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11 August 2017

Mr John Pierce
Chairman
Australian Energy Market Commission
PO Box A2449
SYDNEY SOUTH NSW 1235

John
Dear Mr ~~Pierce~~

Rule Change Proposal – Generator Technical Requirements

The Australian Energy Market Operator (AEMO) requests the Australian Energy Market Commission (AEMC) consider making a change to the National Electricity Rules (NER) under section 91 of the National Electricity Law.

The changes proposed will reform the framework surrounding the connection of generation in the National Electricity Market. They are designed build a modern, advanced, and secure power system in an efficient manner, while minimising the potential for system weaknesses to arise.

The South Australian black system event on 28 September 2016 demonstrated weaknesses in the existing generator performance standards that adversely impacted on the security and reliability of the power system, in particular the ability of connected generating systems to withstand, ride through and support the power system during major contingency events. There is an expectation in the market and the wider community that the market institutions will move swiftly to deal with these weaknesses.

The number of connection applications currently being processed by AEMO is an order of magnitude greater than ever before. As generating systems are long-life assets, there is a need to ensure the capabilities they are built with today will meet the needs of the power system of the future.

AEMO, therefore, requests that this Rule change proposal be processed as expeditiously as is possible within the constraints of the rule making process in the National Electricity Law.

We look forward to working with the AEMC to ensure that the new requirements will be in place in no longer than 6 months.

Should you have any question in regards to this Rule change proposal, please contact Chris Davies, Manager, Strategy and Coordination, on 03 9609 8000.

Yours sincerely

CParrotte

Cameron Parrotte
Executive General Manager – Strategy and Innovation

Attachments: Electricity Rule Change Proposal: Generator Technical Requirements

ELECTRICITY RULE CHANGE PROPOSAL

GENERATOR TECHNICAL REQUIREMENTS

August 2017

AEMO

AUSTRALIAN ENERGY MARKET OPERATOR

CONTENTS

1 SUMMARY

1.1 Context

A transition is taking place in the National Electricity Market (NEM). Traditional synchronous generating units approaching the end of their 30–50 year lifespans are being retired. Over the last 18 months, three coal fired power stations representing just over 2.4 GW of generation has been withdrawn from service.[1] Their replacements mainly consist of asynchronous generating systems. AEMO's current forecasts show approximately 20 gigawatts (GW) of new asynchronous generation is currently proposed for construction.[2] While it is unlikely all of these projects will come to fruition, by comparison, only around 5 GW of new synchronous generation has been proposed for development.[3]

Different technologies naturally have different capabilities. The National Electricity Rules (NER) detail the technical requirements that govern the connection of generating systems to the national grid and the capabilities they must deliver to support power system security. These technical requirements were initially written when the NEM's generation consisted predominantly of synchronous generation plant, with some amendments a decade ago to accommodate new technologies. The technical requirements have not been reviewed since that time, despite significant advances in the capability of asynchronous generation.

AEMO considers the existing requirements no longer adequate to account for the capabilities of asynchronous generation. Technological developments mean that asynchronous generating systems can provide a broader range of system services than they could 10 years ago. Given the transition underway, the NER's generator technical requirements must be reviewed to ensure that new generation delivers the functionality required to operate the power system securely, reliably, and affordably. This needs to occur considering a variety of potential future generation supply scenarios and generating system life cycles. With a high volume of connection applications likely, it is imperative to ensure new generation has the capabilities required to assist in the management of the power system in the future.

In South Australia (SA), this work has already commenced, because SA is experiencing a faster transition in its energy mix than the rest of the NEM, and has experienced a black system event in September 2016.

AEMO has undertaken a significant body of work over the past 12 months to consider potential changes to these technical requirements in SA supporting a review and consultation process by the Essential Services Commission of South Australia (ESCOSA) of the regulatory, licensing and associated arrangements for connection of new electricity generating systems in that State. This process has highlighted a number of deficiencies in the NER framework.

While AEMO has recommended to ESCOSA additional interim performance requirements for generating systems connecting in SA, AEMO strongly supports a national approach to these technical requirements. This Rule change proposal seeks to integrate AEMO's ESCOSA recommendations into the NER, adjusted to suit the broader NEM's conditions and future needs.

The need to update generator performance requirements is not unique to the NEM. Grid codes around the world are being updated for similar reasons. The International Energy Agency (IEA) considers grid code reform designed to effectively and efficiently integrate asynchronous generation into power systems to be critical, and in countries like Australia should be developed during the current phase of the energy transition.[4] The IEA notes this will ensure that generation can perform as required throughout its lifetime, without the need for costlier future retrofits.[5]

Chapter 5 of the NER prescribes, among other things, the technical requirements that generating systems need to meet in order to be connected to the national grid. This proposal recommends updates to these requirements.

[1] AEMO. Generation Information page, at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information. Information current at 19 May 2017.
[2] bid.
[3] bid.
[4] IEA. *Getting Wind and Sun onto the Grid: A Manual for Policy Makers*, March 2017, page 16. Available at: https://www.iea.org/publica ions/insights/insightpublications/getting-wind-and-solar-onto-the-grid html.
[5] bid, p. 16.

1.2 Lessons from the South Australian Black System event

The SA black system event that occurred on 28 September 2016 is relevant to this Rule change proposal. AEMO has investigated the sequence of events that caused the SA power system to collapse, including the identification of root causes and potential remedial actions.[6] It is important that all lessons learned result in changes that can minimise the chances of similar supply disruptions in future.

AEMO's final report into the black system event highlighted the need for changes to the technical requirements in the NER for generating systems in the following areas:[7]

- Reactive output of generating systems during fault conditions.
- Ability of generating systems to remain in service through multiple voltage disturbances.
- Managing the risk of transient asynchronous generator reduction due to a single credible fault.
- Generator over-voltage ride-through capability.
- Managing the impact of reducing system strength on generating system stability by ensuring the relevant access standards include a lower limit of system strength for which a generating system must meet its performance obligations.

More generally, the investigation highlighted the need to have performance standards that specifically and unambiguously describe the expected performance of each generating system.

This Rule change proposal seeks to address all these changes.

1.3 The need to act

The existing generator technical requirements were designed for an era of generating systems with different technological characteristics and performance capabilities.

The SA black system event demonstrated weaknesses in the existing generator performance standards that adversely impacted on the security and reliability of the power system, in particular the ability of connected generating systems to withstand, ride through and support the power system during major contingency events. There is an expectation in the market and the wider community that the market institutions will move swiftly to deal with these weaknesses.

The number of connection applications currently being processed by AEMO is an order of magnitude greater than ever before. As generating systems are long-life assets, there is a need to ensure the capabilities they are built with today will meet the needs of the power system of the future.

AEMO, therefore, requests that this Rule change proposal be processed as expeditiously as is possible within the constraints of the NEL. We look forward to working with the AEMC to ensure that the new requirements will be in place in no longer than 6 months.

1.4 Interim Technical Standards for Generating Systems in South Australia

The consultation undertaken in developing AEMO's advice to ESCOSA underpins this Rule change proposal. While that consultation was focused on SA, numerous participants in other regions are generally involved in projects in the SA region, and the ESCOSA consultation and its outcomes was closely followed by participants throughout the NEM. AEMO repeatedly informed stakeholders throughout the ESCOSA process the new SA licence conditions would form the basis for a Rule change proposal.

[6] Reports on the black system event in South Australia on 28 September 2016 are available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/Power-System-Operating-Incident-Reports.

[7] Refer to Section 7.2.2 – "Generator performance standards" and Appendix X "Assessment of Additional Risks for System Security in South Australia" of AEMO, *Black System, South Australia, 28 September 2016*, March 2017. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/Power-System-Operating-Incident-Reports.

It is recognised that the Australian Energy Market Commission (AEMC) will need to follow the processes prescribed in the National Electricity Law (NEL) in assessing this Rule change proposal. AEMO believes that, in determining how it goes about considering this Rule change proposal, the AEMC should recognise the consultation that has already taken place in developing AEMO's advice to ESCOSA.

1.5 Independent Review into the Future Security of the National Electricity Market

This Rule change proposal addresses a number of the key recommendations arising out of the Independent Review into the Future Security of the National Electricity Market (Finkel Review) relating to *power system security* and reliability. The relevant Finkel Review recommendations are outlined, alongside the relevant section of this Rule change proposal, in Section 2.4. These Finkel Review recommendations have now been endorsed by the Council of Australian Governments (COAG) Energy Council.

1.6 Other strategic linkages

The AEMC has also published its final report on a closely related project; the System Security Market Frameworks (SSMF) Review. The report makes nine recommendations for changes to market and regulatory frameworks to support the shift towards new forms of generation while maintaining power system security. The relevant SSMF recommendations are outlined, alongside the relevant section of this Rule change proposal, in Section 2.6. Alongside these reviews, a number of other complementary reform measures are underway. The scope of this Rule change proposal and AEMO's recommendations have been developed while also considering the work underway in a number of areas including, but not limited to:

- The Rule changes currently under consideration by the AEMC on inertia and system strength.
- AEMO's Ancillary Services Technical Advisory Group process.[8]
- The AEMC's Frequency Control Frameworks Review.[9]

1.7 Transitional arrangements

In light of the large number of new projects involving asynchronous generation actively under consideration, and the expectation that more are likely to emerge from policy initiatives by a number of participating jurisdictions, it is imperative that connection enquiries and connection applications and the resulting connection arrangements be assessed on the basis of these new technical requirements, reflecting the future needs of the power system, rather than the current, outdated, requirements as soon as possible.

As noted above, the general approach to the standards proposed in this document has been the subject of considerable discussion since the SA black system event, including in the context of AEMO's advice to the ESCOSA review.

Therefore, the new technical requirements should apply to all negotiations of performance standards under clause 5.3.4A from the date this request is submitted, even if they result from a connection enquiry or connection application made prior to the proposed new Rule's taking effect, unless there are extenuating circumstances in AEMO's reasonable opinion.

In the absence of appropriate transitional arrangements, implementation of these essential changes will be delayed until the date the new Rule is made. During that time, NSPs and AEMO will likely come under great pressure to finalise negotiations over performance standards and connection agreements before the new requirements take effect, meaning that assets with around 25-year life cycles may be connected under outdated standards that do not ensure the capability required for the future power system.[10]

[8] For further details see: https://www.aemo.com.au/Stakeholder-Consultation/Industry-forums-and-working-groups/Other-meetings/Ancillary-Services-Technical-Advisory-Group.

[9] For further details see: http://www.aemc.gov.au/Markets-Reviews-Advice/Frequency-control-frameworks-review.

[10] AEMO is prepared to disclose data in respect of connection applications in the NEM, including those for which performance standards are still being negotiated on a confidential basis.

AEMO encourages all NSPs and Connection Applicants to immediately start considering the performance requirements specified in this Rule change proposal when assessing new and existing connection enquiries and applications, regardless of what stage they are at in the connection process.

1.8 Next steps

AEMO is cognisant of the need to ensure the programs referred to in Sections 1.5 and 1.6 are consistent and integrated. This proposal is focused on amending the technical requirements AEMO considers essential for new connections in the short term in light of the parallel processes underway. AEMO will work with the AEMC on this proposal and participate in technical workshops in various jurisdictions as required.

The Finkel Review further recommends a comprehensive review of the NER, to be completed by the end of 2020.

Other focus areas being scoped by AEMO as part of a complete NER review, or separate potential Rule change proposals, include the areas outlined in Sections 1.8.1 and 1.8.2.

1.8.1 Application of new performance standards to existing generators

This Rule change proposal does not recommend any changes to the performance standards that are currently in place, however, given the rapidly changing characteristics of the power system, consideration may need to be given to how to utilise existing or provide additional capabilities from existing generation. There are few, if any, other markets around the world where updates to a grid connection regulatory framework do not apply to existing generators.

AEMO will examine whether it would be appropriate for similar changes to be made to the NER.

1.8.2 Other key areas for review

AEMO is considering future Rule changes on:

- Further sections of Chapter 5 not covered in this Rule change proposal, if required.
- Technical requirements for Market Customers and Market Network Service Providers.
- Technical requirements for distributed energy resources (DER) and DER aggregators.
- System restoration

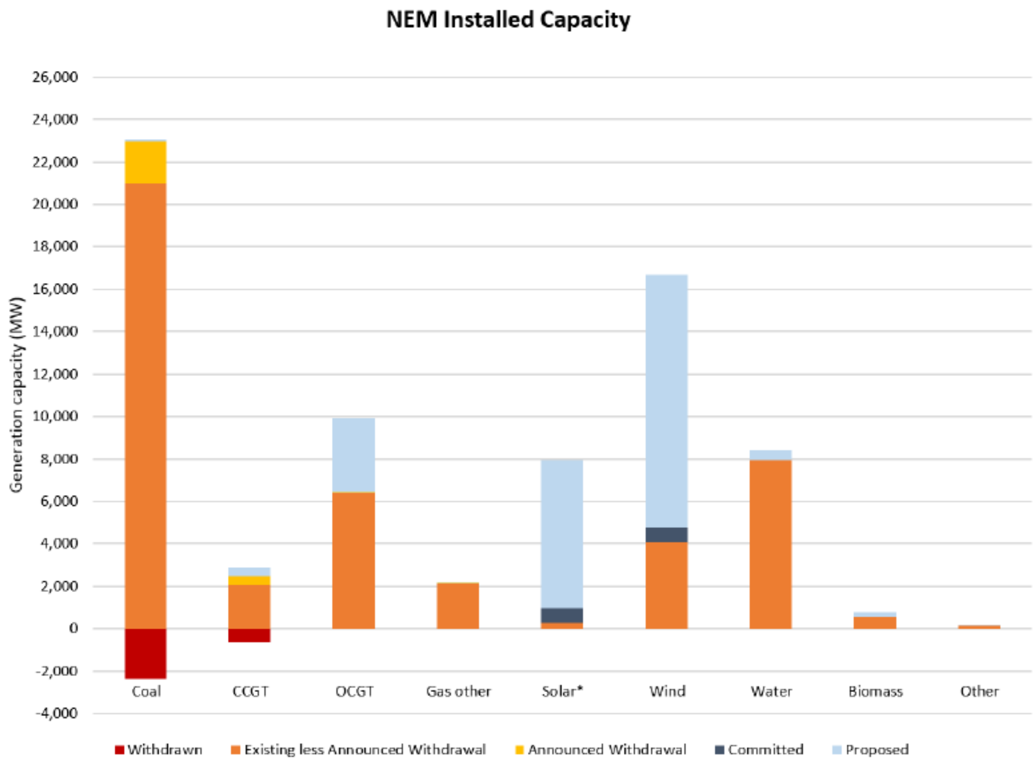
2 RELEVANT BACKGROUND

2.1 Energy transformation

The NEM is experiencing a shift in its generation mix, from predominantly synchronous generation[11], such as coal-fired power stations, towards asynchronous generation[12], such as solar photovoltaic (PV) and wind farms.

Significant new generation capacity is forecast to be installed in coming years, with the overwhelming majority of this plant likely to be asynchronous. As shown in Figure 1 and Table 1, industry has **committed** to almost 1.1 GW of solar PV and wind projects. Further, as noted above, approximately 20 GW of asynchronous generating capacity has been **proposed**, which is around 80% of the total capacity of new generation projects **proposed.** As of May 2017, there were no new synchronous generating systems **committed.**[13]

Figure 1 NEM installed capacity and proposed new generation projects



[11] Synchronous generating systems can be fuelled using coal, gas, diesel, hydro, solar thermal, or geothermal sources. They produce electricity via a rotating shaft with a stator and rotor that is directly connected to the power system by electromagnetic coupling.

[12] Asynchronous generating systems include wind farms, or solar photovoltaic (PV), and batteries that export power to the grid. They are connected to the power system by power electronics and do not have an electromagnetic coupling directly connecting plant to he *network*.

[13] Information about proposed and committed generation is from AEMO's Generation Information web page, at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Genera ion-informa ion.

Table 1 NEM installed capacity (megawatts)

Status	Coal	CCGT	OCGT	Gas other	Solar*	Wind	Water	Biomass	Other	Total
Existing	22,976	2,449	6,434	2,159	274	4,070	7,941	574	139	47,016
Announced withdrawal	2,000	379	34	30	0	0	0	0	0	2,443
Existing less announced withdrawal	20,976	2,071	6,400	2,129	274	4,070	7,941	574	139	44,573
Committed	0	0	0	0	692	690	4	0	0	1,387
Proposed	80	460	3,465	15	6,975	11,938	484	228	53	23,698
Withdrawn	-2,416	-624	0	0	0	0	0	0	0	-3,040

Source: AEMO. Generation Information web page. Information current at 19 May 2017.
* Solar capacity data includes solar thermal, which is a synchronous generation technology, but the vast majority of committed and proposed capacity is utility-scale solar PV, which is an asynchronous generation technology. The solar capacity data does not include rooftop PV, which is also an asynchronous technology.

This transition has brought to the fore the need to review the operational assumptions that were used when the NEM was established.

2.2 A changing way of viewing non-energy services

Maintaining a power system in a secure operating state requires matching supply and demand and maintaining power flows within limits through control of the amount of power dispatched, while managing the provision of transmission and distribution services.

The services that power system operators have traditionally relied on in the pursuit of a secure operating state include voltage control, active power control, reactive power control, inertia, system strength, and disturbance ride-through capabilities. In the NEM, a number of these services are referred to as 'ancillary services', which reflects the fact that synchronous generation could supply these critical services as a natural by-product of generation due to the physical nature of synchronous generation plant, supported by regulatory requirements specifying the provision of that capability at certain levels.

Asynchronous generation did not naturally provide all of these services in the past, and even though technological developments in the past decade mean that asynchronous plant can now provide many of these capabilities, there are insufficient regulatory obligations requiring them to do so.

Internationally, there has been a shift in nomenclature to recognise this change, with EirGrid, the system operator of Ireland, now considering these services as 'system services', and the New York Independent System Operator referring to them as 'essential services'.

The availability of these services is critical to AEMO's ongoing ability to operate the power system securely. Neither AEMO, nor any user of the national grid, can take it for granted that these system services will be available in the future without clear technical requirements in place.

2.3 Current framework

The National Electricity Code (the Code) was first published by the National Electricity Code Administrator (NECA) in November 1998, shortly before commencement of the NEM. It set out the objectives of the market, along with the rights and responsibilities of market participants, the National Electricity Market Management Company (NEMMCO, now AEMO), and NECA.[14]

In December 2001, NECA published a review into the technical requirements to which generating systems must adhere. The objective of the review was to ensure the technical standards protected the integrity of the power

[14] The NER replaced he Code in 2009, while the AEMC serves the rule-making function of NECA, the Australian Energy Regulator (AER) serves NECA's regulatory function, and NEMMCO's functions are now undertaken by AEMO.

system whilst facilitating the objectives of the market, which included ensuring a level playing field for all technologies.

With this objective in mind, the NECA review found that mandating a single set of standards for access to the network was inefficient, observing that:

> "The cost of meeting those standards will vary dramatically for different types of plant. Some types will have the capability significantly to over-achieve a mandatory standard at low cost. Others may be unable to achieve that standard except at prohibitive cost."[15]

Instead, NECA recommended:

- There be flexibility in the access standards by clearly specifying a range within which operators could negotiate with NEMMCO and NSPs for access to the network.
- A minimum standard, below which network access would be refused, should be included.

The standards were next updated in 2007, after NEMMCO submitted a Rule change request to the AEMC to provide for technical standards for certain non-scheduled generating systems, in particular wind generating plant, and to clarify and expand the existing framework for negotiating access of generating systems to the network.

It has now been 10 years since the technical requirements were reviewed. They no longer reflect the capabilities of, or performance required from, generation to support secure operation of the power system.

The IEA notes that while asynchronous generating systems are capable of providing a range of power system security services required to stabilise the grid, until these services are required or incentivised it is unlikely asynchronous generation will provide them.[16] Every new generating system installed under the existing requirements represents a missed opportunity, and potentially a 20-year plus legacy.

AEMO is, therefore, recommending a suite of changes to Schedule 5.2.5, plus other associated changes, to modernise the NER to suit today's requirements and those of the future.

2.4 Independent Review into the Future Security of the National Electricity Market

This Rule change proposal addresses a number of the key recommendations arising out of the Independent Review into the Future Security of the National Electricity Market (Finkel Review) relating to *power system security* and reliability. The relevant Finkel Review recommendations are outlined below, alongside the relevant section of this Rule change proposal.

Table 2 Finkel Review recommendations and how they are addressed by this Rule change proposal

Finkel Review recommendation	How this Rule change addresses the recommendation
Recommendation 2.1: A package of Energy Security Obligations should be adopted. By mid-2018 the Australian Energy Market Commission should:	
Require transmission network service providers to provide and maintain a sufficient level of inertia for each region or sub-region, including a portion that could be substituted by fast frequency response services.	To be addressed in the AEMC rule change on Managing the Rate of Change of Power System Frequency.

[15] National Electricity Code Administrator, "Review of technical standards: final report," December 2001. [Online]. Available at: http://www.neca.com.au/Reviews78ed.html?CategoryID=51&SubCategoryID=188.
[16] Ibid.

Finkel Review recommendation	How this Rule change addresses the recommendation
Require new generating systems to have fast frequency response (FFR) capability.	AEMO is recommending that generating systems have the capability to provide an active power response to changing power system frequency with no delay beyond that required for stable operation or inherent in the plant controls. AEMO considers that this requirement is the most effective way to specify capabilities today that may enable fast frequency responses from capable plant in the future as these services are trialled and better understood. This is further explored in Section 5.12.
Review and update the connection standards in their entirety.	Addressed partially by this Rule change proposal. AEMO has addressed the matters considered critical to power system security. As detailed in Sections 1.8 and 4.3 AEMO will monitor the outcome of the Rule change process to determine if further changes to Chapter 5 are required.
The updated connection standards should address system strength, reactive power and voltage control capabilities, the performance of generating systems during and subsequent to contingency events, and active power control capabilities.	Addressed by this Rule change proposal. Refer to Section 5.
To be approved for connection, new generating systems must fully disclose any software or physical parameters that could affect security or reliability.	AEMO considers this obligation already exists under clauses S5.2.5.8 and S5.2.4. AEMO has made a submission to the Generating System Model Guidelines Rule change to improve the clarity of this requirement. AEMO will continue to work with industry to ensure that this is understood and implemented.
Thereafter, a comprehensive review of the connection standards should be undertaken every three years.	AEMO supports this recommendation Refer to Section 1.8 and 2.5.
Recommendation 2.3: By mid-2018, the Australian Energy Market Operator and Australian Energy Market Commission should:	
Investigate and decide on a requirement for all synchronous generating systems to change their governor settings to provide a more continuous control of frequency with a deadband similar to comparable international jurisdictions.	While the need for mandatory governor response is still being investigated by AEMO through its Ancillary Services Technical Advisory Group[17] and the AEMC's Frequency Control Frameworks Review[18][19], the proposed capabilities in this Rule change proposal for automatic active power response to frequency changes would ensure that a sufficient proportion of new generation has the inherent capability to comply with any future mandatory requirements. Refer to Section 5.12 for more details.

[17] For further details see: https://www.aemo.com.au/Stakeholder-Consultation/Industry-forums-and-working-groups/Other-meetings/Ancillary-Services-Technical-Advisory-Group.
[18] For further details see: http://www.aemc.gov.au/Markets-Reviews-Advice/Frequency-control-frameworks-review
[19] For further details see: http://www.aemc.gov.au/Markets-Reviews-Advice/Review-of-the-Frequency-Operating-Standard.

Finkel Review recommendation	How this Rule change addresses the recommendation
Recommendation 3.4: By mid-2018, the Australian Energy Market Operator and the Australian Energy Market Commission should assess:	
The effectiveness of the new licensing arrangements being developed for generating systems in South Australia and whether they should be applied in other National Electricity Market regions.	This Rule change proposal addresses this recommendation by taking the ESCOSA recommendations for SA and adapting them to suit all NEM regions.

2.5 Framework for regular updates

New technical issues affecting the operation of the NEM will continue to emerge. New opportunities are also likely to become available as manufacturers respond to changes in technology.

The NER do not currently specify a framework for regular updates to technical connection requirements.

If these requirements are not updated to reflect changing power system needs and technological developments, there is a risk that generating systems will be connected to the NEM with technical capabilities inferior to what is possible, commercially available, and required to maintain a secure power system at the most efficient cost.

The Finkel Review recommends[20] a three-year review cycle for these technical requirements. AEMO agrees and will undertake regular reviews as recommended, but does not see the need for a change to the NER to effect this.

2.6 Recommendations from the AEMC's System Security Market Frameworks Review

The AEMC has also published its final report on a closely related project, the SSMF Review. The AEMC's report makes nine recommendations for changes to market and regulatory frameworks to support the shift towards new forms of generation while maintaining power system security.

This Rule change proposal addresses a number of SSMF review recommendations, as outlined in Table 3.

Table 3 SSMF recommendations and how they are addressed by this Rule change proposal

System Security Market Frameworks recommendation	How this Rule change addresses the recommendation
Recommendation 1: 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.	Addressed by this Rule change proposal. Refer to Section 5.10

[20] Finkel review. *Independent Review into the Future Security of the National Electricity Market*, June 2017, Recommendation 2.1, page 21. Available at: http://www.environment.gov.au/system/files/resources/1d6b0464-6162-4223-ac08-3395a6b1c7fa/files/electricity-market-review-final-report.pdf

System Security Market Frameworks recommendation	How this Rule change addresses the recommendation
Recommendation 5: Assess whether mandatory governor response (which control generating systems' response to frequency changes) requirements should be introduced and investigate any consequential impacts (including on the methodology for determining causer pays factors for the recovery of regulation frequency control ancillary services (FCAS) costs).	While the need for mandatory governor response is still being investigated by AEMO through its Ancillary Services Technical Advisory Group[A] and the AEMC's Frequency Control Frameworks Review[B], the proposed capabilities in this Rule change proposal for automatic active power response to frequency changes would ensure that a sufficient proportion of new generation has the inherent capability to comply with any future mandatory requirements. Refer to Section 5.12 for more details.
Recommendation 6: Review the structure of frequency control ancillary services (FCAS) markets, to consider: • any drivers for changes to the current arrangements, how to most appropriately incorporate fast frequency response (FFR) services, or alternatively enhancing incentives for FFR services • any longer-term options to facilitate co-optimisation between FCAS and inertia provision.	While the review of FCAS market structures is beyond the scope of this Rule change proposal[B], the active power control capabilities recommended in this Rule change proposal are intended to be complementary to any future FCAS market structures. Refer to Sections 5.11 to 5.14 for more details.
Recommendation 8: Consider placing an obligation on all new entrant plant, whether synchronous or *asynchronous*, to have fast active power control capabilities.	As noted in Section 2.4, the recommendations in this Rule change proposal for active power control capabilities that respond to changing power system frequency are believed to be the most effective way to specify FFR capabilities today. Refer to Section 5.12 for more details.

