AEMC

REVIEW

Australian Energy Market Commission

CONSULTATION PAPER

System Security Market Frameworks Review

8 September 2016

Inquiries

Australian Energy Market Commission
PO Box A2449
Sydney South NSW 1235

E: aemc@aemc.gov.au
T: (02) 8296 7800
F: (02) 8296 7899

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About the AEMC

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

Executive summary

The electricity industry in Australia is undergoing a fundamental transformation. The last decade has seen a rapid rise in the penetration of new generation technologies, such as wind farms and rooftop solar. In the past, these technologies accounted for only a small fraction of total electricity supply. Now they are a critical part of our power system, and their significance is continuing to grow.

As these technologies make up an increasing proportion of Australia's electricity needs, new approaches to maintaining power system security will be required. To support the continuing transformation of the National Electricity Market (NEM) the Australian Energy Market Commission (AEMC or Commission) has initiated a review into the regulatory frameworks that affect system security in the NEM. This review will also encompass and progress three recent rule change requests that relate to system security.

System security issues

The Australian Energy Market Operator (AEMO) is responsible for maintaining power system security. Power system security refers to AEMO scheduling and operating the power system in a secure and safe operating state, and returning the system to such a state following supply disruptions. System security deals with the technical parameters of the power system such as voltage, frequency, the rate at which these might change and the ability of the system to withstand faults.

In order to maintain the electricity system in a secure operating state, a number of physical parameters must be controlled. Rapid changes in frequency or large deviations from normal operating frequency can lead to instability in the system. In addition, low system strength where large fluctuations in voltage occur may mean that the power system would need to be managed differently and generators may have challenges remaining connected to the system at certain times.

Large spinning conventional generators, such as coal, gas and hydro, resist large rapid changes in frequency and increase system strength. These generators are synchronised to the frequency of the system and support the stability of the system by working together to maintain a consistent operating frequency and maintain the strength of the system in localised networks. Currently, less conventional forms of electricity generators connected to the national electricity system, such as wind and rooftop solar, are not synchronised to the grid and are, therefore, limited in their ability to dampen rapid changes in frequency.

Historically, most generation in the NEM has been synchronous and, as such, the system security services provided by these generators have not been separately valued. As the generation mix shifts to more non-synchronous generation, these services are not provided as a matter of course giving rise to increasing challenges in maintaining the power system in a secure state. Some non-synchronous generators may have capabilities to respond rapidly to sudden changes in electricity supply or consumption.

Currently however, these services are not actively employed in maintaining power system security.

The shift to less conventional forms of generation has been more pronounced in some regions of the NEM than others. South Australia, in particular, has experienced a substantially faster change than other regions as an increasing volume of renewable energy is integrated. When fully available, the interconnector with Victoria allows system security to be maintained. Where there is an unexpected outage of this interconnector at high loading, the risks to system security increase significantly. As the generation mix changes in a similar way across the NEM these risks may become more widespread.

Project framework

The System Security Market Frameworks Review will draw upon the work being undertaken by AEMO as part of its Future Power System Security (FPSS) Program, initiated in December 2015. AEMO has undertaken substantial work on identifying and prioritising current and potential future technical issues to maintaining system security. AEMO has also identified an initial range of technical solutions to these issues and is undertaking further significant analysis to determine the capability of these solutions to meet the requirements of the power system.

The AEMC's Review will identify the changes to market and regulatory frameworks that will be required to deliver the technical solutions identified by AEMO. These changes may include, but are not necessarily limited to, different mechanisms to competitively procure the required system security services, possible changes to standards or the establishment of new standards, or changes to the roles and responsibilities of market participants.

Three rule change requests have recently been received which will be progressed concurrently and in coordination with the System Security Market Frameworks Review. The South Australian Minister for Mineral Resources and Energy and AGL have both submitted rule change requests proposing the introduction of new mechanisms to procure additional system security services to support power system frequency. The South Australian Minister for Mineral Resources and Energy has also submitted a rule change request to address the reductions in system strength.

The AEMC will consider the rule change requests as well as undertake the Review. The output of the Review will be a report to the COAG Energy Council highlighting rule changes and technical changes made in response to the rule change requests received, and recommendations for further action where required, including possible changes to policy or legislative frameworks or recommendations in relation to potential future rule change requests.

This consultation paper is the first stage of stakeholder consultation on both the Review and the three related rule change requests. A separate consultation paper has been published to assist stakeholder consultation on rule change requests also received from the South Australian Minister for Mineral Resources and Energy which relate to emergency frequency control schemes.

Contents

1 Introduction

On 14 July 2016, the Australian Energy Market Commission (AEMC or Commission) initiated a review into the regulatory frameworks that affect power system security in the National Electricity Market (NEM).[1]

The AEMC has also recently received five rule change requests relating to a number of similar and related power system security issues.[2] These rule changes will be progressed concurrently and in coordination with the AEMC's Review.

On 8 September 2016, the Commission published a notice under section 95 of the National Electricity Law (NEL) setting out its decision to commence the rule change process in relation to these rule change requests.

1.1 Outline of this paper

This consultation paper has been prepared to facilitate public consultation on the AEMC's System Security Market Frameworks Review and the related rule change requests.

This paper:

- sets out the AEMC's proposed approach to the System Security Market Frameworks Review and describes the current and potential future issues related to power system security in the NEM;
- sets out a summary of, and a background to, the rule change request submitted by AGL and two of the four rule change requests submitted by the South Australian Minister for Mineral Resources and Energy;
- identifies a number of questions and issues to assist the AEMC in its approach to the Review and to facilitate the consultation on the rule change requests; and
- outlines the process for making submissions.

Stakeholders are encouraged to comment on these or any other aspects of the paper.

1.2 Concepts and background to the review and rule change requests

The electricity industry in Australia is undergoing fundamental change as the proportion of less conventional forms of electricity generation, such as wind and rooftop solar, increases. A large share of this new generation resides within distribution networks and is not centrally controlled by the market operator.

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1 The review was initiated by the AEMC under section 45 of the NEL. Regulatory frameworks refer to the National Electricity Rules and the National Electricity Law.

2 Information on these rule change requests can be found on the AEMC website - http://www.aemc.gov.au/Rule-Changes.

New approaches to maintaining power system security are needed because of the physics of maintaining technical generation parameters like voltage and grid frequency.

AEMO is responsible for maintaining the power system in a secure operating state. Power system security is defined in the rules as the safe scheduling, operation and control of the power system in accordance with the power system security principles.[3] These principles include maintaining the power system in a secure operating state and returning the power system to a secure operating state following a contingency event or a significant change in power system conditions, including a major supply disruption. Power system security is interrelated with the technical parameters of the power system such as voltage, frequency, the rate at which these might change and the ability of the system to withstand faults.

System frequency

In order for AEMO to maintain the electricity system in a secure operating state, the frequency of the system must be maintained within a defined range. Rapid changes in frequency or large deviations from normal operating frequency can lead to instability in the system and the potential disconnection of generation or load.

The ability of the power system to resist large changes in frequency arising from the loss of a generator, transmission line or large industrial load is initially determined by the inertia of the power system. Inertia is naturally provided by large spinning conventional generators that are synchronised to the frequency of the system.

Conventional electricity generation, like hydro, coal and gas, operate with large spinning turbines and alternators that are synchronised to the frequency of the grid. These generators have significant physical inertia and support the stability of the power system by working together to maintain a constant operating frequency.

Currently, less conventional forms of electricity generators connected to the national electricity system, such as wind and rooftop solar, are not synchronised to the grid, have low or no physical inertia, and are, therefore, currently limited in their ability to dampen rapid changes in frequency or respond to sudden large changes in electricity supply or consumption.

Historically, most generation in the NEM has been synchronous and, as such, the inertia provided by these generators has not been separately valued. As the generation mix shifts to smaller and more non-synchronous generation however, inertia is not provided as a matter of course giving rise to increasing challenges for AEMO in maintaining the power system in a secure operating state.

The shift to less conventional forms of generation has been more pronounced in some regions of the NEM than others. South Australia, in particular, has experienced a substantially faster change than other regions as an increasing volume of renewable energy is integrated. Flows on the interconnector with Victoria allow power system

3 Chapter 10 of the NER.

security to be maintained because of inertia provided by generators in other parts of the NEM. Where there is an outage of this interconnector, the risks to system security in South Australia increase significantly because it must rely on inertia provided by generators within the region. If there is minimal generation capacity with the ability to provide inertia in that region, the frequency could be subject to very rapid changes. As the generation mix changes in a similar way across the NEM these risks may become more widespread.

System strength

A secure operating system also requires generating units and network components to be able to operate continuously following a major fault or disturbance to the power system.

System strength is an inherent characteristic of a power system and it relates to the size of the change in voltage for a change to the load (or generation) at a connection point. When the system strength is high at a connection point the voltage changes very little for a change in the loading, however, when the system strength is lower the voltage would vary more with the same change in load.

Recently, the system strength has been reducing in some parts of the NEM power system as a number of synchronous generating units exit the market and are replaced by new generating units, which are non-synchronous, and do not contribute as much to system strength.

Reduced system strength in certain areas of the network may mean that generators are no longer able to meet technical standards and may be unable to remain connected to the power system at certain times. Challenges in maintaining voltage stability and network protection issues may have yet further impacts.

1.3 Purpose of this review

The AEMC's System Security Market Frameworks Review will consider changes to wholesale energy market frameworks to complement increasing volumes of renewable energy and reduced volumes of synchronous generation. The Review will address power system security issues identified above to assist AEMO in maintaining power system security as the industry transforms.

The Review will address the need for possible changes to market arrangements that could lead to more efficient outcomes for energy consumers while delivering a secure operating system.

The impact of renewable energy on power system security was highlighted in the AEMC's Strategic Priorities for Market Development as an important focus in the coming years and this review has been initiated by the Commission to continue its work in this area.

The System Security Market Frameworks Review will draw upon the work undertaken to date by the Australian Energy Market Operator (AEMO) as part of its Future Power System Security (FPSS) Program, initiated in December 2015. AEMO has undertaken substantial work on identifying and prioritising current and potential future technical challenges to maintaining power system security. AEMO has also identified an initial range of technical solutions to the challenges and is undertaking further analysis to determine the capability of these solutions to meet the requirements of the power system.

The AEMC's Review will identify the changes to market and regulatory frameworks that will be required to deliver the technical solutions currently being identified by AEMO. These changes may include, but are not necessarily limited to, different mechanisms to competitively procure the required system security services, possible changes to standards or the establishment of new standards, or changes to the roles and responsibilities of market participants.

