9 September 2016

FROM THE OFFICE OF THE
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Mr Adam Wilson
Chief Executive Officer
Essential Services Commission of South Australia
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Dear Mr Wilson

Technical standards for grid connection of wind farms and inverter-connected generators

Please find attached AEMO's initial advice in relation to technical standards for grid connection of wind farms and inverter-connected generators in South Australia.

South Australia has the greatest proportion of inverter-connected generation relative to its demand of any region in the National Electricity Market (NEM). When combined with the risk of South Australia becoming synchronously separated from the rest of the NEM through interconnector contingency, it places increased reliance on the performance of wind generation for the maintenance of power system security.

Recognising the unique situation in South Australia, the preliminary advice is:

- AEMO has not identified a case to remove the exiting licence conditions at this time, although some amendments may be considered.
- There may be a value in including additional requirements relating to:
    - Frequency control,
    - Rate of change of frequency, and
    - System strength.
- There may also be a case for extending the licence conditions to other technologies such as photovoltaic, battery storage and synchronous generation.

As noted in my letter to you dated 5 August 2016, AEMO will provide a final report by 23 December 2016. That report will include the further findings from a number of investigations currently underway as part of the Future Power System Security program and, to the extent that time allows, feedback from stakeholders received by the Commission during the consultation process.

AEMO looks forward to working collaboratively with the Commission though your review process with the aim of achieving an efficient outcome in the long term interest of South Australian consumers.

Should you wish to discuss these matters further, please contact Frank Montiel, Group Manager Market Policy, Corporate Development on 07 3347 3025 or frank.montiel@aemo.com.au.

Yours sincerely

Karen Olesnicky
Acting Chief Executive Officer

Attachment: Technical Standards for Grid Connected Wind Farms and Inverter-connected generators in South Australia - Preliminary response to ESCOSA

TECHNICAL STANDARDS FOR GRID CONNECTED WIND FARMS AND INVERTER-CONNECTED GENERATORS IN SOUTH AUSTRALIA

PRELIMINARY RESPONSE TO ESCOSA

September 2016

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

IMPORTANT NOTICE

Purpose

AEMO has prepared this document to provide information about technical standards for grid connected wind farms and inverter-connected generators in South Australia, as at the date of publication.

Disclaimer

The information in this document may be subsequently updated or amended. Opinions expressed in this document represent the views of AEMO at the time of writing based on its current understanding of prevailing power system conditions. 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.

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CONTENTS

TABLES

1. INTRODUCTION

The report provides a high level preliminary view of the impact of South Australian wind licence conditions on the technical challenges of maintaining power system security in the future in South Australia (SA).

In preparing this report to the Essential Services Commission of South Australia (ESCOSA), AEMO has considered:

- The background of the existing wind licence conditions
- The changing generation mix in SA and how this impacts on power system security in SA
- The existing wind licence conditions and the implications of these on new generation connections
- Other challenges arising and options for managing these challenges in SA
- The potential to extend the scope of the licence conditions to other technologies and the impact of future market wide changes

AEMO will use this report as a basis for a more detailed report in December that will draw on both analysis AEMO is undertaking, and, to the extent that time allows, any feedback from stakeholders received by ESCOSA during the consultation process.

1.1 Background

The National Electricity Market (NEM) in Australia is operating in a rapidly transforming electricity landscape as centrally located, large synchronous generation is progressively being displaced by often variable, non-synchronous generation, which is increasingly distributed, and consumers become more engaged in optimising their energy purchase through exercising individual choice.

This trend is progressively changing the technical and operational characteristics of the power system. While change is taking place NEM-wide, some technical and operational challenges are emerging more acutely in SA at this early stage, due to the combination of its high quality wind and solar resources, its generation mix, and the risk of SA becoming synchronously separated from the remainder of the NEM through interconnector contingency.

From 2002, following a NEM-wide assessment of the potential challenges that could arise from the increasing investment in wind generation driven by the Renewable Energy Target (RET), it became evident that, due to the nature of its wind resource, SA was an attractive location for investment in wind generation. As a result, to mitigate some of the foreshadowed technical challenges identified by the earlier NEM-wide assessment, ESCOSA took pre-emptive action in 2005 to require that all new wind generation in SA comply with a specific set of technical performance standards,. Those performance standards were imposed through generation licence conditions within SA.

