Electricity

Inquiry into the licensing arrangements for generators in South Australia

FINAL REPORT

August 2017

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The work of the Commission is the result of many people's contributions and this project is no different; however, special mention is required for those individuals who made significant and substantial contributions to this Inquiry:

- Kara O'Sullivan, and
- Kate Morrison.

Table of contents

Glossary of terms

Addendum to AEMO's Final Advice	Addendum to Final Advice: Recommended Technical Standards For Generator Licensing In South Australia: Advice to ESCOSA — prepared by AEMO, published August 2017
AEC	Australian Energy Council
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AGC	Automatic generation control
AGL	AGL Energy
ARENA	Australian Renewable Energy Agency
AS TAG	AEMO's Ancillary Services Technical Advisory Group
Black System event	South Australian Black System event of 28 September 2016
CEC	Clean Energy Council
CIGRE	International Council on Large Electric Systems (or more formally in French, Conseil International des Grands Réseaux Électriques)
CoAG Energy Council	Council of Australian Governments Energy Council
Commission	Essential Services Commission, established under the Essential Services Commission Act 2002
DNSP	Distribution network service provider
DPC	South Australian Government, Department of Premier and Cabinet
Draft Report	Draft Report on the Inquiry into licensing arrangements for generators
DSD	South Australian Government, Department of State Development
ElectraNet	ElectraNet Pty Ltd — the South Australian transmission network service provider
Electricity Act	Electricity Act 1996
EMT	Electromagnetic transient
ENA	Energy Networks Association
ESIPC	Electricity Supply Industry Planning Council
ESC Act	Essential Services Commission Act 2002
ETR	Energy and Technical Regulation Division of the South Australian Government's Department of Premier and Cabinet
EWOSA	Energy and Water Ombudsman SA
FCAS	Frequency Control Ancillary Services
FERC	Federal Energy Regulatory Commission

FFR	Fast frequency response
Final Advice	Recommended technical standards for generator licensing in South Australia: Advice to ESCOSA — prepared by AEMO, published 31 March 2017
Finkel Review	Blueprint for the Future: Independent Review into the Future Security of the National Electricity Market, Final Report, Dr Alan Finkel AO, Chief Scientist for Australia, Chair of the Expert Panel, Ms Karen Moses FAICD, Ms Chloe Munro, Mr Terry Effeney, Professor Mary O'Kane AC, published 9 June 2017
FOS	Frequency Operating Standard
FPSS	AEMO's Future Power System Security program
GPS	Generator performance standards
GWh	Gigawatt hour
HV	High voltage
HVRT	High voltage ride-through
HWF2	Hornsdale Wind Farm Stage 2
Hz	Hertz
Issues Paper	Issues Paper on the Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators published 2 December 2016
kVA	kilovolt ampere
LV	Low voltage
LVRT	Low voltage ride-through
MASS	Market Ancillary Service Specification
Minister	Minister for Mineral Resources and Energy
MW	Megawatt
ms	milliseconds
NEM	National Electricity Market
NER	National Electricity Rules
NERC	North American Electric Reliability Corporation
NSP	Network service provider
PACE	Plan for Accelerating Exploration (PACE) program — the South Australian Government's gas incentives program
Panel	AEMC's Reliability Panel
PV	Photovoltaic
RET	Renewable Energy Target
RoCoF	Rate of change of frequency

Rules	National Electricity Rules
Rule change request	A person (such as an individual, company or Government) (the proponent) requests in writing the Australian Energy Market Commission to make a Rule
SAPN	SA Power Networks – the South Australian distribution network provider
SCADA	Supervisory control and data acquisition
SCR	Short circuit ratio
secs	seconds
SRAS	System Restart Ancillary Services
Technical Regulator	The Technical Regulator as appointed under section 7 of the Electricity Act 1996
TNSP	Transmission network service provider
US, USA	United States of America
X/R ratio	Ratio of system inductive to resistive impedance

Executive Summary

The Essential Services Commission (**Commission**) has conducted an Inquiry (under Part 7 of the Essential Services Commission Act 2002) to determine whether or not there should be any changes to its technical licensing conditions for electricity generators connected to the National Electricity Market (**NEM**). In particular, the Commission has inquired into:

- whether the current conditions for the connection of grid-scale wind-powered electricity generators should be removed, retained or varied, and
- whether any additional or amended conditions should be imposed on other grid-scale power inverter-connected electricity generators (such as solar generation) or other generation technologies and sources (including conventional synchronous generation).

The technical conditions are in place because current national regulatory frameworks and arrangements do not deal adequately with the technical and system impacts of new electricity generation technologies in South Australia, particularly where those are intermittent or otherwise variable. Were such a framework in place, specific local licence conditions may be unnecessary.

The Commission's overall findings and conclusions, reached having considered technical advice from the Australian Energy Market Operator (**AEMO**) and with the benefit of stakeholder submissions obtained through a public consultation process, are that:

- South Australian consumers require a modern, secure, resilient and reliable power system that delivers to them electricity of an appropriate quality standard
- the South Australian power system is undergoing a fundamental transformation, with the technical and system impacts of that transformation not adequately dealt with under the existing national regulatory framework
- during this transformation the power system must integrate all generation technologies including existing and new — into an appropriately diversified generation portfolio that provides energy and essential system security services that meet South Australians' needs
- the provisions of the National Electricity Rules and associated instruments and arrangements do not yet cater for the efficient integration of a changing mix of generation technologies in the South Australian sector of the NEM
- all new generators, regardless of technology or type, seeking to connect to the South Australian power system must have the capabilities to contribute to a secure and resilient power system that meets the modern (and future) needs of South Australian consumers
- there is, therefore, a need for the Commission to continue to impose transitional technical conditions within licences for new electricity generators which are to be connected to the NEM (regardless of generation type) – on the basis that this will assist the Commission in meeting its paramount statutory objective (under the Essential Services Commission Act 2002) of protecting South Australian consumers' long-term interests with respect to the price, quality and reliability of electricity services
- those transitional technical conditions, which will be consistent with and not duplicate existing national rules and frameworks, will require new generators to be better able to:
    - ride through power system disturbances without prematurely disconnecting and also be available to assist with remediating contingency events

- control their energy output to maintain stable operation of the power system (as well as being able to assist with the control of voltage and frequency, if required)
- manage and control voltages to support the network during disturbances and to efficiently transfer power
- be capable of operating in weak system conditions (where limited fault current is available), and
- assist with power system restoration, should there be a major outage on the power system.

- while the new technical conditions will not apply to existing generators at this time, over the coming year (2017-18) the Commission will work with AEMO, network service providers and existing generators to understand the extent to which additional services could be provided by those generators in a cost-efficient manner, and
- the Commission will monitor and review developments in this sector – with a particular focus on changes in NEM rules and associated arrangements – with a view to removing its local technical licence conditions.

The Commission has decided not to impose a requirement on generators to provide electrical inertia (or a fast frequency response) at this time, given other recent regulatory and statutory developments in this area. Among those are a new proposed change to the national electricity rules that aims to require network service providers to provide a threshold level of inertia and for the institution of a new market to facilitate the delivery of inertia above that minimum level.

Overall, the Commission's new conditions will enable all new generators to incorporate cost-effective features to contribute towards a secure and resilient power system as it evolves over time. They will assist in promoting the security, resilience, and reliability of the South Australian power system under a range of scenarios, including the potential for a greater proportion of non-synchronous and other new generation technologies.

Nevertheless, the Commission confirms its position that, were a robust national framework in place for the connection of new generation technologies, specific licence conditions in South Australia may be unnecessary and the licence conditions could be removed.

Background to this Inquiry

This is the third review that the Commission has undertaken into this matter, following reviews in 2005 and 2010.

In those first two reviews, there was a focus on wind-powered electricity generators. This reflected the large numbers of such proposals emerging at the time and the need to integrate them into the South Australian power system in a way that promoted ongoing system stability. The emergence of those proposals was driven by a combination of government policies, particularly the national Renewable Energy Target, as well as the significant wind resource available in South Australia in relatively close proximity to the transmission system.

The finding of those earlier reviews was that NEM rules and arrangements did not, at that time, adequately cater for that integration of new electricity generation technologies. As a result, the Commission developed and imposed additional technical licence conditions as an interim measure, pending changes to those rules and arrangements.

Since 2010, the underlying generation mix in South Australia has changed markedly. There has been a shift from large or grid-scale, centrally-dispatched, synchronous generation towards distributed and intermittent (or variable) non-synchronous generation, connected to the power system through solid state power converters. These include wind-powered electricity generators, as well as a growing proportion of non-dispatched solar photovoltaic systems throughout the distribution grid.

However, the national rules and arrangements have not developed in a similar fashion to meet the challenges presented by the rapid emergence of these new technologies.

Absent those changes, and in the context of its existing technical licence conditions and the changing market in this State, the Commission determined it appropriate to conduct a further review of the licence conditions.

Specific findings and conclusions

The Commission's specific findings and conclusions on the matters relevant to this Inquiry are as follows.

1. Disturbance ride-through capability

The licence conditions for disturbance ride-through capability (and reactive power capability) will be amended and expanded for all new generators to include greater detail in the following areas:

- active power and reactive power responses to a variety of network disturbances
- under and over-voltage disturbance ride-through
- a requirement for generators to remain in continuous uninterrupted operation for a number of repeated fault events
- power system load reduction (partial load rejection), and
- stronger frequency disturbance ride-through capabilities.

2. Voltage control capability

The reactive power capability licence conditions specifically relating to voltage control will be restated for all new generators to incorporate the following intent:

- The generating system must be capable of control by a fast-acting, continuously variable, voltage control system. The voltage control system must be able to receive a local and remote voltage set point.
- The generating system may operate at either a set reactive power, or a set power factor, which is able to be set locally or remotely at any time.
- The voltage, power factor or reactive power control mode of the generating system must be capable of:
    - being overridden by the disturbance ride through requirements during power system disturbances, and
    - automatically reverting to the selected control mode when the disturbance has ceased.

3. Active power control capability

All new generators will be required to incorporate active power control facilities that are capable of:

- providing an automatic active power response to frequency changes
- responding to automatic generation control signals from AEMO
- adjusting the rate of change of active power, and
- communicating the status of its active power controls to AEMO in real time — enabling remote monitoring of the generating unit's active power control settings.

4. System restoration capability

All new generating systems, in the event of a black system and while system load is being restored, will be required to be capable of:

- operating with auxiliary loads only (for a duration to be specified), and
- providing steady-state and dynamic reactive power when operating with auxiliary loads.

5. System strength capability

All new generators will be required to be capable of:

- Individual components of plant within a generating system, which includes but is not limited to generating units and dynamic reactive power plant, must be capable of operating down to the following levels at the high voltage terminals in relation to each component:
    - minimum short circuit ratio of 1.5, and
    - minimum positive sequence system inductive to resistive impedance ratio of 2.

6. Application of new conditions to existing licensees

The Commission will work with licensees to ascertain where assistance could be provided to improve the stability and security of the power system. The Commission considers that, where possible, current generator licensees should provide the additional capabilities and services to the power system to meet the very specific challenges faced in South Australia. Further engagement with licensees and other stakeholders including AEMO and network service providers will be undertaken to progress this matter.

As part of that process, the Commission will consider whether developments in the sector mean that there is still a need to consider additional requirements for existing generators. If there is a need, the Commission will work with AEMO and licensees to seek additional information such as:

- the specific technical capabilities of current generating units or systems with respect to the new technical standards established through this Inquiry
- the physical or technical limitations in meeting the new technical standards, and
- the need for, and cost of, any upgrades that may be required to satisfy the new technical standards.

Implementation and next steps

Model licence conditions reflecting this Inquiry findings and conclusions have been developed and are available for review alongside this Inquiry Report. The model conditions will be applicable to all new applications from the date of publication of this report, having regard to advice from AEMO on the specific circumstances of individual applications received.

Depending on the specific characteristics of a given generation project, the model conditions may be varied to the degree necessary to ensure that South Australian consumers' long-term interests with respect to the price, quality and reliability of electricity services are protected.

1 Introduction

1.1 Purpose of this Inquiry

In June 2016, the Commission commenced an Inquiry under Part 7 of the Essential Services Commission Act 2002 (ESC Act) into the licence conditions that should apply to the electricity generators it licenses under the Electricity Act 1996 (Electricity Act). This is the third review that the Commission has conducted into similar matters — following earlier reviews of licence conditions for wind-powered generators in 2005 and 2010.

Since the 2005 review, the Commission has placed additional conditions on wind-powered generators, requiring them to meet the highest performance standards under the National Electricity Rules (NER).

A key focus for the current Inquiry was whether or not those existing conditions should be maintained, enhanced or otherwise altered, and included a consideration of their application to other emerging electricity generators or other parties.

The technical conditions are in place because the national framework does not deal adequately with the technical and system impacts of intermittent (or variable) electricity generators. Were such a framework in place for existing variable electricity generators and other emerging generation and storage technologies, specific licence conditions in South Australia might be unnecessary.

The Commission has undertaken this Inquiry to review whether the technical standards applicable to electricity generators connecting to the power system in South Australia continue to meet the Commission's objectives for consumers in this State, today and in to the future.

1.2 Scope of this Inquiry

This Inquiry has focused on the technical standards to be included in the licensing requirements for electricity generators to determine whether additional requirements continue to be required for South Australia and, if so, what form they should take and to whom they should apply. In particular, the Commission has inquired into:

- whether the current licence conditions for the grid connection of wind-powered electricity generators should be removed, retained or varied
- whether any additional or amended technical requirements should be imposed on other grid-scale power converter-connected electricity generators (such as solar generation) or other generation technologies and sources (including conventional synchronous generation).

During the course of this Inquiry, it became evident that limiting the analysis to emerging variable technologies would be sub-optimal, and that the interests of consumers would be best served by reviewing the technical standards for all generator technologies and types.

1.3 Advice from the Australian Energy Market Operator

In undertaking this Inquiry, the Commission sought technical advice from the Australian Energy Market Operator (AEMO) — the system operator of the National Electricity Market (NEM). AEMO has substantial technical expertise and in-depth knowledge of power system operation and power system security matters. AEMO has also provided the Commission with advice on similar matters on previous occasions. Furthermore, since being engaged by the Commission, AEMO has had a particular focus on

South Australia arising from its investigations into the black system event of 28 September 2016 (**Black System event**).[1]

The Commission requested that AEMO provide advice in relation to the following matters:

1. The currency of the existing licence conditions relating to technical standards for wind farms connecting to the South Australian electricity network and whether they should be retained, removed or varied.
2. If the existing licence conditions are to be retained, removed or varied, how this should be effected?
3. Whether there is merit in imposing additional technical licence conditions on other invertor connected generation technologies (for example photo-voltaic generators or batteries) to improve power system security in South Australia, and how and why this should be effected?

In requesting this advice, the Commission emphasised the need for AEMO to have regard to current (and developing) requirements of the NER to ensure that any recommendations regarding new technical licence conditions were necessary to address gaps in that framework. Further, the Commission noted the importance of its primary statutory objective: to protect the long-term interests of South Australian consumers with respect to the price, quality and reliability of electricity supply.

During the course of the Inquiry, AEMO provided the Commission with four separate pieces of advice:

1. Preliminary Advice, dated 9 September 2016, which stated that there was a need for the current licence conditions applying to wind generators to remain, albeit with potential revisions, and for the Commission to consider applying specific additional licence conditions regarding technical capabilities to other generation technologies.
2. Interim Advice, dated 24 February 2017, which advised that AEMO was considering a broad range of additional licence conditions on new generation licence applicants and also sought to inform the industry of the possible direction its advice might take.
3. Final Advice, dated 31 March 2017, which, following submissions to the Commission's Issues Paper,[2] set out AEMO recommendations on what technical capabilities should be imposed as licence conditions.[3]
4. An addendum to its Final Advice, dated 1 August 2017, which, following submissions to the Commission's Draft Report, sets out AEMO's final recommendations on what technical capabilities should be imposed as licence conditions.[4]

In addition to the provision of written advice, a number of AEMO representatives presented at the Stakeholder Workshop held in Adelaide on 16 May 2017 and have provided technical support to the Commission in drafting the licence conditions that are set out in Appendix C. The Commission acknowledges the advice and assistance provided by AEMO over the last 12 months, which has been a valuable input into its inquiry process.

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1 This event resulted in the entire outage of the power system across the State and AEMO's detailed report into the matter may be accessed at: www.aemo.com.au.

2 The Commission's, Issues Paper: *Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators*, 2 December 2016, available at: http://bit.ly/GeneratorInquiryIssuesPaper.

3 AEMO, *Recommended technical standards for generator licensing in South Australia*, Final advice to the Commission, 31 March 2017, available at http://bit.ly/Inquiry-SAGeneratorLicensingArrangements-RecommendedTechnicalStandards-AEMOAdvice.

4 AEMO's Addendum to its Final Advice (of 1 August 2017) must be read in conjunction with its Final Advice (of 31 March 2017) which may be found at Appendix E.

1.4 AEMO's intention to submit a Rule change

In its Final Advice, AEMO reinforced that it seeks to maintain a consistent NEM wide, technology-permissive approach to generator performance standards and that the long-term interests of consumers would be best served with a consistent national framework.

AEMO has stated that the need for state-based technical standards indicates that the generator performance standards in the NER require updating to reflect the changing power system. AEMO advised the Commission that the NER should be updated as soon as practicable and that it intends to submit a Rule change to the Australian Energy Market Commission (AEMC) shortly.

AEMO has stated that its recommendations to the Commission will form a key consideration in its upcoming Rule change request.

1.5 Structure of this Report

The rest of this Final Report discusses the Commission's decisions in more detail, as follows:

- Chapter 2 explains the context for the Inquiry, including the factors the Commission considered in making its decisions.
- Chapter 3 sets out the consultation process undertaken, the submissions received and responds to the non-technical issues raised.
- Chapter 4 explains the reasons underpinning the Commission's decisions on the specific technical standards to apply to all new generators.
- Chapter 5 explains the process the Commission will follow in working with existing licensed generators to contribute to a more stable power system.
- Chapter 6 outlines the next steps.

2 The context for this Inquiry

South Australian consumers deserve a modern, secure, resilient and reliable power system that delivers electricity of an appropriate quality standard.

All new generators, regardless of technology or type, seeking to connect to the South Australian power system must have the capabilities to contribute to a secure and resilient power system that meets the modern (and future) needs of South Australian consumers.

The Commission's instruments in meeting its primary objective for electricity consumers include:

- establishing technical standards through its licences for market participants including generators, transmission and distribution network service providers
- establishing service standards through the Electricity Transmission Code, and
- establishing service standards through the Electricity Distribution Code.

The Inquiry is in relation to the first of these instruments and, specifically, in relation to implementing the most appropriate technical standards through the licensing of generators seeking to connect to the South Australian power system.

2.1 Background

The Commission's primary objective under the ESC Act is to protect the long-term interests of South Australian consumers with respect to the price, quality and reliability of essential services.

The Commission's role and functions in the electricity sector are set out in the Electricity Act. One of those functions is to license electricity generators. Under the Electricity Act, a person is not permitted to generate electricity (other than for their own use or if the generator is small with a maximum nameplate output of 100 kVA or less) unless they hold a licence issued by the Commission.[5]

In performing that function, the Commission has, since 2005, put in place, through licence conditions under the Electricity Act, additional technical requirements for wind-powered electricity generators in South Australia. Those conditions oblige wind-powered electricity generation licensees to provide additional capability and performance to support the network.

2.1.1 Past reviews into generator licensing

The need for these conditions was first identified by the Commission in a 2005 review, the scope and findings of which were further reviewed and confirmed by the Commission in 2010. Those reviews occurred in the context of the then growing interest in wind-powered electricity generation in this State. They identified that the interest was driven by the development of technologies and national climate change policy responses, with South Australia the focal point of that interest given the availability of high quality wind resources in this State and their proximity to the transmission network.

Through both the 2005 and 2010 reviews, the Commission identified that, given the different technical characteristics of wind-powered electricity generators and the likely level of investor interest in bringing such technology to market, the then prevailing provisions of the NER did not adequately cater for their integration into the South Australian power system.[6]

[5] For a more detailed description of the legal framework refer to Appendix A.
[6] For a more detailed discussion of the history of this matter refer to Appendix B.

Absent those requirements, wind-powered generators could have operated in South Australia with capabilities lower than those suitable for the future South Australian power system because of the NER's negotiation framework for network connections. While the NER has provision for higher technical standards, there was a risk that generators would only be obliged to meet the minimum standards.

The existing national regulatory framework has not, to date, had the flexibility and speed to change to meet the new challenges presented by the rapid emergence of these new technologies. The Commission has been driving change in this area since 2005, when it first introduced special licence conditions to cater for the differing electrical and physical characteristics of wind-powered generators compared to existing conventional generators.

2.1.2 Wind generator licence conditions to 2017

In that context, the Commission's licence conditions required licensees to have plant and equipment in place to meet the highest standards permitted (but not required) under the NER for access to the network in terms of their ability to ride through faults and disturbances on the network and to provide reactive power. Specifically, they require large wind-powered electricity generators connected to the network to:

- have a capability at the highest standard provided under the NER, to ride through a fault or event on the power system (referred to as the fault ride-through capability), and
- generate and absorb reactive power and to control voltage during and immediately after a fault at the highest standard provided under the NER (referred to as reactive power capability). This additional capability is required so that:
  - a contribution to local voltage control is made during, and immediately, after a disturbance, and
  - the impact of further wind-powered electricity generators on the power system would be minimised, thereby deferring the time at which voltage control might become an issue.

The conditions also imposed requirements in relation to:

- central dispatch[7]
- wind forecasting[8]
- ancillary services,[9] and
- medium sized wind-powered electricity generators rated at between five and 30 MW (which have lesser technical requirements placed on them).[10]

In implementing the conditions, the Commission recognised that a state-based licensing solution is a second-best outcome and that these technical matters ought to be addressed at the national level (through the NER). In that sense, the Commission has always regarded these licence conditions as transitional.

7 Wind generators must not apply to be classified as a non-scheduled generator under the NER.
8 Under the NER, all semi-scheduled wind generators are required to provide data for wind forecasting and the wind licence conditions extend this to all wind generation in South Australia.
9 To ensure that the performance of wind generators is considered in the allocation of the costs of ancillary services, all wind generators in South Australia must be registered as market generators.
10 The need, or otherwise, for these smaller generators to be classified as semi-scheduled is assessed on a case by case basis.

2.2 A changing power system

Since 2010, the underlying generation mix in South Australia has changed markedly. There has been a shift from large-scale, synchronous, centrally-dispatched generation towards distributed and intermittent (or variable) non-synchronous generation, connected to the power system through solid state inverters or power converters. These include wind-powered electricity generators, as well as a growing proportion of non-dispatched rooftop solar photovoltaic (PV) generating systems throughout the distribution grid.

The displacement of thermal power stations (such as at Port Augusta) and the proliferation of wind and power converter-connected generation sources was never anticipated nor was it adequately catered for under the existing national regulatory rules and arrangements.

In the past, when large, synchronous, thermal generators were retired they were replaced by other thermal synchronous generators with similar electrical and physical characteristics. Over recent years, the increasing proliferation of non-synchronous generators combined with the withdrawal of ageing synchronous generators has meant that the inherent properties and qualities of large synchronous generators and the essential system services that they provided are becoming scarce. When the NEM was established in 1998, there was little prospect of significant amounts of wind-powered generation, grid-scale (or even small-scale) solar PV arrays or other power converter-connected non-synchronous generation, nor was the prospect of large-scale battery storage realistically anticipated.

Rapid technological advances, changing climate change policies and shifting customer consumption patterns and behaviour, mean that the traditional model of energy being produced by large synchronous electricity generators is under challenge. Further, the national framework and arrangements were not designed to directly address the associated challenges.

The prospect that the power system, particularly in South Australia, may at times, operate only with non-synchronous generators, is a real one. Managing such a system requires a new approach because of the different characteristics of non-synchronous and synchronous generators.

This changing generation mix will ultimately impact on all generation markets – South Australia, Australia and internationally. However, with an abundance of renewable energy sources, South Australia has both the benefit and challenge of being a world leader in this regard. The precise nature of the future is uncertain; it will depend on many factors. From a broader perspective, this transition is more about making the South Australian power system security highly adaptable and resilient to changes the future may bring.

The present nature of the power system emphasises the need for short-term adjustments to the current framework to allow for both conventional generation and newer technologies to co-exist during transition — hence the need to consider the Commission's current licensing arrangements and the reviews undertaken by national bodies such as AEMO, the AEMC and the Chief Scientist of Australia, Dr Alan Finkel, AO.

2.3 Challenges facing the South Australian power system

In particular, over the past few years, the South Australian power system has experienced the following situations:

1. periods where low levels of synchronous generation and high levels of non-synchronous generation was dispatched
2. periods where no synchronous generation was economically dispatched, and
3. periods where either the power system was separated (that is, electrically islanded) from the NEM, or that there was a credible risk of islanding.

In addition, AEMO has advised that there may be periods in future where demand will be very low or zero due to the increasing volumes of small scale generation embedded within the distribution network.[11]

AEMO has proposed to the Commission that careful consideration must be given to ensuring a secure, resilient, and reliable power system for the State in the context of a greater, and variable, proportion of non-synchronous generation. It has also noted that the high proportion of non-synchronous, intermittent generation in South Australia means that the impact of this type of generation technology on the power system is significantly greater than elsewhere in the NEM.

Furthermore, AEMO has concluded that this warrants additional or tighter technical standards than those that currently apply. AEMO has recommended to the Commission that, until such time as the NER accommodates the integration of new generation technologies, all future electricity generation licences (whatever the generation source) approved by the Commission should be subject to additional conditions, over and above the current set of licence conditions, in order to provide the ability to manage the technical changes affecting the South Australian power system.

AEMO also advises that for the South Australian power system to be resilient and to operate securely under the above situations, it is no longer appropriate to rely on synchronous generators alone to provide the power system with the essential 'system security services' necessary for its proper functioning (more commonly referred to as 'ancillary services' – see below). AEMO has recommended that these essential system services will need to be obtained from non-synchronous generators or as network services.

The transition to a power system dominated by non-synchronous generation technologies, like wind, solar and batteries, will require these generators to provide some of the services previously offered by synchronous plant.

2.4 Ancillary services or system security services

For the successful operation of a power system, several essential services are required in addition to the generation, transfer, and delivery of energy to consumers. These services include voltage control, frequency control, inertia, and system strength. These services are commonly referred to as ancillary services and are provided as an intrinsic by-product of energy production by conventional synchronous generators.[12] AEMO's Final Advice refers to these services as 'system security services' to highlight their critical role in maintaining the power system in a secure operating state.[13]

As non-synchronous wind-powered and solar PV generation displaces conventional synchronous plant, it will become increasingly necessary to find new sources of these system security services.

Non-synchronous generation technologies, including wind, solar PV, and storage, have physical attributes that set them apart from synchronous plant. Synchronous generators have heavy rotating components that are made to spin by electromagnetic forces (an electromagnetic coupling) at a rate that is directly proportional to the frequency of the power system. Due to this coupling, synchronous machines respond instantaneously to disturbances in the power system.

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[11] This low or zero demand can result from the substantial volume of small scale rooftop solar systems embedded throughout the distribution network which effectively serves consumers' demand first thereby offsetting the need for large scale generation (at the wholesale market level).

[12] The use of the term 'ancillary services' may imply that these services are less valued than the energy produced. This may have been the case in the past but as the generation mix changes, the role of ancillary services are increasing in importance.

[13] Internationally, there has been a shift in terminology to recognise the importance of these ancillary services, with Ireland's EirGrid now referring to these services as System Services and the New York Independent System Operator referring to them as Essential Services.

In contrast, non-synchronous generation technologies are primarily connected to the grid through power electronic converters, which are based on fundamentally different physical principles to conventional synchronous generation.

AEMO has noted that examples of the effects of these different physical attributes on the power system includes:

- The heavy rotating parts of synchronous generators have a physical inertia that acts to resist changes to rotational speed. This inertia property means that synchronous generators are able resist changes in frequency, providing an inherent and automatic service to the power system. Generation technologies that connect through power electronic converters are not electromagnetically coupled to the power system and thus cannot provide this service.
- Frequency regulation is a central process operated by AEMO, where generation output is adjusted over short timeframes to control power system frequency close to 50 Hz. The capability to modify active power output to assist in frequency regulation can be enabled in most synchronous generation, but to date has not been a feature of most non-synchronous generation technologies.
- Contingency frequency control capability is provided by generating plant configured to automatically increase or decrease its active power output in response to locally measured changes in power system frequency, in order to correct frequency back towards 50 Hz. This capability is again typically available from synchronous generation technologies but has not been a feature of non-synchronous generation technologies.
- Contribution to system strength refers to the availability of fault current to support detection of faults on the power system. The value of fault level contribution of non-synchronous generators is low compared to synchronous generators.

AEMO has advised that while system security services have not been an inherent characteristic of non-synchronous generators in the past, recent technological improvements over the past decade have resulted in additional functionality within such plant to provide some system security services.

2.5 Work undertaken by other parties

Over the last 12 months, several other reviews have commenced or been completed that related in some way to the material considered by this Inquiry including:

- AEMO's joint work with the AEMC on the System Security Market Framework Review (Final Report released 27 June 2017)[14]
- AEMO's continuing work on its Future Power System Security program (FPSS)[15]
- AEMO's investigations into recent power system events (particularly the Black System event[16])
- the House of Representatives' Standing Committee on the Environment and Energy's inquiry into Modernising Australia's electricity grid[17]

[14] AEMC, *System Security Market Framework Review*, July 2017, available at: http://www.aemc.gov.au/Markets-Reviews-Advice/System-Security-Market-Frameworks-Review.

[15] AEMO, *Future Power System Security Program,* available at: https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/FPSSP-Reports-and-Analysis.

[16] AEMO, *Black System South Australia 28 September 2016*, March 2017, p. 9, available at: http://aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2017/Integrated-Final-Report-SA-Black-System-28-September-2016.pdf.

[17] The Parliament of Australia, House of Representative, Standing Committee on the Environment and Energy, *Inquiry into Modernising Australia's electricity grid*, available at: http://www.aph.gov.au/Parliamentary_Business/Committees/House/Environment_and_Energy/modernelectricitygrid.