A For further details see: https://www.aemo.com.au/Stakeholder-Consultation/Industry-forums-and-working-groups/Other-meetings/Ancillary-Services-Technical-Advisory-Group.
B For further details see: http://www.aemc.gov.au/Markets-Reviews-Advice/Frequency-control-frameworks-review.

2.7 Other relevant reviews

A number of other complementary reform measures are also underway. The scope of this Rule change proposal and AEMO's recommendations have been developed while also considering work underway in the following areas:

- Managing rate of change of power system frequency (inertia) Rule change.
- Managing power system fault levels (system strength) Rule change.
- AEMO's Ancillary Services Technical Advisory Group process.[21]
- The AEMC's Frequency Control Frameworks Review.[22]
- Addressing additional Finkel Review recommendations.
- Generating system model guidelines Rule change.
- Other related activities from AEMO's Future Power System Security Program[23], including:
  - Investigations into rate of change of frequency (RoCoF) withstand capabilities of generating systems.
  - Investigations into future opportunities for fast frequency response (FFR) in the NEM.
  - Investigations into future regulation frequency control ancillary services (FCAS) needs.
  - Investigating transition pathways to a decentralised system.

[21] For further details see: https://www.aemo.com.au/Stakeholder-Consultation/Industry-forums-and-working-groups/Other-meetings/Ancillary-Services-Technical-Advisory-Group.
[22] For further details see: http://www.aemc.gov.au/Markets-Reviews-Advice/Frequency-control-frameworks-review.
[23] For further details see: https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/FPSSP-Reports-and-Analysis.

3 KEY PRINCIPLES

3.1 A national approach

AEMO seeks to maintain a NEM-wide, technology-neutral approach to establishing connection agreements, and believes the long-term interests of consumers will be best met with a consistent national framework.

Different requirements across regions present an unnecessary barrier to the efficient investment in electricity infrastructure that will ultimately lead to less economical outcomes for consumers. Failure to ensure a consistent approach risks the creation of insufficient, inefficient, and uncoordinated generation capabilities in the NEM.

As noted earlier, AEMO recently provided advice to ESCOSA regarding new technical licensing conditions for new generation in SA. The need for state-based performance requirements indicates that the technical requirements in the NER that ultimately result in performance standards for generation require updating to reflect the needs of the changing power system.

The urgency to review technical requirements is further indicated by other participating jurisdictions' seeking their own requirements over and above those in the NER. AEMO understands that New South Wales, Victoria, and Tasmania are contemplating their own performance requirements for new generation.

3.2 Forward-looking standards that are robust to a changing generation mix

In developing these recommendations, AEMO has sought to establish a set of technical requirements that will be capable of supporting a secure power system throughout its transformation.

AEMO has considered how power system security services could reasonably be provided under a number of plausible future scenarios, including:

- Increasing periods where less synchronous generation is dispatched.
- Periods where no synchronous generation would be economically dispatched.
- Periods of low or zero operational demand[24] due to increasing volumes of DER within the distribution networks in the NEM.

Under these scenarios, it is clear synchronous generating systems alone will no longer provide sufficient power system security services. Alternative means of sourcing these services must be found, whether from asynchronous generating plant (where it is reasonable to do so) or as network or non-network services (where services are still required under low operational demand scenarios).

Overall, AEMO recommends that all types of new generation should be required to incorporate cost-effective features that will allow them to contribute towards maintaining a secure and resilient power system.

3.3 Standards should apply to all generation types

Unless there are unavoidable technical reasons why a given technology cannot provide a particular capability, it is equitable the technical requirements should apply consistently to all generation types. Where technical differences exist, the requirements may be adjusted.

Any generating system installed today is likely to remain in service for at least the next 25 years. This means new plant constructed today will plausibly see the scenarios outlined, and thus the consistent application of the

[24] Broadly, this means a *region's* entire electricity demand could be offset by rooftop photovoltaic (PV), which is treated as "negative load" because it is located behind the meter on a customer's premises. In this case, surplus rooftop PV generation would be exported interstate via an interconnector. Operational demand in a region is demand that is met by local scheduled generating units, semi-scheduled generating units, and non-scheduled intermittent generating units of aggregate capacity ≥ 30 MW, and by generation imports to the region. It excludes the demand met by non-scheduled non-intermittent generating units, non-scheduled intermittent generating units of aggregate capacity < 30 MW, exempt generation (such as rooftop PV, gas tri-generation, and very small wind farms), and demand of local scheduled loads.

proposed technical requirements across all generation technologies should ensure the provision of a secure and resilient power supply for the life of the assets.

3.4 Standards should consider generating system size

A number of provisions in clause S5.2.5 include a capacity threshold of 30 megawatts (MW) whereby generating systems below the stated size limit do not need to comply with a particular requirement. The thresholds were included at a time when there was such a low number of small to medium-scale utility generating systems being connected that they would not have a material impact on the operation of the power system. Today, there is a growing trend of generating system projects under 30 MW and, when considered in aggregate, they could have a material impact on the power system.

AEMO is recommending that some size thresholds are removed from clause S5.2.5 so that the technical requirements will apply to all generating systems. Irrespective of plant size, all parties looking to connect generation will be obliged to engage with the relevant NSP in relation to applicable connection requirements. The removal of size thresholds is noted in the relevant sections.

For generating systems smaller than 5 MW, AEMO understands that an NSP may, on case-by-case basis, elect not to apply performance requirements on them. AEMO supports this approach.

This is consistent with AEMO's proposal in Section 9.3.2 relating to the need for consideration of requirements around the integration of DER and DER aggregators into the NEM.

Finally, this Rule change proposal is not intended to impose obligations on *retail customers* with micro EG connections,[25] such as household roof top solar PV systems or small scale household battery storage systems. The connection of these systems is managed between the relevant NSP and the applicant and is dealt with under chapter 5A of the NER.

3.5 Developing the solution

The issues identified in this document are the result of recent operational experience and the important learnings derived from the operation of the power system under extreme conditions.

Assessment of the changes made to international grid codes in the last decade supports the need for change and issues addressed, as evidenced by the proposed requirements for generating system performance during and after faults reflecting international developments.

In developing this Rule change proposal, AEMO's considerations have included:

- Holistic review of the energy transition and future power system requirements.
- Plausible dispatch scenarios including periods of zero or low levels of synchronous generation dispatch.
- Review of power system events and operational experience.
- Experience from negotiating generator connections over the past 10 years.
- Lessons from the SA Black System event, including extensive AEMO modelling.
- Review of international grid codes.
- Consultation with manufacturers.
- Stakeholder consultation (on ESCOSA recommendations).

[25] As that term is defined in clause 5A.A.1 of the NER.

4 OVERVIEW OF PROPOSAL

4.1 Approach to this Rule change submission

The extensive consultation undertaken in developing AEMO's advice to ESCOSA underpins this Rule change proposal. While that consultation was focused on SA, the major participants in other regions are generally involved in projects in the SA region, and the ESCOSA consultation and its outcomes were closely followed by participants throughout the NEM.

This Rule change proposal is based primarily on the recommendations made to ESCOSA for SA, with additional changes and recommendations that reflect stakeholder feedback or differences between the local SA licences and the structure of the NER.

AEMO's proposed changes are detailed in Section 5.

4.2 Summary of proposed changes

AEMO proposes that the AEMC change the following parts of the NER (as outlined further in Section 5).

Clauses marked with an * denote technical recommendations that were consulted upon by ESCOSA and AEMO in the period between April and June 2017.

Those with a ^ denote recommendations that were consulted during ESCOSA's consultation period, but where further changes have subsequently been proposed by AEMO to address stakeholder feedback, or to adapt these recommendations for the NER.

- **NON-TECHNICAL MATTERS**
  - 5.3.4A: Negotiated access standards
  - 5.3.9: Procedures to be followed by a Generator proposing to alter a generating system
  - 5.8.4: Commissioning program
- **SYSTEM STANDARDS**
  - S5.1a.4: Power Frequency Voltage and Figure S5.1.a.1^
- **VOLTAGE CONTROL**
  - S5.2.5.1: Reactive power capability^
  - S5.2.5.13: Voltage and reactive power control^
- **DISTURBANCE RIDE-THROUGH**
  - S5.2.5.3: Generating system response to frequency disturbances*
  - S5.2.5.4: Generating system response to voltage disturbances^
  - S5.2.5.5: Generating system response to disturbances following contingency events^
  - S5.2.5.7: Partial load rejection*
- **ACTIVE POWER CONTROL**
  - S5.2.5.11: Frequency control*
  - S5.2.5.14: Active power control*
- **SYSTEM STRENGTH**
  - S5.2.5.15^
- **MONITORING AND CONTROL**
  - S5.2.6.1: Remote Control and Monitoring^
- **GLOSSARY**
  - Amended definitions:
    - *Continuous uninterrupted operation*

  - New Definitions:
    - *maximum operating level*
    - *rise time*
    - *settling time*
- **TRANSITIONAL RULES**
  - 11.X.1 Definitions
  - 11.X.2 Application of Amending Rule to connection agreements

4.3 Further considerations

Where further, or other, changes to Chapter 5 of the NER can be accommodated without delaying a determination of this Rule change, AEMO recommends the AEMC consider such changes as part of this Rule change proposal.

Where any changes are likely to delay the implementation of AEMO's specific recommendations in this Rule change proposal, AEMO recommends that these be considered at a later date.

Matters that require further consideration include, but are not limited to:

- The extent to which other changes or amendments are required to technical requirements applicable to generators (Schedule 5.2), arising consequentially, or in addition to the recommendations in this proposal.
- The extent to which changes are required to the technical requirements applicable to loads (Schedule 5.3) and market network services (Schedule 5.3a) as a result of the evolving power system.

5 PROPOSED RULE[26]

A draft of the proposed Rule is appended to this document. Section 5 discusses the need for each proposed amendment.

5.1 Negotiated access standards

5.1.1 Statement of issue

In the context of *generation*, the framework for establishing a *connection agreement* under the NER is based on the principle that where proposed *generating plant* cannot meet an applicable *automatic access standard*, the *Generator*, the connecting NSP, and *AEMO* can negotiate an acceptable level of performance within a range between the *automatic access standards* and *minimum access standards*.

The *automatic access standards* represent a "safe harbour" for *Connection Applicants* – if their *plant* meets the *automatic access standards*, they can be assured of *connection* without the need for further analysis by *AEMO* as to whether the *plant* will have an adverse impact on *power system security*. Below that level, their proposed *connection* is subject to review and analysis by *AEMO* to assess the implications for *power system security* and on other *Network Users*.

To maintain a robust *power system*, *AEMO* expects any *negotiated access standards* should be as close as reasonably practicable to the *automatic access standard*. In general terms, the closer a proposed *negotiated access standard* is to the applicable *automatic access standard*, the less its impact on *power system security*. The role of the *minimum access standard* should be to accommodate the *connection* of *generating systems* that are relatively insignificant and where the potential impact on the *power system* and other *Network Users* is likely to be small. *AEMO*, therefore, considers that the *automatic access standard,* rather than the *minimum access standard*, should be considered the default starting point for negotiations for *connections* and wishes to have this made clearer in the NER.

The Australian Competition and Consumer Commission, when it authorised the changes to the former National Electricity Code that first introduced the current framework in 2003 shared the concern that they might lead to a perception among intending applicants that all connections could be made at the *minimum access standard*, saying "if this occurs, the performance of the power system would degrade over time" and "a facility may only be connected below the automatic access standards if it does not have an adverse effect on power system security or quality of supply for other users".[27]

However, it has been *AEMO's* experience that many *Connection Applicants* aim for the lowest level of performance regardless of the needs of the *power system*. This risks negotiations taking place in a manner that is not consistent with the *national electricity objective* (NEO), as it may lead to the *connection* of *generating systems* with inferior performance than is actually required to meet the reasonable needs of an evolving *power system*. AEMO, therefore, considers it important that the NER make clear that the *automatic access standard* is the starting point for the negotiations.

An approach that uses the *minimum access standard* as the default starting point is inconsistent with the requirement in clause 5.3.4A(b)(2) that a *negotiated access standard* must be "set at a level that will not adversely affect *power system security*". The negotiation should also, where possible, cater for technical capabilities and local area *network* needs to avoid over-investment.

Generally, the *access standards* outlined in Schedule 5.2 include a set of criteria to be followed in the process of reaching an acceptable *negotiated access standard*. Over time, minor amendments within each requirement has resulted in inconsistency between the negotiation principles for each requirement. This introduces ambiguity and uncertainty when negotiating *performance standards.* Of particular concern is the reference to *power system security* in clauses S5.2.5.3, S5.2.5.4, S5.2.5.5 and S5.2.5.7, and to the quality of supply to other *Network Users* in clauses S5.2.5.3, S5.2.5.4 and S5.2.5.5, all of which could be construed as applying a less stringent requirement than that which currently applies in clause 5.3.4A.

[26] Section 5 of this document adopts the protocol used in the NER of italicising NER-defined terms.
[27] Determination of the Australian Competition and Consumer Commission on Applications for Authorisation, Amendments to the National Electricity Code, Technical Standards dated 23 February 2003, page 27

AEMO considers that *performance standards* based on *negotiated access standards* are permitted, provided that there is no adverse impact on either *power system security* or the quality of *supply* to other *Network Users*. A negotiation under clauses S5.2.5.3, S5.2.5.4, S5.2.5.5 and S5.2.5.7 could require an examination of the materiality of the impact each proposed *connection* would have on *power system security*, which is inappropriate and has led to adverse outcomes in the NEM to date.

This process for negotiating *performance standards* occurs in parallel with other negotiations between an NSP and a *Connection Applicant* relating to the commercial and technical matters required to establish a *connection agreement. AEMO* acknowledges that the recent Transmission Connection and Planning Arrangements Rule[28] completed by the AEMC considered those technical and commercial negotiations. This proposal only relates to the negotiations required to establish agreed *performance standards.*

5.1.2 Developing the solution

Predicting future *power system security* needs that must be delivered by negotiation today is a difficult task given the changing *generation* mix and *plant* capabilities. The overarching principle should be to encourage the optimum performance of *generation* and, in turn, the *power system,* without 'gold-plating' either.

To deliver such an outcome, *AEMO* has proposed a clearer set of principles in clause 5.3.4A and, where appropriate, within each performance requirement. This is designed to drive a top-down approach to this negotiation, particularly those requirements that impact *power system security* and are critical to the evolution of the *power system*, while providing flexibility for negotiations where appropriate.

A *Connection Applicant* would need to demonstrate that a higher capability is not required for the *power system*, or cannot be provided by the proposed technology. The *power system's* needs (and, in turn, customers' need for access to a secure and efficient *power system*) should be the primary consideration.

In developing its proposal AEMO considered the merits of recommending *minimum access standards* be removed in their entirety, consistent with many other grid codes around the world. The proposed amendments to *automatic access standards* are expected to be low or no cost for *asynchronous generation*, AEMO is aware however some of these standards may be prohibitively costly for *synchronous generation*. In order not to create a barrier to entry for *synchronous generation* which may provide substantial system security benefits, maintaining suitable minimum levels and a negotiable access arrangement that can be applied on a case by case basis depending on the proposal and its connection location, enables a diverse energy supply mix while maintaining system security.

AEMO has recommended changes to *minimum access standards* to remove any potential security risks.

5.1.3 Proposed Rule change

Negotiated access standard
Clause to be updated: 5.3.4A
AEMO recommends that: The technical terms and conditions of *connection agreements* regarding standards of performance must, where possible, aim to meet the *automatic access standards*. Where meeting the *automatic access standard* is not possible, or where it is not required for the secure operation of *power system*, the *Connection Applicant* must provide sufficient evidence to *AEMO* as to why, and deliver the next best capability required for *power system security* as agreed with *AEMO*. The agreed *performance standard* must not fall below the *minimum access standard* and should be as close as practicable to the *automatic access standard*. Furthermore, references to the impact on power system security and the quality of supply to other Network Users are to be deleted from clause S5.2.5.

[28] See http://aemc.gov.au/Rule-Changes/Transmission-Connection-and-Planning-Arrangements.

5.1.4 How the proposal addresses the issues

A clearer framework that drives optimal *generating system* performance while considering the capabilities of *plant* and cost in conjunction with requirements for maintaining security of the *power system* will build a modern, advanced, and secure NEM in an efficient manner, while minimising the potential for system weaknesses to arise.

5.2 Voltage control

5.2.1 Statement of issue

Voltage control is universally required to maintain *power system* stability and maximise *power transfer capability* within *transmission* and *distribution networks*. *Voltage* control via the provision and control of *reactive power* is also fundamental to protecting physical plant from damage. *Voltage* control is required in quasi-steady state (that is, over seconds) to manage changes to *power* flow through *load* and *generation* changes, and in transient timeframes (sub- and multi-cycle) to manage disturbances caused by faults.

As the penetration of DER in *distribution networks* increases, maintaining *distribution network voltages* is becoming more challenging.

Voltage control systems and *reactive power capability* of *generating systems* are inherently related, but are addressed under different parts of Schedule 5.2.

The current technical requirements are insufficient in a number of ways:

1. In clause S5.2.5.1, the *minimum access standard* for *reactive power capability* allows *connection* of *plant* with no *reactive power capability*. This is too low and may result in the *connection* of *generating plant* that cannot support the *power system's* requirements for *power system security* or quality of *supply*.
2. Clause S5.2.5.13 has distinctly different requirements under the *automatic access standard* and the *minimum access standard*. This inconsistency between the upper and lower end of the negotiation range does not support the development of an appropriate *negotiated access standard* where the *automatic access standard* cannot be achieved.
3. Clause S5.2.5.13 presently allows some *generating systems* to be *connected* with only *power factor* or *reactive power* control and no *voltage* control. Where the provision of *voltage* control is mandatory, the performance obligations, particularly for *asynchronous generating systems,* can be limited. The application of fixed *power factor* control and limited *reactive power capability* may render the *voltage* control capability of a *generating system* near-useless, particularly as *network* topography and loading change over time.
4. The *minimum access standard* in clause S5.2.5.13 is ambiguous in relation to the capability and performance requirements for *generating systems* with a *nameplate rating* of less than 30 MW, meaning *voltage* control may not be supplied by *embedded generating units*. Without this capability, *distribution network voltages* might not be able to be maintained within operating limits or investment in additional ancillary support *plant* may be necessary.
5. The proliferation of new *generation* with very limited *voltage* control capability, which can occur due to the present structure of S5.2.5.13, combined with the withdrawal of existing *generation* that provides *voltage* control, places both *power system security* and quality of *supply* at risk.

AEMO is required to ensure that the *power system* is supported by the provision of *reactive power* and *voltage* control capabilities and considers that clauses S5.2.5.1 and S5.2.5.13 require review to enable this to continue to occur.

5.2.2 Developing the solution

The provision of fully capable *voltage control systems* as part of a *generating system* is essential to the ongoing secure management of the NEM. Any lack of *reactive power capability* and coordinated control of that capability will reduce the *power transfer capability* of the *power system* and risk *power system* stability.

Consequently, *AEMO* recommends that all new *generating systems* be capable of continuous *voltage* control with *voltage control systems* that utilise continuously variable *reactive power capability*. AEMO considers that while the range of control capability can be a matter for negotiation and be varied based on *plant* capability, the functional need for control remains.

The proposed solution has been developed based on *AEMO's* operational experience, and following consideration of this issue when developing advice for ESCOSA on *generator* performance requirements in SA.

The proposed solution provides greater consistency between matters addressed by *automatic access standards* and *minimum access standards* under clause S5.2.5.13. In creating this framework, *AEMO* intends that *negotiated access standards* can be developed to address all matters of concern under *voltage* control.

Further, *AEMO* recommends that clause S5.2.5.1 provide a clear link between the *reactive power capability* and the function of such capability, that is, *voltage* control. *AEMO* therefore proposes an amendment to the *minimum access standard* in clause S5.2.5.1 that references the standard agreed to under clause S5.2.5.13.

5.2.3 Proposed Rule change

Voltage control

Clause(s) to be updated: S5.2.5.13 and S5.2.5.1

AEMO recommends that clause S5.2.5.13 be amended as follows:

- The *minimum access standard* requires a *generating system* must have facilities to regulate *voltage* regardless of *connection point voltage* or capacity of the *generating system*.
- The *minimum access standard* allows that *embedded generating systems* may also include *power factor* or *reactive power* regulation modes. Where these regulation modes are included, they are in addition to *voltage* or excitation control. The *generating system* may operate in any control mode as agreed with the NSP and *AEMO* and must be able to be switched to *voltage* or excitation control at any time. Remote control facilities to change the setpoint and mode of regulation must be provided.
- The revised *automatic access standards* and *minimum access standards* include improvements to create consistency between:
    - the functional requirements applicable to *automatic access standards* and *minimum access standards*
    - the specification for performance criteria for *synchronous* and *asynchronous generating units* and *generating systems*
- Definitions for *settling time* and *rise time* have been revised and moved to the Glossary

AEMO recommends that clause S5.2.5.1 be amended as follows:

- the *minimum access standard* for *reactive power capability* is that a *generating system* operating at:

  (1) any level of *active power* output greater than 10% of its *maximum operating level*; and

  (2) 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 required to enable the *generating system* to achieve the continuously controllable *voltage* setpoint range specified in the *performance standard* agreed under clause S5.2.5.13.

5.2.4 How the proposal will address the issue

The secure operation of the *power system* relies on the provision and control of *reactive power* from a multitude of locations and a variety of sources. This recommendation will ensure the provision and control of *reactive power* across *transmission networks* and *distribution networks*, ensuring that *generating systems* continue to play a part in supporting *power system* stability and *power transfer capability*.

AEMO notes optimal *voltage* control relies on contribution from all *Network Users*. While provision of improved *reactive power* and *voltage* control capability from *generating plant* will contribute to *network* operations, there will be continued reliance on *network* auxiliary *plant* and *Customer plant* to contribute to the overall *voltage* support and control of the *network*.

5.3 Disturbance ride-through: overview

Section 5.3.1 provides an overview outlining the need for additional disturbance ride-through capabilities from *generating systems*. *AEMO's* specific, clause by clause disturbance ride-through recommendations are in Sections 5.4- 5.9.

5.3.1 Statement of issue

The ability of *generating systems* to maintain *continuous uninterrupted operation* during and after *power system* disturbances is essential to the secure and reliable operation of any *power system*.

As an increasing number of asynchronous *plant* with similar disturbance response characteristics participate more across the NEM, the risks associated with the NER's existing disturbance ride-through related requirements are considerable. As an overview, they:

1. Might not provide sufficient local *voltage* support through a lack of *reactive power* injection during and following *contingency events* creating risk of transient *voltage* instability.
2. Might exhibit a coincident response of *generating systems* to minor disturbances. To manage the consequences of this coincident response, it is important that new *generation* is equipped with the capability to limit and manage such disturbances.
3. Can allow *active power* recovery that is slower than necessary, which may place increased stress on *interconnectors, network elements*, and other *generating systems* following disturbances, increasing risks to *power system security*.
4. Fail to thoroughly specify performance requirements for *plant* under multiple fault conditions, which may expose the *power system* to loss of significant amounts of *generation,* causing potential *disconnection* and islanding following multiple *contingency events*. If not addressed, this has the potential to cause economic loss, particularly if *plant* operation under extreme conditions leads to cascading *generation* failures and widespread blackouts.

Without reasonable and robust criteria for disturbance ride-through capability, the *power system* must be operated more conservatively[29], resulting in reduced inter-*regional power transfer capabilities* and potential *constraints* on *generation* under some conditions. This can result in diminished *market* access for some *Generators*.

5.4 Disturbance ride-through: reactive current injection and reactive power support

5.4.1 Statement of issue

Inadequate *reactive power* support reduces the effectiveness of local *voltage* levels, leading to a risk of transient *voltage* instability and a reduced ability for the *power system* to recover from disturbances. Sufficient dynamic

[29] For example NER 4.3.1 (e) and (f) require AEMO to observe the boundaries of the *technical envelope* and ensure the *power system* is operated within its limits.

reactive power support close to each *connection point* prevents the propagation of *voltage* dips across the *network* and reduces the risk of consequential *voltage* instability or widespread *generation disconnections*.

The NER currently addresses these issues in the S5.2.5.5 *automatic access standard* as follows:

- The *automatic access standard* in clause S5.2.5.5(b)(2)(i) currently provides a reasonable requirement for performance during and following disturbances, which is based on typical *synchronous generating unit* behaviour and specifies that a *generating system* and each of its *generating units* must be able to supply capacitive reactive current of up to 4% of the maximum continuous current of the *generating system* (in the absence of a disturbance) for each 1% reduction of *connection point voltage*; and
- Clause S5.2.5.5(b)(2)(ii) requires that after *disconnection* of a faulted element, a *generating system* must supply or absorb sufficient *reactive power* to ensure the *connection point* is within the range for *continuous uninterrupted operation* under clause S5.2.5.4.

Both these provisions support the *power system* to remain intact during, and recover from, *contingency events* and other disturbances.

Despite the *automatic access standard* provisions, *AEMO* considers the present reactive current injection and *reactive power* support requirements in the NER are insufficient, as the *minimum access standard* does not require a *generating system* to provide any form of *reactive power* support during a disturbance.

This is insufficient, because 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,* meaning disturbances can be observed across a wider area and more *generation plant* is at risk of *disconnection.* In such circumstances, loss of *supply* is experienced across a wider area than necessary.

5.4.2 Developing the solution

The most efficient way to manage *generating plant* resilience to disturbances, and the broader *network* security impact of disturbances, is to source *reactive power* from *generating plant* at the levels required to ensure *voltage* recovery.

This means more controlled *reactive power* support is needed at the point of *connection* than may currently be required by a *performance standard* based on the *negotiated access standard*. As such, *AEMO* proposes modification to the access standard so that capacitive reactive current injection during a fault is more universally applicable to different *generation* technologies, and can be extended to cover *minimum access standard* requirements.

