Reliability Panel
AEMC

PANEL
DETERMINATION

Reliability Panel AEMC

STAGE ONE DRAFT DETERMINATION

Review of the frequency operating standard

12 September 2017

Submissions due 10 October 2016. Reference: REL0065
Stage one Draft Determination

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AEMC 2017, Review of the frequency operating standard, Stage one Draft Determination, 12 September 2016, Sydney

About the Reliability Panel
The Panel is a specialist body within the Australian Energy Market Commission (AEMC) and comprises industry and consumer representatives. It is responsible for monitoring, reviewing and reporting on reliability, security and safety on the national electricity system, and advising the AEMC in respect of such matters. The Panel's responsibilities are specified in section 38 of the National Electricity Law.

Executive Summary

The Reliability Panel (Panel) has prepared this draft determination for stage one of the frequency operating standard (FOS) Review 2017.

Under the National Electricity Rules (NER), the Reliability Panel (Panel) is responsible for determining the power system security standards, including the frequency operating standards (FOS) that apply to the National Electricity Market (NEM).

What is the FOS?

The FOS include defined frequency bands and timeframes in which the system frequency must be restored following different events, such as the failure of a transmission line or separation of a region from the rest of the NEM. These requirements then inform how AEMO operates the power system, including through applying constraints to the dispatch of generation or procuring ancillary services.

The FOS does not set out the specific arrangements for how frequency is managed, such as the arrangements for generation and load shedding and the specification and procurement of Frequency Control Ancillary Services (FCAS).

The review of the FOS

The Reliability Panel (Panel) is undertaking a review of the FOS that applies for Tasmania and for the mainland NEM. The Panel is proposing to complete this review in two stages. This staged approach reflects the various ongoing reviews of market and regulatory arrangements that are likely to have an impact on the Panel's ability to effectively assess the FOS. In particular, the Panel recognises the interactions between this review and the AEMC's *Frequency control frameworks review* which will consider the market frameworks necessary to support better frequency control.

In addition the Panel recognises the important role that the AEMO ancillary services technical advisory group plays in informing stage two of this review.

This draft determination sets out the Panel's considerations in relation to the draft FOS for stage one of the review (the draft FOS) as well as presenting the Panel's initial thoughts in relation to issues to be considered through stage two of the review.

The draft FOS for stage one of the review

The Panel has made a draft FOS for Tasmania and for the mainland, which responds to a number of issues that were identified in the issues paper to be addressed through stage one of this review. The draft FOS differs from the current FOS in a number of key ways:

- The inclusion of a standard for protected events in the FOS. This is the same as the interim standard that was applied for protected events following the Emergency frequency control schemes rule change. The draft FOS states that following a protected event, the frequency should remain within the emergency frequency excursion tolerance limits.
- The revision of the requirements in the FOS in relation to multiple contingency events. The Daft FOS requires that AEMO use reasonable endeavours to

stabilise and restore the power system following non-credible contingency events and multiple contingency events that are not protected events.

- The revision of the definition of 'generation event' to include the sudden, unexpected and significant change in output from one or more generating systems of 50MW or more within a 30 second period.

  This revision is being made to make it clear that AEMO is able to use contingency FCAS to manage sudden variations of generation output from the increasing quantity of larger variable renewable generation power stations. Under the current regulatory framework the Panel considers that it is more appropriate for these types of variation of generation output to by managed with contingency FCAS as compared to regulating FCAS. This change is expected to result in lower FCAS costs over the short term than would otherwise be the case.

- The revision of the definition of an island for the purpose of application of the FOS for island operation following a separation event. This revised definition maintains the key elements of the existing definition of an island with the addition of a new requirement, that an island must be at least the equal to or greater than an inertia sub-network.

- The increase of the limit for accumulated time error that applies for the mainland from 5 to 15 seconds. The limit of accumulated time error in the draft FOS for Tasmania remains unchanged at 15 seconds.

  The Panel's initial consideration is that there may be a case for the complete removal of the accumulated time error limit. However, there is some possibility that the removal of this time error limit could have unforeseen impacts on large and small consumers. In order to limit the risk, the Panel has decided to initially relax the accumulated time error limit, with a view to the potential for full removal, once consultation has been undertaken with a wider range of consumers.

  The Panel will continue to consult with stakeholders in relation to the potential removal of the accumulated time error limit from the FOS through the course of stage two of this review.

The Panel is seeking stakeholders' views on all aspects of the Draft FOS.

Submissions from stakeholders are due by 10 October 2017.

Issues for consideration in stage two of the Review

During stage two of the Review, the Panel will conduct a thorough review of the settings of the FOS, including examining the boundaries of the various frequency bands and the timeframes for restoration of power system frequency following specific events.

In discussing the issues for consideration during stage two of the review, the Panel has identified three broad sets of power system conditions for which the FOS applies:

- normal operation – no contingency events
- management of credible contingency events
- management of emergency conditions.

Issues relating to the FOS for normal operation

Normal operating conditions refer to operation of the power system in the absence of any contingency event, that is with all generators and network elements operating as expected with no unplanned outages.

In considering how the FOS applies to normal operation during stage two or the review, the Panel may consider:

- Whether the current boundaries for the normal operating frequency band and the normal operating excursion frequency band are set appropriately, with a particular focus on whether tightening this band may deliver improved system security outcomes and what impacts such a change may have on regulating FCAS costs.
- Whether the current stabilisation and recovery times remain appropriate.
- Whether, in the absence of a contingency event, it remains appropriate to maintain the power system frequency within the normal operating frequency band for 99% of the time and allow excursions within the normal operating frequency excursion band for 1% of the time.

Issues relating to the management of credible contingency events

In the FOS, the management of contingency events is prescribed though the settings of the operational frequency tolerance band and a number of narrower bands that set the requirement for certain types of credible contingency events, such as generation, load and network events.

In considering how the FOS applies to the management of credible contingency events during stage two or the review, the Panel may consider:

- Whether the current boundaries of the operating frequency tolerance band are appropriately set to effectively manage the impact of credible contingency events while efficiently allocating contingency FCAS services to the performance of this task.
- Whether it is appropriate for separate frequency bands to apply for load, generation and network events on the mainland, or whether the operational frequency tolerance band should apply for all single contingencies, as is the case in Tasmania.
- Whether the existing lower thresholds for load and generation events are appropriately set in the FOS for the mainland and for Tasmania.
- Whether the existing upper limit on the size of a generation event in Tasmania of 144MW continues to be appropriate and whether this limit should be extended to cover network events in Tasmania, as request by TasNetworks.

Issues relating to the management of emergency conditions

The management of the power system during emergency conditions includes the preparation for and operation of the power system in the event of high impact low probability events, such as non-credible contingency events including multiple contingency events and protected events.

During stage two of the Panel will consider whether or not there exist any immediate drivers for changing the extreme frequency excursion tolerance limit that specifies the limits for satisfactory operation of the power system during emergency conditions.

The Panel is also seeking stakeholders' views on the preliminary issues identified for consideration during stage two of the review.

Submissions from stakeholders on these issues are due by 10 October 2017.

Reliability Panel members

Neville Henderson, Chairman and AEMC Commissioner

Trevor Armstrong, Chief Operating Officer, Ausgrid

Lance Balcombe, Chief Executive Officer, TasNetworks

Murray Chapman, Executive Officer, Strategy & Innovation, AEMO

Mark Collette, Executive Energy, EnergyAustralia

Royce De Sousa, General Manager - Energy & Sustainability, Visy

Gavin Dufty, Manager Policy and Research, St Vincent de Paul Society, Victoria

Miles George, Strategic Adviser, Infigen Energy Ltd

Chris Murphy, Strategic Advisor, Meridian Energy and General Manager – Energy Market Interfaces, Telstra

Richard Wrightson, Executive General Manager, Wholesale Markets, AGL Energy

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1 Introduction

The Reliability Panel has been directed by the Australian Energy Market Commission to undertake a review of the frequency operating standards (FOS) that apply for the NEM mainland and for Tasmania in accordance with its responsibilities under the National Electricity Rules (Rules).[1]

The Panel's draft findings are set out in this report and the Panel invites comments from stakeholders on these draft findings.

1.1 Review of the FOS

NER clause 8.8.1(a)(2) requires the Reliability Panel to review and, on the advice of the Australian Energy Market Operator (AEMO), determine the power system security standards. These standards govern the maintenance of system security and reliability in the NEM; at present the only power system security standards that apply in the NEM are the FOS for the mainland NEM and for Tasmania. The FOS define the range of allowable frequency for the power system under different conditions, including normal operation and following contingency events.

The FOS include defined frequency bands and timeframes in which the system frequency must be restored following different events, such as the failure of a transmission line or separation of a region from the rest of the NEM. These requirements then inform how AEMO operates the power system, including through applying constraints to the dispatch of generation or procuring ancillary services.

The FOS also defines the frequency bands and timeframes which are referred to by the performance standards that apply to generator and network equipment in the NEM. In combination with the FOS, these performance standards align the power system frequency managed by AEMO with the capability of NEM power system equipment, including generating and network systems.

The FOS does not set out the specific arrangements for how frequency is managed, such as the arrangements for generation and load shedding and the specification and procurement of Frequency Control Ancillary Services (FCAS).

1.2 Terms of reference

On 30 March 2017, the Australian Energy Market Commission (AEMC) provided Terms of Reference to the Panel to initiate a review of the FOS (the Review).

Among other things, the Terms of Reference require the Panel to give consideration to:

- Whether the terminology, standards and settings in the FOS remain appropriate.
- What amendments to the Standard may be necessary in light of the AEMC's final determination of the Emergency Frequency Control Schemes rule change published on 30 March 2017.
- Whether further guidance can be provided regarding the definition of what part of the power system the FOS is to be applied following separation from the rest

1 Clause 8.8.1(a)(2) of the NER.

of the NEM. Specifically, whether the FOS should refer to a separated region, or some smaller subsection of a region, for maintenance of frequency following a separation event.

On 12 September 2017 the Commission issued revised terms of reference for the review to accommodate the Panel's proposed staged approach. The revised terms of reference require the Review to be completed by 31 July 2018 in line with recommendation 2.3 from the Finkel Panel report.[2] Recommendation 2.3 from the Finkel Panel report, recommended that by mid-2018, the Australian Energy Market Operator and Australian Energy Market Commission should:[3]

- Investigate and decide on a requirement for all synchronous generators to change their governor settings to provide a more continuous control of frequency with a deadband similar to comparable international jurisdictions.
- Consider the costs and benefits of tightening the frequency operating standard.

These issues are discussed in section 5.1.2.

The revised terms of reference for this Review can be seen in Appendix A.

1.3 Timetable for the Review

In carrying out this review, the Panel will follow a consultation process that is consistent with clause 8.8.3 of the NER and the Terms of Reference. The Panel will consult with stakeholders through seeking submissions on this stage one draft determination and the subsequent draft report for stage two of the review. The Panel will also carry out face to face meetings and a public forum may be arranged as required at the request of stakeholders.

The Panel is proposing to complete this review in a staged manner. These two stages of the review will be commenced at different times and will cover different subject matter. This staged approach reflects the various ongoing reviews of market and regulatory arrangements that are likely to have an impact on the Panel's ability to effectively assess the FOS.

Stage one of the Review will consider what amendments to the FOS may be necessary in light of the recent emergency frequency control scheme rule change, which includes the introduction of the protected event contingency category made in the recent emergency frequency control schemes rule change.[4] Furthermore, there are a number of technical changes to the FOS that can be assessed immediately.

Stage two of the Review will include a general consideration of the various components of the FOS, including the settings of the frequency bands and time requirements for maintenance and restoration of system frequency.

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2 Finkel Panel, June 2017, *Independent Review into the Future Security of the National Electricity Market – Blueprint for the Future, pp.21,61.*

3 Finkel Panel, June 2017, *Independent Review into the Future Security of the National Electricity Market – Blueprint for the Future, pp.21,61.*

4 AEMC, Emergency frequency control schemes, Rule Determination, 30 March 2017.

The following table outlines the key milestones and dates leading to the delivery of the Panel's final report to the AEMC.

Table 1.1 Timetable for the Review

Milestone	Proposed Date
Publication of Issues Paper	11 July 2017
Close of submissions to Issues Paper	1 August 2017
Publication of Draft Determination and Standard – Stage one	12 September 2017
Close of submissions to Draft Determination – Stage one	10 October 2017
Publication of Final Determination and Standard– Stage one	7 November 2017

1.4 AEMO Advice

As per NER clause 8.8.1(a)(2) the Panel is required to, "review and, on the advice of AEMO, determine the power system security standards". Therefore, in addition to consulting with key stakeholders, the Panel also obtained advice from AEMO to support its determination of this Draft FOS for stage one of the review.

The content of this advice is described in further detail in section 3.3.

1.5 Submissions on the Panel's draft determination

The Panel invites written submissions on this draft determination and Draft Standard from interested parties by no later than 10 October 2017. All submissions received will be published on the AEMC's website (www.aemc.gov.au), subject to any claims for confidentiality.

Electronic submissions must be lodged online through the AEMC's website using the link entitled "lodge a submission" and reference code "REL0065". The submission must be on letterhead (if submitted on behalf of an organisation), signed and dated.

Upon receipt of electronic submissions, the AEMC's website will issue a confirmation email. If this confirmation email is not received within three businesses days, it is the submitter's responsibility to ensure the submission has been delivered successfully.

If choosing to make submissions by mail, the submission must be on letterhead (if submitted on behalf of an organisation), signed and dated. The submission may be posted to

Reliability Panel
PO Box A2449
Sydney South NSW 1235
Or by Fax to (02) 8296 7899.

1.6 Structure of the draft determination

The remainder of this draft determination is structured as follows:

- Chapter 2 describes the background to this review, including a summary of recent and ongoing related work programs.
- Chapter 3 sets out the Panel's assessment approach for this review.
- Chapter 4 sets out the key elements of the draft FOS for stage one of the review.
- Chapter 5 sets out the Panel's thinking in terms of the approach to stage two including a preliminary discussion of a number of issues for consideration in stage two.

2 Background

The chapter sets the context for this review including a summary of recently completed and ongoing work programs related to this review of the FOS.

The issues paper for this review provides a description of the concept of power system frequency and frequency control in the NEM.[5]

As described in section 1.2, the Panel is undertaking this review of the FOS in response to a terms of reference provided by the AEMC to amend the FOS following the publication of *Emergency frequency control schemes* rule change.[6] At the same time this review takes place during a time of rapid technological and behavioural change in the power system. As the issues paper identified, the performance of the power system frequency in terms of being maintained within a tight band around 50Hz has degraded in recent years.[7]

2.1 Related Work Programs and rule changes

There are a number of ongoing work programs that relate to this review, including:

- AEMO, *Future power system security work program*
- AEMC, *Rate of change of power system frequency* rule change
- AEMC, *Inertia ancillary service market* rule change
- AEMC, *Frequency control frameworks review* – commenced July 2017
- AEMC, *Reliability frameworks review* – commenced July 2017

In addition, the Panel will consider work progressed by the Ancillary Services Technical Advisory Group as facilitated by AEMO.

2.1.1 Future power system security work program

AEMO is currently developing its Future power system security work program to address operational challenges arising from the changing generation mix in the NEM. Progress reports for this work program were published on 12 August 2016 and 31 January 2017.

In February 2017, as part of this work program, AEMO convened the Ancillary Services Technical Advisory Group, to bring together technical experts from the power industry to investigate solutions for current and future issues relating to ancillary services and power system security. AEMO has engaged the power system advisory firm DIgSILENT to investigate and report on the cause(s) and consequences of the observed changes to the NEM frequency distribution profile.

Preliminary results for the DIgSILENT investigation into frequency control in the NEM

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5 Reliability Panel, *Review of the frequency operating standard* – Issues Paper, 11 July 2017.

6 AEMC, *Emergency frequency control schemes*, Rule Determination, 30 March 2017.

7 Reliability Panel, *Review of the frequency operating standard* – Issues Paper, 11 July 2017, pp.23-25.

The preliminary results of the DIgSILENT analysis were presented to the AS-TAG on 9 August 2017. The Panel understands that the DIgSILENT analysis has confirmed that a reduction in primary frequency response within the NEM during normal operation is a root cause in the degradation of frequency performance observed in recent times. A discussion of primary frequency response and how it relates to the FOS is included in section 5.1.2.

The DIgSILENT analysis also identified that AEMO's automatic generation control (AGC) is not designed to be able make up for the reduction in primary frequency control.[8] The Panel understands that the AGC system is capable of responding to generation and demand imbalance within approximately 30 seconds whereas primary frequency control is able to respond almost immediately to frequency deviations based on local frequency measurement and automatic response through the generator governor control systems. The issue of primary frequency response and the related regulatory frameworks is being considered by the AEMC in the *Frequency control frameworks review,* which is discussed in section 2.1.3.

The DIgSILENT analysis also identified a number of other contributing factors to poor frequency performance in the NEM, including:

- An increase in contrary frequency control behaviour

  Contrary frequency control has been found to occur due to a number of situations where the AGC instruction to generators may run contrary to the recovery of a frequency deviation. For example the frequency is above 50Hz and the AGC system is sending out "raise" signals to generators enabled to provide regulating FCAS. One of the causes of this phenomena is time error correction, which is discussed in section 4.6.

- A reduction in load frequency response due to the increase of inverter supplied loads such as loads supplied by variable speed drives.

- A reduction in system inertia due to the increase of inverter supplied generation in the NEM and the retirement of aging large thermal units. This issues is being addressed by the AEMC in the *Managing the rate of change of power system frequency* rule change and *Inertia ancillary service market* rule change.[9]

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8 The AGC is designed as a secondary control system that centrally measures the power system frequency and sends out "raise" or "lower" signals to the registered generators and loads that are dispatched to provide FCAS to correct the small frequency deviations.

9 See:
http://www.aemc.gov.au/Rule-Changes/Managing-the-rate-of-change-of-power-system-freque
http://www.aemc.gov.au/Rule-Changes/Inertia-Ancillary-Service-Market

2.1.2 Rate of change of power system frequency and Inertia ancillary service market rule changes

On 27 June 2017 the AEMC published a draft rule, *Managing the rate of change of power system frequency*. The main features of the draft rule are:[10]

- An obligation on AEMO to determine sub-networks in the NEM that are required to be able to operate independently as an island and, for each sub-network, assess whether a shortfall in inertia exists or is likely to exist in the future.
- Where an inertia shortfall exists in a sub-network, an obligation on the relevant TNSPs to make continuously available, minimum required levels of inertia, determined by AEMO through a prescribed process.
- An ability for TNSPs to contract with third-party providers of alternative frequency control services, including fast frequency response (FFR) services, as a means of meeting a proportion of the obligation to provide the minimum required levels of inertia, with approval from AEMO.
- An ability for AEMO to enable the inertia network services provided by TNSPs and third-party providers (ie, instruct them to provide inertia) under specific circumstances in order to maintain the power system in a secure operating state.

To complement the obligation on TNSPs to provide a level of inertia associated with maintaining system security, the AEMC considered that it would be important to also introduce a mechanism to provide inertia additional to the minimum secure operating level. This would allow for greater power transfer capability across the network, resulting in realisation of market benefits.

To implement such a market benefits mechanism as soon after the system security obligations as possible, the AEMC decided to progress this mechanism through the *Inertia ancillary service market* rule change. The Panel will monitor developments with regard to this rule change, for which a draft determination is expected to be published by the Commission on 7 November 2017.[11]

2.1.3 Frequency control frameworks review

On the 7 July 2017, the AEMC self-initiated the *Frequency control frameworks review* to investigate the appropriateness of the regulatory and market frameworks that relate to frequency control in the NEM. The scope of this review includes:[12]

- assessing whether mandatory governor response requirements should be introduced and investigating any consequential impacts including on the methodology for determining causer pays factors for the recovery of FCAS costs
- reviewing the structure of FCAS markets, to consider:
  - any drivers for changes to the current arrangements, how to most appropriately incorporate FFR services, or alternatively enhancing

10 AEMC, *Managing the rate of change of power system frequency* – draft rule determination, 27 June 2017, p.iii.

11 AEMC, *System security market frameworks review*- final report, 27 June 2017, pp.36-38.

12 AEMC, *Frequency control frameworks review* – terms of reference, 7 July 2017.

- incentives for FFR services, within the current six second contingency service
- any longer-term options to facilitate co-optimisation between energy, FCAS and inertia provision

- assessing whether existing frequency control arrangements will remain fit for purpose in light of likely increased ramping requirements, driven by increases in solar PV reducing operational demand at times and therefore leading to increased demand variation within a day
- considering the potential of distributed energy resources to provide frequency control services and any other specific challenges and opportunities associated with, their participation in system security frameworks.

2.1.4 AEMC, Reliability frameworks review

On the 22 August the AEMC published an issues paper for the *Reliability frameworks review.*

This review will consider what changes to existing regulatory and market frameworks are necessary to provide an adequate amount of dispatchable capacity in the NEM to meet the reliability standard. This involves longer-term considerations such as having the right amount of investment, as well as shorter-term operational considerations to make sure an adequate supply is available at a particular point in time. To deliver a reliable supply to consumers it is necessary to always have the level of supply to be greater than current demand to allow for unexpected changes. This margin of supply over demand is termed 'reserves', and essentially acts to deal with unexpected developments.

The Reliability frameworks review will examine the regulatory and market frameworks associated with reliability in a holistic manner, and in the context of the NEM's existing industry structure and drivers of reliability frameworks. It will identify any changes to the current reliability frameworks needed to facilitate the efficient investment, retirement, operation and maintenance decisions that are required to produce an adequate supply of dispatchable capacity, given the current and expected environmental policy mechanisms.

The Reliability frameworks review will address the appropriateness of the existing contingency event framework in the NER in light of the issues raised by AEMO in relation to the current and future power system environment, where variances from demand and intermittent supply may be greater than the loss of a largest generator.[13] The Panel notes the commonality between this issue and the Panels consideration of the definition of generation event in the FOS, which is discussed in section 4.4.

13 AEMC, 22 August 2017, *Reliability frameworks review* – Issues Paper, pp.55-59

3 Assessment Approach

This chapter sets out the assessment framework that the Panel has considered when undertaking the review of the FOS.

3.1 The objective of the review

In undertaking the Review of the FOS, the Panel will be guided by the National electricity objective (NEO) which is set out under section 7 of the National Electricity Law (NEL). The NEO is to

> "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."