AEMO has significant work packages to identify the full nature of future power system limitations as well as the technical capability of new technologies to address these needs. AEMO will provide technical input to the System Security Market Frameworks Review to assist with the AEMC's development of any recommendations to change market and regulatory frameworks. During the course of the review, each market agency will contribute expertise, within the scope of their respective roles, to address the technical, regulatory and market framework challenges that are related to maintaining power system security in an evolving NEM. The AEMC and AEMO have released the text of an agreement setting out a collaborative framework for the work of the two agencies in relation to system security in the NEM.[4]

The AEMC's Review will provide recommendations to the COAG Energy Council with an interim report being provided to the Energy Council by the end of 2016.

1.4 Terms of reference and scope

On 14 July 2016, the AEMC published a terms of reference for this self-initiated review. The terms of reference builds on the work undertaken to date by AEMO as part of their FPSS Program.

For any proposed solutions, the terms of reference require the AEMC to:

- identify the reasons for the proposed change and likely impacts on the power system, the NEM and consumers; and
- describe pathways to implementation, including timing, possible interim stages and any necessary changes to the National Electricity Law or National Electricity Rules.

4 AEMC-AEMO scope of work, http://www.aemc.gov.au/Markets-Reviews-Advice/System-Security-Market-Frameworks-Review

The AEMC will consider the rule change requests as well as undertake the Review. The output of the Review will be a report to the COAG Energy Council highlighting rule changes and technical changes made in response to the rule change requests received, and recommendations for further action where required, including possible changes to policy or legislative frameworks or recommendations in relation to potential future rule change requests.

The scope of the Review is confined to power system security. Power system security refers to AEMO maintaining the power system in a secure and safe operating state, and returning it to such a state following a contingency event, including a major supply disruption.

System security is distinct from the reliability of supply which has a consumer focus and describes the likelihood of supplying all consumer needs with the existing generation capacity and network capability.

1.5 The rule change requests

Overview of the rule change requests

The AEMC has received five separate rule change requests from market participants which relate to system security issues in the NEM.[5] These rule change requests are summarised as follows with further detail provided in section 2.4.

1. **Inertia ancillary service market – AGL**

   AGL considers that less synchronous generation in the NEM is leading to a lack of system inertia. This is increasing the susceptibility of the system to rapid changes in frequency and reducing system stability.

   AGL has proposed that a new ancillary service market be established to enable AEMO to procure inertia on a competitive basis when it is needed.

2. **Managing the rate of change of power system frequency – SA Minister for Mineral resources and Energy – SA 'A'**

   Similar to AGL's rule change request, this rule change request also raises as an issue the reduction in system inertia arising from less synchronous generation, leading to high rates of change of frequency and reduced system stability.

   The rule change request proposes that AEMO should be provided with powers to procure the necessary services to maintain power system security. The exact form of these services is not specified.

5 Information on these rule change requests can be found on the AEMC website - http://www.aemc.gov.au/Rule-Changes.

3. **Emergency under-frequency control schemes – SA Minister for Mineral Resources and Energy – SA 'B'**

   This rule change request suggests that less synchronous generation may result in changes in frequency that are too fast for existing emergency frequency control schemes to operate effectively. An increase in distributed energy resources may mean that existing schemes are less effective in shedding load to control frequency.

   The rule change request proposes the development of a regulatory framework to adapt existing emergency under-frequency control schemes to address changed power system conditions.

4. **Emergency over-frequency control schemes – SA Minister for Mineral Resources and Energy – SA 'C'**

   This rule change request raises the issue that the rules do not provide a mechanism for over-frequency emergency control schemes to account for unexpected frequency increases due to excess generation events.

   The rule change request proposes the development and establishment of a regulatory framework for emergency over-frequency control schemes to address sudden excess generation events.

5. **Managing power system fault levels – SA Minister for Mineral Resources and Energy – SA 'D'**

   This rule change request raises as an issue the reduction in system strength associated with the retirement of synchronous generation and the entry of new non-synchronous generation. A reduction in system strength in certain areas of the network may mean that generators no longer meet technical standards and may be unable to remain connected to the system at certain times. Voltage instability and network protection issues may also arise.

   The rule change request proposes that the rules should be changed to allocate responsibility for setting fault levels in different parts of the network that take account of cost, incentives and the allocation of risk.

Approach to assessing the rule change requests

Three of the rule change requests (AGL, SA 'A' and SA 'D') will be progressed concurrently and in coordination with the System Security Market Frameworks Review. The remaining two rule change requests (SA 'B' and SA 'C'), which relate to emergency protection schemes, will be progressed through a separate but related workstream.

This consultation paper is the first stage of stakeholder consultation on both the review and the three related rule change requests identified above. A separate consultation paper has been published to assist stakeholder consultation on the rule change requests related to emergency protection schemes (SA 'B' and SA 'C').[6] Further detail on the Commission's proposed work program for the Review and its approach to assessing all five of the rule change requests is set out in Chapter 3.

1.6 Structure of this report

The remainder of this consultation paper is structured as follows:

- Chapter 2 describes the current issues in the NEM in relation to power system security, including a description of each of the three rule change requests related to the System Security Market Framework Review;
- Chapter 3 sets out the AEMC's System Security Work Program, the assessment approach, and guiding principles for the Review and rule change requests;
- Chapter 4 discusses some potential changes to market and regulatory frameworks which may address the issues raised; and
- Chapter 5 sets out the process for lodging a submission.

1.7 Stakeholder consultation

The AEMC intends to consult broadly in conducting the System Security Market Frameworks Review and in the assessment of the related rule change requests. This paper represents the first stage of consultation on the Review and the three related rule change requests.

A Reference Group comprising senior representatives of the AEMC, AEMO, the Australian Energy Regulator (AER) and the Senior Committee of Officials is being established by the AEMC to provide high level input on related system security matters.

The AEMC, in consultation with AEMO, has also established a technical working group to develop the detailed recommendations for consideration by the Reference Group. In addition to the AEMC and AEMO, the technical working group includes representation from the AER, transmission and distribution network businesses, conventional and renewable generation, retailers, energy service providers, and consumers.

6 AEMC, *National Electricity Amendment (Emergency Under Frequency Control Schemes and Emergency Over Frequency Control Schemes) - Consultation Paper*, 8 September 2016.

2 System security issues

This chapter explains the concept of power system security, describes the recent changes in the power system that have given rise to potential system security challenges, and sets out the issues to be addressed.

2.1 Why does power system security matter?

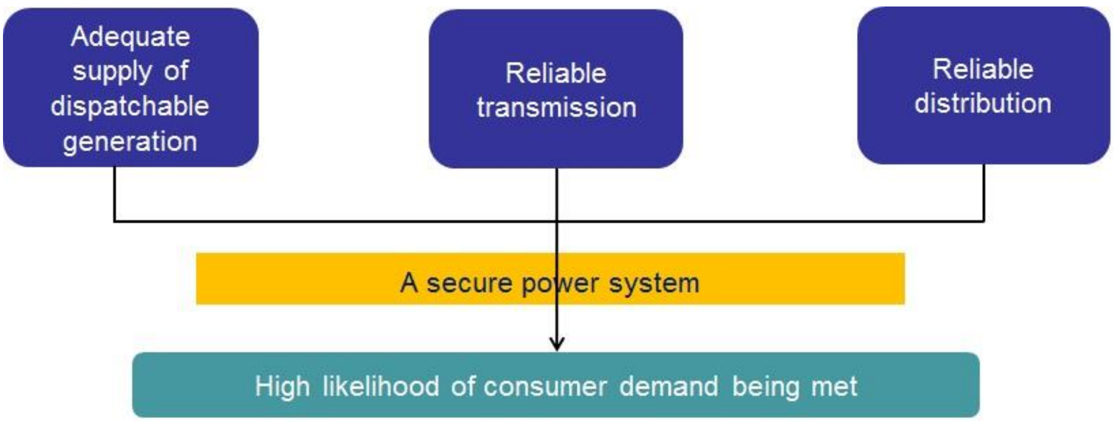
System security is necessary for the efficient functioning of the NEM. AEMO is required under the National Electricity Rules (NER or rules) to operate and maintain the power system in a secure operating state. In order for the electricity system to remain in a secure operating state, there are a number of physical parameters which must be maintained within a defined operating range. An electricity system that operates outside of these strict physical parameters may become unstable, jeopardise the safety of individuals, risk damage to equipment, and lead to the possibility of blackouts.

System security is distinct from reliability

System security is distinct from reliability. The reliability of supply has a consumer focus and describes the likelihood of supplying all consumer needs with the existing generation capacity and network capability. As shown in Figure 2.1, the components of reliability include an adequate supply of dispatchable generation to meet demand and reliable transmission and distribution networks.

A secure operating system is a necessary condition for meeting consumer electricity needs. Security of supply is a measure of the power system's capacity to continue operating within defined technical limits, even in the event of the disconnection of a major power system element such as an interconnector or large generator.

Figure 2.1 Components of system security and reliability



Reliability has historically been the focus of greater attention than system security. Levels of dispatchable generation must be continuously monitored by AEMO as generators retire from the market and new generators take their place. Investments in transmission and distribution networks are ongoing and involve a trade-off between the cost of building and maintaining the networks and the value placed on reliability by customers.

In contrast, the technical characteristics of the electricity system have changed very little over time. The system security services that are provided by generators and network businesses, such as inertia and voltage control, have been sufficient to maintain a continuously secure operating system in a relatively unchanging environment. AEMO has performed its role of continuously monitoring power system security and operating the power system in a secure operating state. The design of the power system has been based on the operation of conventional synchronous generating units and there has been little need in the past to consider potential significant changes to regulatory frameworks.

2.2 Why are we focusing on system security now?

The electricity industry in Australia is undergoing a fundamental transformation. The last decade has seen a rapid rise in the penetration of new generation technologies, such as wind farms and rooftop solar. In the past, these technologies accounted for only a small fraction of total electricity supply. Now they are a critical part of our electricity system and are expected to continue to provide an ever increasing proportion of Australia's electricity needs in the future. At the same time, the market has experienced the closure of a number of large conventional generators. This is creating challenges in maintaining power system security in the NEM.

Currently, wind and photovoltaic (PV) technologies tend to operate differently to more conventional forms of electricity generation, such as hydro, coal or natural gas. The existing fleet of these newer technologies are limited in their ability to provide the range of other power system security services that are ancillary to the generation of electricity but necessary to maintain the secure operation of the electricity system. Most notably, they are not synchronised to the frequency of the electricity system and therefore are currently unable to assist in dampening rapid changes in frequency or responding to fluctuations in supply or consumption.