- the South Australian Legislative Council's State-wide Electricity Blackout and Subsequent Power Outages Inquiry,[18] and
- The Blueprint for the Future: Independent Review into the Future Security of the National Electricity Market by the Expert Panel chaired by the Dr Alan Finkel Chief Scientist of Australia (**Finkel Review**) delivered to the CoAG Energy Council on 9 June 2017.[19]

Amongst the many recommendations made in the Finkel Review, the Commission notes it supported the Commission's process of reviewing generator technical standards:

> *The requirements identified through the ESCOSA process should be extended to have NEM-wide applicability.*[20]

In particular, the Finkel Review recommended that:

> *…updated connection standards should address system strength, reactive power and voltage control capabilities, the performance of generators during and subsequent to contingency events, and active power control capabilities.*[21]

In addition to the AEMC's joint work with AEMO on the System Security Market Framework Review, the Commission also notes the AEMC's recent and forthcoming rule change determinations on several related matters being considered by the Commission. The AEMC's work covers the following rule changes:

- Inertia Ancillary Service Market rule change (draft rule due 7 November 2017)
- Managing the Rate of Change of Power System Frequency rule change (draft rule released 27 June 2017)
- Managing Power System Fault Levels rule change (draft rule released 27 June 2017)
- Generator System Model Guidelines (draft rule released 20 June 2017)
- Contestability of Energy Services (draft rule due 1 September 2017), and
- Emergency Frequency Control Schemes rule change (completed and effective 7 April 2017)

The Commission continues to monitor developments in these areas and will consider how any proposed changes may affect the power system in South Australia and the ongoing need for its state-based licence conditions.

The Commission notes that AEMO will request a rule change to reflect the advice provided to the Commission in relation to this Inquiry (as noted in Section 1.4 above). Finally, partly as a consequence of the issues raised by stakeholders during the consultation process undertaken as part of this Inquiry, AEMO has commenced a review of power system frequency control, FCAS markets and the causer pays regime as part of its Ancillary Services Technical Advisory Group (**AS TAG**).

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18 The Parliament of South Australia, Legislative Council Select Committee, *State-wide Electricity Blackout and Subsequent Power Outages Inquiry*, 2016, available at http://www.parliament.sa.gov.au/Committees/Pages/Committees.aspx?CTId=3&CId=335.

19 Commonwealth of Australia, *Independent Review into the Future Security of the National Electricity Market: Blueprint for the Future*, 2017, available at: http://www.environment.gov.au/energy/publications/electricity-market-final-report.

20 Commonwealth of Australia, p. 60.

21 Commonwealth of Australia, p. 21.

2.5.1 South Australian Government initiatives

In addition to the work by other regulators, the South Australian Government announced its Energy Plan for the State on 14 March 2017.[22] The Plan's initiatives include:

- a new Battery Storage and Renewable Technology Fund — to provide large-scale storage for energy
- a new generation for more competition plan — using the Government's energy purchases to attract a new generator
- a new State-owned gas power plant (276 MW) — to provide a Government-owned source of emergency electricity generation
- more funding for the South Australian gas incentives Plan for Accelerating Exploration (PACE) program — to source and use more local gas to generate electricity
- local powers over the national market — new legislation to give greater local powers over national market operators and privately owned generators which included implementation of the Technical Regulator's generator technical requirements for Development Approval (effective 1 July 2017), and
- a new Energy Security Target — retailers will be required to source a percentage of energy from local generators rather than interstate through the interconnector.

[22] Further detail on the South Australian Government's Energy Plan may be accessed at: http://ourenergyplan.sa.gov.au/index.html.

3 Stakeholder submissions

3.1 Consultation processes undertaken

The Commission is committed to genuine consultation and it has encouraged an open discussion on the matters raised in the Issues Paper,[23] the Draft Report[24] and the recommendations included in AEMO's advice.

On 2 December 2016, the Commission published an Issues Paper to initiate this Inquiry and to seek stakeholders' views on key issues. The Commission and AEMO considered stakeholders' submissions and, on 1 May 2017, a Draft Report was published. From that date, the Commission consulted for a six-week period on both its Draft Report and AEMO's advice. Written submissions on the Draft Report closed Friday, 9 June 2017.

The Commission's consultation was not limited to receiving stakeholders' written submissions. As part of its commitment to consultation, the Commission held a workshop in Adelaide on Tuesday, 16 May 2017, where around 70 stakeholders and industry participants attended. The workshop provided stakeholders with the opportunity to discuss the Commission's Draft Report and AEMO's recommendations and it also provided the Commission and AEMO with the benefit of stakeholders' views.

In addition, the Commission invited stakeholders to make written submissions on the matters covered in the Draft Report, AEMO's Final Advice and the discussions arising from the stakeholder workshop.

Beyond this workshop, the Commission (and AEMO) engaged with several stakeholder groups and continued to work closely with AEMO in considering specific technical concerns raised by stakeholders.[25]

This Final Report includes a consideration of the issues raised through consultation on the Draft Report, and also takes into account the updated advice from AEMO provided in its Addendum in relation to the submissions received during the above processes.

3.2 Submissions received

In total, 27 submissions from across the industry were received to both the Draft Report (15 submissions) and the Issues Paper (12 submissions) as noted in Table 3:1Table .[26]

[23] The Commission's Issues Paper: *Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators*, 2 December 2016, available at: http://bit.ly/GeneratorInquiryIssuesPaper.

[24] The Commission's Draft Report: *Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators,* May 2017, available at: http://bit.ly/InquiryDraftReport.

[25] The Commission's approach to consultation is detailed in its Charter of Consultation and Regulatory Practice which may be accessed at: http://www.escosa.sa.gov.au/consultation/charter-of-consultation-and-regulatory-practice.

[26] Submissions are available at: http://www.escosa.sa.gov.au/projects-and-publications/projects/inquiries/inquiry-into-licensing-arrangements-for-inverter-connected-generators.

Table 3:1 – Submissions received to the Draft Report

Contributor	Description	Draft Report	Issues Paper
AGL Energy (**AGL**)	Generator/Retailer		✓
Australian Energy Council (**AEC**)	Peak body for the (non-networks) energy industry		✓
Clean Energy Council	Peak body for the clean energy industry		✓
Energy and Technical Regulation	South Australian Government Department of Premier and Cabinet (**DPC**) (the Department of State Development (**DSD**)) – responsible for energy policy development and technical regulation	✓	✓
ElectraNet	Transmission network service provider (**NSP**) in South Australia	✓	✓
Energy & Water Ombudsman SA (**EWOSA**)	Independent Ombudsman		✓
EnergyAustralia	Generator/Retailer	✓	
Energy Networks Australia (**ENA**)	Peak body for the transmission and distribution networks industry	✓	
ENGIE	Generator/Retailer	✓	✓
K Summers	Private individual		✓
Meridian Energy Australia	Renewable energy developer and generator		✓
Origin Energy	Generator/Retailer	✓	
Pacific Hydro	Generator/Retailer	✓	
Reach Solar Energy	Solar generation developer	✓	✓
SA Power Networks (**SAPN**)	Distribution NSP		✓
South Australian Chamber of Mines and Energy (**SACOME**)	Peak body for the minerals, energy, extractive, and oil & gas sectors	✓	
SA Council of Social Service (**SACOSS**)	Peak body for the non-government health and community services sector	✓	
Siemens-Gamesa	Manufacturer	✓	
Snowy Hydro	Renewable Energy Generator/Retailer	✓	
TasNetworks	Transmission NSP in Tasmania	✓	
Tilt Renewables	Wind-powered generator and developer	✓	✓
Vestas Australia Wind Technology	Manufacturer	✓	
Total		15	12

3.3 Commission's consideration

The issues raised by stakeholders were carefully considered. Where relevant, certain arguments and submissions have been mentioned in the text of this Final Report, either by direct quotation or by reference to themes or arguments, to assist stakeholders to understand the proposed positions that have been reached.

A failure to reference an argument or submission does not mean that it has not been considered by the Commission in arriving at its conclusions. While not all positions put by stakeholders during consultation have been accepted, all views expressed during consultation have assisted in informing the Commission's consideration of each of the relevant issues and viewpoints.

During consultation, some matters were raised that were not considered to be within the scope for this Inquiry. While the Commission has considered these matters, they relate to issues that fall outside of the Commission's regulatory remit. However, the Commission notes that these matters may lie within the responsibility of others such as AEMO, the AEMC or other regulators. These additional matters relate to concerns with forecasting and dispatch processes, the proper functioning of ancillary markets and the allocation of ancillary costs, or that the NER rules are encouraging behaviours that may have the potential to compromise 'good power engineering system practice'. Section 2.5 notes the work that is being undertaken by both the AEMC and AEMO to address the concerns raised by stakeholders.

3.4 Non-technical issues raised in submissions

Several non-technical issues were raised in submissions and these are broadly categorised and summarised as follows:

- Existing frameworks are working/regulatory duplication: The NER provides a framework for AEMO and a new generator wishing to connect to the power system and achieve the desired outcomes. Any additional conditions required by the Commission creates regulatory duplication.
- Application of new licensing conditions to existing licensees: The application of new licensing conditions would require existing licensees to incur additional cost conditions. Further, there is potential for sovereign risk, unforeseen higher costs, and stranding of assets.
- Technology permissive: Application should be to both synchronous and non-synchronous generation irrespective of the underlying technology and should not unintentionally preclude any technologies.
- Market solutions preferred: If change is required then market-based solutions should be the preferred mechanism to source the requisite power system services.
- Additional matters: Concerns were expressed with the forecasting/dispatch processes, the proper functioning of ancillary markets and the allocation of costs, and concerns that the design and implementation of the market rules and the behaviour market participants are having on the achievement of good power engineering system practice.

The Commission's consideration of the above non-technical matters follows whereas the technical matters raised by stakeholders are considered in Chapter 4, Generator Technical Standards.

3.4.1 Existing frameworks are working/regulatory duplication

3.4.1.1 Submissions

Several submissions to the Draft Report and the Issues Paper questioned the need for jurisdictional licence conditions, stating that the NER already provides AEMO with the ability to manage the connection of new generators through the negotiated framework for generator performance standards (GPS).[27] Stakeholders expressed the view that inclusion of the Commission's licence conditions are unnecessary and result in an additional layer of regulation.[28]

Tilt Renewables noted that if technology is replaced or upgraded at the end of a generator's life, then there would be a requirement under the NER to re-negotiate the GPS. Should the Commission demonstrate a need for special conditions to the licences, they could potentially be re-considered at times of significant technology upgrade or replacement.[29]

Whereas the Energy and Technical Regulation (ETR) division of the South Australian Government's Department for Premier and Cabinet supported the continuation of applying state licence conditions in South Australia, as it considers the current licence conditions for grid connection of wind power electricity are necessary to cater for the State's unique circumstances.[30]

A number of submissions (including Energy Networks Australia (ENA) and ElectraNet) noted the extensive number of reviews and changes occurring across the industry and advised the Commission that it should:

> *… be cognisant of, and consistent with, the outcomes of the large number of concurrent system security related reviews and rule changes being conducted.*[31]

3.4.1.2 Commission's consideration

The Commission's position has been that a national or NEM-wide approach to GPS is preferable. As noted in its request for advice to AEMO and in the Issues Paper, the Commission has consistently stated that its focus, in relation to its responsibilities in licensing and regulating generators, is to remove any unnecessary local requirements once it is satisfied that the NER deal adequately with power system integrity and reliability issues posed by intermittent generation in this State.

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27 AGL Energy, submission to *Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators*, Issues Paper, January 2017, p. 4, available at: http://bit.ly/Inquiry-SAGeneratorLicensingArrangements-Submission-AGL; AEC submission to *Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators*, Issues Paper, February 2017, p.1, available at http://bit.ly/Inquiry-SAGeneratorLicensingArrangements-Submission-AustEnergyCouncil; CEC, submission to *Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators*, Issues Paper, January 2017, p. 5, available at: http://bit.ly/Inquiry-SAGeneratorLicensingArrangements-Submission-CleanEnergyCouncil; ENGIE submission to *Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators*, Issues Paper, January 2017, p. 3, available at http://bit.ly/Inquiry-SAGeneratorLicensingArrangements-Submission-ENGIE; Reach Solar, submission to *Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators*, Issues Paper, January 2017, p. 16, available at http://bit.ly/Inquiry-SAGeneratorLicensingArrangements-Submission-ReachSolarEnergy; Tilt Renewables, submission to *Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators*, Issues Paper, January 2017, pp. 1-2, available at http://bit.ly/Inquiry-SAGeneratorLicensingArrangements-Submission-TiltRenewables.

28 AGL Energy, submission to Issues Paper, pp. 1-2; ENGIE, submission to Issues Paper, p. 3.

29 Tilt Renewables, submission to Issues Paper, p. 3.

30 DSD, submission to *Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators*, Issues Paper, January 2017, p. 1, available at http://bit.ly/Inquiry-SAGeneratorLicensingArrangements-Submission-DeptStateDevelopment.

31 Energy Networks Australia, submission to *Inquiry into the licensing arrangements for generators in South Australia,* Draft Report, 9 June 2017, p. 3, available at: http://bit.ly/InquiryDraftDecision-Submission-EnergyNetworkAust; ElectraNet, submission to *Inquiry into the licensing arrangements for generators in South Australia,* Draft Report, 9 June 2017, p. 3, available at: http://bit.ly/InquiryDraftDecision-Submission-ElectraNet.

In its request for advice to AEMO, the Commission asked whether the current licence conditions for wind generators be retained, removed or varied and whether they should also be applied to power converter-connected generators.[32] Rather than recommend removal of these special conditions, the Commission notes that AEMO, as the national system operator, identified that the NER (and incorporating technical standards) are insufficient to meet the State's current circumstances and that the GPS as defined in the NER require updating (including providing greater clarification) to reflect the needs of a changing power system.

Further, AEMO's review of the Black System event has led it to recommend to the Commission several changes to generation licence conditions in South Australia and to request to the AEMC that similar changes be made to the NER, to address deficiencies in performance standards identified.[33]

In its report on the Black System event, AEMO advised the Commission that it intends to submit a Rule change to the AEMC, in August 2017, requesting appropriate revisions. In the interim, AEMO sees it as appropriate to maintain additional licence conditions that apply in South Australia because of the unique characteristics of its power system.

In arriving at this Final Decision, the Commission has taken into consideration the advice offered by several respondents to the number of reviews and changes occurring the industry. The Commission has reviewed recent developments and has incorporated and adjusted its positions where necessary.

The Commission, however, maintains that, until amendments are made to the NER that satisfy its overall concerns in these matters, then it is appropriate for the Commission to include additional licence conditions to account for the specific characteristics of the South Australian power system in order to protect the long term interests of South Australian consumers.

3.4.2 Technology permissive

3.4.2.1 Submissions

In its submission to the Issues Paper, the CEC raised concerns that applying additional licence conditions to only inverter-connected generators[34] may penalise one technology type over another.[35] It recommended that a framework should be created that applied to all generating technologies.[36]

However, Meridian Energy and Reach Solar submitted that inverter technology can provide additional benefits that synchronous generators cannot. Furthermore, Meridian Energy also noted that new conditions pertaining to frequency control, the rate of change of frequency and system strength would provide all participants with clarity and ensure that current and future technologies align with the prevailing regulatory environment. [37]

Snowy Hydro, in its submission, stated that although the scope of the Inquiry had expanded, it considered that the Commission's application of requirements during the interim period while the Inquiry was underway had not been technology permissive.[38]

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32 The Commission's request for advice to AEMO, *Technical standards for grid connection of wind farms and inverter-connected generators*, available at http://bit.ly/InquiryRequestForAdvice.

33 AEMO, *Black System South Australia 28 September 2017*, p. 9.

34 The reference to inverter-connected generators or, more correctly, power converter-connected generators relates to modern wind-powered and solar photovoltaic generators, batteries and other emerging technologies connected to the power system through power electronic converters (including inverters).

35 CEC, submission to Issues Paper, p. 13, Reach Solar Energy, submission to Issues Paper, p. 14.

36 CEC, submission to Issues Paper, p. 8.

37 Meridian Energy submission *to Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators*, Issues Paper, January 2017, p. 1, available at: http://bit.ly/Inquiry-SAGeneratorLicensingArrangements-Submission-MeridianEnergy; Reach Solar Energy, submission to Issues Paper, p. 14.

38 Snowy Hydro, submission to *Inquiry into the licensing arrangements for generators in South Australia,* Draft Report, 9 June 2017, p. 2, available at: http://bit.ly/InquiryDraftDecision-Submission-SnowyHydro.

3.4.2.2 Commission's consideration

Throughout this Inquiry, the Commission has advocated an outcomes based, technology permissive approach to the adoption of technical standards or conditions — primarily so as not to harm innovation nor to create any unnecessary or artificial barriers to market entry. New technologies are emerging and becoming commercially viable at a rapid rate and the Commission is keen to ensure that its regulatory frameworks are flexible and robust to accommodate these changes.

The Commission notes that, unless there are unavoidable technical limitations as to why a given technology cannot provide a particular service characteristic, standards should be developed for all generation types (subject to size thresholds). In this respect, AEMO has advised that its recommendations have been developed with a view that they should apply to both synchronous and non-synchronous generation where technically feasible to do so.

AEMO has recommended that the Commission require additional licence conditions on all new generators (regardless of technology) such that the South Australian generation fleet is equipped with the capabilities needed to provide a secure and resilient power supply. However, AEMO also noted that there is a need to recognise the differences between the capabilities of various technologies and that licence conditions must be flexible to suit; for example, where there are fundamental physical differences between the capabilities of synchronous and non-synchronous generators, such as the capabilities:

- to provide inertia (and system strength) by synchronous generators (that non-synchronous generators cannot provide to the same extent), or
- to respond to very high rates of change of frequency by power converter-connected non-synchronous generators (that is, not possible by synchronous generators and some non-power converter-connected non-synchronous generators).

The Commission has considered the concerns raised by stakeholders and has endeavoured to frame the licence conditions to balance the need for certainty for applicants and the need to avoid any premature and unintentional exclusion of any existing and future technologies. Accordingly, the Commission considers that a portfolio of generating technologies is likely to provide the widest range of services to the power system (and for the benefit of consumers).

3.4.3 Market solutions preferred

3.4.3.1 Submissions

Many submissions to the Issues Paper stated that should change be required then market-based solutions are the preferred mechanism to provide incentives for the competitive delivery of the requisite power system services rather than requiring licence conditions or the mandating of any particular solution.[39] In particular, AGL noted that:

> *…a number of technical and market solutions can more appropriately and cost effectively address underlying power system performance – when compared to imposing a greater regulatory burden on wind farms and other emerging technologies.*

[39] AGL, submission to Issues Paper, p. 2, AEC, submission to Issues Paper, p. 2; ElectraNet, submission to Issues Paper, p. 3; ENGIE, submission to Issues Paper, p. 1; Reach Solar Energy, submission to Issues Paper, p. 14, Snowy Hydro, submission to Draft Report, p. 3.

AGL also noted that:

> *A market-based approach to reactive power and frequency control requirements will provide the right incentives for wind, or solar, farm proponents to consider providing these two services as part of their connection – if it is in their commercial interests to do so.* [40]

The AEC also noted that:

> *Market based solutions are the most effective option where it is identified that the market can appropriately take the place of regulatory prescription.* [41]

3.4.3.2 Commission's consideration

In 2005, the Commission introduced licence conditions for wind generators as it considered, at the time, that the rapid growth in wind-powered generators seeking to connect to the power system posed potential problems for the power system and consumers. In the decade or so since then, the market and the national rules have yet to move on to the point that South Australian consumers' needs are adequately protected.

Given the limited uptake in the ancillary services markets by generators other than incumbent thermal synchronous generators, changes may be required to ensure that all new generators be required to have the capability to provide these ancillary services (also referred to as essential system security services) or, otherwise, if so directed by AEMO.

Finally, the Commission notes that there are instances either where only a nascent market has developed or no market yet exists particularly for a service to be delivered such as inertia or fast frequency response (FFR).

[40] AGL, submission to Issues Paper, p. 2.
[41] AEC, submission to Issues Paper, p. 2.

4 Generator technical standards

Summary of the Commission's final decision

The Commission considers that all new generators, regardless of technology or type, seeking to connect to the South Australian power system must have the capabilities to contribute to a secure and resilient power system that meets the modern (and future) needs of South Australian consumers.

Accordingly, the Commission will require that all new generators comply with the following requirements:

- maintaining continuous, uninterrupted operation during and following power system faults
- having active power control capabilities to provide a controlled, usable increase or decrease in energy output when required
- controlling voltage to maximise the power transfer capability of the power system
- operating at an agreed minimum power system strength to maintain a secure, stable grid, and
- the ability to assist with system restoration.

With respect to the application of the new licence conditions to existing licensees, the Commission considers that further engagement on this matter is required and, accordingly, will work with licensees and other stakeholders including AEMO, NSPs and other parties over the 2017-18 period to progress this matter.

4.1 Overview of AEMO's recommendations

AEMO's advice to the Commission was based on a range of studies including its work on FPSS program, its collaboration with the AEMC on the System Security Market Frameworks Review[42] and its investigations into recent power system events including the Black System event.

In addition, AEMO has considered several related Rule change requests currently being considered by the AEMC. AEMO has also consulted with technology providers, international grid operators and engaged consultants expert in the integration of non-synchronous machines into power systems.

AEMO recommended the retention of the Commission's existing licence conditions in relation to reactive power[43] and fault ride through — albeit expressed in a different form. In particular, AEMO has recommended that the existing reactive power capability licence clauses (10.1, 10.2, 10.3, and 10.4, see Appendix B) be replaced and restated in terms of a generator's performance — during, and subsequent to, contingency events and system disturbances. In this way, generators will still be required to supply reactive power to meet their performance obligations as contained in the Commission's existing licence conditions.

In summary, AEMO's key recommendations as outlined in its original Final Advice sought to require all new generators to have the following capabilities, as listed in Table 4:1.

[42] AEMC, *System Security Market Framework Review*.

[43] Under this recommendation, generators will still be required to supply sufficient reactive power to meet the performance obligations specified within the Generator Performance Standards negotiated under NER schedule 5.2.5 and defined in the Commission's licence conditions.

Table 4:1 – Overview of AEMO's key recommendations for active power control

Recommendation	Effect of recommendation
Improved voltage and frequency disturbance ride-through performance to maintain continuous, uninterrupted operation during and following power system faults.	This recommendation **updates** and **expands** on the existing special licence conditions on fault-ride through and reactive power capability.
Active power control facilities and capabilities to provide a controlled, usable increase or decrease in energy output when required.	If adopted, this recommendation would result in a **new** licence condition.
Voltage control capabilities – that is, the ability to control voltage by either absorbing or injecting reactive power during normal operations to maximise the power transfer capability of the power system.	This recommendation **retains** aspects of the existing reactive power capability licence condition.
Contributions to system strength – that is, to assist in improving system performance under low system strength conditions to maintain a secure, stable grid.	If adopted, this recommendation would result in a **new** licence condition.
The ability to assist with system restoration	If adopted, this recommendation would result in a **new** licence condition.

Furthermore, AEMO has recommended that its proposed technical standards should apply to all new generators with capacities of 5 MW and greater, regardless of technology, to ensure that the evolving South Australian generation fleet is armed with the capabilities to contribute to a secure and resilient power system.

In addition, AEMO also recommended to the Commission that it:

- require generators to provide more extensive simulation models to AEMO
- require NSPs (as well as generators) to contribute to the stability, security and resilience of the power system
- undertake regular updates to its licensing framework, and
- consider applying as many of the proposed technical standards to existing generators, where feasible.

In its Final Advice, AEMO recommended that there was no need to specify or require generators to provide inertia or fast frequency response.[44]

AEMO has considered stakeholders' submissions to this Inquiry and this has led it to review its recommendations and advice to the Commission. Subsequent to the consultation process, AEMO has modified several of the specific technical details associated with its original recommendations.

[44] AEMO considers that prescriptive requirements on new or existing South Australian generators, alone, would be inefficient and, instead, is considering alternative means to procuring these services which are being considered as part of other concurrent broader technical reviews.

The Commission has considered both AEMO's advice and stakeholders' submissions in arriving at its final decision on the new suite of licensing conditions for new generators. Although greater detail is contained in AEMO's Final Advice and its Addendum to its Final Advice (see Appendix E), an outline of AEMO's recommendations and the Commission's considerations and decisions on these matters follow.

4.2 Disturbance ride-through capability

Summary of the Commission's final decision

The Commission's existing licence conditions for **disturbance ride-through capability** (and reactive power capability) will be amended and expanded to include greater detail in the following areas:

- active power and reactive power responses to a variety of network disturbances
- under and over-voltage disturbance ride-through
- a requirement for generators to remain in continuous uninterrupted operation for a number of repeated fault events
- a power system load reduction (partial load rejection), and
- stronger frequency disturbance ride-through capabilities.

4.2.1 The matter to be addressed

The ability of generating systems to maintain continuous, uninterrupted operation during, and following, system disturbances is considered essential to the secure and reliable operation of a power system. When a power system incorporates a substantial reliance on non-synchronous generation technologies and also experiences the withdrawal of large synchronous generation technologies, the secure and reliable operation of that power system becomes considerably more critical and at risk.

AEMO's analysis of the performance of various generating systems during recent major system disturbances has identified 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 single credible contingency events, all generation technologies must also be resilient to repetitive disturbances — a significant factor in the Black System event.

In addition, the response of the power system to the operation of special protection schemes also needs to be secured. There is a need to improve the capability of generators to withstand over-voltage conditions and load-shedding events to ensure recovery from events that trigger special protection schemes which can have the unintended consequence of introducing short-term over voltages.

4.2.2 Overview of AEMO's disturbance ride through recommendations

AEMO has recommended that the Commission's existing licence conditions for disturbance ride-through capability (and reactive power capability) be amended and expanded to specify:

- active power and reactive power responses to deal with a range of network disturbances
- a requirement for generators to respond to under and over-voltage disturbance ride-through
- a requirement for generators to remain in continuous uninterrupted operation for a number of repeated fault events

- a requirement for non-synchronous generators to manage a significant power system load reduction (partial load rejection), and
- stronger frequency disturbance ride-through capabilities.

The above general recommendations build upon the existing fault ride through and reactive power conditions applied to wind-powered generators since 2005.

AEMO has stated that its recommended performance requirements have been specified to ensure that all generators act in a coordinated manner to support the network as much as possible during contingency events and to maximise the resources available to stabilise and secure the power system immediately after contingency events.

AEMO has provided greater detail on its ride-through recommendations in its advice to the Commission and stakeholders are referred to AEMO's reports.[45] In summary, AEMO's recommendations include that:

1. All generators to meet **reactive current injection** requirements during and subsequent to contingency events (refer to Section 4.2.3).
2. All generators to restore **active power** to at least 95 percent of the level existing just prior to the fault (refer to Section 0).
3. All generators to meet **multiple low voltage disturbance ride-through** requirements (refer to Section 4.2.5).
4. All generators to meet **high-voltage disturbance ride-through** requirements (refer to Section 4.2.6).
5. All non-synchronous generators to meet **enhanced disturbance ride through** requirements (refer to Section 4.2.7).
6. All non-synchronous generators to respond to a **partial load rejection** (refer to Section 4.2.8).
7. All generators to meet **frequency disturbance ride-through** requirements (refer to Section 0).
8. All generators to restrict the **application of protective equipment** such as vector shift and similar types of relays (refer to Section 4.2.10).

4.2.3 Reactive current injection requirements

4.2.3.1 The matter to be addressed

Reactive power is vital to the integrity of a power system. The provision and control of reactive power is necessary for several reasons, including supporting and managing voltages and power flows across the power system generally. Reactive power is vitally important to the power system when it experiences a fault and to ensure that the system is able to remain intact and recover from minor and major network disturbances.

[45] For AEMO's Final Advice and its Addendum to its Final Advice see Appendix E.

4.2.3.2 AEMO's recommendation

AEMO recommended the deletion of the current dynamic reactive power requirement conditions in clause 10.4 of the model wind licence conditions and the replacement of those conditions with specific reactive current injection requirements (and other associated recommendations) as follows:

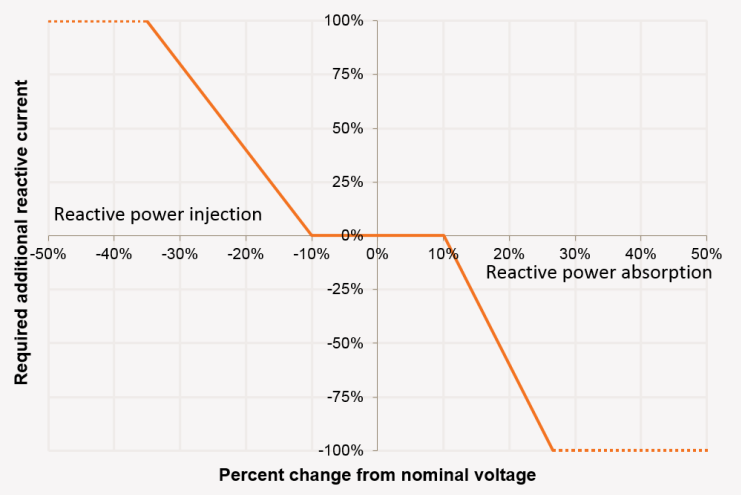
1. The generating system must supply additional capacitive reactive current (reactive injection) of up to four percent of the maximum continuous current of the generating system (in the absence of a disturbance) for each one percent reduction of connection point voltage below 90 percent of normal voltage, as shown in Figure 1. This requirement applies at the low voltage (LV) terminals of the generating units/dynamic reactive support plant/battery storage units (as applicable) for power system disturbances resulting in a voltage drop to 100 percent of normal voltage at the connection point.

2. The generating system must supply additional inductive reactive current (reactive absorption) of up to six percent of the maximum continuous current of the generating system (in the absence of a disturbance) for each one percent increase in connection point voltage above 110 percent of the normal voltage, as shown in Figure 1. This requirement applies at the LV terminals of the generating units/dynamic reactive support plant/battery storage units (if applicable).