The Panel considers that the relevant aspects of the NEO for its review of the FOS are the operation of electricity services, with particular respect to the safety and security of the national electricity system and the price, quality and security of supply of electricity.

In undertaking its review, the Panel will exercise its judgement when considering potential changes to components of the FOS, with a view to striking an appropriate balance between providing improved quality and security outcomes against the cost of delivering those outcomes.[14]

The complexity of optimising the FOS is also related to the fact that while changing any specific component of the FOS may change system security outcomes, it is also likely to impose costs on various participants through meeting more strenuous obligations in relation to the elements of the performance standards related to frequency, or on AEMO through a requirement to procure additional ancillary services or constrain dispatch. The setting of each component of the FOS therefore needs to be considered in terms of the balance between these security benefits and costs.

In its assessment of any changes to the components of the FOS and consistent with satisfying the relevant aspects of the NEO outlined above, the Panel will therefore give consideration to the following principles:

- **Supporting a safe and secure system:** the power system can be considered to be secure when it is operated within specified technical operating limits, including voltage and other stability limits. Maintaining the NEM power system within these technical limits allows it to operate effectively, efficiently and safely.

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14 In this sense the term "quality" refers to electrical power quality which is a measure of the uniformity of the voltage waveform which describes the fluctuating system voltage and the associated frequency. A high level of power quality relates to a stable system voltage at a steady frequency where the power system is resilient to contingency events. A low level of power quality occurs when the system voltage and frequency fluctuate more widely in response to destabilising events.

Supporting a safe and secure system will be a key consideration of the Panel when determining the FOS.

- **Minimising consequences for the prices consumers pay for electricity:** To maintain the safety and security of the national electricity system, AEMO procures ancillary services and operates the system to keep it within specific limits, generators operate and maintain their units in accordance with performance standards, and network service providers maintain and operate their networks in accordance with system standards.

  These activities come at a cost in terms of obligations faced by participants and AEMO and are ultimately borne by consumers through the price they pay for electricity. The Panel will consider how the settings of the FOS are likely to impact on the costs incurred by different participants in maintaining the security of the system.

Ultimately, the Panel's responsibility in determining the FOS is to identify a reasonable, effective and efficient trade-off between the security benefits of a more stringent FOS, against the costs that this would impose on consumers. While it is essential that minimum limits of security and safety are maintained, this should occur at the lowest possible cost for consumers. Furthermore, the Panel will exercise its judgement in deciding whether additional security benefits above this basic, minimum level are warranted, given the incremental costs of providing that additional security. These trade-offs will be central to all of the Panel's consideration in both stage one and two of the review.

3.2 Staging of the review

The Panel is undertaking this review of the FOS in a staged manner, to accommodate changes to the market and regulatory arrangements arising from the work described in section 2.1.

The first stage will address primarily standalone technical and administrative issues and market framework changes stemming from the emergency frequency control scheme rule change.

The second stage will include a general consideration of the various components of the FOS, including the settings of the frequency bands and time requirements for maintenance and restoration of system frequency. Stage two will consider changes to the FOS reflecting ongoing developments of the market and regulatory arrangements and will commence at a later date, once these developments of the market arrangements have been further progressed.

The Panel received 12 submissions from stakeholders in response to the Issues Paper for this review. These submissions were overwhelmingly in favour of the Panel's staged approach to the review of the FOS.[15] AEMO's submission notes that the two stage approach to the review "allows immediate concerns to be addressed while allowing

15 Submissions to the *Review of the frequency operating standard* – Issues Paper: Department of Premier and Cabinet SA, p.1.; ERM Power, p.5; Hydro Tasmania, p.1; Meridian Energy, p.2; Origin Energy, p.1; PIAC, p.1.

more complicated, longer-term matters to be informed by analysis underway by AEMO, the AEMC and industry."[16]

3.2.1 Stage one

This draft determination presents the Panel's draft findings in relation to a number of issues identified in the issues paper for immediate action.

The issues that are being actioned with this draft determination for stage one are:

- Inclusion of a standard to apply to protected events.
- Amendments to the requirements for multiple contingency events
- Review of the definition of terms in the FOS, including:
  - the definition of a generation event.
  - the definitions that relate to island operation in the FOS
- Review of the requirement for accumulated time error in the FOS

Chapter four describes the Panel's considerations in relation to addressing these issues in the related changes that are included in the draft FOS to be determined and published at the end of stage 1.

3.2.2 Stage two

Stage two of the review will commence following the publication of the final determination for stage one. Stage two will involve an assessment of each of the elements of the FOS, including the boundaries of the various frequency bands and the timeframes for restoration of power system frequency following a specific event.

This assessment requires consideration of the complex interactions between the regulatory and market frameworks and the various elements of the FOS. This will in turn require consideration of the trade-offs between system security impacts and costs for consumers.

However, the Panel's ability to meaningfully undertake this analysis is dependent on the progression and further resolution of a number of ongoing reform processes to the market and regulatory arrangements. These review processes are described in section 2.1.

The Panel recognises the strong interdependencies between this review and the outcomes of the AEMC *Frequency control frameworks review* which was initiated on 7 July 2017. The *Frequency control frameworks review* will include consideration of:

- whether mandatory governor response requirements should be introduced
- whether existing frequency control arrangements remain fit for purpose and whether the FCAS markets are appropriately structured.

16 AEMO, Submission to the *Review of the frequency operating standard* – Issues Paper, p.3.

Furthermore the Panel reiterates the importance of the AEMO's investigations into frequency control through the *Future power system security work program* and associated Ancillary Services Technical Advisory Group (AS-TAG).

Chapter five describes the Panel's current thinking in relation to some of the key issues that are likely to be considered to stage two.

3.3 AEMO advice

In determining the Draft FOS, the Panel sought and received relevant technical advice from AEMO relating to the operation of the NEM power system.[17]

The AEMO advice for stage one of the FOS review covers the issues identified for consideration in stage one as set out in section 3.2.1.

A summary of the AEMO advice related to each of these issues is included within the "stakeholder views" sections for each of the stage one issues discussed in Chapter 4.

17 AEMO, *Review of the frequency operating standard*, stage 1 – request for advice, 18 August 2017. See: http://www.aemc.gov.au/Markets-Reviews-Advice/Review-of-the-Frequency-Operating-Standard

4 The draft FOS

This chapter outlines the Panel's key findings for the draft FOS to be determined and published at the end of stage 1 of this review.

- Section 4.1 provides an overview of the key revisions in the Draft FOS. The following sections then describe the Panel's considerations for each of these changes:
- Section 4.2 describes the inclusion of a standard to apply to protected events.
- Section 4.3 describes amendments to the requirements for multiple contingency events.
- Section 4.4 describes the definition of the term, 'generation event'.
- Section 4.5 describes definition of the terms related to island operation.
- Section 4.6 describes the requirement for accumulated time error.

The arrangements and timing for the implementation of the draft FOS at the end of stage 1 are discussed in section 4.7.

4.1 Overview of the draft FOS

The Panel has made the following changes which are incorporated in the Draft FOS for Tasmania and for the mainland:

- inclusion of a standard for protected events
- revision of the requirements in the FOS in relation to multiple contingency events
- expansion of the limit for accumulated time error in the mainland.
- revision of the definition of "generation event"
- revision of the definitions related to island operation.

Box 6.1 presents the key elements of the Draft FOS which is found in full in Appendix A.[18]

Box 4.1 Draft FOS to be determined and published at the conclusion of stage 1

1) Protected events

The draft FOS sets out a standard for protected events. This is the same as the interim standard that was applied for protected events following the Emergency frequency control schemes rule change. The draft FOS states that following a protected event, the frequency should remain within the emergency frequency

18 The Draft FOS for the mainland NEM is set out it Appendix A.1.
The Draft FOS for Tasmania is set out in Appendix A.2.
The definitions that apply for both the Tasmanian and the mainland FOS have been combined and are set out in Appendix A.3.

excursion tolerance limits.

Draft FOS - Part B (f)

> "as a result of any protected event, system frequency should not exceed the *extreme frequency excursion tolerance limits* and should not exceed the applicable generation and load change band for more than two minutes while there is no contingency event or exceed the applicable *normal operating frequency band* for more than ten minutes while there is no contingency event."

2) Multiple contingency events

The draft FOS includes a revised requirement for multiple contingency events. The revised requirement requires AEMO use "reasonable endeavours" to stabilise and restore the power system following non-credible contingency event and multiple contingency event that are not protected events.

Draft FOS - Part B (g)

> "following the occurrence of any *non-credible contingency event* or *multiple contingency event* that is not a *protected event*, AEMO should use reasonable endeavours to:
>
> i. maintain system frequency within the *extreme frequency excursion tolerance limits* and
>
> ii. avoid the system frequency exceeding the applicable generation and load change band for more than two minutes while there is no contingency event or exceeding the applicable *normal operating frequency band* for more than ten minutes while there is no contingency event.

3) Definition of Generation event

The draft FOS includes an amended definition of generation event, to include in this definition the rapid and unexpected change in output from one or more generating systems.

The definition of generation event in the Draft FOS:

> "means:
>
> 1. a *synchronisation* of a *generating unit* of more than 50 MW, or
> 2. a sudden, unexpected and significant increase or decrease in the *generation* of one or more *generating systems,* totalling more than 50MW in aggregate within a period of 30 seconds or less, or
> 3. a *credible contingency event*, not arising from a load event, a *network event*, a *separation event* or a part of a *multiple contingency event*."

4) Definition of an "island" for the FOS

The Draft FOS includes an amended definition of the term "island" to specify that an island must be no smaller than an inertia sub-network.

The definition of the term "island" in the Draft FOS is :

"means a part of the *power system* that includes *generation*, *networks* and *load*, for which all of its alternating current network connections with other parts of the *power system* have been disconnected, provided that the part:

(a) does not include more than half of the combined *generation* of the *regions* formed by the separation event(determined by available capacity before disconnection); and

(b) contains at least one whole *inertia sub-network*."

The definition of inertia sub network is added to the Draft FOS as:

"has the meaning given to it in the rules."

5) Accumulated time error:

The limit on accumulated time error for the mainland in the Draft FOS has been increased from 5 to 15 seconds.

The limit on accumulated time error for Tasmania in the Draft FOS remains unchanged at 15 seconds.

4.2 Inclusion of protected events in the FOS

As discussed in the issues paper, the *Emergency frequency control schemes* final rule introduced into the NER a new classification of contingency event, the protected event.[19] A protected event is a non-credible contingency event that is defined by AEMO and declared by the Panel. It may include any non-credible event or multiple contingency event, where the cost of managing the event as a protected event is in the long term interest of consumers, in accordance with the NEO.[20]

The Panel has determined the FOS that should apply following the occurrence of a protected event. Accordingly, Part B(f) of the Draft FOS includes a requirement that:

> "as a result of any protected event, system frequency should not exceed the *extreme frequency excursion tolerance limits* and should not exceed the applicable generation and load change band for more than two minutes while there is no contingency event or exceed the applicable *normal operating frequency band* for more than ten minutes while there is no contingency event."

This draft FOS for protected events is the same as the interim FOS that was included in the NER as part of the *Emergency frequency control schemes* rule, which introduced the concept of protected events to the NER.[21]

4.2.1 Current requirements of the interim FOS

While the FOS for Tasmania and for the mainland do not currently include a standard for protected events, chapter 11 of the NER includes an interim FOS that applies to all protected events, until such time as the Panel determines the frequency standard that

19 Reliability Panel, Review of the frequency operating standard – Issues paper, 11, July 2017, p.39.

20 AEMC, 2017, *Emergency frequency control schemes*, rule determination, 30 March 2017, pp.62-65.

21 AEMC, 2017, *Emergency frequency control schemes*, rule determination, 30 March 2017.

applies for a protected event.[22] This interim FOS was included in the NER as part of the *Emergency frequency control schemes* rule.

The interim FOS for a protected event is currently set out for Tasmania and for the mainland as follows:

> "For a protected event, system frequency should not exceed the applicable extreme frequency excursion tolerance limits and should not exceed the applicable load change band for more than two minutes while there is no contingency event or the applicable normal operating frequency band for more than 10 minutes while there is no contingency event."

4.2.2 Stakeholder views

Most of the submissions received to the issues paper indicated support for the continuation of the interim FOS for protected events.[23] Within the context of assessing the costs and benefits of applying a tighter or a narrower frequency band for protected events, Energy Australia noted in their submission that:

> "We consider that the ultimate goal of the Reliability Panel should be to keep the parameters as close to the appropriate non-credible contingency definition as possible."[24]

Origin Energy noted in their submission that the frequency band in the FOS for a protected event should be set such that:

> "AEMO use a combination of market mechanisms and EFCS to maintain the NEM in a satisfactory operating state."[25]

The Panel understands that in order for a combination of market mechanisms and EFCS to be utilised to manage protected events, the applicable frequency band is required to be wider than the operation frequency tolerance band, to allow for the operation of EFCS based on frequency relays.[26]

A number of stakeholders noted that the FOS for protected events should be set so as to minimise the cost to consumers.[27]

Some stakeholders suggested that it would be appropriate for individual frequency standards to be defined for each protected event, and that these should be determined through bespoke cost benefit analysis.[28] However, Energy Australia recognised in their submission that the benefits of a consistent approach may be more cost effective than the complexity of setting targeted standards for a large number of protected events.[29]

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22 NER cl. 11.97.2 Interim frequency operating standards for protected events.

23 Submissions to the Issues Paper: ENA p.2; AEMO p.5; TasNetworks, p.6.

24 Energy Australia, Submission to the Issues Paper, p.3.

25 Origin Energy, Submission to the Issues Paper, p.1.

26 Such as the under frequency load shedding schemes that operate below 49Hz.

27 Submissions to the Issues Paper: PIAC, p.1; Energy Australia p.3.

28 Submissions to the Issues Paper: Engie, pp.3-4; Meridian, p.2.

29 Energy Australia, Submission to the Issues Paper, p.3-4.

ERM argued that due the potential for significant impacts from a protected event, the FOS for a protected event should be set tighter than the current FOS for multiple contingencies, at a similar level to that of a separation event.[30]

The South Australian government submission indicated support for the continuation of the interim FOS for protected events, as a starting point, noting that in the event of a protected event, the operation of under frequency EFCS ,"may or may not be successful to avoid cascaded failure depending on the ROCOF at the time". The SA government argues that to address this issue, the Panel should consider including a rate of change of frequency (ROCOF) limit in the FOS for protected events and in the FOS more generally.[31] The consideration of whether the FOS should contain a ROCOF limit is mentioned in section 5.4 as an issue for consideration in stage two of this review.

AEMO Advice

AEMO's advice to the Panel for this review supported the continued application of the interim protected events standard for inclusion in the FOS for the mainland and for Tasmania. AEMO's advice noted that maintaining the power system within the broadest frequency band, the extreme frequency excursion tolerance limit, is appropriate as it allows "flexibility in operational response and economic efficiency to be realised". AEMO stated that:[32]

> "While a broad frequency band means that some load shedding may be allowable as a result of a protected event occurring, this is consistent with the purpose of protected events. The protected events scheme is intended to protect against major consequences such as uncontrolled and significant load shedding or the loss of a region. It would be in planning the protection mechanism for each nominated protected event that AEMO would evaluate the most cost effective options for implementing that protection, and in this evaluation would take into consideration the relative costs and benefits of options that can potentially better contain frequency."

4.2.3 Panel's consideration of the FOS for protected events

The draft FOS for Tasmania and the mainland each include a frequency band and restoration times to apply following the occurrence of a protected event. The frequency band that applies following a protected event in the Draft FOS is the extreme frequency excursion tolerance limit, which is the widest possible frequency band that can apply under the current FOS.[33] The Draft FOS includes a standard for protected events which is unchanged from the interim FOS for protected events.

30 ERM Power, submission to the Issues Paper, p.2.

31 Department of the Premier and Cabinet - South Australia, Submission to the Issues Paper, p.5.

32 AEMO, *Review of the frequency operating standard*, stage 1 – request for advice, 18 August 2017, p.2.

33 The extreme frequency excursion tolerance limit is based on the technical limits of power system equipment.

The Panel considers that this element of the Draft FOS is consistent with the functional purpose of a protected event, which is to limit or reduce the consequences of the non-credible contingency where it is economic to do so.[34]

Setting the allowable frequency following a protected event at the extreme frequency excursion tolerance limit allows AEMO a degree of flexibility in terms of how it manages the frequency consequences of the event, while also helping to limit the extent of the potential costs of the market measures that would be required to maintain the power system frequency in accordance with the FOS.

As stated in AEMO's advice to the Panel, the Panel's approach in the Draft FOS is consistent with the purpose defined in the *Emergency frequency control scheme* rule change, as it maximises the operational flexibility for AEMO in managing the protected event while limiting the ongoing market costs that would be borne by unnecessarily constraining the market to limit the impacts of high impact, low probability events.

This functional purpose of the protected event was established by the AEMC in its final determination for the *Emergency frequency control schemes* rule change. The purpose of a protected event is to limit the consequence of certain high consequence non-credible contingency events, the occurrence of which may otherwise lead to cascading outages that may result in major supply disruptions and potentially a black system condition for all or part of the power system.[35] AEMO identifies such events through the power system frequency risk review; the goal of which is defined in NER clause 5.20A.1(a)(1) as to review the management of:

> "*non-credible contingency events* the occurrence of which AEMO expects would be likely to involve uncontrolled increases or decreases in *frequency* (alone or in combination) leading to *cascading outages*, or *major supply disruptions*;"[36]

Where a protected event is declared, AEMO is able to use a combination of emergency frequency control schemes (generation or load shedding) and the application of operational constraints in order to maintain the power system frequency in accordance with the FOS.

Given that the ultimate purpose of the protected event is to prevent the system collapsing into a black system condition, the Panel considers that the extreme frequency excursion tolerance limit forms the appropriate frequency band for a protected event. This is because AEMO prevents a cascading outage and potential black system by preventing the frequency from moving outside of these extreme limits.[37]

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34 The Reliability Panel considers the costs and benefits of declaring a protected event in accordance with NER cl.8.8.4(d)

35 AEMC, 2017, *Emergency frequency control schemes*, rule determination, 30 March 2017, pp.43-44.

36 NER cl. 5.20A.1(a)(1)

37 The extreme frequency excursion tolerance limits represent the limit of the physical operational capabilities of most generating units in the NEM. If the frequency moves outside of this limit, it is likely that protection systems will cause generators to trip, in order to protect the generating equipment, further worsening the frequency deviation and causing subsequent generators to trip in a cascading outage, potentially leading to a total collapse of system voltage. Thus, by preventing the frequency moving outside of these limits, the risk of a cascading outage and black system is significantly reduced.

In relation to the South Australian government's request that the Panel includes a ROCOF standard as an element of the standard for protected events, the Panel considers that such an inclusion is not warranted at this time. The Panel is of the view that AEMO's system security responsibility for returning the power system to a satisfactory operating state following a protected event is clearly set out in the NER.[38] Furthermore AEMO is required to operate the power system within the limits of the technical envelope.[39] This would include consideration of the capability of operating generation plant, network elements and EFCS, including how this plant is likely to perform under potential ROCOF scenarios that may result for the occurrence of the protected event.

The concept for the inclusion in the FOS of a general limit on rate of change of frequency was raised in submissions by ENA, Engie and TasNetworks.[40] This issue is mentioned in section 5.4 as an issue for further consideration during stage two of the review and is also being considered in the AEMC's *Managing the rate of change of frequency* rule change, which is scheduled to publish a final determination on 19 September 2017.[41]

Alternative approaches

In setting the draft FOS for protected events the Panel considered a number of alternative approaches including:

- Setting a protected event frequency band that was narrower than the extreme frequency excursion tolerance limit but wider than the operational frequency tolerance band.[42]
- Allowing the FOS for each protected event to be determined on a case by case basis.

Setting a standard for protected events that is narrower than the extreme frequency excursion tolerance limit

As suggested by the ERM Power submission to the issues paper, the Panel considered whether there is a basis for setting the protected event FOS at some frequency band that is narrower than the extreme frequency excursion tolerance limit. This would result in a degree of an additional security "buffer" for protected events that are declared, as AEMO would be required to operate the system more conservatively than if a wider protected event FOS were defined. However the application of such a narrower band for protected events would be expected to decrease the operational flexibility for managing protected events and increase the cost of operational measures, including FCAS costs and the market costs resulting from the application of interconnector constraints.

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38 NER clause 4.2.4

39 NER clause 4.3.1(e)

40 Submissions to the Issues Paper: ENA, p.5; Engie, p.5. TasNetworks, pp.8-9.

41 See: http://www.aemc.gov.au/Rule-Changes/Managing-the-rate-of-change-of-power-system-freque

42 In order to allow the operation of relay based emergency frequency control schemes the FOS for protected events must be wider that the operational frequency tolerance band.

For this reason the standard for protected events in the Draft FOS is set equal to the extreme frequency excursion tolerance limits, to maximise operational flexibility as much as is practical and limit the operational costs of preventing a cascading outage subsequent to one of these events occurring.

Determining the FOS for protected events on a case by case basis

As noted by a number of stakeholder submissions, another option for setting a FOS for protected events is that the applicable standard be set on a case by case basis, based on a cost benefit trade-off for each protected event.[43]

This is an approach that was discussed in the AEMC *Emergency frequency control schemes* final determination, which noted that, "there is limited scope for a hi-fidelity approach to setting various post contingency operating states for each protected event."[44] The Commission's final rule included "a single post contingent operating state for protected events in the frequency operating standards (to be determined by the Reliability Panel)."[45]

The Panel recognises that setting a bespoke FOS for each protected event is not likely to be practical and that the regulatory complexity of such an approach would outweigh any benefit from the setting of customised standards for protected events.

As required by clause 8.8.4(d) of the NER, the Panel will consider the costs and benefits of particular protected events when assessing an application from AEMO for the determination of a protected event and any associated protected event EFCS standard.

4.3 Amendments to the requirements for multiple contingency events

The Draft FOS has been revised to require AEMO to use "reasonable endeavours" to stabilise and restore the power system following non-credible contingency events and multiple contingency events that are not protected events. Part B(g) in the draft FOS states:

> "following the occurrence of any *non-credible contingency event* or *multiple contingency event* that is not a *protected event*, AEMO should use reasonable endeavours to:
>
> i. maintain system frequency within the *extreme frequency excursion tolerance limits* and
>
> ii. avoid the system frequency exceeding the applicable generation and load change band for more than two minutes while there is no contingency event or exceeding the applicable *normal operating frequency band* for more than ten minutes while there is no contingency event."