Further, these non-synchronous technologies are quite often installed within distribution networks and are not centrally controlled. They are, in many instances, intermittent in their production of electricity, only generating when the wind blows or the sun shines. This affects AEMO's ability to control the secure operation of the system and maintain a continuous supply of electricity across the interconnected network.

System security is particularly relevant in South Australia

Under current arrangements, the growth in non-synchronous generation, including a large proportion of distributed generation, combined with the withdrawal of conventional synchronous generation can present new challenges for AEMO in the secure operation of the power system. This is particularly the case in regions such as South Australia where there is a high penetration of both wind and solar PV and the extent of interconnection is relatively limited.

An additional dimension to the challenge in South Australia is the role of that region's interconnection with Victoria. When the Heywood interconnector is operating, the high levels of inertia in the broader power system assist in maintaining system security in South Australia. However, when the interconnector is affected by an outage, risks to power system security increase significantly. This is in part due to the sudden change in load immediately following the separation. In addition, high imports on the Heywood Interconnector at the time of the outage is likely to be correlated with fewer synchronous generating units online and therefore lower system inertia in South Australia.

The changing generation mix has consequences for the whole of the NEM

As the generation mix changes in a similar way across the NEM these risks may become more widespread without new approaches to managing system security in a way that complements the underlying generation mix.

Table 2.1, provided by AEMO, shows the total installed generation capacity in the NEM in terms of physical attributes as at June 2016.

Table 2.1 Total installed generation capacity in the NEM[7]

Generation capacity (MW) (% of total)	Queensland	New South Wales	Victoria	South Australia	Tasmania
Synchronous (registered)	12,459 (89%)	15,416 (88%)	11,050 (83%)	2,999 (58%)	2,672 (87%)
Non-synchronous (registered)	12 (0.1%)	897 (5%)	1,230 (9%)	1,473 (29%)	308 (10%)
Non-synchronous (distributed)	1,585 (11%)	1,301 (7%)	957 (7%)	683 (13%)	97 (3%)
Interconnection	Double-circuit AC connection NSW-QLD				
	Three cable DC connection NSW-QLD				
		5 AC lines connecting NSW-VIC			
			Double-circuit AC connection VIC-SA		
			DC connection VIC-SA		
				DC connection VIC-TAS	

7 AEMO, *Future Power System Security Program – Progress Report*, August 2016, p. 9.

AEMO projects that the proportion of distributed intermittent generation will continue to grow across the NEM, with consumer choice, increasing availability of distributed energy resources, and government policies being the primary drivers of the speed and extent of this shift.

The AEMC considers that, in the face of this transition, regulatory frameworks that govern the operation of the NEM need to be flexible and resilient in order that these less conventional forms of electricity generation can be effectively integrated into the market while maintaining the secure operation of the electricity system.

2.3 What is emerging alongside the changing generation mix and how can this be managed?

Based on the work undertaken to date by AEMO as part of its FPSS Program, there are four principal issues that have been identified for which potential changes to market and regulatory frameworks may be required.[8] These issues relate to the transition from conventional centrally dispatched synchronous generation to intermittent, and increasingly more distributed, non-synchronous generation, and include:

1. reduced system inertia which increases the susceptibility of the electricity system to high rates of change of frequency for which existing system security services under normal operating conditions are unable to effectively respond;

2. reduced system strength in certain areas of the network which may mean that generators are no longer able to meet technical standards and may be unable to remain connected to the system at certain times;

3. rates of change of frequency may be too fast for existing emergency frequency control schemes to operate effectively and an increase in distributed energy resources which may mean that existing schemes are less effective in shedding load to control frequency; and

4. an increase in distributed forms of electricity generation, which is not visible to AEMO and affects their ability to assess the operational limits of the power system and dispatch utility-scale generation to meet the residual load.

The first two of these items will be addressed by the AEMC as part of the System Security Market Frameworks Review. The third item will be assessed by the AEMC under a separate but related workstream. A discussion of the rule change requests to address issues associated with the operation of emergency frequency control schemes is provided in a separate consultation paper.[9] The fourth item on the visibility of distributed generation is not within the scope of the AEMC's system security work program.

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8 AEMO, *Future Power System Security Program – Progress Report*, August 2016, p. 17.

9 AEMC, *National Electricity Amendment (Emergency Under Frequency Control Schemes and Emergency Over Frequency Control Schemes) - Consultation Paper*, 8 September 2016.

2.3.1 Managing power system frequency

Changes to power system frequency

The interconnected national electricity system operates within the constraints of a number of defined physical parameters. One such parameter is system frequency. Conventional electricity generation, like hydro, coal and gas, operate with large spinning turbines that are synchronised to the frequency of the grid. Changes in the supply and demand for electricity can act to speed up or slow down the frequency of the system. Conventional generators support the stability of the power system by working together to maintain a constant operating frequency across the interconnected network.

In each generating unit, the large rotating mass of the turbine and alternator has a physical inertia which must be overcome in order to increase or decrease the rate at which the generator is spinning. In this manner, large conventional generators that are synchronised to the system act to dampen changes in system frequency. In the electricity system, the greater the number of generators synchronised to the system, the higher will be the system inertia, and the greater will be the ability of the system to resist changes in frequency due to sudden changes in supply and demand.

In the majority of situations changes in supply and demand are such that variations in frequency are very small. Household lighting, televisions and washing machines being switched on and off are all examples of minor changes in demand happening all the time which change the frequency of the power system. In response to these small changes in frequency, power stations shift output ever so slightly to compensate, thereby maintaining the frequency within normal operating levels.

On occasion, changes in supply and demand can be more substantial. Large generating units and transmission lines may suddenly stop producing or transmitting electricity, and large industrial facilities may suddenly stop consuming. These are referred to in the NER as contingency events. They are less common but tend to result in more significant changes in system frequency.

Whether the system frequency is rising or falling depends on the balance between generation and load. Whenever total generation is higher than total energy consumption the system frequency will be rising and vice versa.

The rate of change of frequency is proportional to the size of the contingency event and the level of system inertia at the time that the contingency occurs. The greater the size of the contingency event, or the lower the system inertia, the faster the frequency will change. See Box 2.1 for a detailed explanation of the relationship between the rate of change of frequency, contingency size, and system inertia.

Box 2.1 Determining the initial rate of change of system frequency

The relationship between the initial rate of change of system frequency, system inertia, and the size of the contingency is defined by the following equation.

$$RoCoF = (25 \times \Delta P)/I$$

Where

RoCoF = The initial rate of change of frequency (Hz/second)

ΔP = The size of the contingency (MW)

I = Inertia (MW.seconds)

The initial rate of change of system frequency is proportional to the size of the contingency and inversely proportional to the level of system inertia.

As an example, a large contingency event such as a non-credible double circuit failure of the Heywood Interconnector between South Australia and Victoria at a time of high power transfer would result in a high rate of change of frequency. The rate of change of frequency would be even higher if there are only a few synchronous generating units contributing inertia in South Australia at the time of the contingency.

Current practices for managing system frequency

In order for the electricity system to remain in a secure operating state, the frequency must be controlled within a strict range. This range is defined by the Frequency Operating Standards (FOS), which sets out the range of allowable frequencies for the electricity system under different conditions, including normal operation, following contingencies, and during emergency situations.[10] Generator, network and end-user equipment must be capable of operating within the range of frequencies defined by the FOS. AEMO is responsible for maintaining the system frequency within the ranges defined by the FOS.[11]

AEMO manages the secure operation of the system by continuously monitoring and, with regard to maintaining system frequency, dispatching sufficient generation to meet consumer demand. Calculations on the level of generation to be dispatched are undertaken every dispatch interval to meet expected energy consumption over the next five minutes. There is a possibility in each five-minute dispatch interval that the level of actual energy consumption is different to what was anticipated. A substantial difference has the potential to result in a large shift in system frequency.

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10 The Reliability Panel sets the level of the Frequency Operating Standards in consultation with AEMO. A review of the Frequency Operating Standards is undertaken by the Reliability Panel based on terms of reference received from the AEMC.

11 Clause 4.3 of the NER.

AEMO may restrict the operation of the power system to reduce the potential size of sudden changes in generation or load. AEMO continually monitors the system to determine the likely impact of the occurrence of the largest credible contingency and may limit flows on the network to reduce the potential size of the contingency, or the likely impact, should it occur.

In addition to constraining the system, variations in frequency are managed in the NEM through the procurement of Frequency Control Ancillary Services (FCAS). These services are provided by generators to control system frequency in response to supply or demand disturbances.

If the level of dispatched generation is significantly below the level of energy consumption, the shedding of load may be required to keep the frequency within the limits of the FOS. Under the NER arrangements, AEMO is obliged to return the power system to a secure operating state following ***any*** contingency event, including all non-credible contingency events.[12] This may include restoring the power system following a range of different events, including the loss of interconnection between two regions to the simultaneous trip of every generating unit within a region.

In any instance that the level of dispatched generation is different to total energy consumption, the rate that the frequency changes will be determined by the size of this difference and the level of system inertia. The lower the system inertia, the greater will be the rate of frequency deviation in response to a given change in supply or demand, and the greater will be the requirement for FCAS to revert the system frequency to normal operating levels.

AEMO procures FCAS to maintain system frequency within the limits of the FOS by ensuring that total generation matches total demand in real time. FCAS is used to meet the FOS under normal system operating conditions and in response to credible contingency events. Under multiple contingency events and non-credible 'separation' events, the under-frequency load shedding (UFLS) scheme is used to prevent the system frequency from breaching the extreme frequency excursion tolerance limits, which define the maximum boundaries of the FOS.[13] Outside of these limits, there are no obligations on generators or loads to remain connected to the system. The UFLS is used as a last resort to minimise the impact of major disturbances in the system to prevent the occurrence of wide ranging blackouts.

12 This obligation is established in various NER powers and the Frequency Operating Standards. This includes clause 4.3.2, which places an obligation on AEMO to achieve the AEMO power system security responsibilities in accordance with the power system security principles. NER clause 4.2.6(c) then sets out these principles, which includes a requirement that adequate load shedding facilities initiated automatically by frequency conditions outside the normal operating frequency excursion band should be available and in service to restore the power system to a satisfactory operating state following significant multiple contingency events. The FOS also require AEMO to maintain the frequency of the power system within the extreme frequency excursion tolerance limits, for any multiple contingency event.

13 A multiple contingency event is defined in the FOS as either a contingency event other than a credible contingency event, a sequence of credible contingency events within a period of five minutes, or a further separation event in an island.