3. The required reactive current may be limited to 100 percent of the rated current of the generating system (for example, maximum reactive current is required to be injected for connection point voltages of less than 65 percent of normal voltage or for connection point voltages of greater than 135 percent of normal voltage).

4. The reactive current injection must be maintained until the connection point voltage returns to within the range of 90 percent to 110 percent of normal voltage.

Figure 4:A: Recommended reactive power response requirements



Source: AEMO

5. A rise time[46] no greater than 30 milliseconds and a settling time[47] no greater than 60 milliseconds applies to reactive current injection requirements.

6. The reactive current injection requirements described above apply for all pre-disturbance reactive power control modes (voltage control, power factor control, or reactive power control).

[46] As defined in clause S5.2.5.13 of the NER.
[47] As defined in clause S5.2.5.13 of the NER.

7. The reactive current response must be adequately damped[48] as defined in the NER.

8. Reactive power consumption, upon application of a fault, must not exceed five percent of the maximum continuous rated current of the generating system, and limited to the duration of the rise time.

9. The post-fault reactive power contribution of the generating system must be sufficient to ensure that the connection point voltage is within the range required for continuous uninterrupted operation under clause S5.2.5.4 of the NER.

4.2.3.3 Submissions

The Commission received three submissions from industry participants in relation to AEMO's final recommendation for reaction current injection requirements.

Tilt Renewables' submission supported the recommendation with respect to wind-powered generators, noting that many modern wind turbines would be capable of meeting the reactive current injection and active power injection requirements. However, it was less certain of the capability of a solar inverter to meet these requirements.[49]

Vestas sought clarity on the reactive power injection/absorption graph particularly regarding requirements below 50 percent. It noted that reactive current injection typically ceases at 20 percent of residual voltage and reactive current absorption ceases at 20 percent above nominal voltage.[50]

Further, ElectraNet submitted that, for inverter-based generators, 'the full reactive current injection capability recommended by AEMO would not be achievable with the currently proposed design.[51] In addition, ElectraNet noted that it may not be possible for new synchronous generating systems to achieve a settling time of no greater than 60 milliseconds. It stated that it is important to consider the inherent difference between generating technologies and their advantages and disadvantages, notwithstanding that the intention for licensing requirements is that they should be technology permissive.[52]

ElectraNet sought clarity regarding the powers of an NSP and noted that it would help to clarify that, where reactive power capability is a licence condition, an NSP can direct a generator to use that capability to support the secure operation of the power system when it is required.[53]

4.2.3.4 Commission's consideration

The Commission agrees that physical technological differences will need to be taken into consideration to the extent that those differences impact a generator's ability to achieve certain requirements. The Commission does not intend to impose licence conditions where there are physical limitations to achieving a set standard. Rather, in those circumstances, the Commission intends to tailor the standards with regard to specific technical capabilities.

In responding to the Commission's request for AEMO to consider technical matters raised in submissions, AEMO recommended rewording the reactive current injection criteria. AEMO's amended recommendation separates requirements for synchronous and non-synchronous generators. In doing so, AEMO has removed the settling time requirements for synchronous generators.

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48 See the Glossary in Chapter 10 of the NER.

49 Tilt Renewables, submission to *Inquiry into the licensing arrangements for generators in South Australia,* Draft Report, 21 June 2017, p. 3, available at: http://bit.ly/InquiryDraftDecision-Submission-TiltRenewables.

50 Vestas, submission to *Inquiry into the licensing arrangements for generators in South Australia,* Draft Report, 9 June 2017, p. 1, available at: http://bit.ly/InquiryDraftDecision-Submission-VestasWindTech.

51 ElectraNet, submission to Draft Report, p. 2.

52 ElectraNet, submission to Draft Report, p. 2.

53 ElectraNet, submission to Draft Report, p. 3.

The Commission agrees that it is appropriate to differentiate reactive current injection requirements between synchronous and non-synchronous generators due to their differing characteristics. In particular, the Commission confirms that settling time requirements will not apply to synchronous generators.

Further, AEMO provided additional information to assist synchronous and non-synchronous generators in interpreting the reactive current injection requirements and has provided Table 4:2 that clarifies the current injection gain and current absorption gain across all voltages.

The Commission is of the view that the additional information provided by AEMO clarifies the reactive current injection requirements and accepts AEMO's recommendation.[54]

In respect of ElectraNet seeking clarity on whether it can direct the utilisation of a generator's reactive power capability, the Commission notes that ElectraNet is licensed in relation to exercising system control over the South Australian power system. In accordance with that licence, ElectraNet has the function of monitoring and controlling the operation of the power system to ensure that the system operates safely and reliably. In carrying out that function, ElectraNet may issue directions to an electricity generator, which must comply with the direction as a condition of its licence.

4.2.3.5 Commission's Final Decision

The Commission will include licence conditions for reactive current injection requirements as follows:

1. The generating system must supply additional capacitive reactive current (reactive injection) of up to four percent of the maximum continuous current of the generating system (in the absence of a disturbance) for each one percent reduction of connection point voltage below 90 percent of normal voltage, as shown in Table 4:1. This requirement applies at the LV terminals of the generating units/dynamic reactive support plant/battery storage units (as applicable) for power system disturbances resulting in a voltage drop to 100 percent of normal voltage at the connection point.
2. The generating system must supply additional inductive reactive current (reactive absorption) of up to six percent of the maximum continuous current of the generating system (in the absence of a disturbance) for each one percent increase in connection point voltage above 110 percent of the normal voltage, as shown in Table 4:2. This requirement applies at the LV terminals of the generating units/dynamic reactive support plant/battery storage units (if applicable).
3. The required reactive current may be limited to 100 percent of the rated current of the generating system (for example, maximum reactive current is required to be injected for connection point voltages of less than 65 percent normal voltage or for connection point voltages of greater than 135 percent of normal voltage).
4. The reactive current injection must be maintained until the connection point voltage returns to within the range of 90 percent to 110 percent of normal voltage.

[54] For AEMO's Final Advice and its Addendum to its Final Advice see Appendix E.

Table 4:2 - Reactive current response by the generating system

Type of generating system	Current injection gain (%)	Current absorption gain (%)	Minimum amount of contribution as a percentage of rated current	Speed of contribution	
				Rise time (ms)	Settling time (ms)
Synchronous	4	6	250	30	N/A
Non-synchronous	4	6	100	30	60

5. 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 X. The exact ratio of negative-sequence to positive-sequence current injection will be specified by the Commission at the time the licence is issued.

6. The generating system must comply with the following response characteristics for reactive current injection:

   (a) For non-synchronous generation systems, a rise time no greater than 30 milliseconds and a settling time no greater than 60 milliseconds applies to reactive current injection requirements.

   (b) For non-synchronous generation systems, the reactive current injection requirements described above apply for all pre-disturbance reactive power control modes (voltage control, power factor control and reactive power control).

   (c) The reactive current response must be adequately damped as defined in the NER.

   (d) Upon occurrence of a fault, reactive power consumption must not exceed five percent of the maximum continuous rated current of the generating system and must be limited to the rise time duration set out in Table 4:2.

   (e) The post-fault reactive power contribution of the generating system must be sufficient to ensure that the connection point voltage is within the following ranges for continuous uninterrupted operation:

      (i) voltages over 110 percent for the durations permitted under NER clause S5.1a.4

      (ii) 90 percent to 110 percent of normal voltage continuously

      (iii) 80 percent to 90 percent of normal voltage for a period of at least 10 seconds, and

      (iv) 70 percent to 80 percent of normal voltage for a period of at least two seconds.

4.2.4 Active power injection requirements

4.2.4.1 The matter to be addressed

AEMO has advised that NER clause S5.2.5.5(b)(2)(iii) requires generating systems to recover their active power output to 95 percent of the pre-disturbance level from 100 milliseconds following fault clearance. While synchronous generators can normally meet this requirement, wind farms take between 100 milliseconds and more than one second to fully recover their active power output.

The potentially slow active power recovery from generators after a major disturbance would result in an increased power transfer across the Heywood Interconnector. Depending on the magnitude of this power transfer, increases the risk of the interconnector losing synchronism and resulting in disconnection, which would lead to separation from the NEM (or islanding). The risk of islanding increases during those periods when imports from Victoria are very high. In addition, the transient instability due to major loss of generation in South Australia will also lead to voltage instability across the network.

AEMO advises that to manage these risks, a minimum active power recovery level and recovery time should be specified for generators.

4.2.4.2 AEMO's recommendation

AEMO has recommended that for all generators:

- Active power should be restored to at least 95 percent of the level existing just prior to the fault between 100 milliseconds and 500 milliseconds after disconnection of the faulted element. The exact active power recovery time will be determined by AEMO and ElectraNet for each specific connection, depending on specific requirements.
- Transient active power consumption upon application of a fault must not exceed one power frequency cycle and must not exceed five percent of the maximum continuous rated current of the generating system.

4.2.4.3 Submissions

As noted above, Tilt Renewables indicated that, although modern wind turbines would be capable of meeting the reactive current and active power injection requirements, it was less certain of solar inverters' capabilities.[55]

Some stakeholders requested clarification on the slowest level of active power recovery that may be acceptable.

4.2.4.4 Commission's consideration

The Commission notes the concerns raised by Tilt Renewables and others and considers that the assessment of active power restoration times should be made on a case-by-case basis as impacts of generator performance vary considerably according to generation type and network location. Notwithstanding, the lower limit on active power recovery of 'no slower than 500 milliseconds' reflects the range of expected performance for active power recovery.

[55] Tilt Renewables, submission to Draft Report, p. 3.

4.2.4.5 Commission's final decision

The Commission will include the active power injection requirements as follows:

1. The generating system must be capable of restoring active power to at least 95 percent of the level existing just prior to a fault within (a period to be specified) milliseconds after disconnection of the faulted element. The exact active power recovery time will be specified at the time the licence is issued and will be between 100 and 500 milliseconds.

2. Upon occurrence of a fault, a generating system's transient active power consumption must not exceed one power frequency cycle and must not exceed five percent of the maximum continuous rated current of the generating system.

4.2.5 Multiple low voltage disturbance ride-through requirements

4.2.5.1 The matter to be addressed

AEMO's investigation into the System Black event found that nine wind farms exhibited a sustained reduction in power. This was as result of a protection feature that was activated - for eight of those wind farms, the protection settings of their wind turbines allowed them to withstand a pre-set number of voltage disturbances within a two-minute period.[56]

4.2.5.2 AEMO's recommendation

In respect of multiple low voltage disturbance ride-through, AEMO recommended that the generating system—including each of its generating units and dynamic reactive power support plant, and battery storage units—must be capable of withstanding any combination of voltage disturbances that result in the voltage, at the respective LV terminals of the equipment, dropping below 85 percent of the nominal voltage for a total duration of 1,800 milliseconds within a five minute interval regardless of disturbance type, duration, and residual voltage at the generating unit's terminals.

4.2.5.3 Submissions

Submissions from Origin Energy[57] and Vestas[58] raised several issues regarding multiple low voltage disturbance ride-through requirements. Further, both entities sought clarity on the total number of low voltage faults that generators must ride through.

Vestas[59] and Origin Energy[60] noted that the multiple ride through capability is a function of both the duration of the fault and the recovery time. That is, the number of fault ride-through occurrences and the energy used for recovery needs to be considered.

Vestas stated that the requirement to meet a total fault duration of 1,800 milliseconds is beyond the capability of its current class of wind turbines and it may be a more challenging to meet requirement when there is a higher number of shorter duration faults rather than a smaller number of longer faults. It requested that the requirement be made clearer by defining the maximum fault duration, minimum interval time between faults, lowest residual voltage on the generator terminals, and the number of multiple faults to ride through within a defined window of time.[61]

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[56] AEMO, *Black System South Australia 28 September 2016*, p. 6, accessible at: http://www.aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2017/Integrated-Final-Report-SA-Black-System-28-September-2016.pdf.

[57] Origin Energy submission to I*nquiry into the licensing arrangements for generators in South Australia*, Draft Report, 9 June 2017, pp. 5-8, available at: http://bit.ly/InquiryDraftDecision-Submission-OriginEnergy.

[58] Vestas submission to Draft Report, pp. 1-2.

[59] Vestas, submission to Draft Report, p. 2.

[60] Origin Energy, submission to Draft Report, pp. 5-6.

[61] Vestas, submission to Draft Report, p. 2.

Vestas also requested clarity on how longer duration shallow voltage faults would be considered. It noted that it is unclear whether this requirement was requiring the generator to survive a long duration of shallow voltage disturbance, as well as, the multiple faults immediately after the voltage disturbance. If that was the case, Vestas noted that this would be beyond the capability of the current class of wind turbines. In addition, Vestas noted that the reference to the five-minute moving window must be understood that once activated, the capability for multiple ride-through is not available again until sufficient time has elapsed to cool down the 'dump load', which typically is around 30 minutes.[62]

In addition, Origin Energy submitted that an unlimited voltage ride-through specification risked damage to plant and protection equipment. It stated that it is not possible to design systems to ride through an unlimited number of faults and it was possible then the capital costs would be significant and under-utilised. Accordingly, Origin Energy recommended that the number of faults should be limited.[63]

4.2.5.4 Commission's consideration

In responding to the Commission request for AEMO to consider technical matters raised in submissions, AEMO has advised the Commission that it recommends amendments to the description of the five-minute interval and the total number of faults. Specifically, AEMO has recommended reducing the total fault duration from 1,800 to 1,500 milliseconds, limiting the number of faults to ride-through to 15 and clarifying that that there is a 30-minute time lapse, as recommended by Vestas.

AEMO has advised the Commission that reducing the total fault duration from 1,800 to 1,500 milliseconds will ensure that the requirements can be met by a wide range of technologies but still maintain a standard that is above the maximum historical duration of faults that has occurred in South Australia. AEMO has limited the number of faults to 15 as each fault should be able to be cleared within 100 milliseconds, totalling 1,500 milliseconds.

The Commission understands that AEMO has sought feedback directly from manufacturers of non-synchronous generators and these manufacturers have confirmed that their products would be able to comply with these requirements.

Having regard to AEMO's revisions and the feedback it sought from manufacturers, the Commission accepts AEMO's amended recommendation. However, the Commission notes that in imposing these requirements, the physical design of synchronous generating systems will need to be taken into consideration and, in some circumstances, may result in revised requirements.

4.2.5.5 Commission's final decision

Accordingly, the Commission will include the amended multiple low voltage disturbance ride-through requirements as licence conditions as follows:

1. The generating system, including each of its generating units', dynamic reactive power support plant and battery storage units, must be capable of withstanding both of the following voltage disturbances within a five-minute interval.

[62] Vestas, submission to Draft Report, p. 2.
[63] Origin Energy, submission to Draft Report, p. 6.

2. Any combination of voltage disturbances causing the voltage at the respective LV terminals of the equipment to drop below 85 percent of the nominal voltage for a total duration of 1,500 milliseconds regardless of disturbance type, duration, and residual voltage at the generating unit's terminals. The total number of voltage disturbances for which successful ride-through is required is limited to 15. Each fault can be a solid fault resulting in 100 percent voltage drop at the connection point with duration not exceeding the longest time expected to be taken for the breaker fail protection system to clear the fault, as set out in Table S5.1a.2 of the NER.

3. A single worst-case long-duration shallow voltage disturbance, causing the voltage at the connection point to drop to 70-80 percent of the normal voltage for a total duration of 2,000 milliseconds.

4. Subject to compliance with the requirements in clause 1, the generating system, including each of its generating units', dynamic reactive power support plant and battery storage units, is not required to withstand any additional voltage variation exceeding ±10 percent of nominal voltage experienced at the respective LV terminals within 30 minutes from the commencement of the first variation. For synchronous generators, consideration will be given to the physical limitations of the plant. This may require a variation to the standard condition to be determined by the Commission at the time of issuing a licence.

4.2.6 High-voltage disturbance ride-through

4.2.6.1 The matter to be addressed

NER clause S5.2.5.4 specifies the continuous uninterrupted operation requirements for a range of voltage disturbances. As the South Australian power system operates with a relatively lower level of system strength, it is expected that voltage disturbance events may not be localised but may become more widespread. In its Final Advice, AEMO has noted that evidence from five relevant electrical islanding events experienced by the South Australian power system indicates that the power system suffered over-voltages of up to 120 percent for several seconds.

4.2.6.2 AEMO's recommendation

AEMO has recommended that generating systems must maintain continuous uninterrupted operation for temporary over voltages for the magnitudes and durations specified in Table 4:3.

Table 4:3 - Required over voltage withstand capability

Temporary overvoltage (% of normal voltage)	110–115	>115–120	>120–125	>125–130	>130–140
Duration (secs)	1,800	30	2	0.2	0.02

4.2.6.3 Submissions

The Commission received one submission regarding this issue from a wind turbine manufacturer. Siemens-Gamesa submitted that high voltage ride through requirements are both technically and economically onerous. It noted that any over-voltage would affect the life-cycle of the semiconductors in a converter and would require manufacturer's upgrading semiconductors to a more robust voltage withstand capability, which would significantly increase costs. Alternatively, it would need to install additional reactive plant, which would also increase the cost of a project.[64]

4.2.6.4 Commission's consideration

The Commission considers that the highest level of performance to withstand voltage disturbances is required. This would mitigate risks of consequential temporary over voltages and enable South Australia to operate as an islanded network for sustained periods. However, the Commission notes Siemen-Gamesa comments regarding the technical and economic consequences.

The Commission requested that AEMO consider Siemen-Gamesa's comments and the limitations that generators may experience in meeting its high voltage disturbance ride-through. In response, AEMO has amended the withstand durations for temporary over-voltages in the 110-115 percent range (from 1,800 to 1200 seconds) and the 115-120 percent range (from 30 to 20 seconds).

AEMO has advised that the reduction from 1,800 to 1,200 seconds is consistent with the findings that were used to support development of the ENSTSO- E network code for mainland Europe.[65] Further, the International Council on Large Electric Systems (CIGRE) has carried out tests on transmission network elements which found that all elements tested were capable of meeting over-voltages of up to 115 percent for 1,200 seconds. [66]

In addition, AEMO has advised the Commission that the reduction from 30 to 20 seconds on over-voltages of up to 120 percent reflects stakeholder feedback, while still being adequate to ensure sufficient time for disconnection of all transmission and distribution capacitor banks.

Having regard to AEMO's revisions and the international evidence provided, the Commission accepts AEMO's amended recommendation.

However, in considering Siemen-Gamesa's feedback, the Commission notes that there may be limitations in some generating systems ability to meet these requirements which may result in revised requirements to be set prior to the issuing of a licence.

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64 Siemens-Gamesa, submission to I*nquiry into the licensing arrangements for generators in South Australia*, Draft Report, 8 June 2017, p. 1, available at: http://bit.ly/InquiryDraftDecision-Submission-SiemensGamesa.

65 ENSTO-E, 2012 *Network Code on Requirements For Grid Connection Applicable to All Generators Frequently Asked Questions,* available at: http://www.acer.europa.eu/Media/News/Documents/120626%20-%20NC%20RfG%20-%20Frequently%20Asked%20Questions%20(2).pdf; ENSTO-E, 2016 *Network Code on Requirements For Grid Connection Applicable to All Generators* available at: *http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R0631&from=EN.*

66 CIGRE WG 33.10,1998, *Temporary Overvoltages: Withstand Characteristics of Extra High Voltage Equipment*, Electra No.179 August, pp. 39-45, available at https://e-cigre.org/publication/ELT_179_3-temporary-overvoltage-withstand-characteristics-of-extra-high-voltage-equipment.

4.2.6.5 Commission's Final Decision

Accordingly, the Commission will include the amended high voltage disturbance ride-through requirements as licence conditions as follows:

1. The generating system must have a level of over-voltage withstand capability consistent with the levels shown in Table 4:4.[67]

2. The generating system must maintain continuous uninterrupted operation for temporary over voltage durations as specified in the Table 4:4.

Table 4:4 - Required over voltage withstand capability

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

4.2.7 Enhanced disturbance ride through requirements for non-synchronous generators

4.2.7.1 AEMO's recommendation

AEMO's Final Advice to the Commission proposed a series of general principles to provide context for its recommendations with respect to the proposed high voltage disturbance ride-through capability discussed above.

AEMO noted that it would be of value for proposed generators to note the following aspects of the current NER framework:

- While low voltage ride-through (LVRT) and high voltage ride-through (HVRT) requirements in the NER are defined at the connection point, the withstand capability of individual generating units is defined at the LV side of the generating unit's transformer. All individual generating units must remain connected for connection point voltages within the LVRT/HVRT withstand requirements, irrespective of the generating system transformer's tap position.
- The LVRT activation threshold defined at LV terminals of the generating units/dynamic reactive support plant/battery storage units (if applicable) must not be less than 85 percent of normal voltage.
- Continuous uninterrupted operation means that for voltage disturbances within the continuous operating range (i.e. connection point voltage fluctuating within 90 percent and 110 percent of normal voltage), active power must be maintained (unless there has been a change in the intermittent power source) and reactive power must be managed to meet voltage control requirements.

4.2.7.2 Submissions

No submissions addressed this specific recommendation.

[67] Unless otherwise specified by the Commission at the time the licence is issued.

4.2.7.3 Commission's consideration

AEMO has advised the Commission that it has further reviewed these general principles and has recommended that these become licence conditions for non-synchronous generating systems.

The Commission is of the view that including these principles as specific licence conditions would provide greater clarity for non-synchronous generating systems. Accordingly, the Commission's decision is to include these requirements as a licence condition.

4.2.7.4 Commission's final decision

The Commission will implement a licence condition as follows:

The non-synchronous generating system must meet the following requirements:

1. The LVRT must not be less than 85 percent of nominal voltage as measured at the LV terminals of the generating units/dynamic reactive support plant/battery storage units (as applicable).
2. Maintain continuous uninterrupted operation for voltage disturbances — that is, active power must be maintained and reactive power must be managed to meet voltage control requirements.[68]
3. Where the LVRT and HVRT requirements in the NER are specified in respect of the generating system's connection point, the withstand capability of individual generating units is to be determined at the LV side of the generating unit's transformer. All individual generating units must remain connected for connection point voltages within the LVRT/HVRT withstand requirements, irrespective of the generating system's transformer tap position.

4.2.8 Partial load rejection

4.2.8.1 Matter to be addressed

The NER clause (S5.2.5.7) relating to partial load rejection deals with generating systems' response to load reduction events. The automatic standard requires that a synchronous generating unit must maintain continuous uninterrupted operation for an event that results in a 30 percent load reduction. Non-synchronous generating units, however, are excluded from this NER clause. This exclusion was introduced as part of a suite of changes arising from an AEMC rule change determination in 2007.[69]

Given that the South Australian power system is likely to move toward even greater levels of non-synchronous generation over time, there is a current and growing risk that a separation or load shedding event could result in insufficient generation resources available to restore stable operation.

[68] For clarity, AEMO states that continuous uninterrupted operation for voltage disturbances means that for voltage disturbances within the continuous operating range (that is, when the connection point voltage fluctuates within 90 percent and 110 percent of normal voltage) active power must be maintained (unless there has been a change in the intermittent power source) and reactive power must be managed to meet voltage control requirements.

[69] AEMC, *National Electricity Amendment (Technical Standards for Wind and other Generator Connections) Rule 2007*, Rule Determination, 8 March 2007, pp. 50-52, available at: http://www.aemc.gov.au/getattachment/dea35ab7-fec7-46dd-9b64-b12a707c3948/Final-Rule-Determination.aspx.

4.2.8.2 AEMO's recommendation

AEMO recommends that all generating systems, including non-synchronous generators regardless of technology, should be required to meet the automatic standard defined under NER clause S5.2.5.7 as follows:

- A non-synchronous generating system must be capable of continuous uninterrupted operation during and following a power system load reduction of 30 percent from its pre disturbance 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.

4.2.8.3 Submissions

No submissions addressed this specific recommendation.

4.2.8.4 Commission's consideration

Clause S5.2.5.7 of the NER contains requirements regarding partial load rejection. However, 'asynchronous' generators are explicitly excluded from this clause.[70] Accordingly, AEMO has recommended that the Commission impose a licence condition on non-synchronous generating systems requiring the generator to meet the automatic access standard as prescribed in clause S5.2.5.7 of the NER. AEMO has advised that it is essential that all local generation remain connected and contribute resources to restore stable and secure operation in the event that the South Australian power system is islanded subsequent to a separation event including potential load shedding.

The AEMC introduced this disapplication in 2007 and stated in its rule determination that this disapplication was warranted because, at the time, there were questions regarding the ability of non-synchronous generators to meet these requirements. Further, the AEMC considered that not applying the clause to non-synchronous generators would not impact upon power system security.[71]

However, the Commission is of the view that technology has advanced and there is no longer a question surrounding non-synchronous generating systems ability to meet this requirement. Further, the Commission's view is that due to the changes that have occurred in the South Australian power system in recent years (and since the AEMC's determination) it would impact South Australian power system security, particularly, when islanded.

4.2.8.5 Commission's Final Decision

Accordingly, the Commission will implement a licence condition as follows:

1. A non-synchronous generating system must be capable of continuous uninterrupted operation during and following a power system load reduction of 30 percent from its pre-disturbance 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.

[70] The actual text of S5.2.5.7 refers to 'asynchronous generating units' — for the purpose of interpreting this clause, the terms 'asynchronous' and 'non-synchronous' are equivalent.

[71] AEMC, *National Electricity Amendment (Technical Standards for Wind and other Generator Connections) Rule 2007*, Rule Determination, 8 March 2007, pp. 50-52.

4.2.9 Frequency disturbance ride-through

4.2.9.1 Matter to be addressed

Generators and large customer loads on the power system have automatic controls that trip in response to the system frequency reaching certain thresholds. If the rate of change of frequency (RoCoF) remains within acceptable limits, this tripping of load or generation can be utilised to arrest a frequency deviation and help to return the power system to within the normal frequency range. If, however, the RoCoF is outside those limits, the controls may not arrest frequency deviations in time, ultimately leading to a cascading failure of the power system.

4.2.9.2 AEMO's recommendation

AEMO recommended that:

- For non-synchronous (power converter-connected) technologies, the generating system must be capable of continuous uninterrupted operation for the following rate of change of frequencies:
  - ±4 Hz/s for 250 milliseconds
  - ±3 Hz/s for one second
- For synchronous generators, AEMO recommends a negotiated access standard for continuous uninterrupted operation, for a range of RoCoF intensities as close as possible to the standard for non-synchronous generation shown above.

4.2.9.3 Submissions

The Commission received three submissions regarding frequency disturbance ride-through requirements.

Origin Energy submitted that it did not support AEMO's proposal for frequency disturbance ride-through, particularly, the widening of frequency tolerance limits for all generators. It noted that increased frequency tolerance increases the risk of damage to generating units.[72]

Further, Origin Energy and Vestas submitted that there would be limited capability for existing licensees to meet these requirements.[73]

ElectraNet was supportive of AEMO's recommendation that non-synchronous generating systems be capable of withstanding ±4 Hz/s for 250 milliseconds and ±3 Hz/s for 1 second. It noted that these recommendations appear to be made in context of refining the existing requirements under the NER.[74]

4.2.9.4 Commission's consideration

The South Australian power system is particularly susceptible to high levels of RoCoF and it is therefore important to have generating systems operating in South Australia that can manage high RoCoFs. Accordingly, the Commission accepts AEMO's recommendation for frequency disturbance ride-through for non-synchronous generating systems.

[72] Origin Energy, submission to Draft Report, p. 6.
[73] Origin Energy, submission to Draft Report, p. 6; Vestas, submission to Draft Report, p. 2.
[74] ElectraNet, submission to Draft Report, p. 3.

However, the Commission notes Origin Energy's concerns regarding the risk of damage to generating units. The Commission recognises that there are some physical limitations on synchronous generating systems ability to meet a higher tolerance limit. Therefore, while the Commission will seek the highest possible performance from new synchronous generators, there may be variations to this standard for synchronous generating systems to be determined prior to the issuing of a licence.

4.2.9.5 Commission's Final Decision

The Commission will implement a licence condition amended as follows:

1. The generating system must be capable of continuous uninterrupted operation for the following rate of change of frequencies:
    a. ±4 Hz/s for 250 milliseconds
    b. ±3 Hz/s for 1 second, until such time as power system frequency breaches the extreme frequency excursion tolerance limits[75]

4.2.10 Voltage phase angle shift

4.2.10.1 Matter to be addressed

In a weak power system such as South Australia's, both the magnitude and phase angle (that is, the vector) of the voltage can change more for a given disturbance than they would in a strong system. Modern non-synchronous generators have sensitive systems installed to protect them from faults occurring on the network. In a weak system, these disturbances can propagate for some time.

One type of protection equipment commonly used in non-synchronous generators is a voltage vector shift protection relay and these are routinely installed by manufacturers. Unfortunately, these relays can be vulnerable to the false detection of some faults. Setting requirements around vector shift protection relays is largely a response to a weak system and helps to avoids spurious triggering.

AEMO has noted that some European countries use voltage vector shift relays for anti-islanding at the distribution system level and which are typically set at 6–12 degrees.[76]

For example, if a sizable amount of local generation was lost (say, 300 MW) due to a moderate disturbance, it is conceivable that a voltage phase angle shift of up to 20 degrees could occur across multiple generators. Voltage vector shift protection relays set at between 6-12 degrees would sense such change and be activated, perhaps, prematurely — this could result in the loss of synchronism particularly during high imports on the Heywood interconnector which could, in the extreme, lead to a black system event.

AEMO advised its concern with the number of transmission and distribution connected generating systems in South Australia that use vector phase shift relays and recommends that generating systems remain connected for a network fault irrespective of the size of the voltage phase angle shift.

4.2.10.2 AEMO's recommendation

AEMO recommended that the generating system must not include any vector shift or similar types of relays which might operate for phase angle changes less than 20 degrees.

[75] For synchronous generators, consideration will be given to the physical limitations of the plant. This may require a variation to this condition, which will be determined by the Commission at the time of issuing of the licence.

[76] For example, Ireland's EirGrid and the United Kingdom's National Grid.

4.2.10.3 Submissions received

No submission addressed this specific recommendation.

4.2.10.4 Commission's consideration

AEMO has advised the Commission that vector shift relays settings of between 6-12 degrees may result in premature tripping of the generating system, which would have otherwise sustained larger phase angle jumps and may create system disturbances that could result in cascading failures on the system.