The inclusion of 'reasonable endeavours' in this requirement on AEMO reflects the impracticality of maintaining the power system frequency within a prescribed band following the occurrence of all possible multiple contingency events. This 'reasonable endeavours' obligation sets out the performance objective for management of multiple

43 Submissions to the Issues Paper: Engie, pp.3-4; Meridian, p.2, Energy Australia, pp.3-4.

44 AEMC, 2017, *Emergency frequency control schemes*, rule determination, 30 March 2017, pp.36-37.

45 Ibid.

contingency events; i.e. to the extent that it is reasonably possible for AEMO to do so, AEMO should maintain the power system frequency within the extreme frequency excursion tolerance limits. The Panel considers that this revised obligation sets a clear performance target to guidepreparations for non-credible contingencies and multiple contingency events, including the design and operation of Emergency frequency control schemes by AEMO and TNSP's.

4.3.1 Current requirements of the FOS

The existing FOS for Tasmania and the mainland each require AEMO to maintain the power system frequency within the extreme frequency excursion tolerance limits following any multiple contingency event.

This obligation is contained in part B (f) of the existing FOS which states that:

> "as a result of any multiple contingency event, system frequency should not exceed the *extreme frequency excursion tolerance limits* and should not exceed the applicable generation and load change band for more than two minutes while there is no contingency event or exceed the applicable *normal operating frequency band* for more than ten minutes while there is no contingency event."

4.3.2 Stakeholder views

A majority of stakeholder submissions supported the removal of a firm obligation to maintain the power system frequency within a given frequency band for multiple contingency events.

However several stakeholders also argued for the retention of some form of general requirement for AEMO to make reasonable attempts to restore the satisfactory operation of the power system following such events.[46]

For example, Engie recognised that there is no practical way that AEMO can respond to the standard for multiple contingency events, other than through a 'best endeavours' type approach. [47]

Similarly, Energy Australia supported either the rephrasing of the multiple contingency requirement in the FOS as a general obligation. Alternatively, Energy Australia suggested specifying the types of multiple contingency events for which the FOS should be maintained, with a firm obligation applied to prevent system collapse for these specific events.[48]

Similarly, ERM supported the firming up of the multiple contingency requirement in the FOS, suggesting that: "the Panel give consideration to redefining the condition to that of the simultaneous trip of all units at the biggest power station defined on a per region basis."

The Government of South Australia noted there may be a benefit in clarifying the performance specification for EFCS as a catch all mechanism to mitigate the impact of

46 Submissions to the Issues Paper: ENA, p.2; SACOSS, p.1; TasNetworks, p.6.

47 Engie, Submission to the Issues Paper, p.4.

48 Energy Australia, Submission to the Issues Paper, pp.3-4.

contingency events that are not protected events or credible contingencies. The Government of South Australia also recognised that the declaration of protected events is likely to protect against the most significant regional non-credible contingencies, and as such there is little reason for any specific regional requirements in relation to multiple contingencies.[49]

AEMO advice

AEMO's advice to the Panel in relation to the inclusion of a general obligation for multiple contingency events in the FOS, is that such an obligation is not required, as AEMO considers that responsibility for managing the impacts of multiple contingency events are clearly defined in the NER.[50]

AEMO claims that clause 4.2.6 of the NER places an obligation on AEMO to coordinate the operation of EFCS to "significantly reduce the risk of cascading outages and major supply disruptions following significant multiple contingency events". NSP's in consultation with AEMO also have an obligation to ensure that:[51]

> "sufficient *load* is under the control of under frequency relays or other *facilities* where required to minimise or reduce the risk that in the event of the sudden, unplanned simultaneous occurrence of multiple *contingency events*, the *power system frequency* moves outside the *extreme frequency excursion tolerance limits*;

AEMO state in their submission that:

> "In combination, these clauses that link to the extreme frequency excursion tolerance limits (and therefore to the FOS Part C since it is where the frequency limits are designated) provide a framework for AEMO to determine settings for EFCSs such as UFLS. Therefore AEMO considers that there is no need for the FOS to contain an explicit band related to multiple contingency events."

4.3.3 Panel's considerations in relation to multiple contingency events

The Panel recognises that there is a need to revise the requirement in the FOS that applies following the occurrence of a multiple contingency event, as the existing requirement is impractical and impossible to fully comply with. Multiple contingency events include an unlimited number of potential events and as such are essentially undefinable. They may include events ranging from the simultaneous loss of two generators (a more probable event), to the simultaneous loss of all generators in a region (an extremely improbable event).

> The NER require that AEMO must use its reasonable endeavours to achieve its power system security responsibilities in accordance with the power system security principles, which include a requirement that:"emergency frequency control schemes are required to be available and in service to:
>
> (1) restore the power system to a satisfactory operating state following protected events; and

49 Department of the Premier and Cabinet - South Australia, Submission to the Issues Paper, p.6.

50 AEMO, *Review of the frequency operating standard*, stage 1 – request for advice, 18 August 2017, pp.3-4.

51 NER clause S5.1.10.1(a)

(2) significantly reduce the risk of cascading outages and major supply disruptions following significant multiple contingency events." [52]

The Panel considers that it is appropriate and practical that this principle in the NER be clarified by maintaining a clear obligation on AEMO to manage the frequency limits set out in the FOS in relation to multiple contingency events. However the Panel recognises that it is not practical to impose a firm performance obligation on AEMO in relation to all possible multiple contingency events. Therefore the requirement in the draft FOS is for AEMO to use 'reasonable endeavours' to maintain and restore the power system frequency following the occurrence of any non-credible contingency event or multiple contingency event that is not a protected event. This requirement specifies the performance target that AEMO should use reasonable endeavours to meet in accordance with the general system security principles in the NER.[53]

The Panel notes that the *Emergency frequency control schemes* final rule revised the power system security principles, including clause 4.2.6(c) of the NER to change what it is that AEMO needed to consider when managing of multiple contingency events. Prior to the final rule being made, NER clause 4.2.6(c) stated:

> "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*."[54]

The Panel recognises that to operate the power system to achieve this principle is impractical and impossible to achieve for all multiple contingency events, as set out in the AEMC *Emergency frequency control schemes* final determination.[55]

However the Panel also recognises the value in clarifying the risks that AEMO should consider when managing multiple contingency events. For example, historically, under frequency load shedding schemes have been designed and coordinated to help maintain the frequency within the extreme frequency tolerance band in the event of sudden and significant non-credible contingency events.

Therefore the Panel considers it appropriate that the FOS reflect the altered power system security principle in the NER by requiring AEMO to take reasonable endeavours to maintain the power system frequency within the extreme frequency excursion tolerance limits following the occurrence of any non-credible contingency event or multiple contingency event that is not a protected event. This obligation

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52 NER Clause 4.2.6(c)

53 NER Clause 4.2.6

Similarly NER clause 4.2.6(b) states that:

"Following a *contingency event* (whether or not a *credible contingency event*) or a significant change in *power system* conditions, AEMO should take all reasonable action:

(1) to adjust, wherever possible, the operating conditions with a view to returning the *power system* to a *secure operating state* as soon as it is practical to do so, and, in any event, within thirty minutes; or

(2) if any principles and guidelines have been *published* under clause 8.8.1(a)(2a), to adjust, wherever possible, the operating conditions, in accordance with such principles and guidelines, with a view to returning the *power system* to a *secure operating state* within at most thirty minutes.

54 NER version 89, clause 4.2.6(c)

55 AEMC, 30 March 2017, *Emergency frequency control schemes* - Final Determination, p.46.

clarifies that AEMO will take reasonable actions to maintain the frequency of the power system, following the occurrence of a multiple contingency event that is not a protected event, taking into account the surrounding circumstances. The Panel considers that this general obligation is not likely to be place a significant additional burden on AEMO, as it clarifies the goal for operation of the power system during emergency conditions.[56]

The Panel considers that this multiple contingency requirement in the draft FOS will assist AEMO by providing clarity and guidance as to how it should prepare for and manage the impact of non-credible contingencies and multiple contingencies that are not protected events, while avoiding imposing undue restrictions on its operational discretion. The Panel considers that retaining some reference to multiple contingencies in the FOS will:

- provide a performance target for the development of AEMO's operational procedures
- provide a performance target for the design of general purpose Emergency frequency control schemes, such as under frequency load shedding schemes, which provide the last line of defence to protect the power system from emergency events
- maintain the alignment between the FOS and the NER in respect of a generating unit response to frequency control (i.e., the ability for a generating unit to operate continuously within prescribed frequency bands for defined time periods)
- maintain AEMO's the discretion and flexibility as to how power system frequency risks are managed.[57]

This element of the draft FOS is consistent with the AEMC's approach to the management of power system frequency risks as set out in the final determination for the *Emergency frequency control schemes* rule; the final rule includes:[58]

> "Recognition that general purpose emergency frequency control schemes and special emergency frequency control schemes are functionally different and treating them so through different processes:
>
> — Special emergency frequency control schemes are linked to the mitigation of one or more protected events and credible contingency events
>
> — General purpose emergency frequency control schemes are linked to the mitigation of non-credible contingency events."

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56 That is, to make reasonable attempts to maintain the power system frequency within the extreme frequency excursion tolerance limit and then ultimately to attempt to return the power system to the normal operating frequency band.

57 AEMO is required to undertake a power system frequency risk review every two years in accordance with rule 5.20A of the NER. This review includes an assessment of the risks of non-credible contingency events that may lead to cascading outages and the options for management of those events, including the development of new or modified emergency frequency control schemes and the request for the declaration of protected events.

58 AEMC, 2017, *Emergency frequency control schemes*, rule determination, 30 March 2017, p.36.

Maintaining the multiple contingency requirement in the FOS provides a general performance target for general purpose emergency frequency control schemes that are not intended to be linked to specific protected events. These general purpose schemes provide general protection against non-credible contingencies and multiple contingency events.

The Panel recognise the importance of maintaining the alignment between the system security standards and the performance standards for generators connected to the NEM. The multiple contingency requirement in Part B(g) of the Draft FOS reflects the access standards for a generating unit response to frequency disturbances set out in NER S5.2.5.3. The automatic access standard includes the requirement that a generating unit shall be able to operate continuously outside the operational frequency tolerance band but within the extreme frequency tolerance excursion for at least the stabilisation time of two minutes. Furthermore to meet the automatic access standard, a generating unit shall be able to operate outside the normal operating frequency band and within the operational frequency tolerance band for at least the recovery time of ten minutes.[59] The revised Part B (g) maintains the reference to the extreme frequency tolerance excursion limit along with the stabilisation and restoration times, in line with the automatic access standard for the connection of generators set out in NER S5.2.5.3.

The Panel considers that the alignment of Part B(g) of the FOS and the access standards for generating unit response to frequency disturbances is important as this aligns AEMO efforts to restore the power system following non-credible contingency events and multiple contingency events with the performance capability of generating units connected to the power system. While it may not be possible to restore the power system to within the normal operating band within ten minutes following all possible non-credible contingency events, the Panel consider that AEMO should use reasonable endeavours to attempt to do so. Although NER clause 4.2.6 (b) requires AEMO to take all reasonable action to restore the power system to a secure operating state within thirty minutes, the Panel considers that AEMO should also endeavour to restore the power system frequency to within the normal operating frequency band within ten minutes as failure to do so is likely to increase the risk of failure of generating units which would negatively impact the restoration process.

The obligation in the FOS to maintain power system frequency within the extreme frequency tolerance excursion limit has been replaced by a “reasonable endeavours” obligation which reflects the uncertainty associated with planning for non-credible and multiple contingency events. This revised requirement gives AEMO flexibility and discretion to assess the preferred approach to managing power system frequency risks, while maintaining the performance target for operation of the power system.

The Panel notes AEMO’s advice, that AEMO does not consider it necessary for the FOS to contain a general obligation in relation to multiple contingency events. In determining the draft stage one standard, the Panel considers that this “reasonable endeavours” requirement for AEMO clarifies the expectations of reasonable operational practise following a multiple contingency event or non-credible contingency event and is consistent with the revised power system security principles mentioned above.

59 NER S5.2.5.3

The Panel does not consider there is any basis for setting a requirement for specific multiple contingency events, as suggested by Energy Australia and ERM, as such an obligation would be covered under the declaration of a protected event, where it is economic to do so.

Part B(g) of the draft standard has also been revised to clarify the type of event that this requirement applies to. The revised wording expands on the reference to multiple contingency events in the current FOS to also include any non-credible contingency event or multiple contingency event that is not a protected event.

4.4 Revision of the definition of generation event

The Draft FOS includes a revised definition of a generation event. The revised definition has been expanded to cover, "a sudden, unexpected and significant increase or decrease in the *generation* of one or more *generating systems* of more than 50MW within a period of 30 seconds or less".

This change has been made to cover the sudden and unexpected increase or decrease of generation output from a generator, particularly as may occur from time to time from large scale solar PV farms, due to sudden change in climatic conditions, such as local cloud cover.

4.4.1 Current arrangements in the FOS

The Panel understands that historically, the current definition of a generation event in the FOS has been interpreted to cover the synchronisation of a generating unit of more than 50MW, or the tripping of a generating unit as the result of a credible contingency.[60] However, this interpretation has not extended to include the rapid variation of generation output of one or more generating units.

The existing definition of 'generation event' varies between the FOS for the mainland and the FOS for Tasmania.

The term "generation event" is defined in the mainland FOS as:

> "a synchronisation of a generating unit of more than 50 MW or a credible contingency, not arising from a network event, a separation event or a part of a multiple contingency event." [61]

And in the FOS for Tasmania as:

> "a synchronisation of a generating unit of more than 50 MW or a credible contingency event in respect of either a single generating unit or a transmission element solely providing connection to a single generating unit, not arising from a network event, a separation event or a part of a multiple contingency event."

60 The Panel notes that the current definition of a generation event does not explicitly refer to generator tripping but instead to a "credible contingency not arising from network event, a separation event or a part of a multiple contingency event".

61 A synchronisation is defined in Chapter 10 of the NER as: "To electrically connect a generating unit or a scheduled network service to the power system."

In practise the Panel understands that these definitions have been interpreted to mean that a generation event for the purpose of the FOS for the mainland and Tasmania is either:

- the connection (synchronisation) of a generating unit of more than 50MW; or
- the disconnection of a generating unit as the result of a credible contingency that is not a network event, a separation event or a part of a multiple contingency event.

The Panel also understands that this interpretation has then informed AEMO's operational decisions in terms of management of the power system, including in terms of whether it classifies different generation events as credible contingency events, which in turn determines whether it manages the consequences of these events through the use of regulating or contingency FCAS.

AEMO has a responsibility to maintain the power system within the normal operating frequency band for normal operation conditions. To do this, AEMO uses regulating FCAS services to account for smaller changes in the balance of generation and load.

AEMO is also required to return the power system to a satisfactory operating state in accordance with the FOS, following the occurrence of any credible contingency or protected event.[62]

A credible contingency event is defined in the NER as a contingency event that is reasonably possible in the surrounding circumstances, an example of a credible contingency event is:[63]

> "the unexpected automatic or manual *disconnection* of, or the unplanned reduction in capacity of, one operating *generating unit*;"

Furthermore a contingency event is defined in the NER as:

> "an event affecting the *power system* which AEMO expects would be likely to involve the failure or removal from operational service of one or more *generating units* and/or *transmission elements*."

As mentioned above, AEMO is required to return the power system to a secure operating state following a contingency event, in accordance with the FOS, and may use contingency FCAS to do so.

However, the Panel understands that there is some uncertainty as to whether the current FOS definition of generation event includes an event such as the sudden unexpected variation of generation output, as may occur from large scale solar PV farms. It may therefore be unclear whether this event can be classified as a contingency event.

If AEMO faces uncertainty as to whether this kind of event can be reasonably classified as a credible contingency, it may not be clear as to whether it can address this event through the use of contingency FCAS, or whether it should be considered as part of

62 NER clause 4.2.4(a)(2)

63 NER Clause 4.2.3(b)(1)

more normal operating conditions, in which case its consequences would be managed through the use of regulating FCAS.[64]

4.4.2 Stakeholder views

The majority of stakeholder submissions support the revision of the definition of generation event to account for and include sudden unexpected variation in generation output as may occur from large scale solar PV farms.[65]

In supporting the proposed revision of the definition of generation event to cover the large and unexpected changed in generation output from a generator or a set of generators AEMO noted that:

"Generation from utility-scale solar plant in the NEM has been observed to change by up to 80-90% of rated capacity in five minutes, or as much as 101 MW in five minutes for a 103MW plant."[66]

The South Australian government suggested that the Panel also consider whether it would be appropriate for the definition of a generation event to be expanded to account for any single points of failure for all types of generation, such as the failure of a "transmission element solely providing connection to a single generating unit".[67]

TasNetworks recognise that the issues of solar PV ramping and high speed wind cut-out are issues that have a growing implication for frequency control in the NEM. TasNetworks stated that these events may be managed as part of normal operation, with regulating FCAS, or as contingency events, with contingency FCAS, depending on the regularity of such events and the availability and capability of regulating and contingency FCAS to effectively maintain the FOS.[68]

AEMO Advice

AEMO has provided the Panel with advice detailing the nature of the challenge relating to the management of large changes in generation output from over short time period, as may occur from solar PV during intermittently cloudy days. This advice supported the Panel's proposal to consider amendments to the definition of a generation event in the FOS and provided additional evidence detailing the benefits of changing this definition in terms increasing operational flexibility for AEMO and reducing the burden of regulating FCAS procurement relative to the do nothing approach.

Building on the information contained in AEMO's submission to the issues paper relating to the scale of variability observed for large scale solar PV farms, AEMO's advice noted that:[69]

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64 The Panel notes AEMO's advice that the current definition of the generation event is unclear. AEMO *Advice to the Reliability Panel for the review of the frequency operating standard*, 18 August 2017, p.9.

65 Submission to the Issues Paper: ENA, p.4; Engie, p.5; Meridian Energy, p.3-4; ERM Power, p.4; AEMO, p.6; Department of the Premier and Cabinet - South Australia, pp.6-7.

66 AEMO, Submission to the Issues paper, 1 August 2017, p.6.

67 Department of the Premier and Cabinet - South Australia, Submission to the Issues Paper. pp. 6-7.

68 TasNetworks, Submission to the Issues Paper, p.12.

69 AEMO, *Review of the frequency operating standard*, stage 1 – request for advice, 18 August 2017, pp.7-11.

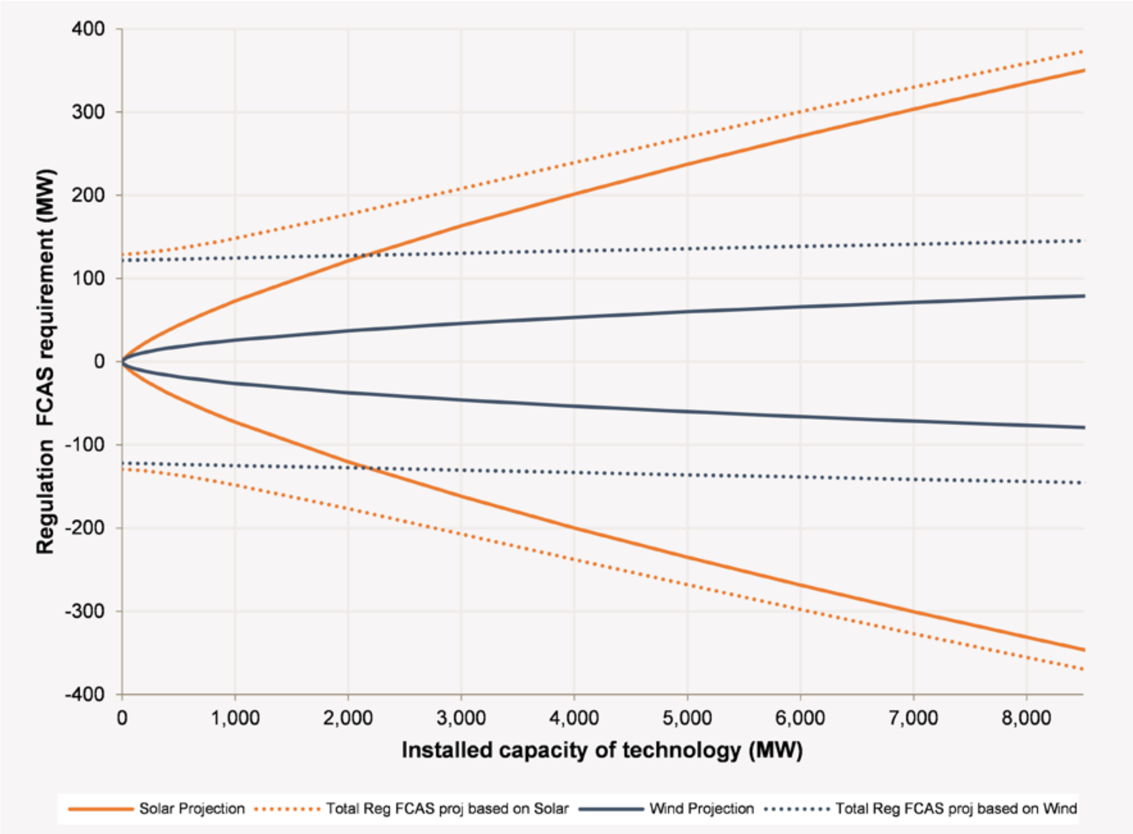
> "AEMO's analysis suggests that utility scale PV variability is especially significant, and likely to lead to a significant increase in regulating FCAS required once 1-2 GW are installed."

And:

> "If this change is not made, AEMO may be required to purchase additional regulating FCAS in order to meet the FOS. Specifically, AEMO would be obligated to try and maintain frequency in the normal operating frequency band for these events."

Figure 4.1 shows the results of AEMO's analysis that projects the quantity of regulating raise and regulating lower FCAS as a function of installed solar PV capacity in the NEM. This analysis shows a marked increase in the volume of both raise and lower regulating service required as the quantity of large scale solar generation increases in the NEM.

