, and requested clarification on the operation of existing arrangements for the application of negotiated performance standards, or limits for re-negotiation of

861 Australian Energy Council, submission to the draft determination, p. 2.
862 ibid.
863 ibid.
864 AGL, submission to the draft determination, p. 4.
865 ibid.
866 Delta Electricity, submission to the draft determination, p. 9.
867 AER, email correspondence with the AEMC, 31 July 2018.
868 Hydro Tasmania, submission to the draft determination, p. 2.
869 ibid.
870 Millmerran Power, submission to the draft determination, p. 1.

standards when existing equipment is replaced or upgraded.[871] Millmerran Power suggested that for existing registered participants, the current negotiated standard should be the default position, with AEMO and the network service provider required to provide detailed technical reasons why any move away from the negotiated standard is absolutely required.[872]

In further consultation, AEMO proposed that clause 5.3.9 include a new provision stating that a generating system is not altered if the proposal is limited to the replacement of an item of plant or equipment within the *generating system* with an item of the same type and the replacement item:[873]

1. is intended to perform the same function as the existing item
2. has identical mechanical or primary electrical characteristics with the existing item, and
3. has no other impact on the operation and performance of the *generating system*.

Final rule

The final rule includes changes to clause 5.3.9 that are the same as the changes proposed in the draft rule.

The Commission appreciates the need to have clarity on when the requirements in clause 5.3.9 apply. The Commission also notes that it would not be appropriate for generators to notify AEMO and provide updated proposed access standards each time they replace a minor piece of equipment. This would create a significant additional burden on routine maintenance that does not affect the performance of the power system.

The Commission intends the term 'alter' to include enough scope for routine or 'like for like' changes in equipment to occur without triggering the obligations in clause 5.3.9. Clearly the replacement of a part with a direct spare part, or a refurbished part, would not be an alteration. The replacement of a part with a similar part, interchangeable part or subsequent version of a part should only be considered to be an alteration if it materially changes the performance of the generating system. If such a material change in performance occurs, it is important for AEMO to be made aware of the changed parameters within which the power system may be capable of performing.

The criteria proposed by AEMO are a useful guide, however the Commission does not consider the changes are appropriate to be included in clause 5.3.9. In particular the requirement that the alteration have no other impact on the operation and performance of the generating system is likely to be too onerous and lead to the need to renegotiate performance standards for relatively trivial changes in performance or operation. The Commission considers the ordinary meaning of the term 'alter' is sufficient to provide the appropriate guidance to parties on when a change to a generating system should trigger clause 5.3.9. Accordingly, the Commission has not included the changes to the draft rule proposed by AEMO.

871 ibid.
872 ibid.
873 AEMO, email correspondence to AEMC, 15 August 2018.

The Commission notes the comments from Hydro Tasmania that where a generating system is altered and there is a new access standard requirement where previously none existed, there is some ambiguity on what the negotiating range will be. The Commission considers that where there is no capability recorded in a generator's performance standards for a new technical requirement, and a negotiation under clause 5.3.9 occurs requiring negotiation between the existing performance standard and automatic access standard, this will effectively result in a negotiation between no capability at all and the automatic access standard. This approach is also relevant where the new rules include a general requirement that was not recorded in a generating system's performance standards. As such, no changes to the proposed wording in the draft rule are required to accommodate Hydro Tasmania's concerns.

The Commission accepts AGL's view that the changes may result in a reduced negotiating range when renegotiating under clause 5.3.9 where a generator's existing performance standard falls between the new automatic and minimum access standards. However, the Commission considers this to be an appropriate outcome. A generator that is altering its equipment should at least meet the level of performance it agreed to on connection, and where it cannot do this, relevant compliance arrangements are in place which include, as a last resort, reducing the level of the performance standard.[874] Further, no evidence has been provided to suggest that this reduced negotiating range could lead to an inefficient increase in costs for consumers. While acknowledging the issue raised by AGL, the Commission does not consider changes to the draft rule are needed to address the issue.

874 This can occur under clause 4.14(p) of the NER.

13 TRANSITIONAL ARRANGEMENTS

BOX 11: 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 the costs and benefits of doing so, and the limitations on the AEMC's rule making powers.

The Commission's final rule commences on 5 October 2018. For connection applicants that have submitted a connection enquiry by that date, but not yet submitted a connection application, 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 under the new arrangements.

The Commission's final rule also includes a transitional period for connection processes that had a connection application submitted on the date of commencement of the rule.

With respect to the transitional period, parties that on 1 February 2019 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 access standards contained in Chapter 5 of the rules in effect immediately before the commencement of the final rule.

The Commission's final rule also addresses matters for ongoing connection processes (those that had submitted a connection application by the commencement date) where a full set of access standards is not agreed by 1 February 2019. 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 network service provider can prepare an offer to connect under the new arrangements.

The final 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.[875] 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 final rule, detailed transitional arrangements are required.

This Chapter sets out the Commission's approach to transitional arrangements for:

- the commencement of the final rule, including determining which connection processes should not be affected by the final rule, and
- arrangements for connection processes that will be affected by the final rule.

For each of these issues, where relevant, this Chapter sets out:

- issues raised by AEMO
- the Commission's draft determination, and
- the final determination.

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) was imperative to ensure the ongoing security of the power system.[876] AEMO argued that failing to do so would mean that assets with long life-cycles may be connected under current arrangements that AEMO considered would not ensure the capabilities required for the future power system.[877]

875 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.

876 Rule change request, p. 7.

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:

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;[878] that is, rules that are expressed to commence on a date before the rule is made and gazetted. It appears this was the intended effect of the transitional arrangements proposed by AEMO set out 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

877 ibid.

878 Section 104 of the NEL provides that a rule made commences operation on the day the relevant notice is published in the South Australian Government Gazette 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.

apply to those territories.[879] If a provision of the NER affects an acquisition of property otherwise than on just terms,[880] 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 Draft determination

This section sets out stakeholder views on the transitional arrangements proposed in the rule change request, AEMO's updated position set out in its submission to the consultation paper, and the Commission's draft rule setting out transitional arrangements.