Having regard to the increased risk to South Australia becoming separated from the NEM with the use of voltage vector phase shift relay protection system or protective function, the Commission will implement this recommendation.

4.2.10.5 Commission's Final Decision

The Commission will implement a licence condition as follows:

1. The generating system must not include any vector shift or similar relay/protective function acting upon voltage phase angle which might operate for phase angle changes less than 20 degrees.

4.3 Voltage control capability

Summary of the Commission's final decision

The Commission will retain the existing reactive power capability licence conditions specifically relating to voltage control but restated to incorporate the following intent:

1 The generating system operated by the licensee must be capable of control by a fast-acting, continuously variable, voltage control system. The voltage control system must be able to receive a local and remote voltage set point.

2 The generating system operated by the licensee may operate at either a set reactive power, or a set power factor, which is able to be set locally or remotely at any time.

3 The voltage, power factor or reactive power control mode of the generating system operated by the licensee must be capable of:

(a) being overridden by the disturbance ride through requirements during power system disturbances, and

(b) automatically reverting to the selected control mode when the disturbance has ceased.

4.3.1 The matter to be addressed

Reactive power is vital to the integrity of a power system. The provision and control of reactive power:

- supports power flow through the transmission network
- manages voltages to within required limits, and
- ensures the system is able to remain intact and recovers from minor and major network disturbances.[77]

[77] The matter of using reactive power capability to respond to system disturbances was addressed in the earlier section on Disturbance Ride Through Capability (see section 4.2.3).

Flexibility in the control characteristics of generation enables operation of the power system to be optimised. The ability to use the reactive power capability of a generator to control voltage during normal operations allows the power transfer capability of the system to be maximised.

4.3.2 AEMO's recommendation

AEMO has recommended that the reactive power capability licence conditions specifically relating to voltage control (current model licence conditions 10.5, 10.6, and 10.7) should be retained but should stand apart from those conditions or technical standards that relate to the performance of a generator during disturbances.

While the licence conditions generally reflect the NER clause S5.2.5.5 and S5.2.5.13 requirements, the NER does not impose mandatory voltage control for generators connecting to systems rated at less than 100 kV. AEMO has advised that voltage control within the distribution networks to be highly beneficial and for this reason has recommended the retention of the current model licence conditions set out in 10.5, 10.6 and 10.7.

In addition, to ensure adequate voltage control and to aid clarity in application of these conditions, AEMO recommends the licence conditions be reworded slightly to reflect that the condition should apply to the entire generating 'system' (as opposed to generating 'plant').

4.3.3 Submissions received

Tilt Renewables is supportive of the changes recommended by AEMO in its Final Advice to the Commission.[78]

No conflicting submissions to the Draft Report were received on this matter. However, several respondents to the Issues Paper and other forums have commented on the necessity, usefulness, efficiency, and cost of the existing reactive power capability licence conditions.

4.3.4 Commission's consideration

The Commission and AEMO have taken stakeholders views into account in its overall consideration of the issues.

In its Final Advice, AEMO has noted that the reactive power capability of many non-synchronous generating systems recently connecting, or applying for connection, in other NEM regions would actually exceed the existing licence condition requirements. This would indicate that compliance with the existing conditions is not necessarily a barrier to non-synchronous generators connecting in South Australia.

AEMO has advised that the existing licence conditions have delivered significant direct and indirect benefits to both generators and to the power system since they were originally introduced. These provisions provide generators with the ability:

- to control and support local network voltages during normal operating conditions, and
- to facilitate optimal power transfers within the network.

In the past, these existing licence conditions have also ensured that wind-powered generators had the capability to meet other aspects of their licensing and performance obligations (including as outlined in the discussion on disturbance ride through capabilities section above).

With respect to voltage control, the Commission considers that this capability is a fundamental requirement for modern power systems particularly during an era of declining synchronous generators.

[78] Tilt Renewables, submission to Draft Report, p. 3.

This reduction in synchronous generation capacity in South Australia since the 2010 review of licence conditions has increased the reliance on the growing amount of non-synchronous variable electricity generation in the region. This almost instantaneous variability in supply output, when demand is also changing, requires generators to have greater flexibility and control to manage voltages and to assist in the optimising power transfers across the network.

The Commission considers that given the sensitivity of the South Australian power system that all new generators should also be able to control voltage in the manner that has been required of existing generator licensees.

4.3.5 Commission's final decision

The Commission will continue to require the intent of the existing model licence conditions 10.5, 10.6 and 10.7 as they relate to voltage control and to extend them to all new entrant generators subject to the restating of the recommendation advised by AEMO:

1. The generating system must be capable of control by a fast-acting, continuously variable, voltage control system. The voltage control system must be able to receive a local and remote voltage set point.
2. The generating system may operate at either a set reactive power, or a set power factor, which is able to be set locally or remotely at any time.
3. The voltage, power factor or reactive power control mode of the generating system operated by the licensee must be capable of:
    a. being overridden by the disturbance ride through requirements during power system disturbances, and
    b. automatically reverting to the selected control mode when the disturbance has ceased.

4.4 Active power control capability

Summary of the Commission's final decision

The Commission will require all new generators to incorporate **active power control** facilities that are capable of:

- providing an automatic active power response to frequency changes
- responding to automatic generation control signals from AEMO
- adjusting the rate of change of active power, and
- communicating the status of its active power controls to AEMO in real time — enabling remote monitoring of the generating unit's active power control settings.

4.4.1 The matter to be addressed

4.4.1.1 Background

As part of the NEM, the South Australian power system operates within a set frequency range around 50 Hertz (Hz). This underpins the safe, secure and reliable transmission of power through the electricity supply chain from generators to consumers. AEMO is responsible for controlling the power system frequency according to the Frequency Operating Standard (FOS).[79]

Controlling power system frequency requires the constant balancing of electricity supply and demand. If electricity supply exceeds demand at moment, the frequency will increase. Conversely, if demand exceeds supply, the frequency will decrease. A stable and resilient power system can respond to such changes with relative ease and the service to consumers remains unaffected. However, if the mismatch between supply and demand is too great, generators and consumers can be disconnected.

AEMO is responsible for matching supply and demand through a centrally coordinated dispatch process. This dispatch process aims to match supply to demand as well as coordinate generation capacity, to be able to quickly respond to changes.

As noted the control of power system frequency requires close matching of the supply and demand for active power[80] — over timeframes far shorter than the five-minute market dispatch interval.

4.4.1.2 What are active power controls and why are they necessary?

Frequency control ancillary services (FCAS) are used to maintain the power system in a nominal band that supports the ongoing secure operation of the power system. Currently, FCAS is provided by precisely increasing or decreasing the active power output from generators. This is done through a special market which AEMO uses to ensure FCAS services are available to increase or decrease output at short notice.

Although any technology can participate in the FCAS market — if technically capable — these services have generally been provided by synchronous thermal generators in South Australia. To provide these services, a generator (such as large synchronous units connected to the NEM) must have the technical capability in-built — these capabilities or facilities are referred to as active power control services. Fundamentally, these capabilities are made possible through the ability of generators to vary their active power output in a precise and controlled manner — either in response to power system conditions or to (automatic generation control) signals from AEMO.

Wind-powered and solar PV generators, in the past, have not been required to provide these services and thus do not have the necessary active power control capabilities to participate in power system frequency control.[81]

As the generation mix in South Australia changes, the share of energy supplied by that generation with active power control capabilities to manage frequency is reducing and this exposes the power system to the risk that there may be insufficient resources available to respond to a disturbance on the power system or to manage the South Australian system if separated from the NEM.

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79 The specific frequency requirements that AEMO must meet under different power system conditions are set out in the frequency operating standard (FOS), which is determined by the Reliability Panel (Panel). The Panel forms part of the AEMC's institutional arrangements that support the national electricity system and its core functions relate to the safety, security and reliability of the national electricity system. A review of the FOS is currently underway and further information on this review may be accessed at: http://www.aemc.gov.au/News-Center/What-s-New/Announcements/Review-of-frequency-operating-standard-gets-underw.

80 Active power (or electrical power) is a measure of the instantaneous rate at which electrical energy is consumed, generated or transmitted.

81 Although this is beginning to change with the HWF 2 Pty Ltd Wind Farm's involvement in an FCAS trial in South Australia and the Musselroe Wind Farm in Tasmania.

4.4.2 Overview of AEMO's active power control capability recommendations

AEMO recommended that all new generators with a capacity of 5 MW and greater, whether synchronous or non-synchronous, seeking to connect to the power system in South Australia have active power control facilities capable of providing the following functionality:

- the capability to provide an automatic active power response to frequency changes (refer to Section 4.4.5)
- the capability to respond to automatic generation control (AGC) signals from AEMO (refer to Section 4.4.6)
- the capability to limit the rate of change of active power within each five-minute dispatch period (refer to Section 4.4.7), and
- the capability to communicate the status of its active power controls to AEMO in real time enabling remote monitoring (refer to Section 4.4.8).

AEMO recommended that all new entrant generators:

- must register with AEMO for the provision of FCAS (specifically, Regulation and Contingency FCAS services) such that these capabilities must be continuously available for service when directed to do so by AEMO, or when required to do so under any other arrangements with the local NSP (refer to Section 4.4.9).

In addition, AEMO recommended that the proposed active power capabilities be installed and fully tested at the time of plant commissioning, including the development of accurate simulation models. If 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. The Commission's consideration of the matter of simulation models and other information requirements is discussed in Section 4.7.1.

A detailed consideration of each of AEMO's recommendations on active power capabilities is provided in the following sections.

4.4.3 Submissions received

Tilt Renewables,[82] Origin Energy[83] and Pacific Hydro[84] raised their concerns regarding the lack of frequency control in the NEM and the effect that AEMO's recommendations on active power control technical standards could have on resolving the situation.

In particular, Tilt Renewables, Origin Energy, Pacific Hydro and Reach Solar[85] raised concerns regarding the requirement for new generators to participate in FCAS markets and the risk that it may reduce frequency control overall. They also noted the work underway with AEMO's technical advisory group on frequency control and advised the Commission that they saw merit for it to consider the outcomes of this investigation before imposing such a requirement.

82 Tilt Renewables, submission to Draft Report, p. 5.
83 Origin Energy, submission to Draft Report, p. 7.
84 Pacific Hydro, submission to *Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators*, Draft Report, 13 June 2017, available at . http://bit.ly/InquiryDraftDecision-Submission-PacificHydro.
85 Reach Solar, submission to Draft Report, p. 2.

Regarding the rate of change of active power limits, Tilt Renewables, EnergyAustralia[86] and Reach Solar requested further clarification on whether the intent was to limit ramp-rates associated with bidding or if it also applied to fuel source variability.

In addition, EnergyAustralia noted that introducing limits on the rate of change of active power output may unfairly penalise new entrants and their ability to respond to price events from the market.[87]

4.4.4 Commission's overall considerations

The Commission considers that the future possibility of the South Australian power system having generators with little ability to control their active power to manage changes in system frequency represents a risk to the operation of a secure and reliable power system. This would be particularly concerning if, and when, the power system is islanded from the rest of the NEM as a result of a contingency event.

AEMO has advised that the connection of generating plant whose active power output cannot be made automatically sensitive to system frequency, or cannot be directly controlled over short timeframes, cannot act to improve the risk profile in South Australia. Accordingly, the Commission considers that the lack of sufficient active power control capabilities has the potential to create an unacceptable risk for consumers in terms of the price, reliability, and quality of electricity supply.

AEMO also advised that some of the recommended active power control capabilities can potentially be negotiated, such as the frequency raise and lower capabilities under S5.2.5.11 of the NER, others cannot.

NER clause S5.2.5.14 specifies the active power controls for generating units and systems but the Commission notes that its application is limited to those generators with capacities of 30 MW or more. The Commission's previous licence conditions applied to generators with capacities of 5 MW or more and AEMO's recommendations remains consistent.

The Commission considers it necessary for all new generators to have the flexibility to modify their active power output in a specific and controlled manner in response to various contingency events or at the direction of either AEMO or the NSP to manage resulting supply-demand imbalances. Accordingly, the Commission will require all new generators to have the recommended active power control capabilities.

4.4.5 Capability for automatic active power response to frequency changes

4.4.5.1 AEMO's recommendation

AEMO recommended that all new entrant generators be required to have the capabilities set out below:

- Generating plant must be capable of automatically providing a proportional increase or decrease in active power output, in response to falling and rising power system frequency respectively.
- The steady state droop[88] setting of this active power response must be adjustable in the range two percent to 10 percent.
- The frequency dead-band for this response must be adjustable in the range from 0 to ±1.0 Hz.

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86 EnergyAustralia, submission to *Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators*, Draft Report, 9 June 2017, p. 3, available at . http://bit.ly/InquiryDraftDecision-Submission-EnergyAustralia.

87 EnergyAustralia, submission to Draft Report, p. 3.

88 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 the dead-band limits).

- Generating plant must be capable of sustaining a response to abnormal frequency conditions for at least 10 minutes[89], subject only to energy resource availability, or other plant technical or regulatory limits.
- 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 frequency leaves the dead-band.
- 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.

AEMO also recommended that the Commission consider the merits of applying these conditions to existing plant where appropriate.

4.4.5.2 Commission's consideration

The capability for generators to provide an automatic active power response to changes in the system frequency is essential to provide a (governor-like) response to changes in power system frequency or to provide FCAS (contingency) services to the market.

AEMO has advised the Commission that a similar capability might be available to it by negotiation of the automatic standard in clause S5.2.5.13 of the NER. However, AEMO recommended that the Commission clarify the expectations for plant performance by mandating the base level of capability in its licence conditions as expressed above.

The Commission notes that this recommendation reflects the United States of America's (US) Federal Energy Regulatory Commission (FERC) proposal[90] for all generators (synchronous and non-synchronous) to have frequency response capabilities if they are to be connected to the interconnected US network.

4.4.5.3 Commission's final decision

The Commission will include the intent of AEMO's recommendation as follows but will not apply it to existing generators (refer to Chapter 5):

1. The generating system must be capable of automatically providing a proportional increase or decrease in active power output, in response to falling and rising power system frequency respectively.
2. To comply with the above clause:
    a. 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 frequency leaves the deadband.
    b. The steady state droop setting of the active power response must be adjustable in the range 2 percent to 10 percent.
    c. The frequency deadband for the active power response must be adjustable in the range from 0 to ±1.0 Hz.

[89] Consistent with existing 300 second contingency FCAS specification and proposals for contingency frequency response capability specified or considered in ERCOT, National Grid, and EirGrid/Soni power systems.

[90] Refer to docket number RM16-6-000, available at: https://www.ferc.gov/whats-new/comm-meet/2016/021816/E-2.pdf.

3. The generating system must be capable of sustaining a response to abnormal frequency conditions for at least 10 minutes, subject only to energy resource availability for intermittent generating systems.

4. The generating system must be capable of applying different deadband and droop settings in response to rising and falling frequency and for different levels of frequency change.

4.4.6 Capability for automatic generation control

4.4.6.1 AEMO's recommendation

AEMO recommended that all new entrant generators to have the following AGC capabilities as described below:

- Generating plant must have active power control capabilities that allow it to participate in existing NEM AGC arrangements. This includes arrangements used for automatic dispatch control of generation, and for frequency regulation.
- At a minimum, this requires:
  - The ability to receive and respond to a remotely determined active power control set-point, updated at a rate of every 4 seconds,[91] transmitted to the site via SCADA.
  - Provision of the following information to AEMO via real-time SCADA:
    - actual active power output
    - maximum raise limit
    - minimum lower limit
    - maximum raise ramp rate, and
    - maximum lower ramp rate.

AEMO also recommended that the Commission consider the merits of applying these conditions to existing plant where appropriate.

4.4.6.2 Commission's consideration

The need for generators to be controlled via AGC signals is necessary for the provision of FCAS services (particularly, the regulation of frequency service)[92] to the market. Regulation FCAS services are used to continually adjust power system frequency within the normal operating frequency band.[93] Regulation FCAS services are provided by increasing or decreasing active power output in response to centrally generated signals sent to generators by the NEM AGC system.

The Commission considers that this is a critical capability and a functionality that all generators should ultimately possess as the South Australian generation mix shifts towards the greater use of non-synchronous generation. Having as much plant available as possible with this capability across the

[91] This is over and above the requirement of S5.2.5.14 of the NER which only requires a scaling of active power set-points.

[92] Frequency regulation is a centrally managed control process to maintain frequency on a continuous basis. AEMO's automatic generation control process detects minor deviations in power system frequency, and sends 'raise' or 'lower' signals to generating units providing regulation FCAS to correct the frequency deviation.

[93] The normal operating frequency band is defined as 48.85-50.15 Hz under nominal conditions. For more information refer to the *NEM Mainland Frequency Operating Standards:* http://www.aemc.gov.au/getattachment/436495bb-89b9-4da6-b258-e24437df9b8a/Frequency-Operating-Standards-(Mainland).aspx.

South Australian power system is likely to assist in maintaining frequency within the normal operating band. Accordingly, the Commission will implement this licence condition.

The Commission will not apply this requirement to existing generators at this stage (refer to Chapter 5 for more detail on the general process to be followed).

4.4.6.3 Commission's final decision

The Commission will require the following capability:

1. The generating system must have active power control capabilities that allow it to participate in existing national electricity market arrangements requiring automatic generation control.
2. At a minimum, the AGC must have the capability to:
    a. receive and respond to a remotely determined active power control set-point, updated at a rate of every 4 seconds, transmitted to the generating system, and
    b. provide the following information to AEMO, upon a request from AEMO under NER clauses S5.2.6.1 or 3.8.2:
        i. actual active power output
        ii. maximum raise limit
        iii. minimum lower limit
        iv. maximum raise ramp rate, and
        v. maximum lower ramp rate.

4.4.7 Capability to limit the rate of change of active power

4.4.7.1 AEMO's recommendation

AEMO recommended that all new entrant generators have capabilities to control the rate of change of active power as set out below and consider the application of these conditions to existing plant where appropriate:

- Generating plant 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.
- Generating plant must be capable of implementing different active power rate limits for different events.
- Generating plant must be capable of implementing different active power rate limits over different time frames.
- Generating plant must be capable of meeting a specified ramp rate limit with accuracy of no more than 10 percent. That is, the variation in active power within the time period specified for the active power rate limit may not deviate by more than 10 percent from a straight line trajectory between the initial and final active power set-points determined by the rate limit.

AEMO also recommended that the Commission consider the merits of applying these conditions to existing plant where appropriate.

4.4.7.2 Commission's consideration

The ability for generators to limit the rate of change of their active power output is important for minimising the risk of significant supply demand imbalances on timescales within a dispatch period.

Such circumstances may result from a change to a generator's remote active power set-point, a trigger from a special protection scheme following a contingency event, or a change in input (wind or solar irradiation) energy to variable energy generators. In addition, different limits may also be required over short timeframes to manage impacts on the network or over long timeframes to manage impacts on the total supply demand balance.

The Commission notes that the requirement for down ramp limits would not be appropriate for variable energy generators because this would be out of its control and largely dependent on the availability of the primary energy source. To insist on this control capability would require the generator to incorporate energy storage to comply — requiring additional cost or otherwise it may be prohibit the development. To ensure a technology is not restricted, the Commission will exempt variable energy generating systems where the reduction in active power is due to primary energy resource availability and is beyond the generating systems reasonable control.

The Commission will include the intent of AEMO's recommendation but will not apply it to existing generators (refer to Chapter 5).

4.4.7.3 Commission's final decision

The Commission will require the following capability:

1. The generating system must be capable of limiting the rate of change of active power, both upwards and downwards (except that variable energy generators would be exempted from the downward ramp limit).
2. The generating system must be capable of implementing different active power rate limits for operation in the normal operating frequency band and for contingency events.
3. The generating system must be capable of setting a ramp rate limit with accuracy of within 10 percent.

4.4.8 Remote monitoring requirements

4.4.8.1 AEMO's recommendation

AEMO recommended that all plant, both existing and new entrant generators, whether synchronous or non-synchronous, to provide it with real-time information about their active power control systems.

4.4.8.2 Commission's consideration

The Commission understands that access to this information has the potential to allow AEMO to more precisely define the power system technical envelope[94] and to better understand real-time ancillary services requirements and capabilities for power system security purposes.[95] These recommendations are consistent with the Electric Reliability Council of Texas (ERCOT) requirements which oblige all generators to notify the system operator regarding changes to active power control settings.[96]

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94 The NER defines the technical envelope to mean the technical boundary limits of the power system for achieving and maintaining the secure operating state of the power system for a given demand and power system scenario. Refer to NER clause 4.2.5.

95 Refer to NER clauses 4.3.1 (e) and (i).

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

Should AEMO not be made informed of any change in the value of any key active power control system limits or settings during real-time operation creates an unnecessary risk for the power system.

The Commission considers that this capability would provide AEMO with a finer level of control of the power system than what may currently exist particularly when managing a contingency event in South Australia.

AEMO advised that it does have the ability to request this information under NER clause S5.2.6.1, however, there is not currently a requirement on generators to have the necessary SCADA signals. In its Addendum to its Final Advice, AEMO has amended its recommendation to focus the revised licence condition on ensuring the generator has the appropriate capabilities.

AEMO advised that some existing synchronous generators may be able to communicate their active power control settings through minor changes to software and SCADA systems, however, the Commission will not apply this requirement to existing generators at this stage (refer to Chapter 5 for more detail on the general process to be followed).

The Commission will include the intent of AEMO's recommendation for all new generators.

4.4.8.3 Commission's final decision

1. The generating system must have the capability to provide real-time information about its active power control settings to AEMO, including mode of operation, deadband and droop parameters and any other active power control setting that may change during real-time operation.

4.4.9 Registration as an ancillary services generating unit

4.4.9.1 AEMO's recommendation

AEMO had recommended that new entrant generators be required to register as ancillary service generating units for the provision of both regulation and contingency FCAS.[97]

It also recommended that the Commission consider applying the requirement for registration as ancillary service generating units to existing generation that has the technological capability to provide regulation and contingency FCAS, having regard to the costs and operational impacts of doing so.

4.4.9.2 Commission's consideration

AEMO had considered that there would be considerable value for new entrants to register as ancillary services generating units and to allow their frequency control capabilities to be used if required for system security purposes, if necessary under direction from AEMO. However, AEMO's Final Advice indicated that its recommendation would not require new generators to participate in FCAS markets but only to be registered to be capable of providing FCAS services and, if required to do so.[98]

Stakeholders have raised concerns about the functioning of current FCAS markets and while a review of FCAS markets is beyond the scope of this Inquiry, the Commission considers that ensuring all generators have the capability to provide frequency control services when required is within scope. Accordingly, the Commission considers that the requirement for new generators to have the capability for active power control is well founded.

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[97] Contingency FCAS services are called upon by AEMO to both stabilise and correct large deviations in power system frequency following the unexpected disconnection of a large generation or load. Under current market arrangements, contingency FCAS services are provided registered generators by increasing or decreasing active power output in response to the frequency conditions at each generator's position in the network.

[98] Once registered as an FCAS provider, participation in the FCAS markets is entirely voluntary — refer to NER clause 2.2.6(a).

Submissions to the Draft Report by Tilt Renewables, Origin Energy, and Pacific Hydro expressed concern with the current state of frequency control and the potential adverse effect of even more FCAS providers would have on frequency control of the power system – particularly when the underlying issues have yet to be identified and resolved.[99] Snowy Hydro stated that any mandatory imposition of technical requirements would be inefficient.[100]

To address the broader concerns with frequency, AEMO has commenced a review of FCAS markets and established the AS TAG. In addition, AEMO is undertaking a trial to examine the provision of FCAS from new entrant wind generation.[101] The above projects will help to better understand the underlying drivers of the issues associated with frequency control and will also clarify if the Market Ancillary Service Specification (MASS) in its current form can be applied to wind-powered and solar PV generating systems.

The Commission notes the concerns raised by stakeholders and the status of the work currently being progressed by AEMO. The Commission understands that the FCAS trial has been delayed and that AEMO's AS TAG is still reviewing the MASS.

With the current indeterminate status of these projects, the Commission considers that it is premature for it to impose a requirement for all generators to register as ancillary services generating units.

Accordingly, the Commission will not introduce a licence at this stage but will continue to monitor developments in this area.

4.4.9.3 Commission's final decision

1. The Commission will not make a licence condition to require licensees (new or existing) to register as an ancillary services generating unit.

4.5 System restoration capability

Summary of the Commission's final decision

The Commission will require all new generating systems, in the event of a black system and while system load is being restored, to be capable of:

- operating with auxiliary loads only (for a duration to be specified), and
- providing steady-state and dynamic reactive power when operating with auxiliary loads.

4.5.1 The matter to be addressed

With the current state of technology, variable energy non-synchronous generators are unable to be contracted by AEMO to provide system restart ancillary services (SRAS) in the event of a black system. The reasons for this lack of capability arise from the intrinsic variability of the primary energy source and the need for a minimum system strength (or fault level) which is not available during black system conditions.

[99] Tilt Renewables, submission to Draft Report, p. 5; Origin Energy, submission to Draft Report, p. 5; Pacific Hydro, submission to Draft Report, p. 5.
[100] Snowy Hydro, submission to Draft Report, p. 3.
[101] Since the development of the Final Advice in March 2017, AEMO and HWF 2 are about to commence an FCAS trial that will evaluate the capability of a variable renewable energy generator to provide FCAS services.

Despite this lack of capability, and provided that a number of synchronous generators are already restarted and are able to provide the minimum fault level required for the stable operation of non-synchronous generating systems,[102] then these generators (and other associated plant) could still make an important contribution to the restoration process by providing voltage and reactive power control as needed.

4.5.2 AEMO's recommendation

AEMO had recommended that the Commission require the following capabilities from all new-entrant generators:

- Subject to provision of minimum fault level by on-line synchronous machines, it must be possible to operate the non-synchronous generating systems for at least three hours with auxiliary loads only.
- When operating with the auxiliary load, the generating system – including each of its generating units, reactive power support plant and battery storage units (if applicable) – must be able to supply 50 percent of their maximum steady-state reactive power capability and full dynamic reactive power capability.
- Successful operation with auxiliary load and provision of static and dynamic reactive power capability must be demonstrated during the commissioning and compliance testing, and must be verified following significant modifications to the generating system and its individual components.
- Electromagnetic transient (EMT) simulation models submitted to AEMO must account for operation with auxiliary loads.

4.5.3 Submissions received

Origin Energy and Vestas submitted that extended operation of plant on auxiliaries for more than 30 minutes may not be possible and could result in damage to the generating system and other items of plant.[103]

4.5.4 Commission's consideration

The Commission notes that AEMO's investigation into the Black System recommended that improvements should be made to the speed of restoration of the system without increasing risk.[104] The Commission considers that having a greater number of generators available would assist in the speedier restoration of the power system and that this would result in a benefit to consumers by possibly reducing the length of the outage.

In addition, the Commission has noted the submissions from Vestas and Origin Energy with respect to the length of time that some generating units can operate on auxiliary loads and will ensure that this duration be limited to the capability of the plant.

The Commission will not apply this requirement to existing generators at this stage (refer to Chapter 5 for more detail on the general process to be followed).

[102] These generating systems is expanded to include generators, dynamic reactive support plant, battery storage units and other associated plant.
[103] Origin Energy Submission to Draft Report, p. 6; Vestas Australia Submission to Draft Report, p. 4.
[104] AEMO, *Black System South Australia 28 September 2016*, p. 102.

4.5.5 Commission's final decision

The Commission will require that:

1. The generating system must have the following capability in the event of a black system:
    a. Where sufficient minimum fault level is available from online synchronous machines, the generating system must be capable of operation with auxiliary loads only for a prescribed duration (to be specified) while system load is being restored.
    b. The generating system, including each of its generating units, reactive power support plant and battery storage units (as applicable) must have the capability to provide steady-state and dynamic reactive power when operating with auxiliary loads only for a prescribed duration (to be specified) while system load is being restored.

4.6 System strength capability

Summary of the Commission's final decision

The Commission will require all new generators to be capable of the following:

- Individual components of plant within a generating system, which includes but is not limited to generating units and dynamic reactive power plant, must be capable of operating down to the following levels at the high voltage terminals in relation to each component:
    a. minimum short circuit ratio of 1.5, and
    b. minimum positive sequence system inductive to resistive impedance ratio of 2.

4.6.1 The matter to be addressed

System strength is an inherent and important characteristic of a well-functioning power system. It is important to the stability of a power system and can materially affect its operation. If system strength is low it can result in issues with voltage control, short circuit current, inertia and synchronising torque.

One measure of system strength is the available fault current or the short circuit ratio (SCR) at a given location. Another measure of system strength is the ratio of system inductive to resistive impedance (X/R ratio) — a low X/R ratio also reflects degrading system strength. Higher fault currents are representative of a stronger power system, whereas lower fault currents are representative of a weaker power system.

Fault currents can vary across the network — are highest closer to synchronous generation and are influenced by the number of nearby synchronous generators and whether they are connected by different transmission lines.

AEMO has advised that low system strength can degrade the performance of the power system and compromise its security, in the following ways:

- the inability to control voltage during normal system operations such as switching of transmission lines or transformers, switching reactive plant (capacitors and reactors), transformer tap changing, and routine variations in load or generation
- the operation of power electronic converter interfaced generators outside their minimum SCR limits could give rise to generating systems' instability and consequent disconnection from the grid

- the incorrect operation of protection systems — either in not sensing only those specific conditions for which they were installed or for not being sufficiently sensitive to faults on the equipment they were intended to protect, and
- the inability to prevent voltage dips from spreading across the network.[105] In a weak network area, voltage dips arising from a fault can be deeper, more severe, more widespread, and can last longer than in a strong network. This longer propagation of voltage dips may result in more non-synchronous generators activating their fault ride-through at the same time which may cause more concerns.

Given the current state of technology, non-synchronous generation does not contribute to system strength as much as synchronous generation, if at all.

System strength reduces with increasing levels of non-synchronous generation and also with the withdrawal of synchronous generators which contribute more to the level of available fault current. Both these drivers can lead to a system-wide weak power system and compromise its stability and security.

Finally, a lack of system strength in the network may mean that generators are no longer able to meet their agreed technical standards and be unable to remain connected to the power system.