Figure 4.1 Required Regulating FCAS Vs installed Solar PV capacity – mainland NEM[70]



AEMO considered that management of this kind of increased variable generation output through the use of contingency FCAS will help to minimise FCAS costs over the

70 AEMO, Advice to the Reliability Panel for the review of the frequency operating standard, 18 August 2017, p.10.
Note: that these projections are indicative only, as they depend on limited data and assume no material changes to solar farm behaviour or systematic improvements in forecasting.

near term, until such time as the size of variable renewable generation power stations exceed that of the largest generating units that currently operate in the NEM.[71]

In terms of the size threshold against which the variation of generation is measured, AEMO supported the application of the current 50MW threshold as the lower limit for the unexpected variation of generation output. However, AEMO also noted that this value of 50MW may need to be subject to a more detailed review to assess its ongoing appropriateness in relation to the nature of the power system.[72]

For the time element of this threshold, AEMO propose that:[73]

> "the appropriate timeframe would be less than or equal to 30 seconds, which is an approximate response time of the regulation FCAS service (implemented through AGC)."

In proposing a maximum time limit of 30 seconds, AEMO recognised that due to the functional limitations of existing equipment, the response capability of regulating FCAS to manage variation of generation output of over 50 MW is limited to a minimum response time in excess of 30 seconds. AEMO's advice was that contingency FCAS is more suited to respond to variation of generation output of over 50 MW within a time period less than 30 seconds, therefore the time limit for the variation of generation output should be less than or equal to 30 seconds..

AEMO regard this change as a high priority that will realise immediate operational and economic benefit for the NEM:[74]

> "AEMO regards that this is an important change, as these kinds of generation events are already occurring, and are anticipated to become larger and more frequent as committed solar farms are commissioned. Some of these may be in service by summer of 2017-18."

The Panel also notes AEMO's suggested definition for a generation event:[75]

> "a rapid, unforeseen increase or decrease in the real power injection to the power system from one or more generating units, consistent with what AEMO considers to be a credible contingency event under clause 4.2.3 of the NER".

The Panel notes that in suggesting this definition of generation event, AEMO effectively argued that the existing NER definition of a contingency event may already allow for the rapid change in generation from a generating unit to be defined as credible

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71 This is because by "transferring" management of the consequences of these kinds of events from regulation to contingency FCAS, it may be possible to reduce the volume of regulation FCAS procured, while managing the consequence of these events through the contingency FCAS that has already been procured to manage the largest contingency. This may result in an reduction in the aggregate volume of regulation and contingency FCAS procured. Currently, the largest credible generation contingency in the NEM is frequently the loss of the CS Energy - Kogan Creek unit, which has a rated capacity of 744 MW.

72 AEMO, Advice to the Reliability Panel for the review of the frequency operating standard, 18 August 2017, p.8.

73 AEMO, Advice to the Reliability Panel for the review of the frequency operating standard, 18 August 2017, p.8.

74 Ibid, p.11.

75 Ibid. p.9.

contingency event.[76] Accordingly, AEMO proposed that to allow it to address this rapid change in output as a contingency event, the FOS should point clearly to the existing NER clauses that describe contingency events and credible contingency events.

4.4.3 Panel considerations in relation to the definition of generation event

The Panel considers that this issue identified by AEMO is likely to have material consequences, if left unaddressed. However, it also considers that the solution proposed in AEMO's advice will not provide sufficient certainty and clarity in terms of how the frequency consequences of these rapid variations in generator output should be managed.

Accordingly, the Panel has set out changes to the definition of generation event in the FOS that clearly define the kinds of events that AEMO should include in its consideration of a generation event, to include the rapid variation of output from generating systems within a 30 second time period.

Materiality of issue

As evidenced in table 4.1 below, the Panel is aware that there is a large quantity of new large scale solar PV generation capacity scheduled to be connected to the NEM power system over the next twelve months. As noted by AEMO, the particular characteristics of large scale solar PV mean that this generation may be particularly likely to exhibit large swings in output in relatively short periods of time.

Table 4.1 shows a summary of all operational and committed large scale solar PV generation with a generator capacity of over 50MW. This table shows that installed large scale solar PV capacity, from plants larger than 50MW, will grow by 640MW over the next twelve months, from the current 211MW, reaching 851MW by August 2018.

The Panel notes the increase in the maximum plant size from the current 102MW at Nyngan solar farm to 150MW with the connection of the Clare Solar Farm in Queensland in summer 2017/18 and 220MW with the connection of the Bungala Solar Power Project in South Australia in August 2018.

Table 4.1 Snapshot of upcoming and existing large scale solar PV generation (>50MW)[77]

NEM Region	Plant Name	Commercial Use Date	Nameplate Capacity (MW)
Victoria	Gannawarra Solar Farm	April 2018	50
South Australia	Bungala Solar Power Project	August 2018	220
Queensland	Clare Solar Farm	Summer 2017/18	150

76 Ibid.

77 AEMO, Generation information, 5 June 2017. https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information

NEM Region	Plant Name	Commercial Use Date	Nameplate Capacity (MW)
	Hamilton Solar Farm	March 2018	57.5
	Whitsunday Solar Farm	March 2018	57.5
NSW	Broken Hill Solar Plant	In service	53
	Moree Solar Farm	In service	56
	Nyngan	In service	102
	Manildra Photovoltaic Solar Farm	Winter 2018	50
	Parkes Solar Farm	Summer 2017/18	55
Total existing large scale solar PV generation greater than 50MW			**211**
Total committed large scale solar PV generation greater than 50MW			**640**

The Panel recognises the potential operational challenges presented by the expected increase in large scale solar PV generation, given AEMO's analysis of the potential impacts on variable generation output from increased large scale solar penetration.

The Panel also considers that these challenges may at least in part reflect the current uncertainty as to how the current FOS definition of generation event has been interpreted, specifically in terms of how this definition has been translated into operational practices.

Implications of uncertainty regarding the FOS

The Panel considers that the existing definition of generation event in the FOS is insufficiently clear, in that it does not explicitly account for rapid variation of output from a generating unit or generating system. Consequently, as noted above, the current wording of the FOS has typically been interpreted to refer solely to events such as a generator synchronisation or trip.

The Panel understands that this has resulted in AEMO managing any rapid variations in generation output (particularly from large scale solar PV power stations) through the deployment of regulating FCAS coordinated through AEMO's centrally managed automatic generation control system, as opposed to being managed through contingency FCAS.

The Panel considers that under the current definition of generation event this increase in the maximum size and the total installed capacity of large scale solar PV generation is likely to drive an increase in the quantity and cost of regulating FCAS procured by AEMO to offset the expected variation in generation output and associated frequency excursions. However, in some instances, it may be more efficient to rely on contingency FCAS to address the frequency consequences of these kinds of events.

In the draft FOS, the definition of generation event has therefore been revised to explicitly include these kinds of rapid unexpected variation of generation output. The Panel consider that this will provide increased clarity in terms of allowing AEMO to manage the consequences of these events through the use of contingency FCAS, rather than relying solely on regulating FCAS.

The Panel understands that while this may allow for these kinds of events to result in broader frequency excursions, it will also allow AEMO to use contingency FCAS to rebalance the power system, in the event that the unexpected variation of generation output exceeds the threshold of 50MW within a 30 second period.

The size threshold for this generation event is supported by AEMO's advice to the Panel and is equal to the size limit for the synchronisation of a generation unit from previous iterations of the FOS for the mainland and for Tasmania. The 30 second time limit within which the variation of generation output must occur is based on AEMO's advice and the response time for regulating FCAS, via the AGC system.[78]

The Panel understands that, over the next couple of years, this revision is not expected to drive a material change in the quantity of contingency FCAS procured in the NEM under normal operating conditions. The basis for this is that the quantity of contingency FCAS purchased in each dispatch interval is set in order to mitigate the largest single credible contingency event. This credible contingency may involve the failure or disconnection of a one transmission element or a single generating unit[79]. Currently the single largest generating unit in the mainland NEM is the 744 MW Kogan Creek steam turbine operating by CS Energy in Queensland.

However the Panel understands that over the longer term the size of large scale solar PV generating systems is expected to increase, as supported by the recent announcement of plans by Equis to build a 1000MW solar PV farm over the next four years near Wandoan in Queensland.[80] With this in mind the Panel will consider the long term costs and benefits of this definition of generation event and the associated threshold of 50MW as part of stage two of the review of the FOS.

The Panel also recognises that in many cases, the entry of new generation may occur in clusters, that is, with multiple generating systems locating in the same area. This might include several small solar farms locating at a single location where there is both network capacity available as well as strong solar resource. These individual solar farms are likely to exhibit the same rapid changes in generation output, as they will all be affected by the same climatic conditions.

In order to allow for the effective management of the impacts of these kinds of small, co-located variable generators, the draft stage one FOS generation event definition refers to a total capacity of generating systems being equal to or greater than 50MW. This will allow for AEMO to manage the frequency impacts of these kinds of generators through the use of contingency FCAS.

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78 AEMO, *Review of the frequency operating standard*, stage 1 – request for advice, 18 August 2017, pp.8.

79 NER clause. 4.2.3(b)

80 Toowomba Chronicle, 1000 megawatt Equis Energy solar farm approved in western Queensland, 4 August 2017.

4.5 Revision of the definitions in the FOS related to island operation

The Draft FOS includes a revised definition of an island for the purpose of application of the FOS for island operation following a separation event. This new definition of "island" replaces the current terms "electrical island" and "abnormal frequency island" as used in the mainland FOS. This revised definition maintains the key elements of the existing definition of an island with the addition of the requirement, that an island must be at least the equal to or greater than an inertia sub-network.

The definition of an island in the Draft FOS is:

> "a part of the *power system* that includes *generation*, *networks* and *load*, for which all of its alternating current network connections with other parts of the *power system* have been disconnected, provided that the part:
> (a) does not include more than half of the combined *generation* of each of two *regions* (determined by available capacity before disconnection); and
> (b) contains at least one whole *inertia sub-network*."

The definition of an inertia sub-network is included in the Draft FOS as:

> "has the meaning given to it in the Rules."

In the Draft FOS, these definitions apply to both the mainland and Tasmania as set out in Appendix A.3.

4.5.1 Current definitions in the FOS related to Island operation

In the current FOS for Tasmania, the definition of an "island" is as follows:

> "means a part of the Tasmanian power system that includes scheduled generation, networks and load for which all of its alternating current network connections with other parts of the power system have been disconnected"

In the FOS for the mainland NEM the term "island":

> "means either an electrical island or an abnormal frequency island."

The definition of an "electrical island":

> "means a part of the power system that includes generation, networks and load, for which all of its network connections with other parts of the power system have been disconnected, provided that the part does not include more than half of the generation of each of two regions (determined by available capacity before disconnection)."

and an "abnormal frequency island":

> "means a part of the power system that includes generation, networks and *load* for which all of its alternating current network connections with other parts of the power system have been disconnected, provided that the part does not include more than half of the generation of each of two *regions (determined by available capacity before disconnection)."*

The difference between an electrical island and an abnormal frequency island is that for an electrical island all network connections have been disconnected, whereas for an abnormal frequency island all alternating current network connections have been disconnected but any DC interconnections could still be operating. The result is that an abnormal frequency island may still be connected to the remainder of the power system by one or more direct current network elements, allowing power transfer but not a common frequency. An example of this is the separation of the South Australian region through the disconnection of the Heywood interconnector, where the Murraylink DC interconnector remains connected. The resultant South Australian island would be an abnormal frequency island as defined in the current FOS.

4.5.2 Stakeholder views

The majority of stakeholder submissions to support the clarification of the characteristics of an island for the purpose of island operation as set out in the FOS.[81]

In supporting the principle to clarify the characteristics of an island for the FOS TasNetworks noted that:[82]

> “The basic characteristics of a viable electrical island are considered the same as for intact operating conditions and revolve around the need for stable frequency and voltage control as well as the continued operability of protection systems that ensure the safety of people, plant and network equipment.“

TasNetworks also raised a number of additional considerations in their submission that relate to island operation, including:[83]

a) Whether a viable island should capable of withstanding any single credible contingency event (often referred to as N-1)?

b) Whether an island formed due to a protected event should be more resilient than an island involving a small sub-section of a single NEM region?

c) Whether AEMO’s market systems have the ability to control scheduled generating units for an island that forms within the Tasmanian region?

d) Whether an island that does not meet the requirements set out in the FOS can be retained in service for a period of time to allow network customers to transition to alternate energy supplies, such as back-up generation?

The Panel’s consideration on items a) and b) are incorporated below in section 4.5.3. The Panel notes that items c) and d) are issues related to operation of the power system and are best resolved through a collaborative approach by AEMO and TNSP’s.

AEMO Advice

AEMO’s advice supports the proposed revision of the definition of an island for the FOS, including inclusion of the linkage to an inertia sub-network. AEMO notes that:[84]

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81 Submissions to the Issues Paper: ENA, p.3; SACOSS, p.1; Engie, pp. 4-5; Meridian Energy, p. 3; TasNetworks, p. 6; ERM Power, pp.3-4; AEMO, p. 5; Hydro Tasmania, p. 1; Department of the Premier and Cabinet - South Australia, p. 6.

82 TasNetworks, Submission to the Issues Paper, pp.6-7.

83 Ibid. p.7.

"Inertia sub-networks are intended to be areas that can be managed in a secure operating state, which by definition implies adequate control of frequency. Therefore this linkage is sensible and practical."

4.5.3 Panel's considerations for definitions associated with island operation

For the Draft FOS the Panel has reduced the complexity of the definitions that relate to island operation by setting one definition of an island that applies for both the mainland FOS and the Tasmanian FOS. In addition the definition of an "island" in the Draft FOS replaces the previous terms of "electrical island" and "abnormal frequency island" as used in the current FOS for the mainland.

The Panel considers that for the purpose of frequency control, there is no difference between an "electrical island", where all network connections are disconnected and an "abnormal frequency island" where all alternating current network connections are disconnected.[85] For this reason the stage one Draft FOS does not include the terms "electrical island" and "abnormal frequency island".

The Panel recognises that the island operation FOS should only apply to an island within the power system which is capable of being operated independently following a separation event. Therefore the Draft FOS includes revised definitions which provide additional clarity as to the minimum size of an island for the purpose of island operation in accordance with the FOS.

The Panel considers that the basic goal of island operation is the same as the goal for operation of the power system as a whole, which is that the sub-network forming the island must be capable of being returned to and maintained in a secure operating state following the separation event that caused the islanding. A "secure operating state" is defined in the NER as being the satisfaction of the following two conditions:[86]

1. The system parameters, including frequency, voltage and current flows are within the operational limits of the system elements, referred to as a "satisfactory operating state"
2. The system is able to recover from a credible contingency event or a protected event, in accordance with the power system security standards.

It may be difficult for AEMO to maintain a secure operating state for any part of the power system that is islanded, as certain islanded portions of the network may not be capable of being operated independently as viable islands.

The issue of the ability for an islanded system to be operated independently was discussed as part of *Managing the rate of change of power system frequency* rule change. The draft rule includes a new power for AEMO to determine inertia sub-networks and

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84 AEMO, Advice to the Reliability Panel for the review of the frequency operating standard, 18 August 2017, p.4.

85 As frequency is only shared through AC network connections, not through DC network connections. If an island is formed with a DC network connection still in operation the DC connection acts in the electricity and FCAS markets in a similar way to a generator, by offering energy and FCAS through the DC connection. An example of this is the Basslink interconnector connecting the mainland NEM with Tasmania.

86 NER Rule 4.2.2 and Rule 4.2.4

criteria for assessing the viability for the independent operation of those sub-networks (with interim inertia sub-networks being deemed to be the regional boundaries). Clause 5.20.B.1(d) of the draft rule specifies that: [87]

> "in determining and adjusting the boundaries of *inertia sub-networks*, AEMO must take into account the following matters:
>
> (1) connections between the proposed *inertia sub-network* and adjacent parts of the *national grid*;
>
> (2) the likelihood of the proposed *inertia sub-network* being *islanded*; and
>
> (3) the criticality and practicality of maintaining the proposed *inertia sub-network* in a *satisfactory operating state* if it is *islanded* and being able to return to a *secure operating state* while *islanded*."

The Panel considers these requirements set out in the *Managing the rate of change of power system frequency* draft rule align closely with the requirements for defining the lower limit of an islands for the maintenance of the FOS.[88] Therefore, the revised definitions of electrical island and abnormal frequency island in the Draft FOS include the new requirement that the resultant sub-network "is at least equal to or greater than an inertia sub-network." This requirement enables an island for the purpose of maintaining power system frequency in accordance with the FOS to be larger than an inertia sub-network but not smaller.

Under this definition of an island, AEMO would not be required to maintain the FOS for a separated portion of the network that did not contain at least one whole inertia sub-network, as it would not be practical to do so. However where an island forms that does contain at least one whole inertia sub-network the FOS for island operation would apply, including the relevant normal operation and contingency frequency bands. The Panel recognises that this definition of an island in the Draft FOS is not linked to the likelihood of an island forming through the occurrence of a contingency event, including a protected event. The Panel consider that the *Managing the rate of change of power system frequency* draft rule requires AEMO to take into account the likelihood of the proposed sub-network being islanded, which will include the nature of the event that may form the island.[89]

4.6 The limit for accumulated time error in the FOS

The Draft FOS increases the limit for accumulated time error that applies for the mainland from 5 to 15 seconds. The limit of accumulated time error in the Draft FOS for Tasmania remains unchanged at 15 seconds.

The Panel's initial consideration is that there may be a case for the complete removal of the accumulated time error limit. However, there is some possibility that the removal of

87 AEMC, *Managing the rate of change of power system frequency* - draft rule, 27 June 2017. Clause. 5.20B.1.

88 The Panel recognises that this linkage to an inertia sub-network creates a dependency with the publication of the *Rate of change of power system frequency* final rule which is scheduled for publication on 19 September 2017. The stage one revised FOS final determination for the *Review of the frequency operating standard* will be published on 7 November 2017. Any subsequent changes between publication of this stage one Draft FOS will be accounted for in the final stage one FOS.

89 AEMC, *Managing the rate of change of power system frequency* - draft rule, 27 June 2017. Clause. 5.20B.1.

this time error limit could have unforeseen impacts on large and small consumers. In order to limit the risk, the Panel has decided to initially relax the accumulated time error limit, with a view to full removal once consultation has been undertaken with a wider range of consumers.

The Panel will continue to consult with stakeholders in relation to the intention to remove the accumulated time error limit from the FOS through the course of stage two of this review.

4.6.1 Current requirements of the FOS

Accumulated time error is the cumulative sum of the difference between the actual power system frequency over time and the nominal system frequency of 50Hz.[90]

The FOS currently requires AEMO to limit the accumulated time error related to the power system frequency to:

- 5 seconds for the mainland NEM
- 15 seconds for Tasmania

Historically, limiting accumulated time error was important to maintain accurate time keeping when synchronous clocks that depended on the power system frequency were common place. The Panel understands that the reliance on synchronous clocks has diminished in recent times and that limiting the accumulated time error does not improve the reliability or security of the power system.[91]

4.6.2 Stakeholder views

The majority of stakeholders support the relaxation or removal of the requirement in the FOS for AEMO to limit accumulated time error.[92]

ERM Power indicated that they are not aware of any issue that would impact the operation of Oakey Power Station as a result of the removal of a limit on accumulated time error.[93]

Engie explained in their submission that the removal of accumulated time error from the FOS may help resolve an issue relating to market participants finding it hard to reconcile FCAS causer pays outcomes. Currently frequency control and the causer pays mechanism is based on a frequency error and a time error (integral) component. The removal of a limit on accumulated time error may allow for the simplification of this element of the causer pays mechanism and improve transparency for market participants.[94]

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90 See Reliability Panel, *Review of the frequency operating standard* – Issues Paper, 11 July 2017, pp.14-15, 42-43.

91 Ibid.

92 Submissions to the Issues Paper: SACOSS, p.1; Engie, p.5; Meridian Energy, p.3; ERM Power, p.4; AEMO, p6-7; PIAC, p.1.

93 ERM Power, Submission to the Issues Paper, p.4.

94 Engie, submission to the Issues Paper, p.5.

A number of stakeholders indicated their support for the removal of an obligation to limit accumulated time error while also supporting the maintenance of the reporting of accumulated time error as a measure of power system frequency performance.[95]

AEMO advice

AEMO's advice to the Panel supports the removal or relaxation of the requirement to limit accumulated time error as a largely unnecessary obligation. AEMO's investigations indicate that there are no system security (or reliability) benefits from conducting time error correction. In terms of the potential impact on electricity customers from the removal of the limit on accumulated time error, AEMO state that:[96]

> "AEMO is not aware of any critical processes or equipment that would be adversely impacted by these proposed changes. AEMO is also unaware of any complaint being received concerning time error. However, those potentially impacted may not be customers with whom AEMO has typically had direct interaction."

AEMO's indicates that the removal of the limit on accumulated time error, and corresponding cessation of time error correction, may reduce the quantity and cost of regulating FCAS by as much as 1% per annum, representing approximately $1million in FCAS costs.[97]

AEMO's analysis of the recent power system frequency performance have also identified time error correction as a process that occasionally acts contrary to the frequency control goals for the power system. This is described further in section 4.6.3.

While AEMO supports the removal of accumulated time error in principle, they recognise the need for stakeholders to be given adequate opportunity to engage with this issue, to understand the implications and provide feedback where necessary. As such AEMO supports a phased approach to the removal of time error correction, with the aim to finalise its removal in stage two of the review of the FOS.[98]

4.6.3 Panel's considerations for accumulated time error

This section outlines the Panel's considerations in relation to the costs and benefits of the practise of time error correction in the NEM, where time error correction is the operational process used to limit accumulated time error in accordance with the limit set in the FOS.

This forms the basis for:

- The relaxation of the limit on accumulated time error that applies in the mainland NEM in the Draft FOS to be equal to the current limit that applies in the Tasmanian FOS of 15 seconds.

95 Submissions to the Issues Paper: ENA, p.4; TasNetworks, p.8; HydroTasmania, p.1.

96 AEMO, Advice to the Reliability Panel for the review of the frequency operating standard, 18 August 2017, pp.5-7.

97 Ibid.

98 Ibid.

- The potential for the ultimate removal of the obligation to limit accumulated time error from the FOS for the mainland and for Tasmania through the course of stage two of the review.