13.3.1 First round 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.[881] However, some stakeholders questioned whether there was a system security need that would justify the rapid transition to any new arrangements, as proposed by AEMO.[882]

Many stakeholders considered that the transitional arrangements proposed by AEMO could significantly impact existing and planned investments.[883] 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.[884]

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.[885] Energy Networks Australia suggested that for this reason it would be reasonable that some transitional period is provided for that is fair, transparent and predictable.[886]

A number of stakeholders suggested alternative arrangements for the transition and implementation of any new rules.

879 Electricity (National Scheme) Act 1997 (ACT), s 5; National Electricity (Northern Territory) (National Uniform Legislation) Act (NT), s 6.

880 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.

881 Submissions to the consultation paper: ENA, p. 12; Ergon Energy and Energex, p. 12; TasNetworks, p. 2.

882 Submissions to the consultation paper: AGL p. 8; CEC p. 2; Terrain Solar, p. 2.

883 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.

884 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.

885 Submissions to the consultation paper: ENA, p. 12; Ergon and Energex, p. 12; Powerlink, p. 3.

886 ENA, submission to the consultation paper, p. 12.

For more detailed information on stakeholder views on the transitional arrangement issues raised by AEMO in its rule change request, see section 13.3 of the draft determination.

13.3.2 AEMO's updated position

AEMO's submission to the consultation paper provided further information on its view of the urgency underpinning the need for a rapid transition to new arrangements, as well as further views on the appropriate approach to transitional arrangements.

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. 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.

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. 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. 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.

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. AEMO considered that:

- 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.

13.3.3 Draft rule

The Commission made a draft rule setting out transitional arrangements that it proposed should apply to the implementation of a final rule. The Commission's draft rule included arrangements that:

- provide that the final rule would commence on the date that is 8 weeks after the date of the final determination,[887] 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.[888]

The draft rule created a framework for determining whether a full set of access standards was agreed for a proposed connection as at the date of commencement. This required 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;[889] 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.[890]

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.[891] 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.[892]

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 would 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.[893]

The draft rule also addressed matters for connection applicants that do not have a full set of access standards agreed on the date the final rule commences. Under those arrangements, from the commencement date the network service provider must:

- where a connection applicant has made a connection enquiry but not yet made an application to connect, within 10 business days:[894]

887 Clause 11.107.1 of the draft rule (definition of commencement date).
888 Clause 11.107.3(g) of the draft rule.
889 Clause 11.107.3(e)(1) of the draft rule.
890 Clause 11.107.3(e)(2) of the draft rule.
891 Clause 11.107.3(e)(1)(ii) and 11.107.3(e)(2) of the draft rule.
892 Clause 11.107.3(f) of the draft rule.
893 Clause 11.107.5(d) of the draft rule.
894 Clause 11.107.2(b)(3) of the draft rule.

    - 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):[895]
    - 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 did 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.[896]

The draft rule allowed the network service provider to 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.[897]

Commencement and application of a final rule

The Commission considered in its draft determination that the power system is rapidly transforming, with large numbers of new connections in development, and the changes in the draft rule to address important system security issues should be implemented as quickly as possible. However the Commission also sought to balance this need to implement the changes quickly with the need to minimise costs to connection applicants during the transition. The appropriate balance was sought to be struck by:

- setting an appropriate commencement date for the final rule
- determining which ongoing connection processes the new rule will apply to, and

895 Clause 11.107.3(b)(3) of the draft rule.

896 Clauses 11.107.2(c) and 11.107.3(c) of the draft rule.

897 Clause 11.107.3(d) of the draft rule.

- setting arrangements for those ongoing connection processes for which the new rules will apply.

Commencement date

The Commission set a commencement date in the draft rule that is 8 weeks from the date of the final determination, to address risks to connection applicants from a final rule starting immediately on the date of the final determination. The Commission considered that allowing this short period of time would allow time for:

- 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 considered the length of this period of time between publication of a final determination and commencement of a final rule would 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.

Application to ongoing connection processes

The Commission noted in its draft determination that there is no clearly defined milestone under the existing connections process in the NER that is appropriate for use 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, the Commission noted 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.[898]

The Commission considered that, on balance, 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.[899] It was considered 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.

898 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.

899 Note, the new rules would apply to any renegotiation of performance standards at a later date in clause 5.3.9.

The draft rule, described above, included mechanisms to determine which connection applicants have a full set of agreed access standards and can proceed to connection based on the rules that were in force immediately prior to the commencement date.

Arrangements for connection processes that will be affected by a final rule

The Commission also included guidance for ongoing connection processes that would be affected by a final rule. This guidance was considered appropriate to help the parties strike the right balance between the need to efficiently achieve and maintain system security, and the costs for connection applicants that are partway through the connection process.

The arrangements in the draft rule were intentionally not prescriptive to reduce the risk of making arrangements that are not appropriate for some of the many different circumstances (some of which could not reasonably be anticipated by the Commission) that could apply for connections. The Commission considered it 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.

13.4 Final determination

This section sets out stakeholder views on the Commission's draft rule and the Commission's final determination.

13.4.1 Stakeholder views on the draft rule

Stakeholders generally accepted the appropriateness of the proposal in the draft rule to allow connection applicants that have a full set of access standards agreed for their ongoing connection process, to proceed on the basis of the rules in force immediately before the commencement of the final rule. Stakeholders also generally agreed with:

- the mechanism proposed for determining which connection applicants have a full set of agreed access standards, and
- the arrangements for ongoing connection processes that would be affected by a final rule.

Energy Networks Australia and TransGrid proposed removing the transitional arrangements applying to parties that as at the commencement date have made a connection enquiry but not a connection application, because all parties have had a long time to become aware of the changes and because they will stretch the resources of network businesses for little benefit.[900] Energy Networks Australia also noted that if this approach is not acceptable, they suggest the obligation on network service providers should be limited to advising the connection applicant that the enquiry will be treated as an enquiry under the new Chapter 5 and to provide a link to the final rule drafting and any information packs on the access standards that the network may have updated.[901]

900 Submissions to the draft determination: Energy Networks Australia, pp. 10-11; TransGrid, p. 2.

901 Energy Networks Australia, submission to the draft determination, pp. 10-11.

Ergon and Energex noted that the arrangements should be limited to completed and accepted applications, to reduce the wasted effort of assessing inadequate submissions by the commencement date.[902]

Advisian made the general comment that if the access standards are raised too high, then a significant number of projects will rush to attempt to connect under the old rules, and capital may exit the Australian market under the new rules.[903]

Most stakeholders focussed on the commencement date. AEMO and some network businesses considered that 8 weeks is an appropriate period of time, while one network business and most connection applicants and consultants considered that more time was needed.