The proposed response is similar to the assumed response of synchronous *generation* – the prescription has not been required historically due to the assumed behaviour of traditional *generation*. This capability is essential to support the *network* during disturbances and to aid recovery after a disturbance has been removed.

This capability is consistent with requirements mandated in Denmark[30] and Germany[31], where asynchronous generating units must inject reactive current during and after voltage dips in similar amounts to that being proposed by *AEMO*. *AEMO* performed modelling and simulations to investigate this issue as part of its investigations into the 2016 black system event in SA[32] and has developed its recommendations based on the learnings from this analysis.

The recommended reactive current injection requirements were consulted on by ESCOSA. Stakeholders requested clarity on how to interpret *AEMO's* recommendations, and clarified the obligations for *synchronous generating units*. *AEMO* has used this feedback to revise its final recommendations to ESCOSA and this Rule change proposal.

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[30] Energinet, *Technical Regulation 3.2.5 for wind power plants above 11kW*, July 2016. [Online]. Available at: https://en.energinet.dk/Electricity/Rules-and-Regulations/Regulations-for-grid-connec ion.

[31] Tennet TSO GmbH, *Grid Code - High and extra high voltage*, November 2015. [Online]. Available at: https://www.tennet.eu/fileadmin/user_upload/The_Electricity_Market/German_Market/Grid_customers/tennet-NAR2015eng.pdf.

[32] Refer to Appendix X.4 of AEMO, *Black System, South Australia, 28 September 2016*, March 2017. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/Power-System-Operating-Incident-Reports.

5.4.3 Proposed Rule changes

Disturbance ride-through: reactive current injection requirements
Clause to be updated: S5.2.5.5

AEMO recommends that clause S5.2.5.5 be amended such that:

- The *automatic access standard* requires that a *generating system* must supply additional capacitive reactive current (reactive injection) of 4% of the maximum continuous current of the *generating system* (in the absence of a disturbance) for each 1% reduction of *connection point voltage* below 90% of *normal voltage*, as shown in Figure 2 and Figure 3.
- The *minimum access standard* requires that a *generating system* must supply additional capacitive reactive current (reactive injection) of 2% (of the maximum continuous current of the *generating system* (in the absence of a disturbance) for each 1% reduction of *connection point voltage* below 90% of *normal voltage*, as shown in Figure 2 and Figure 3.

AEMO recommends that all *access standards* require the following:

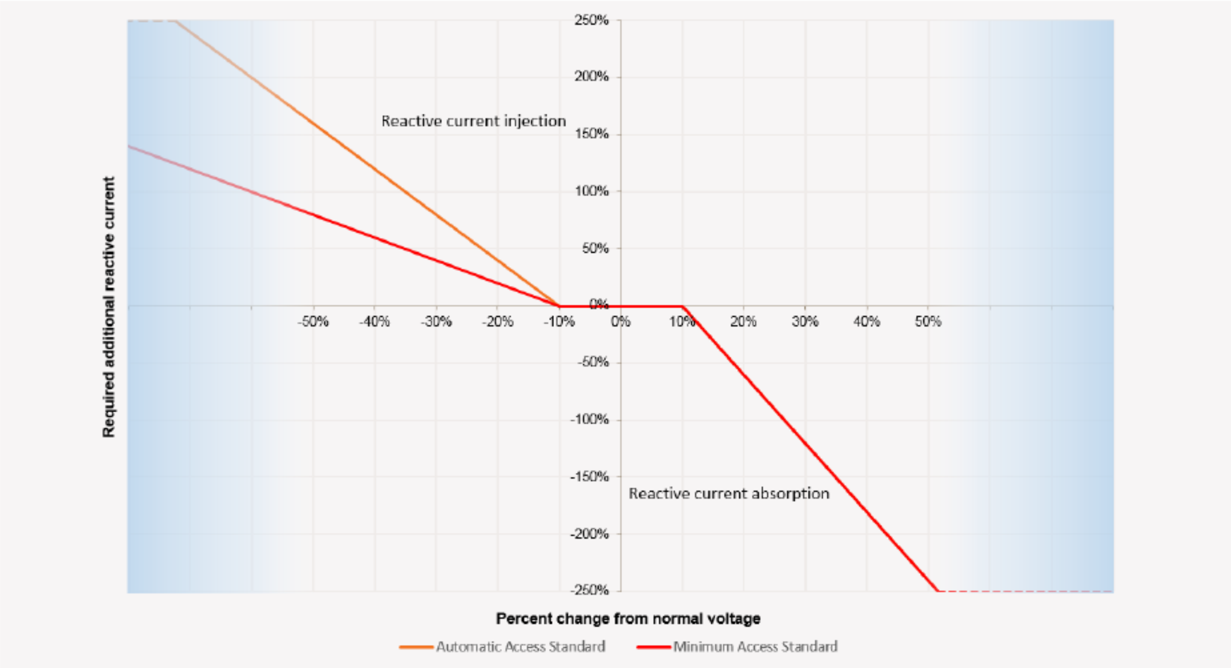
- The required reactive current injection may be limited to 100% of the rated current of an *asynchronous generating system* and may be limited to 250% of the rated current of a *synchronous generating system*.
- The reactive current injection must be maintained until the *connection point voltage* returns to within the range of 90% to 110% of *normal voltage*.
- The definition of *continuous uninterrupted operation* needs to be reviewed to include these and other disturbance ride-through requirements.
- For measurement purposes, this reactive current contribution and *voltage* deviation may be assessed at the applicable LV terminals of the *generating units* or reactive support *plant* within a *generating system*.
- The amount of reactive current injection required may be calculated using phase-to-phase, phase-to-ground, or sequence components of *voltage*. For the last method, the ratio of negative-sequence to positive-sequence current injection must be confirmed with *AEMO* and the NSP for various types of *voltage* disturbances.
- A rise time no greater than 30 milliseconds (ms) and a settling time no greater than 60 ms applies to reactive current injection requirements.
- *Reactive power* consumption upon application of a fault must not exceed 5% of maximum continuous rated current of the *generating system* and limited to the duration of rise time.
- The post-fault *reactive power* contribution of the *generating system* must be sufficient to ensure that the *connection point voltage* is within the range for *continuous uninterrupted operation* under clause S5.2.5.4.

Notes to the proposed amendments supporting the provision of reactive power support during and subsequent to disturbances

1. A graphical representation of these requirements is provided in Figure 2 and Figure 3.
2. Note that the inductive reactive current (reactive current absorption) requirements shown in the figures are detailed in Section 5.6. It should be noted that the *settling time* requirement does not apply to *synchronous* machines in the context of fault current contribution because:
   - *Settling time*, as defined in clause S5.2.5.13, relates to the delay in a *control system* between a change in input signal and the associated change in output quantity has settled to within an error band of less than a specified percentage of the output quantity.
   - *Settling time* is a term that applies to close-loop *control systems*. Unlike *asynchronous plant*, the fault current contribution of *synchronous generating systems* is provided through an intrinsic and uncontrolled response.

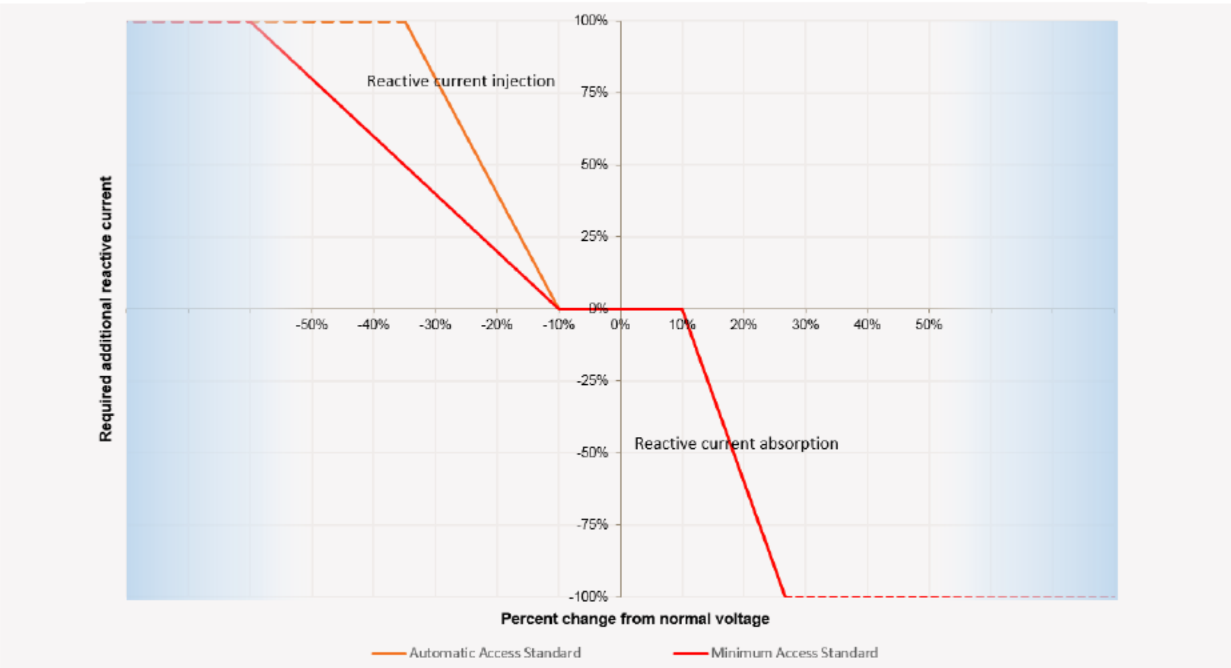
The fault current contribution of *synchronous generating systems* changes during a fault due to presence of large DC components in the fault current. This is unlike a power electronic controlled system, such as a wind turbine or solar inverter where the DC component is practically eliminated.

Figure 2 Reactive current injection requirements for synchronous generating systems*



*Note that the *automatic access standard* and *minimum access standard* for inductive reactive current (reactive current absorp ion) response are the same and detailed in Sec ion 5.6.

Figure 3 Reactive current injection requirements for asynchronous generating systems



*Note that the *automatic access standard* and *minimum access standard* for inductive reactive current (reactive current absorp ion) response are the same and are detailed in Section 5.6.

5.4.4 How the proposal will address the issues

AEMO's proposal ensures that all *generating systems* have the appropriate capability to respond to disturbances within the *power system.* The required response in the form of reactive current contribution will assist the local *network* maintaining adequate *voltage stability* to ensure the *power system* remains intact and is able to recover stable operation following clearance of an electrical fault.

This proposed capability provides each *generating system* with the capability to, as far as practical, manage *connection point voltages* so as to ensure the least risk of *disconnection* during or subsequent to disturbances, supporting the overall secure operation of the NEM.

5.5 Disturbance ride-through: multiple low voltage disturbance ride-through

5.5.1 Statement of issue

The ability of *generating systems* to maintain *continuous uninterrupted operation* during and following *power system* disturbances is essential to the secure and reliable operation of any *power system*. Analysis of the performance of various *generating systems* during recent major system disturbances has highlighted the need to ensure that all *generating systems* are able to provide support to the network both **during** and **after** disturbances.

As well as providing support to the *network* during *credible contingency events*, all types of *generating systems* also need to be resilient to repetitive disturbances. This was a significant factor in the September 2016 SA black system event. It is imperative that the learnings from assessment of that event are leveraged and incorporated into industry best practice to minimise risk exposure of the *power system* in the future. A scenario-based assessment of the impacts of simultaneous ride-through of *generation* is presented in Appendix X of *AEMO's* final report on the SA black system on 28 September 2016.[33]

Low *voltage* withstand requirements are specified in clause S5.2.5.4, and *AEMO* has identified the following issues:

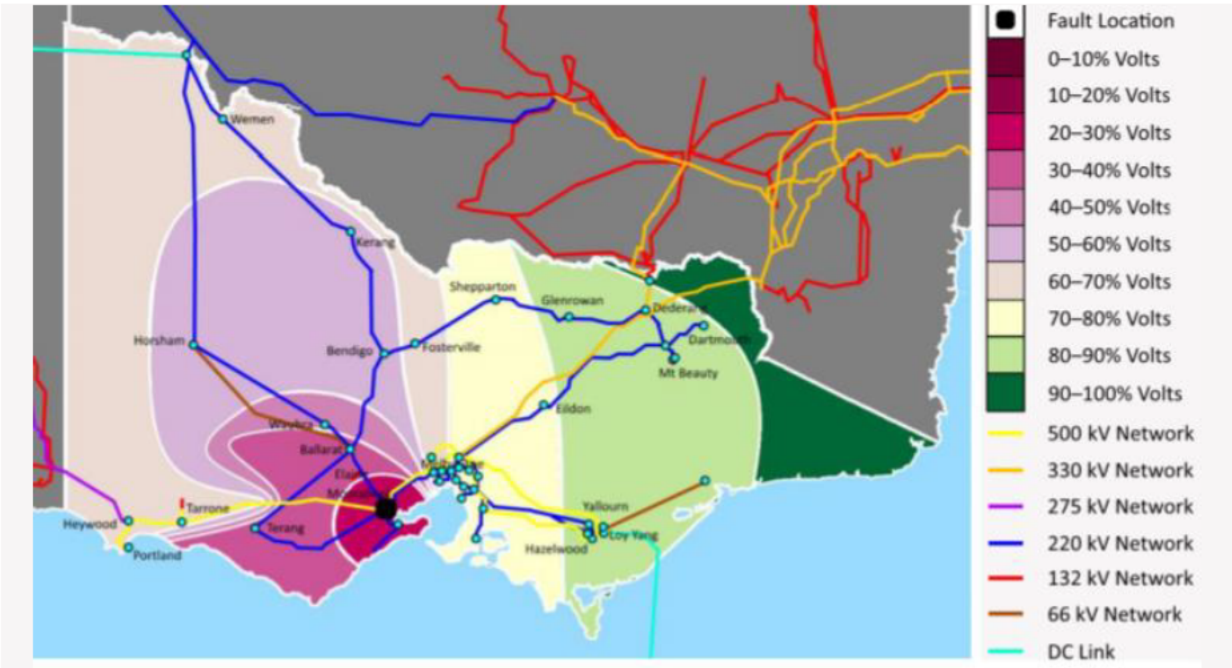
1. The *automatic access standard* provides an envelope for *continuous uninterrupted operation*. However, the requirement to withstand multiple low *voltage* events is not explicitly stipulated. With no clear obligation stated with respect to multiple disturbance events there is a risk of uncoordinated *disconnection* of *generation*, which would exacerbate the consequences of any such event.
2. The *minimum access standard* is insufficient, as it only requires *generating systems* to maintain *continuous uninterrupted operation* down to *connection point voltages* of 90% of *normal voltage*. *AEMO* has observed that as the proportion of *asynchronous generation* in the NEM increases, the impact of disturbances will be more widely observed and, consequently, *voltage* dips below 90% of *normal voltage* will likely become more common due to reduced system strength.

Figure 4 demonstrates this phenomenon via a graphical representation of the impact of an electrical fault in a part of the Victorian *transmission network* where there is little *synchronous generation,* but substantial *asynchronous generation*. It shows the depth and spread of a *voltage* dip resulting from a fault at Moorabool.[34] In the example, the *voltage* dip is observed below 80% of *nominal voltage* on the *transmission network* throughout central and western Victoria. The *minimum access standard* for under-*voltage* withstand capability is thus no longer adequate in a *power system* with increasing *asynchronous generation* and reduced system strength.

Connection of *generating systems* with no capability to maintain *continuous uninterrupted operation* at 90% of *normal voltage* will become increasingly problematic, and will increase the risk of multiple independent *generating systems disconnecting* from the *network* for remote and relatively minor disturbances. In turn, this risks causing an imbalance in *generation* and demand, affecting security of *supply*.

[33] AEMO, *Black System, South Australia, 28 September 2016*, March 2017. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/Power-System-Operating-Incident-Reports.
[34] AEMO. 2017 *Victorian Annual Planning Report*, June 2017. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Victorian-transmission-network-service-provider-role/Victorian-Annual-Planning-Report.

Figure 4 Voltage dip propagation for a three phase fault at Moorabool



Source: AEMO 2017 *Victorian Annual Planning Report*.

5.5.2 Developing the solution

A key factor in the September 2016 black system event in SA was the combined responses of numerous different *generating systems* to a series of disturbances. The coincident (or closely timed) *disconnection* of multiple *generating units* across SA contributed to the loss of *power system* stability. Ensuring *generating systems* can withstand multiple *voltage* disturbances will require precise requirements for multiple fault ride-through capability. Establishing such parameters has already occurred in Denmark and Germany[35,36] and the need for specifying requirements for repeated disturbances has been acknowledged in a special report by the North American Electric Reliability Corporation (NERC)[37], however, at the time of writing no requirements have been specified.

In setting an acceptable level of performance, *generating system* technology has some bearing. In the wind turbines typically installed today, total fault duration is the most critical factor because it determines the amount of heat dissipated across the dynamic braking chopper or dump resistor connected to the power electronic converter's DC-link. Similar concepts apply to the inverters that interface solar photovoltaic (PV) or storage systems with the *network*. Older forms of wind turbine technology tend to have more limitations on multiple disturbances, citing concerns regarding residual charge of auxiliary power supplies and potential mechanical stress in wind turbine components.

To develop a proposed *access standard* for multiple disturbance ride-through, *AEMO* has surveyed a number of technology manufacturers and reviewed historical records derived from the SA *transmission network* to determine past exposure to this type of event.

The manufacturers advised of the capability of *asynchronous generating system* technology to withstand disturbance events, as shown in Table 4. The information provided to AEMO indicates that modern *asynchronous generating system* technology can meet the proposed multiple fault ride-through requirements. Table 4 compares the capability of a number of major wind and solar equipment manufacturers to withstand multiple fault conditions, and demonstrates that the proposed rule in Section 5.5.3 is a standard feature of many types of *plant*.

35 Energinet.DK, *Technical regulation 3.2.5 for wind power plants above 11 kW 2016*, Available at: https://www.tennet.eu/electricity-market/german-customers/grid-customers/grid-connection-regulations.

36 Tennet TSO GmbH, "Grid Code", 1 December 2012. [Online]. Available at: https://www.tennet.eu/electricity-market/german-customers/grid-customers/grid-connection-regulations/.

37 NERC, 2012. Special Assessment Interconnection: Requirements for Variable Generation, Available at: http://www.nerc.com/files/2012_IVGTF_Task_1-3.pdf.

Table 4 Capability of various types of wind and solar plant to withstand multiple faults

Manufacturer	Total fault duration withstand capability (ms)	LVRT activation threshold (% of nominal voltage)	Pre-set limit allowing maximum number of successful ride-through events	Compliant or able to modify operation to comply with the proposed requirements
Manufacturer 1	1,800–2,400	80	N/A	Yes
Manufacturer 2	Unknown	80	N/A	Unclear
Manufacturer 3	1,800–2,000	90	15	Yes
Manufacturer 4	>2,400	90	20	Yes
Manufacturer 5	2,000	60–80	N/A	Yes
Manufacturer 6	2,000	85	10	Yes

Synchronous generating systems are not known to have *protection systems* that would *disconnect* the *plant* on the basis of the number of disturbance events detected. *Synchronous generating systems* in their response to disturbance events are most susceptible to stability concerns, particularly when faced with severe (nearby) disturbances and are relatively unaffected by shallow (remote) disturbances. In determining the capability of *synchronous generating systems* to meet *performance standards* for multiple disturbance ride-through, it will be essential to ensure that a range of factors, such as the dead time, lockout setting and reclaim time of any *automatic reclose equipment* is considered.

AEMO's report into the 2016 black system event in SA noted the outcome of an investigation by ElectraNet into the maximum number of faults within 2-, 30-, and 120-minute intervals recorded in ElectraNet's *transmission network* over the period 2007 to 2016.

This investigation determined the following:

- Within 2 minutes – 5 faults.
- Within 10 minutes - 11 faults.
- Within 120 minutes – 16 faults.

AEMO has used this information in determining this Rule change proposal, which seeks to maximise the fault ride-through capability of new *generating plant* within the physical limits of leading modern *generation* technology.

As highlighted in section 4.2, the new proposed requirement for how many *voltage* disturbances a *generating system* must maintain *continuous uninterrupted operation* were developed during the ESCOSA review in order to address risks to the *power system* revealed by the SA black system event. *AEMO* has made minor changes to the format of its recommendations in transferring them from the licensing framework used in SA to the NER:

- ESCOSA recommendations were specified at the terminals of *generating units*, as this is the most direct way to specify performance capabilities for items of *generating plant* to maintain *continuous uninterrupted operation* during multiple faults.
- The *connection agreements* established under the NER relate to the interface formed between *generating systems* and *NSPs* at *connection points*, rather than at *generating units* that are within the *generating system*.
- Due to the diversity in *voltage* levels between a *connection point* and at the terminals of each *generating unit* it is appropriate to extend the cumulative time period for multiple disturbance ride-through events within a 5-minute period to reflect an equivalent level of performance.

The recommended *automatic access standard* is that a *generating system* must maintain *continuous uninterrupted operation* for up to 15 events within any 5-minute period causing the *connection point voltage* to drop below 90% of *normal voltage* for a total duration of 1,800 ms. This has been increased from 1,500 ms compared with the ESCOSA recommendations. This duration applies to the *automatic access standard,* the proposed *automatic access standard* and *minimum access standards* are described more completely below.

5.5.3 Proposed Rule change

Disturbance ride-through: multiple low voltage disturbance ride-through
Clauses to be updated: S5.2.5.4 and S5.2.5.5
AEMO recommends that the *automatic access standards* and *minimum access standards* in clause S5.2.5.5 be amended to ensure that *generating systems* maintain *continuous uninterrupted operation* in the event of multiple disturbances as follows: • The *automatic access standard* is that a *generating system* and each of its *generating units* and reactive *plant* must maintain *continuous uninterrupted operation* for up to 15 *voltage* disturbances in any 5-minute period causing the *connection point voltage* to drop below 90% of *normal voltage* for a total duration of 1,800 milliseconds. • The *minimum access standard* is that a *generating system* and each of its *generating units* and reactive *plant* must maintain *continuous uninterrupted operation* for any up to 15 *voltage* disturbances in any 5-minute period causing the *connection point voltage* to drop below 90% of *normal voltage* for a total duration of 1,000 milliseconds. *AEMO* further recommends that the *minimum access standard* in clause S5.2.5.4 in relation to *continuous uninterrupted operation* at less than 90% of *normal voltage* needs to be amended. The *minimum access standard* has been amended to include the following: • A *generating system,* including all operating *generating units,* must be capable of *continuous uninterrupted operation* where a *power system* disturbance causes the *voltage* at the *connection point* to vary in the range of 80% to 90% of *normal voltage* for a period of at least 5 seconds, and 70% to 80% of *normal voltage* for a period of at least 2 seconds. *AEMO* recommends that the criteria for *negotiated access standards* detailed in S5.2.5.4 and S5.2.5.5 should be more closely aligned, and proposes changes to achieve consistency and provide a less ambiguous framework.

5.5.4 How the proposal will address the issues

The proposed Rule addresses the identified issues by:

1. Explicitly stating the requirement to withstand multiple low *voltage* events within the physical limits of leading modern generation technology.
2. Recommending changes to the S5.2.5.4 *minimum access standard* to increase the minimum withstand capability of *generating plant* for low *voltage* disturbances.

5.6 Disturbance ride-through: high voltage disturbance ride-through

5.6.1 Statement of issue

The changing nature of *connected plant* and control and operational strategies are leading to greater difficulty in managing *power system voltages*. There is some risk that temporary over-*voltages* in excess of current standards may be experienced under extreme operational outcomes, such as fast-acting *load shedding* schemes or *protected events*. Measured responses obtained from the five recent islanding events that have occurred in the SA *power system* indicate high temporary over-*voltages* of up to 120% for several seconds.

Further, *AEMO* has simulated case studies in which a special protection scheme is used to form a stable electrical island in SA following its separation from the rest of the NEM during the 2016 black system event. These simulations show temporary over-*voltages* above 120% of *normal voltage* occurring for over a second, resulting in a number of *generating systems disconnecting* from the *power system*, which prevents a stable electrical island from being formed.[38]

The current withstand requirements in the NER are detailed below:

1. The *system standard* in clause S5.1a.4 notes that *voltage* should not rise above 120% of *normal voltage* for more than 0.42 seconds (approximately) following a *credible contingency event*. The *automatic access standard* in clause S5.2.5.4 requires *generating systems* to withstand over-*voltages* corresponding to the *system standard*. This is significantly shorter than the duration of simulated temporary over-*voltages* in SA following *network* separation.
2. This means power frequency voltage envelope specified in clause S5.11.4 of the NER might not be sufficient in facilitating the transition to stable operation of an islanded *region*, risking *plant* damage and, potentially, a *black system* if *plant disconnects* to protect itself.
3. Further, the increased reliance on high speed protection schemes such as under-*voltage* or under-*frequency load shedding*, which is aimed at supporting *power system security* as the *power system* operates in scenarios of greater stress, may also result in conditions of temporary over-*voltages* beyond the current *system standards*.

Special protection schemes are designed such that *power system security* can be maintained following their operation, including consideration of transient over-*voltage* conditions that may occur. *AEMO* proposes to increase the capability of *generating systems* to withstand over-*voltage* conditions and *load shedding* events to support recovery from events that trigger special protection schemes with the unintended consequence of introducing short-term over-*voltages*.

5.6.2 Developing the solution

AEMO proposes three actions to control the risks associated with temporary over-*voltages*. Fundamentally, *generating systems* must be able to withstand the prevailing *network* conditions and to undertake control action to regulate their output.

AEMO recommends that:

1. The *system standard* for power frequency voltage be increased;
2. Over-*voltage* withstand requirements for *generating systems* be increased consistent with the revised *system standard;* and
3. *Generating systems* must have an inductive reactive current injection response as part of high *voltage* ride-through (HVRT) response. The inductive reactive current injection is similar to the requirements for capacitive current injection for low *voltage* disturbance events under clause S5.2.5.5.

AEMO considers that these changes will enable the implementation of high-speed, pre-emptory special protection schemes to manage high risk events to be implemented.