During the course of stage two, the Panel will also consider whether there is a benefit in maintaining some form of reporting function in relation to accumulated time error as a measure of frequency performance, and in what form such a reporting function may take.

Throughout the coming months, the Panel intends to consult with industry and customer representatives in relation to the intention to remove the limit on accumulated time error. The Panel is keen to hear from interested parties, particularly smaller consumers, in relation to this proposed change to the FOS.

The purpose of time error correction

Historically, time error correction was used to maintain the frequency of the power system within defined limits. The purpose of this was to support various pieces of consumer equipment that included time keeping devices, where the mechanism of time keeping was the power system frequency itself. The practice of time error correction of the power system frequency was necessary to keep these synchronous clocks accurate.

While some household appliances may use synchronous clocks for time keeping, the Panel understands that it is now rare for industrial processes to rely on the use of synchronous clocks for time keeping. Digital clocks based on quartz crystal resonators are now the standard mechanism for accurate time keeping.

Regulating FCAS and time error correction

During normal operation, the power system frequency is maintained within the normal operating frequency band by regulating FCAS. The primary purpose of regulating FCAS is to correct small frequency deviations away from 50Hz.[99] However, in order to comply with the limit on accumulated time error, regulation FCAS is also used to perform time error correction, separate from any real time frequency correction. Time error correction is the process of manipulating the power system frequency up or down by a small amount for the purpose of reducing any accumulated time error that may build up as a result of the power system frequency deviating away from 50Hz form some time.

Box 4.2 provides a description of how time error correction operates in in the NEM.

Box 4.2 Time error correction in the NEM

In the NEM, time error correction is coordinated automatically by AEMO's Energy Management System (EMS), which monitors the power system frequency and coordinates the operation of regulating FCAS through automatic generation

99 AEMO, Fact Sheet-Frequency Control, 8 August 2016. https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Reports/AEMO-Fact-Sheet_Frequency-Control---Final.pdf

control (AGC) signals. The EMS tracks the system frequency and any accumulated time error and sends signals to generators enabled to provide regulating FCAS in order to correct small frequency deviations and reduce the value of any accumulated time error in accordance with the limits in the FOS.[100]

There are two variables determined by AEMO's systems which relate to time error correction:

- the required quantity of regulating FCAS purchased in each 5 minute dispatch interval
- the target power system frequency.

For Tasmania the quantity of regulating FCAS is set at a constant level of 50MW.[101] For the mainland NEM , the quantity of regulating FCAS varies between a base value of 130 MW for raise services and 120 MW for lower service and a maximum of 250MW depending on the cumulative time error.[102]

In the absence of time error correction the target power system frequency set by the EMS is equal to 50.00Hz. The practise of time error correction involves the modification of this target power system frequency in order to reduce any accumulated time error in accordance with the limits in the FOS for Tasmania and the mainland. To correct a positive accumulated time error, the target frequency is set below 50 Hz, while to correct a negative time error the target frequency is set above 50Hz. The Panel understands that, depending on the size of the accumulated time error, the target frequency may vary between 49.95 and 50.05 Hz.

AEMO's advice to the Panel indicates that it is likely that the benefits of limiting accumulated time error no longer justify the costs associated with the practise of time error correction, subject to satisfactory consultation to fully understand and evaluate any impacts on customers.[103]

The costs of time error correction

There are a number of costs associated with the practise of time error correction, including:

- increased quantity of regulating FCAS
- system security implications as a result of small changes to AEMO's control system target frequency while time error correction is operating

Increased regulating FCAS

As set out in box 4.2, AEMO varies the quantity of regulating FCAS procured for the mainland in response to the size of the accumulated time error. This practise can be in

102 AEMO, *Constraint Implementation Guidelines for the National Electricity Market*, June 2015, p. 27.

102 AEMO, *Constraint Implementation Guidelines for the National Electricity Market*, June 2015, p. 27.

102 AEMO, *Constraint Implementation Guidelines for the National Electricity Market*, June 2015, p. 27. AEMO, *SO_OP_3715---Power System Security Guidelines*, 15 May 2017, p.47.

103 AEMO, Advice to the Reliability Panel for the review of the frequency operating standard, 18 August 2017, p.7.

part attributed to an appropriate approach to managing the power system frequency, i.e. as the frequency diverges away from 50Hz for a longer period, the accumulated time error builds up and the quantity of regulating FCAS is increased (up to a limit of 250MW) to increase the size of the control response.

However once the real frequency error is corrected, an accumulated time error may remain, at which point the additional regulating FCAS is no longer performing a frequency control function, rather it is performing time error correction.

AEMO's advice is that the value of this additional regulating FCAS purchased for the purpose of time error correction on the mainland may be as much as $1 million per annum, based on data from January 2016 to June 2017.[104]

System security considerations

AEMO's advice to the panel is that time error correction does not provide any system security or reliability benefits.[105] AEMO's analysis suggests that approximately 20% of the time that time error correction is being undertaken, it is actually mildly degrading power system frequency control. This degradation occurs when the time error correction target frequency is counter to the actual time frequency goal.

For example, a positive time error is corrected by running the power system at slightly below 50Hz for a period of time, as described in Box 4.2. If at the same time, a contingency event occurs that results in a temporary shortage of generation in the power system the power system frequency will fall, and due to the operation of time error correction, fall from a lower starting point. As a result, by the time the frequency deviation is arrested, the frequency may have diverged further from 50Hz, than if time error correction were not being undertaken.[106] This counter acting frequency control is likely to place a heavier load on contingency FCAS and may result in an increased likelihood of the power system frequency diverging outside the operational frequency tolerance band, which would result in automatic load shedding.

In summary the practise of time error correction is understood to be unnecessary as there are not understood to be any significant benefits, while there are mild economic and system security costs. As a result the Panel is relaxing the limit on accumulated time error that applies in the mainland to 15 seconds, in line with the current limit that applies in the Tasmanian FOS. The Panel will consider the removal of a limit on accumulated time error as part of stage two of the review of the FOS.

4.7 Arrangements for implementation of the Standard

The Panel proposes that the revised stage one FOS will take effect on publication of the final stage one FOS, which is planned for 7 November 2017.

The Panel invites comment from stakeholders on this timing and necessary arrangements required for the implementation of the stage one FOS.

104 Ibid. p.5.

105 Ibid. p.6.

106 Ibid. pp.6-7

5 Issues for consideration in stage two of the Panel's review of the FOS

This chapter provides an initial outline of the some of the issues that may be relevant to the Panel's consideration in stage two of this review. It is not a determination of the issues discussed within it.

This chapter follows on from the Panel's description of its proposed approach to stage two, as set out in the issues paper.[107] It is intended to build on that initial discussion, by providing further details regarding the kinds of matters the Panel is likely to consider through the general approach framework established in the issues paper.

During stage two, the Panel will conduct a thorough review of the settings of the FOS, including examining the boundaries of the various frequency bands and the timeframes for restoration of power system frequency following specific events.

This chapter sets out a number of issues in accordance with the three broad sets of power system conditions:

- normal operation – no contingency events
- management of credible contingency events
- management of emergency conditions.

The following sections set out a number of preliminary issues identified for consideration through stage two of the review, broken out into these three broad sets of power system conditions.

The issues discussed in this chapter are not a definitive list of all the issues that will be considered in stage two. Stakeholders are encouraged to comment on the issues identified, and to highlight any other issues that should be included in the Panel's consideration of the FOS in stage two.

5.1 Normal operation

This section sets out the following matters related to the normal operation of the power system:

- A summary of the normal operating processes, including the normal operating frequency band
- A description of the issues surrounding making changes to the settings of the normal operating frequency band and the normal operating frequency excursion band
- A description of the issues related to the introduction of automatic governor response and primary frequency control as they relate to normal operation of the power system.

107 The issues paper provides a more detailed description of the operational role of the FOS and how it fits within the broader market and regulatory frameworks for the NEM. See: Reliability Panel, 11 July 2017, *Review of the frequency operating standard – Issues paper*.

5.1.1 Normal operating processes: the normal operating frequency band and the normal operating frequency excursion band

Normal operating conditions refer to operation of the power system in the absence of any contingency event, that is with all generators and network elements operating as expected with no unplanned outages. Normal operation is equivalent to AEMO operating the power system within a satisfactory operating state.[108]

The purpose of the normal operating bands is to set the boundaries for stable power system frequency in the absence of disturbances, in order to support efficient and predictable operation of generation, networks and consumers' equipment. Maintaining the frequency within these bands for normal operation also supports more predictable and controllable frequency excursions, if a contingency event were to occur.

There are a number of minor imbalances between supply and demand that may occur during normal operation of the system and which may result in some frequency variation within the normal bands. These kinds of events included within the scope of normal operation include:

- errors in the 5-minute demand forecasts that are used in the dispatch process
- generating systems not following their dispatch targets
- errors in the 5-minute forecasts of variable intermittent generation, such as wind or solar, that are used in the dispatch process
- smaller generating systems or loads partially reducing their output or consumption, or tripping altogether.

In each case, these kind of events may result in imbalances between load and available generation, causing the frequency to either rise or fall. However, the extent of the imbalance between available generation and load caused by these events is usually relatively small, at least compared to the kinds of imbalances expected for a larger contingency such as the tripping of a large generating system or load. Accordingly, the size of the subsequent frequency change is also typically relatively small.

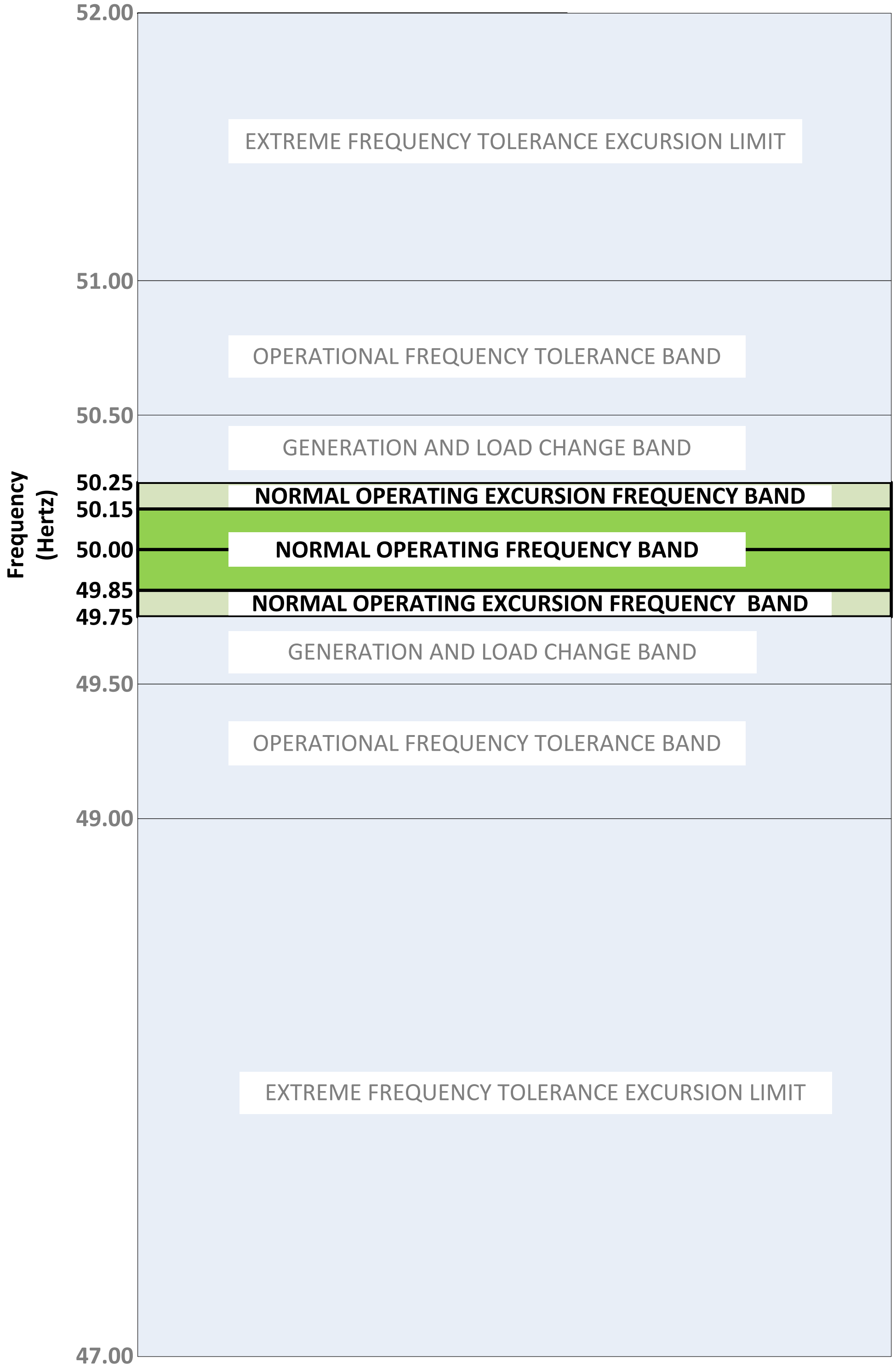
The frequency bands in the FOS that apply for normal operation of the power system are the:

- normal operating frequency band
- normal operating frequency excursion band. This means that the frequency should not move beyond these boundaries, for the kinds of minor events described above.

The settings for these bands are common between the mainland NEM and Tasmania and are displayed below in figure 5.1.

108 NER clause 4.2.2 states that "The *power system* is defined as being in a *satisfactory operating state* when: (a) the *frequency* at all energised *busbars* of the *power system* is within the *normal operating frequency band*, except for brief excursions outside the *normal operating frequency band* but within the *normal operating frequency excursion band;*"

Figure 5.2 **The normal operating frequency band and the normal operating frequency excursion band**



Normal operating frequency band

In the NEM, the power system is maintained within the normal operating frequency band through the operation of regulating FCAS.

The normal operating frequency band is currently set within the boundaries of 49.85Hz to 50.15Hz.

Regulating FCAS are procured by AEMO and used to correct for the small mismatches between available generation and load that occur in the absence of a large contingency. Regulating FCAS typically involves enabled generators providing small changes in their output to address these small frequency disturbances.

The operation of regulating FCAS is coordinated by AEMO's automatic generator control (AGC) system. The AGC monitors minor changes in the power system frequency and adjusts the output of regulating FCAS generating units accordingly.[109] However, using the AGC and regulating FCAS to control frequency is a reasonably slow process, due to the communication delays between the AEMO control centre, where the frequency is measured, and generating units, where the regulating FCAS is provided.[110]

The normal operating frequency band is relevant to control of frequency during normal operating conditions in a number of ways.

Firstly, the settings of the boundaries of the normal operating frequency band itself have a bearing on the quantity, and therefore the cost, of the regulating FCAS needed to keep the frequency within these boundaries. In theory, the tighter the settings of the normal operating frequency band, the more regulating FCAS that is likely to be needed to maintain the frequency in this band.

However, the amount of regulating FCAS necessary to keep the frequency within the normal operating frequency band may also depend on the extent to which generator governors operate and provide an automatic, primary frequency control function within this band. This will in turn depend on whether the associated generating systems have their governors "switched on" to provide an automatic response, and whether generators have their dead-bands set within the normal operating frequency band.

This issue, including a more detailed description of how governor response and deadband settings may be relevant to our stage two considerations of the FOS, is discussed in more detail in section 5.1.3.

More generally, automatic governor response, as well as the associated dead-band settings, is being considered by AEMO's ancillary services technical advisory group (ASTAG) and the AEMC's frequency control frameworks review.[111]

The normal operating frequency band also sets the threshold for the commencement of operation of contingency FCAS. That is, the contingency FCAS used to manage the

109 While regulating FCAS is centrally controlled through the AGC system, contingency FCAS (once enabled) operates automatically based on local frequency measurement.

110 AEMO's advice to the Panel for stage one of this review indicates that the regulating FCAS is able to effectively provide a frequency response within approximately 30seconds, as compared to fast contingency FCAS which responds within approximately 6 seconds.

111 For the AEMO AS-TAG see: www.aemo.com.au/Stakeholder-Consultation/Industry-forums-and-working-groups/Other-meetings/Ancillary-Services-Technical-Advisory-Group
For the AEMC Frequency control frameworks review see: http://www.aemc.gov.au/Markets-Reviews-Advice/Frequency-control-frameworks-review

frequency disturbances caused by a contingency event begin to operate once the frequency moves outside of the boundary of the normal operating frequency band.[112]

This means that a narrower normal operating frequency band (that is, setting the boundaries of the normal operating frequency band closer to the nominal frequency of 50Hz) increases the size of the frequency range within which contingency FCAS operates, and may result in an earlier "triggering" of these services. A narrower normal operating frequency band may therefore change the quantity of contingency FCAS procured and used, which may have implications for the costs of these services.

The boundaries of the normal operating frequency band will therefore also be relevant to consideration of the management of contingency events and the appropriate setting for the operational frequency tolerance band. This is discussed in more detail in section 5.2.

Normal operating frequency excursion band

The normal operating excursion frequency band is currently set between the boundaries of 49.75Hz and 50.25Hz.

Under the current FOS the frequency is allowed to deviate outside of the normal operating frequency band and into the normal operating excursion frequency band, even in the absence of a contingency event, provided:

- the frequency remains within the normal operating frequency band for 99% of the time
- the frequency remains within the normal operating frequency excursion band (a band that is ±0.1Hz wider than the normal operating frequency band)
- the frequency returns to the normal operating frequency band within 5 minutes.

The normal operating excursion frequency band was included in the mainland FOS following the 2001 Reliability Panel review. This statistical tolerance essentially "softens" the operational limit set by the normal operating frequency band, with the result being that the quantity and cost of regulating FCAS procured by AEMO is incrementally reduced.[113]

This is achieved as the presence of the normal operating excursion frequency band gives AEMO the flexibility to allow power system frequency to move outside of the normal operating frequency band for short periods of time. This flexibility allows AEMO to reduce its exposure to high regulating FCAS price events, thus reducing overall FCAS costs.

5.1.2 Potential issues related to varying the normal operating frequency band and the normal operating frequency excursion band

Stage two of the review may consider revising the settings in the FOS for the normal operating frequency band and the normal operating frequency excursion band.

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112 Once enabled by the NEM dispatch engine, contingency FCAS is provided automatically based on local frequency measurement; as such it tends to respond more rapidly than regulating FCAS which is centrally controlled via the AGC.

113 Reliability Panel, September 2001, *Frequency operating standards – Determination*, p.9.

The Panel notes recommendation 2.3 from the Finkel Panel report, which recommended that by mid-2018, the Australian Energy Market Operator and Australian Energy Market Commission should:[114]

- Investigate and decide on a requirement for all synchronous generators to change their governor settings to provide a more continuous control of frequency with a deadband similar to comparable international jurisdictions.
- Consider the costs and benefits of tightening the frequency operating standard.

Consideration of dead-band and automatic governor response settings is being addressed through the AEMC Frequency control frameworks review. Stage two of the review of the FOS will include consideration of the potential benefits and costs of tightening the FOS by narrowing the normal operating frequency band. However, as discussed below, this will also consider the implications of any changes to the market regulatory frameworks to implement any dead-band or mandatory governor response requirements, in as much as they impact on the settings of the FOS.

Generally, the Panel considers that its assessment in stage two of the settings of the normal operating frequency band and the normal operating excursion frequency band is likely to include consideration of whether:

- the current boundaries for the normal operating frequency band and the normal operating excursion frequency band are set appropriately, with a particular focus on whether this may deliver improved system security outcomes and what impacts it may have on regulating FCAS costs.
- the current stabilisation and recovery times remain appropriate
- in the absence of a contingency event, it remains appropriate to maintain the power system frequency within the normal operating frequency band for 99% of the time and allow excursions within the normal operating frequency excursion band for 1% of the time.

These issues are discussed in further detail below.

Impact of varying the boundaries of the normal operating frequency band on regulating FCAS

The Panel expects that, in the absence of any other changes to the market and regulatory arrangements, "narrowing"[115] the normal operating frequency band may increase the quantity required and therefore the cost of regulating FCAS. Conversely, broadening the normal operating frequency band may reduce the quantity required and therefore the cost of procuring regulating FCAS.

114 Finkel Panel, June 2017, *Independent Review into the Future Security of the National Electricity Market – Blueprint for the Future, pp.21,61.*

115 That is, setting the boundaries of the normal operating frequency band closer to the nominal frequency of 50Hz.

However, any variation in the costs of regulating FCAS would need to be assessed against the relative benefits for maintaining the frequency within a relatively narrower or broader normal operating frequency band.

For example, the Panel understands that one of the potential benefits of setting a narrower normal operating frequency band is that if a credible contingency occurs, the frequency is more likely to be closer to the nominal frequency value of 50Hz. This may in turn provide more time for contingency FCAS to correct the change in frequency and restore the frequency to the normal operating band following the occurrence of the contingency event.

The Panel also understands that keeping the frequency in a narrower band closer to the nominal value 50Hz value may act to reduce the extent of corrective actions needed from regulating services. This may in turn reduce the total costs of regulating services.

Finally, any consideration of the impacts of varying the normal operating frequency bands will also require consideration of the function of the AGC. The AGC controls how regulating FCAS keeps the frequency within the normal operating frequency band (and the normal operating frequency excursion band). Given that it is the function of the AGC that controls regulating FCAS, the Panel understands that narrowing the boundaries of the normal operating frequency band will therefore require greater intervention by the AGC.

The Panel therefore intends to take into consideration the current performance capability of the AGC system and regulating FCAS, along with potential new and improved methods and services for frequency control during normal operation.

For example, AEMO has recently published a working paper on fast frequency response, which outlined potential roles for fast frequency response in the NEM. One of the capabilities investigated in this paper is “fast frequency regulating” which would be a centrally controlled regulating FCAS with a response time of between 5 and 10 seconds, as compared to the current AGC response time of approximately 30seconds.[116]

Any such changes in the operation and capability of the AGC and regulating services generally are likely to be highly relevant to the appropriate boundaries of the normal operating frequency band.

Consideration for varying the stabilisation and recovery timeframes

The current FOS for the mainland and for Tasmania states the power system frequency, “should not exceed the applicable *normal operating frequency band* for more than five minutes on any occasion.” That is, following an excursion outside the normal operating frequency band, the power system frequency shall be restored to the normal operating frequency band within 5 minutes.