In the following years, a number of changes to the arrangements under the NEM were implemented which had the effect of better integrating wind generation into the NEM. In 2010 ESCOSA revised the wind licence conditions, removing some of the original conditions, to reflect these changes.

The Australian Energy Market Operator (AEMO) observes that SA is not alone in taking these precautions, with a number of markets throughout the world also applying specific technical requirements on wind and other non-synchronous generators connecting to their grids[1].

For example Hydro Quebec has had a requirement for wind farms to have the capability of providing synthetic inertia for a number of years. Other jurisdictions, such as Ontario are beginning to consider the requirement.

[1] ERCOT, EirGrid Ontario, Hydro Quebec, South Africa

A requirement to provide over-frequency droop response has been implemented by EirGrid in Ireland, ERCOT in Texas and in South Africa. This is similar in principle to Australia's mandatory requirement incorporated in AS4777 for small scale inverters. Such a service could be a more effective way to implement an emergency over-frequency response, potentially replacing (or complementing) an over-frequency generation shedding (OFGS) scheme.

These examples demonstrate that international jurisdictions are actively evolving the technical conditions they apply to wind generation as the generation mix and power system dynamics of those jurisdictions change. While these international developments are not necessarily indicative of the appropriate standards for Australia to adopt due to different power system characteristics, they support the periodic review of connection conditions to confirm their ongoing suitability for future conditions.

1.2 Wind licence conditions review

ESCOSA has indicated to AEMO that it will shortly commence a further review of the regulatory, licensing and associated arrangements for connection of grid-scale wind and other power electronic connected electricity generation plant in SA.

In undertaking this inquiry, ESCOSA has 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, and
- whether there is merit in additional or amended technical requirements being imposed on other power electronic connected generation technologies (for example solar).

In late 2015, AEMO commenced its NEM-wide Future Power System Security (FPSS) program to identify and address the challenges arising from the changing generation mix with non-synchronous generation replacing synchronous generation in the NEM. In order to draw on that continuing FPSS work as input to the advice requested by ESCOSA, AEMO intends to provide the advice in two stages:

- a preliminary response (this report) providing an initial view of the areas relevant to consideration of the matters ESCOSA is reviewing, and of potential directions the advice might take, drawing on the FPSS work carried out to date; and
- a final, more considered, response in December 2016, drawing on the results of a number of investigations currently underway as part of the broader FPSS program, and, to the extent time allows, any feedback received by ESCOSA during the consultation on its issues paper. .

As AEMO progresses its FPSS program there is potential for the development of NEM-wide technical requirements which could be implemented through the National Electricity Rules (NER) or associated procedures and guidelines. Where those outcomes intersect with local measures deployed within SA, ESCOSA, may consider it appropriate to revisit its position again, as was done in 2010 following changes at the national level.

1.3 South Australian generation mix

The generation mix in SA continues to evolve, with traditional thermal generation being progressively displaced by new non-synchronous generation, predominantly inverter-connected entering the market at both grid-scale and behind the meter.

The current status of generation in SA[2] is summarised in Table 1.

[2] The synchronous and registered non-synchronous generation capacity is from the 2016 Electricity statement of opportunities: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities. The non-synchronous distributed capacity is the rooftop and commercial PV installed capacity from the National Electricity Forecasting Report dynamic interface http://forecasting.aemo.com.au

Table 1 The current status of generation in South Australia (July 2016)

Status/Type	Synchronous (MW)	Non synchronous (MW)	Non synchronous (distributed) – predominately photovoltaic (PV) (MW)	Total (MW)
Existing	2,767	1,473	673	4912
Committed	-	225	-	225
Proposed	540	3,653	-	4,193
Withdrawn	1,025	-	-	1,025

A number of new power stations have connected in SA since the 2010 review of the wind licence conditions while others have withdrawn fully or partially as summarised in Table 2.