Frequency control ancillary services

FCAS is currently divided into two components – regulation and contingency. Regulation FCAS is used to control system frequency in response to minor variations in supply and demand. Contingency FCAS is used to control frequency in response to major variations in frequency caused by contingency events such as the loss of a generating unit or a significant transmission line. Contingency FCAS acts to arrest steep rates of change of frequency and then stabilises and recovers the system frequency over time to bring it back to within the normal operating frequency bands.

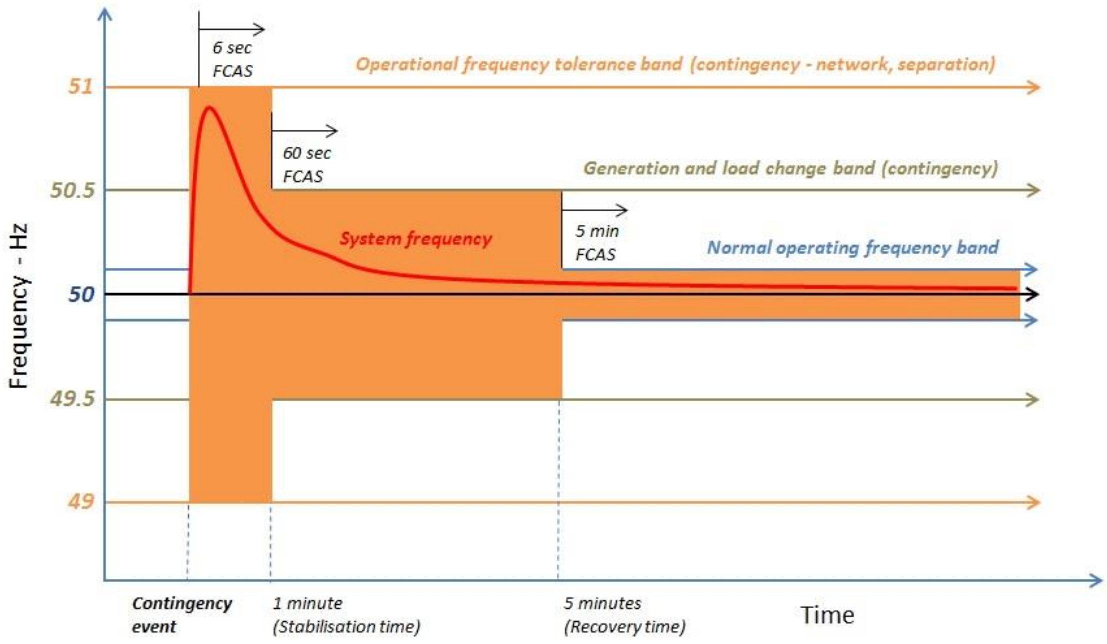
AEMO coordinates regulation FCAS provided by market participants through its central dispatch process. AEMO continually monitors the electricity system through the Automatic Generation Control (AGC) system and sends control signals to the generators providing regulation FCAS to adjust output in response to minor changes in system frequency. There are two regulation FCAS markets – one to correct a minor drop in frequency (raise) and the other to correct a minor rise in frequency (lower).

Contingency FCAS is coordinated locally by generators in response to larger frequency deviations that occur following contingency events. These local technologies are designed to detect and respond to frequency deviations and include generator governor responses, load shedding, rapid generation response, and rapid unit unloading.

There are six contingency FCAS markets – six-second markets, 60-second markets, and five-minute markets for both raise and lower services. The six-second services are used to arrest major changes in frequency following a contingency event. The 60-second services are used to stabilise frequency. The five-minute services are delayed responses used to recover frequency to normal operating levels following a major change in frequency.

Figure 2.2 shows how contingency FCAS operates to control frequency deviations following a credible contingency event. In this example, a contingency event based on a sudden large loss of load to the system results in an excess of generation and a steep increase in system frequency. The six-second contingency FCAS response is used to arrest the frequency excursion before it exceeds the operational frequency tolerance band of 51 Hz. The 60-second contingency FCAS response stabilises the frequency, followed by the five-minute FCAS response to recover the frequency to within the normal frequency operating band.

Figure 2.2 Control of system frequency through FCAS



At any point in time, the steepness of the frequency curve represents the rate of change of frequency (RoCoF). As can be seen, the RoCoF is highest immediately following the occurrence of the contingency event.

Current and potential future issues with controlling system frequency

As the market experiences a shift from synchronous generation to non-synchronous generation, the level of system inertia decreases, which leads to a higher RoCoF for a given change in supply or demand. Currently, most FCAS is provided by synchronous generators. As the number of synchronous generators reduces the level of available FCAS also reduces, making it more difficult for AEMO to manage excursions in system frequency when they occur.

A higher RoCoF leads to a greater reliance on fast FCAS to control system frequency and maintain system frequency within the FOS. As this shift occurs over time, some circumstances may eventuate where the RoCoF is so high that contingency FCAS is insufficient for AEMO to keep the system frequency within the operating frequency tolerance band under normal market operations. This may occur because the speed of available contingency FCAS is too slow to arrest the frequency following a change in generation or load. The fastest response contingency FCAS operating within a six-second timeframe may not be able to arrest significant deviations in frequency occurring over timeframes less than one second.

If FCAS was insufficient to arrest the frequency change, AEMO would rely on the UFLS to control system frequency and avoid cascading generator tripping and system black outs. However, it is also possible that the frequency sensing relays on existing emergency protection schemes may be too slow to respond in time to arrest the rate of frequency change. Existing UFLS schemes utilise relays that detect a change in the frequency and open a circuit breaker to shed successive load blocks in a controlled manner. However, these relays have been designed to meet the historically slower RoCoF levels in the NEM. It may be that the speed in the change of frequency is far too high for these existing relays to catch. The capability of emergency protection schemes to control system frequency is the subject of two rule change requests submitted by the South Australian Minister for Mineral Resources and Energy. A separate consultation paper has been published by the AEMC to facilitate stakeholder consultation on these issues.[14]

Automatic access standards currently require generating units to withstand a RoCoF of 4 Hz per second for 0.25 seconds.[15] Generators may negotiate a lower access standard. However, the minimum access standards require generating units to remain connected through an event where RoCoF reaches up to ±1 Hz per second for more than one second.[16] There is no obligation on generators to remain connected to the system through an event where the RoCoF exceeds these levels, even if the system frequency remains within the bounds of the FOS. As system inertia reduces, conditions may arise where the RoCoF exceeds ±1 Hz per second, which may result in generators being inadvertently disconnected from the electricity system.

Disconnection of synchronous generators may further increase the RoCoF and make it more difficult for the remaining generators to stay connected, particularly in cases where the generators that disconnect first are contributing to system inertia. In this manner, a system disturbance that results in a high RoCoF could very quickly result in cascading tripping of generators.

At present, the rules do not enable AEMO to manage the rate of change of system frequency.[17] In addition, there are currently no market or regulatory mechanisms for generators to supply, or for AEMO to acquire, inertia or fast response frequency control services to limit the rate of change of frequency.

The FCAS provided by synchronous generators is usually not faster than a few seconds. Inverter based generators, such as wind and PV, may have the potential to provide a much faster FCAS response. As part of its FPSS work program, AEMO is investigating the capabilities of different technologies to provide fast frequency response services.

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14 AEMC, *National Electricity Amendment (Emergency Under Frequency Control Schemes and Emergency Over Frequency Control Schemes) - Consultation Paper*, 8 September 2016.

15 Schedule 5.2.5.3(c) of the NER. This only applies to generators post 2007.

16 Schedule 5.2.5.3(b) of the NER. This only applies to generators post 2007.

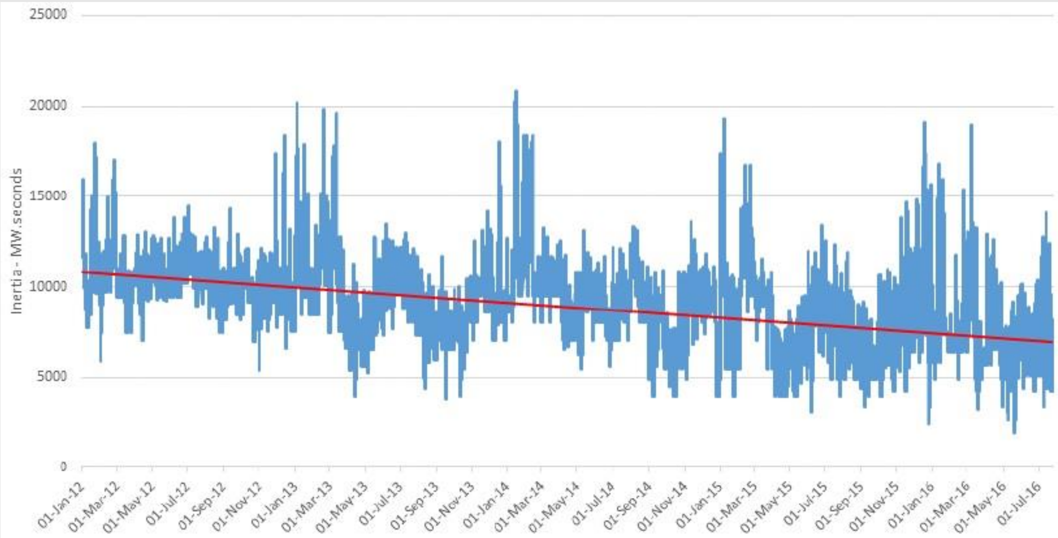
17 AEMO has an obligation to operate the power system within the bounds of the Frequency Operating Standards and can put in place security constraints to manage RoCoF in order to remain in a secure operating state.

Box 2.2 Current frequency issues in South Australia

Investigations undertaken through AEMO's Future Power System Security Program have shown that the initial challenges of restricting high rates of change of frequency are most acute in South Australia.

South Australia has experienced a high level of investment in non-synchronous generation relative to its total generation capacity. In addition, a number of conventional synchronous generators have recently retired. Figure 2.3 shows AEMO's analysis of decreasing levels of system inertia in South Australia over time.