In assessing whether this 5 minute recovery timeframe continues to be appropriate, the Panel will consider any potential benefits of varying this timeframe against the cost implications of making such a change. For example, in theory, while broadening the restoration timeframe may reduce the requirement for regulating FCAS, this may also expose the system to greater risk of breaching the operational frequency tolerance

116 AEMO, August 2017, Fast frequency response in the NEM – Working Paper, pp.30 - 31

bands, if a contingency event were to occur in that timeframe. This may result in an increased risk of load shedding, should a contingency event occur.[117]

Conversely, tightening the restoration timeframe may reduce this risk but may come at the cost of increased regulating FCAS.[118]

Consideration for varying the allowance to exceed the normal operating frequency band for 1% of the time

As discussed in section 5.1, the current FOS includes an allowance that, during normal operation, the power system frequency may exceed the normal operating frequency band for 1% of the time, provided that the frequency does not exceed the normal operating excursion frequency band.

This requirement is included in the FOS as a mechanism that allows AEMO some operational flexibility to manage the quantities of regulating FCAS procured.

In considering this requirement, the Panel recognises that the relationship between the normal operating frequency band and the normal operating excursion frequency band is allowed for under NER clause 4.2.2 which states:

> "The *power system* is defined as being in a *satisfactory operating state* when:
>
> > (a) the *frequency* at all energised *busbars* of the *power system* is within the *normal operating frequency band*, except for brief excursions outside the *normal operating frequency band* but within the *normal operating frequency excursion band*"[119]

These "brief excursions" are limited by the FOS to be no more than 1% of the time cumulatively, with a requirement or the frequency to be restored to the normal operating frequency band within 5 minutes.

This requirement in the FOS for the total exceedance of the normal operating frequency band to be equal to or less than 1% of the total time, could be varied in a number of ways:

- The amount of time that the power system frequency can exceed the normal operating frequency band and remain within the normal operating excursion frequency band could be altered. For example, the 1% allowance could be increased to 2% or 5%.

  Such a change may be expected to reduce the quantity and cost of regulating FCAS, although this change would also result in a broadening of the allowable power system frequency distribution, that is, increasing the total amount of time in which the frequency is further away from the nominal value of 50Hz and closer to the boundary of the operational frequency tolerance band.

117 This is because if the frequency is "closer" to the operation frequency tolerance band when a contingency event occurs, there is an increased risk that the frequency may breach the operational frequency tolerance band, which the Panel understands to be the trigger point for the commencement of load shedding schemes.

118 The Panel also notes that the physical capabilities of the AGC will also be relevant to the ability to use regulating services to drive a faster return to the normal operating frequency band.

119 NER Clause 4.2.2.

If a contingency event were to occur during these time periods, there would be less time for contingency FCAS to act, increasing risk that the frequency may breach the operational frequency tolerance band, resulting in load shedding.[120]

- The ability for the frequency to be in the normal operating frequency excursion band for 1% of the time could be removed entirely, effectively removing the normal operating excursion frequency band. While this may in principle increase the cost of regulating FCAS, this will be dependent on the actual boundary settings of the normal operating frequency band.

The Panel intends to request further advice from AEMO to support the consideration of these options through stage two of the review.

5.1.2 Discussion of primary frequency control and governor response

Recent investigations into the frequency performance of the system have highlighted the potential role of primary frequency response.[121]

Primary frequency response is an instantaneous service that is provided continuously via generator governor controls in response to local frequency variation.[122]

In the NEM, generators do not always provide governor response from their generating systems, unless they are dispatched for contingency FCAS. Historically, many generating units would provide some response to a change in frequency outside of their governor dead-bands but within the normal operating frequency band.[123] The Panel understands that this behaviour, while not mandated, was largely an artefact of the older generator control systems, where the governor settings, such as the boundaries of the governor deadband, were not capable of being easily, or rapidly, changed.

However, the Panel understands that in recent years, a number of generators have installed upgraded governors which facilitate easier adjustment to generator governor control systems. This has resulted in a reduction in the number of units offering primary frequency response capability. The AEMC is considering whether governor response should be mandatory as part of its frequency control framework review, which will be informed by the work of AEMO's ASTAG.[124]

If governor response was mandatory, this could be implemented in a number of ways. For example, this could potentially include a requirement for some or all generators to

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120 Assuming that no additional contingency FCAS has been procured by AEMO for the time periods in which the frequency has moved out of the normal operating frequency band into the normal operating frequency excursion band.

121 AEMO has convened the ancillary service technical advisory group, which has led a number of discussions and considerations of the causes and potential solutions to the current frequency degradation being observed in the NEM. This has included some discussion on the role of automatic governor response / primary frequency control in managing the frequency.

122 CIGRE, 2010, *Ancillary Services: an overview of International Practices*, p.7.

123 A governor dead-band is a frequency band within which the generator governor does not vary the output of the generator, therefore governor frequency response occurs outside the governor dead-band. Historically governor dead bands were set a

124 See: http://www.aemc.gov.au/Markets-Reviews-Advice/Frequency-control-frameworks-review

keep their governors on whenever their generating systems are operating, with a further requirement that the governor dead-band settings be sufficiently narrow that the governors will start to operate within the normal operating frequency band.[125]

Such an outcome could have implications for the setting of the normal operating frequency band.

For example, any increase in the amount of governor response to provide primary frequency control may be relevant to the amount (and cost) of regulating FCAS needed to keep the frequency within given normal operating frequency band boundaries.[126] This may in turn support a change to the value of the normal operating frequency band boundaries, as it will affect the total cost of meeting a given set of boundary values.

These potential implications for the FOS are one of the main reasons the Panel has decided to split its review into two stages. This will allow the AEMC and AEMO to progress their analysis and development of the market regulatory frameworks, including any introduction of mandatory governor response and / or primary frequency control, to a stage that is sufficient for the Panel to effectively assess the implications of these changes for the FOS.

5.2 Management of credible contingencies

A secure power system must be able to absorb and recover from significant disturbances that may occur from time to time. These disturbances may be due to the unexpected failure of generation or network elements resulting in a temporary and unexpected imbalance of supply and demand, known as contingency events.

Secure operation in the NEM is defined as a state in which the power system is able to recover from the contingency events that AEMO considers to be reasonably possible in the surrounding circumstances.[127] Such contingency events are known as credible contingency events.[128]

AEMO is required to maintain the power system frequency within the applicable contingency bands for load, generation and network events when these credible contingency events occur, and must return the frequency to the normal operating frequency band within a specified time period. AEMO procures contingency raise and lower FCAS, which increase or decrease the frequency, to allow it to manage the consequences of these more significant frequency variations.

In the FOS, the management of contingency events is prescribed though the settings of the operational frequency tolerance band and a number of narrower bands that set the requirement for certain types of credible contingency events, such as generation, load

125 The Panel notes that there are a number of potential ways in which this high level obligation could be implemented, for example through the introduction of some kind of market for a primary frequency control service. This particular example is used here solely for the purposes of illustrating potential implications for the settings of the FOS.

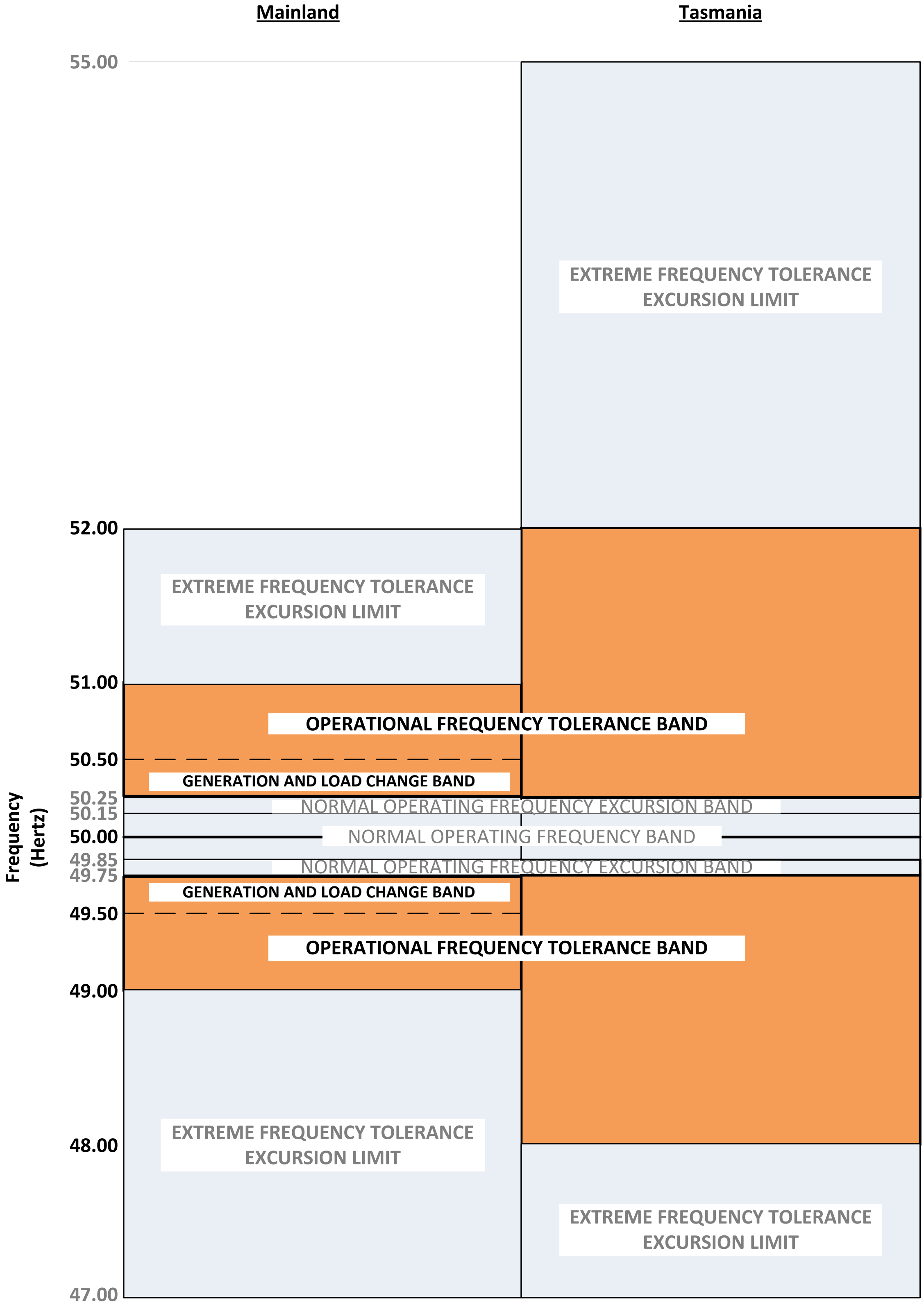
126 Primary frequency control tends to act in tandem with regulation FCAS to dampen smaller frequency variations. Increased volumes of primary frequency control may therefore improve the function and therefore reduce the required quantity of regulating FCAS.

127 NER Clause 4.2.4 (a)

128 NER Clause 4.2.3 (b)

and network events. The current settings for the operational frequency tolerance bands for Tasmania and the mainland are shown in figure 5.2.

Figure 5.2 The operational frequency tolerance band



Operational Frequency Tolerance Band

The operational frequency tolerance band defines broadest frequency range that is allowed following a credible contingency such as:

- the synchronisation or tripping of a large generating system
- the connection or disconnection of a large load
- the tripping of a single network element such as a transmission line or transformers.

The operation frequency tolerance band for an interconnected system is 49.0 Hz to 51.0 Hz for the mainland FOS and 48.0 Hz to 52.0 Hz for Tasmanian FOS.

It also serves as the boundary beyond which controlled load shedding, traditionally supplied through automatic under frequency load shedding schemes, is triggered.

Credible contingency events are expected to be relatively infrequent but, as they are typically more severe in terms of their impact on the frequency. The relevant frequency band is the operational frequency tolerance band which is set wider than the normal operating frequency band, to reflect these larger impacts.

In the NEM, contingency FCAS are procured by AEMO and are available to respond when the frequency moves outside the boundaries of the normal operating frequency band. AEMO procures enough contingency FCAS so that the frequency is expected to be kept within the operational frequency tolerance band following the occurrence of any credible contingency event.

A trade-off between frequency performance and the cost of contingency FCAS exists when considering the width of the operational frequency tolerance band and associated event specific contingency bands.

For example, narrowing the operational frequency tolerance band may provide some security benefits, in that AEMO may be required to operate the system more conservatively to meet the tighter limits. This might include AEMO procuring more contingency FCAS to keep the system frequency within a narrower band, or constraining the system to reduce the risk of the frequency moving outside of this band. These actions may increase the frequency stability of the system, by acting to keep the frequency closer to the nominal 50Hz.

Furthermore, by bringing the trigger point for load shedding closer to the normal operating frequency band, a narrower operational frequency tolerance band may increase the likelihood that load-shedding occurs.[129] While this would come at an immediate cost to the parties whose load may be shed, it also helps to reduce the likelihood that power system frequency will move beyond its technical limits (the extreme frequency excursion tolerance limits) and become susceptible to collapsing to a black system. As such, by increasing the likelihood of load shedding, a narrower operational frequency tolerance band may also act to reduce the risk of a black system occurring.

However, narrowing the operational frequency tolerance band would also likely come with increased costs. For example, it would likely result in an increased procurement of

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129 The boundary of the operational frequency tolerance band typically serves as the point at which automatic load shedding schemes are triggered.

contingency FCAS. This is because contingency FCAS only commences operation once the frequency moves outside the normal operating frequency band, but needs to keep the frequency within the operational frequency tolerance band. If the operational frequency tolerance band is narrowed and is brought closer to the normal operating frequency band, it follows that there is less frequency "buffer", or time available, within which contingency FCAS must act to stabilise and recover the power system frequency. More contingency FCAS would therefore be required to stabilise and recover the frequency within the narrower operational frequency tolerance band.

Conversely, the operational frequency tolerance band could be widened. While a broader operational frequency tolerance band could reduce the need for contingency FCAS, it may also become more difficult to manage more extreme frequency excursions events.

5.2.1 Different bands for different contingencies

The FOS for the mainland has narrower allowable frequency bands for load or generation contingencies, compared to network events. This is because network events are generally more severe than load or generation events so the FOS for the mainland allows a wider range for frequency deviations. However, in Tasmania, the same bands of allowable frequencies apply for all single contingencies.

For an interconnected system the mainland FOS sets:

- the generation or load event band as 49.5Hz – 50.5Hz
- the network event band as equal to the operation frequency tolerance band of 49.0 Hz – 51.0 Hz.

For an interconnected system the Tasmanian FOS sets the generation, load and network event bands as being equal to the operational frequency tolerance band of 48.0Hz – 52.0Hz.

In stage two of the review that Panel will consider if it is appropriate for separate frequency bands to apply for load, generation and network events on the mainland, or whether the operational frequency tolerance band should apply for all single contingencies, as is the case in Tasmania.

5.2.2 The thresholds and limits for contingency events

Currently the FOS includes a number of thresholds on the size of a contingency in order for a particular event to be treated as a generation or load event under the FOS. In addition the Tasmanian FOS includes a maximum limit on the size of a generation event that must be managed through contingency FCAS. During stage two of the review, the Panel intends to consider whether any changes are warranted to the FOS in respect of these thresholds and limits.

Threshold for load events

The current FOS for the mainland includes a 50MW threshold that applies to the increase or decrease of customer load in order to qualify as a load event under the FOS. The equivalent load event threshold in the Tasmanian FOS is 20MW, as the Tasmanian system is smaller than the mainland NEM and more sensitive to frequency disturbances.

Threshold for generation events

As discussed in section 4.4 the current FOS for mainland and for Tasmania both include a threshold of 50MW that applies to the synchronisation (connection) of a generating unit.[130]

The Panel is aware that there may be a case to vary these thresholds for different modes of power system operation, such as an interconnected system or during island operation. For example, following a credible or non-credible tripping of the Heywood interconnector that islands South Australia, currently the same 50MW threshold would apply as when the is the South Australian region is fully interconnected with the rest of the mainland. This may not be appropriate as the islanded power system is significantly smaller and therefore the islanded frequency may be more sensitive to smaller power imbalances.

All else being equal, an increase of the threshold for contingency events is likely to:

- increase the amount of regulating FCAS required to manage the frequency within the normal operating frequency band, in the absence of a contingency
- increase the amount of inertia that would be required for the AGC to be able to contain the frequency within the normal operating frequency band.[131]

Stage two of the review will consider the appropriateness of the current 50MW and 20MW thresholds for the mainland and Tasmania, as well as whether smaller thresholds should apply for some of the regions if they are islanded. In considering these thresholds the Panel will also consider:

- the size of the generating systems within the region
- the size of the larger loads within the region.

Limit on the size of a generation event in Tasmania

The current FOS for Tasmania includes a limit of 144MW that sets the maximum size for a generation event. This limit was included in the Tasmanian FOS in order to reduce the quantity of contingency FCAS that would be required to mitigate loss of generating units larger than 144MW.[132] In practise for Tasmania, the connection of a single

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130 The Panel understands that the 50MW threshold that forms part of the definition of a generation event strictly applies only to the synchronisation of a generation unit, not to a credible contingency relating to a generating unit. This may be interpreted differently in terms of power system operation. That is to say, the Panel also understands that the 50MW threshold is often treated as applying to the generation event more generally for operational purposes.

131 The panel understands that the link between contingency size and the required operating level of inertia is being considered through the AEMC's *Managing the rate of change of power system frequency* rule change. AEMC, 27 June 2017, *Managing the rate of change of power system frequency* – Draft Determination, p.27.

132 When the current Tasmanian FOS was determined, the Panel facilitating the process of adapting the Tasmanian FOS to be compatible with the installation and operation of the 210MW Tamar Valley CCGT power station, which was to be the largest single generating unit in operation in Tasmania. As part of the determination of the Tasmanian FOS the Panel included the 144MW limit on the size of a generation event to reduce the amount of contingency FCAS that the operation of this new

generating unit larger than 144MW requires the corresponding operation of an automatic load shedding scheme that is able to operate instantaneously in the event of a contingency impacting the large generating unit. This type of EFCS or special protection scheme operates to effectively limit the size of the maximum contingency for which AEMO must purchase contingency FCAS to 144MW.

The TasNetworks submission to the Issues Paper requested that the Panel consider extending the current limit on the size of a generation event to also apply to network events. This request is based on TasNetworks knowledge of more renewable generating systems intending to connect to the Tasmanian power system, where the combined size of the generating units behind a single transmission element will exceed 144MW. TasNetworks state in their submission that this arrangement is not able to be captured by the existing definition of generation event and the corresponding limit of 144MW.[133]

TasNetworks provide the example of the Musselroe Wind Farm which commenced operation in 2013 with a rated capacity of 168MW. TasNetworks analysis suggest that the Musselroe wind farm may be driving a requirement for AEMO to purchase more than 144MW of contingency FCAS approximately 16% of the time.[134]

The Panel will consider this issue further during the course of stage two of the review, and investigate options to address the most appropriate way to manage contingency events in the Tasmanian power system, including the potential to vary the FOS in relation to generation and network events and the limits that apply for the Tasmanian FOS.

5.3 Management of emergency conditions

The management of the power system during emergency conditions includes the preparation for and operation of the power system in the event of high impact low probability events, such as non-credible contingency events including multiple contingency events and protected events.

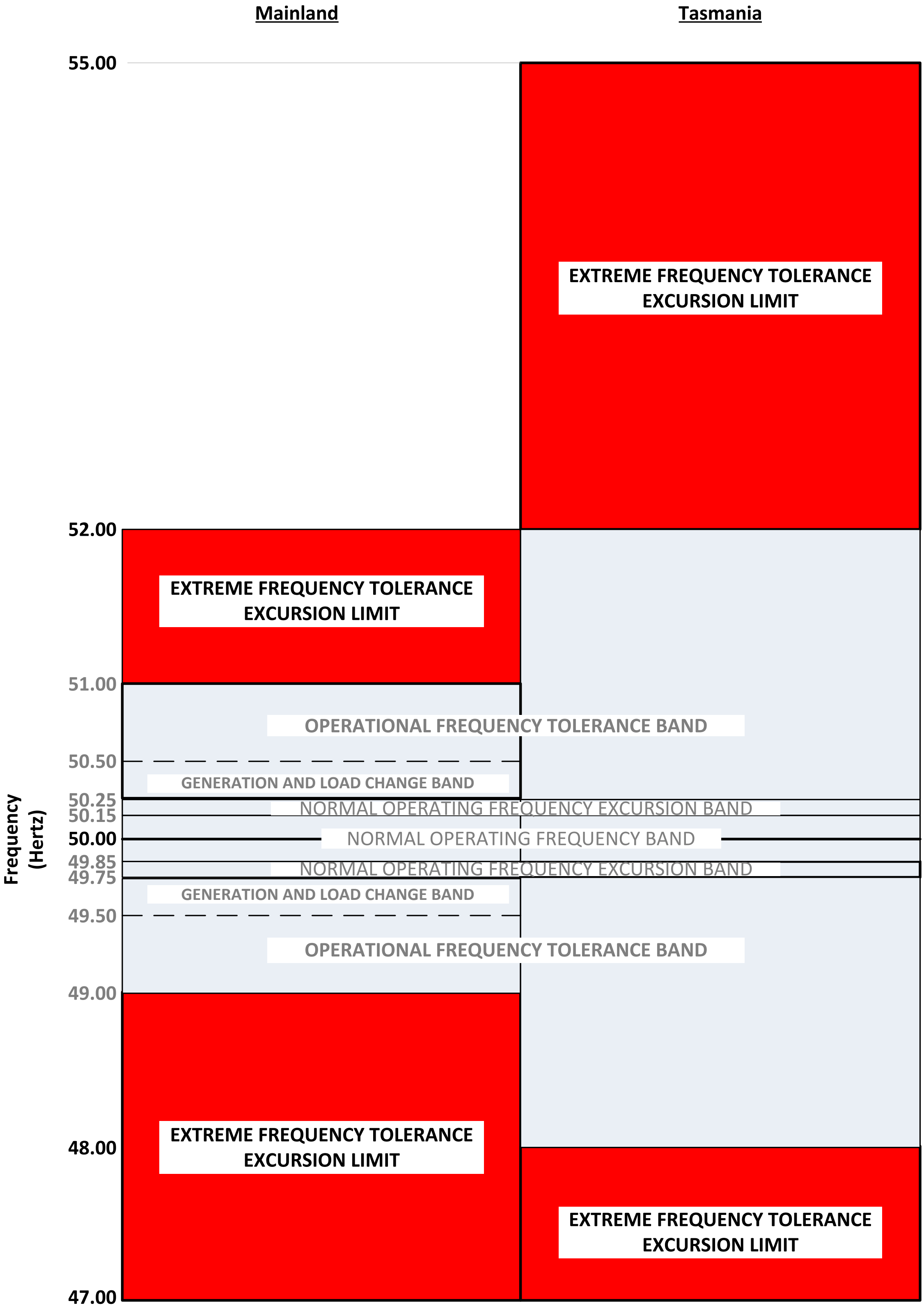
The component of the FOS that specifies the limits for satisfactory operation of the power system during emergency conditions is the extreme frequency excursions tolerance limit which is displayed below in figure 5.3.

generating unit was expected to require in order to meet the FOS. Reliability Panel, 18 December 2008, *Tasmanian frequency operating standard* – Final Report, p.17.