Table 2 Generation built since 2010

Generator	Fuel type	Size (MW)	Status
North Brown Hill Wind Farm[3]	Wind	132	Commissioned May 2011
The Bluff Wind Farm[3]	Wind	52.5	Commissioned May 2010
Snowtown Stage 2[4]	Wind	270	Commissioned November 2014
Port Stanvac	Diesel	65	Commissioned May 2011
Playford B	Coal	240	Retired May 2016
Northern	Coal	546	Retired May 2016
Pelican Point	Gas	478	Reduced to half capacity (239 MW) April 2015

Industry participants are required to regularly advise AEMO about the status of existing generating units and proposed generation projects currently under development in each region.

Proposed projects can be at different stages of development, and are categorised as follows:

- Committed projects, representing generation that is considered to be proceeding.
- Proposed projects, which are further identified as either:
  - Advanced proposals, representing generation at an intermediate stage of development, or
  - Publicly announced proposals, representing generation at an early stage of development.

The AEMO generation information page[5] reports information on the capacity of existing, withdrawn, committed, and proposed generation projects in the NEM as received from industry participants. This

[3] Licenced under the original (2005) wind licence conditions
[4] Licenced under the present (2010) wind licence conditions
[5] http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/~/link.aspx?_id=8AA86A5C53DA447CBB2B20EE791B2D66&_z=z

information was updated as part of the *2016 Electricity Statement of Opportunities*[6] (ESOO) and identifies a number of proposed and committed new generation projects in SA

SA has three committed wind farm projects:

- Hornsdale Stage 1 (102.4 MW) currently under commissioning.
- Hornsdale Stage 2 (102.4 MW).
- Waterloo expansion (19.8 MW), currently under construction.

Most of the proposed new generation investment in SA is wind generation, with 17 proposed projects, totalling 3,176 MW. The largest of these projects are:

- Hornsdale Stage 3 (109 MW)
- Ceres (up to 670 MW).
- Woakwine (400 MW).
- Palmer (309 MW).
- Kongorong (up to 240 MW).

In the Port Augusta area, several large solar proposals have also been announced including both photovoltaic (PV) and solar thermal technologies as well as hybrid wind/solar arrangements.

- Port Augusta Renewable Energy Park – combined wind and PV farm (175 MW solar and 200 MW wind, totalling 375 MW).
- Aurora Solar Energy – solar thermal plant with molten salt energy storage (110 MW).
- Port Augusta Solar – solar thermal plant with graphite block energy storage (100 MW).
- Bungala Solar Power –PV farm (100–300 MW).

The PV generators are connected through power electronic converters while the solar thermal generators are synchronous generators. Neither type would be covered by the existing ESCOSA wind licence conditions and would be subject to the connection negotiation process detailed in the NER.

Using data from the *2016 National Electricity Forecasting Report*[7] (NEFR) Table 3, shows that rooftop PV is forecast to continue to grow rapidly in SA. The growth in rooftop PV has led to a shift in the timing of the minimum demand in SA from overnight to midday. SA is forecast to have negative minimum demand by 2027 (with excess generation from rooftop PV to export).

Table 3 Effective capacity (after allowing for reduced efficiency of aged panels) – rooftop PV (MW)

	rooftop PV (MW)
2016–17	718
2020–21	1,024
2025–26	1,467
2030–31	1,787
2035–36	1,942

The above compilation of past and potential future changes to the generation mix in SA highlights the speed at which the technical characteristics of the power system will change with non-synchronous, inverter-connected plant displacing synchronous plant. In this context, AEMO strongly supports

[6] http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities
[7] http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/~/-/media/080A47DA86C04BE0AF93812A548F722E.ashxesoo

ESCOSA's initiative to keep its connection conditions under close review, and welcomes the opportunity to link that work with the NEM-wide FPSS program.

2. EXISTING WIND LICENCE CONDITIONS

2.1 Existing wind licence conditions

In applying the existing SA wind licence conditions, ESCOSA recognised that SA was unique in the NEM with very high current penetration of wind generation and prospective future penetrations of wind and large scale PV generation. SA also has only a single AC interconnector connecting it to the NEM, and therefore under certain rare circumstances, it may become synchronously isolated from the remainder of the NEM.