Figure 2.3 System inertia in South Australia over time[18]



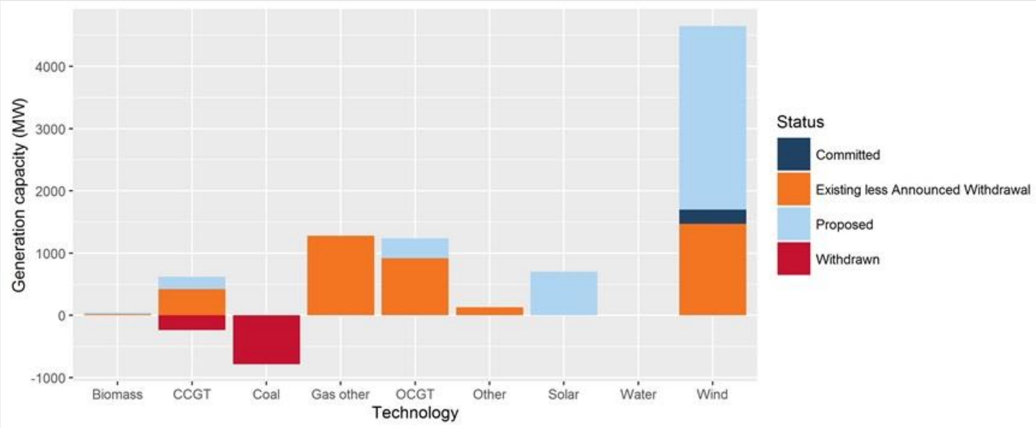
AEMO notes that this decline in system inertia does not affect the stable operation of the power system in South Australia as long as the Heywood Interconnector to Victoria remains in service. This is because system inertia is provided to South Australia via the AC link.

However, an unexpected failure of the Heywood Interconnector may see insufficient inertia available in South Australia to maintain secure operation of the islanded system. The recent upgrade of the Heywood Interconnector has increased the size of the contingency that would result.

Figure 2.4 is taken from AEMO's 2016 Electricity Statement of Opportunities and shows that all of the committed projects, and the majority of proposed projects, in South Australia are all non-synchronous forms of generation.

18 AEMO, *Future Power System Security Program – Progress Report*, August 2016, p. 21.

Figure 2.4 **South Australia existing and potential new developments by generation type**[19]



The failure of a single line on the Heywood Interconnector is currently classified as a credible contingency.[20] AEMO currently uses a combination of FCAS procurement and constraining the interconnector to limit the impacts of a credible contingency. In such circumstances, the FOS specifies that the system frequency in South Australia may drop to 47 Hz immediately following separation from the rest of the NEM. This is lower than the frequency standard for the other NEM regions and is due to a decision by the South Australian jurisdiction because of the expense that would be required to procure FCAS in South Australia to meet a higher frequency standard.

The sudden and unexpected simultaneous failure of both lines on the Heywood Interconnector is currently considered a non-credible contingency. As such, AEMO has no powers to manage the impacts on system security that would result should this occur and must rely on the operation of the under-frequency load shedding scheme to arrest a drop in system frequency and maintain system security. Further, there is currently no over-frequency generator shedding scheme in place should a non-credible loss of the interconnector cause a sudden rise in frequency.

Question 1

Do you consider that the issues outlined above cover the matters that need to be considered going forward in managing changes in system frequency?

19 AEMO, Generation information – Electricity Statement of Opportunities, August 2016, https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information.

20 With one line already out of service, the sudden loss of the remaining line is also considered a credible contingency.

2.3.2 Managing power system strength

System strength

System strength is an inherent characteristic of a power system and it relates to the size of the change in voltage as a result of a change to the load (or generation) at a connection point. When the system strength is high at a connection point the voltage changes very little for a change in load, however, when the system strength is lower the voltage would vary more with the same change in load.

System strength is also often referred to as fault level. The fault level is the magnitude of the abnormally high current that flows when an item of electrical equipment is damaged, or when lightning or bushfire smoke causes an arc between conductors on an over-head line. In these instances, a large fault current will flow into a fault on a strong system, while a relatively low fault current will flow into a fault on a weak system.

Contributions to the strength of the system come from the synchronous generating units in the power system, with little or no contributions from non-synchronous generation.[21] Thus the system strength depends on the number of synchronous generating units operating near the connection point and the degree to which these units are electrically linked to the connection point.

Current and potential future issues with managing system strength

Historically, high fault levels in the NEM have been a concern. This is because load growth leads to new generation being installed. There is a risk that the resulting fault currents can exceed the ratings of the network components, particularly the circuit breakers that are required to interrupt the fault current, potentially damaging equipment.[22] High fault levels can be managed through restrictions placed by AEMO on some generation and the network configuration. However, recently the system strength has been reducing in some parts of the NEM power system as a number of synchronous generating units have been exiting the market and the new generating units that replace them are non-synchronous, and thus don't contribute as much to system strength.

AEMO has identified a number of technical issues associated with low system strength[23] and these issues have been discussed in the South Australian Government's

21 Modern inverter connected generating units (such as type 4 wind farms, battery storage and solar) can be made to provide some fault current. However, the majority of these inverters shutdown during a fault and do not provide a contribution to the fault current.

22 Circuit breakers are the large switches in the network used to disconnect and re-connect system equipment such as lines, cables, transformers, generating units and customer loads. These circuit breakers need to have the capability to disconnected equipment, even when a large fault current is flowing. A circuit breaker is likely to explode if it attempts to open when the fault current exceeds its rating.

23 AEMO, *Future Power System Security Program - Progress Report*, August 2016, p. 45.

rule change request on the management of power system fault levels.[24] These issues include:

- reducing the effectiveness of the protection systems used by the network businesses, generators and large customers, thus potentially requiring the replacement or readjustment of the affected protection systems;
- increasing the difficulty for the network businesses to maintain stable voltages; and
- reducing the ability of inverter connected generating units (such as modern wind, solar PV, battery storage) to operate continuously following a major fault or disturbance to the power system, potentially meaning that some existing generating units are no longer able to meet their generator performance standards under all conditions.[25]

The rules do not provide mechanisms to manage a reduction in the strength of the system. In particular, no entity is responsible for maintaining the system strength at a connection point and there are no system standards for system strength because it varies significantly throughout the power system and under different conditions. Also, the rules are not explicit as to whether a generator is required to modify its generating units if they no longer comply with the technical standards at the reduced system strength.[26]

Question 2

What do you consider to be the issues associated with low power system strength?

2.4 The rule change requests

This section provides a summary of the rule change requests recently received by the AEMC that relate to the System Security Market Frameworks Review. A separate consultation paper has been published to facilitate consultation on the two rule change

24 Minister for Mineral Resources and Energy (South Australia), *Rule change request – Managing Low Power System Fault Levels*, 12 July 2016, p. 1.

25 Generators are required to meet the technical performance requirements in Schedule 5.2 of the rules, which include requirements to ride through system faults. Generators negotiate the required technical performance at the time of their connection, based on the power system information that is available at that time. The negotiated performance is registered with AEMO, who use this information when managing the security of the power system. The generators must develop an ongoing compliance program to ensure ongoing compliance with their technical performance is maintained and the AER performs audits on selected generators.

26 This question may have been addressed in the connection agreement between the generator and associated network business, but these agreements are commercially sensitive and hence confidential.

request received from the South Australian Minister for Mineral Resources and Energy on the operation of emergency protection schemes.[27]

2.4.1 Inertia ancillary services market - AGL

AGL considers that the changing mix of generation capacity in the NEM has led to a decreasing supply of inertia.[28] AGL suggests that inertia, as an increasingly scarce service, should be appropriately valued in the market.

AGL considers that additional complementary measures are required to ensure that the current NEM energy-only market design delivers ongoing security and reliability of electricity supply as the sectoral transformation continues.[29]

According to AGL, the introduction of an inertia ancillary services procurement mechanism would be an appropriate response to the declining supply of inertia and would effectively manage the transformation of the sector.[30]

In its view, the current issues associated with the sectoral transformation may be only transitory as the capability of consumers to manage their energy usage through generation and storage improves over time.[31] However, AGL notes that it is currently unclear as to how long this sectoral transformation will take and that steps should be taken now to mitigate any potential adverse impacts.

AGL proposes that the inertia ancillary services procurement mechanism would only apply when the supply of inertia drops below a set threshold to be determined by AEMO.[32] The level of inertia to be procured by AEMO would be based on the possibility of the occurrence of certain contingency events. AGL provides the example of an inertia level based on both lines of the Heywood Interconnector unexpectedly coming out of service. At present this is not considered a credible contingency and, as such, AEMO is not required to manage the system to take into account the possibility of it occurring.

AGL proposes that procurement of inertia should occur on a competitive basis through a tender contract process conducted by AEMO. AEMO would administer the procurement and determine the quantity of inertia to be contracted. AEMO would conduct the tender/auction process, determine any relevant terms and conditions, and the timeframes for the inertia to be procured.

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27 AEMC, *National Electricity Amendment (Emergency Under Frequency Control Schemes and Emergency Over Frequency Control Schemes) - Consultation Paper*, 8 September 2016.

28 AGL, *Rule change request – NEM Wide Inertia Ancillary Service*, 24 June 2016, p. 3.

29 AGL, *Rule change request – NEM Wide Inertia Ancillary Service*, 24 June 2016, p. 2.

30 AGL, *Rule change request – NEM Wide Inertia Ancillary Service*, 24 June 2016, p. 3.

31 AGL, *Rule change request – NEM Wide Inertia Ancillary Service*, 24 June 2016, p. 4.

32 AGL, *Rule change request – NEM Wide Inertia Ancillary Service*, 24 June 2016, p. 4.

AGL suggests that the procurement mechanism would apply across the NEM and that cost recovery occur on a regionalised basis with a 50/50 split between customers and incumbent generators.

AGL considers that the proposed rule will provide improved system security to the benefit of energy consumers and will also benefit providers of the inertia from having the service they provide appropriately valued.[33]

2.4.2 Managing the rate of change of power system frequency - SA Government

Similar to the issues raised in AGL's rule change request, the South Australian Government has identified that the changing generation mix is reducing levels of system inertia which, under some circumstances, could result in a high rate of change of frequency and the disconnection of some generation.[34]

The SA Government notes that the rules do not provide the market or regulatory means for AEMO to acquire services to limit the rate of change of frequency.[35] The SA Government considers that the rules should be amended to enable AEMO to procure the necessary services via an ancillary service agreement.

In support of these agreements, guidelines should be developed by AEMO for the acquisition of the services. The SA Government proposes that these guidelines contain technical information, information on the contracting process for AEMO and service providers to follow, and guidance on the factors that AEMO would take into consideration when deciding on a procurement contract.

The SA Government also proposes the development of a system standard for rate of change of frequency to assist in the management of power system security and clarify the responsibilities of AEMO, network businesses and market participants. The development of the standards should be undertaken by the Reliability Panel with a process for the determination of the level of the standards to be prescribed in the rules.