AEMO considered that extending the commencement date beyond 8 weeks is not appropriate because industry have been aware of the proposed changes for 12 months, which AEMO considered is sufficient for connection applicants to submit and finalise the connection process based on the current framework.[904] AEMO also considered that a further extension to the commencement date is not warranted as connection applicants are able to submit or revise proposals according to their own timeframes, and do not need to see the final rule first.[905]

TasNetworks, Ergon Energy and Energex also considered that 8 weeks is appropriate. TasNetworks considered extending the timeframe will dilute the benefits of the new rule, noting also that the AEMC consultation process has been sufficient for connection applicants to become aware of the changes and factor them into their forward risk profiles.[906] Ergon Energy and Energex considered that even though there is likely to be a rush to complete access standards before a commencement date that is 8 weeks after the final determination is made, this will be the case for any date chosen.[907] Ergon Energy and Energex strongly supported this date, noting that some flexibility to accept minor outstanding matters related to access standards would also be helpful.[908]

Meridian Energy supported the proposed timeframe for implementation as being both pragmatic and fair for all parties.[909]

A number of stakeholders suggested more time is needed between the date a final determination is made and the date the final rule commences, mostly due to limitations in the capacity across the industry to process connections. Most of these stakeholders suggested that at least 6 months is required,[910] three suggested a start date of 1 February 2019,[911] and one suggested 20 weeks.[912]

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902 Ergon Energy and Energex, submission to the draft determination, p. 7.
903 Advisian, submission to the draft determination, pp. 4-5.
904 AEMO, submission to the draft determination, p. 14.
905 ibid.
906 TasNetworks, submission to the draft determination, p. 10.
907 Ergon Energy and Energex, submission to the draft determination, p. 7.
908 ibid.
909 Meridian Energy, submission to the draft determination, p1.
910 Submissions to the draft determination: Australian Energy Council, p. 2; Canadian Solar, p. 2; EnergyAustralia, p. 2; Origin Energy, p. 2; Eneflux, p. 4.

The Australian Energy Council considered 8 weeks is insufficient given the practical complexities in the negotiating framework, as well as increased modelling requirements that can only be completed by a handful of experts that can take, at a minimum, several months to produce before discussions with counterparties can take place.[913] AGL, Canadian Solar, Origin Energy, EnergyAustralia, GE Australia, Eneflux and Lloyd's Register all noted that more time is needed to account for the limited availability of expertise to conduct modelling and studies supporting the negotiation of access standards, which is outside of the control of connection applicants.[914]

AGL also noted the 8 week transitional period does not sufficiently balance regulatory and operational market risks with the commercial risks faced by connecting generators, introducing real commercial risks for parties negotiating connection.[915] AGL proposed a commencement date of 1 February 2019, with projects that have less than 50% of access standards agreed by that date automatically going under the new rules, and the rest having 6 months to finalise negotiations on their access standards.[916] AGL also requested further guidance on the operation of mechanisms for conditionally approved access standards.

The Clean Energy Council and the Victorian Department of Environment, Land, Water and Planning (DELWP) also supported a commencement date of 1 February 2019.[917] The DELWP was concerned that with an eight week transition period projects supported by the Victorian government that are in the advanced stages of development may be unable to appropriately accommodate the new requirements, and maintain committed project timelines.[918] This concern related to both projects already supported by the Department and those potentially arising from current programs.

The Australian Energy Council, Origin Energy, EnergyAustralia, Canadian Solar and Eneflux all suggested a transition period of 6 months between making a final determination and the commencement of the final rule.[919] GE Australia suggested a date that is 20 weeks after the final determination.[920]

Eneflux suggested that the transitional arrangements should include an explicit requirement for AEMO and network service providers to act in good faith, or, create an alternative mechanism to grandfather the rules for "advanced applications" at the time of the final determination.[921]

911 Submissions to the draft determination; AGL, p. 5; Clean Energy Council, p. 4; Department of Environment, Land, Water and Planning (Victoria), p. 1.

912 GE Australia, submission to the draft determination, p. 2.

913 Australian Energy Council, submission to the draft determination, p. 2.

914 Submissions to the draft determination: AGL, p. 4; Canadian Solar, p. 2; Origin Energy, p. 2; GE Australia, p. 2; Lloyd's Register, p. 13; EnergyAustralia, p. 2; Eneflux, p. 4.

915 AGL, submission to the draft determination, p. 4.

916 ibid, p. 5.

917 Submissions to the draft determination: Clean Energy Council, p. 4; Department of Environment, Land, Water and Planning (Victoria), p. 1.

918 Department of Environment, Land, Water and Planning (Victoria), submission to the draft determination, p. 1.

919 Submissions to the draft determination: Australian Energy Council, p. 2; Canadian Solar, p. 2; EnergyAustralia, p. 2; Origin Energy, p. 2; Eneflux, p. 4.

920 GE Australia, submission to the draft determination, p. 2.

921 Eneflux, submission to the draft determination, p. 4.

Canadian Solar also requested that during the transition period, AMEO and the AEMC hold workshops on the new rules.[922]

13.4.2 Final rule on transitional arrangements

This section sets out the Commission's views addressing stakeholder comments, and notes any changes from the draft determination.

Transitional date for ongoing connections

The Commission agrees with stakeholder views that a transitional period of 8 weeks from the date of the final determination for ongoing connections would likely present challenges across the industry. This includes the likelihood that a short transition period would put pressure on the capacity of networks to process proposed access standards, as well as stretch the capacity of consultants and experts needed for complex modelling and studies to support the negotiation of access standards.

The objective of a transitional period for ongoing connections is to allow time for connection applicants with relatively well progressed negotiations to be able to finalise an agreement on access standards under the existing rules if they choose to do so, with minimal disruption to their connections. Allowing this to occur is required to avoid the significant costs of remodelling and renegotiation for those advanced stage projects that do not pose a risk to power system security or quality of supply. Based on the evidence provided by stakeholders, the Commission considers an 8 week transition period is unlikely to provide sufficient time to achieve this outcome, and could lead to a number of connections that do not pose a risk to the power system being delayed and disrupted. The Commission also considers that a period of six months is an unnecessarily long period of time to achieve the desired objective.