4.6.2 AEMO's recommendation

To address the underlying drivers of reductions in system strength, AEMO recommended that the Commission considers:

- a licence condition on NSPs to maintain a short circuit ratio at each connection point within a range agreed in each connection agreement, and
- licence conditions on connecting generators to ensure that their plant is designed to maintain certain standards, taking into account the prevailing network conditions.

Furthermore, AEMO recommended to the Commission that it require susceptible items of plant (such as individual generating units, dynamic reactive power support plant, and storage interface units) within the connecting party's generating system to be capable of operating correctly down to the following levels at the high voltage (HV) terminals of each item of plant:

- Minimum short circuit ratio of 1.5.
- Minimum positive sequence X/R ratio of 2 (ratio of system inductive to resistive impedance).

The above criteria should apply in conjunction and no criterion can override another.

AEMO also recommended that the Commission consider the merits of applying these conditions to existing plant where appropriate.

4.6.3 Submissions received

The recommendation requiring susceptible plant to be capable of correct operation down to a mandated minimum system strength was generally supported by ElectraNet in its submission. It considered that this requirement was justified given the current state of generation dispatch and the number of proposals for non-synchronous generation.[106]

[105] A voltage dip is a drop in network voltage that arises following a fault or switching event.
[106] ElectraNet, submission to Draft Report, p. 3.

In its submission, Vestas expressed its concern with the general requirement to meet the specified SCR and X/R ratio capability and noted that the performance of a wind turbine generator capability is dependent on control system tuning, and additional compensation equipment.[107]

Tilt Renewables encouraged the Commission to include:

> *… a detailed description of the methodology for calculating changes in system strength …*

and also noted that it:

> *…has the potential to either economically support the system or to make connection of new generation uneconomical depending on its formulation.*[108]

Similarly, Pacific Hydro noted that the:

> *Provided that the setting of the minimum fault levels is open and transparent and NSPs must publish the existing fault level (actual) and the maximum and minimum for each location in the network the proposal will be workable. Any lack of transparency will lead to manipulation in commercial negotiations.*[109]

4.6.4 Commission's consideration

The Commission notes that the AEMC has released its final report[110] into its System Security Market Frameworks Review.[111] In respect of system strength, the AEMC recommended that:

- networks be responsible for maintaining a minimum level of system strength for each connected generator, and
- new connecting generators pay for remedial action if they have caused the minimum system strength for other generators to be breached.

In addition to its final report, the AEMC, concurrently, released its draft determination on the South Australian Government's request for a Rule change on managing power system fault levels.[112] The AEMC's draft determination reflected the final report's recommendations for an enhanced framework to require NSPs to maintain system strength at generating system connection points above an agreed minimum level under a defined range of conditions. In addition, AEMO will be required:

- to identify locations in the network where system strength is below, or likely to be below, the registered minimum short circuit levels, and
- to develop and maintain short circuit ratio calculation guidelines that NSPs are required to follow when assessing their compliance with their obligations to maintain the system strength and when assessing the potential impacts of new connections on the short circuit ratios being provided to existing generating systems.

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107 Vestas, submission to Draft Report, p. 3.
108 Tilt Renewables, submission to Draft Report, p. 5.
109 Pacific Hydro, Submission to Draft Report, p. 8.
110 AEMC, *System Security Market Frameworks Review Final Report*, 27 June 2017, available at: http://www.aemc.gov.au/Markets-Reviews-Advice/System-Security-Market-Frameworks-Review/Draft/AEMC-Documents/Final-report.aspx.
111 AEMC, *System Security Market Frameworks Review Final Report* and associated rule changes are available at: http://aemc.gov.au/Major-Pages/System-Security-Review.
112 Information on the AEMC's draft determination on this rule change may be accessed at: http://www.aemc.gov.au/Rule-Changes/Managing-power-system-fault-levels.

In arriving at its final decision, the Commission acknowledges that the AEMC's draft Rule determination seeks to address the first two recommendations made to it by AEMO and also addresses the concerns raised by stakeholders in regard to those matters.

In its Addendum to its Final Advice, AEMO has recommended to the Commission that it not make licence conditions in relation to the obligations on connecting parties and NSPs for system strength as the AEMC's draft determination has proposed a framework that best addresses these issues.

The Commission will monitor developments with respect to these matters and, at this stage, will not introduce any licence conditions.

AEMO's third and final system strength recommendation relates to the operation down to the levels specified at the HV terminals of plant. The Commission notes that this requirement is not at the ultimate connection point[113] with the NSP but is required at each and every individual element of plant — which could be several kilometres away (as could be the case for a widely dispersed generating system such as a wind farm) – and this is not common practice nor ideal.

AEMO advised that, as the performance of these individual elements determines the performance of the generating system at the connection point, a specified performance requirement at the HV terminals of susceptible items of plant within the connecting party's generating system may be the most effective way to achieve the desired outcome for consumers.

AEMO also advised that if generators were capable of operating down to low short circuit ratios, that this would reduce costs because if a new non-synchronous generator were to lower the local short circuit ratio, it would be considered to be creating a larger problem and, therefore, should be exposed to higher costs from the NSP to maintain the available short circuit ratio above the agreed minimum for existing generators.

AEMO advised that it appears to be the most practical way of minimising costs to future generators and, ultimately, to consumers. In addition, AEMO has suggested that there would be potential benefits to project developers, including:

- establishing a clear benchmark that all equipment manufacturers would need to meet in future would allow developers to utilise standard products rather than requiring customised designs to suit individual site conditions
- reducing the overall system strength that the connecting party would need to negotiate from the NSP at the connection point would minimise the connecting party's need for additional system strength and any costs associated with procuring this additional support, and
- resulting, potentially, in a more efficient connection process due to a lower number of iterations associated with satisfying generator performance standard requirements under weak system conditions.

The Commission accepts AEMO's advice that the costs to consumers will be minimised[114] if generators were capable of operating down to low short circuit ratios. The Commission considers that this approach will allow more generators to be located near one another without requiring additional network augmentation or else by constraining generators' output to manage weak system conditions.

[113] The connection point forms the notional dividing line of responsibility between the party seeking to be connected and the NSP.

[114] That is, the cost to consumers of incorporating increasing volumes of non-synchronous generation will be minimised.

Until an alternative methodology can be developed, however, that provides an equitable and transparent signal at the connection point, the proposed capability — that is, at the HV terminals within the connecting party's generating system — appears to be the most practical manner of minimising costs to future generators and, ultimately, customers.

AEMO advised that this system strength obligation could be obtained from existing generators, however, the Commission will not apply this requirement to existing generators at this stage (refer to Chapter 5 for more detail on the general process to be followed).

4.6.5 Commission's final decision

The Commission will require all new entrant generators to meet the following capability:

1. Individual components of plant within a generating system, which includes but is not limited to generating units and dynamic reactive power plant, must be capable of operating down to the following levels at the high voltage terminals in relation to each component:
    a. minimum short circuit ratio of 1.5, and
    b. minimum positive sequence X/R ratio of 2.

4.7 Other matters

4.7.1 Inertia

Physical inertia from synchronous machines plays an important role in slowing the rate of change of frequency when there is a mismatch between supply and demand, allowing time for frequency control mechanisms to respond. Non-synchronous generators are unable to provide inertia. AEMO advises that the Heywood interconnector with Victoria provides inertia to operate the South Australian power system. The risk to South Australia arises when it is separated from the NEM and the local power system needs to be operated as an islanded network. At that point there may be insufficient inertia on line to mitigate any subsequent risks.

In its Final Advice, AEMO recommended to the Commission that it not include licence conditions associated with the provision of inertia. It advised that a static technical obligation on generators to provide inertia would have the following drawbacks:

- it would not lend itself to co-optimisation of inertial requirements with other power system attributes such as system strength
- it would not lend itself to optimisation of locational distribution of inertia, and
- it would not necessarily deliver a secure power system.

However, given the importance of maintaining a minimum amount of inertia in the SA power system regardless of generator dispatch patterns, AEMO suggested that the Commission may wish to consider whether the procurement of inertia services for South Australia could be expedited through appropriate licence conditions for NSPs.

The Commission notes that the AEMC and AEMO are progressing several work streams that may impact the consideration of these issues including:

- the AEMC has issued its final report into its System Security Market Frameworks Review (released 27 June 2017)
- the AEMC's consideration of the Inertia Ancillary Service Market rule change request initiated by AGL (draft rule due 7 November 2017)

- the AEMC has issued its draft determination on Managing the Rate of Change of Power System Frequency rule change request initiated by the South Australian Government (draft rule released 27 June 2017)
- the AEMC's Frequency Control Frameworks Review (initiated in July 2017), and
- AEMO established the Ancillary Services Technical Advisory Group which is reviewing frequency control, the FCAS markets and the causer pays regime.

In summary, the AEMC's System Security Market Frameworks Review final report has made several recommendations in this area but the most relevant to the provision of inertia include the following:

1. placing an obligation on Transmission Network Service Providers (TNSP) to provide minimum required levels of inertia, or alternative equivalent services, to allow the power system to be maintained in a secure operating state, and
2. establishing a market-based mechanism to realise the market benefits that could be obtained through the provision of inertia above the minimum obligation on TNSPs. [115]

In addition, the Commission notes that the South Australian Government has introduced its technical requirements for inertia for new generators through its development application process.

Given these recommendations, AEMO's advice, the work that continues to be undertaken by the AEMC and AEMO in these areas, and the Government's initiatives, the Commission will continue to monitor developments in this area and, at this stage, will not make a licence condition in relation to inertia.

4.7.2 Fast frequency response

AEMO advises that analysis has shown that enabling FFR services in the NEM may allow the frequency operating standards to be met with a lower level of synchronous inertia, and potentially a lower cost in the long term. However, there is little global experience in procuring or operating FFR, and careful consideration of the specific requirements of the NEM will be required.

AEMO has indicated that its recommendations regarding active power control capabilities are seen as broadly compatible with FFR provision from generators, without prescribing at this time specifically how these responses must be delivered. Therefore, AEMO has not recommended additional licence condition requirements specifically for FFR capability.

In its System Security Market Frameworks Review final report, the AEMC recommended the following approach to the implementation of FFR services:

1. require new non-synchronous generators to have the capability to provide FFR services, and
2. establish a market for the provision of FFR services.

In addition, the Commission notes that the South Australian Government has introduced its technical requirements for FFR for new generators through its development application process. [116]

Given these recommendations, AEMO's advice, the work that continues to be undertaken by the AEMC and AEMO in these areas, and the Government's initiatives, the Commission will continue to monitor developments in this area and, at this stage, will not make a licence condition in relation to FFR.

[115] AEMC, *System Security Market Frameworks Review*, Final Report, p. v.
[116] AEMC, *System Security Market Frameworks Review*, Final Report, p. v.

4.7.3 Simulation models

AEMO's operational experience with the South Australian power system has identified a need for clearer guidelines regarding the simulation models that generators must provide during the connection process. Until such time as these guidelines are clearly stated under the NER, AEMO recommends that, as part of the licence application process, for new generators, the Commission emphasises the following:

- pre-validation against the actual response of generating system elements including all protection or control systems deployed with the operational generator
- the provision of more detailed models where standard generating system models are deemed insufficient, and
- changing control systems and/or settings of the individual generating system elements if the submitted models exhibit uncharacteristic or unexpected responses.

The absence of a particular generator protection feature in wind farm simulation models submitted to AEMO was a relevant factor in events which led to the Black System event.

Several submissions provided conditional support for AEMO's request for more detailed modelling. In particular, Origin Energy and Vestas noted that detailed modelling could be provided as long as any responsibilities, including confidentiality agreements, were made clear and AEMO provided sufficient reasons for requiring the data and the benefit to system security.[117]

Origin Energy noted that there is a cost to producing data and that significant rework and time is invested in producing such information due to the poor sharing practices between parties. It further noted that if modelling requirements were clearly outlined at the start of the process, it would reduce the time taken and prevent excessive costs.[118] Pacific Hydro noted that it is possible to provide more detailed models on future projects but it might be costly for existing generators.[119]

ElectraNet supported AEMO's recommendation for more detailed models and noted that these models may also be necessary for NSPs to carry out their system planning obligations.[120] Vestas submitted that it would provide these models to third parties, such as NSPs, if the party requests the model on a need to know basis, together with a confidentiality agreement. Vestas expressed concern that models could be distributed to unknown parties which could impact Vestas' competitiveness.[121]

4.7.3.1 Commission's consideration

The Commission notes that AEMO has lodged a Rule change request with the AEMC on Generating System Model Guidelines.[122] In its Draft Determination of 20 June 2017, the AEMC noted that increased clarity regarding the arrangements for model data provision would support more efficient operation of, and investment in, the NEM, particularly as this relates to maintaining the security of the power system.[123]

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117 Origin Energy, submission to Draft Report, p. 8; Vestas, submission to Draft Report, p. 3.
118 Origin Energy, submission to Draft Report, p. 8.
119 Pacific Hydro, submission to the Draft Report, p. 8.
120 ElectraNet, submission to Draft Report, p. 3.
121 Vestas, submission to Draft Report, p. 3.
122 AEMO, *Electricity Rule Change Proposal*, Rule change submission for revision of AEMO's Generating System Model Guidelines, October 2016, available at http://www.aemc.gov.au/getattachment/3799ab08-dd3d-49b4-b171-8e4ad631e860/Rule-change-request.aspx.
123 AEMC, *Generating System Model Guidelines*, Draft Rule Determination, 20 June 2017, available at: http://www.aemc.gov.au/getattachment/a8974d27-969f-4f54-b587-4bc4f9c32d19/Draft-Determination.aspx.

The Commission accepts the AEMC's position and should the draft rule determination be implemented as stated, then it is anticipated that no further action will be taken by the Commission in respect of requiring licence applicants to provide additional information.

The Commission also notes that AEMO's recommendations regarding the provision of simulation models is part of its registration process and outside the Commission's remit. However, the Commission supports AEMO requesting such data when sufficient reasons are provided. Further, the Commission may request licence applicants provide that information as part of its licence application where that information is required for AEMO to assess an applicant's ability to meet the Commission's licence conditions.

4.7.4 Aggregation of small generators

AEMO also commented on matters relating to the growth in small generators and energy storage systems and the potential for these to be aggregated into larger operating blocks. The potential for the growth of these systems has highlighted to AEMO the need to have access to data relating to the operation and performance of a wider range of equipment connected to the power system.

To address this challenge, AEMO has prepared a list of data requirements needed to efficiently perform its functions into the future. At the same time, AEMO is consulting with industry on the need for frameworks that will capture and make available the required data, and is collaborating with the ENA to explore the potential role of distribution system operators in providing this visibility.

The Commission notes AEMO's suggestion that there may be consequences in the aggregation of small generators[124] and will work with AEMO and the industry to investigate these issues and potential resolutions.

[124] The aggregation of small generators into larger operating blocks may create unintended consequences through sudden changes in generating output resulting in the prospect of frequency and voltage disturbances on the power system when these blocks are switched in and out of service.

5 Application of new conditions to existing licensees

Summary of the Commission's final decision

The Commission will work with licensees to ascertain where assistance could be provided to improve the stability and security of the power system.

The Commission considers that, where possible, current generator licensees should provide the additional capabilities and services to the power system to meet the very specific challenges faced in South Australia. Further engagement with licensees and other stakeholders including AEMO and NSPs will be undertaken to progress this matter. As part of this process, the Commission will seek additional information from licensees such as:

- the specific technical capabilities of current generating units or systems with respect to the new technical standards
- the physical or technical limitations in meeting the new technical standards, and
- the need for, and cost of, any upgrades that may be required to satisfy the new technical standards.

5.1 The matter to be addressed

As part of the Inquiry, the Commission reviewed the current regulatory framework for existing electricity generation licensees to identify whether it should apply the proposed licence conditions to existing licensees.

The Commission recognised that the application of any new licence conditions to new entrant generators does not resolve the issues that the electricity network in South Australia is currently experiencing with the current generation fleet or is likely to experience in the future. In other words, the benefits to be realised by the new licence conditions would not occur for a number of years. In addition, as a number of existing generators in South Australia will continue to operate over a similar timeframe as any new generators, there may be a need for current generators to assist in providing additional capabilities to improve system security and resilience now and in the long term.

The Commission sought comment from AEMO and stakeholders on whether it should apply any of the new licence conditions to existing licensees.

5.2 AEMO's recommendation

AEMO has recommended that the Commission considers applying some of the additional licence conditions to existing generation licensees, having regard to:

- the physical limitations of some existing generating units
- the likely cost of enabling the capability of each generating unit, and
- the incremental benefits that would be gained by enabling existing generating units.[125]

In particular, AEMO has recommended that the Commission consider applying additional licensing conditions on existing generating licensees in the following areas:

- voltage control capability

[125] AEMO, Final Advice p. 4.

- operation down to low system strength levels[126]
- active power control capability, and
- disturbance ride-through capability.

5.3 Stakeholder submissions

Several submissions to the Issues Paper and Draft Report supported the Commission applying new licence conditions to existing generation licensees in certain circumstances.[127]

ElectraNet and SA Power Networks submitted to the Issues Paper that while, as a general principle, new licence conditions should not be applied to existing generation licensees, there may be some cases where the new licence conditions could be satisfied at a low cost. In such circumstances they state, the Commission should limit the application of any new licence conditions to existing generation licensees that can satisfy such conditions in a cost-effective manner.[128]

ElectraNet also stated that it is essential that the Commission carefully consider any costs that would be incurred by existing generation licensees as any imposts may hasten departure of generators to the detriment of system security.[129]

The South Australian Government's submission (made by ETR) stated that it is not uncommon for energy entities to face and be responsive to changes in laws or rules so long as there has been reasonable consultation and an assessment of the costs and benefits. On that basis, ETR recommended that the Commission should undertake further analysis of the costs, impacts and benefits of applying the additional licence conditions to existing generation licensees and consult on the findings of that analysis.[130]

However, several submissions to both the Issues Paper and the Draft Report expressed concerns regarding the application of the additional licence conditions to existing generation licensees.[131] In particular, several generators and peak bodies representing generators and energy retailers submitted there is a risk that imposing new licence conditions may not be financially viable for a number of existing generation licensees and could lead to investment uncertainty and sovereign risk.[132] Origin Energy and Snowy Hydro noted that the costs involved in having to comply with the additional

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126 AEMO's investigations have highlighted that some of the capabilities recommended (for example, operation down to low system strength) may be obtainable from some non-synchronous generators through a control system upgrade.

127 DSD, submission to Issues Paper, p. 2; ElectraNet submission to *Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators*, Issues Paper, January 2017; p. 3, available at: http://bit.ly/Inquiry-SAGeneratorLicensingArrangements-Submission-ElectraNet; EWOSA, submission to *Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators*, Issues Paper, January 2017, p. 1; available at: http://bit.ly/Inquiry-SAGeneratorLicensingArrangements-Submission-EWOSA; SA Power Networks submission to *Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators*, Issues Paper, January 2017, p. 2, available at http://bit.ly/Inquiry-SAGeneratorLicensingArrangements-Submission-SAPowerNetworks.; DPC, submission to *Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators*, Draft Report, 5 May 2017, p. 2, available at http://bit.ly/InquiryDraftDecision-Submission-TechnicalReg; SACOSS, submission to *Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators*, Draft Report, 1 June 2017, p. 1, available at . http://bit.ly/InquiryDraftDecision-Submission-SACOSS.

128 ElectraNet, submission to Issues Paper, p. 3; SA Power Networks, submission to Issues Paper, p. 2.

129 ElectraNet, Submission to Draft Report, p. 2.

130 DSD, submission to Issues Paper, p. 2; DPC, submission to Draft Report, p. 1.

131 AGL, submission to Issues Paper, p. 5; AEC, submission to Issues Paper, pp. 1-2; CEC, submission to Issues Paper, p. 14; ENGIE, submission to Issues Paper, p. 4; Meridian Energy submission to Issues Paper, p. 2; Reach Solar Energy; submission to Issues Paper, pp. 13-14; Tilt Renewables, submission to Issues paper, pp. 2-3; Origin Energy, submission to Draft Report, p. 1; EnergyAustralia, submission to Draft Report, 9 June 2017, p. 3; ENGIE, submission to Inquiry into licensing arrangements under the Electricity Act 1996 for inverter-connected generators, Draft Report, 9 June 2017, p. 4, available at: http://bit.ly/InquiryDraftDecision-Submission-ENGIE.

132 AGL, submission to Issues Paper, p. 5; AEC, submission to Issues Paper, pp. 1-2; ENGIE, submission to Issues Paper, p. 4; Meridian Energy; submission to Issues Paper, p. 2; Reach Solar Energy, submission to Issues Paper, pp. 13-14; Tilt Renewables, submission to Issues paper, pp. 2-3; EnergyAustralia, submission to Draft Report, p. 3.

licence conditions would be prohibitive, could result in damage to existing infrastructure and that any increase in costs would be passed onto consumers.[133] The AEC also noted that it may not be technically possible to alter some existing generators.[134]

In addition, ENGIE submitted that, regardless of whether the costs of imposing new licence conditions on existing generators were low or the benefits high, a more efficient allocation of costs would be to spread them across the industry instead of singling out individual participants.[135]

EnergyAustralia recommended that before the Commission decides on whether the application of new licence conditions to existing generators is warranted, it should consult further with generators on a number of matters including the details of the proposed methodology, assessment criteria and approach. It also suggested that the Commission ensures that it gathers information on a variety of matters, including the potential physical limitations of generators.[136]

AGL and the AEC also submitted that market-based solutions should be the preferred approach to resolving issues with system security but, if the market was unable to deliver, contracts could be established to procure the additional capabilities required.[137]

5.4 Commission's consideration

The Commission takes a considered and measured approach to making changes to regulatory instruments that may affect current licensees but this is balanced against the need to ensure that the Commission is able to meet its primary objective of protecting the long-term interests of consumers.

The Commission's preliminary position in the Draft Report was that there may be a need for current licensed generators to provide additional capabilities and services to the power system to meet the specific challenges faced in South Australia. It recognised that the application of any new licence conditions to new entrant generators does not resolve the issues that the electricity network in South Australia is currently experiencing with the current generation fleet or is likely to experience in the near future. In other words, the benefits to be realised by the new licence conditions would not occur for a number of years as new generators bring with them the capabilities expressed in the proposed technical conditions. In addition, as a number of existing generators in South Australia will continue to operate over similar time periods as new generators, there is a need for current generators to assist in providing additional capabilities to improve system security and resilience in the long term.

In addition, the Finkel Review noted that:

> *Whilst it will be difficult to apply updated standards to existing generators, other incentives could be considered to encourage those generators to augment their technical capabilities. In particular, a large number of older generators do not have to comply with any connection standards.*[138]

The Commission notes that some existing licensees have already made system software changes as a result of issues identified through the Black System event that mirror some of the new technical standards recommended by AEMO.

However, the Commission acknowledges that some licensed generators may be unable to satisfy the new licence conditions or that the costs to upgrade their facilities to meet the new requirements would be inefficient.

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133 Origin Energy, submission to Draft Report, p. 3-4.; Snowy Hydro, submission to Draft Report, p. 3.
134 AEC, submission to Issues Paper, pp. 1-2.
135 ENGIE, submission to Draft Report, p. 4.
136 EnergyAustralia, submission to Draft Report, p. 3.
137 AGL, submission to Issues Paper, pp. 4-5; AEC, submission to Issues Paper, p. 2.
138 Commonwealth of Australia, p. 60.

The Commission reaffirms its position from the Draft Report — that there may be a need for current generator licensees to provide additional capabilities and services to the power system to meet the very specific challenges faced in South Australia.

However, the Commission accepts the views expressed by EnergyAustralia and ETR that further engagement on this matter is required and, accordingly, will work with licensees and other stakeholders including AEMO, NSPs and other parties over the 2017-18 period to progress this matter. Although the exact details of the process are yet to be resolved, licensees may expect that the Commission will seek further information such as:

- the specific technical capabilities of current generating units or systems with respect to the new technical standards
- the physical or technical limitations in meeting the new technical standards, and
- the need for, and cost of, any upgrades that may be required to satisfy the new technical standards.

The Commission's initial focus will be to identify and work with those generating systems (or units) with the potential for the greatest possible gains at the lowest possible cost.

Interested licensees who would like to be considered sooner rather than later should register their interest with the Commission as soon as possible.

6 Next steps

6.1 Process for updates to the generator licensing framework

The South Australian power system's continuing transition means that new technical issues affecting the operation of the NEM are likely to continue to emerge. As the energy transition progresses, the regulatory framework must also evolve in order to maintain the security and reliability of the power system. In some cases, these emerging issues are most efficiently addressed through new or updated technical standards.

AEMO has recommended that there is merit in establishing a framework that allows the technical standards applying to generators to be regularly updated to reflect changing power system needs and technological developments. This recommendation is consistent with the approach adopted by the United States national reliability body, the North American Electric Reliability Corporation (NERC). A key conclusion of the NERC's major review of the United States reliability standards was that it is necessary to conduct annual updates given the pace at which technology is advancing.

To this end, AEMO has proposed that the Commission consider the costs and benefits of establishing a framework where the technical standards that apply to generators are periodically reviewed.

The Commission's previous practice has been to internally review its generator licence conditions on a frequent basis but undertake major reviews at approximately five year cycles. In the Draft Report, the Commission sought submissions from stakeholders to determine an efficient timeframe for the review of licence conditions to ensure that they remain relevant and appropriate. While the Commission received no submissions regarding efficient timeframes, the Commission received several submissions expressing a preference for regulatory certainty and minimal changes in technical requirements. Further, Snowy Hydro submitted that continuous changes to mandatory technical requirements for generators would increase the investment risk for existing and future generation plant owners.[139]

The Commission considers that, if AEMO's proposed rule change is successful, the application of the Commission's licence conditions may no longer be required. However, if there is still a need for the Commission to impose technical licence conditions then reviews will need to be carried out to reflect changing power system needs.

In addition, the Finkel Report noted:

> *In its submission to the Review, GE recommends developing "a rules regime that is agile and incentivises generation performance that supports grid stability". Going forward, in light of the ongoing technological change facing the NEM, the AEMC should undertake a comprehensive review of the connections standards every three years.*[140]

The Commission will continue to monitor technological developments and liaise with AEMO, the AEMC and stakeholders to determine whether the Commission's licence conditions remain fit-for-purpose in accordance with Commission's objectives under section 6 of the ESC Act. If the Commission considers that this is no longer the case, it will respond at that time.

[139] Snowy Hydro, p. 3.
[140] Commonwealth of Australia, pp. 52-53.

6.2 Process for applicants in applying for a generator licence

The Commission recognises that the nature of the licence conditions and the technical differences between types of generators will add complexity to the licence application process. Further, the Commission is cognisant that there are a number of regulatory approval processes that a potential generator is required to complete prior to generating electricity.

The Commission is committed to working with other regulators, including the Technical Regulator and AEMO, and other stakeholders, such as ElectraNet, in order to streamline processes that applicants are required to complete. Further, the Commission encourages all potential licence applicants to engage with the Commission on the licence application process as early as practicable to ensure that appropriate information regarding the Commission's approval process is obtained.

6.3 Legislative requirements

Under the Inquiry provisions of the ESC Act, a copy of the Inquiry's Final Report must be provided to the Treasurer — who is then required to lay before both Houses of Parliament, a copy of the Final Report within 12 sitting days after its receipt.

6.4 Implementation date

The model licence conditions will apply from the date of publication of this Final Report on the Commission's web site.

Appendix A — Legal Framework

Powers and functions of the Essential Services Commission under the Essential Services Commission Act 2002

The regulatory functions of the Essential Services Commission (**Commission**) are set out in Section 5 of the Essential Services Commission Act 2002 (**ESC Act**). Provisions relevant to the regulation of generators are replicated below:

5 — Functions

The Commission has the following functions:

(a) to regulate prices and perform licensing and other functions under relevant industry regulation Acts;

(b) to monitor and enforce compliance with and promote improvement in standards and conditions of service and supply under relevant industry regulation Acts;

(c) to make, monitor the operation of, and review from time to time, codes and rules relating to the conduct or operations of a regulated industry or regulated entities;

…

In performing these functions, the following objectives (including the Commission's primary objective when undertaking any function) inform and guide the Commission. They are set out in Section 6 of the ESC Act and include the following:

6—Objectives

In performing the Commission's functions, the Commission must —

(a) have as its primary objective protection of the long term interests of South Australian consumers with respect to the price, quality and reliability of essential services; and

(b) at the same time, have regard to the need to —

(i) promote competitive and fair market conduct; and

(ii) prevent misuse of monopoly or market power; and

(iii) facilitate entry into relevant markets; and

(iv) promote economic efficiency; and

(v) ensure consumers benefit from competition and efficiency; and

(vi) facilitate maintenance of the financial viability of regulated industries and the incentive for long term investment; and

(vii) promote consistency in regulation with other jurisdictions.

With regard to the Commission's principal statutory objective, three elements of service delivery are captured – price, quality and reliability.

The electricity industry is declared to be a regulated industry for the purposes of the ESC Act. [141] This allows the Commission to regulate electricity by requiring operators to hold a licence subject to various

[141] Electricity Act 1996, section 14D.

conditions. It does not set prices for generation operations that are connected to the National Electricity Market. There is a market-based mechanism that sets wholesale prices.

Commission's licensing functions under the Electricity Act 1996

The Commission has licensing functions in relation to the electricity industry, including the issuing of a licence and ensuring compliance with licence conditions once issued.

Under section 15 of the Electricity Act 1996 (**Electricity Act**), a person must not carry on operations in the electricity market unless they hold a licence authorising those operations. This includes the generation, transmission, distribution, retailing of electricity, and the system control over a power system.

Pursuant to the Electricity Act, generation means the operation of any kind of electricity generating plant and all incidental and related operations, but does not include anything declared by regulation not to be generation of electricity.[142] As such, the following types of generation are required to hold a licence:

- thermal generation systems
- hydro generation systems
- tidal generation systems
- solar PV systems, and
- energy storage systems.