The SA Government considers that the procurement of the required services via an ancillary services agreement will ensure they are acquired through a competitive and efficient process to the benefit of consumers.[36] The SA Government considers that there are likely to be some costs involved in procuring the service via agreements but that any ongoing purchase costs are likely to be minimal as the services will only be required on an occasional basis.

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33 AGL, *Rule change request – NEM Wide Inertia Ancillary Service*, 24 June 2016, p. 5.

34 Minister for Mineral Resources and Energy (South Australia), *Rule change request – Managing power system frequency*, 12 July 2016, p. 1.

35 Minister for Mineral Resources and Energy (South Australia), *Rule change request – Managing power system frequency*, 12 July 2016, p. 2.

36 Minister for Mineral Resources and Energy (South Australia), *Rule change request – Managing power system frequency*, 12 July 2016, p. 4.

2.4.3 Managing power system fault levels - SA Government

The SA Government considers that an increase in the level of non-synchronous generation has resulted in low fault levels in some areas of the power system.[37] Low fault levels can:

- reduce the effectiveness of network equipment including protection systems that detect and clear faults on the network; and
- impact on the ability of inverter-connected plant to ride through faults on the system.

The SA Government notes that fault levels are determined locally depending on the contributions of generators connected nearby. A generator may experience reduced system strength if a non-synchronous generator connects nearby or if a nearby synchronous generator retires or is not online. The generator may have originally complied with its performance standards for fault ride through but may no longer be able to due to changes in the surrounding network for which it has no control. The SA Government notes that there are currently no obligations on the network operator to maintain fault levels.

The SA Government considers that the rules should be amended to ensure that issues associated with low fault levels can be accommodated and to allocate responsibility for controlling fault levels in different parts of the network.[38]

The SA Government notes that obligations may be imposed on new connecting generators in relation to fault level contributions. While fault levels may be reduced if a synchronous generator retires, it is not clear how any obligations would be able to apply to these generators.

37 Minister for Mineral Resources and Energy (South Australia), *Rule change request – Managing power system fault levels*, 12 July 2016, p. 1.

38 Minister for Mineral Resources and Energy (South Australia), *Rule change request – Managing power system fault levels*, 12 July 2016, pp. 1-2.

3 The System Security Work Program

The chapter sets out the Commission's proposed framework for undertaking the System Security Market Frameworks Review and for assessing the five related rule change requests.

3.1 Overview

The AEMC's System Security Work Program comprises the System Security Market Frameworks Review and the five related rule change requests recently received on system security matters. The rule change requests are as follows:

1. 'AGL inertia': Inertia ancillary services market (AGL)
2. 'SA A': Managing the rate of change of power system frequency (SA Minister for Mineral Resources and Energy)
3. 'SA B': Emergency under-frequency control schemes (SA Minister for Mineral Resources and Energy)
4. 'SA C': Emergency over-frequency control schemes (SA Minister for Mineral Resources and Energy)
5. 'SA D': Managing power system fault levels (SA Minister for Mineral Resources and Energy)

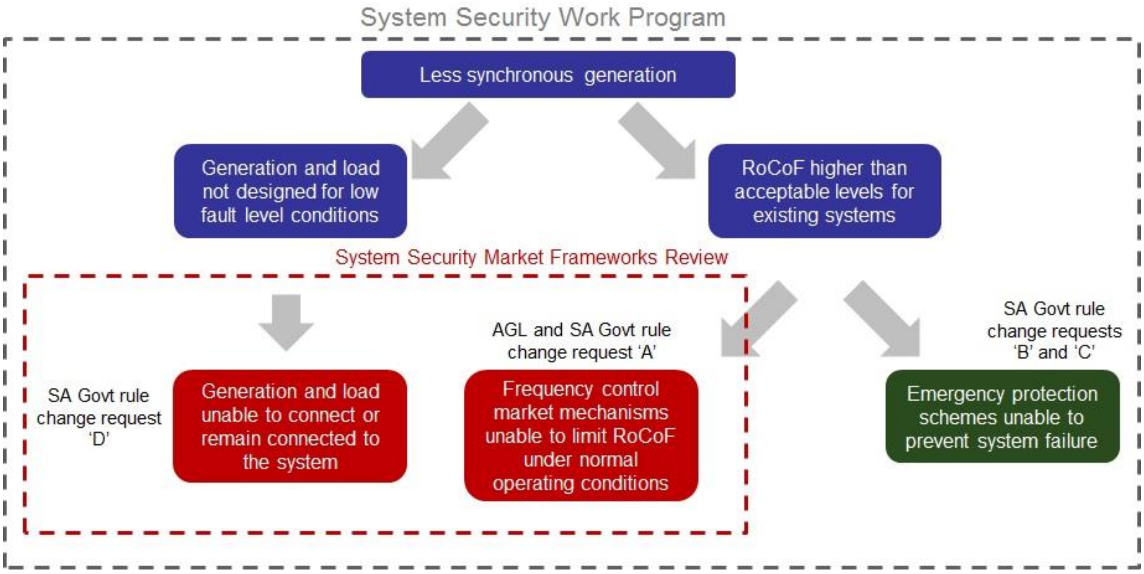
Figure 3.1 shows the relationship between the issues to be considered under the System Security Work Program and how these issues relate to the System Security Market Frameworks Review and the related rule change requests.

The AGL rule change request and the South Australian Government's rule change requests 'A' and 'D' will be progressed concurrently and in coordination with the AEMC's Review. These three rule change requests will need to be assessed in the same timeframe as it is likely that the solutions to the issues raised will be interdependent.

The South Australian Government's rule change requests 'B' and 'C' will be progressed separately to the Review and the other three rule change requests. It is anticipated that potential changes to the rules arising from these rule change requests may address some of the more immediate concerns in relation to the governance and operation of emergency protection schemes, particularly as it applies to managing the impact of a sudden separation of South Australia from the rest of the NEM. A discussion of these rule change requests is provided in the AEMC's consultation paper.[39]

39 AEMC, *National Electricity Amendment (Emergency Under Frequency Control Schemes and Emergency Over Frequency Control Schemes) - Consultation Paper*, 8 September 2016.

Figure 3.1 AEMC System Security Work Program



3.2 Collaboration with AEMO

Through its Future Power System Security Program and Power System Issues Technical Advisory Group (PSITAG), AEMO has undertaken extensive work to identify and prioritise current and potential future challenges to maintaining system security, and has been working to better understand and quantify the likely impacts. Potential technical solutions to the challenges are also being identified.

AEMO is continuing its work and may take immediate action to maintain system security under the current rules. AEMO will also complete its work advising the COAG Energy Council and may propose rule changes to the AEMC or broader changes to ministers as part of that work.

AEMO will provide technical advice as the AEMC conducts its review of whether market frameworks are suitable to enable the maintenance of a secure power system. While each organisation has its own governance and accountabilities, the AEMC and AEMO will maintain close communication on their individual activities and collaborate, seeking to ensure that these activities deliver a coordinated package of measures to maintain future power system security.

The AEMC and AEMO have released the text of an agreement setting out a collaborative framework for the work of the two agencies in relation to system security in the NEM. Terms of the agreement include that:

- each organisation will work under its own governance framework to deliver on its respective obligations;
- the AEMC and AEMO jointly work to develop proposals and recommendations, and report to the COAG Energy Council;

- collaboration between the AEMC and AEMO will be undertaken in a manner consistent with the terms of the existing Memorandum of Understanding; and
- the AEMC and AEMO will undertake consultation with external stakeholders as part of the joint project.

3.3 NEO assessment

In undertaking the System Security Market Frameworks Review, the Commission will be guided by the National Electricity Objective (NEO). The Commission's assessment of the related rule change requests must also consider whether the proposed rules promote the NEO as set out under section 7 of the NEL as follows:

"The objective of this law is to promote efficient investment in, and efficient operation and use of, electricity services for the long-term interests of consumers of electricity with respect to:

- price, quality, safety, reliability and security of supply of electricity; and
- the reliability, safety and security of the national electricity system."

Based on a preliminary assessment of the issues raised by the Review and the related rule change requests, the Commission considers that the relevant aspects of the NEO for further consideration are the efficient investment in and operation of electricity services with respect to the safety and security of the national electricity system and the price of supply of electricity.

As part of the Review, the Commission proposes to develop recommendations for potential changes to regulatory frameworks, and to test the proposed rules, through consideration of the following propositions in relation to the promotion of the NEO:

- The safety and security of the national electricity system provides operational and investment certainty to market participants. This leads to efficient price signals and minimises the costs of investment in the long-term interests of consumers of electricity.
- The competitive procurement of services minimises the costs of maintaining the security of the national electricity system, thereby lowering the price of electricity to consumers.
- Where changes to regulatory frameworks are required they should be designed, to the extent feasible, to coordinate options for the maintenance of system security such that total system cost is minimised.

3.4 Principles

The Commission has set out a number of principles to guide the development of recommendations on potential changes to market and regulatory frameworks that affect system security in the NEM. These principles will also be used to guide the Commission's assessment of the rule change requests in addition to the NEO.

1. **Technology neutral:** Regulatory arrangements should be designed to take into account the full range of potential market and network solutions. They should not be targeted at a particular technology, or be designed with a particular set of technologies in mind. Technologies are changing rapidly and, to the extent possible, a change in technology should not require a change in regulatory arrangements.

2. **Competitive procurement:** Competition and market signals generally lead to better outcomes than prescriptive rules or centralised planning since they are more flexible to changing conditions and give businesses the ability to meet consumers' needs as efficiently as possible. Such outcomes should be less likely to change over time, creating regulatory certainty. As part of any market-based solution, the market should be designed to maximise opportunities for the provision of services in order to send the right price signals and lower the overall cost of achieving a secure electricity system.

3. **Flexible:** Regulatory arrangements must be flexible to changing market conditions. They must be able to remain effective in achieving system security over the long term in a changing market environment. Regulatory or policy changes should not be implemented to address issues that arise at a specific point in time.

   Further, NEM-wide solutions should not be put in place to address issues that have arisen in a specific jurisdiction only. Solutions should be flexible enough to accommodate different circumstances in different jurisdictions. They should be effective in maintaining system security where it is needed while not imposing undue market or compliance costs on other areas.

4. **Risk allocation:** Regulatory arrangements should be designed to explicitly take into consideration the trade-off between the risks and costs of meeting system security requirements. Risk allocation and the accountability for investment decisions should rest with those parties best placed to manage them. Under a centralised planning arrangement, risks are more likely to be borne by customers. Solutions that are better able to allocate risks to market participants such as businesses who are better able to manage them are preferred where practicable.