The Commission however still considers it appropriate to balance the benefits of reducing the risks faced by the limited number of parties that are well progressed in the connection process, against the potential impact of such connections on the efficient management of the power system in a secure state. No clear evidence has been provided showing the system security or cost impact that would arise from increasing the transitional period by a further short period of time. No clear evidence has been provided showing what capabilities would not be able to be obtained from connecting generating systems under the current rules that would lead to adverse cost or security outcomes due to a short extension to the transition period.

In light of the above, the Commission considers that the appropriate balance is struck with a longer transitional period than the 8 week period set out in the draft rule, and that an appropriate period of time is closer to 18 to 20 weeks. As such the Commission has set a date for the transition of the new rules for ongoing connections at 1 February 2019.

922 Canadian Solar, submission to the draft determination, p. 2.

Commencement date

The Commission notes that the draft rule proposed delaying the 'commencement date' of the final rule for 8 weeks from the date of the final determination. However, on reflection this is not appropriate, as a transitional period is only appropriate for ongoing connections. New connection applications made after the final determination should be made on the basis of the new rules. For this reason, the final rule should commence as soon as possible, and provide a transitional period for parties that, as at the date of the final determination, had submitted a connection application.

This approach aligns with the objective that a transition period account for the significant costs that would otherwise have been faced for connections that are relatively advanced in the process to agree access standards, and that all other connections should proceed on the basis of the new rules. To achieve this, the new rules need to commence as soon as possible so that connection applications may still be submitted between the date of the final determination and 1 February 2019. The transitional arrangements for the final rule therefore include a new requirement clarifying that the rule commences on 5 October 2018, so that any connection application made after that date must proceed on the basis of the new rules.

As a result of this change, it is also appropriate to note another consequence of these changes for the obligations on network service providers. The obligations in the draft rule on network service providers to inform parties that had submitted a connection enquiry, but not yet submitted a connection application, that the new rules applied to them and provide them with certain other information where relevant, began from the commencement date (which was to be 8 weeks after the date of the final determination). Under the final rule, the commencement date will now be 5 October 2018. Further, a new transitional date (1 February 2019) is included for projects that had an existing connection application on the commencement date. The Commission considers these obligations to provide certain information to parties that have submitted a connection enquiry should apply from the new commencement date. There is no reason to wait until 1 February 2019 to inform parties that have submitted a connection enquiry that the new rules now apply to their project.

Other matters

The Commission does not agree with Energy Networks Australia and TransGrid that the Commission should remove the obligations on network service providers to use their reasonable endeavours to provide certain information to connection applicants that have lodged a connection enquiry but not yet lodged a connection application. The Commission does not consider this obligation to be too onerous, as it is likely to be able to be fulfilled by a simple communication to the applicant noting that the NER have changed in this area (and their connection enquiry will be treated as a valid enquiry under the new rules), that accordingly any information previously provided by the network service provider in response to a connection enquiry may no longer be appropriate, and that any new connection application from the date of the final determination should be on the basis of the new rules.

The Commission also notes that the obligation is limited to reasonable endeavours, and is not intended to impose onerous obligations on network service providers to identify long inactive applicants, or to make detailed comments on the validity or otherwise of information that may have been previously provided.

ABBREVIATIONS

AC	Alternating current
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AGC	Automatic generation control
ARENA	Australian Renewable Energy Agency
ASMC	Australian Sugar Milling Council
CEC	Clean Energy Council
Commission	See AEMC
DELWP	Department of Environment, Land, Water and Planning
ENA	Energy Networks Australia
ESCOSA	Essential Services Commission of South Australia
FCAS	Frequency control ancillary services
FFR	Fast frequency response
HV	High voltage
HVRT	High voltage ride-through
Hz	Hertz
kA	Kiloamperes
kV	Kilovolts
LV	Low voltage
LVRT	Low voltage ride-through
MASS	Market ancillary service specification
MCE	Ministerial Council on Energy
MVA	Megavolt-ampere
MVAR	Megavolt-ampere reactive
MW	Megawatt
MWh	Megawatt Hour
ms	Milliseconds
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
NTNDP	National transmission network development plan
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 ISSUES RAISED IN SUBMISSIONS

This appendix sets out particular issues raised in the second round of consultation on this rule change request that are not discussed in the main sections of the final determination, and the AEMC's response to each issue.

Table A.1: Stakeholder views

STAKEHOLDER	COMMENT	AEMC RESPONSE
Assessment framework		
AEMO, pp. 5-11	The NEO should be interpreted as requiring investment decisions that take into account what is reasonably foreseeable. There is therefore a need to ensure the access standards are forward looking. Even short term operating scenarios are uncertain, and should be accounted for in the access standards, for example the voltage control implications of the closure of Hazelwood Power Station.	The Commission has set out its assessment framework in Chapter 3. This includes noting that the rassessment adheres to the principles underpinning the current framework within which connections occur, being a shallow connections framework. It is not within the scope of this rule change to change the principle of shallow connections that underpins the overarching connections framework in the NER.
Negotiating process		
Energy Networks Australia, p. 4	The 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 which are ultimately borne by customers.	The draft rule did not value economic considerations for connection applicants above the secuirty of the power system. Rather, AEMO and network service providers maintained their ability to reject a proposed negotiated access standard on the basis that it would adversely affect power system security or quality of power

STAKEHOLDER	COMMENT	AEMC RESPONSE
		supply.
Meridian Energy, p. 1	Moving to a regime where the automatic access standard is the expectation for all connecting parties, unless they can demonstrate otherwise, is unlikely to yield the most efficient outcome for consumers given the power system currently operates in a safe and secure manner with numerous parties connected under the minimum access standard.	The draft rule included the ability for a connection applicant to propose a lower level of performance, taking into account the commercial feasiblity of meeting the automatic access standard. This should result in an economically efficinent outcome that does not unnecessarily increase costs for consumers.
Canadian Solar, p. 2	There are significant modelling issues, with information becoming out of date before a project gets to 'committed' status. Futher, inverter manufacturers are constantly updating their models to suit new requirements requested by AEMO. The rules should include a provision to oblige NSPs and AEMO to agree to certain modelling information once it's distributed to the applicant, the information should be valid for a reasonable period of time while applicant performs the required studies.	The Commission considers it is not within the scope of this rule change request to consider this issue, but that it may be appropriate to consider this issue in the ongoing *Review into the coordination of generation and transmission investment*.
WSP, p. 2	The connecting applicant should be provided with any technical information to allow themselves to replicate any studies carried out by the NSPs and/or AEMO.	The Commission considers it is not appropriate to require the provision of this information, given this may conflict with other confidentiality obligations. A detailed review of information provision requriements would be required before considering changes to this framework.