For the *system standard* to be revised, all elements of the *power system* must be capable of withstanding the higher requirements, not just *generating systems*. The proposed over-*voltage* withstand levels have been considered in investigations by CIGRE[39], which indicated that all *transmission network* elements tested by the CIGRE Working Group are capable of meeting over-*voltages* of up to 115% for 1,200 s. Accordingly, *AEMO* believes the *system standard* for temporary over-*voltages* could be raised as proposed without affecting existing elements of the *transmission and distribution systems*.

The recommended requirements for operation in over-*voltage* conditions have been developed by considering measured data, *power system* study results and comparing these with the requirements currently imposed by two

[38] Refer to Appendix Y 5 of AEMO, *Black System, South Australia, 28 September 2016*, March 2017. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/Power-System-Operating-Incident-Reports.
[39] CIGRE WG 33.10,"Temporary Overvoltages: Withstand Characteris ics of Extra High Voltage Equipment", Electra No.179, August 1998, pages. 39-45.

international grid codes (Hydro Quebec[40] and ENTSOE[41]), and the stated capability of a number of major wind turbine and solar inverter manufacturers which often represent the least capable *plant* with respect to over-*voltage* withstand. A comparison of over-*voltage* withstand capability from equipment manufacturers and the international grid standards is in Table 5, which demonstrates that the proposal in Section 5.6.3 is in line with international requirements and can be delivered by modern technology.

Table 5 Comparison of over-voltage withstand capability of various wind and solar plant manufacturers and international grid standards

		Temporary over-voltage (%)				
		110–115	**115–120**	**120–125**	**125–130**	**130–140**
Duration (seconds)	**Manufacturer 3**	Continuous up to 114%, 60 thereafter	60	60	Not specified	0
	Manufacturer 5	Continuous	Continuous	2	2	1
	Manufacturer 6	3600	3600	2	2	0.1
	ENTSOE	Continuous up to 118%, 1200-3600 thereafter	Not specified	Not specified	Not specified	Not specified
	Hydro Quebec	300	30	2	0.1	0.1
	NER Figure S5.1a.1	0.9	0.4-0.9	0.1-0.4	0.02-0.1	0.02 for 130% only
	AEMO Proposed	1,200	20	2	0.2	0.02

Note the HVRT capability quoted by the manufacturers is defined at the LV terminals of the *generating units*.

5.6.3 Proposed Rule changes

Disturbance ride-through: high voltage disturbance ride-through

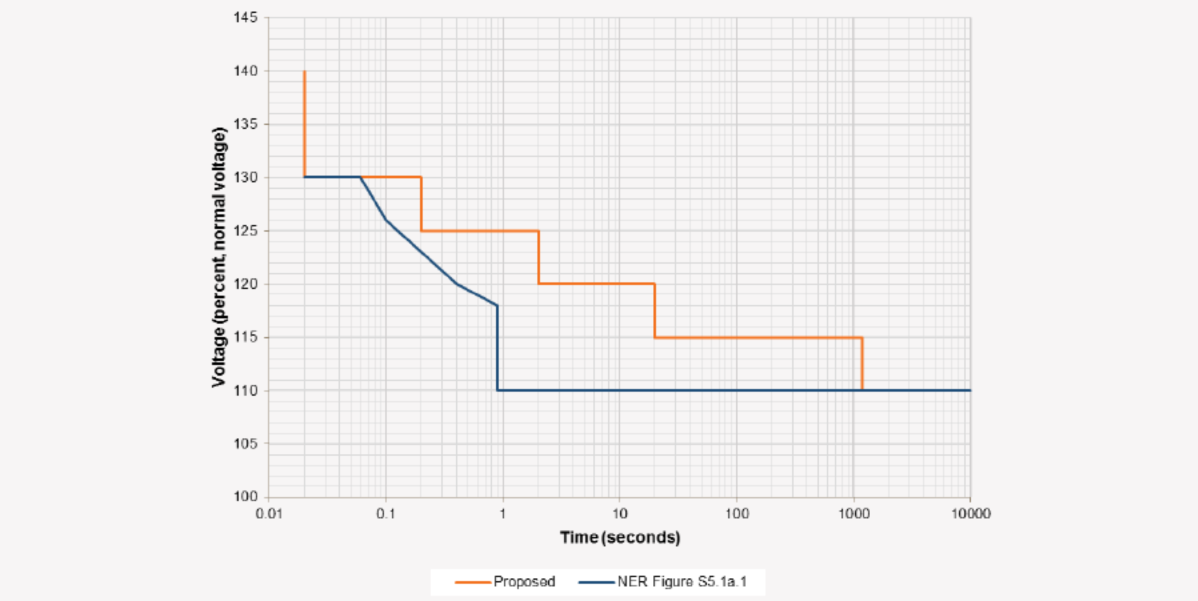
Clauses to be updated: S5.1a.4, S5.2.5.4 and S5.2.5.5

AEMO recommends that the *system standard* for *power frequency voltage* in S5.1a.4 be amended to accommodate consequential temporary over-*voltages* caused by *regional* separation or *load shedding*, and to facilitate an orderly *power system* recovery including sustained islanded operation. The proposed amendment replaces Figure S5.1a.1 with the increased requirement shown in Figure 5.

[40] "Transmission Provider Technical Requirements for the Connection of Power Plants to the Hydro-Quebec Transmission System," February 2009. [Online]. Available at: http://www.hydroquebec.com/transenergie/fr/commerce/pdf/exigence_raccordement_fev_09_en.pdf.

[41] ENTSO-E, "Commission Regulation establishing a network code on requirements for grid connection of generators," 14 April 2016. [Online]. Available at: https://www.entsoe.eu/major-projects/network-code-development/requirements-for-generators/Pages/default.aspx.

Figure 5 Proposed *system standard* for power frequency over voltage



AEMO does not recommend any direct change to the clause S5.2.5.4 *access standards* for over-*voltage* withstand, however, greater performance capability will be required due to direct reference to the amended *system standard*.

The recommended amendments to the *system standard* in clause S5.1a.4 and the *access standards* in clause S5.2.5.4 are such that *generating systems* must maintain *continuous uninterrupted operation* for temporary over-*voltages* for the magnitudes and durations specified in Table 6 and Figure 5.

Table 6 Required over-voltage withstand capability

Temporary over-voltage (% of normal voltage)	110–115	115–120	120–125	125–130	130–140
Duration (seconds)	1,200	20	2	0.2	0.02

AEMO recommends that clause S5.2.5.5 be amended to require an inductive reactive current response to over-*voltage* conditions. The amended *automatic access standard* and *minimum access standard* are equivalent and require that a *generating system* supply additional inductive reactive current (reactive absorption) of 6% of the maximum continuous current of the *generating system* (in the absence of a disturbance) for each 1% increase in *connection point voltage* above 110% of the *normal voltage*, as shown in Figure 2 and Figure 3 in Section 5.4.3.

Details regarding reactive current injection are described in Section 5.4, consistent with requirements for low *voltage* disturbances.

Finally, *AEMO* recommends amendments to the *access standards* for partial load rejection in clause S5.2.5.7. This is discussed further in Section 5.8.

5.6.4 How the proposal will address the issues

Amending the *access standards* for over-*voltage* withstand and control requirements to reflect the demands of a modern *power system* as proposed will support the resilience of the *power system* to rare but high consequence events. Prescribing more comprehensive performance requirements for temporary over-*voltages* will contribute to ensuring that *plant*, including *generating systems*, can withstand conditions following faults and that *generating* *systems* will contribute to the response required to stabilise the *power system* and facilitate sustained islanded operation of parts of the NEM if required.

5.7 Disturbance ride-through: active power recovery

5.7.1 Statement of issue

Active power recovery by *generating systems* subsequent to *contingency events* contributes to several aspects of *power system* stabilisation. Most significantly, restoration of *active power* to the level existing just prior to a fault assists in restoring the local and wider *network* power transfers towards pre-contingency conditions, restoring *voltages* to within the normal operating envelope and reducing reliance on provision of *voltage* control/support services derived from reactive current injection.

While most *synchronous generating plant* can normally recover *active power* output within a few hundred milliseconds of a disturbance, *asynchronous generating plant* can take between 100 milliseconds and more than 1 second to fully recover their *active power* output. If a large proportion of *generating systems* have slow *active power* recovery, this can cause:

- Transient instability which will inherently lead to *voltage* instability.
- Increased *power* swings across *interconnectors*, leading to an increased risk of *interconnector protection systems* operating (leading to *disconnection* and potentially further cascading events); and
- Implementation of operating limits that restrict the amount *asynchronous generation* that can be online in a *region* at risk of islanding.

To manage the root cause of this risk, a minimum *active power* recovery level and associated time period should be a mandatory component of all *generating systems*. The present *active power* recovery requirements for *generating systems* are specified in the *automatic access standards* or *negotiated access standards* under clause S5.2.5.5 only. The issue here is that there is no equivalent requirement for *active power* recovery specified within the *minimum access standard*.

AEMO has identified that the continued *connection* of significant amounts of *generating systems* that cannot meet the *automatic access standard* requirements and for which there is no clear *negotiated access standard* obligation will place the secure operation of the *power system* at risk.

While slow *active power* recovery was not the primary cause of the 2016 black system event in SA, the phenomena are closely related. The SA event is one example of *voltage* instability driving *regional* separation. While SA is particularly exposed to these risks under conditions of high imports from Victoria, this phenomenon may emerge in any *region* or localised area with weak *interconnection* to the rest of NEM.

5.7.2 Developing the solution

AEMO has developed its recommendations based on the learnings from this analysis of the SA *power system*, and in considering the standards used internationally.

Modelling and simulations were performed to investigate this issue as part of AEMO's investigations into the 2016 black system event in SA.[42] This analysis identified that with 1,400 MW of wind generation in SA, a *single credible contingency* could result in a transient *active power* reduction of over 200 MW, for between 0.5 and 1.5 seconds.

The recommended *active power* recovery rates are similar to those that have been established overseas. National Grid (UK) requires the active power output of both *synchronous* and *non-synchronous generating plant* to be restored to at least 90% of the level available immediately before the fault within 500 ms of the fault being cleared (for faults up to 140ms in duration).[43] EirGrid (Ireland) mandates similar capabilities, but only from wind farms.[44]

[42] Refer to Appendix X.1 of AEMO, *Black System, South Australia, 28 September 2016*, March 2017. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/Power-System-Operating-Incident-Reports.

[43] National Grid Electricity Transmission plc, "The Grid Code Issue 5 Revision 20," 20 February 2017. [Online]. Available at: http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=8589935310.

[44] EirGrid, "EirGrid Grid Code Version 6.0," 22 July 2015. [Online]. Available at: http://www.eirgridgroup.com/site-files/library/EirGrid/GridCodeVersion6.pdf.

The recommended *active power* recovery times were consulted on by ESCOSA, who did not receive any objections to the recommended levels. Stakeholders requested clarity on how the final *active power* recovery time would be negotiated. *AEMO* has used this feedback to revise its final recommendations to ESCOSA and this proposed Rule.

5.7.3 Proposed Rule change

Disturbance ride-through: active power recovery

Clause to be updated: S5.2.5.5

AEMO proposes that the *minimum access standard* in clause S5.2.5.5 for *active power* recovery be amended as follows:

- A *generating system* must restore *active power* to 95% of the level existing just prior to a fault within 1 second following *disconnection* of a faulted element.
- A framework for negotiating an acceptable *active power* recovery time has also been proposed. This framework ensures that a *performance standard* based on a *negotiated access standard* should be determined based on *power system security*, quality of *supply*, *plant* capability (these three are being addressed by *AEMO's* proposed changes to clause 5.3.4A) and expected reduction in *generation* by *AEMO* and the NSP for each *connection* depending on specific requirements.
- Recognising that *asynchronous generating systems* generally require time to measure data, detect a disturbance and produce an appropriate and controlled response to that disturbance, *AEMO* proposes acceptable criteria regarding transient *active power* consumption upon application of a fault. These requirements are such that a *generating system's* response should not exceed one power frequency cycle and must not exceed 5% of the maximum continuous rated current of the *generating system*.

5.7.4 How the proposal will address the issues

The proposed *minimum access standards* will ensure that all *generating* systems have a minimum *active power* recovery time to support *power system security*. Such capabilities will be essential if the NEM is to operate with increasing levels of *asynchronous* generation.

5.8 Disturbance ride-through: partial load rejection

5.8.1 Statement of issue

To facilitate the secure and stable operation of the NEM subsequent to *load shedding* or *regional* separation, it is essential that all *generation* can remain *connected* and contribute to the restoration of a stable and secure *power system*.

Clause S5.2.5.7 deals with *generating systems'* response to *load* reduction; AEMO's concern with this provision is that:

1. The *automatic access standard* requires that a *generating unit* maintain *continuous uninterrupted operation* for an event that results in a 30% load reduction but excludes application of the partial load rejection requirements to *asynchronous generating systems.*
2. *AEMO* considers that there is no technical reason for this exclusion and that the changing mix of *generation* requires broader application of the partial load rejection to all *generating systems*.
3. Where participation of *asynchronous generation* in the *market* represents a significant portion of *supply*, it is imperative that it participates in the support and management of the *network* under stress and does not trip off, which could result in insufficient *generation* to manage the *power system* effectively.

5.8.2 Developing the solution

Given the expected penetration of *asynchronous generation*, *AEMO* recommends an extended application of clause S5.2.5.7. This is to mitigate the risk of mass *disconnection* of a large portion of *generation* during a major system disturbance, ensuring the availability of sufficient *generation* and *control* capability to restore stable operation.

Overseas, National Grid in the UK requires both synchronous and asynchronous generating systems to have the capability to withstand partial load rejection events.[45]

AEMO has made further recommendations on *generating system* inductive reactive current injection following disturbances that result in over-*voltage* conditions in Section 5.6.3. These reactive current injection requirements are intended to assist in the restoration of stable *power system* operation subsequent to *load shedding* or *regional* separation.

This recommendation was consulted on by ESCOSA, who did not receive any objection from stakeholders.

Finally, *AEMO* recommends a minor amendment to the table in clause 5.3.9(d) such that clause S5.2.5.7 is included in column 2 in the event that a *voltage control system* is proposed to be altered.

5.8.3 Proposed Rule change

Disturbance ride-through: partial load rejection
Clause to be updated: S5.2.5.7
AEMO recommends clause S5.2.5.7 be amended such that it applies to all *generating systems*. *AEMO* recommends a further minor amendment to clause S5.2.5.7 such that the term *generating unit* be replaced with *generating system,* to better reflect current terminology and the inclusion of all types of *generating systems*. *AEMO* recommends the table in clause 5.3.9(d) be modified to include S5.2.5.7 as an affected clause for a proposed alteration to a *voltage control system*.

5.8.4 How the proposal will address the issues

Applying clause S5.2.5.7 to *asynchronous generation* will ensure that all *generation* has the capability to support and assist in the restoration of stable and secure operating conditions subsequent to a major system incident that has resulted in either large scale *load shedding* or *regional* separation.

5.9 Disturbance ride-through: rate of change of frequency withstand capability

5.9.1 Statement of issue

The *technical envelope* needs to evolve with technology and energy supply source. *AEMO* observed a rate of change of *frequency* (RoCoF) of approximately 6 Hz/s for 0.4 seconds in SA following its separation from the rest of the NEM in September 2016.[46] The *frequency* disturbance ride-through requirements are specified in clause S5.2.5.3, including the RoCoF withstand capability for *generating units*. The issue with the existing RoCoF standards is that a *generating unit* must be able to withstand and maintain *continuous uninterrupted operation* of

[45] National Grid Electricity Transmission plc, "The Grid Code Issue 5 Revision 20," 20 February 2017. [Online]. Available at: http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=8589935310.

[46] AEMO. *Black System, South Australia, 28 September 2016*, March 2017. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/Power-System-Operating-Incident-Reports.

±4 Hz/s for 0.25 seconds and 1 Hz/s for 1 second for the *automatic access standard* and *minimum access standard*, respectively; the RoCoF observed in SA was well in excess of this capability.

As the *generation* mix continues to change, the occurrence of higher RoCoF events may become more prevalent following the separation of any *region,* or major *load shedding* event, or *generation* shedding event. Increasing RoCoF introduces a risk that the present withstand level of *generating units* is too low to cope with prevailing RoCoF levels in the NEM and, without change, *generating units* may *disconnect* from the *power system* as a consequence of a major system disturbance. Further still, in the event of a negative RoCoF, *disconnection* will exacerbate the initial shortfall of *generation* to meet demand, resulting in *frequency* falling further and potentially causing cascading failures in the *power system*, eventually resulting in a *black system*.

5.9.2 Developing the solution

The *AEMC* is currently consulting on the following related Rule change proposals from the SA Government:

1. Emergency frequency control schemes (complete).
2. Managing rate of change of frequency (draft determination published).

The first of these introduces a *power system frequency* risk review every two years, the second suggests that NSPs will be responsible for procuring inertia where *AEMO* has identified a risk.

With the NEM experiencing higher levels of RoCoF than when *performance standards* were last reviewed, it follows that the RoCoF withstand capability of *generation* must be reviewed to reflect the prevailing *network* conditions, and that operating practices should be tailored to manage the current RoCoF risk.

In developing a solution, a technology-neutral approach is preferred, applying identical standards to all technologies. However, the fundamental capabilities of *synchronous* and *asynchronous generation* to withstand RoCoF during extreme *frequency* disturbances differ significantly. Certain *synchronous plant* is susceptible to severe damage under high RoCoF and must be allowed to *disconnect* to protect itself. This difference needs to be recognised to achieve the most efficient use or *plant* and maintain a secure *power system*, without creating an unreasonable barrier to entry for certain technology types.

This fundamental difference in RoCoF withstand capability of *synchronous* and *asynchronous generation* is acknowledged in the grid codes of Great Britain[47] and South Africa[48], which set more stringent RoCoF requirements for *asynchronous generation*. Denmark recently increased the RoCoF that new *generation* must be capable of withstanding[49], indicating the importance of this requirement. In Canada, Hydro Quebec requires all *generating systems* to withstand a negative RoCoF of 4 Hz/s for over a second[50], which is more stringent than what is proposed.

AEMO notes that RoCoF withstand capability alone cannot manage the risks associated with high RoCoF. Operational practice, *ancillary services* and potentially *network* investments will be required to limit RoCoF. However, the NEM will be more resilient to disturbances in the future by making the underlying capability available to support the *power system* and assist in its restoration to a *satisfactory operating state* following severe disturbance events.

ESCOSA consulted on the recommended RoCoF withstand levels. In its submission to ESCOSA, Origin Energy commented extensively on the potential risks to *synchronous generating plant* if high RoCoF withstand requirements are imposed.[51]

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[47] National Grid Electricity Transmission plc, "The Grid Code Issue 5 Revision 20," 20 February 2017. [Online]. Available: http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=8589935310.

[48] Eskom Transmission Division, "Grid Connection Code for RPPs," July 2016. [Online]. Available: http://www.nersa.org.za/Admin/Document/Editor/file/Electricity/TechnicalStandards/Newable%20Energy/SAGC%20Requirements%20for%20Renewable%20Power%20Plants%20Rev%202%209.pdf.

[49] Energinet, "Technical Regulation 3.2.5 for wind power plants above 11kW," July 2016. [Online]. Available: https://en.energinet.dk/Electricity/Rules-and-Regulations/Regulations-for-grid-connec ion.

[50] "Transmission Provider Technical Requirements for the Connection of Power Plants to the Hydro-Quebec Transmission System," February 2009. [Online]. Available: http://www.hydroquebec.com/transenergie/fr/commerce/pdf/exigence_raccordement_fev_09_en.pdf.

[51] Origin Energy submission to ESCOSA: http://www.escosa.sa.gov.au/ArticleDocuments/1049/20170623-Inquiry-LicensingArrangementsGeneratorsDraftReportSubmission-OriginEnergy.pdf.aspx?Embed=Y.

AEMO has considered all of these factors in developing its proposal, and has recommended technical requirements that seek to maximise the capability from *synchronous* and *asynchronous* technologies in a way that considers the physical differences of the two technologies. Accordingly, this recommendation sets different performance requirements for *synchronous* and *asynchronous generating systems*.

5.9.3 Proposed Rule change

Disturbance ride-through: frequency disturbance ride-through

Clause to be updated: S5.2.5.3

AEMO recommends amendments to clause S5.2.5.3 to ensure that *generating systems* can operate satisfactorily and contribute to the stability and recovery of the *power system* following severe disturbances such as *regional* separation or major *load* or *generation* shedding. The recommended changes reflect different requirements for *synchronous* and *asynchronous generating systems* as follows:

Asynchronous generating systems

An *asynchronous generating system* and each of its operating *generating units* must be capable of *continuous uninterrupted operation* for the following rate of change of *frequencies*:

- ±4 Hz/s for 250 milliseconds and ±3 Hz/s for 1 second.

AEMO recommends that there only be an *automatic access standard* for rate of change of *frequency* withstand capability for *asynchronous generating systems*.

The proposed requirement is equivalent to meeting the existing *automatic access standard* in clause S5.2.5.3, but with a higher level of performance required over 1 second.

Synchronous generating systems

A *synchronous generating system* and each of its operating *generating units* must be capable of *continuous uninterrupted operation* for the following rate of change of *frequencies*:

- *Automatic access standard*: ±4 Hz/s for 250 milliseconds and ±3 Hz/s for 1 second
- *Minimum access standard*: ±1 Hz/s for 1 second

A *performance standard* based on a *negotiated access standard* may be agreed if *AEMO* is satisfied that the withstand capability is appropriate for the technology and necessary to protect *plant* from damage. *AEMO* recognises that there are physical limits to the intensity and duration of RoCoF exposure that each *synchronous generating system* can withstand before suffering damage.

AEMO recommends a *negotiated access standard* for *continuous uninterrupted operation* for a range of RoCoF intensities as close as possible to the *automatic access standard*.

5.9.4 How the proposal will address the issues

The proposal seeks to maximise the capability that can be obtained from new *generation* at marginal cost that will, over time, increase the resilience of the NEM to cope with extreme *frequency* disturbances and assist in the restoration of the *power system* to a *satisfactory operating state* following a major disturbance. The recommendations reflect international standards and incorporate feedback received during prior consultations on this issue.

5.10 System strength

5.10.1 Statement of issue

System strength is an inherent characteristic of any *power system* – it is an important factor contributing to the stability of a *power system* under all reasonably possible operating conditions, and can materially impact the way the *power system* operates.[52]

Low system strength could result in *power system security* issues, with areas of particular concern being:

- *Asynchronous plant* stability.
- Incorrect operation of *protection systems.*
- *Voltage* control.
- *Synchronous plant* stability.

Left unmanaged, these issues could result in additional *generation* tripping during *power system* disturbances, loss of *load* due to mal-operation of *network* equipment, and public safety risks if faults are not being cleared.

On 27 June 2017, the *AEMC* published a draft determination and rule entitled: National Electricity Amendment (Managing power system fault levels) Rule 2017.[53] The draft rule allocates responsibility for the management of system strength issues, including:

- Providing an enhanced framework that requires NSPs to maintain the system strength at nominated points in the *network* above an agreed minimum level under a defined range of conditions; and
- Introducing a requirement on new *connecting generating systems* to 'do no harm' to the minimum level of system strength being provided to any nearby *generating system connection points*.

AEMO supports these two proposals, but notes that an additional complementary requirement is needed to ensure the long-term cost to consumers is minimised.

Where a new *asynchronous generating system connects* to a part of the *network* that is expected to remain strong for a long time, and where there are few existing *asynchronous generating systems* already *connected*, there may be little incentive for either the *Generator* or the NSP to seek to maximise the ability of the new *connection* to operate stably under weaker system conditions. If this *generating system* is allowed to *connect*, but is susceptible to instability when local *short circuit ratios* fall even slightly, the 'do no harm' provisions proposed by the *AEMC* would see any future *generating system connecting* nearby bearing the cost of ensuring the existing *generating system* remains stable. Had the first *generating system* been required to maximise its ability to operate under weaker system conditions, the costs of *connection* of future *generating systems* (and consequently consumers), would be minimised.

The NER currently allow an NSP to ensure that a *generating system* must be capable of operating correctly down to the worst expected system strength at the *connection point*. However, the proposed new rule does not allow NSPs to require further capability from the *generating system* to make efficient use of the available system strength in an area and minimise costs for future *generation connections*.

5.10.2 Developing the solution

AEMO's proposed solution is the result of extensive consideration of system strength issues as part of its Future Power System Security Program and the *AEMC's* SSMF Review, as well as *AEMO's* advisory work for ESCOSA.[54]

AEMO recommended to ESCOSA that an equitable and transparent signal needs to be provided to connecting parties to improve *connecting generating systems'* resilience to low system strength conditions. *AEMO* noted it would be ideal to specify this capability at the *connection point* of the new *generating systems* (as the *connection*

52 Refer to AEMO System Strength Fact Sheet for more information: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Reports/AEMO-Fact-Sheet-System-Strength-Final-20.pdf.

53 AEMC draft Rule and draft determination on managing power system fault levels is available at: http://www.aemc.gov.au/Rule-Changes/Managing-power-system-fault-levels.

54 Refer to Section 5.2.2 of AEMO's Preliminary Advice to ESCOSA, available at: http://www.escosa.sa.gov.au/ArticleDocuments/1048/20170331-Inquiry-RecommendedTechnicalStandardsGeneratorLicensingSA-AEMOadvice.pdf.aspx?Embed=Y.

point is the notional dividing line of responsibility), but also noted a number of potential benefits to project developers by specifying the capability at the HV terminals of susceptible items of *plant* within the *generating system*.

AEMO's final recommendation to ESCOSA was a licence requirement specific to SA that the requirement be specified at the *HV* terminals of susceptible items of *plant*. As the *performance standards* are all specified at the *connection point*, *AEMO* has adapted its recommendation for the purposes of this proposal to specify the requirement at the *connection point*. *AEMO's* informal discussions with a number of NSPs suggest that specification of this obligation at the *connection point* is likely to be the most practical.

AEMO does not consider it practical to provide for a negotiable range (between an *automatic access standard* and a *minimum access standard*) in relation to this technical requirement in the same way as others. Tuning of settings to demonstrate agreed performance, and undertaking studies to demonstrate that other aspects of the technical requirements can still be met, would result in a significant amount of additional effort and increase the time required for negotiation of *performance standards*.

Accordingly, *AEMO* has proposed that only a *minimum access standard* be applied in the case of system strength. The recommended level has been chosen such that it will eliminate the *connection* of poor performing *generating systems* in the NEM, while being within the capabilities of a majority of *plant* manufacturers.