As identified in the previous chapter, a number of synchronous generators have retired or changed dispatch patterns leading to reductions in the dispatch of synchronous generation and an increasing reliance in SA on generation from wind farms, embedded rooftop PV and flows on the interconnectors from Victoria.

Since the introduction of the existing wind licence conditions a number of new wind farms have been connected or are in the process of being connecting to the SA power system, indicating that the existing wind licence conditions are not acting to impede new generation locating in the region, however it is appropriate to review the outcomes of the conditions to ensure that they do deliver efficient investment.

AEMO has also seen increasing evidence of new generation being installed in other regions that are offering performance standards that would meet the existing ESCOSA wind licence conditions even though the SA conditions do not apply there. This indicates that the technology now available across the marketplace has matured to the point where the more onerous conditions applying in SA do not represent the degree of incremental cost above NEM-wide conditions as might previously have been the case.

2.2 Technical standards

In its 2010 review of the wind licence conditions ESCOSA concluded that that it was necessary and prudent to continue to apply a measured and cautious approach to wind generation licensing in SA in order to meet the long term interests of SA consumers with respect to the quality and reliability of electricity supply and such determined the continuing need for special technical standards to be imposed on future wind generators.

AEMO is not aware of a case having been made since that time to support withdrawal of the existing wind licence conditions at this time. However, there may be a case for modifying or broadening the wind licence conditions as follows:

- The current scope of licence conditions is restricted to wind generation, but given the potential for new generation in SA to be based on any of a wider range of technologies, it may be appropriate to be broadened to cover other technologies beyond wind.
- AEMO is aware of the views of some stakeholders that there is a need to make some adjustments to the existing wind licence conditions based on the learnings to date. In preparing subsequent advice, AEMO will consider evidence received through stakeholder submissions to the ESCOSA consultation process on the case for any adjustments, including costs and benefits.

2.2.1 Fault ride-through capability

The existing wind licence conditions require that:

1. Each generating unit 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.
2. The licensee is not required to comply with clause 1(b) in respect of a generating unit which the Licensee is authorized 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.
3. The licensee is not required to comply with clause 1(c) in respect of a generating unit which the licensee is authorized 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.

Following the clearance of a fault on the power system Clause S5.2.5.5 of the NER requires generators to recover their active power injection. While synchronous generators can achieve this very quickly, wind farms take between 100 milliseconds to more than 1 second to fully recover their active power injection. The wind licence conditions require wind farms in SA to meet the automatic access standard and, subject to wind availability, must recover to 95% of their active power output prior to the fault within 100 milliseconds. Recovery over a longer period, as would be allowed under a negotiated standard would prolong the supply demand mismatch and hinder the recovery of the power system.

The potential loss of large amounts of generation subsequent to a fault event introduces a range of risks including voltage instability, transient instability and loss of frequency control. These phenomena are inter-related and it is important for secure network operation to maintain stability in relation to each of these risks.

The wind licence conditions impose different fault ride through requirements for three phase faults on transmission and distribution systems. AEMO considers that the conditions allow sufficient flexibility, requiring generating systems to ride through three phase transmission faults for primary clearance time, which is in most instances (i.e. above 132 kV) is around 120 milliseconds, whereas a longer clearance time applies for three phase distribution faults (where a clearing time of up to 430 milliseconds applies). This is critical as distribution lines are not constructed to the same standards as transmission, they rarely have an overhead earth wire and have lower insulation distance (i.e. greater risk of flashover) and consequently the risk of a three phase fault occurring is higher in these systems compared with transmission systems.

Compounding this issue is that at the distribution level, generating systems are more likely to have an impact on other network users being connected more closely to load. Unstable operation of such

systems can have a detrimental impact in terms of quality of supply to these users and/or additional maintenance costs for SA Power Networks via increased tap changer operation.