STAKEHOLDER	COMMENT	AEMC RESPONSE
WSP, p. 3	Suggest it would help if NSPs were requried to provide details of whether a negotiated access standard would be acceptable, and short reasons as to why, at an early stage.	The Commission considers it is not appropriate to require the provision of this information at this stage of the connection process, given it is at an early stage in the process where the eventual connection of the generating system, and its proposed design, is often highly uncertain, and also taking into account the potentially large administrative cost for networks that are not able to be recovered in fees at connection enquiry stage.
Reactive power control		
Energy Networks Australia, p. 8	We have reservations about AEMO being granted the ability to change the operating state of distribution networks it has no visibility of. Any procedure agreed to between AEMO and the distribution network service provider needs to consider the increasing level of smaller non-scheduled generating on 11/22kV distribution feeders and any remote changes in the voltage control model, when distribution network service providers are responsible for the management of local voltage and thermal limits.	The requirement in the final rule for a procedure for switching between control modes does not constrain or specify the circumstances that may be considered prior to switching. This provides scope for considering matters relevant to reactive power control mode switching in distribution networks. Further, the final rule has limited the circumstances in which remote switching is likely to occur.
Meridian Energy Australia, p. 4	We are concerned that the draft rule, which "provides that the mode of reactive power arrangements apply irrespective of the	The Commission's final rule does not pre-judge the modes most appropriate for application at different levels of the power system or for

STAKEHOLDER	COMMENT	AEMC RESPONSE
	connection point voltage and the capacity of the generating system", will pose significant barriers to entry for small or community-owned generating systems with what MEA Group perceives as negligible benefit for a secure operating system.	generators of different sizes. The final rule provides scope for the AEMO, the network service provider, and connection applicant to specify the modes of operation most suitable for conditions at the connection point. The minimum access standard provides for the capability to operate in a single control mode. A connection applicant for a small community owned generator can propose connection at this level, taking into account the commercial feasibility of the automatic access standard.
TasNetworks, p. 4	Remote control equipment to change the setpoint and control mode should be required unless otherwise agreed with AEMO and the network service provider. Generators, AEMO and NSPs should be able to negotiate an appropriate outcome based on the generator location, type and surrounding network requirements, while still being able to achieve the automatic access standard. For clarity, an acceptable outcome may be that remote control capabilities to change the setpoint are required, but facilities to change the control mode are not.	The Commission's final rule does not include explicit requirements for remote control equipment in the automatic access standard (b)(2A). The final rule includes a general requirement for the procedure for switching to be agreed upon and documented. Agreement and documentation may include whether remote or manual switching capabilities are required as provided for under S5.2.6.1. S5.2.6.1 does not require remote control facilities for mode of voltage control under the minimum access standard. Connection applicants can therefore seek a negotiated access standard that allows for manual switching.

STAKEHOLDER	COMMENT	AEMC RESPONSE
Lloyd's Register, p. 6	In order for reactive control mode switching to be properly considered as part of the connection process, the NSP should be required to advise as part of its clause 5.3.3 response that such a procedure is contemplated, and to provide reasonable assistance to the connection applicant in the formulation and design of the required procedure.	The final rule requires that, where multiple reactive power control modes are required, all parties to agree on a procedure for switching between modes (g1). Such agreement will require AEMO and the network service provider to negotiate with the connection applicant in the formulation and design of the procedure.
General Electric Australia, p. 7	Point from where Remote control is desired is not clear. Within the plant, HMI has this mode selection & setpoint fields. For remote interface from outside the plant, need additional hardwiring/logic modifications. Please consider clarifying the text.	The point where remote control is provided is a matter for negotiation between the connection applicant, AEMO and the network service provider. The final rule does not pre-judge and provides the flexibility for the implementation to reflect the specific circumstances which apply to the connection.
Reactive current response during disturbances		
TasNetworks, p. 8	As the voltage of the MV collector system may return to within the maximum threshold limits of 85% to 112% prior to the connection point being restored to 90% to 110%, the only mechanism to sustain a reactive response in accordance with S5.2.5.5 is via a PPC which has visibility of the connection point voltage. TasNetworks considers it is important that this fact be clearly communicated in the AEMC's final determination.	The Commission's final rule has unified all reactive response requirements under S5.2.5.5 as being in respect of connection point voltages rather than a mix of connection point and generator terminal voltages. The automatic and minimum access standard also provides additional flexibility for the duration to be sustained until the connection point voltage recovers to 90% or 110% of normal or such other voltage range agreed with the Network

STAKEHOLDER	COMMENT	AEMC RESPONSE
		Service Provider and AEMO (b)(3)(i) and (c)(3)(i). This avoids the inconsistency noted by TasNetworks and creates scope for a range of technical means to be applied in meeting the requirements.
Nordex, p. 16	Please take into account that a DFIG wind turbine also contribute a negative sequence reactive current beside the positive sequence reactive current during asymmetrical faults. The negative sequence reactive current will help to symmetrize the voltages during an asymmetrical fault. Please, consider the reactive current contribution as fulfilled if the absolute value of negative sequence reactive current contribution plus the absolute value of positive sequence reactive current equals the amount of the maximum continuous current of a generating system.	The Commission's final rule includes a general requirement S5.2.5.5(i)(3) providing flexibility for negative sequence components of current to be accounted for by agreement with AEMO.
Lloyd's Register, p. 7	The minimum rise time and settling time requirement for reactive current injection or absorption under the minimum standard, subclause (c)(4), should be removed. In place of this, the negotiating framework will apply to ensure the automatic standard requirements are achieved where appropriate, but that a lower rise time or settling time may be	The Commission has provided additional flexibility in the speed of response requirements in the minimum access standard of S5.2.5.5(c)(6) by removing the 180 ms maximum allowable rise time where AEMO and the NSP require a reactive response duration of greater than 2 seconds. This change is to allows a longer rise time or settling time to be