3.5 Assessment approach

The Commission intends to adopt the following approach to assessing the rule change requests and developing recommendations as part of its review, on potential changes to market and regulatory frameworks that affect system security.

1. **Define the issues**

The Commission considers that the first step in the assessment framework is to define the problem or issues that have been identified in relation to system security in the NEM.

Through its Future Power System Security Program, AEMO has undertaken extensive work to identify and prioritise current and potential future challenges to maintaining system security. These challenges all stem from the transition to greater levels of non-synchronous generation, including:

- high rates of changes of system frequency following a sudden change in supply or demand as a result of reduced levels of system inertia. A reduction in synchronous generation may reduce the availability of frequency control ancillary services to respond to high rates of change of frequency, with the remaining frequency control services, and emergency protections schemes, potentially being too slow to respond; and
- localised reductions in system strength which may mean that the power system is too weak, thereby reducing the effectiveness of some types of system protection functions, impacting the ability of some generators to ride through faults, and making the local network more susceptible to voltage instability.

A detailed discussion of these issues is contained in AEMO's Future Power System Security Program Progress Report.[40] AEMO's work on these issues, and its work on the visibility of distributed energy resources, is ongoing.

2. **Determine the services that may be required in the future to address the issues and maintain system security**

As identified by AEMO and the proponents to the rule change requests, the transition to non-synchronous forms of generation has reduced levels of system inertia which has the potential to result in high rates of change of frequency following a significant change in generation or load.

Some technologies may have the capability to respond rapidly to high rates of change of frequency. The extent to which these technologies can act as substitutes for the reduced levels of system inertia is the subject of ongoing investigations by AEMO.

3. **Determine the options available to procure the necessary services**

The AEMC's Review will identify the changes to market and regulatory frameworks that will be required to deliver the technical solutions identified by AEMO. These changes may include, but are not necessarily limited to, different mechanisms to competitively procure the required system security services,

40 AEMO, *Future Power System Security Program – Progress Report*, August 2016.

possible changes to standards or the establishment of new standards, or changes to the roles and responsibilities of market participants.

4. **Assess the range of options against the NEO and guiding principles**

   Any recommendations for potential changes to market and regulatory frameworks developed by the Commission will need to result in net benefits to the market and promote the NEO. The Commission's assessment of the rule change requests and the development of recommendations in this review will also be guided by the framework principles.

In July 2016, the AEMC assumed rule making responsibility for parts of the NER in the Northern Territory. The National Electricity (Northern Territory) (National Uniform Legislation) Act 2015 allows for an expanded definition of the national electricity system in the context of the application of the NEO to rules made in respect of the Northern Territory, as well as providing the AEMC with the ability to make a differential rule that varies in its terms between the national electricity system and the Northern Territory's local electricity system.

The AEMC's power to make a differential rule for the Northern Territory includes changes made to Chapter 6 of the NER. As the rule change requests include a suggestion the AEMC consider changes to chapter 6, the Commission will consider the applicability of the rule change requests to the Northern territory as part of the Review.[41]

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41 http://www.aemc.gov.au/Energy-Rules/National-electricity-rules/National-Electricity-Rules-(Northern-Territory) for a version of the NER as it applies in the Northern Territory

4 Potential changes to market frameworks

As identified by AEMO and the proponents of the rule change requests, additional services may be required for AEMO to maintain power system security. This chapter provides a discussion of some possible changes to market frameworks that could assist in the provision of additional system security services. The changes discussed are not exhaustive and other possible changes may exist which are not contemplated here.

4.1 Roles and responsibilities and the establishment of standards

As described in section 2.3, contingency FCAS is currently procured at the beginning of each five-minute dispatch interval. AEMO determines the level of contingency FCAS to be procured to maintain system security should the largest single credible contingency occur.

If sufficient contingency FCAS is unavailable, or the contingency FCAS that is available is too expensive, AEMO may constrain the system to reduce the size of the largest single credible contingency.[42]

In order to procure inertia, AEMO considers the size of the largest single credible contingency as well as the level of the RoCoF that, if exceeded, may compromise system security. A system standard for RoCoF may be required in order to determine how much inertia is needed in response to a credible contingency.

Setting a system standard for RoCoF

As discussed in section 2.3, AEMO has the power to procure services in case of a credible contingency but must rely on emergency protection schemes to control frequency in response to all non-credible contingencies.

Currently, all non-credible contingencies are treated in the same manner regardless of the probability of occurrence or potential impact on the system. However, there are some non-credible contingencies where the probability is sufficiently high, and the consequences of it occurring sufficiently detrimental, that it may be appropriate for AEMO to procure some level of system security services to either prevent or respond.

One such non-credible contingency is the possible double circuit failure of the Heywood Interconnector between South Australia and Victoria. The failure of a single line on the Heywood Interconnector is currently classified as a credible contingency. AEMO currently constrains the interconnector to limit the impacts of a credible contingency on the interconnector.

While a sudden and unexpected failure of both lines simultaneously is currently considered a non-credible contingency, the fact that both lines are physically located on

42 We understand that AEMO has the capability to co-optimise the procurement of FCAS with the application of constraints on interconnectors through the NEM dispatch engine.

the same transmission tower suggests that it is not outside the realms of possibility that a double circuit failure could occur.[43]

Through its FPSS program, AEMO has studied the likely impacts of a non-credible separation of South Australia from the rest of the NEM. It has concluded that there is a significant risk of a state-wide blackout in South Australia should this occur when there is minimal synchronous generating units online in South Australia.[44]

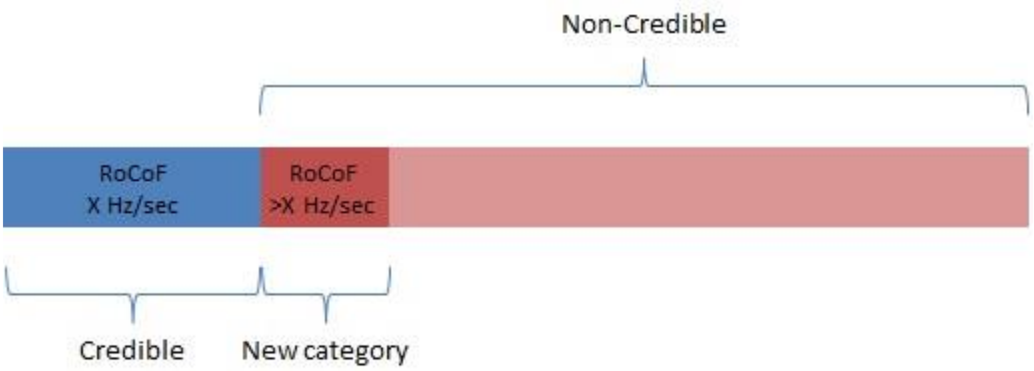
This raises the question of whether AEMO should also be given the power to procure sufficient services to maintain system security in the event of certain non-credible contingencies. AGL has proposed this as part of its rule change request, suggesting that the risk exists that, in the event of interconnector failure, sufficient services would not be present within the region to meet system needs.[45] AGL describes this within the context of a lack of system inertia. However, this would be included in the procurement of other system security services such as fast response FCAS.

Determining the level of the standard

In order for AEMO to determine the level of system security services to procure, a system standard for RoCoF would need to be determined. One standard could be set for normal operating conditions and for the possibility of credible contingencies.

Another standard could be set for the possibility of a subset or new category of certain non-credible contingencies. This would likely be set to a higher RoCoF to avoid AEMO consistently procuring system security services to maintain system frequency due to events with a very low probability of occurrence. Put another way, the setting of the standard would recognise both the low probability of a non-credible separation and the high consequences of such an event, ie a greater loss of load or generation. Figure 4.1 shows how these RoCoF system standards might be set.

Figure 4.1 Possible RoCoF system standards



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43 AEMO is currently permitted to redefine credible contingencies and has a process to redefine double circuits as credible under known risks of fires and storms.

44 AEMO, *Future Power System Security Program – Progress Report*, August 2016, p. 23.

45 AGL, *Rule change request – NEM Wide Inertia Ancillary Service*, 24 June 2016, p. 4.

Consideration would also need to be given to determining the entity responsible for setting the level of the RoCoF standard. Currently, the Reliability Panel is responsible for setting the level of the Frequency Operating Standards and the determination of a RoCoF standard could potentially be incorporated into this process.

The level of this standard would need to be consistent with the technical capabilities of generating units. If the standard is set too high, some generators may disconnect from the system under normal operating conditions.

Since 2008, new connecting generators have been required to register their performance in relation to their ability to withstand rates of system frequency change. The automatic access standard requires connecting generators to withstand 4 Hz/second for 0.25 seconds.[46] A lower standard of access may be negotiated by the generator. However, the minimum access standard requires connecting generators to be able to remain online through a RoCoF as high as 1 Hz/second for one second.[47] Some older generating units have a registered performance as low as 1 Hz/second. The capabilities of generating units that connected pre-2008 are unknown, or only known as a consequence of historical incidents. AEMO is currently undertaking an investigation of the capabilities of different generating units to withstand high RoCoF.

System strength

The rules do not provide mechanisms to manage a reduction in the strength of the system. In particular, no entity is responsible for maintaining the system strength at a connection point and there are no system standards for system strength because it varies significantly throughout the power system and under different conditions.[48] Also, the rules are not explicit as to whether a generator is required to modify its generating units if they no longer comply with the technical standards at the reduced system strength.[49]

Question 3

Do you consider it beneficial to set a standard for RoCoF? What format should this standard take and what factors should be taken into account when setting the standard? Who should set it?

Would the establishment of a new standard trigger significant additional costs to comply?

Do you consider there to be a role for maintaining system strength? Who should be responsible for undertaking this role or how should the responsibility be determined?

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46 Clause S5.2.5.3(b) of the NER.

47 Clause S5.2.5.3(c) of the NER.

48 AEMO always retains the responsibility for maintaining power system security.

49 This question may have been addressed in the connection agreement between the generator and associated NSP, but these agreements are commercially sensitive and hence confidential.

4.2 Additional system security services

Synchronous generators provide inertia whenever they are online and connected to the power system. The level of inertia provided is an inherent physical property of the generating unit and acts to dampen changes in system frequency following a sudden shift in generation or load. This is different to frequency response services which involve a power injection following a change in frequency in order that the system frequency can be stabilised back to normal operating levels. As such, all frequency response services involve a time delay following the change in generation or load, with some response services being faster than others.