5.10.3 Proposed Rule

System strength

Proposed new clause: S.2.5.15

AEMO recommends a new *access standard* as follows:

Minimum access standard

The *minimum access standard* is a *generating system* and each of its *generating units* must be capable of *continuous uninterrupted operation* for any *short circuit ratio* to a minimum of 3.0 at the *connection point*.

AEMO notes that the defined term *short circuit ratio* is used in the Draft National Electricity Amendment (Managing power system fault levels) Rule 2017 and recommends that this new defined term be included in this provision.[55]

5.10.4 How the solution will address the issues

The proposed solution will complement the *AEMC's* proposed new rule, and provide NSPs with the ability to require further capability from *generating systems* in order to make efficient use of the available system strength in an area and minimise costs for future *generation connections*.

This measure ensures a higher level of capability from *generating plant* to manage system strength at a lower overall cost to consumers, delivering *power system security* in an efficient manner in accordance with the NEO.

5.11 Active power control requirements

This Section 5.11 provides an overview of *AEMO's active power* recommendations and the drivers for them, alongside how these recommendations have been designed in parallel with the Finkel and *AEMC* SSMF Reviews and *AEMO's* Ancillary Services Technical Advisory Group process.

AEMO's specific, clause by clause recommendations are located in sections 5.11 to 5.15. In each of these sections, reference to *active power* control relates to control of *active power* output from a *generating system* via:

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

1. Dispatch or *AGC*; and
2. Operating a *generating system* or *generating unit* in *frequency response mode*.

5.11.1 Statement of issue – overview

Control of *power system frequency* requires continuous matching of the *supply* and demand for *active power*.

In the NEM, *frequency* control is managed via a combination of three mechanisms, namely:

- *market ancillary services* (also referred to as *frequency* control *ancillary services* (FCAS)) - participation in the FCAS markets is voluntary, and until recently, these markets have been successful in supplying sufficient capacity at low cost, relative to the *spot market*;
- primary *frequency* control through an automated governor response on some *generating plant* - provision of automatic governor-like response is not mandatory under the NER; and
- synchronous inertia (which slows the RoCoF) – provision of synchronous inertia currently occurs as a by-product of *synchronous generating plant* operating in the *market*. A framework for future procurement of inertia is being considered by the *AEMC* through its SSMF Review. For these and other reasons there has been little incentive for new *Generators* to install the necessary *active power* control capabilities to support any of these mechanisms. The need for *generation* to be able to control *active power* and respond to *network* conditions is changing. Over the longer term, it is unclear what combination of market mechanisms and mandatory technology capabilities or performance obligations may ultimately be used to provide adequate control of *power system frequency*.

Such is the concern here, a number of different reviews have made recommendations in this area; as noted earlier, both the Finkel Review and SSMF Review are recommending:

- Assessment of the need for mandatory governor response in *synchronous generation*; and
- Requiring FFR capabilities in new *generating plant*

Further, the *AEMC's* SSMF Review final report recommended a complete review of FCAS markets.

In parallel with these reviews of *frequency* control frameworks, it is important to consider the role that *performance standards* can have in supporting any future frameworks to deliver the most efficient long-term outcomes for consumers.

5.11.2 Developing the solution

AEMO has ensured the *active power* recommendations in this Rule change proposal are complementary to these and details its response to these recommendations in Sections 5.11 to 5.14. The key is that the *active power* control capabilities proposed have been purposefully designed to allow the future development of other *frequency* control arrangements, and are consistent with a wide range of alternative models for future *frequency* control.

While there is still work to do to prove the role of FFR in managing *power system frequency* in a low inertia *power system*, mandatory standards that guide new entrants towards the provision of services such as FFR may aid the transition to market-based solutions in the future, where such standards are low cost and may deliver long-term efficiencies for consumers.

The *active power* control capabilities proposed are ultimately based on a projection of what will be required in future from all types of *generation* to increase the ability to control *power system frequency* in the long term. Where the Finkel and SSMF Reviews are indicating the need for governor control on all *synchronous plant* to operate the *power system* of the future with low levels of *synchronous generation*, governor-like controls will also be required from *asynchronous plant* if the NEM is to operate with a high penetration of *asynchronous generation*. As such, and bearing in mind that other work programs are examining governor response, this Rule change proposal makes recommendations in line with this consideration.

While the contingency and regulation FCAS markets are voluntary, and despite increasing volatility in some of these markets, no *asynchronous generator* has yet been registered as a *Market Participant* in any the NEM's FCAS markets.

In this regard there are a number of perceived barriers to entry:

- The cost to enable FCAS capabilities if they were not agreed between the *Generator* and equipment manufacturer at time of purchase.
- Commercial issues if financing and warranties did not consider the provision of FCAS.

AEMO's proposal seeks to ensure that any such barriers are removed by requiring the fundamental capabilities be installed on all new *generating plant*. In parallel to this Rule change proposal, AEMO is working with the Australian Renewable Energy Agency (ARENA) and Hornsdale Stage 2 Wind Farm to demonstrate the capability of wind farms to provide all 8 types of FCAS with appropriate active power controls.[56]

These capabilities will assist in allowing secure and reliable operation with the widest possible range of future *generation* technology mix and *dispatch* patterns. They have been proposed bearing in mind both normal *power system* conditions, and conditions following *credible contingency events* and *non-credible contingency events*.

A review of international grid codes indicates that the key *active power* control capabilities proposed here are consistent with requirements present in other major grid codes around the world.[57] Consideration of international codes also highlights that the NEM is unusual in that it does not mandate the delivery of *frequency response mode* capabilities to deliver continuous and ongoing support and control of *power system frequency*.

5.11.3 Proposed Rule changes – overview

AEMO recommends the NER include requirements for new *generation* to have *active power* control facilities with the capability to provide the following services (which are detailed by each service below):

- Automatic *active power* response to *frequency* changes.
- *AGC.*
- Controlled rate of change of *active power.*
- Enhanced remote monitoring requirements to provide real-time information regarding *active power* control.

These capabilities must be installed and fully tested at the time of commissioning and accurate simulation models provided. Where the *generation* is dependent on an inherently variable energy source, testing and commissioning of these capabilities must be performed under a range of energy input conditions.

These recommendations would not require the *active power* control capabilities listed above to be made continuously active, or bid into existing markets for FCAS, but they must be continuously available for service. They may be used voluntarily by the *Generator,* when directed to do so by *AEMO*, or when required to do so under other arrangements with the relevant NSP.

Some of the recommended *active power* control capabilities can potentially be negotiated under current *connection* arrangements[58], but some cannot. To provide clarity, *AEMO* proposes amending the *access standards.* Control capabilities have been specified with existing *frequency* control arrangements in mind, and are intended in the near term to allow existing arrangements to continue, with voluntary participation in real-time markets for the procurement of FCAS.

5.12 Frequency response mode capability

5.12.1 Statement of issue

Primary *frequency* control is typically provided by *generating systems* using *frequency response mode* capabilities to deliver a controlled response to a local *frequency* measurement.[59]

[56] Further information available at: http://aemo.com.au/Media-Centre/AEMO-and-ARENA-looking-to-evolve-tradi ional-electricity-market.

[57] Examples include droop response and ramping limits set out under provisions developed by the North American Electric Reliability Corporation (NERC) / US Federal Energy Regulatory Commission (FERC), and similar requirements set by ENSTO-E and other small grids that are susceptible to 'islanding' events.

[58] For example, frequency raise and lower capability under S5.2.5.11 of the NER.

[59] Primary frequency control includes automa ic governor-like responses to small changes in frequency, and rapid responses to large changes in frequency such as the NEMs 6s and 60s contingency FCAS services.

The availability of this *frequency* control capability is expected to decline as *generation* evolves and there are no direct incentives for *Generators* to install these capabilities within new *generating systems* to replace it.

AEMO understands that the inclusion of *frequency response mode* capability can be achieved in modern *asynchronous generating systems* for little cost if requested at the time of procurement.

While the NEM's *frequency* control framework is currently under review (as noted in Section 5.11), there is a need to ensure that future *generation* is equipped with the fundamental capabilities required to ensure that *frequency* control services can be delivered at least cost to consumers under any future frameworks.

AEMO considers that all *generating systems* should provide sufficient control capability to be able to respond to locally sensed changes in *power system frequency*.

As the NER do not set a minimum requirement for such *frequency* control capabilities, AEMO is recommending amendments to clause S5.2.5.11 to incorporate minimum requirements for *frequency response mode* capability.

5.12.2 Developing the solution

AEMO notes that the *automatic access standard* in clause S5.2.5.11 already specifies a *frequency* control response capability. *AEMO's* proposal seeks to clarify the *frequency* response expectations for *plant* and to extend this capability to the *minimum access standard* as appropriate.

AEMO has proposed that *generating systems*' response to locally sensed *frequency* variations be a droop type response. This is because the droop setting may be adjustable and response triggered by movement of *power system frequency* outside a dead-band. Further, *AEMO* has observed that *Generators* and NSPs find the existing specification of required response characteristics is difficult to interpret and apply.

The recommended automatic *active power* response to *frequency* changes was consulted on by ESCOSA and there were no objections to the proposed requirements. Stakeholders commented that participation in the FCAS markets is voluntary and issues relating to *frequency* performance in the NEM are being investigated through a number of industry reviews and trials.[60] *AEMO* has used this feedback to revise its final recommendations to ESCOSA and this proposal, with recommended capabilities seen as complementary to the various frequency control reviews underway.

Requiring such capability is consistent with a recent submission[61] from the US Federal Energy Regulatory Commission (FERC) seeking comment on requirements for all generating systems (that is, synchronous and asynchronous) to have frequency response capabilities if they are to be connected to the interconnected US network.

5.12.3 Specification of fast frequency response capabilities

Further to the Finkel and SSMF Review recommendations on governor control and FFR[62], *AEMO* believes there is likely to be long-term benefits from having FFR capabilities in the *power system*. However, it is not yet clear how these capabilities should best be specified or how their value would be captured. The balance between short-term and long-term procurement would need to be determined through careful market, technical, and economic analysis, and industry consultation. This could be adjusted over time in response to experience.

The GE analysis recently published by *AEMO* showed that enabling FFR services in the NEM may allow the *frequency operating standard* (FOS) to be met with a lower level of *synchronous* inertia, and potentially a lower cost in the long term.[63] However, there is little global experience in procuring or operating FFR, and careful consideration of the specific requirements of the NEM will be required. As such, AEMO cautions against immediately committing to prescriptive or long-term procurement options for FFR. It would be preferable to start out

[60] Refer to Section 2.7– Other relevant reviews

[61] Docket no RM16-6-000 available at: https://www.ferc.gov/whats-new/comm-meet/2016/021816/E-2.pdf.

[62] See recommendation 8 on page vi of AEMC's System Security Market Frameworks Review Final Report: http://www.aemc.gov.au/getattachment/f510069a-791b-4e4d-8bc0-9e6a216be7a2/Final-report.aspx.

[63] GE Energy Consulting, *Technical Capabilities for Fast Frequency Response: Final Report*, March 2017. Available: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Reports/2017-03-10-GE-FFR-Advisory-Report-Final---2017-3-9.pdf; AEMO, *Fast Frequency Response: Release of GE Energy Consulting Report*, page 1, March 2017. Available: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Reports/FFR-Coversheet-2017-03-10a.pdf.

with a series of trials to demonstrate the technical capabilities and potential benefits of FFR for real-world *frequency control*. This could be transitioned to a more structured market or tendering process over time.

AEMO's recommended *active power* control capabilities are seen as broadly compatible with FFR from *generating systems*, without prescribing at this time specifically how these responses must be delivered. This is captured by specifying that the *active power* response to the changing *power system* must be provided with no delay, beyond that required for stable operation, or inherent in the plant controls, once frequency leaves the dead-band.

AEMO believes that this requirement is the most effective way to specify capabilities today that may enable FFR from capable *plant* in future as these services are trialled and better understood.

5.12.4 Proposed Rule change

Frequency response mode capability

Clause to be updated: S5.2.5.11

AEMO recommends that clause S5.2.5.11 be amended as follows:

- The *automatic access standard* is a *generating system* must be capable of automatically providing a proportional:
  - decrease in *power transfer* to the *power system* in response to a rise in *power system frequency*;
  - increase in *power transfer* to the *power system* in response to a fall in *power system frequency*; and
  - sufficiently rapidly and sustained for a sufficient period for the *Generator* to be in a position to offer measurable amounts of services to the *spot market* for each of the *market ancillary services*.
- The *minimum access standard* is a *generating system* with a nameplate rating of 30 MW or more must be capable of automatically providing a proportional:
  - decrease in *power transfer* to the *power system* in response to a rise in *power system frequency*;
  - increase in *power transfer* to the *power system* in response to a fall in *power system frequency*; and
  - sufficiently rapidly and sustained for a sufficient period for the *Generator* to be in a position to offer measurable amounts of services to the *spot market* for at least one of the *market ancillary services*.
- The general requirements are the *frequency response mode* shall be based on a droop function with the following characteristics:
  - The steady state droop[64] setting of this *active power* response must be adjustable in the range 2% to 10%.
  - The *frequency* dead-band for this response must be adjustable in the range from 0 to +/- 1.0 Hz.
  - An *active power* response to changing *power system frequency* must be provided with no delay beyond that required for stable operation, or inherent in the *plant* controls, once *power system frequency* leaves the dead-band.

[64] The droop characteristic is defined with respect to the registered MW capacity of the generating system (Pmax) and applies from 50 Hz (rather than from he dead-band limits).

- Response to rising and falling *frequency* may be different in both dead-band and droop settings and in the response shape or characteristics. Different levels of droop may be applied for different levels of *frequency* change. The response characteristics must be agreed with AEMO, noted within the *performance standards* and demonstrated by *plant* models.

5.12.5 How the proposal will address the issues

AEMO has proposed requiring that new *generating systems* be installed with the capability to deliver *frequency* support services to the *power system* through the ability to operate in *frequency response mode*.

The provision of the capability is designed to deliver a highly capable and flexible *generation* fleet that can contribute to efficient long-term outcomes for consumers.

The proposed requirement recognises that there will be some technologies that are not equipped to provide such services or have limited capability.

5.13 Capability for active power control via automatic generation control

5.13.1 Statement of issue

Regulation FCAS are used to continually adjust *power system frequency* within the *normal operating frequency band*.[65] Raise and lower regulation FCAS are provided by increasing or decreasing *active power* output in response to signals sent to *generating systems* by *AEMO's AGC*.

Very few *semi-scheduled generating units* have provided the necessary *active power* control capabilities required to participate in existing 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. Only *generating units* that are classified as *ancillary services generating units* typically have *AGC* capability for the purposes of provision of regulation FCAS.

AEMO considers that the inclusion of *AGC* capability from more *connected generation* is warranted to ensure the continued efficient operation of the NEM.

5.13.2 Developing the solution

The NEM relies on *AGC* to deliver regulation FCAS. Historically, delivery of *AGC* signals to a *generating unit* was relatively complex, with many older *power stations* relying on manual *control systems*. Modern *generating systems* have significant remote control capability and *AEMO* considers integration of *AGC* to these *control systems* to be a relatively straightforward exercise.

AEMO recommends that all *scheduled* and *semi-scheduled generating systems* include *AGC* capability to ensure that procurement and delivery of regulation FCAS in the future remains efficient.

The California Independent System Operator (CAISO) has successfully trialled AGC on large, intermittent, asynchronous generation and has stated that this capability is necessary for the integration of large amounts of asynchronous generation.[66]

[65] Defined as 49.75-50.25 Hz and 49.85 to 50.15 Hz for 99% of the ime under nominal conditions. For more information refer to the *NEM Mainland Frequency Operating Standards*, available at: http://www.aemc.gov.au/getattachment/436495bb-89b9-4da6-b258-e24437df9b8a/Frequency-Opera ing-Standards-(Mainland).aspx.

[66] CAISO, "Using Renewables to Operate a Low Carbon Grid," 2016. [Online]. Available at: https://www.caiso.com/Documents/UsingRenewablesToOperateLow-CarbonGrid.pdf.

The recommended capability for *active power* control via *AGC* was consulted on by ESCOSA, and there were no objections to the proposed requirements. Stakeholders commented on the fact that participation in the FCAS markets is voluntary and issues relating to frequency performance in the NEM are being investigated through a number of industry reviews and trials.[67] *AEMO* used this feedback to revise its final recommendations to ESCOSA and this proposal, with recommended capabilities seen as complementary to the various *frequency* control reviews underway.

Consistent with recommendations made in relation to *frequency response mode*, this recommendation seeks to ensure that *generation* is sufficiently capable to deliver such a response.

5.13.3 Proposed Rule change

Active power control by automatic generation control
Clause to be updated: S5.2.5.14 and S5.2.6.1
AEMO recommends amending clause S5.2.5.14 such that *scheduled* and *semi-scheduled generating systems* must have the capability for receiving and automatically responding to a new target *active power* output level or limit delivered from the *AGC,* as updated at a typical rate of once every four seconds. To support this, clause S5.2.6.1 also requires amendment such that a *generating system* must be equipped with remote control capability to receive appropriate *AGC* signals via the SCADA system.

5.13.4 How the proposal will address the issues

The control of *generation* by *AGC* is necessary for *AEMO* to manage *power system frequency* in accordance with the FOS.

AEMO has proposed requiring that new *generating systems* be installed with the capability to receive and respond to *AGC* signals.

The provision of *AGC* capability by a broader range of *generation* is designed to deliver a highly capable and flexible *generation* fleet that can contribute to efficient long-term outcomes for consumers.

The proposed requirement recognises that *non-scheduled generating systems* are not suitable to provide such services.

5.14 Capability to limit active power and ramp rate

5.14.1 Statement of issue

Strong potential exists for uncontrolled ramping of new technologies that are forecast to be deployed. Any dispersed *non-scheduled generation* or storage systems that respond in aggregate to price signals have the potential to influence the *supply*-demand balance. Further, sudden increase or decrease in *generation* in an area can have adverse impact to local *network* loading and performance. It has already been observed that ramping of separate, but closely *connected*, solar PV *generation* at sun-up and sun-down can influence not only the *supply*-demand balance, but also local *network* quality of *supply*.

Rapid and large changes in *supply* and demand present two significant issues to manage in *power system* operation. On a global scale, such actions can affect the *supply*-demand balance and affect *power system frequency*. On a local scale, rapid changes in *power* transfer can affect *transmission* and *distribution network voltages*.

The *connection* of distributed energy resources and *small generating systems* is increasing, and exposure to high *ramp rates* will impact *power system* operations.

[67] Refer to Section 2.7– Other relevant reviews

Further, the ability for *generating systems* to limit the rate of change of their *active power* output within a *dispatch interval* is important for minimising the risk of significant *supply*-demand imbalances.

AEMO's concern is that:

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

There are examples where fast *active power* ramping is expected to arise. In the case of solar PV systems, the morning ramp-up and afternoon ramp-down periods are particularly problematic, especially where numerous solar PV systems are located in close proximity.

Further, the increasing participation of *non-scheduled generation* and *small generating systems* that are price-responsive together with more sophisticated load and storage systems that respond to price signals, increases the exposure of the *power system* to fast and uncontrolled changes in *supply* and demand.

Dispatching generating systems with appropriate *ramp rates* will become a critical factor for *AEMO* in managing the *supply* and demand balance of the NEM in the future.

5.14.2 Developing the solution

As with the other *active power* requirements, fundamentally, the ability of a *generating system* to limit its rate of change of *active power* output is a capability that must be delivered by the *generating system* itself. This capability is required by the grid codes of Quebec[68], Denmark[69], and South Africa.[70]

A capability to remotely set a *ramp rate* for a *generating system* will ensure that *power system security* can be maintained into the future.

The recommended capability for limiting *active power ramp rates* was consulted on by ESCOSA, who did not receive any objections to the proposed capabilities. Stakeholders did, however, raise the following concerns:

- Any limit placed on the rate of reduction in *active power* output was seen to be unreasonable where the reduction in *active power* is due to energy resource availability for *intermittent generating systems* beyond the *generating systems'* reasonable control; and
- Consideration should be given to the impact of any *ramp rate* limits on the ability of *Market Participants* to respond to price events from the *market*.

AEMO has used this feedback to revise its final recommendations to ESCOSA and this proposal. *AEMO's* recommended changes to the NER only relate to ensuring *generating systems* have the 'capability' to limit *active power ramp rates*. Implementation of these *ramp rates* is covered by Chapters 3 and 4 of the NER.

[68] "Transmission Provider Technical Requirements for the Connection of Power Plants to the Hydro-Quebec Transmission System," February 2009. [Online]. Available at: http://www.hydroquebec.com/transenergie/fr/commerce/pdf/exigence_raccordement_fev_09_en.pdf.

[69] Energinet, "Technical Regulation 3.2.5 for wind power plants above 11kW," July 2016. [Online]. Available at: http://www.energinet.dk/SiteCollec ionDocuments/Engelske%20dokumenter/El/TR%203.2.5%20for%20wind%20power%20plants%20above%2011%20kW,%20rev.%204.1.PDF.

[70] Eskom Transmission Division, "Grid Connection Code for RPPs," July 2016. [Online]. Available at: http://www.nersa.org.za/Admin/Document/Editor/file/Electricity/TechnicalStandards/Newable%20Energy/SAGC%20Requirements%20for%20Renewable%20Power%20Plants%20Rev%202%209.pdf.

5.14.3 Proposed Rule change

Capability to limit active power and ramp rate

Clause to be updated: S5.2.5.14 and S5.2.6.1

AEMO recommends amending clause S5.2.5.14 as follows:

- This clause shall apply to all *generating systems,* and the previous size limitations are recommended to be removed.
- The *minimum access standard* shall require that *semi-scheduled* and *scheduled generating systems* must be capable of limiting the rate of change of *active power*, both upwards and downwards, to below a rate of change set-point in the *active power control system*.

AEMO recommends amending clause S5.2.6.1 to include that *generating systems* have adequate remote control and monitoring equipment to meet the requirements of clause S5.2.5.14. That is, *generating systems* must be capable of:

- Receiving and responding to different *active power ramp rate* limits.
- Receiving and responding to *active power* limits.

5.14.4 How the proposal will address the issues

With the *generation* mix being capable of rapid change in *active power* output, the capability to control the rate at which *active power* increases and decreases will ensure that the *power system frequency* and *voltages* levels can be controlled within required limits.

Further, enhancing the ability to limit *active power* to manage *network* loading will ensure that the *power system* can be operated securely and within technical limits as *generation* evolves. This enables inclusion of a greater proportion of *asynchronous generating systems* and distributed energy resources. *AEMO* recognises there is currently little international experience with the use of *active power ramp rate* limits outside of small, islanded *power systems*. Potential benefits of this capability include:

- Limiting *active power* ramps on start-up or planned shutdown of *plant*, or when a *constraint* on *active power* output is engaged or released.
- Management of electrical islands, or potential islands, with high instantaneous penetration of variable renewable *generation*.
- Managing the impact of rapid short-term changes in *active power* output on the local *network*.

5.15 Remote monitoring and control

5.15.1 Statement of issue

The increasing complexity of the *power system* and the necessity for faster operational actions leads to the need for greater automation and coordination of many different *power system* elements. Real-time information allows *AEMO* to specify the *technical envelope*[71] to maintain *power system security* more precisely, and to understand better the real-time *ancillary services* requirements and capabilities for *power system security* purposes.[72] Understanding the status of *plant* and *control equipment* is essential to achieve more efficient *power system* operation.

The development of automatic *power system* control functionality through systems such as *AEMO's* VAR Dispatch Schedule System provides opportunities for optimised control of the *power system* and broader application of *AGC*

[71] Refer to NER clause 4.2.5.
[72] Refer to NER clauses 4.3.1 (e) and (i).

capability of *generating systems* as proposed in Section 5.13. To effectively capture the capability of modern technology and develop a more advanced, automated and efficient *power system*, the NER must be updated to facilitate better remote control and monitoring capability for *generating systems* than is presently required. The integration of storage systems into the NEM *supply* mix requires expanded information for integration into *central dispatch*.

5.15.2 Developing the solution

Real-time status information and controllability can only be provided by the *generating system* having sufficient remote monitoring and control capability. Providing real-time information regarding control system settings is consistent with the Electric Reliability Council of Texas (ERCOT) requirements set out in BAL-001 TRE -1, which obliges all generators to notify the system operator about changes to *active power* control settings.[73]

5.15.3 Proposed Rule change

Remote monitoring and control requirements
Clause to be updated: S5.2.6.1
AEMO recommends that clause S5.2.6.1 be amended as follows: • A *Generator* must provide real-time information about its *generating system's active power control systems,* including mode of operation to *AEMO* via SCADA. • A *generating system* must have the capability to receive and implement *voltage control* setpoint and mode selection (where appropriate). • A *generating system* with energy storage must provide indication of the available energy of the storage system (in MWh).

5.15.4 How the proposal will address the issues

Providing *AEMO* with enhanced real-time signals, and the inclusion of remote control equipment to integrate with automatic *control systems* that are used to operate the *power system* with greater speed and automation will facilitate optimal *power system* operations. The proposed rule will ensure clearer *access standards* for remote control and monitoring capabilities.

5.16 Minor rule changes

AEMO has identified a number of minor, or clarification changes to be made in Chapter 5. These are detailed in Appendix 1.

[73] Refer to R7 in BAL-001-TRE available here: http://www.nerc.com/pa/Stand/Reliability%20Standards/BAL-001-TRE-1.pdf.

6 HOW THE PROPOSED RULE CONTRIBUTES TO THE NATIONAL ELECTRICITY OBJECTIVE (NEO)

The NEO promotes efficient investment in, and efficient operation and use of, electricity services for the long-term interests of consumers of electricity with respect to price, quality, safety, reliability, and security of supply of electricity and the reliability, safety, and security of the national electricity system.

This proposal delivers a framework that will provide services essential to security of supply and security of the national electricity system over the long term at the most efficient cost possible.

As the Australian energy system transforms, a broad package of reforms will be required to ensure the NEM continues to satisfy the NEO. Revised technical requirements for connection to the national grid is one element of these reforms, designed to ensure the secure and reliable operation of the power system, and should only be applied where it is efficient to do so. AEMO has sought to apply this test of reasonableness to all its recommendations, and believes this Rule change proposal strikes a reasonable balance between security and price.