STAKEHOLDER	COMMENT	AEMC RESPONSE
	negotiated where this would otherwise involve substantial cost for additional reactive plant without any material improvement in system security.	negotiated where a system conditions justify prioritising response duration over response speed.
Continuous uninterrupted operation - Definition		
Lloyd's Register, p. 12	The wording of item (d) should be adjusted to insert the word "operating" before "so as not to exacerbate or prolong".	The Commission has removed "so as to" from part (d) of the definition to delineate part (d) as an independent condition in the definition of continuous uninterrupted operation, rather than one that applies only in relation to parts (a), (b) and (c).
TasNetworks, p. 8	Remove "so as to" from part (d) of the definition	As above.
Continuous uninterrupted operation - Multiple voltage disturbances		
Clean Energy Council, p. 5	It is recommended that S5.2.5.5(b)(1A) be updated through the following additional clauses:- S5.2.5.5(1A)(x) cause the generating unit's active power, reactive power or voltage at the connection point to become unstable as assessed in accordance with the power system stability guidelines established under clause 4.3.4(h) S5.2.5.5(1A)(xi) cause a material reduction in	A generating system would likely be able to disconnect under clause S5.2.5.10 if a condition is detected that would lead to active power, reactive power or voltage at the connection point to become unstable, or if a condition is detected that would lead to pole slipping.The intent of accounting for material reductions in system strength is more holistically captured by the wording in the final rule around "material reduction in power transfer capability", which would also likely result in material reductions in

STAKEHOLDER	COMMENT	AEMC RESPONSE
	system strength by removing network elements or synchronous generating units from service affecting the stability of the generating system	system strength.
GE Australia, p. 5	S5.2.5.5(b)(1)(iii): 430 ms seems long. Can the generator stay synchronized? Can all auxiliaries stay connected? Would the process be affected by speed profile of pumps and fans? Recommend to change this value to maximum 250 ms.	This requirement is not within the scope of this rule change and has not changed from the previous version of the NER.
GE Australia, p. 5	S5.2.5.5(b)(1A)(ii): Does the term "otherwise" mean where there are no auto reclosures? We assume the voltage drops below 50% for both 2 x 3-ph faults with auto-reclosure and 1 x 3-ph fault without auto reclosure. We understand no single-phase auto reclosure is considered.	Yes. Where three-phase automatic reclosure is not permitted, up to one three phase fault where voltage at the connection point drops below 50% of normal voltage applies for this clause. Note that auto reclosure is also considered in S.5.2.5.5(h).
Lloyd's Register, p. 12	A simplified approach to the multiple disturbance access standards is appropriate as follows:- The minimum access standard is that a generating system and its generating units must be capable of continuous uninterrupted operation for a sequence of three hard two-phase-to-ground faults and three shallow faults within a five minute period, with fault timings and durations matching the sequence in the	It is not appropriate to specify requirements in the NER in relation to a historical event, rather than engineering principles. The suggested automatic access standard falls within the negotiable range in the final rule. The combinations of disturbances that should be modelled by connection applicants can be specified by AEMO or the NSP at the time of connection application. Additional guidance will

STAKEHOLDER	COMMENT	AEMC RESPONSE
	lead up to the September 2016 event in South Australia, and where the faults are applied at the closest point in the transmission network to the generating system connection point.- There is either no automatic access standard, or the automatic access standard requires continuous uninterrupted operation for a sequence of six hard two-phase-to-ground faults and nine shallow faults within a five-minute period, where the hard and shallow faults may occur in any order and at arbitrary times within this period, and are applied at the closest point in the transmission network to the generating system connection point.	also be provided by AEMO in its Guidelines for assessment of generator proposed performance standards.
GE Australia, p. 5	No time difference between faults implies no recovery.	If there is effectively no time difference between disturbances, recovery is required after clearance of the last disturbance. There is time difference between faults specified in the minimum access standard, as well as a new condition included that there be no more than 3 disturbances within any 30 second period.
Pacific Hydro, p. 4	Into S5.2.5.5(b)(1A) and (c)(1A) insert:"provided that none of the events:(vii) island the generating system or cause a material reduction in power transfer capability of the generating system by removing network	The Commission considers it is appropriate to not specify clearance times for the disturbances listed in clauses S5.2.5.5(b)1 or S5.2.5.5(c)(1). A generating system would likely be able to disconnect under clause S5.2.5.10 if a condition

STAKEHOLDER	COMMENT	AEMC RESPONSE
	elements from service;(viii) result in a fault type that fails to clear in accordance with S5.1.9 leading to an unstable generating unit or power system;(ix) result in a fault type that causes a synchronous generating unit or synchronous condenser to trip for loss of synchronism;(x) cause a material reduction in system strength by removing network elements or synchronous generating units from service affecting the stability of the generating system;"	is detected that would lead to active power, reactive power or voltage at the connection point to become unstable, or if a condition is detected that would lead to pole slipping.The intent of accounting for material reductions in system strength is more holistically captured by existing wording around "material reduction in power transfer capability", which would also likely result in material reductions in system strength.
GE Australia, p. 6	We assume the positive sequence voltage is referred for RMS-type analysis.	This requirement can be addressed with AEMO or the NSP at time of application.
TransGrid, p. 6	Delete S5.2.5.5(b)(1)(i) and add at end "(iv) any credible contingency event not referred to in subparagraphs (i), (ii) or (iii)".	This would not result in a change in intent from the wording in the final rule.
TransGrid, p. 7	The term "islanding" in subclauses S5.2.5.5(b)(1A)(vii) and S5.2.5.5(c)(1A)(vi) would benefit from a definition. Undefined, islanding could be construed to include the separation of one region from the rest of the NEM, or creation of an island with a local load.	"Islanding" in its context is "islanding of the generating system". The term is not italicised, and in this context clearly does not include islanding of a region. Defining the term would lead to confusion with existing defined terms for "island" which refer to an islanded region. Further, "island with a local load" would depend on whether there is a material reduction in power transfer capability.
TransGrid, p. 7	The 100 MW threshold has no effect as events	The final determination inserts the drafting