2.2.2 Reactive power capacity

The existing wind licence conditions require that:

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.
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% of the reactive power required to meet the power factor referred to in clause 1 on a dynamically variable basis; and
   (b) the balance of the reactive power required to meet the power factor referred to in clause 1 on a non-dynamic basis.
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.
4. For the purposes of clause 2(a):
   (a) dynamically variable means continuous modulation of the reactive power output over its range, with an initial response time or dead time < 200 milliseconds and a rise time (as defined in Clause S5.2.5.13 of the NER) < 1 second following a voltage disturbance on the network; and
   (b) for a period of ≤ 2 seconds on any single occasion, a short-term overload capability may be used to meet the 50% requirement, provided that use of that short-term overload does not cause a breach of any other licence condition.
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.
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.
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.

Dynamic reactive support is important in assisting with ensuring voltage recovery and maintaining voltage stability subsequent to a network fault. At a local level, enhanced voltage recovery assists in active power recovery. On a broader system level sufficient voltage and active power recovery supports short and longer term voltage stability, facilitating a more resilient system.

Power transfer limits are improved by these wind licence conditions. Voltage stability limits are one of a number of SA network limits setting import capability from Victoria on the Heywood interconnector,

based on voltage collapse between the Victorian border and Adelaide for trip of a 275 kV line, or trip of the largest single MW infeed in SA.

Reactive support is also be provided at the transmission level by ElectraNet.

There may be a need to consider if the current framework is sufficiently flexible to allow (or drive) an efficient split between reactive support on the transmission system by ElectraNet, and reactive support at multiple connection points by new generators. It may be appropriate to modify the conditions to introduce a level of negotiation into the ESCOSA conditions would have potential to avoid inefficiencies, while not compromising locational signals to site where the overall costs are minimised.

2.3 Other matters

The wind licence conditions contain a number of requirements to improve the way wind generation in SA supports efficient dispatch and maintenance of power system security within the NEM:

- Optimised Dispatch - Wind generators must not apply to have the generating plant classified as non-scheduled under the NER.
- Wind Forecasting – Under the NER all semi-scheduled wind generators are required to provide data for wind forecasting, the wind licence conditions extend this to all wind generation in SA.
- Cost Allocation of Ancillary Services - To ensure that the performance of wind generators in considered in the allocation of the costs of ancillary services, all wind generators in SA must be registered as market generators.
- Small Wind Generators - The need or otherwise for wind generators of 5 – 30 MW nameplate rating to be classified as semi-scheduled is assessed on a case by case basis.

ESCOSA has not specifically requested AEMO to comment on these other requirements. However, the growth in smaller generating systems and energy storage systems and the potential for these to be aggregated into larger operating blocks has highlighted the need for AEMO 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 Energy Networks Association (ENA) to explore the potential role of distribution system operators in providing this visibility.

Also related to the need for visibility of smaller generating plant, in December 2015 ENGIE submitted a rule change request to the AEMC that considers some of the issues around smaller generators and seeks to expand the range of generators that would be taken in to account or come under the control of AEMO's central dispatch process.

2.4 Conclusion

The reduced amount of synchronous generation in SA since the last review of the wind licence conditions has increased the reliance of the power system on the growing amount of wind generation in the State. AEMO is not currently aware of evidence that the incremental costs imposed by the existing wind licence conditions are acting as an impediment to wind developers wishing to access the superior wind resources in the State, as developers continue to be active in SA and are prepared to meet the specifications required by ESCOSA to access the local wind resources. A number of connection applications for inverter connected generation in other NEM regions would also meet the ESCOSA wind licence conditions which may indicate that compliance with these conditions is not necessarily a barrier to that technology connecting in SA however it is appropriate to review the outcomes of the conditions to ensure that they do deliver efficient investment while providing for a secure operation of the power system.

For these reasons, AEMO's preliminary assessment is that there is no evident case for removing the existing wind licence conditions at this time. However, as discussed in the next section, there may be a case for expanding the scope and application of the wind licence conditions to cover a number of future challenges identified in AEMO's FPSS program.

3. FUTURE POWER SYSTEM SECURITY PROGRAM

3.1 Overview

AEMO is responsible for maintaining the NEM power system in a secure operating state vital for power system operations and security of the NEM.