Generation forms a central part of the electricity supply chain, and is one of the elements that supports power system security via the provision of a number of the services required to operate a stable power system. Generation that performs in unexpected or unwanted ways can cause major supply disruptions and so the performance standards applicable to generation should seek to address both of these areas.

Generation commissioned in the near future may be in place for at least 20–30 years, and potentially much longer, and form part of a very different generation mix to that seen today. As noted in Section 3.2, for the generation fleet to be able to operate flexibly under a variety of future scenarios, it is important to equip new generating systems with the best possible capabilities known today to enable this future flexibility. Inclusion of these capabilities at the design stage can often be done for low (or no) cost. Failure to include these capabilities may leave a costly legacy for future electricity consumers.

AEMO's recommendations are based on the latest knowledge and experience in operating the power system, including the lessons learned from the black system event in SA on 28 September 2016.

The recommendations have also been benchmarked against international grid standards, while not imposing requirements that have not already been met by manufacturers internationally.

Considering each of the broad areas of AEMO's recommendations in turn:

- **Negotiated access standards** – to obtain the best possible performance from new generating systems, it is reasonable to require them to meet, or be close to, the automatic access standard unless they can demonstrate why a lower standard should be accepted and power system security and quality of supply will not be affected.
- **Voltage control** is a localised issue requiring local support. The resilience and security of the NEM is increased if every generator can contribute to voltage control at its connection point, as poor local performance can propagate throughout the network.
- **Disturbance ride-through** – as demonstrated in the analysis following the SA black system, performance of generating systems during and after system disturbances can have a significant impact on security of supply. AEMO's recommendations seek to maximise the disturbance ride-through capabilities of generating systems, within the limits of equipment.
- **Protection systems** – adequate protection systems are critical to ensure electrical infrastructure can be operated safely and without damage. However, as demonstrated by the SA black system event, incorrect or unexpected protection system operation can significantly affect power system security.
- **Active power control** – the ability to effectively control active power levels is critical to balance supply and demand and keep power system frequency within secure limits. As the generation mix changes, it will become necessary to source active power controls from new generating systems. The recommendations in this proposal collectively ensure that future generation will have suitable capabilities to operate within whatever

future frequency control frameworks are applied in the NEM, reducing any barriers to efficient delivery of frequency control.

AEMO acknowledges that it is not efficient to require generating systems to solve all technical issues arising as a result of the energy transition. There are a range of alternative solutions, including establishing market frameworks and amending the access standards for distribution network service providers (DNSPs) and Market Customers that will also assist in resolving these issues.

AEMO's recommendations are designed to ensure existing capabilities are not lost and to take advantage of technological developments in generating system design that provide capability at low additional cost. Amended technical requirements have only been recommended where AEMO considers that a technical requirement is likely to be the most efficient way of addressing an identified technical issue and is consistent with international developments. The expected costs and benefits of AEMO's proposal are presented in Section 7.

7 EXPECTED BENEFITS AND COSTS OF THE PROPOSED RULE

AEMO considers that the proposed Rule has profound benefits for comparatively small costs.

A key benefit of the proposed Rule is that it will establish a set of technical requirements that will be capable of supporting a secure power system throughout its transformation. It will create a foundation for a leading edge generation fleet that is able to operate securely across a range of likely future scenarios, irrespective of whether the generation mix is predominantly synchronous, predominantly asynchronous, or a mixture of the two. The IEA, the Finkel Review and the SSMFR have all identified new technical standards as a critical element of the reforms required to effectively and efficiently integrate asynchronous generation into power systems.

The Finkel Review noted that “it is difficult to show quantitatively that the state of the power system is decreasing”.[74] It also is difficult to quantify the potential benefits of a more secure power system. However, any marginal cost is in stark contrast to the cost of the SA black system event in 2016, which was estimated at $367 million.[75]

As the cost structures associated with different generation types continue to evolve, the proposed reforms will enhance the ability of the power system to integrate low cost asynchronous generation sources. The Rule change proposal also promotes competition in the ancillary services markets. Establishing a base level of active power control capability for all generating systems will minimise the long-term linkages and dependencies between the operation of wholesale energy markets and the availability of these services, and should ultimately assist consumers by obtaining these services at the lowest overall cost.

For example, forecasts in SA indicate increasing periods of low operational demand, during which few large transmission- or distribution-connected generating systems will be required to meet demand. During these periods, wind or large-scale PV generation is likely to be the lowest marginal cost source of supply, but will not be able to operate unconstrained if it cannot also respond to the active power control requirements necessary to maintain the secure operation of the power system. The proposed control capabilities are consistent with the capabilities of scheduled generating systems, and are understood to be within the capabilities of modern semi-scheduled generating systems.

AEMO has developed its recommendations to take advantage of global technological developments while minimising potential costs. For manufacturers of power generation equipment, Australia is not a big market by international standards, and manufacturers are unlikely to develop new off-the-shelf products just for the Australian market. For each proposed change, AEMO has sought to consider international precedents, and make recommendations that can be met by a majority of manufacturers. By proposing technical requirements that are similar to standards that already exist elsewhere in the world, Australia will be able to capitalise on economies of scale from global manufacturers.

In searching for new security capability, AEMO liaised with equipment manufacturers and examined what other grid codes demand from their generation fleets. Not only are these recommendations consistent with global best practice, but AEMO has been advised by manufacturers that the capabilities required are largely standard in new asynchronous plant so they come with no, or only marginal, additional cost. Given the investment being required is unavoidable as it delivers capability the NEM cannot function without, doing so via a marginal cost at worst is consistent with the NEO.

AEMO understands that the proposed active power control capabilities can be made available via software modifications for most types of generation and, in some cases, via the installation of additional communications equipment. AEMO understands that major additional hardware or plant will not be required in the majority of cases to provide these capabilities, and that the proposed capabilities can be provided by most equipment manufacturers without significant increases in cost.

[74] Finkel Review. *Independent Review into the Future Security of the National Electricity Market*, June 2017, page 51. Available at: http://www.environment.gov.au/system/files/resources/1d6b0464-6162-4223-ac08-3395a6b1c7fa/files/electricity-market-review-final-report.pdf.
[75] Business SA, 2016.

The key risk associated with active power control capabilities for new entrant generation is seen around the procurement of capability that is installed, ultimately at increased cost to consumers, and then not required or utilised over the long term. Consideration of this risk has led to the specification of these capabilities in such a manner that they minimise increases in capital costs for new entrant generation, while still providing valuable capability to the power system both in the short term and into the future.

In light of this approach, AEMO believes the majority of recommended automatic access standards can be met by the majority of generating systems at little or no marginal cost increase.

AEMO acknowledges that some of the proposed technical requirements have the potential to impose costly physical constraints on some synchronous generating units. In these cases, the proposed framework provides flexibility to accommodate negotiated access standards where power system security can still be assured.

Further, AEMO has updated its initial proposals in light of stakeholder feedback received during the consultation process as part of the ESCOSA review. For the most part, stakeholders did not suggest that the proposed requirements would be unduly costly to implement.

On balance, AEMO considers that the benefits of the proposed Rule are significantly greater than the costs.

8 FURTHER CONSIDERATIONS

8.1 Stakeholder engagement

8.1.1 Consultation to date

As noted at the outset, this proposal builds on AEMO's work for ESCOSA in updating its generator licence conditions for SA. Consultation during the ESCOSA review process was extensive and, while it focused on the system needs of SA's network, the feedback is transferrable to this proposal. This is because it is focused on the technical capability of new plant technology and what are the maximum and minimum boundaries of this capability, and the costs involved in delivering to these boundaries. Further, AEMO consistently advised stakeholders that the ESCOSA recommendations would form the basis of this proposal. As such, AEMO was able to garner NEM-wide feedback, which included:

- A day-long workshop with industry.
- 15 formal submissions from industry.
- One-on-one briefings with the Clean Energy Council and Australian Energy Council.
- Liaison with manufacturers on technical capabilities and cost implications.

The ESCOSA submissions, while acknowledging were in relation to the ESCOSA licence conditions, raised few material concerns regarding the proposed technical requirements and indicated an overall acceptance of the need for the change. These submissions to ESCOSA can be found on ESCOSA's website.[76] How AEMO considered this feedback when developing the Rule changes has been noted throughout this proposal.

Manufacturers' feedback has indicated the proposed capabilities can be delivered by modern asynchronous plant at no or marginal cost.

8.1.2 Future consultation

AEMO was able to work closely with stakeholders on the vast majority of the proposed Rule changes during the ESCOSA process, and seeks an equally collaborative approach during the AEMC's consultation on this proposal.

8.2 Transitional matters

In light of the large number of new projects involving asynchronous generation actively under consideration, and the expectation that more are likely to emerge from policy initiatives from a number of participating jurisdictions, it is imperative that connection enquiries and connection applications and the resulting connection arrangements be assessed on the basis of these new technical requirements, reflecting the future needs of the power system, rather than the current, outdated requirements, as soon as possible.

As noted above, the general approach to the technical requirements proposed has been the subject of considerable discussion since the SA black system event, including in the context of AEMO's advice to the ESCOSA review.

Therefore, the new technical requirements should apply to all connection agreements entered into from the date this request is submitted, even if they result from a connection enquiry or connection application made prior to the proposed new Rules taking effect.

AEMO encourages all NSPs and applicants to immediately start considering the standards in this Rule change proposal when assessing new and existing connection enquiries and applications, regardless of what stage they are at in the connection process.

[76] ESCOSA. *Inquiry into the licensing arrangements for generators in South Australia* webpage: http://www.escosa.sa.gov.au/projects-and-publications/projects/inquiries/inquiry-into-licensing-arrangements-under-the-electricity-act-1996-for-inverter-connected-generators/inquiry-into-licensing-arrangements-under-the-electricity-act-1996-for-inverter-connected-generators.

9 NEXT STEPS

This Rule change proposal is one key element among a number of energy market reform measures both underway and set to commence. AEMO understands that the AEMC will be giving priority to its consideration of this proposal.

Where further, or other, changes to Chapter 5 of the NER can be accommodated without delaying determination of this Rule change proposal, AEMO recommends the AEMC consider such changes in conjunction with this Rule change proposal.

Matters that require further consideration are discussed in the sections below.

9.1 Application of new performance standards to existing Generators

As noted in AEMO's final report on the SA black system[77], the changes recommended in this proposal would, based on current policy, only apply to new generating systems. While it is critical to obtain additional capabilities from new generation, the SA black system event encourages consideration of whether additional capabilities should also be sought from existing generation. It is possible that the costs of complying with some aspects of these proposed changes could be low even for existing generating systems. Application of these new requirements to existing generating systems should be considered.

There are few, if any, other markets around the world where updates to a grid connection regulatory framework do not apply to existing generating systems.

AEMO will examine whether it would be appropriate for similar changes be made to the NER.

9.2 Schedule 5.3a: Conditions for connection of market network services

The performance requirements for market network service providers is very much derived from the requirements for customers.

By definition, a market network service facility, such as an interconnector between regions, is a critical element in the power system, and in this regard such facilities should be designed to perform at the same level that is required for the supply side of the power system, that is, generators.

Continuous uninterrupted operation for market network service facilities during frequency disturbances, voltage disturbances, and contingency events is critical to maintaining power system security. Without such capability, maintaining secure power transfer capacity and sharing ancillary services between regions is placed at risk.

While there are some withstand capabilities presently required for frequency and voltage disturbances, the requirements are less specific than those applied to generators. Further, there are no specific requirements with respect to contingency events.

AEMO recommends that the access standards for Market Network Service Providers be reviewed in the near term. Criteria addressing minimum short circuit ratio for stable operation, immunity to frequency disturbances, an ability to ride through voltage disturbances, response to contingency events, and protection for unstable operation should all be considered.

[77] Reports on the black system event in SA on 28 September 2016 are available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Market-notices-and-events/Power-System-Operating-Incident-Reports.

9.3 Other key areas for review

AEMO is also considering future Rule change proposals in the following areas.

9.3.1 Further sections of NER Chapter 5 not covered in this Rule change

AEMO will consider if there is a need to make any further changes to Chapter 5 in the near term. At any rate, AEMO will be reviewing the generator technical requirements within three years, as recommended in the Finkel Review.

9.3.2 Technical requirements for distributed energy resources (DER) and DER aggregators

In addition to this Rule change proposal, AEMO is considering the need for a subsequent review into whether technical standards on DER should be addressed explicitly with the NER.

Many DER systems are connected to the network via inverters that provide an electronic interface to the power system. The technical properties of these inverters are currently set by Standards Australia through the AS 4777 standard. The current standard, revised in 2015, provides a clear benchmark for the expected performance of inverters for certain fluctuations in the power system, improving the predictability of the system.

As standards for inverters are in the remit of Standards Australia, any changes to the inverter standard are expected to have a long lead time for development and implementation.

For standards to assist in grid stability, the frameworks for standard development would need to be adaptive to the pace of technology development. Any future review of technical standards for DER would need to consider whether the revised Australian Standard provides sufficient coverage of required DER capability and performance, and whether any consideration of these issues is required in the NER.

The review may also consider what technical standards are required from parties that aggregate DER to provide energy and system services, and what performance information could be obtained remotely from the DER. The 'virtual power plants' aggregators bring to the market may be expected to meet similar technical requirements as any large generator, as they could be of similar size and thus have similar network and market impact. Any such provisions would be subject to physical limitations of their communication and control architectures, and any physical limitations of the DER they are aggregating. Technical standards for DER aggregators may provide a useful bridge between the NER and Australian Standards for obtaining the necessary capabilities from DER.

9.3.3 Technical requirements for market customers

AEMO recommends that access standards for Market Customers should be reviewed for currency and effectiveness. This recommendation is made for the following reasons:

- Market Customer access standards have not been reviewed for many years.
- The existing access standards are primarily concentrated on areas relating to quality of supply, with little consideration given to matters where Market Customer *facilities* may influence matters relating to *power system security*.
- Recent changes to access standards applicable to generators mean inconsistency has emerged between similar access standard requirements for generators and other Registered Participants.
- As the expectations regarding Market Customer participation in and interaction with the NEM are likely to change as the market and power system evolve, it is important access standards that are fit for purpose apply.

9.3.4 System restoration

System restart ancillary services, or SRAS, are provided by generation with the capability to start without using power from the grid, to re-energise the transmission network and other generating plant. AEMO must procure SRAS that will restore sufficient generation and transmission in each NEM electrical sub-network to supply a given level of demand within a set timeframe determined by the System Restart Standard.

At its current state of development, asynchronous generation technology is unable to provide SRAS capability. This primarily stems from the source intermittency and the need for a minimum system strength or fault level that is not available during black system conditions. However, contribution to voltage and reactive power control during system restoration from asynchronous generation will likely be important once sufficient synchronous machines have been restarted to provide the minimum fault level required for stable operation of the asynchronous generating units, dynamic reactive support plant, and battery storage units.

As conventional synchronous generation withdraws from the market, other generation is either not incentivised or not capable of providing SRAS. This is particularly true if the system is weak, with low fault levels that affect the ability to re-energise the transmission network.

Future work should explore the ability of non-synchronous generation to:

- Provide voltage and reactive support during system restoration.
- Capably provide system restart services.

MEASURES AND ABBREVIATIONS

Units of measure

Abbreviation	Unit of measure
GW	Gigawatts
Hz	Hertz
kV	Kilovolt
kVA	Kilovolt-amp
ms	Millisecond
MW	Megawatt
s	Second
VAR	Volt-ampere reactive

Abbreviations

Abbreviation	Expanded name
AC	Alternating current
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AGC	Automatic Generation Control
COAG	Council of Australian Governments
DC	Direct current
DER	Distributed Energy Resources
DNSP	Distribution network service provider
EMT	Electromagnetic transient
ENA	Energy Networks Association
ESCOSA	Essential Services Commission of South Australia
FCAS	Frequency control ancillary services
FFR	Fast frequency response
FOS	*frequency operating standard*
GPS	Generator performance standards
HV	High voltage
HVRT	High voltage ride-through
LV	Low voltage
LVRT	Low voltage ride-through
NECA	National Electricity Code Administrator
NEL	National Electricity Law
NEM	National Electricity Market
NEO	National electricity objective
NER	National Electricity Rules

Abbreviation	Expanded name
NSP	Network service provider
PV	Photovoltaic
RoCoF	Rate of change of frequency
SA	South Australia
SCADA	Supervisory Control and Data Acquisition
SCR	Short circuit ratio
SRAS	System restart ancillary services
SSMF	System Security Market Frameworks
TNSP	Transmission Network Service Provider

APPENDIX A. CLERICAL AND CLARIFICATION CHANGES TO CHAPTER 5

Table 7 Minor and clarification changes to Chapter 5

Clause	Statement of issue	Recommendation
5.3.4A(f)(3)	The demarcation between the connecting NSP and AEMO's respons bility seems blurred.	Redraft for clarity.
5.3.9(d)	Clerical error	The table requires updating: • in the auxiliary supplies section 5.2.8 should refer to 5.2.7 (S5.2.8 was renumbered to S5.2.7 in later versions of the NER) • in the protection system section S5.2.5.10 should be included
S5.1a.7	Clarification of intent	Suggest modification in red: Except as a consequence of a contingency event, the *average voltage* unbalance, measured at a *connection point*, should not ~~vary by more than~~ exceed the amount set out in column 2 of Table S5.1a.1, when determined over a 30 minute averaging period. As a consequence of a *credible contingency event*, the average *voltage unbalance*, measured at a connection point, should not ~~vary by more than~~ exceed the amount set out in column 3 of Table S5.1a.1, when determined over a 30 minute averaging period. The average *voltage* unbalance, measured at a *connection point*, should not ~~vary by more than~~ exceed the amount set out in column 4 of Table S5.1a.1 for the relevant nominal *supply voltage*, when determined over a 10 minute averaging period.
S5.2.5.3	Modern terminology The Rules were originally written around generating "units", however changes from Version 13 started to refine language to reflect modern technology	Proposed title changes in red: "Generating ~~unit~~ system response to frequency disturbance"
S5.2.5.3(d)	Amendment of clause 5.3.4A(b) to clarify the basis on which performance standard based on the negotiated access standards are to be agreed makes sub-paragraphs ((1) & (3) redundant.	Delete sub-paragraphs (1) & (3).
S5.2.5.4(c)	Amendment of clause 5.3.4A(b) to clarify the basis on which performance standard based on the negotiated access standards are to be agreed makes sub-paragraphs ((1) & (3) redundant.	Delete sub-paragraphs (1) & (3).
S5.2.5.4(d)(3)	The provision seems to be referring to something that no longer makes any sense to connecting parties, NSPs or AEMO.	Deleted.
S5.2.5.5(c)(1)	Amendment of clause 5.3.4A(b) to clarify the basis on which performance standard based on the negotiated access standards are to be agreed makes sub-sub-paragraphs (B) & (C) in sub-paragraphs (ii) & (iii) redundant. Sub-paragraphs (1)(ii) & (iii) are substantially identical.	Delete sub-sub-paragraphs (B) & (C) in sub-paragraphs (ii) & (iii). Consolidate sub-paragraphs (ii) & (iii).
S5.2.5.5(f) (new)	Italicise 'generating'.	The reference to 'generating *plant*' should be replaced with: '*generating plant*'.

Clause	Statement of issue	Recommendation
S5.2.5.7(e)	Amendment of clause 5.3.4A(b) to clarify the basis on which a performance standard based on a negotiated access standard is to be agreed makes this provision redundant.	Delete.
S5.2.5.11(a)	The term is now used in clause S5.2.5.1(a) in addition to clause S5.2.5.11. The definition is clarified by making reference to the maximum level to which a *generating unit* can be *dispatched*, rather than *sent out generation*.	Amend and transfer definition of 'maximum operating level' to the Glossary.
S5.2.5.13(b) & (d)	A number of requirements apply to both synchronous and asynchronous generation and can be difficult to work out the differences.	Regroup identical requirements under a new sub-paragraph and separate those that apply only to synchronous and those that apply only to asynchronous.

APPENDIX

GENERATOR TECHNICAL REQUIREMENTS RULE CHANGE PROPOSAL

RECOMMENDED CHANGES TO THE NATIONAL ELECRICITY RULES

5.3.4A Negotiated access standards

(b) A *negotiated access standard* must:

(1) be ~~no less onerous than the corresponding *minimum access standard* provided by the *Network Service Provider* under clauses 5.3.3(b1)(4) or S5.4B(e)~~ as close as practicable to the *automatic access standard* and no less than the corresponding *minimum access standard*;

(2) be set at a level that will not adversely affect *power system security*;

(3) be set at a level that will not adversely affect the quality of *supply* for other *Network Users*; and

(4) in respect of *generating plant*, meet the requirements applicable to a *negotiated access standard* in clauses S5.2.5, S5.2.6, S5.2.7 and S5.2.8.

(c1) A *Connection Applicant* submitting a proposal for a *negotiated access standard* under clause 5.3.4(e), clause 5.3A.9(f) or paragraph (h)(3), 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).

(c2) A *Network Service Provider* must following the receipt of a proposed *negotiated access standard* under clause 5.3.4(e), clause 5.3A.9(f) or paragraph (h)(3), consult with *AEMO* as soon as practicable in relation to *AEMO advisory matters* for that proposed standard.

Note

This clause is classified as a civil penalty provision under the National Electricity (South Australia) Regulations. (See clause 6(1) and Schedule 1 of the National Electricity (South Australia) Regulations.)

(d) *AEMO* must within 20 *business days* following the submission of a proposed *negotiated access standard* under clause 5.3.4(e), clause 5.3A.9(f) or paragraph (h)(3), respond to the *Network Service Provider* in writing in respect of any *AEMO advisory matters*.

(e) A *Network Service Provider* must within 30 *business days* following the receipt of a proposed *negotiated access standard* in accordance with clause 5.3.4(e), clause 5.3A.9(f) or paragraph (h)(3), accept or reject a proposed *negotiated access standard*.

Note

This clause is classified as a civil penalty provision under the National Electricity (South Australia) Regulations. (See clause 6(1) and Schedule 1 of the National Electricity (South Australia) Regulations.)

(f) The *Network Service Provider* must reject the proposed *negotiated access standard* if that *connection*, or alteration of the *generating plant* (as the case may be), at the *negotiated access standard* proposed by the *Connection Applicant* would:

(1) on *AEMO's* reasonable advice, adversely affect *power system security*;

(2) in the *Network Service Provider's* reasonable opinion, adversely affect quality of *supply* for other *Network Users*;

~~(3) in the reasonable opinion of *AEMO* or the *Network Service Provider*, in respect of a *AEMO* advisory matter or a matter allocated to the *Network Service Provider*, respectively, be lower than the corresponding *minimum access standard*;~~

(3) in the *Network Service Provider's* reasonable opinion, or *AEMO's* reasonable advice given under paragraph (d) in respect of an *AEMO advisory matter*, the performance of that *connection* or alteration would be lower than the corresponding *minimum access standard*; or

(4) in respect of *generating plant*, in *AEMO's* reasonable opinion, not satisfy paragraph (b)(4).

Note

This clause is classified as a civil penalty provision under the National Electricity (South Australia) Regulations. (See clause 6(1) and Schedule 1 of the National Electricity (South Australia) Regulations.)

(g) If a *Network Service Provider* rejects a proposed *negotiated access standard*, the *Network Service Provider* must when rejecting the proposed *negotiated access standard*, advise the *Connection Applicant* of a *negotiated access standard* that the *Network Service Provider* will accept.

Note

This clause is classified as a civil penalty provision under the National Electricity (South Australia) Regulations. (See clause 6(1) and Schedule 1 of the National Electricity (South Australia) Regulations.)

(h) The *Connection Applicant* may in relation to a proposed *negotiated access standard* advised by a *Network Service Provider* in accordance with paragraph (g):

(1) accept the proposed *negotiated access standard*;

(2) reject the proposed *negotiated access standard*;

(3) propose an alternative *negotiated access standard* to be further evaluated in accordance with the criteria in paragraph (b); or

(4) elect to adopt the relevant *automatic access standard* or a corresponding *plant standard*.

(i) An *automatic access standard* or if the procedures in this clause 5.3.4A have been followed a *negotiated access standard*, that forms part of the terms and conditions of a *connection agreement*, is taken to be the *performance standard* applicable to the *connected plant* for the relevant technical requirement.

5.3.9 Procedure to be followed by a Generator proposing to alter a generating system

[The only changes proposed by AEMO are to the table]

Column 1 **(altered equipment)**	**Column 2** **(clause)**
machine windings	S5.2.5.1, S5.2.5.2, S5.2.8
power converter	S5.2.5.1, S5.2.5.2, S5.2.5.5, S5.2.5.12, S5.2.5.13, S5.2.8
reactive compensation plant	S5.2.5.1, S5.2.5.2, S5.2.5.5, S5.2.5.12, S5.2.5.13
excitation control system	S5.2.5.5, S5.2.5.7, S5.2.5.12, S5.2.5.13
voltage control system	S5.2.5.5, S5.2.5.7, S5.2.5.12, S5.2.5.13
governor *control system*	S5.2.5.7, S5.2.5.11, S5.2.5.14
power *control system*	S5.2.5.11, S5.2.5.14
protection system	S5.2.5.3, S5.2.5.4, S5.2.5.5, S5.2.5.7, S5.2.5.8, S5.2.5.9, S5.2.5.10
auxiliary supplies	S5.2.5.1, S5.2.5.2, S5.2.7~~8~~

Column 1 **(altered equipment)**	**Column 2** **(clause)**
remote control and monitoring system	S5.2.5.14, S5.2.6.1, S5.2.6.2

5.8.4 Commissioning program

(a) Prior to the proposed commencement of commissioning by a *Registered Participant* of any new or replacement equipment that could reasonably be expected to alter performance of the *power system*, the *Registered Participant* must advise the relevant *Network Service Provider* and *AEMO* in writing of the commissioning program including test procedures and proposed test equipment to be used in the commissioning.

(b) Notice under clause 5.8.4(a) must be given not less than:

(1) 3 months prior to commencement of commissioning for a *connection* to a *transmission network* or for a *connection* to a *distribution network* for a *facility* that exceeds 30MW capacity or causes export of *power* to a *transmission network*; or

(2) ~~and not less than~~1 month prior to commencement of commissioning for any other *connection* to a *distribution network*.