A person carrying out the operation of generating electricity is not required to be licensed, if:

- the operations are carried out for self-consumption
- consumption is by a designated body[143]
- consumption by a person at premises occupied or used by the person as a tenant or licensee where that person is not charged for supply of electricity except as an unspecified part of rent or charges for the occupation or use of the premises[144]
- the generating plant has a rated nameplate output of 100 kVA or less, or
- they do not supply electricity for reward to or by means of a transmission or distribution network.[145]

Additionally, section 80(1) of the Electricity Act provides that the Commission can, with the approval of the Minister for Mineral Resources and Energy (**Minister**), issue an exemption from the requirements of Part 3 of the Electricity Act, including the requirement to be to be licensed (or from various licence conditions). Exemptions are only granted by the Commission in exceptional circumstances.

[142] Electricity Act 1996, section 4(1).
[143] A designated body is defined by the Electricity (General) Regulations as a body or group of persons designated by the Minister by notice in the Gazette.
[144] Electricity (General) Regulations 2012, regulation 15(1).
[145] Electricity (General) Regulations 2012. regulation 15(2).

Licence applications

A person or entity seeking an electricity licence must make an application to the Commission by filling out an application form and providing all information required for the issue of a licence. Prior to the Commission reviewing a licence application, a person must also pay the appropriate application fee which is set by the Minister.

Once an application is received, the Commission must consider that application and may issue, or refuse to issue, the licence.

In considering a licence application, the Commission must have regard to its objectives set out in the ESC Act and may only issue a licence if satisfied that:

- the applicant is a suitable person to hold the licence
- the issue of the licence will not result in the same person holding both a licence authorising the operation of a distribution network and a licence authorising retailing of electricity
- in the case of a licence authorising the generation of electricity – the generating plant (or proposed generating plant) will generate electricity of the appropriate quality for the relevant transmission or distribution network
- in the case of a licence authorising the operation of a transmission or distribution network – the network has (or the proposed network will have) the necessary capacity for transmitting or distributing electricity safely
- in the case of a licence authorising retailing of electricity – the applicant will be able to meet reasonably foreseeable obligations under contracts for the sale of electricity
- in the case of a licence authorising system control over a power system – the applicant will be able to adequately exercise system control functions
- in the case of a licence authorising other operations in the electricity supply industry for which a licence is required under the Electricity (General) Regulations – the applicant meets any special requirements imposed for holding that licence, and
- any criteria or conditions prescribed by regulation. [146]

In order to assess the licence application, the Commission requires applicants to provide sufficient information with applications. As a minimum, applicants are required to submit information addressing the following matters:

- corporate and legal information
- regulatory information, including:
  - information to satisfy the Commission that the applicant can meet the relevant licence conditions and has (or will have) a robust compliance program in place to ensure this, and
  - information to satisfy the Commission that the issuing of a licence is consistent with its objectives.

[146] Electricity Ac, section 17(2).

- technical and human resource information, including:
  - information in relation to the technical capacity of the applicant to comply with the conditions of the licence, and
  - evidence that the applicant can properly and safely conduct the business authorised by the licence, including details of experience in the energy market and copies of its risk management strategy and compliance program, and
- financial information.

Prior to issuing a licence for an operation that is connected to the national electricity market, the Commission may seek advice from the Australian Energy Market Operator (AEMO) on matters of technical capacity. In particular, for a wind generation licence, the Commission will seek advice from AEMO on whether the applicant will be able to meet key special licence conditions (as summarised below).

Licence conditions

Each electricity licence issued by the Commission contains a variety of conditions. Sections 21-24A of the Electricity Act requires the Commission to make a licence subject to various conditions.

Specifically, section 21 provides that for all electricity licences:

21—Licence conditions

(1) The Commission must make a licence subject to conditions determined by the Commission—

(a) requiring compliance with applicable codes or rules made under the ESC Act;

(b) requiring compliance with specified technical or safety requirements or standards;

(c) relating to financial or other capacity to continue operations under the licence;

(d) requiring the licensee to have all or part of the operations authorised by the licence audited and to report the results of the audit to the Commission;

(e) requiring the licensee to notify the Commission about changes to officers and, if applicable, major shareholders of the entity;

(f) requiring the licensee to provide information to the Commission;

(g) requiring the licensee to comply with the requirements of any scheme approved and funded by the Minister for the provision by the State of customer concessions or the performance of community service obligations by licensees; and

(h) any further conditions the Commission is required by regulation to impose.

Sections 22-24A of the Electricity Act contain additional licence conditions that the Commission must include for the different licensed operations. This includes specific licence conditions for the operations of transmission, distribution, generation, retailing and system control.

In particular, section 22 applies to licences authorising the generation of electricity:
22—Licences authorising generation of electricity

(1) The Commission must make a licence authorising the generation of electricity subject to conditions determined by the Commission—

(a) requiring compliance with directions of the system controller; and

(b) requiring the electricity entity not to do anything affecting the compatibility of the entity's electricity generating plant with any transmission or distribution network so as to prejudice public safety or the security of the power system of which the generating plant forms a part; and

(c) requiring the electricity entity—

(i) to prepare and periodically revise a safety, reliability, maintenance and technical management plan dealing with matters prescribed by regulation; and

(ii) to obtain the approval of the Commission (which may only be given by the Commission on the recommendation of the Technical Regulator) to the plan and any revision; and

(iii) to comply with the plan as approved from time to time; and

(iv) to audit from time to time the entity's compliance with the plan and report the results of those audits to the Technical Regulator; and

(d) requiring the electricity entity to provide to AEMO such information as it may reasonably require for the performance of its functions; and

(e) requiring the electricity entity—

(i) to grant to each electricity entity holding a licence authorising the operation of a transmission or distribution network rights to use or have access to the entity's electricity generating plant that are necessary for the purpose of ensuring the proper integrated operation of the State's power system and the proper carrying on of the operations authorised by the entity's licence; and

(ii) in the absence of agreement as to the terms on which such rights are to be granted, to comply with any determination of the Commission as to those terms; and

(iii) to comply with any code provisions in force from time to time under the Essential Services Commission Act 2002 establishing a scheme for the resolution of disputes in relation to such rights; and

(f) requiring the electricity entity to maintain insurance against any liability for causing a bushfire and to provide the Commission with a certificate of the insurer or the insurance broker by whom the insurance was arranged certifying (in a manner approved by the Commission) that the insurance is adequate and appropriate given the nature of the operations carried on under the entity's licence and the risks entailed in those operations.

In addition, the Commission may also make a licence subject to any further conditions it considers appropriate. In accordance with this power, the Commission previously imposed specific licence conditions for wind generation. These current conditions (which have applied since 2010) include requirements regarding:

- reactive power, and
- fault ride-through capability.

These conditions are detailed in Appendix B.

Appendix B — 2010 licence conditions for wind-powered generation licensees

The additional licence conditions previously imposed on wind-powered generation licensees in relation to fault ride-through and reactive power requirements are set out below. [147]

9. Fault Ride-Through Capability

9.1 Each generating unit which the licensee is authorised to operate under this licence must comply with:

(a) the automatic access standards for generating system response to disturbances following contingency events specified in clause S5.2.5.5(b)(1) of the NER; and

(b) subject to clause 2, the automatic access standards for generating system response to disturbances following contingency events specified in clause S5.2.5.5(b)(2) of the NER; and

(c) subject to clause 3, the automatic access standards for generating system response to voltage disturbances specified in clause S5.2.5.4 of the NER.

9.2 The licensee is not required to comply with clause 1(b) in respect of a generating unit which the Licensee is authorised to operate under this licence where:

(a) the minimum access standard requirements specified in clause S5.2.5.5(c)(2) of the NER in relation to generating system response to disturbances following contingency events; and

(b) the requirements of clauses S5.2.5.5(d), (e) and (f) of the NER are satisfied in respect of that generating unit.

9.3 The licensee is not required to comply with clause 1(c) in respect of a generating unit which the licensee is authorised to operate under this licence where:

(a) AEMO and the relevant network service provider have agreed, pursuant to clause 5.2.5.4(c)(3) of the NER, that there would be no material adverse impact on the quality of supply to other network users or of power system security as a result of that non-compliance; and

(b) The requirements of clauses S5.2.5.4(c), (d), (e) and (f) of the NER are otherwise satisfied in respect of that generating unit.

10. Reactive Power Capability

10.1 The electricity generating plant operated by the licensee must at all times be capable of continuous operation at a power factor of between 0.93 leading and 0.93 lagging at real power outputs exceeding 5 MW at the connection point.

10.2 The electricity generating plant operated by the licensee must at all times be capable of providing:

(a) subject to clause 4(b), at least 50 per cent of the reactive power required to meet the power factor referred to in clause 10.1 on a dynamically variable basis; and

(b) the balance of the reactive power required to meet the power factor referred to in clause 10.1 on a non-dynamic basis.

[147] The full suite of the Commission's model electricity generator licence conditions may be accessed at: http://www.escosa.sa.gov.au/industry/electricity/licensing/licence-applications.

10.3 At generation levels below full rated output the electricity generating plant operated by the licensee must be capable of:

(a) absorbing reactive power at a level at least pro-rata to that of full output; and

(b) delivering reactive power at a level at least pro-rata to that of full output.

10.4 For the purposes of clause 10.2(a):

(a) dynamically variable means continuous modulation of the reactive power output over its range, with an initial response time or dead time of less than 200 milliseconds and a rise time (as defined in clause S5.2.5.13 of the NER) of less than 1 second following a voltage disturbance on the network; and

(b) for a period of not more than 2 seconds on any single occasion, a short-term overload capability may be used to meet the 50 per cent requirement, provided that use of that short-term overload does not cause a breach of any other licence condition.

10.5 The reactive power capability of the electricity generating plant operated by the licensee must be capable of control by a fast-acting, continuously variable, voltage control system which is able to receive a local and remote voltage set point.

10.6 The electricity generating plant operated by the licensee must be able to operate at either a set reactive power, or a set power factor, which is able to be set locally or remotely at any time.

10.7 The power factor or reactive power control mode of the electricity generating plant operated by the licensee must be capable of:

(a) being overridden by voltage support mode during power system voltage disturbances; and

(b) automatically reverting to power factor or reactive power mode when the disturbance has ceased.

Appendix C — 2017 model licence conditions for new generators

Interpretation of this schedule

1. Interpretation

1.1 Terms used in this schedule and also in the National Electricity Rules (NER) have the same meaning in this schedule as they have in those rules (unless otherwise specified or unless the context otherwise requires).

1.2 For the purposes of this schedule, the term:

Commission - means the Essential Services Commission, established under the Essential Services Commission Act 2002.

continuous uninterrupted operation means that, for voltage disturbances within the continuous operating range (that is, connection point voltage fluctuating within 90 percent and 110 percent of normal voltage), active power must be maintained (unless there has been a change in the intermittent power source) and reactive power must be managed to meet voltage control requirements.

Disturbance ride through capability

2. Disturbance ride through capability – general requirements

2.1 The non-synchronous generating system must meet the following requirements:

(a) The low voltage ride-through activation threshold (LVRT), as measured at the low voltage (LV) terminals of the generating units and dynamic reactive support plant (as applicable), must not be less than 85 percent of nominal voltage.

(b) The generating system must maintain continuous uninterrupted operation for voltage disturbances as specified in clauses 3, 7 and 8.

(c) Where LVRT and high voltage ride-through (HVRT) requirements in the NER are specified in respect of the generating system's connection point, the withstand capability of individual generating units is to be determined at the LV side of the generating unit's transformer. All individual generating units must remain connected for connection point voltages within the LVRT/HVRT withstand requirements, irrespective of the generating system's transformer tap position.

3. Disturbance ride-through (reactive current injection)

3.1 The generating system must supply additional capacitive reactive current (reactive current injection) of up to 4 percent of the maximum continuous current of the generating system (in the absence of a disturbance) for each 1 percent reduction of connection point voltage below 90 percent of normal voltage, as shown in Table 1. This requirement applies at the LV terminals of the generating units and dynamic reactive support plant (as applicable) for power system disturbances resulting in a voltage reduction of up to 100 percent of normal voltage at the connection point.

3.2 The generating system must supply additional inductive reactive current (reactive current absorption) of up to 6 percent of the maximum continuous current of the generating system (in the absence of a disturbance) for each 1 percent increase in connection point voltage above 110 percent of the normal voltage, as shown in Table 1. This requirement applies at the LV terminals of the generating units and dynamic reactive support plant (as applicable).

3.3 The reactive current injection must be maintained until the connection point voltage returns to within the range of 90 percent to 110 percent of normal voltage.

Table 1: Reactive current injection requirements

Reactive current response	Current injection gain (%)	Current absorption gain (%)	Minimum amount of contribution as percentage of rated current	Speed of contribution	
				Rise time (millisecond)	Settling time (millisecond)
Synchronous	4	6	250	30	N/A
Non-synchronous	4	6	100	30	60

3.4 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 X. [148]

3.5 The generating system must comply with the following response characteristics for reactive current injection:

(a) A rise time no greater than 30 milliseconds and a settling time no greater than 60 milliseconds applies to reactive current injection requirements.[149]

(b) The reactive current injection requirements described above apply for all pre-disturbance reactive power control modes (voltage control, power factor control and reactive power control).[150]

(c) The reactive current response must be adequately damped as defined in the NER.

(d) Upon occurrence of a fault, reactive power consumption must not exceed 5 percent of maximum continuous rated current of the generating system and must be limited to the rise time duration set out in Table 1.

[148] The exact ratio of negative-sequence to positive-sequence current injection will be specified by the Commission at the time the licence is issued.
[149] The settling time requirement does not apply to synchronous generators.
[150] This requirement does not apply to synchronous generators.

(e) The post-fault reactive power contribution of the generating system must be sufficient to ensure that the connection point voltage is within the following ranges for continuous uninterrupted operation:

(i) voltages over 110 percent for the durations permitted under NER clause S5.1a.4;

(ii) 90 percent to 110 percent of normal voltage continuously;

(iii) 80 percent to 90 percent of normal voltage for a period of at least 10 seconds; and

(iv) 70 percent to 80 percent of normal voltage for a period of at least 2 seconds.

4. Disturbance ride through (active power injection requirements)

4.1 The generating system must be capable of restoring active power to at least 95 percent of the level existing just prior to a fault within X milliseconds after disconnection of the faulted element.[151]

4.2 Upon occurrence of a fault, a generating system's transient active power consumption must not exceed one power frequency cycle and must not exceed 5 percent of the maximum continuous rated current of the generating system.

5. Multiple low voltage disturbance ride-through

5.1 The generating system, including, but not limited to, each of its generating units and dynamic reactive power support plant, must be capable of withstanding both of the following within a five minute interval:

(a) Any combination of voltage disturbances causing the voltage at the respective low voltage (LV) terminals of the equipment to drop below 85 percent of the nominal voltage for a total duration of 1,500 milliseconds regardless of disturbance type, duration, and residual voltage at the generating unit's terminals. The total number of voltage disturbances for which successful ride-through is required is limited to 15. Each fault can be a solid fault resulting in 100 percent voltage drop at the connection point with duration not exceeding the longest time expected to be taken for the breaker fail protection system to clear the fault, as set out in Table S5.1a.2 of the NER.

(b) A single worst-case long-duration shallow voltage disturbance, causing the voltage at the connection point to drop to 70- 80 percent of the normal voltage for a total duration of 2,000 milliseconds.

5.2 Subject to compliance with the requirements in clause 5.1, the generating system, including, but not limited to, each of its generating units and dynamic reactive power support plant, is not required to withstand any additional voltage variation exceeding ±10 percent of nominal voltage experienced at the respective LV terminals within 30 minutes from the commencement of the first variation.[152]

[151] The exact active power recovery time will be specified by the Commission at the time the licence is issued and will be between 100 and 500 milliseconds.

[152] For synchronous generators, consideration will be given to the physical limitations of the plant. This may require a variation to this condition, to be determined by Commission at the time of issuing of the licence.

6. Disturbance ride-through (high voltage disturbance ride-through)

6.1 The generating system must have a level of over-voltage withstand capability consistent with the levels shown in Table 2.[153]

6.2 The generating system must maintain continuous uninterrupted operation for temporary over voltage durations as specified in Table 2.

Table 2: Required over voltage withstand capability

Temporary overvoltage (% of normal voltage)	110–115	>115–120	>120–125	>125–130	>130–140
Duration(s)	1,200	20	2	0.2	0.02

7. Disturbance ride-through (partial load rejection)

7.1 The non-synchronous generating system must be capable of continuous uninterrupted operation during and following a power system load reduction of 30 percent from its pre-disturbance 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.

8. Disturbance ride-through (frequency disturbance ride-through)

8.1 The generating system must be capable of continuous uninterrupted operation for any combination of the following rates of change of frequency:

(a) ±4 Hz/s for 250 milliseconds

(b) ±3 Hz/s for 1 second, until such time as power system frequency breaches the extreme frequency excursion tolerance limits. [154]

9. Disturbance ride-through (voltage phase angle shift)

9.1 The generating system must not include any vector shift or similar relay/protective function acting upon voltage phase angle which might operate for phase angle changes less than 20 degrees.

Voltage control capability

10. Voltage control capability

10.1 The generating system must be capable of being controlled by a fast-acting, continuously variable, voltage control system which must be able to receive a local and remote voltage set point.

10.2 The generating system must be capable of operating at either a set reactive power level or a set power factor, which must be able to be set locally or remotely at any time.

[153] Unless otherwise specified by the Commission at the time the licence is issued.

[154] For synchronous generators, consideration will be given to the physical limitations of the plant. This may require a variation to this condition, to be determined by the Commission at the time of issuing of the licence.

10.3 The voltage, power factor and reactive power control mode of the generating system must be capable of:

(a) being overridden by the disturbance ride through requirements specified in clauses 2 to 9 (inclusive) during power system voltage disturbances, and

(b) automatically reverting to power factor or reactive power mode when the disturbance has ceased.

System strength

11. System strength

11.1 Individual components of plant within a generating system, which includes but is not limited to generating units and dynamic reactive power plant, must be capable of operating down to the following levels at the high voltage terminals in relation to each component:

(a) minimum short circuit ratio of 1.5, and

(b) minimum positive sequence X/R ratio of 2.

Active power control capability

12. Active power control capability

12.1 The generating system must be capable of automatically providing a proportional increase or decrease in active power output, in response to falling and rising power system frequency respectively.

12.2 To comply with clause 12.1:

(a) 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 frequency leaves the deadband.

(b) The steady state droop setting of the active power response must be adjustable in the range 2 percent to 10 percent.

(c) The frequency deadband for the active power response must be adjustable in the range from 0 to +/- 1.0 Hz.

12.3 The generating system must be capable of sustaining a response to abnormal frequency conditions for at least 10 minutes, subject only to energy resource availability for intermittent generating systems.

12.4 The generating system must be capable of applying different deadband and droop settings in response to rising and falling frequency and for different levels of frequency change.

13. Active power control capability (AGC capability)

13.1 The generating system must have active power control capabilities that allow it to participate in existing national electricity market arrangements requiring automatic generation control (AGC).

13.2 At a minimum, the AGC must have the capability to:

(a) receive and respond to a remotely determined active power control setpoint, updated at a rate of every four seconds, transmitted to the generating system, and

(b) provide the following information to AEMO, upon a request from AEMO under NER clauses S5.2.6.1 or 3.8.2:

(i) actual active power output;

(ii) maximum raise limit;

(iii) minimum lower limit;

(iv) maximum raise ramp rate; and

(v) maximum lower ramp rate.

14. Active power control capability (rate of change of active power)

14.1 The generating system must be capable of limiting the rate of change of active power, both upwards and downwards. A generating system is not required to comply with a limit on the rate of reduction of active power where the reduction in active power is caused by energy resource availability for intermittent generating systems.

14.2 The generating system must be capable of implementing different active power rate limits for operation in the normal operating frequency band and for contingency events.

14.3 The generating system must be capable of setting a ramp rate limit with accuracy of within 10 percent.

15. Active power control capability

15.1 The generating system must have the capability to provide real-time information about its active power control settings to AEMO, including mode of operation, deadband and droop parameters and any other active power control setting that may change during real-time operation.

System restoration

16. System restoration

16.1 Where sufficient minimum fault level is available from online synchronous machines, the generating system must have the following capability in the event of a black system:

(a) the generating system must be capable of operation with auxiliary loads only for X minutes[155] while system load is being restored, and

(b) the generating system, including, but not limited to, each of its generating units and dynamic reactive power support plant (as applicable) must have the capability to provide steady-state and dynamic reactive power when operating with auxiliary loads only for X minutes while system load is being restored.[156]

[155] The exact duration will be specified by the Commission at the time the licence is issued.
[156] The exact duration will be specified by the Commission at the time the licence is issued.

Appendix D — Overview of the electricity generation market in South Australia and the development of licence conditions

South Australia's electricity generation market has been transitioning from one based on conventional large centrally-located, thermal electricity generators to one that is based on smaller, distributed, renewable generation technologies, with variable (or intermittent) output characteristics. The Australian Energy Market Operator (AEMO) notes that the transition from the old to the new generation technologies has been more extensive than anywhere else in Australia.

An overview of the development of the generation market from the early 2000s to the present day follows.

The generation market to 2004

Independent regulation of the electricity industry commenced in South Australia in 1999, following the commencement of the NEM in 1998. Since that time, the Essential Services Commission (Commission) has been the statutory licensing authority for all new electricity generators.

Prior to 2004, the Commission generally licensed coal, gas and diesel-fired electricity generators — collectively referred to as conventional thermal generation — that had largely been installed under an earlier regime.

Towards the end of 2004, there was increased interest in wind-powered generation in the State due to its sound wind resources, which are in close proximity to transmission lines. In addition, the commencement of a Australian Government subsidy scheme (Renewable Energy Target (RET)), along with Australian, State and Local Government support, provided a supportive environment for investors.

This created a keen interest in wind-powered generation and led to the installation of approximately 450 megawatts (MW) of wind-powered electricity generation by November 2004. At that time, the Commission was also aware of proposals for approximately 1,260 MW of new wind-powered generating capacity. This new wind-powered capacity of 1,700 MW (installed and proposed) was in the context of an existing total South Australian market capacity of 3,454 MW at that time.

As the licensing authority, the Commission needed to be satisfied that South Australian consumers' long-term interests would be appropriately protected (with respect to the price, quality and reliability of electricity) when considering whether or not to agree to issue a licence to a new wind-powered electricity generator.

The 2005 review

Given the significant number of wind-powered generation proposals seeking licences (more than 10 individual projects), during 2005 the Commission took advice from AEMO's South Australian predecessor, the Electricity Supply Industry Planning Council (ESIPC), as to whether or not it could license those proposed projects while still protecting the long-term interests of consumers. The Commission was concerned that the differing electrical characteristics of wind-powered electricity generators compared to existing conventional electricity generators may create unintended consequences.

ESIPC's advice was that significant levels of wind-powered generation would have major technical implications, given the prevailing National Electricity Rules (NER). It advised that:

- the level of wind could be capped, or
- additional technical licence requirements could be placed on wind-powered electricity generators to make them deliver additional electrical performance to better contribute to system stability, quality and reliability.

ESIPC also advised that it was not possible to predict market pricing impacts from wind-powered generation, given that there was insufficient evidence of practices and behavioural changes (if any) which might arise from the intermittent nature of such generation.

Having noted that these technical issues would best be dealt with by revising the NER (as it considered that non-conventional generation would eventually become a national issue, particularly given Australian Government subsidies for renewables such as the RET), the Commission determined that it would adopt the second option.

The Commission did not want to artificially restrict any technologies nor to introduce the likelihood of any market distortions a cap might bring. It noted that it would look to revise or remove the local requirements once the NER adequately catered for wind and related technologies.

The Commission therefore developed technical licensing principles and conditions, the effect of which was to require wind-powered electricity generators to participate in the dispatch process of the national market (as until then they had been regarded as 'negative demand'), to have additional plant and equipment installed and to provide wind forecasting information.[157]

The 2010 review

In 2010, the Commission reviewed the above arrangements and found that, while the NER had advanced, they still did not cater for South Australia's unique circumstances with respect to the relative contribution of wind-powered generation to the State's total generating capacity.

Therefore, while it made some adjustments to the terms of its technical licence conditions, the Commission retained special conditions for wind-powered electricity generators.

The Commission also noted that, while the introduction of wind had resulted in an increase in spot price volatility in the wholesale electricity market, the pricing impacts of wind were a matter for the national market rather than technical licence conditions.

The Commission's standard additional technical conditions for wind-powered generators required them to meet higher performance standards with respect to fault ride-through capability and reactive power capability. The conditions also maintained the requirements in relation to central dispatch, wind forecasting and ancillary services.

Finally, the Commission confirmed its position that the technical principles and special licence conditions were intended to be transitional and that the NER were the most appropriate way to deal with the technical issues raised by non-conventional generation.

[157] The Commission's *Statement of Principles for Wind Licensing*, available at: http://www.escosa.sa.gov.au/library/100430-LicenceConditionsWindGenerators-FinalDecision.pdf.

The South Australian generation market in 2017

The changing supply mix

Over the last seven years and in particularly the last 12 to 18 months, changes across the South Australian electricity generation market have accelerated, including:

- the withdrawal of coal-fired plant, which has changed the generation mix fundamentally (as it proportionally increases the penetration of wind generation and other non-synchronous forms of generation, refer to Figure D.1)
- continuing interest in new investment in wind, solar and other generation sources
- the growing commercial and technical viability of battery storage and related technologies
- the increasing interest in micro-grid technologies (whether stand-alone or connected to the National Electricity Market (NEM))
- risks which arise if the high voltage interconnectors with Victoria are out of service, and
- the availability and pricing of gas for electricity generation.

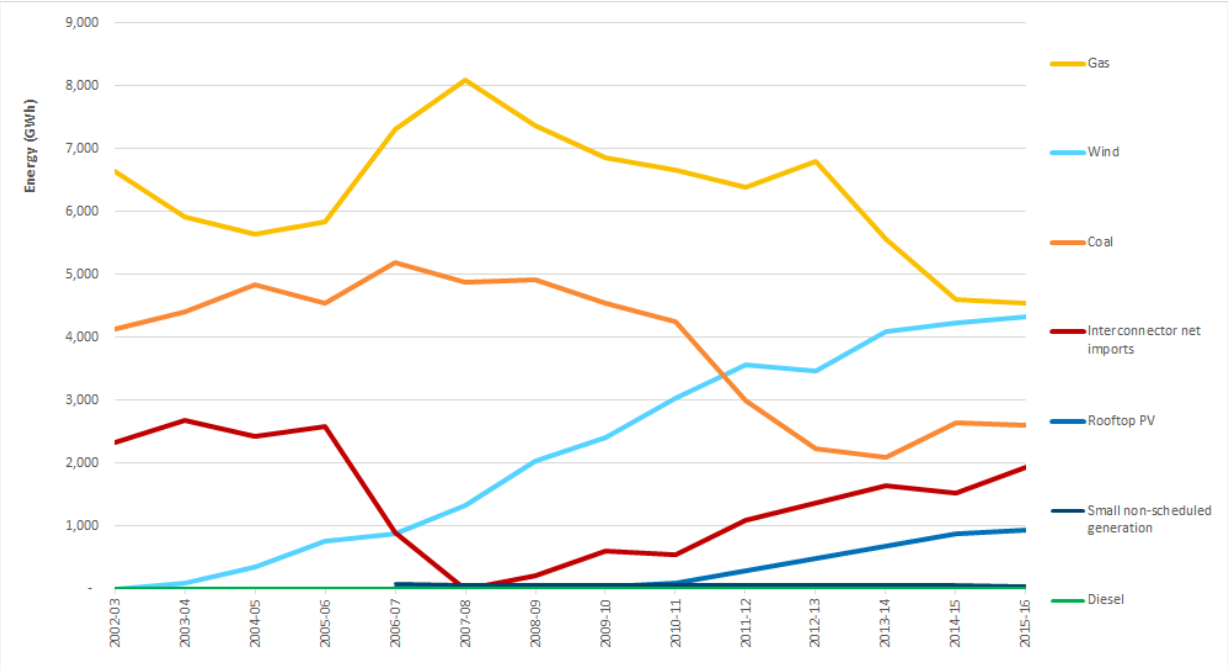
The size of the South Australian generation market

By April 2017, the Commission had issued 40 electricity generation licences throughout South Australia — 35 of which authorise the operation of approximately 5,021 MW of grid-connected generation plant. Of those, 18 are licensed wind-powered electricity generators (17 national electricity market participants and one non-market), with a total capacity of 1,696 MW – over one-third of the State's total grid-connected generation capacity. As a result, South Australia has the highest penetration of wind generation compared to total generating capacity in Australia, and also ranks among the highest penetration levels to be found in the world.

Furthermore, SA Power Networks advise that there were approximately 195,042 small-scale rooftop solar PV installations with a total approved capacity of 777 MW resulting in an effective capacity of 629 MW connected to its distribution network in South Australia by 31 December 2016.

The extent of the growth in variable energy generation technologies, both in large-scale wind-powered and small-scale solar photovoltaic (PV) generation, is shown in Figure D.1. It highlights the changing generation mix in South Australia and the speed of that transition since 2003-04, when the first wind-powered electricity generators were installed. Electricity generation from coal and gas-fired plants has reduced over that period and culminated in the withdrawal of coal-fired generation in May 2016.

Figure D.1: South Australian energy generation by fuel type/source, 2002-03 to 2015-16 (GWh)



Source: The Commission from AEMO data

Note: Data not available for Rooftop PV and small non-scheduled generation prior to 2006-07.

Application of special licence conditions

Since 2002, there have been two major changes to the Commission's 'model' licence conditions arising from the 2005 and 2010 reviews. Consequently, South Australia's fleet of wind-powered electricity generators are currently subject to three slightly differing sets of licence conditions:

- The first set of licence conditions reflected the general licensing conditions for all electricity generators prior to the Commission undertaking studies on this matter and were applied to the very first wind-powered generator farm (Starfish Hill — which was licensed on 29 January 2002).
- The second set of licence conditions were introduced on 30 September 2005 and incorporated a set of special licensing conditions and wind licensing principles following the Commission's 2005 review.
- The third set of licence conditions were introduced on 3 May 2010 following the Commission's 2010 review of the applicability of national frameworks within the South Australian context.
- Additional licence conditions were placed on Hornsdale Wind Farm Stage 2 after advice from AEMO in February 2017.