The electricity landscape is rapidly transforming as synchronous generation is progressively being displaced by non-synchronous generation, which is changing the operational characteristics of the power system. Consumers are also becoming more active in meeting and managing their electricity demand, resulting in increasing amounts of distributed energy resources, such as PV, generating to the power system.

Against this backdrop, AEMO established the FPSS[8] program to formalise and accelerate the work it has undertaken in the last few years to address operational challenges arising from the changing generation mix. If left unaddressed, these challenges will test the efficiency and adequacy of current operational and market processes.

The FPSS program takes a strategic approach to studying future power system security requirements, and will evolve to accommodate new challenges and changing context as new products and services enter the market.

The program applies three core phases to each technical challenge, which will be conducted in parallel:

- Identification and definition of the challenges
- Specifying the potential technical solutions
- Implementation of the solutions.

AEMO enlisted the expertise of a technical advisory group, with representatives from all industry sectors, regulatory and government agencies, and consumers, to inform its analysis to identify and define the challenges. Four areas have been identified as the most immediate priorities:

- Frequency control.
- Management of extreme power system conditions.
- Visibility of the power system (information, data, and models).
- System strength.

AEMO is now working to better understand the details of the challenges identified including an understanding of where and when the challenges may arise. Regions that can become separated from the remainder of the NEM, such as SA, will be the first to experience these challenges.

AEMO is also considering the range of technical solutions that are available or are likely to become available in the near future to address the challenges.

AEMO will be working in collaboration with the Australian Energy Market Commission (AEMC) to determine the most efficient regulatory framework to deliver the technical solutions to the challenges identified.

This may include a mix of:

- Real time markets, such as changes to the existing frequency control ancillary services (FCAS) markets,
- Contract markets similar to the existing system restart ancillary service (SRAS) or network support ancillary service (NSCAS) markets,

[8] http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/FPSSP-Reports-and-Analysis

- Additional system standards and appropriate obligations for their enforcement, and
- Revisions to technical standards.

The FPSS work has highlighted that the impact of the changing power system is not coming from any one particular technology, but is being driven by the broader change from synchronous to non-synchronous generation. In general, most non-synchronous generators are connected through power electronic converters.

The work to implement the long term NEM-wide solutions may take some time and, given SA's unique position with respect to its generation mix and its risk of becoming separated from the rest of the NEM, there may be value in implementing some short term solutions through extensions to the ESCOSA wind licence conditions. If this was to take place, there would be opportunities to harmonise these conditions with wider solutions if and when they are incorporated into the national regulatory framework.

Such a process would be similar to that followed for the original 2005 wind licence conditions that included requirements that ESCOSA believed were adequately covered in changes to the NER by the time of the revised 2010 wind licence conditions and as a consequence were withdrawn as specific local requirements.

The following sections provide AEMO's present thinking on the high priority challenges identified with specific implications for the SA power system.

3.2 Frequency control

Under normal operating conditions frequency control ancillary services (FCAS) can be sourced from anywhere in the mainland NEM regions. However, AEMO must sometimes source SA FCAS requirements locally. This is necessary when SA has separated from the remainder of the NEM or there is a credible risk of separation. Currently SA has a small number of generators registered to provide FCAS, and, like the rest of the NEM, to date they have been exclusively synchronous generators.

AEMO is investigating if there are any technical reasons why this might be the.

While this work is ongoing, AEMO understands that it is technically possible for wind generation to provide active power control and we are aware of this capability being a mandatory requirement in other jurisdictions such as the PJM market in the USA.

Inertia is a further power system property, that must be provided from within SA when SA is at credible risk of separation from the remainder of the NEM, to limit the rate of change of frequency (RoCoF) following the occurrence of a contingency separation event that results in supply / demand imbalance. As part of the FPSS program, AEMO is investigating the extent to which power electronic connected technologies can provide an inertia-like response or a faster frequency response and how this may reduce the need for synchronous inertia.