STAKEHOLDER	COMMENT	AEMC RESPONSE
	in S5.2.5.5(c)(1)(ii) of the minimum access standard are credible contingency events.	"other than a fault referred to in subparagraph (ii)" into S5.2.5.5(c) (i). This means that credible contingencies referred to in (i) will refer to non-fault contingencies such as load and generator tripping events.
TransGrid, p. 8	Subclause S5.2.5.5(b)(1A)(iii) refers to one fault cleared by a circuit breaker fail protection system with no voltage depression requirement specified. TransGrid seeks clarification on whether subclause S5.2.5.5(b)(1A)(i) requirements are specified with a primary protection system and subclause S5.2.5.5(b)(1A)(iii) requirements are specified with connection point voltage above 50%.	The automatic access standard requires up to 15 disturbances with up to six deep faults below 0.5pu voltage. The one disturbance cleared by a breaker fail protection or similar back-up protection system could either by one of the 6 deep faults or one of the others.
TransGrid, p. 8	There is a need to specifically define the requirements relating to subclause S5.2.5.5(b)(1A)(v) in relation to the voltage depression and fault clearance requirements to be applied for this sub-clause.	This clause defines the time delay between any of the two disturbances referred to in clause s5.2.5.5(b)(1A)(v). The individual disturbances will have voltage depression and clearance time requirements.
TransGrid, p. 9	The events in the minimum standard defined in subclause S5.2.5.5(c)(1) appropriately do not include faults cleared in the time required by breaker fail. However it is included in such events in subclause S5.2.5.5(c)(1A). TransGrid suggests that it would be appropriate to remove subclause S5.2.5.5(c)(1A)(ii).	The Commission agrees and, for consistency with the requirements of the existing clause, removed the breaker fail requirement from the minumum access standard in the final rule. The requirement remains in the automatic access standard, as per AEMO's proposal.

STAKEHOLDER	COMMENT	AEMC RESPONSE
TransGrid, p. 9	S5.2.5.5(b)(1A)(ii): the clause infers that there are parts of the network where three-phase automatic reclosure is permitted, and by inference, parts of the network where three-phase automatic reclosure is not permitted. The specific use of the term "three-phase" appears to be alluding to single phase automatic reclosure. In TransGrid's network, a subset of transmission lines have facilities to trip and reclose a single faulted phase. However, the same facilities also have the ability to automatically reclose three-phases. TransGrid suggests a review of subclause S5.2.5.5(b)(1A)(ii).	S5.2.5.5(b)(1A)(i) already includes a requirement for up to six deep faults which could be single phase faults, noting that under S5.2.5.5(h) an unsuccessful operation of auto reclose equipment counts as separate disturbances. The purpose of S5.2.5.5(b)(1A)(ii) is to limit the number of deep three phase faults to one, except where three phase auto reclosure is allowed.
WSP, p. 4	S5.2.5.5(c)(1)(ii)(A) suggestion: "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, or a greater limit based on what AEMO and the Network Service Provider both consider to be reasonable in the circumstances (including providing detailed technical reasons as to why a greater limit is suitable)"	There is a requirement through the negotiation process in Clause 5.3.4A to provide technical reasons for proposing a performance standard that is not equivalent ot any automatic access standard.
Continuous uninterrupted operation - Voltage disturbances		
Advisian, p. 3	The new rules also mandate high voltage levels for significant periods of time (clause S5.2.5.4)	For a requirement that is reletively arduous for particular equipment to comply with, the

STAKEHOLDER	COMMENT	AEMC RESPONSE
	which most existing generator or industrial installations, which include transformers, capacitor banks or motor, are not able to safely achieve.	capability range between automatic and minimum access standards, and the negotiation process in clause 5.3.4A, allow for a balance between power system security and quality of supply on the one hand, and the technical limits of a generating system, the local power system conditions and commercial feasibility of meeting the automatic access standard, on the other hand.
AGL, p. 3	The 90-110% normal voltage continuous operation requirement is ambiguous with respect to the status of the grid. It is unclear in the draft rule if this obligation would apply to steady-state or a low voltage ride-through response. AGL notes that if sections of the grid, including the local NSP assets, shut down, steady-state is lost, making it incredibly difficult for an impacted generator to meet the parameters of continuous uninterrupted operation.	A generating system's required response to low-voltage disturbances (e.g. reactive power injection), including those specified in clause S5.2.5.4, is outlined in clause S5.2.5.5. This response forms part of a generator's obligations to maintain continuous uninterrupted operation when required to do so. It is important that generating systems maintain continuous uninterrupted operation for power system conditions more onerous than those expected from just steady-state or a single credible contingency in order to avoid cascading outages.
Ergon Energy and Energex, p. 6	Further clarification is also required if the expectation is that dedicated and shared connection assets (for example, upstream transformers) will need to be rated for 110%-	Clarification is provided in the relevant section of the final determination.

STAKEHOLDER	COMMENT	AEMC RESPONSE
	115% voltage for twenty minutes.	
Lloyd's Register, p. 9	In Lloyd Register's view, a less onerous standard (for example, 70% to 80% for 1 second and 80% to 90% for 2 seconds) would likely address concerns about restraining particular technologies while still guaranteeing a higher degree of resilience as a floor level. It would, for example, most likely have functioned no worse than the proposed standard in regard to the grid-separation events recently observed in South Australia.	For a requirement that is reletively arduous for particular equipment to comply with, the capability range between automatic and minimum access standards, and the negotiation process in Clause 5.3.4A, allow for a balance between power system security and quality of supply on the one hand, and the technical limits of a generating system, the local power system conditions and commercial feasibility of meeting the automatic access standard, on the other hand.
Lloyd's Register, p. 9	As to current practice, Lloyd's Register's recent experience with NEM generator connections is that virtually none have proposed to connect at the current S5.2.5.4 minimum standard; most or all have been above at least the proposed S5.2.5.4 minimum standard for overvoltage; but many are not above the proposed S5.2.5.4 minimum standard for undervoltage. Lloyd's Register is familiar with at least one major generator supplier and active NEM participant whose plant is not designed to operate at 80% terminal voltage for 5 seconds and likely could not be redesigned to do so without incurring substantial additional cost.	For a requirement that is reletively arduous for particular equipment to comply with, the capability range between automatic and minimum access standards, and the negotiation process in Clause 5.3.4A, allow for a balance between power system security and quality of supply on the one hand, and the technical limits of a generating system, the local power system conditions and commercial feasibility of meeting the automatic access standard, on the other hand.