As discussed in section 2.4, current frequency response is delivered through regulation and contingency FCAS or, in extreme cases, automatic load shedding. As the market transitions to greater levels of non-synchronous generation, and the level of system inertia decreases, the propensity for high rates of change of system frequency to occur increases. There is a risk that, under some conditions, the RoCoF may be so great that existing FCAS is too slow to operate in response.

Currently, the fastest mechanism for the procurement of FCAS is based on a response time in the order of seconds. AEMO has identified that the future power system may require frequency response services that can be activated in milliseconds.

While synchronous generators currently provide the majority of six-second FCAS, it appears unlikely that the response time of these services could be shortened. It is possible that inverter based generators such as wind and storage could provide a much faster FCAS response.

Fast response FCAS is not a perfect substitute for inertia as it will always include some delays in its operation and so some level of inertia will be required for the foreseeable future. As the electricity system is currently designed, only synchronous inertia can be used to resist rapid changes in frequency that would happen immediately upon the occurrence of a loss of generation or load.

At present the technical capability of rapid response FCAS, and hence the degree to which it is a substitute for synchronous inertia, is not well understood. AEMO is continuing work in this area to better understand the role that fast response FCAS could play in maintaining system security with decreasing levels of system inertia.

Question 4

What roles do you consider services such as inertia and fast frequency response should play in maintaining system security in the NEM? How else could RoCoF be managed?

4.3 Procurement of additional system security services

The Commission considers that if additional system security services are to be procured then they should be procured in accordance with the principles set out in section 3.4.

This section discusses a number of potential procurement mechanisms and options for cost recovery. Initial thoughts are provided to facilitate consultation. This section does not cover all aspects that would need to be considered in the development and application of these options.

4.3.1 Procurement options

New mechanisms for the procurement of additional system security services could be established for the provision of inertia and fast frequency response. These mechanisms are discussed below and include, but are not limited to, obligations on market participants, contract tender processes, and five-minute procurement.

It is possible that a mechanism for the procurement of only one of these services is sufficient, although it is likely that a lowest cost arrangement would be obtained through a mechanism that procures both services, or separate mechanisms for each service which are co-optimised. There would likely also be a requirement to co-optimise the procurement of these services with the energy market.

In each case, an obligation on generating units to provide additional system security services would need to establish that these generating units could withstand high RoCoF. For example, if a contingency event were to occur that resulted in a high RoCoF, there would be a risk that generating units with an obligation to provide fast frequency response may disconnect from the system before they have time to respond. If these generators were also providing inertia then there would be the possibility of an even higher RoCoF resulting, leading to a risk of cascading failure of the system.

Technical obligation

An obligation on generators could be established to provide a pre-determined level of system security services as a condition of market participation.

The Commission envisages that any obligation to provide a set level of inertia or fast frequency response may only apply to new generating units. However, in considering this, it would be necessary to determine whether this obligation could also apply to existing generators. To apply to existing generators, some may need to invest in new equipment to provide the additional services based on system conditions that were potentially different at the time that they originally connected. It is also possible that a number of generators simply could not meet the requirements irrespective of the level of investments made.

There is a possibility that generators may be able to meet their obligations by procuring the required level of inertia from another generator or provider. This would have the benefit of encouraging inertia to be provided by generators that can do so at lower cost. It is possible that inertia could be provided from a range of market participants.

It is also not clear how much inertia or fast frequency response would need to be provided by each generator. It is likely that the level of the obligations would need to be conservative in order that sufficient services are available at any time and under any circumstances. For example, if only a few generating units were online at the time that a contingency event occurred, these generating units would need to provide enough of the required services to maintain system security. The conservative nature of these obligations would mean that most of the time there would likely be an over-supply of inertia or fast-frequency response procured.

A judgement would also need to be made on how much inertia versus fast frequency response would need to be provided by generators. Further work needs to be undertaken on the extent to which these services can act as substitutes. Nevertheless, it is clear that, for the foreseeable future, there will need to be some level of system inertia provided due to the time delay associated with fast frequency response services. However, placing obligations on generators to only provide inertia services may not result in the most efficient outcome if lower cost fast frequency response alternatives are available.

Further, the obligation, once set, could not be readily adjusted over time. In situations where limited inertia or fast frequency response is available, the restriction on AEMO's ability to procure additional services may mean that it would need to constrain the system more often to limit the impact on system security.

Tender process

Inertia or fast frequency response services could be procured by AEMO through a competitive tender process. This mechanism is proposed by both AGL and the SA Government in their respective rule change requests as the appropriate method of procurement.[50]

Providers of these services would enter into a contractual arrangement with AEMO to provide these services when they are needed to maintain system security. AEMO would determine the capacity of services to be contracted based on meeting the level of the RoCoF standard.

It is possible that the responsible entity for undertaking the tender process for the provision of the services would be AEMO. AEMO would set out the terms and conditions of procurement and the timeframes for the provision of services.

Providers would need to demonstrate capabilities to AEMO with the requirements of the services to be set out in the Market Ancillary Services Specifications (MASS).

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50 AGL, *Rule change request – NEM Wide Inertia Ancillary Service*, 24 June 2016, p. 4; Minister for Mineral Resources and Energy (South Australia), *Rule change request – Managing Power System Frequency*, 12 July 2016, p. 2.

Once AEMO enters into contracts with service providers, the level of the service could not be readily adjusted over time. It would be possible to include some flexibility in the contracts such that service providers were only required to physically provide the service when inertia levels in the system fall below a pre-determined threshold. However, the amount required in real-time would likely depend on system and market conditions, including the amount of fast frequency response available at the time. Nevertheless, in situations where limited inertia or fast frequency response is available, the restriction on AEMO's ability to procure additional services may mean that it would need to constrain the system more often to limit the impact on system security.

Five-minute procurement

A five-minute procurement of inertia or fast frequency response would operate similar to existing FCAS procurement mechanisms. AEMO would determine the level of services to be procured prior to each five-minute dispatch interval in order that the RoCoF system standard is not exceeded in the event of a sudden loss of generation or load.

This procurement method might allow for the level of services provided to be adjusted dynamically to meet variable system conditions. The costs of procuring the required levels of inertia or fast frequency response could be co-optimised, through the NEM dispatch engine, with the alternative costs of constraining the system.

The non-linear nature of the provision of inertia services may mean that a five-minute procurement mechanism for inertia services would present some challenges when calculating the optimal dispatch arrangement through the National Electricity Market Dispatch Engine (NEMDE). Unlike the provision of energy or FCAS, generators either provide full inertia when online, regardless of generation output, or no inertia when offline. A generator dispatched through NEMDE to provide inertia would operate at their minimum generating level. The size of the minimum level of output for some generators may mean that other generators are constrained off despite offering lower priced energy in the merit order. It is also unclear how NEMDE would solve for time dispatch inflexibilities in generators coming online to provide inertia services.

A mechanism that procures other forms of service, such as fast frequency response, may allow other technologies to compete to provide these services.

Question 5

Do you consider it beneficial to establish new mechanisms for the procurement of additional systems security services?

What form of mechanism do you consider to be preferable and which services should the mechanism be targeted at?

4.3.2 Cost recovery

Irrespective of the design of the procurement mechanism, there will be a cost associated with the provision of the system security service.

The recovery of costs associated with a 5-minute mechanism to procure inertia or fast response FCAS could adopt similar arrangements to those that currently exist for FCAS. Cost recovery arrangements will be an important consideration in sending appropriate market signals to guide the need for the service.

FCAS costs are recovered from market participants depending on the type of service. Contingency raise services are procured to manage the loss of the largest generator on the system and so the costs for these services are recovered from generators. Contingency lower services are procured to manage the loss of the largest load or transmission element on the system and the costs of these services are recovered from customers. In both cases, the costs are pro-rated across market participants on the basis of energy generated or consumed in the trading interval.

For the regulation services, costs are recovered on the basis of the response of generators and loads to frequency deviations. Market participants that cause the frequency to deviate are assigned a high causer pays factor, while those that correct frequency deviations are assigned a low factor. Regulation FCAS payments are recovered from market participants on the basis of these factors.

Alternatively, procurement through a contract tender process would see AEMO pay market participants for the provision of the services. These costs may be recovered from market participants through a method similar to the existing arrangements for the recovery of SRAS. AGL has proposed the procurement of inertia services through a contract tender process with a cost recovery arrangement based on a 50/50 split between customers and incumbent generators.[51]

An obligation on generators to provide additional system security services, such as inertia or fast response FCAS, as a condition of market participation, would see the costs borne by the generators that provide the service. It would be expected that these costs would be passed through to consumers to the extent that competition permits.

Question 6

What form of cost recovery do you consider to be preferable in the design of a mechanism to procure additional system security services?

Should the cost recovery mechanism be designed to create stronger incentives to provide the required services?

51 AGL, *Rule change request – NEM Wide Inertia Ancillary Service*, 24 June 2016, p. 4.

5 Lodging a submission

The Commission has published a notice under section 95 of the NEL for the rule change requests that relate to this consultation paper inviting written submissions. Submissions are to be lodged online or by mail by 13 October 2016 in accordance with the following requirements.

Where practicable, submissions should be prepared in accordance with the Commission's Guidelines for making written submissions on rule change requests. The Commission publishes all submissions on its website, subject to a claim of confidentiality.

All enquiries on this project should be addressed to Sebastien Henry on (02) 8296 7800.

5.1 Lodging a submission electronically

Electronic submissions must be lodged online via the Commission's website, www.aemc.gov.au, using the "lodge a submission" function and selecting the relevant project reference code as follows:

EPR0053 – System Security Market Frameworks Review

ERC0208 – Inertia Ancillary Services Market

ERC0214 – Managing Power System Frequency

ERC0211 – Managing Power System Fault Levels

Comments made in submissions that do not reference a particular project code will be treated as comments that apply to all and any of the rule change requests and the Review.

The submission must be on letterhead (if submitted on behalf of an organisation), signed and dated.

Upon receipt of the electronic submission, the Commission will issue a confirmation email. If this confirmation email is not received within 3 business days, it is the submitter's responsibility to ensure the submission has been delivered successfully.

5.2 Lodging a submission by mail

The submission must be on letterhead (if submitted on behalf of an organisation), signed and dated. The submission should be sent by mail to:

Australian Energy Market Commission
PO Box A2449
Sydney South NSW 1235

Or by Fax to (02) 8296 7899

The envelope must be clearly marked with the relevant project reference code, as above.

Except in circumstances where the submission has been received electronically, upon receipt of the hardcopy submission the Commission will issue a confirmation letter.

If this confirmation letter is not received within 3 business days, it is the submitter's responsibility to ensure successful delivery of the submission has occurred.