AEMO has commissioned a range of advice on frequency control from international experts, and is still in the process of finalising that work, so present thinking is preliminary. However, there is potential for this work to indicate that there is merit in the introduction of some additional requirements in SA, including the following:

- Mandatory provision of capability to provide FCAS – both responding to regulation signals and responding to local frequency measurements
- Making participation in the FCAS markets compulsory.
- Mandatory capability to provide a fast frequency response (e.g. faster than 1 second response time) or an inertia-like response

3.3 Management of extreme power system conditions

AEMO has reviewed the periods of exposure of the SA system to high RoCoF if a non-credible[9] separation event (simultaneous trip of both circuits of the Heywood Interconnector) occurred. This has been affected by the recent withdrawal of synchronous generation in SA, which reduces the inertia in the region and the upgrade to the Heywood Interconnector which has increased the potential size of the contingency. AEMO's assessment indicated that, following a non-credible separation event:

- The likelihood of the power system operating in a mode that is susceptible to high RoCoF following a rare separation event has increased. Existing emergency frequency control schemes (such as under-frequency load shedding (UFLS)) are increasingly unlikely to prevent a black system[10] across SA.
- There is presently no emergency scheme (such as an OFGS scheme) to co-ordinate the shedding of generation in response to high frequencies in the region.

The NEM does not have system standard for RoCoF in Clause S5.1 of the NER obliging AEMO or NSPs to maintain RoCoF within defined bounds, however there are connection standards applying to new generators, including Clause S5.2.5.3 of the NER (Generating unit response to frequency disturbances) which requires generators to ride through a defined frequency disturbance unless, for the automatic standard, the RoCoF is outside the range of –4 Hz to 4 Hz per second for more than 0.25 seconds or for the minimum standard, -1 Hz to 1 Hz per second for more than one second. The difference in the time frames means that in some cases the minimum standard may in fact be more onerous than the automatic standard.

These observations indicate there is merit in investigating the costs, benefits and risks of recommending a further range of additional licence conditions such as:

- A requirement for new generation to be capable of meeting both the minimum and the automatic standards of Clause S5.2.5.3 of the NER with respect to RoCoF.
- an ability for new generation to quickly ramp down on over-frequency and participate in over-frequency generation schemes.

AEMO is not aware of any evidence that new generation would require significant additional equipment to meet such technical requirements, but these would substantially improve the ability to sustain power system conditions that are potentially becoming more likely.

3.4 System strength

Power electronic connected generation technologies such as wind turbines and PV systems require a certain minimum fault level or the corresponding minimum SCR for stable and satisfactory operation. The required fault level is generally provided by nearby on-line synchronous machines. The only practical method at present to maintain minimum fault levels is to ensure a minimum quantity of synchronous machines are online.

A reduction in system strength has been observed in particular parts of SA as the generation mix has changed. System strength is a local issue and is expected to decline as synchronous generation in a region is displaced in dispatch by non-synchronous generation, partially due to the lower fault contribution of inverter-connected plant compared to synchronous plant.

A new power electronic connected generating system connecting to a weak area of the network will reduce the system strength seen by other generators connected in the vicinity. This is because each power electronic connected generating system will get a portion of the overall available fault level in the area rather than the entire fault level. This issue is exacerbated by the fact that locations attracting

[9] Non-credible contingency events are defined in the National Electricity Rules, and broadly refer to events that are very rare and unexpected, such as the loss of multiple generating systems/units or multiple lines.

[10] A black system is defined in the National Electricity Rules as the absence of *voltage* on all or a significant part of the *transmission system* or within a *region* during a *major supply disruption* affecting a significant number of customers

multiple non-synchronous generation installations are often also in remote and isolated parts of the network, meaning that the available fault level is already low to begin with. Examples of such parts of the network include parts of SA.

Reduced system strength can have a number of effects on the local power system:

- Power electronic converter interfaced devices require a minimum fault level to operate stably and reliably. Reduced system strength could impact their ability to ride through faults on the system and meet their agreed generator performance standards.
- Voltage control in response to small and large system disturbances is also affected by system strength, with weaker systems more susceptible to voltage instability or collapse.
- Compromise the effectiveness of network and generating systems' protection functions, such as over-current and distance protection relays that detect and clear equipment faults, and the ability of non-synchronous generation to operate as designed.
- Result in greater difficulty in maintaining stable voltages in some parts of the network, particularly during disturbances.