Table D:1 identifies the capacity of the wind-powered electricity generation plant currently installed in South Australia and the relevant version of the licence conditions applicable to each plant.

Table D:1 — South Australian wind-powered generation plant installed as at 11 April 2017

Generator	Licensed capacity (MW)	Date licence issued	Special licence conditions	Year and version of applicable special licence conditions
Semi-scheduled market generators				
Clements Gap Wind Farm	57.8	03/06/2005	N	-
Hallett 1 (Brown Hill) Wind Farm	94.5	10/03/2006	Y	2005 v1
Hallett 2 (Hallett Hill) Wind Farm	71.4	13/03/2008	Y	2005 v1
Hallett 4 (North Brown Hill) Wind Farm	132.3	09/12/2009	Y	2005 v1
Hallett 5 (The Bluff) Wind Farm	52.5	25/09/2012	Y	2010 v2
Hornsdale Stage 1 Wind Farm	100	12/05/2016	Y	2010 v2
Hornsdale Stage 2 Wind Farm	100	13/02/2017	Y	2010 v2 plus additional items
Lake Bonney Stage 2 Wind Farm	159.5	22/03/2006	Y	2005 v1
Lake Bonney Stage 3 Wind Farm	39	23/12/2009	Y	2005 v1
Snowtown Wind Farm	98.7	09/01/2007	Y	2005 v1
Snowtown Stage 2 South Wind Farm	126	23/07/2013	Y	2010 v2
Snowtown Stage 2 North Wind Farm	144	10/07/2012	Y	2010 v2
Waterloo Wind Farm Stage 1	111	16/10/2009	Y	2005 v1
Waterloo Wind Farm Stage 2	19.8	17/12/2015	Y	2010 v2
Non-scheduled market generators				
Canunda Wind Farm	46	01/10/2004	N	-
Cathedral Rocks Wind Farm	66	22/10/2004	N	-
Lake Bonney Wind Farm	80.5	22/07/2002	N	-
Mount Millar Wind Farm	70	23/09/2004	N	-
Starfish Hill Wind Farm	34.5	29/01/2002	N	-
Wattle Point Wind Farm	90.75	14/04/2004	N	-
Non-market generator				
Barunga Range	2.1	09/02/2011	N	-

In summary, the number and size of wind farms subject to the three different sets of licence conditions, at 11 April 2017, include:

- Eight wind farms representing approximately 448 MW of installed capacity that are subject to the requirements of the NER that were applicable at the time (and are not subject to special licence conditions)
- Seven wind farms representing approximately 706 MW of installed capacity that are subject to the special licence conditions introduced in September 2005
- Five wind farms representing approximately 442 MW of installed capacity that are subject to the updated special licence conditions introduced in May 2010, and
- One wind farm of 100 MW of installed capacity (under construction) that is subject to the May 2010 special licence conditions and also subject to additional requirements as advised by AEMO.

Appendix E — AEMO Addendum to Final Advice

ADDENDUM TO FINAL REPORT: RECOMMENDED TECHNICAL STANDARDS FOR GENERATOR LICENSING IN SOUTH AUSTRALIA

ADVICE TO ESCOSA

August 2017

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

IMPORTANT NOTICE

Purpose

AEMO has prepared this document to provide advice to the Essential Services Commission of South Australia to assist in its review of technical standards for generation licenses. This document is not intended for use by any other person.

Disclaimer

This document or the information in it may be subsequently updated or amended. This document does not constitute legal or business advice, and should not be relied on as a substitute for obtaining detailed advice about the National Electricity Law, the National Electricity Rules, or any other applicable laws, procedures or policies. AEMO has made every effort to ensure the quality of the information in this document but cannot guarantee its accuracy or completeness.

Accordingly, to the maximum extent permitted by law, AEMO and its officers, employees and consultants involved in the preparation of this document:

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Version control

Version	Release date	Changes
1	August 2017	Initial release

CONTENTS

TABLES

FIGURES

1. SUMMARY

1.1 Background

The Essential Services Commission of South Australia (ESCOSA) is reviewing the regulatory, licensing, and associated arrangements for connection of new electricity generators in South Australia (SA), and sought advice from AEMO in relation to two matters:

- The currency of the existing special licence conditions relating to technical standards for wind farms connecting to SA's electricity network.
- Whether there is merit in additional or amended technical requirements being imposed on other inverter-connected generation technologies (for example, photovoltaics (PV)).

ESCOSA released an Issues Paper on 2 December 2016, setting out the scope and issues to be considered in its review into licensing arrangements for connection of generation in SA.

In March 2017, AEMO provided detailed advice to ESCOSA on the above matters in its report *Recommended Technical Standards for Generator Licensing in South Australia* (March advice).[1]

On 1 May 2017, ESCOSA released a Draft Report as part of its Inquiry into the licensing arrangements for generators in South Australia.

Stakeholders were then invited to express their views on the matters raised in the Draft Report (including the advice received from AEMO). As part of this consultation, ESCOSA and AEMO also held a workshop for stakeholders and other interested participants. Consultation on the Draft Report closed on 9 June 2017, and 15 submissions were received by ESCOSA and AEMO. (See Section 2 for detail on consultation and feedback.)

ESCOSA has asked AEMO to update the March advice, taking into consideration the feedback from stakeholders and any further learnings since that time.

1.2 Document purpose

This document represents AEMO's revised advice to ESCOSA on these matters. It takes into account the lessons and feedback gathered by AEMO and ESCOSA since March 2017, including:

- Stakeholder feedback to ESCOSA's Issues Paper.
- Stakeholder feedback to ESCOSA's Draft Report (including AEMO's March advice).
- Analysis into the 28 September 2016 Black System event in SA.
- Learnings from AEMO's Future Power System Security program[2].
- Other informal AEMO consultations with equipment manufacturers and stakeholders.
- Lessons from international Grid Codes.
- Learnings from collaboration with AEMC in developing the *Managing power system fault levels* Rule change[3]

This updated advisory document is presented as an addendum to the March advice and should be read in conjunction with that advice.

[1] AEMO. *Recommended technical standards for generator licensing in South Australia*, March 2017. Available at: http://www.escosa.sa.gov.au/ArticleDocuments/1048/20170331-Inquiry-RecommendedTechnicalStandardsGeneratorLicensingSA-AEMOadvice.pdf.aspx?Embed=Y.

[2] AEMO's Future Power System Security (FPSS) Program seeks to ensure that system security is maintained in the NEM as the generation mix continues to change. FPSS reports and analysis are available at: https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/FPSSP-Reports-and-Analysis

[3] AEMC 2017, *Managing power system fault levels*, Draft rule determination, 27 June 2017, Sydney, available at: http://aemc.gov.au/Rule-Changes/Managing-power-system-fault-levels

1.3 Document structure

This document is structured as follows:

- Section 1 – Introductory summary of process to date
- Section 2 – A summary of stakeholder feedback received and AEMO's response to this feedback.
- Section 3 – AEMO's revised recommendations to ESCOSA, including justifications for changes since the March advice.

1.4 Principles guiding AEMO's advice

AEMO's March advice stated a number of guiding principles that have been used as a basis for AEMO's recommendations. These are summarised below for context.

Long-term interests of consumers

ESCOSA's final decision on generator licence conditions must have regard to its primary statutory objective, which is to protect the long-term interests of SA consumers with respect to the price, quality, and reliability of essential services.

AEMO has sought to ensure that these recommendations are consistent with this objective.

A national approach to technical standards

AEMO seeks to maintain a NEM-wide, technology-neutral approach to generator performance standards, and believes that the long-term interests of consumers will be best met with a consistent national Rules framework.

The need for these state-based technical standards in South Australia is a clear indication that the generally applicable generator performance standards, as defined in the National Electricity Rules (NER), require updating urgently to reflect the needs of the changing power system so as to ensure its continued safety, security and reliability. AEMO believes the NER should be updated as soon as practicable, and is in the process of drafting an urgent Rule change proposal to the Australian Energy Market Commission (AEMC), proposing appropriate revisions. AEMO is also exploring options to align technical standards for generation in Western Australia with those in the NEM.

In the interim, to guarantee the capabilities of the generation fleet in SA, AEMO appreciates it as appropriate to maintain special licence conditions that apply only in SA. Putting in place these interim arrangements in South Australia, however, does not mean that changes to the generally applicable generator performance standards across the NEM under the NER can be delayed, however, as similar issues may well arise in other jurisdictions and it is important that the standards are consistent across the NEM.

The final recommendations to ESCOSA in this report will therefore form the foundation of AEMO's Rule change request to the AEMC. Ideally, any new licence conditions imposed by ESCOSA would be transitional arrangements that are eventually able to be repealed, in whole or in part, when the technical standards in the NER are updated.

Looking to the future

In developing these recommendations, AEMO has sought to establish a set of generator technical standards that will be capable of supporting a secure power system throughout the transition away from a power system structured around centrally connected, thermal generation.

A characteristic of this transition is the displacement of synchronous generation[4] by non-synchronous generation.[5] Changes to the generation mix have occurred at a faster pace in South Australia than in the rest of the NEM. Since AEMO's previous advice to ESCOSA on generator licence conditions in 2010, the proportion of non-synchronous generation capacity in the SA region has increased from 20% to over 43%, with this trend expected to increase in the future.

AEMO has considered how all necessary system 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 within the region.
- Periods of low, zero, or negative operational demand[6] due to increasing volumes of generation within the distribution network.

Under such scenarios, synchronous generators alone will no longer provide sufficient system security services[7]. Alternative means of procuring these services must be found, whether from non-synchronous generators (where it is reasonable to do so) or as network or non-network services (where services are still required under low operational demand scenarios).

Historically, system operators have relied on the inherent characteristics of synchronous generators to manage power system security. Non-synchronous generators such as wind and solar were viewed as peripheral technologies that were not expected to manage power system security. In fact, many grid codes were initially designed so these generators would trip off in response to a frequency or voltage disturbance. With increasing penetrations of wind and PV, non-synchronous generators are no longer fringe players. These technologies are now core elements of the SA power system.

AEMO's advice recommends that all types of generators should be required to incorporate cost-effective features that will allow them to contribute towards a secure and resilient power system

Applying technical standards only where efficient to do so

The recommendations in this document are designed to be applied as part of a broader package of reforms.

Technological improvements over the last decade mean modern plant often includes additional functionality that can help to stabilise the power system, but these capabilities may not be provided without a standard that requires them.

AEMO's recommendations are designed to take advantage of technological developments that provide additional capability at low additional cost.

Higher standards have only been recommended where AEMO considers that a technical standard applied to generators is likely to be the most efficient way of addressing an identified technical issue.

It is unlikely to be efficient to require generators to solve all technical issues arising as a result of the energy transition. Where it is no longer efficient to source the requisite system services from generation, there are a range of alternative solutions, including establishing market frameworks and/or identifying new roles for network businesses to play in maintaining a secure power system.

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[4] Synchronous generators 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

[5] Non-synchronous generators include wind farms, or solar PV generators, 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 the generator to the network

[6] Broadly, this means SA's entire electricity demand could be offset by rooftop PV (which is treated as "negative load" because it is located behind the electricity meter, on a customer's premises). In this case, surplus rooftop PV generation would be exported interstate via an interconnector. More formally, 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.

[7] These non-energy system services include voltage control, frequency control, synchronous inertia, and provision of fault current.

Conditions should apply to all generation types, not just wind

Unless there are unavoidable technical reasons why a given technology cannot provide a particular service characteristic, AEMO recommends that standards should apply to all generation types greater than 5 MW, a level consistent with AEMO's standing registration exemption for small generating systems. [8]. The recommendations in this paper refer to generating systems that exceed this threshold.

Any generating unit installed today is likely to remain in service for at least the next 20 years, and will plausibly need to operate when there is very little synchronous generation online. Accordingly, AEMO is recommending that ESCOSA apply consistent licence conditions on all new generators (regardless of technology), such that the SA generation fleet is equipped with the capabilities it needs to provide a secure and resilient power supply for the life of the assets.

Where there are intrinsic physical differences between synchronous and non-synchronous generators, the final licence conditions may need to articulate two similarly intentioned licence requirements.

Applying this philosophy, AEMO has focused on the fundamental needs of the system, as well as what can reasonably be expected from all generators in the future. In some cases this will increase the range of capabilities expected from synchronous generation, while also acknowledging it is no longer practical to treat non-synchronous generators as fringe players.

Application of conditions to existing generators

Much of the current generation fleet in SA will remain in service for a similar timeframe to any new generating units and in order to improve system security and resilience outcomes in the shorter term, consideration should be given to deriving additional capability from the current generation fleet.

Accordingly, AEMO recommends that ESCOSA consider how some capabilities could be obtained from existing generation in South Australia, with due regard to:

- The physical limitations of some existing generating units.
- The likely cost of enabling the capability for each generating unit.
- The incremental benefits that would be gained by enabling existing generating units.

If ESCOSA implements this recommendation, AEMO proposes to work with ESCOSA and stakeholders on a case by case basis to undertake this assessment of the existing generation fleet.

1.5 Summary of changes to AEMO's recommendations

AEMO's March advice included recommended changes to licence conditions in the following areas:

- Reactive power capability.
- Provision of dynamic reactive power.
- Voltage control capability.
- Disturbance ride-through.
- System strength.
- Active power control capability.
- System restoration.

AEMO's updated recommendations to ESCOSA in Section 3 largely reflect AEMO's earlier advice in each of the above areas, with the key changes summarised below in Table 1.

[8] For more information, refer to AEMO's Guide to NEM Generator classification and exemption, available at: http://www.aemo.com.au/-/media/Files/PDF/Generator-Classification-and-Exemptions-Guide.pdf

Table 1 Summary of key changes to AEMO recommendations

Focus area	Comments on changes since March advice
Disturbance ride-through – General principles	A series of general principles were proposed that applicants should note. On further review, AEMO has decided that these principles warrant application as a specific licence condition.
Disturbance ride-through – Reactive current injection requirements	Based on feedback from stakeholders, AEMO has updated its March advice to: • Amend the wording of reactive current injection criteria applicable to synchronous generators. • Include additional information to assist with interpretation of reactive current injection requirements for synchronous and non-synchronous plant.
Disturbance ride-through – Active power injection requirements	In response to stakeholder feedback, AEMO has clarified the slowest rate of active power recovery that may be acceptable.
Disturbance ride-through – Multiple low voltage disturbance ride-through	In response to stakeholder feedback, AEMO has: • Clarified the total number of low voltage faults new entrant generators must have the capability to ride through. • Provided further information on how longer duration shallow voltage faults are considered.
Disturbance ride-through – High voltage disturbance ride-through	Based on stakeholder feedback raising concerns about the original over voltage withstand durations, AEMO has amended the withstand durations for temporary over voltages in the 110–115% range and the 115–120% range.
System strength – an NSP licence condition to maintain an agreed short circuit ratio at the connection point	Based on the AEMC's June 2017 draft determination on the *Managing power system fault levels* Rule*, AEMO no longer considers it necessary for ESCOSA to develop an additional NSP licence condition in this area.
System strength – A generator licence condition to meet its GPS at the connection point for the range of short circuit ratios agreed with the NSP in the connection agreement	As in the previous recommendation, AEMO believes this issue can best be addressed through the *Managing power system fault levels* Rule change currently being assessed by the AEMC.
Active power control capability – ability to limit rate of change of active power	AEMO has clarified the wording of this recommendation to ensure the intent is clear.
Active power control capability – ability to provide real-time information about active power control settings	While AEMO can request this information under S5.2.6.1 of the NER, there is no current requirement for Generators to have the necessary SCADA signals. Accordingly AEMO has amended its recommendation to focus the revised licence condition on ensuring the generator has the appropriate capabilities. Use of this capability will be determined by AEMO under its existing NER powers.
Active power control capability – registration for frequency control ancillary services (FCAS)	This previously proposed requirement has been removed following feedback from stakeholders, and pending the outcomes of: • AEMO's Ancillary Services Technical Advisory Group (AS TAG) process. • Current trials for provision of FCAS from new entrant wind generation. • Outcomes from the AEMC's Frequency Control Frameworks Review.
System restoration	AEMO has proposed amended requirements in this area following feedback from stakeholders that suggested the requirements as originally stated may result in damage to generating systems and other items of plant.

* AEMC 2017, *Managing power system fault levels*, Draft rule determination, 27 June 2017, Sydney, available at: http://aemc.gov.au/Rule-Changes/Managing-power-system-fault-levels

AEMO has also revised the wording of its final recommendations to make them more readily applicable as licence conditions.

Full details of AEMO's revised recommendations to ESCOSA are provided in Section 3.

2. SUMMARY OF SUBMISSIONS RECEIVED

2.1 Consultation undertaken

As noted in Section 1.1, ESCOSA published its Draft Report on 1 May 2017, together with AEMO's March advice, and allowed approximately two months for submissions from stakeholders.

To facilitate the submissions process, ESCOSA hosted a day-long consultative forum, in conjunction with AEMO, on 16 May 2017. The forum included presentations with targeted question and answer sessions on each of the major areas of focus of AEMO's technical recommendations.

ESCOSA and AEMO received 15 submissions in response to the Draft Report (including AEMO's March advice), from a variety of stakeholders:

- NGO/Industry groups (SACOME, Energy Networks Australia, SACOSS)
- Generators/retailers (Energy Australia, Origin Energy, Pacific Hydro, Snowy Hydro, Engie).
- Original Equipment Manufacturers (Siemens-Gamesa, Vestas).
- Developers (Tilt Renewables, REACH Solar).
- Network Service Providers (NSPs – TasNetworks, ElectraNet).
- Government (SA Department of Premier and Cabinet, Energy and Technical Regulation (ETR) Division).

It is important to note that the industry stakeholders who responded operate not only in South Australia but also in other regions of the NEM.

This feedback has complemented other consultation by AEMO with market participants, industry groups, original equipment manufacturers, developers, NSPs, and Government since the commencement of ESCOSA's review in July 2016 and in the preparation of AEMO's Final Report on the Black System in South Australia on 28 September 2016.[9]

[9] AEMO. *Black System South Australia – 28 September 2016*, March 2017. Available at: http://aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2017/Integrated-Final-Report-SA-Black-System-28-September-2016.pdf.

2.2 Issues summary

Table 2 presents a summary of issues raised by stakeholders on the technical recommendations presented in AEMO's March advice, and of AEMO's response to the issues raised.

Table 2 Submissions – issues summary

Focus area	Issue raised	Raised by	AEMO response
Disturbance ride-through – Reactive current injection & absorption	Reactive current injection from non-synchronous plant typically stops at 20% of residual voltage, reactive current absorption typically stops at 20% above nominal voltage. Synchronous generation may not be capable of settling times no greater than 60 ms.	Origin Vestas ElectraNet	AEMO has clarified expectations for reactive current absorption at low voltage and clarified application of settling time to synchronous generators.
Disturbance ride-through – Active power injection requirements	The technical recommendation as proposed in the draft report does not provide guidance on how the level of active power recovery that may be negotiated.	Vestas Pacific Hydro	AEMO has proposed amended wording for this recommendation, clarifying that the expected level of active power recovery will be assessed on a case-by-case basis between 100 and 500 ms.
Disturbance ride-through – Multiple low voltage disturbance ride-through (LVRT)	The proposed recommendation does not specify a limit to the number of faults that plant must ride through. Unlimited voltage ride through risks damage to plant and protection equipment. Number of faults should be capped at an agreed level. It may not be possible to design systems to ride through unlimited number of faults (both voltage and frequency).	Vestas Origin Energy Australia	AEMO has proposed a maximum number of faults and a cumulative time period for multiple LVRT, including shallow faults.
Disturbance ride-through – High voltage disturbance ride-through	Meeting the proposed over voltage withstand capability requirements may be costly and affect the lifespan of generating system components.	Siemens-Gamesa	AEMO has reduced the proposed level of over voltage withstand capability following consideration of international grid codes.
Disturbance ride-through –Frequency disturbance ride through	Origin suggested that the proposed rate of change of frequency (RoCoF) withstand requirements for new generators risk damage. Almost impossible for existing generation to meet requirements. ElectraNet was generally supportive of proposed amendments to the level of RoCoF for which generators can maintain continuous uninterrupted operation in the context of amendments to NER clause S5.2.5.3.	Origin ElectraNet	AEMO maintains that a level of RoCoF withstand capability as close as possible to the recommended levels should be negotiated for new entrant synchronous plant in SA.
System strength – a generator licence condition to meet its GPS at the connection point for the range of short circuit ratios agreed with the NSP in the connection agreement	Opposed to general requirement of SCR and X/R – capability is dependent on control system tuning, and additional compensation equipment	Vestas	AEMO maintains that requiring susceptible items of plant within the connecting party's generating system must be capable of operating correctly down to a minimum short circuit and X/R ratio is a sensible complementary policy while the AEMC is developing the *Managing power system fault levels* Rule change.

Focus area	Issue raised	Raised by	AEMO response
Active power control capability – ability to limit rate of change of active power	Introducing of limits on the rate of change of active power output from new generators as proposed by AEMO, may unfairly penalise new entrants and their ability to respond to price events from the market.	Energy Australia	AEMO has clarified the wording of this recommendation and will consider this issue in further work. AEMO maintains that it may be necessary to limit the rate of change of active power output from generators in the future due to potential impacts to system security if large and unexpected changes in generation output occurs.
Active power control capability – registration for FCAS	Participation in FCAS markets is currently voluntary and issues relating to frequency performance in the NEM are being investigated through a number of industry reviews and trials.	Pacific Hydro REACH Solar Origin	AEMO has removed this proposed requirement awaiting the outcomes of: • AEMO's Ancillary Services Technical Advisory Group (AS TAG) process. • Current trials for provision of FCAS from new entrant wind generation. • Outcomes from the AEMC's Frequency Control Frameworks Review.
Other matters of interest to ESCOSA – Ability to assist with system restart	Vestas suggested that if ESCOSA's proposed requirement relates to availability of backup power systems to support auxiliary loads while import from grid is not possible, then it cannot be met, as wind farm backup power may be limited to 30 minutes. Some generators may be at risk of damage if required to provide voltage control at low or zero load for longer than 30 minutes when assisting with system restart. Voltage control arrangements for system restart should be consistent with other NER obligations that relate to NSPs.	Vestas Origin ElectraNet	AEMO has clarified the basis of this recommendation and amended it to take consideration of the period of time for which each generating system is able to operate only on auxiliaries while provided voltage support to the power system during restart.

3. REVISED RECOMMENDATIONS

3.1 How to interpret revised recommendations

The revised recommendations provided in this section take into account the lessons and feedback gathered by AEMO and ESCOSA since March 2017, including:

- Stakeholder feedback to ESCOSA's Draft Report including AEMO's March advice.
- Stakeholder feedback to ESCOSA's Issues Paper.
- Final analysis of the 28 September 2016 state-wide blackout in SA.
- Learnings from AEMO's Future Power System Security program.
- Other informal AEMO consultations with equipment manufacturers and stakeholders.
- Lessons from international Grid Codes.
- Learnings from collaboration with AEMC in developing the *Managing power system fault levels* Rule change[10]

As noted, these revised recommendations have been written as an addendum to the March advice and should be read in conjunction with that advice.[11]

Where AEMO's recommendations have changed significantly from its March advice, supporting justification is provided in this addendum, otherwise the reasons for AEMO's final recommendations are provided in the March advice.

The wording of these final recommendations has also been amended in places to make them more easily applicable as licensing conditions.

3.2 Format of revised recommendations

AEMO's revised recommendations are provided in Section 3.3 below.

For simplicity, AEMO has structured its final recommendations in a tabular format, including the following information for each final recommendation:

- Relevant focus area (such as disturbance ride-through).
- Reference to relevant section of AEMO's March advisory report to ESCOSA.
- Related NER Clause(s).
- Summary of AEMO's March recommendation.
- Details of why AEMO's final recommendations differ from its March advice (if at all).
- Detailed final recommendations to ESCOSA on amended licence conditions.
- Guidance notes to support interpretation of AEMO's final recommendations (not to be included in the final licence conditions).

[10] AEMC 2017, *Managing power system fault levels*, Draft rule determination, 27 June 2017, Sydney, available at: http://aemc.gov.au/Rule-Changes/Managing-power-system-fault-levels

[11] AEMO. *Recommended technical standards for generator licensing in South Australia*, March 2017. Available at: http://www.escosa.sa.gov.au/ArticleDocuments/1048/20170331-Inquiry-RecommendedTechnicalStandardsGeneratorLicensingSA-AEMOadvice.pdf.aspx?Embed=Y.

3.3 Summary of revised recommendations

"Report Section" refers to the relevant section of AEMO's March 2017 advice to ESCOSA: *Recommended technical standards for generator licensing in South Australia*, available at: http://www.escosa.sa.gov.au/ArticleDocuments/1048/20170331-Inquiry-RecommendedTechnicalStandardsGeneratorLicensingSA-AEMOadvice.pdf.aspx?Embed=Y. All references to AEMO's March 2017 advice to ESCOSA refer to the same report.

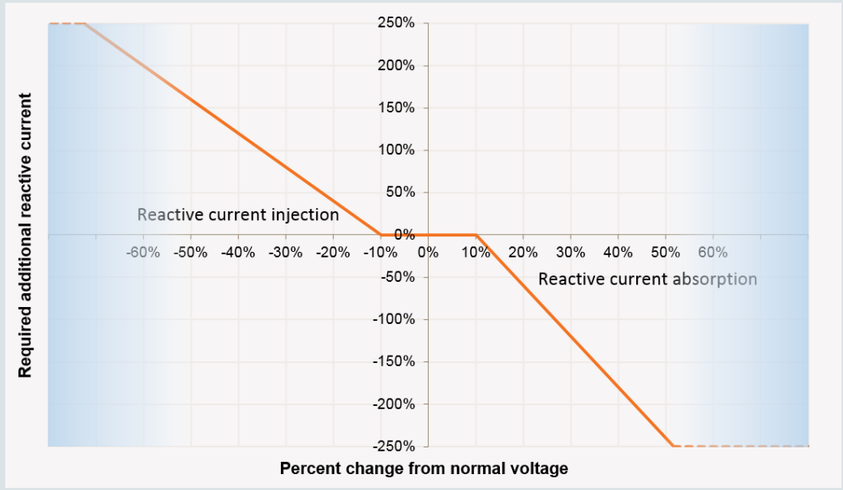
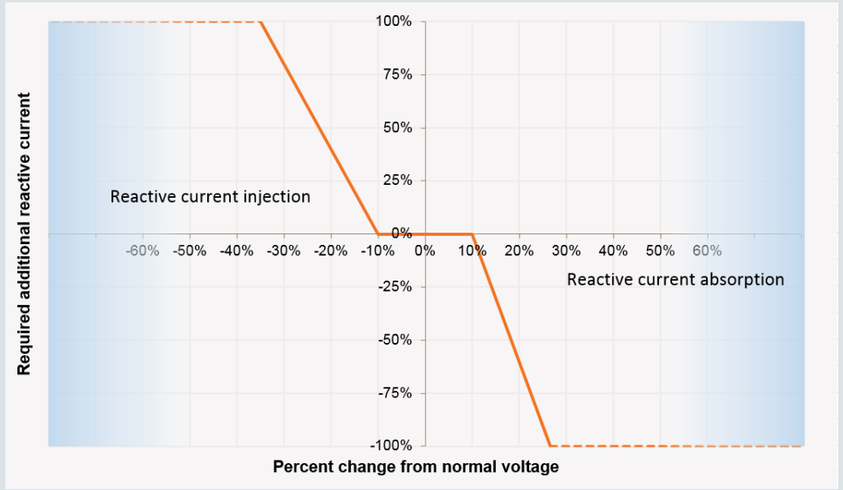
Table 3 Revised technical recommendations

#	Report section	Focus area	Related NER Clause(s)	Summary of interim recommendations	Supporting notes (issues raised/justification of final recommendations)	Revised final recommendation to ESCOSA
1	2.3.1	Reactive power capability	S5.2.5.1	AEMO recommends that ESCOSA replace current special licence conditions 10.1, 10.2, and 10.3 relating to reactive power capability with the set of recommended licence conditions described in Chapter 3 of AEMO's March 2017 advice to ESCOSA.	Refer to justification in AEMO's March 2017 advice to ESCOSA.	AEMO recommends that ESCOSA replace current special licence conditions 10.1, 10.2, and 10.3 relating to reactive power capability with the set of recommended licence conditions described below (refer recommendations 4 and 5).
2	2.3.2	Provision of dynamic reactive power	S5.2.5.1	AEMO recommends that the current dynamic reactive power requirements conditions in clause 10.4 of the ESCOSA special licence conditions be removed and replaced with specific requirements relating to disturbance ride-through. These requirements are described in detail in Chapter 3 of AEMO's March 2017 advice to ESCOSA.	Refer to justification in AEMO's March 2017 advice to ESCOSA.	AEMO recommends that ESCOSA replace current special licence conditions 10.4 relating to dynamic reactive power capability with the recommended licence conditions described below (refer recommendations 4 and 5).
3	2.3.3	Voltage control capability	S5.2.5.5 S5.2.5.13	Generators should comply with the newly worded clauses 10.5, 10.6, and 10.7 regarding voltage control	Refer to justification in AEMO's March 2017 advice to ESCOSA.	The generating system which the licensee is authorised to operate under this licence should comply with the following newly worded clauses 10.5, 10.6, and 10.7 regarding voltage control: 10.5 The generating system operated by the licensee must be capable of control by a fast-acting, continuously variable, voltage control system. The voltage control system must be able to receive a local and remote voltage setpoint. 10.6 The generating system operated by the licensee must have the capability to operate at either a set reactive power level, or a set power factor, which is able to be set locally or remotely at any time. 10.7 The voltage, power factor or reactive power control mode of a non-synchronous generating system operated by the licensee must be capable of: (a) being overridden by the disturbance ride through requirements (conditions in items 4 to 11 in this table) during a power system disturbance; and (b) automatically reverting to the selected control mode when the disturbance has ceased.
4	3.3.1	Disturbance ride-through – General principles	S5.2.5.4	To provide context for AEMO's recommendations related to disturbance ride-through capability, applicants should note:	In AEMO's March 2017 advice to ESCOSA a series of general principles were proposed that applicants should note. Upon further review, AEMO has decided	A non-synchronous generating system must meet the following requirements: • The LVRT activation threshold – as measured at the low voltage (LV) terminals of the generating units and other relevant items of plant (including, but not limited to dynamic reactive power plant) must not be less than 85% of nominal voltage. • Maintain continuous uninterrupted operation for voltage disturbances wherever specified in licence conditions.