STAKEHOLDER	COMMENT	AEMC RESPONSE
Lloyd's Register, p. 8	There are network locations (for example, major urban areas or locations near large hydropower facilities) where large voltage excursions due to low system strength are highly unlikely and will remain so for the foreseeable future.	The capability range between the automatic and minimum access standards, and the negotiation process in Clause 5.3.4A, allows for a balance between power system security and quality of supply on the one hand, and the technical limits of a generating system, the local power system conditions and commercial feasibility of meeting the automatic access standard, on the other hand.
GE Australia, p. 4	S5.2.5.4(a)(6) to (8) (normal and under-voltages): recommend text "subject to no other limiters acting" to be added.	Any conditions that may affect compliance with a performance standard can be agreed between the connection applicant, AEMO and the NSP as part of the negotiation process.
TransGrid, p. 5	TransGrid proposed making changes to draft rule subclauses S5.2.5.4(a) and S5.2.5.4(b) as underlined below:"… must be capable of continuous uninterrupted operation where a power system disturbance causes any phase or combination of phase voltages at the connection point to vary within the following ranges …"	The Commission understands that AEMO intends for the over-voltage requirements to be measured in relation to the highest voltage of any phase, and the under-voltage requirements to be measured in realtion to the lowest voltage of any phase. This matter can be clarified during the connection application process.
Consequential changes and other matters		
AEMO, p. 29	AEMO proposed in its submission a new requirement for network service providers to send connection enquiry forms (that meet the	The Commission does not consider it is appropriate to include this new requirement. The administrative burden of introducing this

STAKEHOLDER	COMMENT	AEMC RESPONSE
	requirements of Schedule 5.4) to AEMO. AEMO considered this information is necessary due to AEMO's responsibilities for broader network and integrated system planning, and because it is experiencing occasions where development of a project has commenced during the connection enquiry stage, before AEMO has been notified of the project. AEMO also noted it intends to use the information to better inform its review of connection applications and the negotiation of performance standards.	requirement would not be justified by the limited utility of the information, given there is much scope for a project to change or to not proceed after the connection enqiry stage. Further, the Commission does not consider it is appropriate to take connection enquiries into account in the negotiation of performance standards.
TasNetworks, p. 12	A number of references to various Australian Standards in Chapter 5 are out of date and should be changed. Specific changes were proposed.	The Commission considers it is not within the scope of this rule change to address those issues, which relate to issues that have not been raised by AEMO in its rule change request. Any party other than the AEMC is able to submit a rule change request to address these issues.
TasNetworks, p. 11	A clear description is needed of what is meant by the requirement to be 'capable' of a particular technical requirement. Taking frequency control mode as an example, being capable should mean that the equipment is able to be operated in that mode at any time, even if it is not registered to provide FCAS.	A general discussion of the meaning of 'capability' is provided in Chapter 5 of the final determination. The Commission does not consider there is a need to define the term in Chapter 10 of the NER.
Energy Networks Australia, pp. 5-6	It would be helpful to have more clarity on the application of the new rules, to have a table	The Commission does not consider it is necessary to provide this information. It is up to

STAKEHOLDER	COMMENT	AEMC RESPONSE
	that shows how the new rules apply to different sizes and types of generator.	the parties to consider and interpret the rules, which we consider are the appropriate resource to be used for the purposes of compliance.
Eneflux, p. 4	Proposed that a provision be added under Clause 4.14 for AEMO to maintain and publish a register of projects that have completed the 5.3.4A process and as such have agreed GTPS.	The Commission considers it is not with in the scope of this rule change request to consider this issue, but that it may be appropriate to consider this issue in the ongoing *Review into the coordination of generation and transmission investment*.
Millmerran Power, p. 1	In relation to renegotiation of performance standards under clause 5.3.9 of the NER, for existing registered participants, the current negotiated standard should be the default position, with AEMO and the NSP required to provide detailed technical reasons why any move away from the negotiated standard is absolutely required.	The Commission considers the negotiation framework under the final rule is an appropriate mechanism to address the renegotiation of performance standards under clause 5.3.9, noting that when proposing a negotiated access standard the Generator may take into account the cost and commercial feasiblity of meeting the automatic access standard.

B LEGAL REQUIREMENTS UNDER THE NEL

This appendix sets out the relevant legal requirements under the NEL for the AEMC to make this final rule determination.

B.1 Final rule determination

In accordance with section 102 of the NEL the Commission has made this final rule determination in relation to the rule proposed by AEMO.

The *National Electricity Amendment (Generator technical performance standards) Rule 2018 No. 10* is published with this final rule determination.

The Commission's reasons for making this final rule determination and the final rule are set out in section 2.4.

The key features of the final rule are also described in section 2.4.

B.2 Power to make the rule

The Commission is satisfied that the more preferable final rule falls within the subject matter about which the Commission may make rules. The more preferable final rule falls within section 34 of the NEL as it relates to regulating the operation of the national electricity market, 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 final 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.[923]

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 the Australian Energy Market Operator (AEMO)'s declared network functions.[924] The more preferable final 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 final rule amends the following rules of the NER that are currently classified as civil penalty provisions under 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 (g), and clause 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.

The Commission does not consider any other provisions of the final rule should be classified as civil penalty provisions.

B.5 Conduct provisions

The more preferable final rule does not amend any clauses that are currently classified as conduct provisions under the NEL or the National Electricity (South Australia) Regulations. The Commission does not propose to recommend to the COAG Energy Council that any of the proposed amendments made by the final rule be classified as conduct provisions.

B.6 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.[925] Under those Regulations, only certain parts of the NER have

923 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.

924 Section 91(8) of the NEL.

925 National Electricity (Northern Territory) (National Uniform Legislation) (Modifications) Regulations.

been adopted in the NT.[926] 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.[927] However, the proposed rule relates to parts of the NER that will apply in the Northern Territory from 1 July 2019.

926 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).

927 National Electricity (Northern Territory) (National Uniform Legislation) Act 2015.