(c) The relevant *Network Service Provider* and *AEMO* must, within 15 *business days* of receipt of such advice under clause 5.8.4(a), notify the *Registered Participant* either that they:

(1) agree with the proposed commissioning program; or

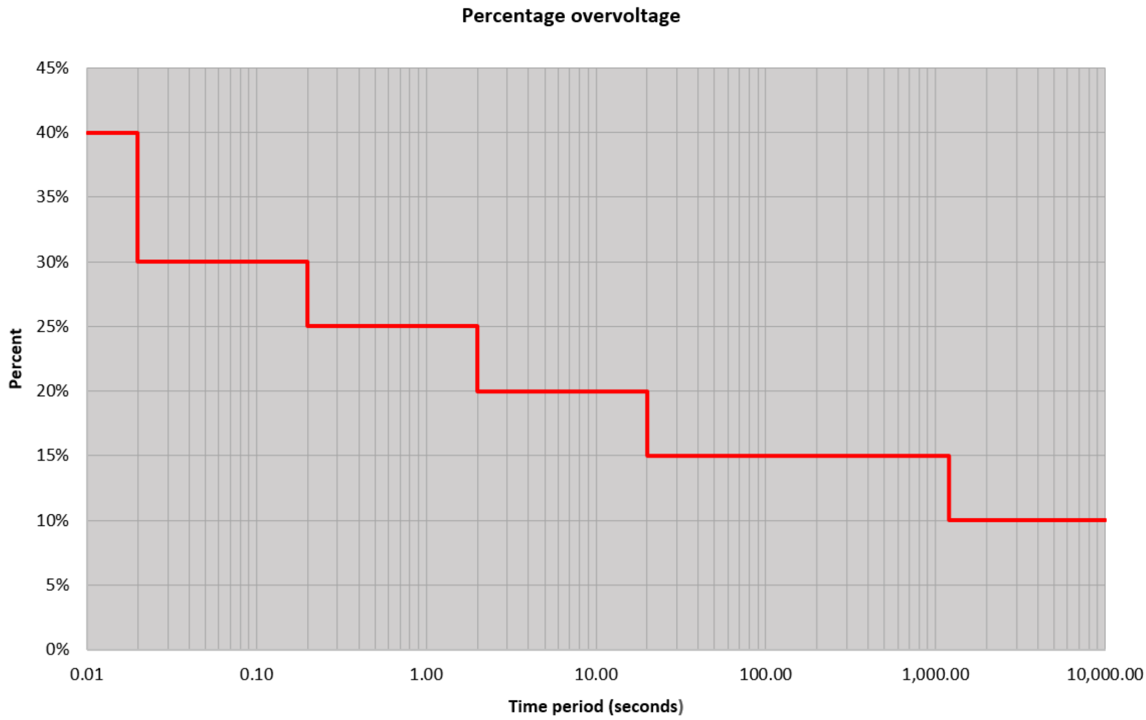
(2) require changes to it in the interest of maintaining *power system security*, safety or quality of *supply*.

(d) If the relevant *Network Service Provider* or *AEMO* require changes to the proposed commissioning program, then the parties must co-operate to reach agreement and finalise the commissioning program within a reasonable period.

(e) A *Registered Participant* must not commence the commissioning until the commissioning program has been finalised and the relevant *Network Service Provider* and *AEMO* must not unreasonably delay finalising a commissioning program.

S5.1a.4 Power frequency voltage

[The only changes proposed by AEMO are to replace Figure S5.1a.1. with the following]



S5.2.5 Technical requirements

S5.2.5.1 Reactive power capability

Automatic access standard

(a) The *automatic access standard* is a *generating system* operating at:

(1) any level of *active power* output greater than 10% of its *maximum operating level*; and

(2) 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 0.395.

Minimum access standard

(b) The *minimum access standard* is a *generating system* operating at:

(1) any level of *active power* output; and

(2) 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 required to enable the *generating system* to achieve the continuously controllable *voltage* setpoint range specified in the *performance standard* agreed under clause S5.2.5.13.

~~no capability is required to supply or absorb *reactive power* at the *connection point*.~~

Negotiated access standard

(c) When negotiating a *negotiated access standard*, the *Generator* and the *Network Service Provider*:

(1) must subject to any agreement under paragraph (d)(4), ensure that the *reactive power capability* of the *generating system* is sufficient to ensure that all relevant *system standards* are met before and after *credible contingency events* under normal and planned *outage* operating conditions of the *power system*, taking into account at least existing projects and *considered projects*;

(2) may negotiate either a range of *reactive power* absorption and supply, or a range of *power factor*, at the *connection point*, within which the *plant* must be operated; and

(3) may negotiate a limit that describes how the *reactive power capability* varies as a function of *active power* output due to a design characteristic of the *plant*.

(d) If the *generating system* is not capable of the level of performance established under paragraph (c)(1) the *Generator,* depending on what is reasonable in the circumstances, must:

(1) pay compensation to the *Network Service Provider* for the provision of the deficit of *reactive power* (supply and absorption) from within the *network*;

(2) install additional equipment *connecting* at the *generating system's connection point* or another location, to provide the deficit of *reactive power* (supply and absorption), and such equipment is deemed to be part of the *generating system*;

(3) reach a commercial arrangement with a *Registered Participant* to provide the deficit of *reactive power* (supply and absorption); or

(4) if the inability to meet the performance level only occurs for particular operating conditions, agree to and document as part of the proposed *negotiated access standard*, operational arrangements by which the *plant* can achieve an agreed level of performance for those operating conditions.

(e) The *Generator* may select one or more options referred to in paragraph (d).

General requirements

(f) An *access standard* must record the agreed value for *rated active power* and where relevant the method of determining the value.

(g) An *access standard* for consumption of *energy* by a *generating system* when not supplying or absorbing *reactive power* under an *ancillary services agreement* is to be established under clause S5.3.5 as if the *Generator* were a *Market Customer*.

S5.2.5.3 Generating ~~unit~~ system response to frequency disturbances

(a) For the purposes of this clause S5.2.5.3:

normal operating frequency band, **operational frequency tolerance band**, or **extreme frequency excursion tolerance limits** are references to the widest range specified for those terms for any condition (including an "island" condition) in the *frequency operating standards* that apply to the *region* in which the *generating unit* is located.

stabilisation time and **recovery time** mean the longest times allowable for *power system frequency* ~~system frequency~~ at the *connection point* to remain outside the operational frequency tolerance band and the normal operating frequency band, respectively, for any condition (including an "island" condition) in the *frequency operating standards* that apply to the region in which the *generating unit* is located.

transient frequency limit and **transient frequency time** mean the values of 47.5 Hz and 9 seconds respectively, or such other values determined by the *Reliability Panel*.

Automatic access standard

(b) The *automatic access standard* is a *generating system* and each of its *generating units* must be capable of *continuous uninterrupted operation* for *frequencies* in the following ranges:

(1) the lower bound of the extreme frequency excursion tolerance limits to the lower bound of the operational frequency tolerance band for at least the stabilisation time;

(2) the lower bound of the operational frequency tolerance band to the lower bound of the normal operating frequency band, for at least the recovery time including any time spent in the range under subparagraph (1);

(3) the normal operating frequency band for an indefinite period;

(4) the upper bound of the normal operating frequency band to the upper bound of the operational frequency tolerance band, for at least the recovery time including any time spent in the range under subparagraph (5); and

(5) the upper bound of the operational frequency tolerance band to the upper bound of the extreme frequency excursion tolerance limits for at least the stabilisation time,

unless the rate of change of *frequency* is outside the range of –4 Hz to 4 Hz per second for more than 0.25 seconds, –3Hz to 3Hz per second for more than one second, or such other range as determined by the *Reliability Panel* from time to time.

Note:

The automatic access standard is illustrated in the following diagram. To the extent of any inconsistency between the diagram and paragraph (b), paragraph (b) prevails.

[Figure not included]

Minimum access standard

(c) The *minimum access standard* is a synchronous *generating system* and each of its *generating units* must be capable of *continuous uninterrupted operation* for *frequencies* in the following ranges:

(1) the lower bound of the extreme frequency excursion tolerance limits to the transient frequency limit for at least the transient frequency time;

(2) the transient frequency limit to the lower bound of the operational frequency tolerance band for at least the stabilisation time;

(3) the lower bound of the operational frequency tolerance band to the lower bound of the normal operating frequency band for at least the recovery time including any time spent in the ranges under subparagraphs (1) and (2);

(4) the normal operating frequency band for an indefinite period;

(5) the upper bound of the normal operating frequency band to the upper bound of the operational frequency tolerance band for at least the recovery time including any time spent in the ranges under subparagraph (6) unless the *generating system* has a *protection system* to trip a *generating unit* if the *frequency* exceeds a level agreed with *AEMO*; and

(6) in respect of a *generating system*:

(i) of 30 MW or more; and

(ii) that does not have a *protection system* to trip the *generating unit* if the *frequency* exceeds a level agreed with *AEMO*,

the upper bound of the operational frequency tolerance band to the upper bound of the extreme frequency excursion tolerance limits (including an "island" condition) for at least the transient frequency time,

unless the rate of change of *frequency* is outside the range of -2Hz to 2Hz per second for more than 0.25 seconds, -1 Hz to 1 Hz per second for more than one second or such other range as determined by the *Reliability Panel* from time to time.

Note:

The minimum access standard is illustrated in the following diagram. To the extent of any inconsistency between the diagram and paragraph (c), paragraph (c) prevails.

[Figure not included]

Negotiated access standard

(d) A *negotiated access standard* ~~can be accepted by the *Network Service Provider* provided that *AEMO* and the *Network Service Provider* agree that:~~

~~(1) the *negotiated access standard* is as close as practicable to the *automatic access standard* while respecting the need to protect the *plant* from damage;~~

~~(2)~~ 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*.~~; and~~

~~(3) there would be no material adverse impact on quality of *supply* to other *Network Users* or *power system security*.~~

(e) *AEMO* must advise on matters relating to *negotiated access standards* under this clause S5.2.5.3.

S5.2.5.4 Generating system response to voltage disturbances

Automatic access standard

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

(1) *voltages* over 110% for the durations permitted under clause S5.1a.4;

(2) 90% to 110% of *normal voltage* continuously;

(3) 80% to 90% of *normal voltage* for a period of at least 10 seconds; and

(4) 70% to 80% of *normal voltage* for a period of at least 2 seconds.

Minimum access standard

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

(1) *voltages* over 110% for the durations permitted under clause S5.1a.4; and

(2) in the range of:

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

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

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

(3) 80% to 90% of *normal voltage* for a period of at least 5 seconds; and

(4) 70% to 80% of *normal voltage* for a period of at least 2 seconds.

Negotiated access standard

(c) In negotiating a *negotiated access standard*, a *generating system* and each of its operating *generating units* must be capable of *continuous uninterrupted operation* for the range of *voltages* specified in the *automatic access standard* except where *AEMO* and the *Network Service Provider* agree that~~:~~

~~(1) the *negotiated access standard* is as close as practicable to the *automatic access standard* while respecting the need to protect the *plant* from damage;~~

~~(2)~~ the ~~*generating plant* that would be tripped~~total reduction of *generation* in the *power system* as a result of any *voltage* excursion within levels specified by the *automatic access standard*, ~~is not more than~~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; and~~

~~(3) there would be no material adverse impact on the quality of *supply* to other *Network Users* or *power system security*.~~

(d) In carrying out assessments of proposed *negotiated access standards* under this clause S5.2.5.4, *AEMO* and the *Network Service Provider* must at a minimum, take into account:

(1) the expected performance of existing *networks* and *considered projects*;

(2) the expected performance of existing *generating plant* and other relevant projects; and

~~(3) any corresponding *performance standard* (or where no *performance standard* has been registered, the *access standard*) that allows *generating plant* to trip for *voltage* excursions in ranges specified under the *automatic access standards*.~~

(e) *AEMO* must advise on matters relating to *negotiated access standards* under this clause S5.2.5.4.

General requirement

(f) The *access standard* must include any operational arrangements necessary to ensure the *generating system* and each of its *generating units* will meet its agreed performance levels under abnormal *network* or *generating system* conditions.

S5.2.5.5 Generating system response to disturbances following contingency events

(a) In this clause S5.2.5.5 a fault includes:

(1) a fault of the relevant type having a metallic conducting path; and

(2) a fault of the relevant type resulting from reclosure onto a fault by the operation of *automatic reclose equipment*.

Automatic access standard

(b) The *automatic access standard* is:

(1) a *generating system* and each of its *generating units* must remain in *continuous uninterrupted operation* for up to fifteen ~~a~~ disturbances within any five-minute period caused by any combination of the following events~~ that is~~:

(i) a *credible contingency event* other than a fault referred to in subparagraph (iv);

(ii) a three phase fault in a *transmission system* cleared by all relevant primary *protection systems*;

(iii) a two phase to ground, phase to phase or phase to ground fault in a *transmission system* cleared in:

(A) the longest time expected to be taken for a relevant *breaker fail protection system* to clear the fault; or

(B) if a *protection system* referred to in subparagraph (A) 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; and

(iv) a three phase, two phase to ground, phase to phase or phase to ground fault in a *distribution network* cleared in:

(A) the longest time expected to be taken for the *breaker fail protection system* to clear the fault; or

(B) if a *protection system* referred to in subparagraph (A) 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,

provided that none of the events ~~is not one that~~ would *disconnect* the *generating unit* from the *power system* by removing *network elements* from service and that the total time that the *voltage* at the *connection point* is less than 90% of *normal voltage* for 1,800 milliseconds; and

(2) 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), must supply to or absorb from the *network*:

(i) to assist the maintenance of *power system voltages* during the application of the fault~~,~~:

(A) capacitive reactive current ~~of at least the greater of~~ in addition to its pre-disturbance ~~reactive current and~~ 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 ~~(from its pre fault level)~~ of *connection point voltage* below 90% of *normal voltage*~~during the fault~~;

(B) inductive reactive current in addition to its pre-disturbance reactive current and 6% of the maximum continuous current of the *generating system* including all operating *generating units* (in the absence of a disturbance) for each 1% increase of *connection point voltage* above 110% of *normal voltage*;

during the disturbance and maintained until the *connection point voltage* recovers to between 90% and 110% of *normal voltage*,

(ii) after *disconnection* of the faulted element, *reactive power* sufficient to ensure that the *connection point voltage* is within the range for *continuous uninterrupted operation* under clause S5.2.5.4; and

(iii) from 100 milliseconds after *disconnection* of the faulted element, *active power* of at least 95% of the level existing just prior to the fault.

Minimum access standard

(c) The *minimum access standard* is:

(1) a *generating system* and each of its *generating units* must remain in *continuous uninterrupted operation* for ~~the~~ up to fifteen disturbances within any five-minute period caused by any combination of the following events~~ that is~~:

(i) a *credible contingency event* other than a fault referred to in subparagraph (iii);

(ii) a single phase to ground, phase to phase or two phase to ground fault in a *transmission system*, or *distribution network*, 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~~:~~

~~(A)~~ the total reduction of *generation* in the *power system* due to that fault would not exceed 100 MW,~~;~~

~~(B) there is unlikely to be an adverse impact on quality of *supply* to other *Network Users*; and~~

~~(C) there is unlikely to be a material adverse impact on *power system security*; and~~

~~(iii) a single phase to ground, phase to phase or two phase to ground fault in a *distribution network*, 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:~~

~~(A) the total reduction of *generation* in the *power system* due to that fault would not exceed 100 MW;~~

~~(B) there is unlikely to be an material adverse impact on quality of *supply* to other *Network Users* or *power system security*; and,~~

~~(C) there is unlikely to be a material adverse impact on *power system security*,~~

provided that none of the events ~~is not one that~~ would *disconnect* the *generating unit* from the *power system* by removing *network elements* from service and that the total time that the *voltage* at the *connection point* is less than 90% of *normal voltage* for 1,000 milliseconds; and

(2) subject to any changed *power system* conditions or energy source availability beyond the *Generator's* reasonable control ~~after *disconnection* of the faulted element, each~~a *generating system* and each of its *generating units* must, in respect of the types of fault described in subparagraphs (1)(ii) and (iii), supply to, or absorb from, the *network*:

(i) to assist the maintenance of *power system voltages* during the fault:

(A) 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;

(B) 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;

during the disturbance and maintained until *connection point voltage* recovers to between 90% and 110% of *normal voltage;*

(ii) after *disconnection* of the faulted element, ~~deliver to the *network*, *active power* and 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 under clause S5.2.5.4~~.~~; and

(iii) from 1,000 milliseconds after *disconnection* of the faulted element, *active power* of at least 95% of the level existing immediately prior to the fault.

Negotiated access standard

(d) A *generating system* and each of its operating *generating units* must be capable of:

(1) *continuous uninterrupted operation* for the range of disturbances; and

(2) supplying and absorbing the *active power*, *reactive power* and reactive current,

specified in the *automatic access standard* except where *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.

(e~~d~~) In carrying out assessments of proposed *negotiated access standards* under this clause S5.2.5.5, the *Network Service Provider* and *AEMO* must take into account, without limitation:

(1) the expected performance of:

(i) existing *networks* and *considered projects*;

(ii) existing *generating plant* and other relevant projects; and

(iii) *control systems* and *protection systems*, including auxiliary systems and *automatic reclose equipment*; and

(2) the expected range of *power system* operating conditions.

(f~~e~~) A proposed *negotiated access standard* may be accepted if the *connection* of the *plant* at the proposed access level would not cause other *generating* ~~generating~~ *plant* or *loads* to trip as a result of an event, when they would otherwise not have tripped for the same event.

(g~~f~~) *AEMO* must advise on matters relating to *negotiated access standards* under this clause S5.2.5.5.

General requirement

(h~~g~~) The *access standard* must include any operational arrangements to ensure the *generating system* including all operating *generating units* will meet its agreed performance levels under abnormal *network* or *generating system* conditions.

(i) For the purposes of paragraphs (b)(2)(i) and (c)(2)(i):

- (i) the reactive current contribution may be limited to:
  - (A) the maximum continuous current of an *asynchronous generating system* including all operating *generating units*; or
  - (B) 250% of the maximum continuous current of a *synchronous generating system* including all operating *generating units*;
- (ii) 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*;
- (iii) the reactive current contribution required may be calculated using phase to phase, phase to ground, or sequence components of *voltage*. When using sequence components, the ratio of negative-sequence to positive-sequence current injection must be agreed with *AEMO* and the *Network Service Provider* for various types of *voltage* disturbances; and
- (iv) the reactive current response must have a *rise time* of no greater than 30 milliseconds, a *settling time* of no greater than 60 milliseconds and must be *adequately damped*;
- (v) any *reactive power* 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*; and
- (vi) any *active power* 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 milliseconds.

S5.2.5.7 Partial load rejection

~~(a)~~ For the purposes of this clause S5.2.5.7 **minimum load** means minimum *sent out generation* for continuous stable operation.

~~(b) This clause S5.2.5.7 does not apply to an *asynchronous generating unit*.~~

Automatic access standard

(c) The *automatic access standard* is a *generating system* ~~*unit*~~ must be capable of *continuous uninterrupted operation* during and following a *power system load* reduction of 30% from its predisturbance level or equivalent impact from separation of part of the *power system* in less than 10 seconds, provided that the *loading level* remains above minimum load.

Minimum access standard

(d) The *minimum access standard* is a *generating system* ~~*unit*~~ must be capable of *continuous uninterrupted operation* during and following a *power system load* reduction of 5% or equivalent impact from separation of part of the *power system* in less than 10 seconds provided that the *loading level* remains above minimum load.

Negotiated access standard

~~(e) If in accordance with clause 5.3.4A the *Generator* and the *Network Service Provider* determine a *negotiated access standard* is to apply, the *Network Service Provider* must consult *AEMO* to ensure that the *negotiated access standard* does not materially adversely affect *power system security*.~~

(f) *AEMO* must advise on matters relating to *negotiated access standards* under this clause S5.2.5.7.

General requirements

(g) The actual partial load rejection performance must be recorded in the ~~*access*~~ <u>*performance*</u> *standards*.

S5.2.5.11 Frequency control

(a) For the purpose of this clause S5.2.5.11:

~~**maximum operating level** means in relation to:~~

~~(1) a *non-scheduled generating unit*, the maximum *sent out generation* consistent with its *nameplate rating*;~~

~~(2) a *scheduled generating unit* or *semi-scheduled generating unit*, the maximum *sent out generation*;~~

~~(3) a *non-scheduled generating system*, the combined maximum *sent out generation* consistent with the *nameplate ratings* of its in-service *generating units*; and~~

~~(4) a *scheduled generating system* or *semi-scheduled generating system*, the combined maximum *sent out generation* of its in-service *generating units*.~~

minimum operating level means in relation to:

(1) a *non-scheduled generating unit*, its minimum *sent out generation* for continuous stable operation;

(2) a *scheduled generating unit* or *semi-scheduled generating unit*, its minimum *sent out generation* for continuous stable operation;

(3) a *non-scheduled generating system*, the combined *minimum operating level* of its in-service *generating units*; and

(4) a *scheduled generating system* or *semi-scheduled generating system*, the combined minimum *sent out generation* of its in-service *generating units*.

~~**pre disturbance level** means in relation to a *generating unit* and a *frequency* disturbance, the *generating unit's* level of output just before the *system frequency* first exceeds the upper or lower limit of the *normal operating frequency band* during the *frequency* disturbance.~~

~~**system frequency** means the *frequency* of the *transmission system* or *distribution system* to which the *generating unit* or *generating system* is *connected*.~~

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

Automatic access standard

(b) The *automatic access standard* is:

(1) a *generating system's* <u>*power transfer*</u> ~~*active power* transfer~~ to the *power system* must not:

(i) increase in response to a rise in <u>*power system frequency* at the *connection point*</u> ~~system frequency~~; or

(ii) decrease in response to a fall in *power system frequency* at the *connection point* ~~system frequency~~;

(2) a *generating system* must be capable of automatically providing a proportional:

(i) decrease in *power transfer* to the *power system* in response to a rise in *power system frequency* at the *connection point*; and~~reducing its *active power* transfer to the *power system*:~~

~~(i) whenever the system frequency exceeds the upper limit of the *normal operating frequency band*;~~

(ii) increase in *power transfer* to the *power system* in response to a fall in *power system frequency* at the *connection point*; and~~ by an amount that equals or exceeds the least of:~~

~~(A) 20% of its maximum operating level times the percentage *frequency* difference between system frequency and the upper limit of the *normal operating frequency band*;~~

~~(B) 10% of its maximum operating level; and~~

~~(C) the difference between the *generating unit's* pre disturbance level and minimum operating level, but zero if the difference is negative; and~~

~~(iii) sufficiently rapidly for the *Generator* to be in a position to offer measurable amounts of lower services to the *spot market* for *market ancillary services*; and~~

~~(3) a *generating system* must be capable of automatically increasing its *active power* transfer to the *power system*:~~

~~(i) whenever the system frequency falls below the lower limit of the *normal operating frequency band*;~~

~~(ii) by the amount that equals or exceeds the least of:~~

~~(A) 20% of its maximum operating level times the percentage *frequency* difference between the lower limit of the *normal operating frequency band* and system frequency;~~

~~(B) 5% of its maximum operating level; and~~

~~(C) one third of the difference between the *generating unit's* maximum operating level and pre disturbance level, but zero if the difference is negative; and~~

~~(iii)~~ sufficiently rapidly and sustained for a sufficient period for the *Generator* to be in a position to offer measurable amounts of *market ancillary services* ~~raise services~~ to the *spot market* for each of the *market ancillary services*.

Minimum access standard

(c) The *minimum access standard* is:

(1) a *generating system* under relatively stable input energy, *power transfer* ~~*active power* transfer~~ to the *power system* must not:

(i~~1~~) increase in response to a rise in *power system frequency* at the *connection point* ~~system frequency~~; or ~~and~~

(ii~~2~~) decrease more than 2% per Hz in response to a fall in *power system frequency* at the *connection point* ~~system frequency.~~;

(2) a *generating system* with a *nameplate rating* of 30MW or more must be capable of automatically providing a proportional:

(i) decrease in *power transfer* to the *power system* in response to a rise in *power system frequency* at the *connection point*; and

(ii) subject to paragraph (c)(i)(ii), increase in *power transfer* to the *power system* in response to a fall in *power system frequency* at the *connection point*, sufficiently rapidly and sustained for a sufficient period for the *Generator* to be in a potion to offer measurable amounts of *market ancillary services* to each of the *spot market* for at least one of the *market ancillary services*.

Negotiated access standard

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

~~(e) The *negotiated access standard* must record the agreed values for maximum operating level and minimum operating level, and where relevant the method of determining the values and the values for a *generating system* must take into account its in-service *generating units*.~~

(f) *AEMO* must advise on matters relating to *negotiated access standards* under this clause S5.2.5.11.

General requirements

(g) Each *control system* used to satisfy this clause S5.2.5.11 must be *adequately damped*.

(h) The amount of a relevant *market ancillary service* for which the *plant* may be registered must not exceed the amount that would be consistent with the *performance standard* registered in respect of this requirement.

(i) For the purposes of paragraphs (b)(2) and (c)(2):

(1) the change in *power transfer* to the *power system* must occur with no delay beyond that required for stable operation, or inherent in the *plant* controls, once *power system frequency* at the *connection point* leaves a dead-band around 50 Hz;

(2) This dead-band must be set within the range 0 to ±1.0 Hz. Different dead-band settings may be applied for a rise or fall in *power system frequency* at the *connection point*;

(3) The *frequency* droop must be set within the range of 2% to 10%; and

(4) A *generating system* is not required to operate below its minimum operating level in response to a rise in *power system frequency* at the *connection point*, or above its *maximum operating level* in response to a fall in *power system frequency* at the *connection point*.

(e) The *performance standard* must record:

(1) the agreed values for *maximum operating level* and minimum operating level and, where relevant, the method of determining the values and the values for a *generating system* must take into account its in-service *generating units;*

(2) the dead-band and droop settings applied; and

(3) the agreed time for sustained response in *power transfer* to a rise or fall in *power system frequency* at the *connection point*.

S5.2.5.13 Voltage and reactive power control

(a) For the purpose of this clause S5.2.5.13:

~~**rise time** means 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.~~

~~**settling time** means 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.~~

static excitation system means in relation to a *synchronous generating unit*, an *excitation control system* that does not use rotating machinery to produce the field current.