133 TasNetworks, Submission to the Issues Paper, pp.2-5.

134 Ibid. pp.3-4.

Figure 5.3 The extreme frequency tolerance excursion limit



The extreme frequency excursion tolerance limit defines the maximum allowable frequency excursions from the nominal 50 Hz value. The equipment in the power system is designed to operate to this range, at least for short periods. Beyond these frequency limits, network equipment and generating systems may be damaged, and therefore, such equipment will include over and under frequency protection systems to remove equipment from service under very extreme frequency conditions.

For example, generating systems are typically fitted with these protection systems, which will trip them off the system once the frequency goes beyond certain limits. However schedule 5.2.5.3 of the NER requires that all connecting generating systems are able to operate continuously within the extreme frequency excursion tolerance limit for 2 minutes.[135] This requirement is imposed on connecting generating systems so that they can be expected to remain connected and operating continuously for the most likely multiple contingencies, where the frequency would be expected to be maintained within the extreme frequency excursion tolerance limit within 2 minutes.

The size of the extreme frequency excursion tolerance limit reflects the capability of the generating systems within the power system. Most steam and gas turbines can operate between 47 Hz and 52 Hz for short periods but generally trip instantaneously when the frequency is outside this range to avoid damage. In addition, the turbines often are unstable outside this range. Hydro generating units can be designed to operate safely with a larger range of frequencies, which is the basis of the wider extreme frequency tolerance excursion limit for Tasmania of 47 Hz to 55 Hz.

The inverters used to connect type 3 and 4 wind turbines, grid connected solar PV and battery systems can be designed to operate over a range of frequencies. The cost of the inverters will increase as the size of the allowable range of frequencies increases, but this is unlikely to materially increase the cost of such generation and the proponents of such existing generation projects appear to be able to meet the current standards quite easily.

Emergency frequency control schemes aim to maintain the frequency within the extreme frequency excursion tolerance limit. These schemes include:

- automatic under-frequency load shedding schemes
- automatic over-frequency generator shedding schemes
- special protection schemes

Most power systems include an emergency under-frequency load shedding scheme which consists of under-frequency relays at the distribution network service providers' substations and at transmission connected customer substations. These relays are set to progressively trip blocks of load (consumers) whenever the frequency falls below the lower limit of the operational frequency tolerance band due to the occurrence of a contingency event that has caused an imbalance in supply and demand.

As the frequency drops further, blocks of load are shed in order to quickly rebalance supply and demand, and thus arrest the falling frequency. The emergency under-frequency load shedding schemes in the NEM can operate reliably if there is

135 This requirement is relaxed to 9 seconds for the minimum access standard, with the generating system required to continue to operate for 2 minutes with the frequency as low as 47.5 Hz, with the agreement of AEMO and the associated network service provider. The minimum access standard also allows for the generator and AEMO to agree on a lower over-frequency capability that is less extreme.

sufficient load under control of the relays and the frequency falls at a rate that is sufficiently slow.[136]

Emergency generator shedding schemes are used to manage large over-frequency events. Large over-frequencies are generally very uncommon because large loads are less common than large generating systems, and these loads are unlikely to trip together as a multiple contingency. Large over-frequencies can also occur in an exporting region following the trip of an interconnector, but again this is rare as it only occurs when there is a coincident non-credible trip at a time of high export flows.[137] In some instances emergency over-frequency generator shedding schemes are implemented to progressively shed generation as the frequency rises, which mirrors the operation of an under-frequency load shedding scheme.

In addition to these schemes, special protection schemes are sometimes used to manage emergency frequency control. Such schemes operate in different ways but generally trip a pre-armed block of load or generation in response to a specific event such as the trip of an interconnector. That is, instead of responding to the falling or rising frequency that results, the SPS trips the load or generation directly. This increases the speed of response to the event which may in some instances prevent a cascading outage[138] or even a black system event.[139]

In general, under and over frequency load shedding schemes are triggered once frequency diverges outside the operating frequency tolerance band and act to maintain frequency within the extreme frequency excursion tolerance band.[140]

The size of the extreme frequency excursion tolerance limit depends primarily on the technical capability of the generating systems within the power system. The Panel invites stakeholders to provide feedback on the existence of any immediate drivers for change to the extreme frequency excursion tolerance limit.

5.4 Other Issues related to stage two of the review of the FOS

The Panel is aware of a number of additional issues that have been raised for consideration during stage two of the review, including:

136 Up to 60% of the load must be made available to the UFLSS. The jurisdictional system security coordinator determines which loads are shed first.
The AEMC understands that the UFLSS in South Australia uses relays that take about 500ms to operate. This means that it can operate up to a rate of change of frequency (RoCoF) of 3 Hz per second. If the frequency falls faster than this it is likely that the UFLSS will operate too slowly, and the frequency will reach the lower limit of extreme frequency excursion tolerance limit before enough load blocks have been shed.

137 A large over-frequency should not happen following a credible interconnector trip because AEMO would be required to procure sufficient contingency FCAS to keep the frequency within the operational frequency tolerance band.

138 Insert definition of cascading outage.

139 Insert definition of black system event.

140 There are exceptions to this statement, such as special protection schemes, that are triggered due to occurrence of a specific contingency event, in order to mitigate the impact of that event. Examples of these are the special protection schemes that operate in Tasmania to mitigate the impact of the failure of Basslink.

- consideration as to whether the FOS should include a limit on ROCOF[141]
- consideration of improving the structure and consistency of the FOS document.[142]

The Panel invites comment on these issues and any other issues that stakeholders feel are relevant to stage two of the FOS review. These issues will be considered and addressed in subsequent reports through the remainder of stage one and into stage two of the review.

5.5 Further AEMO advice to support stage two

In order to support the assessment of the issues identified for consideration through stage two of the review, the Panel will request further advice from AEMO.

Based on the Panel's initial considerations this advice may include:

- an estimate how much regulating FCAS would be required for a range of potential settings for the normal operating frequency band
- advise on whether there is a size of normal operating frequency band that minimises the FCAS requirements
- the impact of mandatory governor response on the expected quantity of regulating FCAS required to meet the FOS during normal operation
- advice to describe the optimal power system stability characteristics in terms of frequency control (including minimum inertia and primary frequency control)
- the current and potential future functional capability of the AGC and regulating FCAS and the extent to which it will be able to effectively control the power system frequency control within the normal operating frequency band.

141 Submission to the Issues Paper: ENA, p.5; Engie, p.5; TasNetworks, pp.8-9; Department of the Premier and Cabinet - South Australia, pp.7-8.

142 AEMO, *Review of the frequency operating standard*, stage 1 – request for advice, 18 August 2017, p.11.

Abbreviations

AC	alternating current
AGC	automatic generation control
AS-TAG	Ancillary Services Technical Advisory Group
DC	direct current
EFCS	emergency frequency control schemes
ESCOSA	Essential Services Commission of South Australia
FCAS	frequency control ancillary services
FFR	fast frequency response
FOS	frequency operating standards
GW	Giga-Watt
MW	Mega-Watt
NEL	National Electricity Law
NEM	National Electricity Market
NEMDE	National electricity market dispatch engine
NEO	National Electricity Objective
NER	National Electricity Rules
TNSP	transmission network service provider

A The draft frequency operating standard

The Panel has made a draft determination to amend, in accordance with clause 8.8.3(a)(1) of the Rules and section 38 of the NEL, the NEM Mainland frequency operating standards which form part of the *power system security standards*. These amendments are contained in this Appendix A.

A.1 Draft frequency operating standards for the mainland NEM

A.1.1 Part A Summary of the draft frequency operating standards for the mainland NEM

The NEM Mainland *frequency operating standards* set out in Part B are summarised in the following tables for convenience. To the extent of any inconsistency between these tables and Part B below, Part B prevails. The following table applies to any part of the NEM Mainland *power system*, other than an *island* or during periods of supply scarcity during load restoration:

Table A.1.1 Draft NEM Mainland Frequency Operating Standards – interconnected system

Condition	Containment	Stabilisation	Recovery
Accumulated time error	15 seconds	n/a	n/a
No contingency event or load event	49.75 to 50.25 Hz, 49.85 to 50.15 Hz - 99% of the time	49.85 to 50.15 Hz within 5 minutes	
Generation event or load event	49.5 to 50.5 Hz	49.85 to 50.15 Hz within 5 minutes	
Network event	49 to 51 Hz	49.5 to 50.5 Hz within 1 minute	49.85 to 50.15 Hz within 5 minutes
Separation event	49 to 51 Hz	49.5 to 50.5 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes
Protected event	47 to 52 Hz	49.5 to 50.5 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes
Multiple contingency event	47 to 52 Hz (reasonable endeavours)	49.5 to 50.5 Hz within 2 minutes (reasonable endeavours)	49.85 to 50.15 Hz within 10 minutes (reasonable endeavours)

Table A.1.2 Draft NEM Mainland Frequency Operating Standards – island system

Condition	Containment	Stabilisation	Recovery
No contingency	49.5 to 50.5 Hz		

Condition	Containment	Stabilisation	Recovery
event, or load event			
Generation event, load event or network event	49 to 51 Hz	49.5 to 50.5 Hz within 5 minutes	
The separation event that formed the island	49 to 51 Hz or a wider band notified to AEMO by a relevant Jurisdictional Coordinator	49.0 to 51.0 Hz within 2 minutes	49.5 to 50.5 Hz within 10 minutes
Protected event	47 to 52 Hz	49.0 to 51.0 Hz within 2 minutes	49.5 to 50.5 Hz within 10 minutes
Multiple contingency event including a further separation event	47 to 52 Hz (reasonable endeavours)	49.0 to 51.0 Hz within 2 minutes (reasonable endeavours)	49.5 to 50.5 Hz within 10 minutes (reasonable endeavours)

Table A.1.3 Draft NEM Mainland Frequency Operating Standards – during supply scarcity

Condition	Containment	Stabilisation	Recovery
No contingency event or load event	49.5 to 50.5 Hz		
Generation event, load event or network event	48 to 52 Hz (Queensland and South Australia) 48.5 to 52 Hz (New South Wales and Victoria)	49 to 51 Hz within 2 minutes	49.5 to 50.5 Hz within 10 minutes
Protected event	47 to 52 Hz	49.0 to 51.0 Hz within 2 minutes	49.5 to 50.5 Hz within 10 minutes
Multiple contingency event or separation event	47 to 52 Hz (reasonable endeavours)	49.0 to 51.0 Hz within 2 minutes (reasonable endeavours)	49.5 to 50.5 Hz within 10 minutes (reasonable endeavours)

The mainland *frequency operating standards* during *supply scarcity* apply if:

1. A situation of *supply scarcity* is current.
2. In cases where an island incorporates more than one region then the critical frequency to be adopted is to be the maximum value of the critical frequencies for these regions (e.g. for an island comprised of the regions of Victoria and South Australia the critical frequency would be 48.5 Hz)

3. The power system has undergone a contingency event, the frequency has reached the Recovery frequency band and AEMO considers the power system is sufficiently secure to begin load restoration.
4. The estimated amount of load available for under-frequency load shedding within the power system or the island is more than the amount required to ensure that any subsequent frequency excursions would not go below the proposed Containment and Stabilisation bands as a result of a subsequent generation event, load event, network event or a separation event during load restoration.
5. The amount of generation reserve available for frequency regulation is consistent with AEMO's current practice.

A.1.2 Part B - The draft frequency operating standards for the mainland

For the purposes of the Rules, the *frequency operating standards*, forming part of the power system security and reliability standards that apply in the mainland are:

(a) except in an island or during supply scarcity, the accumulated time error should not exceed 5 seconds;

(b) except as a result of a contingency event or a load event, system frequency should not exceed the applicable *normal operating frequency excursion band* and should not exceed the applicable *normal operating frequency band* for more than five minutes on any occasion and not for more than 1% of the time over any 30 day period;

(c) as a result of a generation event or a load event, system frequency should not exceed the applicable generation and load change band and should not exceed the applicable *normal operating frequency band* for more than five minutes;

(d) as a result of any network event, system frequency should not exceed the applicable *operational frequency tolerance band* and should not exceed the applicable generation and load change band for more than one minute or exceed the applicable *normal operating frequency band* for more than five minutes;

(e) as a result of any separation event, system frequency should not exceed the applicable island separation band and should not exceed the applicable generation and load change band for more than two minutes or exceed the applicable *normal operating frequency band* for more than ten minutes; and

(f) as a result of any *protected event*, system frequency should not exceed the *extreme frequency excursion tolerance limits* and should not exceed the applicable generation and load change band for more than two minutes while there is no *contingency event* or exceed the applicable *normal operating frequency band* for more than ten minutes while there is no *contingency event*.

(g) following the occurrence of any *non-credible contingency event* or multiple *contingency event* that is not a *protected event*, AEMO should use reasonable endeavours to:

  iii. maintain system frequency within the *extreme frequency excursion tolerance limits* and

iv. avoid the system frequency exceeding the applicable generation and load change band for more than two minutes while there is no *contingency event* or exceeding the applicable *normal operating frequency band* for more than ten minutes while there is no *contingency event*.

A.1.3 Part C - Application of Rules Terms for the mainland

For the purposes of these *frequency operating standards* and Chapters 4, 5 and 10 of the Rules, a term shown in Column 1 of the following table:

i) has the corresponding range shown in Column 3 of the table for an island;

ii) has the corresponding range shown in Column 4 during supply scarcity; and

iii) has the corresponding range shown in Column 2 of the table otherwise.

Table B.4 Draft NEM mainland frequency operating standards – Rule terms

Column 1	Column 2	Column 3	Column 4
Term	**Normal range (Hz)**	**Island range (Hz)**	**Supply scarcity range (Hz)**
normal operating frequency band	49.85 to 50.15	49.5 to 50.5	49.5 to 50.5
normal operating frequency excursion band	49.75 to 50.25	49.5 to 50.5	49.5 to 50.5
operational frequency tolerance band	49.0 to 51.0	49.0 to 51.0	48.0 to 52.0
extreme frequency excursion tolerance limit	47.0 to 52.0	47.0 to 52.0	47.0 to 52.0[143]

143 Previously this table incorrectly listed the extreme frequency excursion tolerance limit during supply scarcity as 47.0Hz – 55.0Hz. The upper limit has been corrected to 52.0Hz in this draft FOS.

A.2 Draft frequency operating standards for Tasmania

A.2.1 Part A Summary of the Standards for Tasmania

The Tasmanian *frequency operating standards* set out in Part B of this appendix are summarised in the following tables for convenience. To the extent of any inconsistency between these tables and Part B below, Part B prevails. Table A.2.1 applies to any part of the Tasmanian power system:

Table A.2.1 Tasmanian frequency operating standards – interconnected system

Condition	Containment	Stabilisation	Recovery
Accumulated time error	15 seconds		
No contingency event or load event	49.75 to 50.25 Hz 49.85 to 50.15 Hz, 99% of the time	49.85 to 50.15 Hz within 5 minutes	
Load event	48.0 to 52.0 Hz	49.85 to 50.15 Hz within 10 minutes	
Generation event	48.0 to 52.0 Hz	49.85 to 50.15 Hz within 10 minutes	
Network event	48.0 to 52.0 Hz	49.85 to 50.15 Hz within 10 minutes	
Separation event	47 to 55 Hz	48.0 to 52.0 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes
Protected event	47 to 55 Hz	48.0 to 52.0 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes
Multiple contingency event	47 to 55 Hz (reasonable endeavours)	48.0 to 52.0 Hz within 2 minutes (reasonable endeavours)	49.85 to 50.15 Hz within 10 minutes (reasonable endeavours)

Table A.2.2 applies to an island within the Tasmanian power system:

Table A.2.2 Tasmania frequency operating standards – island operation

Condition	Containment	Stabilisation	Recovery
No contingency event or load event	49.0 to 51.0 Hz		
Load and generation event	48.0 to 52.0 Hz	49.0 to 51.0 Hz within 10 minutes	
Network event	48.0 to 52.0 Hz	49.0 to 51.0 Hz within 10 minutes	
Separation event	47 to 55 Hz	48.0 to 52.0 Hz within 2 minutes	49.0 to 51.0 Hz within 10 minutes

Condition	Containment	Stabilisation	Recovery
Protected event	47 to 55 Hz	48.0 to 52.0 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes
Multiple contingency event	47 to 55 Hz (reasonable endeavours)	48.0 to 52.0 Hz within 2 minutes (reasonable endeavours)	49.0 to 51.0 Hz within 10 minutes (reasonable endeavours)

A.2.2 Part B: the Frequency operating standards for Tasmania

For the purposes of the Rules, the frequency operating standards, forming part of the power system security and reliability standards, that apply in Tasmania are:

(a) except in an island or following a multiple *contingency event*, the accumulated time error should not exceed 15 seconds;

(b) except as a result of a *contingency* or a l*oad* event, system frequency should not exceed the applicable *normal operating frequency excursion band* and should not exceed the applicable *normal operating frequency band* for more than five minutes on any occasion and for not more than 1% of the time over any 30 day period;

(c) as a result of a generation event, system frequency should not exceed the applicable generation change band and should not exceed the applicable *normal operating frequency band* for more than 10 minutes;

(d) as a result of a load event, system frequency should not exceed the load change band and should not exceed the applicable *normal operating frequency band* for more than 10 minutes;

(e) as a result of any network event, system frequency should not exceed the applicable *operational frequency tolerance band* and should not exceed the applicable *load change band* for more than one minute or the applicable *normal operating frequency band* for more than 10 minutes;

(f) as a result of any separation event, system frequency should not exceed the applicable island separation band and should not exceed the applicable load change band for more than two minutes or the applicable *normal operating frequency band* for more than 10 minutes;

(g) as a result of any *protected event*, system frequency should not exceed the *extreme frequency excursion tolerance limits* and should not exceed the applicable generation and load change band for more than two minutes while there is no *contingency event* or exceed the applicable *normal operating frequency band* for more than ten minutes while there is no *contingency event*.

(h) following the occurrence of any *non-credible contingency event* or multiple *contingency event* that is not a *protected event*, AEMO should use reasonable endeavours to:

i. maintain system frequency within the applicable *extreme frequency excursion tolerance limits* and

ii. avoid the *system frequency* exceeding the applicable *load change band* for more than two minutes while there is no *contingency event* or exceeding the applicable *normal operating frequency band* for more than 10 minutes while there is no *contingency event*;

(i) the size of the largest single generator event is limited to 144 MW,[144]which can be implemented for any *generating system* with a capacity that is greater than 144 MW by the automatic tripping of load;

A.2.3 Part C Application of Rules terms

For the purposes of these *frequency operating standards* and the Rules, a term shown in column 1 of the following table has the corresponding range shown in column 3 of the table for an island and has the corresponding range shown in column 2 of the Table otherwise.

Tasmanian Frequency Operating Standards – Rule terms

Term	Normal range (Hz)	Island range (Hz)
normal operating frequency band	49.85 to 50.15	49.0 to 51.0
normal operating frequency excursion band	49.75 to 50.25	49.0 to 51.0
operational frequency tolerance band	48.0 to 52.0	48.0 to 52.0
extreme frequency excursion tolerance limit	47.0 to 55.0	47.0 to 55.0

144 AEMO may in accordance with clause 4.8.9 direct a Generator to exceed the 144 MW contingency limit if AEMO reasonably believes this would be necessary in order to maintain a reliable operating state.

A.3 Part D - Definitions for the frequency operating standards

Term	Definition
accumulated time error	means, in respect of a measurement of *system frequency* that AEMO uses for controlling *system frequency*, the integral over time of the difference between 20 milliseconds and the inverse of that *system frequency*, starting from a time *published* by *AEMO*.
available capacity	has the meaning given to it in the Rules.
connection point	has the meaning given to it in the Rules.
contingency event	has the meaning given to it in the Rules.
credible contingency event	has the meaning given to it in the Rules.
extreme frequency excursion tolerance limits	has the meaning given to it in the Rules.
frequency operating standards	has the meaning given to it in the Rules and are the standards set out in Part B of this document.
Generating system	has the meaning given to it in the Rules.
generating unit	has the meaning given to it in the Rules.
generation	has the meaning given to it in the Rules.
Generation change band	for the mainland - means the frequency range of 49.0 to 51.0 Hz in respect of an island and the frequency range of 49.5 to 50.5 Hz otherwise. for Tasmania - means the frequency range of 48.0 to 52.0 Hz in respect of an island and otherwise.
generation event	means: 1. a *synchronisation* of a *generating unit* of more than 50 MW, or 2. a sudden, unexpected and significant increase or decrease in the *generation* of one or more *generating systems,* totalling more than 50MW in aggregate, within a period of 30 seconds or less, or 3. a *credible contingency event*, not arising from a load event, a *network event*, a *separation event* or a part of a *multiple contingency event*."