<table>
<tr><th>#</th><th>Report section</th><th>Focus area</th><th>Related NER Clause(s)</th><th>Summary of interim recommendations</th><th>Supporting notes (issues raised/justification of final recommendations)</th><th>Revised final recommendation to ESCOSA</th></tr>
<tr><td></td><td></td><td></td><td></td><td>Expected LVRT/HVRT withstand requirements, irrespective of generating system transformer’s tap position.
The LVRT activation threshold.
Definition of continuous uninterrupted operation.</td><td>that these principles warrant application as a specific licence condition. AEMO has adjusted its final recommendations accordingly.
This licence condition only-applies to non-synchronous generators. [12]</td><td>Where low voltage ride-through (LVRT) and high voltage ride-through (HVRT) requirements in the NER are specified in respect of the connection point, the withstand capability of individual generating units is to be determined at the low voltage (LV) side of the generating unit’s transformer. All individual generating units must remain connected for connection point voltages within the LVRT/HVRT withstand requirements, irrespective of the generating system transformer’s tap position.
_____
Notes:
For the purpose of this licence condition, continuous uninterrupted operation for voltage disturbances means that for voltage disturbances within the continuous operating range (i.e. connection point voltage fluctuating within 90% and 110% of normal voltage), active power must be maintained (unless there has been a change in the intermittent power source) and reactive power must be managed to meet voltage control requirements. This definition is provided to allow parties to interpret obligations for voltage disturbance under this license condition and is intended to complement rather replace the existing NER definition.</td></tr>
<tr><td>5</td><td>3.3.1</td><td>Disturbance ride-through – Reactive current injection requirements</td><td>S5.2.5.5</td><td>Require new entrant generators to be able to meet reactive current injection requirements during and subsequent to contingency events.
In response to stakeholder feedback on application to synchronous generators, AEMO has amended the wording of reactive current injection criteria (specifically settling time).
AEMO has also included additional information to assist with interpretation of reactive current injection requirements for synchronous and non-synchronous plant</td><td>Refer to justification in AEMO’s March 2017 advice to ESCOSA.
Identified issues include:
- Cut-off for reactive power injection based on LV conditions
- Cut-off for reactive power injection based on HV conditions
- Application of reactive current injection criteria to synchronous generators</td><td>The generating system which the licensee is authorised to operate under this licence must comply with the following:
The generating system must supply additional capacitive reactive current (reactive current injection) 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 below 90% of normal voltage, as shown in Table 4. This requirement applies at the LV terminals of the generating units and other relevant items of plant (including, but not limited to dynamic reactive power plant) for power system disturbances resulting in a voltage reduction of up to 100% of normal voltage at the connection point.
The generating system must supply additional inductive reactive current (reactive current absorption) of up to 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 Table 4 below. This requirement applies at the LV terminals of the generating units and other relevant items of plant (including, but not limited to dynamic reactive power plant).
The reactive current injection must be maintained until the connection point voltage returns to within the range of 90% to 110% of normal voltage.
Table 4 Reactive current injection requirements<table><tr><th>Reactive current response</th><th>Current injection gain (%)</th><th>Current absorption gain (%)</th><th>Minimum amount of contribution as percentage of rated current</th><th colspan="2">Speed of contribution</th></tr><tr><th></th><th></th><th></th><th></th><th>Rise time (ms)</th><th>Settling time (ms)</th></tr><tr><td>Synchronous</td><td>4</td><td>6</td><td>250</td><td>30</td><td>N/A</td></tr><tr><td>Non-synchronous</td><td>4</td><td>6</td><td>100</td><td>30</td><td>60</td></tr></table>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 ESCOSA for various types of voltage disturbances.
The generating system which the licensee is authorised to operate under this licence should comply with the following response characteristics for reactive current injection:
A *rise time* (as defined in clause S5.2.5.13 of the NER) no greater than 30 milliseconds (ms) and a s*ettling time* (also as defined in clause S5.2.5.13 of the NER) no greater than 60 ms applies to reactive current injection requirements. The settling time requirement does not apply to synchronous machines.
For a non-synchronous generating system, the reactive current injection requirements described above apply for all pre-disturbance reactive power control modes (voltage control, power factor control, or reactive power control).</td></tr>
</table>

[12] ‘LVRT/HVRT threshold characteristics and obligations to maintain continuous uninterrupted operation in the context of this license recommendation are only relevant to non-synchronous generation. The existing NER provisions for continuous uninterrupted operation and obligations to ride through under voltage events remain suitable for describing the performance of synchronous plant.

#	Report section	Focus area	Related NER Clause(s)	Summary of interim recommendations	Supporting notes (issues raised/justification of final recommendations)	Revised final recommendation to ESCOSA
						• The reactive current response must be *adequately damped* as defined in the NER (Glossary, Chapter 10). • 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 following range for continuous uninterrupted operation: – Voltages over 110% for the durations permitted under NER clause S5.1a.4; – 90% to 110% of normal voltage continuously; – 80% to 90% of normal voltage for a period of at least 10 seconds; and – 70% to 80% of normal voltage for a period of at least 2 seconds. _____ Notes: • A graphical representation of these requirements is provided below in Figure 1 and Figure 2 for explanatory purposes. • It should be noted that the term '*settling time'* does not apply to synchronous machines in the context of fault current contribution because: – *Settling time* as defined in 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. – Unlike non-synchronous plant, the fault current contribution of synchronous generators is provided through an intrinsic and uncontrolled response. – The fault current contribution of synchronous generators does not settle during the 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. • Note that voltage disturbances in this condition are defined at the connection point, while performance characteristics are defined at the LV terminals the generating units and other relevant items of plant (including, but not limited to dynamic reactive power plant). Accordingly, the final reactive current injection/absorption limits at LV terminals will be determined by generating system component impedances behind the connection point - as indicated by the dotted lines in Figure 1 and Figure 2.

#	Report section	Focus area	Related NER Clause(s)	Summary of interim recommendations	Supporting notes (issues raised/justification of final recommendations)	Revised final recommendation to ESCOSA
						Figure 1 Reactive current injection requirements for synchronous generators  **Figure 2 Reactive current injection requirements for non-synchronous generating system** 
6	3.3.1	Disturbance ride-through – Active power injection requirements	S5.2.5.5(b)(2)	Require new entrant generators to be able to restore active power to at least 95% of the level existing just prior to the fault between 100 and 500 ms after disconnection of the faulted element. The exact	Refer to justification in AEMO's March 2017 advice to ESCOSA. Some stakeholders have requested clarification on the slowest level of active	The generating system must be capable of restoring active power to at least 95% of the level existing just prior to a fault between 100 and 500 ms after disconnection of the faulted element, with recovery no slower than 500ms. The exact active power recovery time must be specified by ESCOSA. Transient active power consumption upon application of a fault must not exceed one power frequency cycle and must not exceed 5% of the maximum continuous rated current of the generating system.

#	Report section	Focus area	Related NER Clause(s)	Summary of interim recommendations	Supporting notes (issues raised/justification of final recommendations)	Revised final recommendation to ESCOSA
				active power recovery time should be determined by AEMO and ElectraNet for each specific connection depending on specific requirements. Transient active power consumption upon application of a fault should not exceed set limits.	power recovery that may be acceptable AEMO considers that assessment of active power restoration time should be made on a case-by-case basis as impacts of generator performance vary considerably according to generation type and network location. Notwithstanding this, AEMO has included a lower limit on active power recovery of 'no slower than 500ms' to more clearly specify the range of expected performance for active power recovery.	
7	3.3.1	Disturbance ride-through – Multiple low voltage disturbance ride-through	S5.2.5.4 S5.2.5.5	Require new entrant generators to be able to meet multiple low voltage disturbance ride through requirements.	Refer to justification in AEMO's March 2017 advice to ESCOSA. AEMO received stakeholder feedback from Origin and Vestas requesting: • Clarity on the total number of low voltage faults new entrant generators must have the capability to ride through. • Further information on how longer duration shallow voltage faults are considered. AEMO has proposed amendments to description of 5 minute interval and the total number of faults in response to stakeholder feedback. Further, based on stakeholder feedback, the total fault duration was reduced from 1800 ms to 1500 ms to ensure the requirements can be met by as wide a range of technologies as possible,	Multiple low voltage disturbance ride-through The generating system – including each the generating units and other relevant items of plant (including, but not limited to dynamic reactive power plant) – must be capable of withstanding both of the following within a 5-minute interval: 1. Any combination of voltage disturbances causing the voltage at the respective LV terminals of the equipment to drop below 85% of the nominal voltage for a total duration of 1,500 ms regardless of disturbance type, duration, and residual voltage at the generating unit's terminals. The total number of voltage disturbances for which successful ride-through is required will be limited to 15. Each fault can be a solid fault resulting in 100% voltage drop at the connection point whose duration not exceeding the longest time expected to be taken for the breaker fail protection system to clear the fault, as set out in Table S5.1a.2 of National Electricity Rules. 2. A single worst-case long-duration shallow voltage disturbance, causing the voltage at the connection point drop to 70-80% of the normal voltage for a total duration of 2000 ms. 3. Subject to compliance with the above requirements, the generating system is not required to withstand any additional voltage variation exceeding ±10% of nominal voltage experienced at the respective LV terminals within 30 minutes from the commencement of the first such variation. For synchronous generating systems, the ability to withstand a certain number of faults will be dictated in-part by the physical design of the proposed generating units. Synchronous generators must be able to withstand the above combination of disturbances, unless otherwise agreed with ESCOSA and documented in this licence condition. _____ Notes: Some equipment manufacturers currently use control settings that act by counting the number of successive faults. The requirement to withstand a total duration of multiple faults must override any such manufacturer control settings. Where it is necessary to include protection settings that act on the number of faults, three or more different settings must be applied across the generating system to minimise loss of generation due to simultaneous disconnection of all individual generating units. In any case, the generating system must successfully ride through the total disturbance duration specified above. The proposed licence condition seeks to maximise the fault ride-through capability of new generators, within the physical limits of leading modern generation technology.

#	Report section	Focus area	Related NER Clause(s)	Summary of interim recommendations	Supporting notes (issues raised/justification of final recommendations)	Revised final recommendation to ESCOSA
					This revised level is still above the maximum historical duration of faults that has occurred in the SA.	For a non-synchronous generating system, the most critical factor in setting an acceptable level of generator performance is the total fault duration is, as it determines the amount of heat dissipated across the dynamic braking chopper or dump resistor connected to the DC-link in power electronic converters. Such a scheme is universally used for all modern type 3 and 4 wind turbines for enhanced fault ride-through capability. AEMO has consulted with multiple non-synchronous manufacturers and understand that they are able to comply with the proposed conditions - often as a standard feature in their latest products. For synchronous generators, the most critical factor in setting an acceptable level of generator performance is the number of faults they must withstand. In its submission to the Consultation, Origin Energy recommended imposing a practical limitation on the number of ride through events that generators would be expected to perform against. The proposed limit of 15 faults is based on the maximum number of historical faults within 2, 30, and 120 minute intervals in ElectraNet's transmission network, as highlighted in AEMO's final report into the 28 September 2016 SA black system. The Danish[A] and German Grid Codes are the only grid codes known to AEMO with precise requirements on multiple fault ride-through capability. The need for definition of requirements for repeated disturbances has been acknowledged in a special report by the United States national reliability body, the North American Electric Reliability Corporation (NERC).[B] However, at the time of writing, no specific requirements have been defined. Examples of conditions where successful fault ride-through response is required include: 1. Up to 12 faults each cleared within 120 ms (with any magnitude of voltage dips) + one 2000 ms fault resulting in connection point voltage to drop to 0.7 pu. 2. Up to 15 faults each cleared within 100 ms (with any magnitude of voltage dips) + one 2000 ms fault resulting in connection point voltage to drop to 0.7 pu. 3. Up to 5 faults each cleared within 220 ms + 4 faults each cleared within 100 ms (with any magnitude of voltage dips) + one 2000 ms fault resulting in connection point voltage to drop to 0.7 pu.
8	3.3.1	Disturbance ride-through – High voltage disturbance ride-through	S5.2.5.4 S5.1a.4 S5.1.4	Require new entrant generators to be able to meet high-voltage disturbance ride-through requirements.	Refer to justification in AEMO's March 2017 advice to ESCOSA. Based on stakeholder feedback raising concerns about the original over voltage withstand durations, AEMO has amended the withstand durations for temporary over voltages in the 110–115% range (from 1800s to 1200s) and the 115–120% range (from 30s to 20s). The reduction from 1800 s to 1200 s makes the requirements consistent with findings[C] used to support development of the ENSTSO- E network code for mainland Europe.[D] These over voltage withstand levels have been considered in investigations by CIGRE[E] indicating that all transmission network elements tested by the	The generating system must have a level of over voltage withstand capability consistent with the levels shown in Table 5 below, unless otherwise agreed with ESCOSA. The generating system must maintain continuous uninterrupted operation for temporary over voltage durations as detailed in its licence. **Table 5 Required over voltage withstand capability** **Temporary over voltage (% of normal voltage)** | **110–115** | **115–120** | **120–125** | **125–130** | **130–140** Duration(s) | 1,200 | 20 | 2 | 0.2 | 0.02 Notes: • The HVRT capability is nominally defined at the LV terminals of the generating units. However, for the purpose of compliance with high-voltage disturbance ride-through requirements, the point of compliance can be defined as the connection point or LV terminals of the generating units as agreed on a case-by-case basis with AEMO and relevant NSP. • The proposed requirements apply irrespective of the size of the positive - and negative - sequence phase angle shifts. Detailed power system modelling has been undertaken by AEMO to support review of the Black System event in SA on 28 September 2016. Further detail on this work can be found in Appendix X of AEMO's final incident report.[F] This work has highlighted the importance of temporary generator over voltage withstand capability to avoid the tripping of generators following the credible and non-credible separation of the SA region from the rest of the NEM. AEMO's modelling of credible and non-credible separation scenarios for the SA region has indicated that, without an adequate level of over voltage withstand capability as set out in Table 5, new entrant generators may trip off following a credible or non-credible separation event. NER S5.1.4 requires TNSPs to plan and design the transmission network to control transient and steady-state voltage magnitude for credible contingencies and protected events, within the envelope described by system standard clause S5.1a.4. Clause S5.1.4 (a) suggests that under the NER, NSPs cannot set the automatic standard for S5.2.5.4 for a new generator at a level beyond the system standard set out in S5.1a.4.

#	Report section	Focus area	Related NER Clause(s)	Summary of interim recommendations	Supporting notes (issues raised/justification of final recommendations)	Revised final recommendation to ESCOSA
					CIGRE Working Group are capable of meeting over voltages of up to %115 for 1200 s. The reduction from 30s to 20s on over voltages of up to 120% reflects stakeholder feedback, while still being adequate to ensure sufficient time for disconnection of all transmission and distribution capacitor banks.	The recommended levels for over voltage withstand in Table 5 exceed the level of the system standard and cannot be easily negotiated by an NSP under the current NER framework. For these reasons, AEMO recommends that as an interim measure to reduce the risk of a cascading outages following a credible or non-credible separation event, ESCOSA require a level of over voltage withstand capability be negotiated on case-by-case basis for new entrant generators as close as possible to the recommended levels. In the longer term, AEMO suggests that the development of necessary over voltage withstand capability required for the power system to remain within system standard S5.1a.4 for credible contingencies and protected events, would be the responsibility of ElectraNet in accordance with NER S5.1.4. It is expected that the necessary over voltage capability could be supplied at least cost with a combination of generator performance requirements (i.e. over voltage withstand capability) and the use of network plant (e.g. Static VAR Compensators (SVCs)).
9	3.3.2	Disturbance ride-through – Partial load rejection	S5.2.5.7	Require generators to meet the automatic access standard requirements defined under NER clause S5.2.5.7.	Refer to justification in AEMO's March 2017 advice to ESCOSA. Requirements for synchronous generators in relationship to this recommendation are covered under S5.2.5.7. A license condition is required for non-synchronous generators in this regard as these generators are expressly excluded from this clause.	A non-synchronous generating system must be capable of continuous uninterrupted operation during and following a power system load reduction of 30% from its pre disturbance 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.
10	3.3.3	Disturbance ride-through – Frequency disturbance ride-through	S5.2.5.13	Require generators to be able to meet amended performance requirements for frequency disturbance ride-through.	Refer to justification in AEMO's March 2017 advice to ESCOSA.	A non-synchronous generating system must be capable of continuous uninterrupted operation for any combination of the following rate of change of frequencies: • ±4 Hz/s for 250 ms; • ±3 Hz/s for 1 s, until such time as power system frequency breaches the extreme frequency excursion tolerance limits (defined in the NER, and set in the Reliability Panel's Frequency Operating Standards).[G] A synchronous generating system must be capable of continuous uninterrupted operation for a range of RoCoF intensities as determined by ESCOSA, and documented in the licence. _____ Notes: Unlike non-synchronous generating systems that interface with the network via a converter, synchronous generation is directly connected to the power system via electromagnetic coupling. As a result, there are physical limits to the intensity and duration of RoCoF exposure that each synchronous generator can withstand before suffering damage. ESCOSA should seek the highest possible performance from new synchronous generators, noting the physical limits of these machines.
11	3.3.4	Disturbance ride-through – Voltage	S5.2.5.8	Restrict application of vector shift and similar types of relays	Refer to justification in AEMO's March 2017 advice to ESCOSA.	The generating system must not include any vector shift or similar relay/protective function acting upon voltage phase angle which might operate for phase angle changes less than 20 degrees.

#	Report section	Focus area	Related NER Clause(s)	Summary of interim recommendations	Supporting notes (issues raised/justification of final recommendations)	Revised final recommendation to ESCOSA
		phase angle shift				
12	5.3.2	System strength	n/a	Consider an NSP licence obligation to maintain a short circuit ratio at each connection point within a range agreed in the relevant connection agreement	AEMO believes this issue can be best addressed through the AEMC's *Managing power system fault levels* system strength Rule change.[H] The AEMC's draft determination on this Rule change was published on June 27th 2017 and recommends an enhanced framework in the NER that requires network service providers (NSPs) to maintain the system strength at generating system connection points above an agreed minimum level under a defined range of conditions.	AEMO is not recommending an NSP licence condition for maintaining system strength at the connection point.
13	5.3.2	System strength	n/a	A generator licence condition to meet its GPS at the connection point for the range of short circuit ratios agreed with the NSP in the connection agreement (and which the NSP has undertaken to maintain).	As with item 12, AEMO believes this issue can best be addressed through the Rule change currently being assessed by the AEMC on *Managing power system fault levels* Rule change.[H]	AEMO is not recommending generator licence to address operation of the generating system if levels of system strength are below what is stipulated in the generating system's GPS.
14	5.3.2	System strength	n/a	Require susceptible items of plant (such as individual generating units and dynamic reactive power support plant) within the connecting party's generating system to be capable of operating correctly down to the following levels at the HV terminals of each item of plant: • Minimum short circuit ratio of 1.5. • Minimum positive sequence X/R ratio of 2 (ratio of system	This recommendation was supported by ElectraNet in its submission, which it thought was justified given the current state of generation dispatch and number of proposals for non-synchronous generation in the state. In its submission, Vestas noted its opposition to a general requirement of SCR and X/R capability, noting that this capability is dependent on control system tuning, and	Susceptible items of plant (including, but not limited to, individual generating units and dynamic reactive power plant) within the connecting party's generating system must be capable of operating correctly down to the following levels at the HV terminals of each item of plant: • Minimum short circuit ratio of 1.5. • Minimum positive sequence X/R ratio of 2. The above criteria should apply in conjunction and no criterion can override another. Where an even lower tolerance exists (as may be required to satisfy recommendation 13), the actual plant tolerance is to be documented in this licence condition. Any departure from the proposed capability may be determined by ESCOSA based on demonstrated plant performance from dynamic electro-magnetic transient (EMT) power system analysis.

#	Report section	Focus area	Related NER Clause(s)	Summary of interim recommendations	Supporting notes (issues raised/justification of final recommendations)	Revised final recommendation to ESCOSA
				inductive to resistive impedance). The above criteria should apply in conjunction and no criterion can override another.	additional compensation equipment. The costs to consumers associated with incorporating increasing volumes of non-synchronous generation in SA will be minimised if generators are capable of operating down to low short circuit ratios. This will allow more generators to be located near one another without necessitating additional network augmentation or constraining generator output to manage weak system conditions. Until an alternative methodology can be proposed that provides an equitable and transparent signal at the connection point, the proposed capability at the HV terminals of susceptible plant within the connecting party's generating system appears the most practical way of minimising costs to future generators and, ultimately, customers.	
15	6.3.1	Active power control capability	S5.2.5.11	All new entrant generators should have the capability to provide an automatic active power response to a change in system frequency	Refer to justification in AEMO's March 2017 advice to ESCOSA.	The generating system shall have following capabilities: • It must be capable of automatically providing a proportional increase or decrease in active power output, in response to falling and rising power system frequency respectively. – 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 frequency leaves the deadband. – The steady state droop setting of this active power response must be adjustable in the range 2% to 10%. – The frequency deadband for this response must be adjustable in the range from 0 to +/- 1.0 Hz. (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 the dead-band limits).) • It must be capable of sustaining a response to abnormal frequency conditions for at least 10 minutes, subject only to inherent limits on energy resource availability. • Response to rising and falling frequency may be different, in both deadband and droop settings, and in the response shape or characteristics. Different levels of droop may be applied for different levels of frequency change.

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16	6.3.2	Active power control capability	S5.2.5.14	All new entrant generators should have the capability to be controlled by NEM Automatic Generation Control (AGC) signals on a 4-second basis	Refer to justification in AEMO's March 2017 advice to ESCOSA.	The generating system must have the following AGC capabilities: • It must have active power control capabilities that allow it to participate in existing NEM arrangements requiring Automatic Generation Control. This includes arrangements used for automatic dispatch of generation, and for frequency regulation. • At a minimum, the AGC based controls must have: – The ability to receive and respond to a remotely determined active power control setpoint, updated at a rate of every 4 seconds, transmitted to the generating system. (This is over and above the requirement of S5.2.5.14 of the NER, which only requires a scaling of active power setpoints.) – The capability to provide the following information to AEMO: o Actual active power output. o Maximum raise limit. o Minimum lower limit. o Maximum raise ramp rate. o Maximum lower ramp rate. Notes: Any request for this information would be made by AEMO under NER S5.2.6.1 or provided by a generator as a part of the dispatch process under NER 3.8.2.
17	6.3.3	Active power control capability	S5.2.5.14	All new entrant generators should have the capability to limit the rate of change of active power within the timescale of a dispatch period	Refer to justification in AEMO's March 2017 advice to ESCOSA. Advice updated to indicate use of central dispatch process to advise rate limits. Advice updated to clarify that down ramp limits are exempted for variable input energy. Wording of the requirements has been simplified from the original proposed text.	The generating system shall have the following capabilities to control the rate of change of active power: • It must be capable of limiting the rate of change of active power, both upwards and downwards. • It must be capable of implementing different active power rate limits for operation in the normal operating frequency band and for contingency events. (For example, different rate limits may be specified for responding to a remote active power setpoint change, or for responding to a special protection scheme trigger following a contingency event.) • It must be capable of setting a ramp rate limit with accuracy of within 10%. (That is, the variation in active power within the time period specified for the active power rate limit may not deviate by more than 10% from a straight line trajectory between the initial and final active power setpoints determined by the rate limit.) Notes: • Limits on active power ramp rates when responding to a change in energy market target or dispatch limit would be advised by AEMO using existing central dispatch processes described in NER clause 3.8.21. • NSPs may choose to specify additional ramp rate limits, beyond any energy market ramp limit set by AEMO through the central dispatch process. • A generator is not expected to comply with a limit on the rate of reduction in active power, where the reduction in active power is due to energy resource availability for intermittent generating systems beyond the generating systems reasonable control.
18	6.3.4	Active power control capability	S5.2.6 (b)	All plant is required to provide real time information about their active power control systems to AEMO in order to support its role as independent system operator.	Refer to justification in AEMO's March 2017 advice to ESCOSA. Amended requirements to reflect AEMO's revised policy on notification of active power controls for existing and new entrant generators AEMO has the ability to request this information under S5.2.6.1 of the NER, however there is not	The generating system must have the capability to provide real-time information about its active power control settings to AEMO. The mode of operation of the generating system's active power control system must be capable of being provided in real-time to AEMO via SCADA. This capability shall include the value of any key active power control system limits or settings which may change during real-time operation.

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					currently a requirement on Generator's to have the necessary SCADA signals. Accordingly AEMO has amended its recommendation to focus the revised licence condition on ensuring the generator has the appropriate capabilities. Use of this capability will determined by AEMO under its existing NER powers.	
19	6.3.5	Active power control capability	2.2.6(a)	New entrant generators should be required to register as ancillary service generating units for the provision of both regulation and contingency FCAS	This previously proposed requirement has been removed: • Following feedback from stakeholders including Tilt, Origin and Snowy Hydro. • Awaiting the outcomes of current trials for provision of FCAS from new entrant wind generation. These trials will clarify if the MASS in its current form can be applied to wind and solar farms. • Awaiting the outcomes of AEMO's Ancillary Services Technical Advisory Group (AS TAG) process.	This previously proposed requirement has been removed. No additional licence conditions are recommended.
20	7.3.1	Simulation models	n/a	Recommends that, as a part of the licence application process for new generators, ESCOSA emphasise to generators to the importance of providing suitable pre-validated models and data representing their generating system and all elements of associated protection systems to AEMO in accordance with principles set out on this report	Refer to justification in AEMO's March 2017 advice to ESCOSA. While no licence condition is recommended, AEMO encourages intending participants to note the potential need for more sophisticated power system models in order for NSPs and AEMO to assess the generators true performance in the SA power system.	No additional licence conditions are recommended.

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21	8.3.2	System restoration	n/a	To assist with system restoration following a potential black system event, AEMO recommends that ESCOSA require assessment of a set of capabilities that can be used during system restoration from new entrant generators	Refer to justification in AEMO's March 2017 advice to ESCOSA. AEMO has proposed amended requirements in this area following feedback from stakeholders, including Origin and Vestas that extended operation of plant on auxiliaries may result in damage to generating systems and other items of plant.	The applicant shall achieve and maintain for the term of its licence, a capability specified by ESCOSA in the following areas: 1. the generating system shall be capable of operation with auxiliary loads only while system load is being restored, for an agreed duration as specified by ESCOSA ; 2. the generating system – including each the generating units and other relevant items of plant (including, but not limited to dynamic reactive power plant) – must have the capability to provide steady-state and dynamic reactive power when operating with auxiliary loads only and while system load is being restored. _____ Notes: • To provide a useful contribution, generating systems should be able to supply at least 20% of their maximum steady-state reactive power capability and full dynamic reactive power capability when operating with the auxiliary load or under light load conditions. • The ability to operate with auxiliary loads while system load is being restored is only required where a sufficient minimum fault level is available from online synchronous machines. • Successful operation with auxiliary load or while system load is being restored and provision of static and dynamic reactive power capability must be demonstrated during the commissioning and compliance testing, and must be verified following any significant modifications to the generating system and its individual components. • Any EMT-type simulation models submitted to AEMO must account for operation with auxiliary loads. • AEMO is aware that this capability is not inherent in the basic design of many types of generating system. As such AEMO recommends that ESCOSA seek a minimum of thirty minutes and a maximum of three hours capability in regard of this clause, and only where it does not require the installation of significant additional auxiliary plant with the generating system (e.g. batteries).

A Energinet.DK, 2016,Technical regulation 3.2.5 for wind power plants above 11 kW, available at: https://www.energinet.dk/SiteCollectionDocuments/Engelske%20dokumenter/El/55986-10_v1_Grid%20Code%203%202%205_v%204%201-30%20%20September%202010.pdf.
B ERC, 2012. *Special Assessment Interconnection: Requirements for Variable Generation*, available at: http://www.nerc.com/files/2012_IVGTF_Task_1-3.pdf.
C ENSTO-E, 2012 *Network Code on Requirements For Grid Connection Applicable to All Generators Frequently Asked Questions,* available at: http://www.acer.europa.eu/Media/News/Documents/120626%20-%20NC%20RfG%20-%20Frequently%20Asked%20Questions%20(2).pdf.
D ENSTO-E, 2016 *Network Code on Requirements For Grid Connection Applicable to All Generators* available at:*http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R0631&from=EN.*
E Cigre WG 33.10,1998, *Temporary Overvoltages: Withstand Characteristics of Extra High Voltage Equipment*, Electra No.179 August, pp. 39-45.
F AEMO. *Black System South Australia – 28 September 2016*, March 2017. Available at: http://aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2017/Integrated-Final-Report-SA-Black-System-28-September-2016.pdf.
G Current version: AEMC, 2009, Application of Frequency Operating Standards During Periods of Supply Scarcity, available at: http://www.aemc.gov.au/getattachment/436495bb-89b9-4da6-b258-e24437df9b8a/Frequency-Operating-Standards-(Mainland).aspx.
H Refer to AEMC's website for further information: http://www.aemc.gov.au/Rule-Changes/Managing-power-system-fault-levels.

MEASURES AND ABBREVIATIONS

Units of measure

Abbreviation	Unit of measure
Hz	Hertz
kV	Kilovolt
kVA	Kilovolt-amp
ms	Millisecond
MW	Megawatt
s	Second

Abbreviations

Abbreviation	Expanded name
AC	Alternating current
AEMC	Australian Energy Market Commission
AGC	Automatic Generation Control
DC	Direct current
DER	Distributed Energy Resources
EMT	Electromagnetic transient
ENA	Energy Networks Association
ESCOSA	Essential Services Commission of South Australia
FCAS	Frequency control ancillary services
FFR	Fast frequency response
GPS	Generator performance standards
HVRT	High voltage ride-through
LV	Low voltage
LVRT	Low voltage ride-through
NEM	National Electricity Market
NER	National Electricity Rules
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
TNSP	Transmission Network Service Provider

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