Automatic access standard

(b) The *automatic access standard* is:

(1) a *generating system* must have *plant* capabilities and *control systems* sufficient to ensure that:

(i) *power system* oscillations, for the frequencies of oscillation of the *generating unit* against any other *generating unit*, are *adequately damped*;

(ii) operation of the *generating system* does not degrade the damping of any critical mode of oscillation of the *power system*; and

(iii) operation of the *generating system* does not cause instability (including hunting of *tap-changing transformer control systems*) that would adversely impact other *Registered Participants*;

(2) a *control system* must have:

(i) for the purposes of disturbance monitoring and testing, permanently installed and operational, monitoring and recording *facilities* for key variables including each input and output; and

(ii) *facilities* for testing the *control system* sufficient to establish its dynamic operational characteristics;

(2A) all *generating systems* must have a *voltage control system* that:

(i) regulates *voltage* at the *connection point* or another agreed location in the *power system* (including within the *generating system*) to within 0.5% of the setpoint;

(ii) regulates *voltage* in a manner that helps to support *network voltages* during faults and does not prevent the *Network Service Provider* from achieving the requirements of clause S5.1a.3 and S5.1a.4;

(iii) 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 agreed location on the power system, without reliance on a *tap-changing transformer*; and

(iv) has limiting devices to ensure that a *voltage* disturbance does not cause the *system* or any of its *generating units* to trip at the limits of its operating capability;

(3) each ~~a~~ *synchronous generating* ~~*system*~~ *unit* must have an *excitation control system* that:

~~(i) regulates *voltage* at the *connection point* or another agreed location in the *power system* (including within the *generating system*) to within 0.5% of the setpoint;~~

(ii) is able to operate the stator continuously at 105% of *nominal voltage* with *rated active power* output;

~~(iii) regulates *voltage* in a manner that helps to support *network voltages* during faults and does not prevent the *Network Service Provider* from achieving the requirements of clause S5.1a.3 and S5.1a.4;~~

~~(iv) allows the *voltage* setpoint to be continuously controllable in the range of at least 95% to 105% of *normal voltage* at the *connection point* or the agreed location, without reliance on a *tap-changing transformer*;~~

~~(v) has limiting devices to ensure that a *voltage* disturbance does not cause the *generating unit* to trip at the limits of its operating capability;~~

(vi) has an excitation ceiling *voltage* of at least:

(A) for a static excitation system, 2.3 times; or

(B) for other *excitation control systems*, 1.5 times,

the excitation required to achieve *generation* at the *nameplate rating* for rated *power factor*, rated speed and *nominal voltage*;

(vii) has *settling times* for a step change of *voltage* setpoint or *voltage* at the location agreed under subparagraph (2A)(i) of:

(A) generated *voltage* less than 2.5 seconds for a 5% *voltage* disturbance with the *generating unit* not *synchronised*;

(B) *active power*, *reactive power* and *voltage* less than 5.0 seconds for a 5% *voltage* disturbance with the *generating unit synchronised*, from an operating point where the *voltage* disturbance would not cause any limiting device to operate; and

(C) in respect of each limiting device, *active power*, *reactive power* and *voltage* less than 7.5 seconds for a 5% *voltage* disturbance with the *generating unit synchronised*, when operating into a limiting device from an operating point where a *voltage* disturbance of 2.5% would just cause the limiting device to operate;

(viii) is able to increase field *voltage* from rated field *voltage* to the excitation ceiling *voltage* in less than:

(A) 0.05 second for a static excitation system; or

(B) 0.5 second for other *excitation control systems*; and

(ix) has a *power system* stabiliser with sufficient flexibility to enable damping performance to be maximised, with characteristics as described in paragraph (c); and

(x) has reactive current compensation settable for boost or droop; and

(4) the *voltage control system* for a *generating system*~~, other than one~~ comprised of *asynchronous generating units*~~,~~ must have~~ a *voltage control system* that~~:

~~(i) regulates *voltage* at the *connection point* or an agreed location in the *power system* (including within the *generating system*) to within 0.5% of its setpoint;~~

~~(ii) 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;~~

~~(iii) 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 agreed location in the *power system*, without reliance on a *tap changing transformer*;~~

~~(iv) has limiting devices to ensure that a *voltage* disturbance does not cause the *generating unit* to trip at the limits of its operating capability;~~

(v) with the *generating system connected* to the *power system*, ~~has~~ *settling times* for *active power*, *reactive power* and *voltage* due to a step change of *voltage* setpoint or *voltage* at the location agreed under clause subparagraph (2A)(i), of less than:

(A) 5.0 seconds for a 5% *voltage* disturbance with the *generating system connected* to the *power system*, from an operating point where the *voltage* disturbance would not cause any limiting device to operate; and

(B) 7.5 seconds for a 5% *voltage* disturbance with the *generating system connected* to the *power system*, 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;

(vi) ~~has~~ *reactive power rise time*, for a 5% step change in the *voltage* setpoint, of less than 2 seconds; and

(vii) ~~has a *power system* stabiliser with sufficient flexibility to enable damping performance to be maximised, with characteristics as described in paragraph (c); and~~

(viii) ~~has~~ reactive current compensation.

(c) A *power system* stabiliser provided under paragraph (b) must have:

(1) for a *synchronous generating unit*, measurements of rotor speed and *active power* output of the *generating unit* as inputs, and otherwise, measurements of *power system frequency* at the *connection point* and *active power* output of the *generating unit* as inputs;

(2) two washout filters for each input, with ability to bypass one of them if necessary;

(3) sufficient (and not less than two) lead-lag transfer function blocks (or equivalent number of complex poles and zeros) with adjustable gain and time-constants, to compensate fully for the phase lags due to the *generating plant*;

(4) an output limiter, which for a *synchronous generating unit* is continually adjustable over the range of –10% to +10% of stator *voltage*;

(5) monitoring and recording *facilities* for key variables including inputs, output and the inputs to the lead-lag transfer function blocks; and

(6) *facilities* to permit testing of the *power system* stabiliser in isolation from the *power system* by injection of test signals, sufficient to establish the transfer function of the *power system* stabiliser.

Minimum access standard

(d) The *minimum access standard* is:

(1) a *generating system* must have *plant* capabilities and *control systems*, including, if appropriate, a *power system* stabiliser, sufficient to ensure that:

(i) *power system* oscillations, for the frequencies of oscillation of the *generating unit* against any other *generating unit*, are *adequately damped*;

(ii) operation of the *generating unit* does not degrade:

(A) any mode of oscillation that is within 0.3 nepers per second of being unstable, by more than 0.01 nepers per second; and

(B) any other mode of oscillation to within 0.29 nepers per second of being unstable; and

(iii) operation of the *generating unit* does not cause instability (including hunting of *tap-changing transformer control systems*) that would adversely impact other *Registered Participants*;

(2) a *generating system* comprised of *generating units* with a combined *nameplate rating* of 30 MW or more must have *facilities* for testing its *control systems* sufficient to establish their dynamic operational characteristics;

(3) the *voltage control system* for a ~~*generating unit* or~~ *generating system* ~~and each of its *generating units*~~ must ~~have *facilities*~~:

(i) regulates ~~s~~ *voltage* at the *connection point*, or at another agreed location on the *power system* or within the *generating system*, to within 2% of the setpoint~~, *power factor* or *reactive power* as agreed with the *Network Service Provider* and *AEMO*~~;

(ii) regulate *voltage* in a manner that helps to support *network voltages* during faults and does not prevent the *Network Service Provider* from achieving the requirements of clause S5.1a.3 and S5.1a.4;

(iii) allow 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*;

(iv) have limiting devices to ensure that a *voltage* disturbance does not cause the *generating unit* to trip at the limits of its operating capability;

~~where the *connection point nominal voltage* is 100 kV or more,~~ must have ~~*facilities* to regulate *voltage* in a manner that does not prevent the *Network Service Provider* from achieving the requirements of clauses S5.1a.3 and S5.1a.4; or~~ and

(v) where the *generating units* are *embedded generating units* ~~*connection point nominal voltage* is less than 100 kV~~, may have *facilities* to regulate ~~*voltage* or~~ *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 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;

(4) an *excitation control system* for a *synchronous generating unit*~~,~~ that is part of a *generating system* ~~comprised of *generating units*~~ with a ~~combined~~ *nameplate rating* of 30 MW or more~~,~~ must ~~have an *excitation control system* that~~:

~~(i) regulates *voltage* at the *connection point*, or at another agreed location on the *power system* or within the *generating system*, to within 2% of the setpoint, *power factor* or *reactive power* as agreed with the *Network Service Provider* and *AEMO*~~;

(i~~i~~) operate the stator continuously at 102% of *nominal voltage* with *rated active power* output;

~~(iii) regulates *voltage* in a manner that helps to support *network voltages* during faults and does not prevent the *Network Service Provider* from achieving the requirements of clause S5.1a.3 and S5.1a.4;~~

~~(iv) 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*;~~

~~(v) has limiting devices to ensure that a *voltage* disturbance does not cause the *generating unit* to trip at the limits of its operating capability;~~

~~(vi) has limiting devices to ensure that a *voltage* disturbance does not cause the *generating unit* to trip at the limits of its operating capability;~~

(~~v~~ii) have~~s~~ an excitation ceiling *voltage* of at least 1.5 times the excitation required to achieve *generation* at the *nameplate rating* for rated *power factor*, rated speed and *nominal voltage*;

(~~v~~iii) subject to co-ordination under paragraph (j~~i~~), have~~s~~ a *settling* time for a step change of *voltage* setpoint or *voltage* at the location agreed under subparagraph (3)(i):

(A) for *active power*, *reactive power* and *voltage* ~~*time*~~ of less than 5.0 seconds for a 5% *voltage* disturbance with the *generating unit* synchronised, from an operating point where such a *voltage* disturbance would not cause any limiting device to operate; and

(B) in respect of each limiting device, *active power*, *reactive power* and *voltage* less than 25 seconds for a 5% *voltage* disturbance with the *generating unit synchronised*, when operating into a limiting device from an operating point where a *voltage* disturbance of 2.5% would just cause the limiting device to operate;

(i~~x~~v) have~~s~~ over- and under-excitation limiting devices sufficient to ensure that a *voltage* disturbance does not cause the *generating unit* to trip at the limits of its operating capability; and

(5) the *voltage control system* for a *generating system* comprised of *asynchronous generating units* with a ~~combined~~ *nameplate rating* of 30 MW or more ~~and which are *asynchronous generating units*,~~ must ~~have a *control system* that~~:

~~(i) regulates *voltage* at the *connection point*, or at another agreed location on the *power system* or within the *generating system*, to within 2% of the setpoint*power factor* or *reactive power* as agreed with the *Network Service Provider* and *AEMO*;~~

~~(ii) 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;~~

~~(iii) 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 agreed location in the *power system*, without reliance on a *tap changing transformer*;~~

~~(iv) has limit control to ensure that a *voltage* disturbance does not cause the *generating system* or any of its *generating units* to trip at the limits of its operating capability;~~

(i~~v~~) subject to co-ordination under subparagraph (j~~i~~), have~~s~~ a *settling times* for *active power*, *reactive power* and *voltage* due to a step change of *voltage* setpoint or *voltage* at the location agreed under clause subparagraph (3)(i), of less than:

(A) ~~7.~~5.0 seconds for a 5% *voltage* disturbance with the *generating unit* ~~electrically~~ connected to the *power system* from an operating point where such a *voltage* disturbance would not cause any limiting device to operate; and

(B) 25 seconds for a 5% *voltage* disturbance with the *generating unit connected* to the *power system*, 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

~~(iii) has limiting devices to ensure that a *voltage* disturbance would not cause the *generating unit* to trip at the limits of its operating capability.~~

(~~v~~ii) have *reactive power rise time*, for a 5% step change in the *voltage* setpoint, of less than 5 seconds.

Negotiated access standard

(e) If a *generating system* cannot meet the *automatic access standard*, the *Generator* must demonstrate to the *Network Service Provider* why that standard could not be reasonably achieved and propose a *negotiated access standard*.

(f) The *negotiated access standard* proposed by the *Generator* under paragraph (e) must be 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*.

(g) Where *power factor* or *reactive power* regulation modes are included, these are in addition to *voltage* control or excitation control. The *generating system* may operate in any control mode as agreed with the *Network Service Provider* and *AEMO* and must be able to be switched to *voltage* control or excitation control at any time. *Remote control equipment* to change the setpoint and mode of regulation must be provided.

(h~~g~~) *AEMO* must advise on matters relating to *negotiated access standards* under this clause S5.2.5.13.

General requirements

(i~~h~~) A limiting device provided under paragraphs (b), ~~and~~ (c) or (d) must:

(1) not detract from the performance of any *power system* stabiliser; and

(2) be co-ordinated with all *protection systems*.

(j~~i~~) The *Network Service Provider* may require that the design and operation of the *control systems* of a *generating unit* or *generating system* be coordinated with the existing *voltage control systems* of the *Network Service Provider* and of other *Network Users*, in order to avoid or manage interactions that would adversely impact on the *Network Service Provider* and other *Network Users*.

(k~~j~~) Any requirements imposed by the *Network Service Provider* under paragraph (j~~i~~) must be recorded in the *access standard*.

(l~~k~~) The assessment of impact of the *generating units* on *power system* stability and damping of *power system* oscillations shall be in accordance with the guidelines for *power system* stability established under clause 4.3.4(h).

S5.2.5.14 Active power control

(a) The *automatic access standard* is a *generating system* ~~comprised of~~ ~~*generating units*~~ ~~with a combined~~ ~~*nameplate rating*~~ ~~of 30 MW or more~~ must have an *active power control system* capable of:

(1) for a *scheduled generating unit* or a *scheduled generating system*:

(i) maintaining and changing its *active power* output in accordance with its *dispatch instructions*; ~~and~~

(ii) ramping its *active power* output linearly from one level of *dispatch* to another; and

(iii) receiving and automatically responding to signals delivered from the *AGC*, as updated at a rate of once every four seconds;

(2) subject to energy source availability, for a *non-scheduled generating unit* or *non-scheduled generating system*:

(i) automatically reducing or increasing its *active power* output within 5 minutes, at a constant rate, to or below the level specified in an instruction electronically issued by a *control centre*, subject to subparagraph (iii);

(ii) automatically limiting its *active power* output, to below the level specified in subparagraph (i); and

(iii) not changing its *active power* output within 5 minutes by more than the raise and lower amounts specified in an instruction electronically issued by a *control centre*; and

(3) subject to energy source availability, for a *semi-scheduled generating unit* or a *semi-scheduled generating system*:

(i) automatically reducing or increasing its *active power* output within 5 minutes at a constant rate, to or below the level specified in an instruction electronically issued by a *control centre*;

(ii) automatically limiting its *active power* output, to or below the level specified in subparagraph (i);

(iii) not changing its *active power* output within 5 minutes by more than the raise and lower amounts specified in an instruction electronically issued by a *control centre*; ~~and~~

(iv) ramping its *active power* output linearly from one level of *dispatch* to another~~.~~; and

(v) receiving and automatically responding to signals delivered from the *AGC*, as updated at a rate of once every four seconds.

Minimum access standard

(b) The *minimum access standard* is a *generating system* ~~comprised of~~ ~~*generating units*~~ ~~with a combined~~ ~~*nameplate rating*~~ ~~of 30 MW or more~~ must have an *active power control system* capable of:

(1) for a *scheduled generating unit* or a *scheduled generating system*:

(i) ~~,~~ maintaining and changing its *active power* output in accordance with its *dispatch instructions*; and

(ii) receiving and automatically responding to signals delivered from the *AGC*, as updated at a rate of once every four seconds

(2) for a *non-scheduled generating system*:

(i) reducing its *active power* output, within 5 minutes, to or below the level required to manage *network* flows that is specified in a verbal instruction issued by the *control centre*;

(ii) limiting its *active power* output, to or below the level specified in subparagraph (i); and

(iii) subject to energy source availability, ensuring that the change of *active power* output in a 5 minute period does not exceed a value specified in a verbal instruction issued by the *control centre*; and

~~(iv) being upgraded to receive electronic instructions from the *control centre* and fully implement them within 5 minutes; and~~

(3) subject to energy source availability, for a *semi-scheduled generating unit* or a *semi-scheduled generating system*:

(i) ~~,~~ maintaining and changing its *active power* output in accordance with its *dispatch instructions*~~.~~;

(ii) not changing its *active power* output within five minutes by more than the raise and lower amounts specified in an instruction electronically issued by a *control centre*; and

(iii) receiving and automatically responding to signals delivered from the *AGC*, as updated at a rate of once every four seconds.

Negotiated access standard

(c) A *negotiated access standard* may provide that if the number or frequency of verbal instructions becomes difficult for a *control centre* to manage, *AEMO* may require the *Generator* to upgrade its *facilities* to receive electronic instructions and fully implement them within 5 minutes.

(d) The *negotiated access standard* must document to *AEMO's* satisfaction any operational arrangements necessary to manage *network* flows that may include a requirement for the *non-scheduled generating system* to be operated in a manner that prevents its output changing within 5 minutes by more than an amount specified by a *control centre*.

(e) *AEMO* must advise on matters relating to *negotiated access standards* under this clause S5.2.5.14.

General requirements

(f) Each *control system* used to satisfy the requirements of paragraphs (a) and (b) must be *adequately damped*.

S5.2.5.15 System Strength

Minimum access standard

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

S5.2.6 Monitoring and control requirements

S5.2.6.1 Remote Control and Monitoring

Automatic access standard

(a) The *automatic access standard* is a *generating system*~~:~~

~~(1) *scheduled generating unit*;~~

~~(2) *scheduled generating system*;~~

~~(3) *non-scheduled generating unit* with a *nameplate rating* of 30 MW or more;~~

~~(4) *non-scheduled generating system* with a combined *nameplate rating* of 30 MW or more;~~

~~(5) *semi-scheduled generating unit*; or~~

~~(6) *semi-scheduled generating system*,~~

must have *remote monitoring equipment* and control equipment to transmit to, and receive from, *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.

(b) The quantities referred to under paragraph (a) that *AEMO* may request include:

(1) in respect of a *generating system*:

(i) the status of all switching devices that carry the *generation*;

(ii) *tap-changing transformer* tap position(s) and *voltages*;

(iii) *active power* and *reactive power* aggregated for groups of identical *generating units*;

(iv) either the number of identical *generating units* operating or the operating status of each non-identical *generating unit*;

(v) *active power* and *reactive power* for the *generating system*;

(vi) *voltage control* setpoint and mode (where applicable);

(2~~1~~) in respect of a *generating unit* with a *nameplate rating* of 30 MW or more:

(i) current, *voltage*, *active power* and *reactive power* in respect of *generating unit* stators or power conversion systems (as applicable);

~~(ii) the status of all switching devices that carry the *generation*; and~~

~~(iii) *tap-changing transformer* tap position;~~

~~(2) in respect of a *generating system* that includes a *generating unit* with a *nameplate rating* of less than 30 MW:~~

~~(i) its connected status, *tap-changing transformer* tap position and *voltages*;~~

~~(ii) *active power* and *reactive power* aggregated for groups of identical *generating units*;~~

~~(iii) either the number of identical *generating units* operating or the operating status of each non-identical *generating unit*; and~~

~~(iv) *active power* and *reactive power* for the *generating system*;~~

(3) in respect of an auxiliary supply system with a capacity of 30 MW or more associated with a *generating unit* or *generating system*, *active power* and *reactive power*;

(4) in respect of *reactive power* equipment that is part of a *generating system* but not part of a particular *generating unit*, its *reactive power*;

(5) in respect of a ~~wind farm type of~~ *semi-scheduled generating system* all data specified as mandatory in the relevant *energy conversion model* applicable to that type of *semi-scheduled generating system*;~~:~~

~~(i) wind speed;~~

~~(ii) wind direction;~~

~~(iii) ambient temperature; and~~

(6) in respect of a *scheduled generating system* or *semi-scheduled generating system:*

(i) maximum *active power* limit;

(ii) minimum *active power* limit;

(iii) maximum *active power* raise ramp rate; and

(iv) maximum *active power* lower ramp rate;

(7) in respect of a energy storage system, the available energy (in MWh);

(8) in respect of a run-back scheme agreed with the *Network Service Provider*:

(i) run-back scheme status; and

(ii) *active power*, *reactive power* or other control limit, as applicable;

(9) 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*; and

(10~~6~~) any other quantity that *AEMO* reasonably requires to discharge its *market* and *power system security* functions as set out in Chapters 3 and 4.

(c) The remote control quantities referred to under paragraph (a) that *AEMO* may request include:

(1) in respect of a *generating system*:

(i) *voltage control* setpoint;

(ii) *voltage control* mode (where applicable); and

(2) in respect of a *scheduled generating system* or *semi-scheduled generating system*:

(i) *AGC* control; and

(3) in respect of a *non-scheduled generating system*:

(i) *active power* limit; and

(ii) *active power* ramp limit.

Minimum access standard

(d~~c~~) The *minimum access standard* is a *generating system* must have *remote monitoring equipment* and control equipment to 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.~~:~~

~~(1) *scheduled generating unit*;~~

~~(2) *scheduled generating system*;~~

~~(3) *non-scheduled generating system* with a combined *nameplate rating* of 30 MW or more;~~

~~(4) *semi-scheduled generating unit*; or~~

~~(5) *semi-scheduled generating system*,~~

~~must have *remote monitoring equipment* to transmit to *AEMO's control centres* in real time:~~

~~(6) the *active power* output of the *generating unit* or *generating system* (as applicable);~~

~~(7) if *connected* to a *transmission system*, the *reactive power* output of the *generating unit* or *generating system* (as applicable); and~~

~~(8) if a wind farm type of *generating system*:~~

~~(i) number of units operating;~~

~~(ii) wind speed; and~~

~~(iii) wind direction,~~

~~in accordance with rule 4.11.~~

(e) The remote monitoring quantities referred to under paragraph (d) that *AEMO* may request include:

(1) in respect of a *generating system connected* to a *transmission system*, or *connected* to a *distribution system* with a *nameplate rating* of 30 MW or more:

(i) the status of all switching devices that carry the *generation*;

(ii) *tap-changing transformer* tap position(s) and *voltages*;

(iii) *active power* and *reactive power* for the *generating system*;

(iv) *voltage control* setpoint and mode (where applicable); and

(v) in respect of *reactive power* equipment that is part of the *generating system* but not part of a particular *generating unit*, its *reactive power*;

(2) in respect of a *generating unit* with a *nameplate rating* of 30 MW or more, current, *voltage*, *active power* and *reactive power* in respect of *generating unit* stators or power conversion systems (as applicable);

(3) in respect of an auxiliary supply system with a capacity of 30 MW or more associated with a *generating unit* or *generating system*, *active power* and *reactive power*;

(5) in respect of a *semi-scheduled generating system* all data as specified in the relevant *energy conversion model* applicable to that type of *semi-scheduled generating system*;

(5) in respect of a *scheduled generating system* or *semi-scheduled generating system:*

(i) maximum *active power* limit;

(ii) minimum *active power* limit;

(iii) maximum *active power* raise ramp rate;

(iv) maximum *active power* lower ramp rate;

(v) *AGC*;

(7) in respect of an energy storage system, the available energy (in MWh);

(8) in respect of a run-back scheme agreed with the *Network Service Provider*:

(i) run-back scheme status; and

(ii) *active power*, *reactive power* or other control limit as applicable;

(9) 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*; and

(10) any other quantity that *AEMO* reasonably requires to discharge its *market* and *power system security* functions as set out in Chapters 3 and 4.

(f) The *remote control* quantities referred to in paragraph (e) that *AEMO* may request include:

(1) in respect of a *generating system*:

(i) *voltage control* setpoint;

(ii) *voltage control* mode (where applicable); and

(2) in respect of a *scheduled generating system* or *semi-scheduled generating system:*

(i) *AGC* controls; and

(3) in respect of a *non-scheduled generating system*:

(iv) *active power* limit; and

(v) *active power* ramp limit.

Negotiated access standard

(g~~d~~) *AEMO* must~~may~~ advise on matters relating to *negotiated access standards* under this clause S5.2.6.1.

GLOSSARY

Amended Definitions

continuous uninterrupted operation

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 not to exacerbate or prolong the disturbance or cause a subsequent disturbance for other *connected plant.*

New Definitions

maximum operating level

In relation to:

(1) a *non-scheduled generating unit*, the maximum *sent out generation* consistent with its *nameplate rating*;

(2) a *scheduled generating unit* or *semi-scheduled generating unit*, the maximum *generation* to which it may be *dispatched* and as provided to *AEMO* in the most recent *bid and offer validation data*;

(3) a *non-scheduled generating system*, the combined maximum *sent out generation* consistent with the *nameplate ratings* of its in-service *generating units*; and

(4) a *scheduled generating system* or *semi-scheduled generating system*, the combined maximum *generation* of its in-service *generating units* to which it may be *dispatched* and as provided to *AEMO* in the most recent *bid and offer validation data*.

rise time

In relation to 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.

settling time

In relation to 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.

TRANSITIONAL RULES

11.X Rules Consequential on the making of the National Electricity Amendment (Generator Technical Requirements) Rule 201X

11.X.1 Definitions

Amending Rule means the XYZ Rule.

commencement date means the date on which the Amending Rule commences operation.

transition date means the date *AEMO* request that the *AEMC* make the Amending Rule was submitted to the *AEMC*.

11.X.1.1 Application of Amending Rule to connection agreements

(a) The Amending Rule applies from the transition date in respect of all *connection applications* for new or altered *generating systems* or *generating units* made before the commencement date where the *performance standards* have not yet been finalised as at the transition date.

(b) If a *performance standard* agreed on or after the transition date is below the level of the applicable *minimum access standard* specified in the Amending Rule:

(i) for the purposes of the *Rules* and unless, in *AEMO's* reasonable opinion, there are extenuating circumstances, from the commencement date, the applicable *minimum access standard* applies to the exclusion of the relevant *performance standard*; and

(ii) the *Connection Applicant* and *Network Service Provider* must negotiate an amendment to the *performance standard* to ensure it is consistent with the Amending Rule and, where the relevant *minimum access standard* is an *AEMO advisory matter*, the *Network Service Provider* must first consult with, and have received advice from, *AEMO*.

(c) *AEMO* may exempt a *performance standard* from the application of paragraph (b) where AEMO considers that the *performance standard* will not adversely affect *power system security*.

(d) Any action taken by *AEMO* or a *Network Service Provider* prior to the commencement date in anticipation of the commencement of the Amending Rule is deemed to have been taken for the purpose of the Amending Rule and continues to have effect for that purpose.