Term	Definition
Interconnector	A *transmission line* or group of *transmission lines* that connects the *transmission networks* in adjacent regions.
island	means a part of the *power system* that includes *generation*, *networks* and *load*, for which all of its alternating current network connections with other parts of the *power system* have been disconnected, provided that the part: (a) does not include more than half of the combined *generation* of each of two *regions* (determined by available capacity before disconnection); and (b) contains at least one whole inertia sub-network.
island separation band	for the mainland - means: (a) in respect of a part of the power system that is not an island, the operational frequency tolerance band; (b) in respect of an island that includes a part of the power system to which no notice under paragraph (c) applies, the operational frequency tolerance band; and (c) otherwise in respect of an island, the frequency band determined by the most restrictive of the high limits and low limits of frequency ranges outside the operational frequency tolerance band notified by Jurisdictional Coordinators to AEMO with adequate notice to apply to a nominated part of the island within their respective jurisdictions. for Tasmania - means the *extreme frequency excursion tolerance limits*
Jurisdictional Coordinator	has the meaning given to it in the Rules.
load	has the meaning given to it in the Rules.
Load change band	for the mainland - means the frequency range of 49.0 to 51.0 Hz in respect of an island and the frequency range of 49.5 to 50.5 Hz otherwise. for Tasmania - means the frequency range of 48.0 to 52.0 Hz in respect of an island and otherwise.
load event	for the mainland - means an identifiable connection or disconnection of more than 50 MW of customer load (whether at a *connection point* or otherwise), not arising from a *network event, a generation event, a separation event* or a part of a *multiple contingency event*. for Tasmania - means an either an identifiable increase or decrease of more than 20 MW of customer load (whether at a *connection point* or otherwise), or a rapid change of flow by a *high voltage* direct current interconnector to or from 0 MW for the purpose of

Term	Definition
	starting, stopping or reversing its power flow, not arising from a network event, a *generation event, a separation event* or a part of a *multiple contingency event*
Market network service provider	has the meaning given to it in the Rules.
multiple contingency event	means either a *contingency event* other than a *credible contingency event,* a sequence of *credible contingency events* within a period of 5 minutes, or a further *separation event in an island.*
National grid	has the meaning given to it in the Rules.
AEMO	has the meaning given to it in the Rules.
network	has the meaning given to it in the Rules.
network event	means a *credible contingency event* other than a *generation event*, a separation event or a part of a *multiple contingency event.*
normal operating frequency band	has the meaning given to it in the Rules.
normal operating frequency excursion band	has the meaning given to it in the Rules.
operational frequency tolerance band	has the meaning given to it in the Rules.
power system	has the meaning given to it in the Rules.
power system security and reliability standards	has the meaning given to it in the Rules.
publish	has the meaning given to it in the Rules.
region	has the meaning given to it in the Rules.
Rules	The Rules means National Electricity Rules
separation event	means a *credible contingency* event in relation to a *transmission element* that forms an *island.*
supply scarcity	means the condition where *load* has been disconnected either manually or automatically, other than in accordance with dispatch instructions or service provision, and not yet restored to supply.
Synchronisation	The act of synchronising a *generating unit* or a scheduled network service to the *power system*
synchronisation	has the meaning given to it in the Rules.
system frequency	means the frequency of a part of the *power system,* including the *frequency* of an *island.*

Term	Definition
Technical envelope	has the meaning given to it in the Rules.
transmission element	has the meaning given to it in the Rules.

B Summary of stakeholder submissions

Stakeholder	Issue/Comment	Reliability Panel Response
FOS for Protected Events		
ENA	ENA supports the inclusion of protected events in the FOS and notes that the interim FOS is useful.	Noted. See section 4.2.
ENGIE	ENGIE suggest that the FOS for each protected event be individually specified.	Noted. See section 4.2.
Meridian Energy	Meridian Energy considers that the Panel should balance cost burdens against the likelihood and significant of protected events.	Noted. See section 4.2.
TasNetworks	TasNetworks is supportive of the interim FOS for protected events, subject to more rigorous analysis being undertaken.	Noted. See section 4.2
ERM Power	ERM believe that the FOS for a protected event should be set equivalent to a separation event base on the expected impact of the event.	Noted. See section 4.2
AEMO	AEMO consider that the interim FOS for protected events are workable and has not identified any reason to vary them.	Noted. See section 4.2
Origin Energy	Origin note that where a protected event is declared, a combination of market mechanisms and EFCS should be used to manage the impact of that event.	Noted. See section 4.2
Energy Australia	Energy Australia consider that the FOS for protected events should be set as close to the current non-credible contingency standard as possible to minimise cost of compliance. Energy Australia recognise that the consistency benefits of a blanket FOS for protected events may outweigh the benefits of customised settings for each protected event due to the complexity of bespoke solutions.	Noted. See section 4.2
Department of the Premier and Cabinet, South Australia	The South Australian government support the interim FOS for protected events as a starting point, however note that this standard will not be adequate for South Australia in the absence of additional security obligations. The South Australian government request that the Panel consider including a limit on the rate of change of frequency as an element of the	Noted. See section 4.2

Stakeholder	Issue/Comment	Reliability Panel Response
	FOS for protected events on a case by case basis	
Multiple contingency events in the FOS		
ENA	ENA propose that a "reasonable endeavours" requirement be included in the FOS in relation to management of the power system following multiple contingency events.	Noted. See section 4.3
SACOSS	SACOSS believe that it is important for the FOS to retain some requirement in relation to power system operation following multiple contingency events.	Noted. See section 4.3
ENGIE	ENGIE support the removal from the FOS of the requirement for managing the power system following multiple contingency events.	Noted. See section 4.3
TasNetworks	TasNetworks accepts the practical limitations of eth current requirement for managing the power system frequency following multiple contingency events. They consider that a 'reasonable' or 'best endeavours' approach would be a worthwhile option to explore.	Noted. See section 4.3
ERM Power	The FOS for multiple contingency events should define specific events for which the extreme frequency tolerance excursion limit should be maintained, such as the simultaneous loss of all generating units at a single power station.	Noted. See section 4.3
Energy Australia	Energy Australia support the revision of the multiple contingency requirement as a general obligation, alternatively this requirement could be expressed as a targeted obligation to prevent system collapse for specific events.	Noted. See section 4.3
Department of the Premier and Cabinet, South Australia	The South Australian government while there is a case for revision of the requirement in the FOS for multiple contingency events, however there is ""little reason to consider a region-specific element of the FOS related to multiple contingency events."	Noted. See section 4.3
Definitions related to island operation		
ENA	ENA considers there are similarities between the goals for power system management for protected events, inertia sub-networks and island operation under	Noted. See section 4.5.

Stakeholder	Issue/Comment	Reliability Panel Response
	the FOS. ENA does not see any need for alignment of the requirements for island operation under the FOS and sub-networks for procurement of system restart ancillary services.	
SACOSS	SACOSS support clarification of the characteristics of an island for the FOS.	Noted. See section 4.5.
ENGIE	ENGIE suggest that the FOS contain a set of principles that can be applied by AEMO to determine which section in the NEM may be treated as potential islands for the purpose of the FOS.	Noted. See section 4.5.
Meridian Energy	Meridian Energy support a simple and sensible measure to determine the characteristics of a viable island for the maintenance of the FOS.	Noted. See section 4.5
TasNetworks	TasNetworks support further guidance on the characteristics of a viable island for the FOS and lists a number of specific concerns related to this issue.	These concerns are addressed in detail in section 4.5.
ERM Power	ERM supports the suggested revision of the definition of an island for the FOS. The definition should be linked to the goal of satisfactory operation of the island.	Noted. See section 4.5
AEMO	AEMO believe that the definition of an island for the FOS should be consistent with the requirements for an inertia sub-network.	Noted. See section 4.5
Origin Energy	Origin supports consistency of policy in general, including that the subnetworks for the inertia and SRAS are aligned with the regions for island operation under the FOS. The goal of an island is to maintain safe and secure operation to ensure plant operating within their performance standards are not damaged or forced to trip off.	Noted. See section 4.5
PIAC	PIAC recommend that the Panel consider cost benefit trade-offs as well as technical considerations when determining the characteristics of an island for the FOS.	Noted. See section 4.5
Department of the Premier and Cabinet, South Australia	The South Australian government agree with the proposed revision to the definition related to island operation under the FOS.	Noted. See section 4.5

Stakeholder	Issue/Comment	Reliability Panel Response
Definition of a generation event		
ENA	ENA support the revision of the definition of the term “generation event” so it is more operationally realistic. Such a revision should account for the sudden and unexpected increase or decrease of generation output.	Noted. See section 4.4.
ENGIE	ENGIE support the standardisation of terminology definitions amongst the NEM regions as much as is practicable.	The draft FOS for stage one includes a single set of definitions that applies to both Tasmania and the mainland NEM.
Meridian Energy	Meridian supports the general standardisation of the definition of terms in the FOS. Meridian also support the revision of the definition of generation event to reflect actual changes in generation performance in light of newer technologies such as inverter based generation.	Noted. See section 4.4.
TasNetworks	In terms of the definition of generation event and the issue of rapid and unexpected variation of generation output, TasNetworks suggest that the Panel consider whether these events should be treated as part of normal operation or as contingency events.	Noted. See section 4.4. this issue will be considered further during stage two of the review as discussed in section 5.1 and 5.2.
ERM Power	ERM support the standardisation of the definition in the FOS, where appropriate. ERM support also the revision of the definition of a generation event, suggesting the following wording: “the unforecast and sudden decrease or increase exceeding 50MW of generator output from a generating unit”	Noted. See section 4.4.
AEMO	AEMO support the revision of the definition of generation event definition, noting that the revised definition should: • cover the sudden unexpected variation of generation resulting from a common event • be linked to the declaration of a credible contingency, to be determined by AEMO.	Noted. See section 4.4.
Department of the Premier and Cabinet, South	The South Australian government agree with the proposal to revise the definition of a generation event, adding that the	Noted. See section 4.4.

Stakeholder	Issue/Comment	Reliability Panel Response
Australia	consideration of a single point of failure impacting a network element solely providing connection to generation element should also be considered.	
Consideration of accumulated time error		
ENA	ENA suggest that the requirement in the FOS to limit accumulated time error may be reduced by a guideline in order to maintain the reporting of time error as a measure of system performance.	Noted. See section 4.6,
SACOSS	SACOSS believe that the FOS should no longer require AEMO to limit accumulated time error.	Noted. See section 4.6,
ENGIE	ENGIE support the removal of accumulated time error from the FOS as its relevance has diminished.	Noted. See section 4.6,
Meridian Energy	Meridian Energy support the relaxation or removal of the limit on accumulated time error in the FOS. They note that accumulated time error is of little value in today's digital world where all consumer have access to accurate time keeping devices.	Noted. See section 4.6,
TasNetworks	TasNetworks notes that the reduced dependence on time error likely justifies the removal of a formal accumulated time error standard. TasNetworks notes there is continued value in the reporting of accumulated time error as a measure or power system performance.	Noted. See section 4.6,
ERM Power	ERM support the removal of accumulated time error from the FOS, pending further analysis by the Panel that confirms the benefits of this change.	Noted. See section 4.6,
AEMO	AEMO is not aware of any consumer complaints in relation to time error and accurate time keeping, including following the islanding events and manual resetting of time error. AEMO offers to assist the Panel to investigate the costs and benefits of time error correction with a view to discontinuing or relaxing the requirement to limit accumulated time error.	Noted. See section 4.6,
PIAC	PIAC recognise that synchronous clocks have become less common, therefore the	Noted. See section 4.6,

Stakeholder	Issue/Comment	Reliability Panel Response
	importance of obligations relating to accumulated time error have diminished.	
Stage two issues		
ENA	ENA propose that the panel consider the inclusion in the FOS of a limit on rate of change of frequency.	Noted for consideration during stage two. See section 5.4.
ENGIE	ENGIE note that stage two could consider whether the FOS should contain a standard for rate of change of frequency.	Noted for consideration during stage two. See section 5.4.
Meridian Energy	Meridian Energy request that the Panel consider in depth the potential impacts of the introduction of significant quantities of distributed storage at both a utility and household scale and how the FOS can interact with such devices to enhance system security.	Noted for consideration during stage two. See chapter 5.
TasNetworks	TasNetworks raised a number of issues for further consideration during stage two of the review including: • Consider extending the 144MW limit on a generation event to cover network events. • Consider including a ROCOF limit in the FOS. • Consider the impact of demand response mechanism and ancillary service unbundling rule change relating to the performance of fast FCAS delivered through switching controllers. • recommended that load and generation events in the TFOS be separated.	Noted for consideration during stage two. • See section 5.2.2. • See section 5.4. • to be address in the *Frequency control frameworks review*. • see section 5.2.1.
ERM Power	ERM suggest that a more refined breakup of the probabilistic distribution of the power system frequency during normal operation be considered. ERM suggest that the frequency distribution for normal operation be specified by as many as 5 frequency bands with corresponding percentage of time requirements.	Noted for consideration during stage two. See section 5.1.
Origin Energy	Origin support a review to update the Value of customer reliability (VCR) Origin request that the Panel consider how new FFR services may impact the FOS.	Noted. VCR is estimated by AEMO. Noted, see section 5.1.2.
PIAC	PIAC note that it is essential that the Panel bear in mind the cost implications related to measures intended to increase system	Noted.

Stakeholder	Issue/Comment	Reliability Panel Response
	security.	
Energy Australia	Energy Australia note the following points for consideration during stage two: • The normal operating frequency band and the contingency bands are most suitable for determination by a cost benefit assessment. • The Panel should examine what "good frequency control" within the NEM is, including assessing the benefits of a tighter frequency distribution during normal operation. • The Panel should identify drivers of change that may impact frequency control such as new generation technologies and behind the meter response.	Noted for consideration during stage two. • see section 5.1 • see section 5.1. • see chapter 5.
Department of the Premier and Cabinet, South Australia	The South Australian government request that the Panel consider the inclusion of a limit on rate of change of frequency in the FOS.	Noted for consideration during stage two. See section 5.4.

C Terms of Reference

Revised – 12 September 2017

Introduction

Under section 38 of the National Electricity Law (NEL) and clause 8.8.3(c) of the National Electricity Rules (NER), the Australian Energy Market Commission (AEMC) requests that the Reliability Panel (the Panel) undertake a review of the frequency operating standards that apply in the National Electricity Market (NEM). This review is related to and is intended to complement the ongoing work program that the AEMC is undertaking to enable the maintenance of power system security in the NEM.

Background

The frequency operating standard*s* (FOS): NER clause 8.8.1(a)(2) requires the Reliability Panel to review and, on the advice of AEMO, determine the power system security standards. These standards may include various matters but at present include standards for the range of allowable frequency of the power system under different conditions, including normal operation and following contingencies. These standards are set out in the FOS.

The FOS set out the frequency standards to which AEMO operates the power system. This includes defined frequency bands and timeframes in which the system frequency must be restored to these bands following different events, such as the failure of a transmission line or separation of a region from the rest of the NEM. These requirements then inform how AEMO operates the power system, including through applying constraints to the dispatch of generation or procuring ancillary services.

The FOS currently consists of two separate standards: one for the mainland NEM, and one for Tasmania. This reflects the different physical and market characteristics of the Tasmanian region as opposed to the mainland NEM. The frequency operating standard for Tasmania was last reviewed and determined by the Reliability Panel on 18 December 2008. The frequency operating standard for the mainland was last reviewed and determined by the Reliability Panel on 16 April 2009.

The Panel's role and responsibility in relation to the FOS: Clause 8.8.1(a)(2) of the National Electricity Rules (NER or the rules) requires the Reliability Panel to: "review and, on the advice of AEMO, determine the power system security standards". The reliability panel is required to determine the FOS as a subset of the power system security standards.

The Emergency frequency control scheme rule change: On 30 March 2017 the AEMC published the final rule and accompanying final determination for the Emergency Frequency Control Schemes rule change (ERC0212).

A number of issues relevant to the Panel's review of the FOS were identified or addressed in the final rule determination of the emergency frequency control schemes rule change. These include:

- A review of the appropriateness of the requirements in the FOS that relate to multiple contingency events.[145] Currently, the FOS defines the standard to which AEMO manages the power system following any multiple contingency event. AEMO has argued that this is impractical, as it is not possible to maintain the FOS for all multiple contingencies.
- How the new event classification for "protected events" can best be incorporated into the FOS. The Emergency frequency control schemes rule change introduced a new category of contingency event, the "protected event". AEMO is now required to maintain the frequency of the power system within certain bands for these events. These requirements will be defined in the FOS.

The final rule for the Emergency frequency control schemes rule change includes an interim frequency standard that shall apply for any protected event(s) that may be declared prior to this review of the FOS being completed. Accordingly, following the review, the revised FOS for protected events may replace this interim requirement.

Scope of the review

The Panel is requested to undertake a review of the NEM mainland and the Tasmanian frequency operating standards.

In undertaking this review, the Panel should give consideration to key system security issues currently being addressed by the AEMC and AEMO. This should include, but is not limited to, the consequences of the changing NEM generation fleet, including the impacts of decreased system inertia and associated rates of change of frequency following a contingency event.

Relatedly, the Panel should give consideration to the findings and recommendations of the following work programs:

- AEMC's system security market framework review;
- AEMO's Future Power System Security review;
- AEMC Frequency Control Frameworks Review
- Rule change requests currently on foot that are relevant to the issues that will need to be considered in the review, including the *Managing the rate of change of power system frequency* rule change.

Given these key issues and the ongoing work programs, in undertaking this review, the Panel should give consideration to:

- Whether the terminology, standards and settings and definitions in the FOS remain appropriate.

145 Part B (f) of the Frequency Operating Standard for the mainland.
Part B (g) of the Frequency Operating Standard for Tasmania.

- What amendments to the FOS may be necessary in light of the AEMC's final determination of the Emergency frequency control schemes rule change published on 30 March 2017
- Whether further guidance can be provided regarding the definition of what part of the power system the FOS is to be applied following separation from the rest of the NEM. Specifically, whether the FOS should refer to a separated region, or some smaller sub-section of a region, for maintenance of frequency following a separation event.
- Other issues related to the FOS as determined by the Panel.

The Panel's review of the FOS must consider and determine FOS to apply to both Tasmania and the mainland regions of the NEM. This must include consideration of the different physical and market characteristics relating to the power system. Given that Tasmania and the mainland are electrically separated in terms of frequency, the review shall consider the different physical and market characteristics of each of these regions in determining the settings for the FOS.

Timing and Consultation Process

In conducting this review the Panel may determine its own approach, including the staging of issues to be addressed, but must carry out the review to develop the FOS in accordance with the following consultation processes:

- Give notice to all registered participants of commencement of this review.
- Publish an issues paper for consultation with stakeholders following the notification of the commencement of the review and invite submissions for a period of at least three weeks. This paper should outline the key issues and questions the Panel will consider when determining the FOS.
- Publish a draft report or reports and invite submissions for a period of at least four weeks.
- At the time of publishing the draft report(s), notify stakeholders that they may request a public meeting on the draft report(s) within five business days of the draft report(s) being published.
- If stakeholders have requested a public meeting, notify stakeholders that a public meeting will be held. At least two weeks' notice of the public meeting must be given.
- Publish a final report or reports and submit this report(s) to the AEMC no later than six weeks after the period for consultation on the draft report(s) has closed.

The Panel may decide on its own timing for delivery of the review, provided the review is completed by 31 July 2018.

D Past Reviews of the FOS

D.1 Reliability Panel Review: Application of FOS During Periods of Supply Scarcity 2009

Following the blackout that occurred in Victoria on 16 January 2016, related to severe bushfire activity, the reliability panel revised the FOS for the mainland NEM to support a more rapid restoration of supply following a major power system incident. An additional table was added to the FOS for the Mainland NEM to apply during periods of supply scarcity, following automatic load shedding.

This change was made in an effort to shorten the restoration time for the power system following major incidents through the increased utilisation of available generation capacity. The FOS during period of supply scarcity is wider than that for normal interconnected system conditions, which reduces the amount of FCAS that are required to manage the power system frequency, this in turn slightly increase the generation capacity available to supply load, and thus reduces the restoration time.

D.2 Reliability Panel Review: Tasmanian FOS Review 2008

The FOS that applies for Tasmania was last reviewed and determined by the reliability panel on 18 Dec 2008.[146] At that time the Panel considered revisions to the Tasmanian FOS that would more closely align the FOS for Tasmania with that for the mainland NEM. A primary goal for the review was to set the standard to support a more diverse range of electricity generating technologies to increase the security and reliability of energy supplies in Tasmanian and facilitate competition.

The 2008 review made the following changes to the FOS for Tasmania:

- increasing lower limit of the extreme frequency excursion tolerance limit from 46 Hz to 47 Hz
- increasing the lower limit of the load, generator and network event band to 48 Hz, thus requiring the under frequency load shedding scheme (UFLSS) to operate between 48 and 47 Hz
- aligning the upper limit of the operational tolerance frequency band for load, generator and network events to 52 Hz, thus allowing efficient thermal generating units to meet the minimum access standards
- aligning the recovery times for load, generator and network events to 10 minutes
- reducing the over frequency limit for extreme events under island conditions from 60 Hz to 55 Hz
- a limit of 144MW was applied to the size of a contingency event that must be managed in accordance with the FOS.

146 In 2006, the Panel conducted a review of the FOS that applies to Tasmania following the inclusion of Tasmania in the NEM. This review confirmed that the previous FOS for Tasmania would continue to apply until such time as the Panel completed a more thorough review. See: AEMC Reliability Panel, 2006, [146146] Tasmanian Reliability and Frequency Standards – determination.

D.3 Reliability Panel Review: FOS (Mainland NEM)

The FOS for the mainland NEM was thoroughly reviewed and determined by the reliability Panel on 30 September 2001. This review was undertaken to address the growth of the NEM, including the addition of the Queensland region into the interconnected NEM.

The 2001 review made the following changes to the FOS for the mainland NEM:

- relaxation of the normal frequency band from 49.9 - 50.1 Hz to 49.85 - 50.15 Hz
- creation of a probabilistic tolerance for the normal band of 99 per cent of the time
- amalgamation of the standard for load disturbances with the standard for single generator disturbances
- increase of the maximum time to stabilise the power system frequency following multiple contingencies
- establishment of a uniform base standard when a contingency event may result in separation of parts of the network and provide for a Jurisdictional Co-ordinator to advise NEMMCO of a relaxation of this requirement
- tighten the standards that apply to island operation in the absence of disturbing events
- amend the allowable time error from 3 seconds to 5 seconds.

The relaxation of the normal operating frequency band and the addition of the probabilistic tolerance of 99 per cent were intended to reduce the quantity of ancillary services required to be procured by the market operator. This change also allowed the market operator to, within limits, vary the amount of ancillary service in response to market price.