While the automatic access standards are generally considered the highest performance expected from a given generating system, when operating under low system strength conditions, a negotiated access standard with firm guidelines on the negotiation framework may be a more appropriate condition.

These observations indicate there is merit in considering potential additional licence conditions such as a requirement that:

- new power electronic connected generating systems be capable of operating at the low levels of system strength likely to be seen as the network evolves and local synchronous generating units withdraw and are replaced by non-synchronous generating systems, and
- any new power electronic connected generating systems connecting to a weak area of the network do not reduce the system strength seen by other generators connected in the vicinity to an unacceptable level that would impact on the ability of those generators to continue to meet their generator performance standards.

4. SCOPE OF WIND LICENCE CONDITIONS

As the independent power system operator for the NEM, AEMO seeks to maintain a NEM wide, technology neutral approach to the generator performance standards to be negotiated as part of the connection process.

4.1 Technological

A number of other new technologies such as large scale PV and battery storage are power electronic connected and may exhibit similar responses to wind farms covered by the existing wind licence conditions.

The potential growth in the installation of these other technologies could impact on the performance of the power system, particularly in SA.

Some of the solutions to the challenges may be impacted by the performance of new synchronous generators due to the limited negotiation guidelines for Clause S5.2 of the NER making it challenging for AEMO and NSPs to negotiate performance standards higher than those proposed by the developer. For example AEMO is aware of synchronous generation plant connected and proposed for connection in SA that has limited reactive capability and fault ride-through performance.

Consequently there may be a case to broaden the wind licence conditions to include other power electronic connected generators and even synchronous generators.

4.2 Locational

In the case of the existing ESCOSA wind licence conditions, the requirements apply to all new wind generation in SA, potentially distorting the playing field between SA and other regions of the NEM, However, as discussed above there is extensive evidence of new wind generation wishing to locate in SA.

The preliminary results of AEMO's FPSS program are suggesting there may be a need to make changes to overall NEM frameworks to accommodate the changing generation mix. However, AEMO recognises that SA is unique with:

- the highest concentration of wind generation in the NEM,
- very high penetration of rooftop PV,
- a single AC interconnector that means that, on rare occasions, SA may be synchronously isolated from the remainder of the NEM, and
- changing generation patterns that are showing reductions in the dispatch of synchronous generation.

The initial wind generation licence conditions in 2005 pre-empted a series of rule changes to better integrate wind generation into the NEM. Some of the early licence conditions were removed once the NER was amended to introduce semi-scheduled generation and amend technical standards to better recognise wind generation and implement wind forecasting through the AWEFS system.

In the same way, in order to maintain power system security in SA, until such time as AEMO progresses its FPSS program to a point where its findings are incorporated in the National Electricity Rules AEMO's preliminary view is there is not a clear case for removing the specific SA wind licence conditions and there may be a need to add additional requirements.

5. NEXT STEPS

5.1 Summary

At present AEMO does not have evidence to indicate a clear case to remove the existing wind licence technical conditions.

Following consideration of the performance of new generation and its impact on the power system, AEMO will undertake further analysis of the present and potential future generation mix in SA and determine if it is appropriate for ESCOSA to impose further conditions on new connecting wind or other technology generators in SA.

The analysis may show a need to expand the scope of the licence conditions to further power electronic connected technologies such as large solar and battery storage and potentially to apply some conditions on new synchronous generation.

AEMO is suggesting stakeholders provide feedback to ESCOSA on the ability of new generation to perform within the expected power system conditions in SA. AEMO also is progressing with our work on the FPSS program and consider the ESCOSA request to review the existing wind licence conditions as part of that work.

The results of all of this work will allow AEMO to present ESCOSA with more detailed findings to inform the review of the wind licence conditions.

5.2 Final report

AEMO will provide ESCOSA with a more detailed report expected in December incorporating further learnings from our FPSS work and, to the extent time allows, any feedback ESCOSA receives from stakeholders on its issues paper.

This report will include results of further analysis on the impacts of the existing wind licence conditions on the security if the SA power system and on the ability for new generators to successfully connect to the power system.